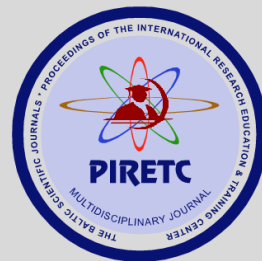


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THE IMPORTANCE OF UNCERTAINTY DETERMINATION DURING TECHNOLOGICAL TEMPERATURE MEASUREMENTS

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ABSTRACT

As we know, one of the trends in the development of metrological control activities of enterprises and organizations is the calibration of measuring instruments through the assessment of measurement uncertainty. This process is an important factor to increase the accuracy of measurements, ensuring product quality, minimize the amount of waste products and increase the competitiveness of the organization. Such a parameter can be, for example, the standard deviation (mean squared error of the measurement results) or a number that is exactly divisible by it, or the width of the confidence interval. Measurement uncertainty combines several components. Some of these components can be estimated based on the statistical distribution of the results of a series of observations and characterized by their standard deviations. Considering that more than 50% of the measurements performed during technological processes are covered by temperature measurements, then we can say that the errors occurring during temperature measurements directly affect the quality of the product significantly. In the conducted research, the uncertainty in the temperature measurements performed during the technological processes was determined and the importance of determining this uncertainty was analyzed.

Keywords: Metrological assurance, temperature measurements, technological process, statistical distribution, thermodynamics, uncertainty, metrology, accuracy, error, calibration.

Introduction

According to the Law of the Republic of Azerbaijan "On Ensuring the Uniformity of Measurements", the calibration of measuring instruments is considered as a set of operations performed to determine the actual values of the metrological characteristics of the measurement. In this regard, if the measuring instrument used during the technological process is not intended for use in the field of state regulation of ensuring the uniformity of measurements or will not be used, then that measuring instrument can be subjected to the calibration procedure. Thus, in the Republic of Azerbaijan, the calibration procedure of measuring instruments is considered a voluntary process, unlike the verification procedure [1].

It should be noted that any legal entity (individual entrepreneur) without accreditation for the right to carry out calibration works has the right to calibrate measuring instruments, because according to the Law of the Republic of Azerbaijan "On Ensuring the Uniformity of Measurements", such accreditation is voluntary. In this case, the calibration of the measuring instruments should be carried out using standards of quantitative units that can be traced in accordance with the state primary standards of the corresponding quantitative units. This involves determining the fact that the quantitative units of standards used during calibration comply with state standards and have valid inspection certificates. Accreditation of the right to calibrate measuring instruments, as mentioned above, is voluntary, but it is more convenient to obtain this right for the metrological

service in order to recognize the results of calibration, as well as to improve the image of the enterprise as a whole [2].

According to the ISO/IEC 17025-2017 standard, a mandatory part of the calibration of measuring instruments is the estimation of measurement uncertainty. As we mentioned, measurement uncertainty is a non-negative parameter that characterizes the spread of quantitative values attributed to the measured quantity on the basis of measurement data. The measurement result of the quantity should be accompanied by some quantitative characterization of the quality of the measurement result, so that it is possible to assess its reliability when using this result. Without such information, the measurement results cannot be compared with each other or with the values specified in the specification or standard. This requires an easy-to-use, understandable and generally accepted procedure to characterize the quality of a measurement result, that is, to estimate and express its uncertainty [3-4].

We use correlation of the terms of the theory of uncertainty with the terms of the classical theory of accuracy (in brackets):

- Uncertainty of the measurement result (error of the measurement result),
- uncertainty type A (random error),
- type B uncertainty (systematic error),
- the standard uncertainty (standard deviation of the error) of the measurement result,
- expanded uncertainty (confidence limits) of the measurement result,
- coverage probability, coverage probability (confidence probability),
- coverage ratio, coverage ratio (error distribution coefficient)

The concept of measurement uncertainty refuses to divide these groups into systematic and random errors, referring to the difficulty of distinguishing them. Instead, data processing approaches are classified into two types: A and B.

The differences between these groups, as in the case of errors, are not based on the sources of occurrence, but on the method of obtaining their values. The classification of measurement uncertainty into types A and B is presented only to show that there are two different ways of estimating uncertainty components. Both estimation methods are based on the probability distribution, and the uncertainty components (regardless of the estimation method) are quantitatively characterized by the same parameter - the standard deviation. Type A conditions are estimated as standard uncertainties equal to the standard deviations of the arithmetic means of multiple measurements. Type B conditions are estimated as standard uncertainties, which are obtained from periodic data on the variability of input quantities [5-6].

A Type B uncertainty assessment can be based on the following information:

- information from the calibration certificate;
- the value of the quantity taken from authoritative publications;
- information on the standardized metrological characteristics of the measuring instrument.

Calculation of the uncertainty of the temperature measuring instrument

As we know, thermoelectric converters are often used in industrial and laboratory temperature measurements. This is due to the possibility of their application in a wide range of temperatures, as well as the convenience of installation. Like any measurement, temperature measurement using TP is characterized by the degree of approximation of the result to the true value. There are two approaches to estimating parameters of measurement accuracy. One approach is based on the concepts and terms of the theory of uncertainty, the other - on the concepts and terms of the



theory of errors, which are still more widely used in normative documents in the field of metrology, used in the Wold metrology system of ensuring the unity of measurements. Currently, in some standards related to thermometry, the term "measurement uncertainty" has been introduced instead of the term "measurement error". The concept of "uncertainty of measurements" has received worldwide distribution and is introduced as a mandatory condition for the certification of verification laboratories according to the international standard ISO/IEC 17025 [7].

The concept of "measurement uncertainty", which is currently being introduced into practice, makes it quite easy to calculate the measurement uncertainty both in production and in the laboratory, and to compare the measurement results obtained in different laboratories. Knowledge of the uncertainty of the measurements taken in production allows you to optimize technological processes with greater accuracy. The purpose of this work is to determine the uncertainty of temperature measurement by thermocouples using various measuring circuits. [8-9]

In the course of the study, the calculation of the measurement uncertainty during the calibration of the PR320 temperature calibrator with an upper measurement limit of 1300 °C and a reduced allowable error of 0.5% was performed.

As a reference, a PR320 temperature calibrator with an upper measurement limit of 1300 °C and a reduced permissible error limit of 0.02 % was used, as well as a 5649 R type thermocouple with a relative permissible error limit of ± 0.03 %.

We present the measurement uncertainty calculation for the 30-40 °C point.

Calculation of uncertainties and processing of measurement results ISO/IEC Guide 98-3:2008 "Measurement uncertainty. Part 3" was carried out according to the normative document.

As we know, uncertainty calculation consists of the following several steps.

- Uncertainty assessment;
- Determination of type A uncertainty;
- Determination of type B uncertainty
- Calculation of extended uncertainty;
- Final uncertainty.

In classical metrology, the measurement error was usually expressed by the boundaries of the confidence interval calculated on the basis of the dispersion of the measurement results, the largest and smallest values of the interval in which the desired (true) value of the measurement result is located with a given probability, i.e., the measurement error were evaluated directly from the results of these measurements, namely, from the variance of the results. At the same time, the components of the "error" from the "errors" of the certified value of the standard sample or the calibration dependence were not taken into account.

During the research work, 5 measurements were made and the following values were obtained: 34; 35; 36; 38; 40 °C. (Fig. 1)

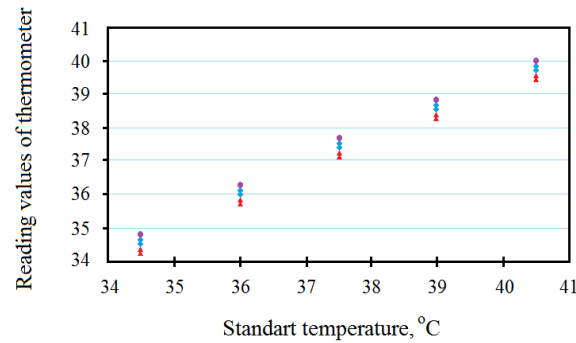


Figure 1: Temperature measurements result

We find the average value of the temperature according to the formula 1:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad (1)$$

Next, we calculate the standard deviation of the arithmetic mean using the following equation (Formula 2):

$$S = \sqrt{\frac{1}{(n_i - 1) \cdot n} \sum_{i=1}^n (x_i - \bar{x}_i)^2} \quad (2)$$

We calculate the type A uncertainty during the temperature measurement performed in the above sequence.

Calculating type B uncertainty, however, requires a different process. We must take into account all the factors affecting the measurement operation at this time.

In order to evaluate the type B uncertainty during the performed process, we used the basic reduced error limits of the 0.02% standard known from the technical documentation. Then the absolute error will have a uniform distribution within the range of ± 0.5 °C.

The standard uncertainty of type B is calculated by the following formula 3:

$$U_{B1} = \frac{X_{B1}}{\sqrt{3}} = \frac{0,5}{1,732} = 0,2886 \text{ °C} \quad (3)$$

The standard uncertainty of the calibrator resolution is calculated using the uniform distribution formula 4.

$$U_{B2} = \frac{X_{B2}}{\sqrt{12}} \quad (4)$$



Where X_{B2} is the unit of the last digit of the calibrated sensor reading (Formula 5).

$$U_{B2} = \frac{X_{B2}}{\sqrt{12}} = \frac{0,1}{3,4641} = 0,02886 \text{ }^{\circ}\text{C} \quad (5)$$

Next, we calculate the standard total uncertainty through the input quantity uncertainty contributions (Formula 6):

$$u_c = \sqrt{u_A^2 + u_{B1}^2 + u_{B2}^2} \quad (6)$$

The expanded uncertainty is calculated using the following formula 7:

$$U = k \cdot u_c \quad (7)$$

Contribution of the uncertainty of each input quantity x_i to the uncertainty of the measured quantity (total uncertainty) is calculated as follows formula 8:

$$u_i(y) = c_i \cdot u(X_i) \quad (8)$$

The measurement uncertainty budget for 5649 R-type thermocouple calibration is given in the table 1.

Table 1. The measurement uncertainty budget for 5649 R-type thermocouple

Parameter	Value
Estimation of input quantity, $^{\circ}\text{C}$	500
Output value, $^{\circ}\text{C}$	501
Standard uncertainty, $^{\circ}\text{C}$	0,02886
Standard total uncertainty, $^{\circ}\text{C}$	0,021
Distribution	normal
Effective number of degrees of freedom	1
Contribution to uncertainty, $^{\circ}\text{C}$	0,023
Extended uncertainty	0,043

Thus, the expanded uncertainty at the 500 $^{\circ}\text{C}$ calibration point was 0.0043 $^{\circ}\text{C}$.

According to ISO/IEC 17025:2017, the laboratory must estimate the measurement uncertainty for all calibrations, including its own equipment.

In the previous version of the standard, there was no requirement to calibrate their own equipment, which created major problems for the metrological service, as it would be necessary to develop calibration procedures for its own equipment. Accordingly, the next challenge is whether

the metrology service staff has sufficient competence to do it, how and when to do it, and to develop its calibration methods, as well as to calculate and estimate measurement uncertainties. In European countries, this problem was solved by the introduction of departments for the development of calibration methods depending on the types of measurements (optical, geometric, electrical, etc.). [10]

The requirements to ensure the reliability of measurement results are as follows: the laboratory must have a procedure to control the reliability of its results. The data obtained should be recorded to identify trends and where possible statistical methods should be used to analyze the results. A plan for such monitoring should be developed and analyzed. Monitoring refers to both internal and external audits, and the plan refers to actions to be taken by laboratory personnel if monitoring is performed.

In this work, we tried to theoretically substantiate two important points in the procedure for estimating the uncertainty of the temperature measurement in the interval, which arises due to the presence of verification uncertainties in the calibration points. First, it was proved that if the total correlated uncertainties exceed the uncorrelated ones, it is possible to use linear interpolation to obtain the uncertainties in the interval. Secondly, it was shown that in order to express the uncertainty of the temperature difference measured by two thermometers calibrated with the same equipment, it is necessary to take into account the correlation, which will reduce the total uncertainty of the difference several times. In addition, it is possible to use a simplified formula, excluding all correlated uncertainties. The uncertainty of the difference in the interval can be calculated by linear interpolation of uncorrelated total uncertainties between calibration points.

Conclusions

The problem of obtaining information from the listed sources is also related to their incompatibility with the realities of the Republic of Azerbaijan. By the data of previous measurements, we mean the data specified in the calibration certificate, but if we consider that this certificate was obtained from an organization that is not accredited for the right to perform calibration, the data on measurement uncertainty cannot be considered reliable. If we take into account the resources obtained through practical or theoretical means, then the problem of loss of time and resources for the metrological service arises. Information about measurement uncertainties, if of foreign origin, is very rarely found in the passports or operating instructions of the measuring instrument. Such information is available, but the manufacturer usually does not provide any information on measurement uncertainty. It is not entirely clear which reference books the ambiguities refer to. Most likely, these reference books are available in foreign practice for calibration of measuring instruments, but not in the Republic of Azerbaijan.

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ADVANTAGES OF INTRODUCING AN INTEGRATED MANAGEMENT SYSTEM IN EDUCATION

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ABSTRACT

Education is a fundamental need of every member society, therefore, every citizen should be concerned the quality of education provided by providers of educational services. But while the results may not always be guaranteed and yet educational institutions can play a decisive role in ensuring the expected quality in education. These problems can be solved by the Integrated Management System in Education (IMS). This is a guide for improving the management of the enterprise, created on the basis of international management experience. What can we get from IMS and why are we introducing it into the education system? IMS integrates management systems based on the requirements of international and national standards. We also consider the algorithm for the implementation and development of the IMS at EI. This process includes three subsequent steps: preliminary, preliminary and main. With ISO certification, we can: improve our education system; enhance the reputation of your school; promote equal opportunities for all students, regardless of their religion, ethnic or cultural background, gender, ability/disability, etc. ISO certifications for the education industry help school systems to navigate a complex and competitive environment, also help customers in the industry by implementing education industry standards.

Keywords: education, management system, standards digitalization.

Introduction

The quality of education has a significant impact on the socio-economic development of society. The development of education in Azerbaijan is one of the priorities of the state policy.

Over the years, there have been quite a few changes in all sectors, including in the field of education. For a long time, Azerbaijan, like other post-Soviet Republics, worked and received education according to one single scheme and formula. But after the collapse of the USSR, Azerbaijan began to create a new model of quality education, both in general education schools and in the country's higher educational institutions. But time does not stand still and our country strives for everything new and progressive.

In the late 1990s, private international universities and schools began to appear in Azerbaijan. Parents chose the school and universities at will, in accordance with plans for the future. The society was divided into three subgroups - a private school/university, a public education or a school/university with an international curriculum. The Turkish curriculum has become the leader in the education market. For some time, everyone was happy, the choice was not small.

Everything is new and in demand, but the time has come for the first graduates of the new curriculum. And a new picture of non-compatibility and non-demand has emerged. There came a period of Performance in the educational field. And it was at this point that we got a little confused. Naturally, it is very difficult to solve such multi-way problems with a large number of unknowns in a short period of time. But today this difficult task with a large number of unknowns



has become solvable, because we have begun to see more clearly what we want from education for the quality future of our children and our country.

The improvement of the quality of life is the basis of public policy in developed countries, including Azerbaijan. The ideas oriented to the creation of quality management systems are the components of the provision of a high level of quality of products and services. That is, high quality is guaranteed not from product certification, but through the introduction of quality management systems.

Education is a fundamental need of every member of society; therefore, every citizen should be concerned about the quality of education provided by providers of educational services. But while the results may not always be guaranteed, educational institutions can play a decisive role in ensuring the expected quality of education.

These problems can be solved by the Integrated Management System in Education (IMS).[1],[2] On the example of the positive results of the leading companies in the world, which in the basis of their management, use the algorithm of the IMS. What can we get from the IMS and why do we implement it in the education system? IMS combines management systems based on the requirements of international and national standards: Fig.1.

- ISO 9000 (quality);
- ISO 14001 (environmental protection);
- OHSAS 18000 (occupational health and safety), and some others [3]

This is a guide for improving the management of the enterprise, created on the basis of international management experience.

Although the quality management system has some shortcomings, quite a few enterprises have declared certification of quality systems, or intend to do so in the near future.

Recognizing the importance of quality education for all, ISO developed ISO 21001, the first ever standard for an education management system.

It aims to improve the outcomes and quality of educational institutions for the particular attention and expectations of those who use their services.

6 specific marks of ISO 21001 are planned to be marked, which include but are not limited to:

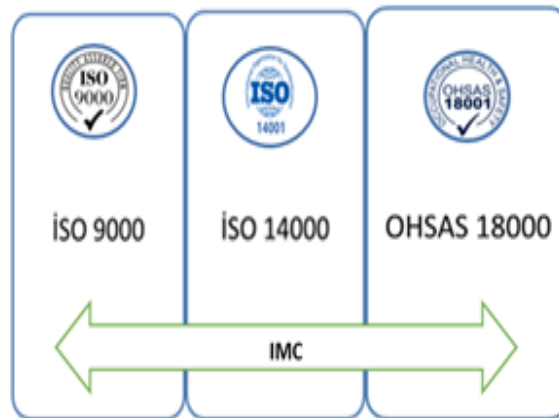
- mission, vision, goals and action plans;
- inclusive and equitable education for all;
- more personalized learning and response to special education needs;
- sequential processes and assessment tools;
- models for improvement;
- increasing the authority of the educational organization. ISO 21001 is designed to fully standardize the education business, from goals to methods to adjustments.

In addition, ISO technical committee ISO/TC 232 is developing standards that describe the requirements for learning services provided outside of formal education, such as ISO 29993, which covers all types of lifelong learning, including vocational education and in-company training. The International Organization for Standardization (ISO) has put forward countless sets of standards that benefit business and industry operations. However, ISO's work is not limited to these areas. It can also be useful in other areas that we don't see as often, such as education.

The business is a consumer or purchaser of OS. He must evaluate quality in terms of obtaining the maximum benefit from the funds spent on training. But there is a difficulty here, due to the fact that the costs are known at the moment, and the effectiveness of their investment will appear only

over time. And since the activity of an enterprise depends on the influence of many other factors, it is almost impossible to unambiguously assess the role of training in terms of value. In this regard, the interest of businesses in training their employees depends primarily on the requirements of the law.

An educational institution is an organization that provides educational institutions, that is, their manufacturer and seller. It considers quality as a way to achieve competitive success.



The state, representing the interests of the whole society, should be vitally interested in the high quality of educational institutions since well-educated citizens form the basis of the country's intellectual capital. The state is neither a buyer nor a seller of OS. Even in the system of higher education, by providing state-funded places for students, it plays the role of an investor rather than expecting a return on invested funds.

Quality is a very multifaceted and ambiguous characteristic of products, services, management systems, etc. Fig.2. In the OS system, quality, on the one hand, is the main characteristic, and on the other hand, it has a number of features:

- It is impossible to objectively assess the quality of EI using measurable instrumental methods and verifiable indicators. And this is one of the conditions for the functioning of modern management systems. The various approaches currently in use are based on expert evaluation or on the results of questionnaires;
- There are too many factors that affect the quality of EI.[4] There are too many factors that influence the quality of EI. They are staffing of an EI organization of all levels and specialties, material and technical support, availability of demanded programs, classrooms and training workshops, multimedia various communications, the level of students' training, and many others. Moreover, some of these factors are variable, some of them are interrelated, and some of them do not depend on the organization that provides EI;
- Many experts consider that the most important criterion for the quality of educational institutions is the existence of a quality management system (QMS) certificate. But this opinion is valid only if the QMS is really developed, implemented and successfully functioning. The main reason is the unwillingness and inability of management to change the nature of management from linear-functional to process-based, which is the basis of modern management systems.

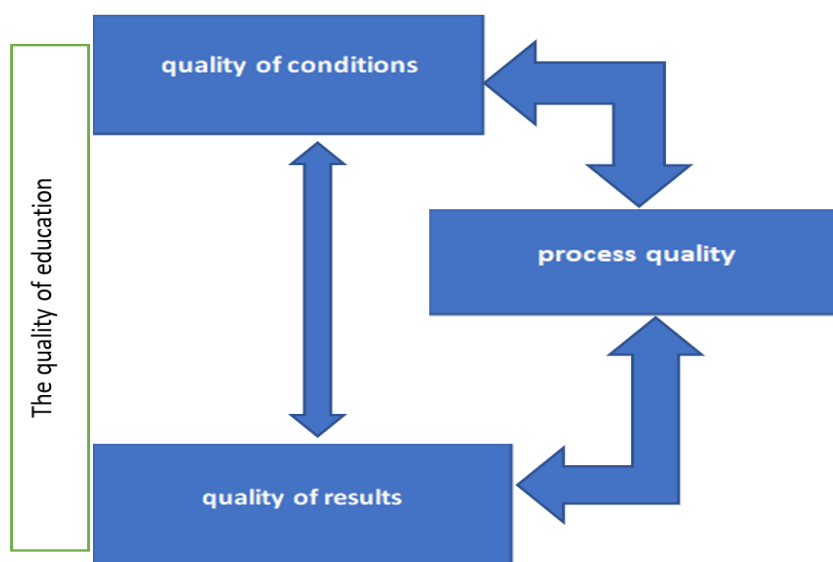


Figure 2: Linking the quality of education - with the characteristics of products services, management system, etc

I would also like to note that ISO 21001 sets guidelines for many organizations related to how education is carried out and how students should be approached and managed, it is certain that over time the standards will lead to a more uniform educational ecosystem. This does not mean that all institutions and teachers should be the same or even teach the same. Specific problems should be dealt with in a similar manner so that one student facing difficulty in a given environment is not less likely to overcome the problem than another student facing the same situation in another institution.

Quality supply problem in higher education

The expansion and deepening of the Bologna Process in higher education in Azerbaijan is directly related to the quality of its foundation. Some experts believe that the Bologna Declaration does not reflect a method for accurately defining the problem of quality of education, despite the fact that at the conference of ministers of education in Paris, quality was the main issue every time. Subsequent dynamics have shown that the higher education system offers three levels of quality: the high school, the country and Europe as a whole. The primary responsibility for quality in higher education lies in the use of mutually acceptable criteria and methods. The challenge is to keep the following in mind when ensuring quality.

Considering the degree of responsibility and interest of the university and the organization interested in the issue;

Evaluation of the program and the work of the university, as well as the evaluation of external peer reviews, as well as student participation in the evaluation and printing of results;

Considering the perfection of the system of accreditation procedures and the accuracy of the certification mechanism;

The level of international cooperation, participation in international networking and network cooperation;

Preparation and publication of training manuals, textbooks;

Level of contact with students, level of use of new teaching methods, encouragement of free work with students, and so on.

At the European level, the Berlin Conference, together with the European Association of Universities, the European Students' Union and the European Network for Quality Assurance in Higher Education, offers guidelines for establishing a common concept, procedure and methodology. These guidelines include the introduction of accreditation and the development of a quality assurance system for foreign experimentation in certain universities.

The quality of higher education is explained a number of reasons. In Europe, the government does not actively intervene in the work of higher education institutions and is outside the process of regulating the higher education system. In many European national education systems, there has been interference in the process of entering and leaving the academic process in the last 10 years.

It is necessary to develop a methodology for designing education so that one of the most important indicators of education is the result of education. In other words, to evaluate the effectiveness of education is planned (curriculum content, duration of training, etc.), not the process of implementation, but the result of education, knowledge, worldview, employment, free education and self-education process based on such criteria as their ability to implement. In this case, the focus is on the educational process (educational programs, student success - 33), and it should be aimed at improving the level of professional and personal training. Finally, in the organization and implementation of the quality of higher education, the mutual recognition of diplomas and degrees, as well as the comparison of the documents submitted, that it can be done, that it can be reliable, that the staff is competitive in the labor market and that they can reflect the process of declining training, have the right professional training and habits, etc. combine and other aspects, such as this. Provision of manifested qualities, on the other hand, is directly connected with the organization of curriculum in higher education institution, regulation of relations between teachers and students, organization of its ability for educational learning and formation of free learning skills, in other words, the development of personnel able to continue competing in the educational sector market depends on it. In general, the quality of education is characterized by indicators that reflect the real educational results of social and personal expectations to which it refers. The concept of education is usually reflected in two main forms, such as the result (education) and the learning process. In both cases, the factors affecting education are governing bodies, educational institutions, educational programs, students, and teachers. And assessing the quality of education requires adding to the list of bidders and those who benefit from the educational service, mainly individuals, production, society and government, education is a system. It is necessary to assess and evaluate what. That is, it is important to define the object and the criteria for evaluation. If the objects and subjects of evaluation are defined, then it covers the entire education system and its elements.

Evaluation, on the other hand, is done by government agencies. On this basis, 34 different options arise. Experience shows that there are two forms of assessment, mainly internal and external. Internal assessment is primarily self-evaluation and mutual evaluation of teachers and students, internal quality monitoring, internal evaluation of educational programs is an internal evaluation of the educational institution. The application of the evaluation methods shown has led to the elimination of deficiencies and factors that negatively affect quality in higher education institutions, which they can. For example, during the academic year, faculty evaluation opportunities for students include seminars, lab evaluations, checks ("Passed Completely") during



discharge, during the submission of certain assignments, and so on. Finally, there are final examinations and performance reviews (if verbal or written, in the form of a test). Student assessments of instructors, on the other hand, are based on responses to surveys administered at least twice during the semester and on the results of individual faculty students' opinions of what an instructor might be like. In many cases, a faculty member's personal qualities may call into question the outcome of this evaluation. Therefore, attitudes toward students must be objectively governed by full internal discipline.

During the educational process, a democratic environment should be created in which students can inform themselves and the organizers of the educational process about their relationship with the teacher (inform him). In this case, measures can be taken to regulate the relationship between the teacher and the teacher. In general, the issue of self-esteem and self-control is one of the most discussed issues in the world. Methodological guidelines and recommendations do not yet exist. However, this is necessary during the period of introduction of continuous education. Internal monitoring can be carried out 2-3 times during a regular semester. The survey is conducted between students and a professor-teacher team. Each survey includes 10 to 12 questions. The goal is to fully cover the educational process. The goal is to evaluate each subject, textbook and learning materials, as well as the condition of the classroom, library, canteen, and so on. In other words, it is aimed at assessing the performance of all institutions that perform the functions of educational institutions. Since we are talking about teachers and students, it is in their interest to appreciate each other. It will be more effective if specific evaluation criteria are applied for each question. Results are generally timely for each faculty, governing body and service.

Internal curriculum assessment standards have been prepared by the Ministry of Education of Azerbaijan, and elective and vocational science education for higher education institutions is recommended to be included in the curricula. Education, on the other hand, primarily attracts educators and professionals. However, if education is to be universal, it will be aimed at defining the structure and content of education. There is a great need, as we say, for the development of standards for higher professional education. At least those who work in this process - employers, entrepreneurs, civic organizations, and so 36 Internal evaluations of 36 educational institutions are more applicable to institutions of higher education. Improving the efficiency of the educational process and the effectiveness of the governing body is a major factor.

According to the report prepared for the prose: - mission, purpose, - structure, content, duration and requirements of the Educational program, - the main goal of the direction of research, the results of scientific schools, - creation of quality system, - student body, success rate, assessment of the possession of the curriculum, their achievements, their success in the labor market and in continuing education, - main financial indicators of the management body and their provision, etc. should be taken into account. Assessment of individual achievement will address the Process in two forms:

(1) Final State Attestation.

(2) Evaluation of the quality of education (faculty). Despite the fact that there are many wishes for their work, they are still evaluated only by attestation.

The ISO governing body evaluates public institutions that are subjects of higher education. Other institutions of interest, teaching and educational institutions do not participate in the process of evaluating its work. 37 In conclusion, it should be noted that evaluating the work of an educational institution, identifying and improving the criteria for its quality, increasing its productivity, is unique to achieving high results. At the same time, it requires a rejection of

formalism, maximum objectivity and impartiality. In this sense, the human factor always comes first.

Conclusions

In the detention report, which is currently in Azerbaijan Institute for Standardization of Processes of All Educational Institutions in with the ISO requirement to ensure compliance with the quality of work in the field education. Also measurement and development algorithm ISM in OS. This process includes three subsequent steps: preliminary, preliminary and main.

By obtaining the ISO certificate, we will be able to:

- Improve your education system
- Hang in the glory of an educational institution
- Coexist with the existence of opportunities for all students, regardless of their affiliation, ethnicity or religion cultural background, gender, ability/disability.
- Provide individual training and selective response for all students.
- Stimulate excellence and innovation
- Make education more secondary (physical or online modifications).

ISO certifications for the education industry help schools systems to navigate in a complex and competitive environment, also help customers in the industry by implementing education industry standards.

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REGISTRATION METHODS OF CARDIAC ACTIVITY

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ABSTRACT

This article consists of an introduction, material and methods, analysis of heart rate variability, conclusion and a list of references. This paper is devoted to the development of a heart rate monitor model for diagnosing heart rate variability. The obtained estimates of the main parameters of uniform oscillations are the dynamic series. The obtained estimates of the kind of main parameters of uniform oscillations particularly are the for all intents and purposes dynamic series, which really is quite significant. In the methods for recording cardiac activity for all intents and purposes are considered: sphygmography, cardiography, echocardiography and phonocardiography, pulsometry, the processing of the for all intents and purposes signal recording system in a subtle way. With the help of analysis obtains information about the influence of the heart on the paper of the autonomic nervous system and also about a number of particularly humoral and reflex characteristics, so the obtained estimates of the very main parameters of uniform oscillations basically are the basically dynamic series in a subtle way. Matlab program automate processing of measuring. Finally describes the results of experimental studies and modeling of processes in the Multisim environment. A model of ECG signal processing in the Multisim13 software package was built and the ECG signal was simulated.

Keywords: Sphygmography, pulsometry, signal generation, comparative analysis, registrations, pulsogramm, heart rate.

Introduction

Based on the paper carried out, it can be noted that the sphygmography technique, which is one of the methods for recording cardiac activity on a graph, allows one to quickly obtain objective information about a number of diagnostic parameters that characterize the state of the cardiovascular system using a non-invasive method [1].

The graphic representation of fluctuations in the movements of the arterial wall during the cardiac cycle reflects the nature of the blood flow in the arterial system. Thus, the shape of the sphygmogram allows obtaining objective information about the functional state of this system. When forming a pulse wave, it is necessary to distinguish between cardiac and vascular components. The devices used to record the pulse wave are called heart rate monitors.

Material and methods

The purpose of the paper: the development of a heart rate monitor model for recording the activity of the cardiovascular system and analyzing pulse signals, it is necessary to perform the following tasks.

- graph of cardiac activity, comparative analysis of registration methods;
- study of existing methods of signal processing of impulse waves;

- simulation of impulse signals;
- development of algorithms to remove artifacts;
- designing a heart rate monitor to assess the performance of pulse waves;
- Generation of ECG signals and study of models.

Variability is the variability of heart rate in response to the influence of various parameters, including any factors. Indicators of heart rate variability allow you to give a general assessment of the patient's condition, reflect important indicators that control the physiological functions of the body. These indicators include functional reserves of control mechanisms and autonomic balance [2].

Analysis of heart rate variability. With the help of analysis, one can obtain information about the influence of the heart on the paper of the autonomic nervous system and about a number of humoral and reflex factors.

A single-channel ECG recording is carried out. With the help of these records, using software, sequential RR-intervals are calculated and a rhythmogram is built, which is influenced by physiological processes.

Then the RR-histogram of the distribution of intervals, the scatterogram are built and the indicators of descriptive statistics are calculated.

These indicators include RR-mean value of the interval, range of variations, heart rate, statistical deviations, mode and its amplitude.

Method of pulsometry

In this paper, we will consider the concepts of pulse and pulse wave, as we consider the issues of registration and analysis of pulse waves - the sphygmography method, which is one of the main methods of graphic recording of cardiac activity.

The pulse is the jerky vibrations of the walls of the arteries associated with cardiac cycles. Pulse wave is a wave of increased pressure that occurs when blood leaves the left ventricle during systole, propagating through the aorta and arteries. The force arising from the deformation of the aorta can be divided into two aggregates located perpendicular and parallel to the axis of the vessel. Normal accumulation ensures the continuity of blood circulation, while tangential (parallel) accumulation is considered the source of the arterial impulse. Figure 2.1 shows the process of recording a pulsogram. Aortic pulse wave velocity is of great interest in medicine. With age, the elasticity of the walls of the arteries decreases, and the speed of the pulse wave increases. For young individuals, the speed of propagation of the pulse wave is 5.5 - 8.0 m/s.

One of the methods for studying the pulse is sphygmography [3].

Sphygmography (Fig. 2.1) is a method of graphic registration of the arterial pulse.

On the sphygmogram, a sharp increase is distinguished - anacrotic (a), a decrease - catacrotic (C), as well as a dichrotic increase (DA) with a decrease. With anacrosis, there is a rapid outflow of blood from the left ventricle into the arteries. Catacrot corresponds to the period in the phase when the blood is removed naturally. During the catacrotic period, a downwardly directed teether called an orifice (incisura) occurs and it corresponds to left ventricular systole when the pressure is lower than in the aorta. At the lowest point of the incision, the aortic valve closes completely. At this time, the diastolic part (DA) begins. The subsequent decrease in the curve corresponds to the uniform flow of blood in the central vessels during diastole. Heart rate variability means its variability in response to physical, emotional stress and other external, internal factors. The closer it is to normal or slightly above average, the easier it is for the body to adapt to new conditions.



High values are in well-trained athletes, while maintaining a healthy lifestyle, when a person receives sufficient loads and recovers well after them. Low heart rate variability is typical for diseases: angina pectoris, myocardial infarction, diabetic polyneuropathy, changes in the heart muscle with increased pressure (hypertrophic cardiomyopathy). A decrease in the indicator to critical values indicates the risk of sudden cardiac arrest.

An increase is a sign of the body's readiness for stress, indicates the correctness of treatment for diseases. For the study, the method of rhythmography is used (ECG for 5 minutes and exercise or daily monitoring, Apple Watch). Data evaluation is carried out using methods of mathematical analysis. For example, a person's heart rate is 60 beats per minute. This means that one second passes between successive contractions. If there is variability, then one interval will be 0.8 seconds and the next 1.2 seconds. This is a simplified approach, but in fact, both the heart rate and the intervals between successive beats will change.

This is completely normal, because at rest the rhythm should become slower, and during physical, emotional stress it accelerates in order to improve the nutrition of the internal organs and the brain. Heart rate variability is one of the adaptive (adaptive) reactions. Therefore, the faster the heart changes rhythm, the better a person is adapted to survive in a variety of environmental conditions [4].

For example, in well-trained and endurance athletes, the heart is slow at rest, but during activity there is a significant acceleration very quickly. Similarly, after training, they need very little time to restore their original performance.

Processing of the signal recording system Pulse signal information reflects the following:

Pulse Wave Processing

Information about the pulse signal reflects:

- the shape of the pulse wave.

In studies, they find the relationship between various types of diseases and the values of the parameters of the shape of the pulse signal;

- dynamic changes in the parameters of the pulse waveform, i.e. oscillatory processes.

Automated methods for analyzing the pulse signal should include the development of processing algorithms for the analysis of both types of information. The implementation of these methods causes difficulties due to the specific features of the signals associated with a wide variety of signal shapes and the presence of artifacts.

The method for analyzing the rhythmic structure of the pulse signal of the radial artery consists of the following main steps:

1. Automatic determination of the characteristic points of single fluctuations of the pulse signal artifacts and a number of other factors.
2. Formation of dynamic series of amplitude and time parameters of characteristic points.
3. Calculation of statistical characteristics of the generated time series.
4. Evaluation of the degree of information content of the generated features and the construction of a diagnostic decision rule based on algorithms for classifying data analysis.

The results are a series of diagnostic data related to pulse signal parameters, such as pulse rate, arrhythmia degree, the ratio of sympathetic and parasympathetic regulation, the ratio of pulse rate and respiration, a number of parameters of the vascular system.

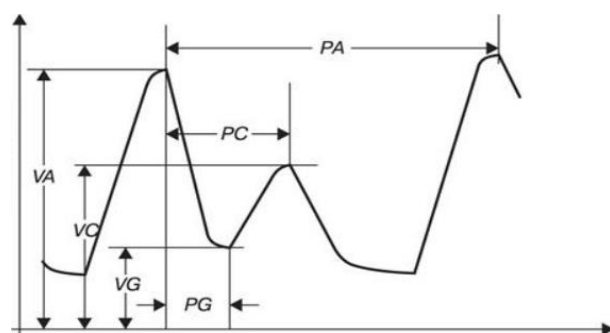


Figure 2.1: Pulsogramm

RA is the duration of the pulse wave, (PC - PG) – dicrotic wave rise time, PG is the catacrotic fall time.

In real signals (Figure 2.2), the amplitude of the main impulse wave is different.

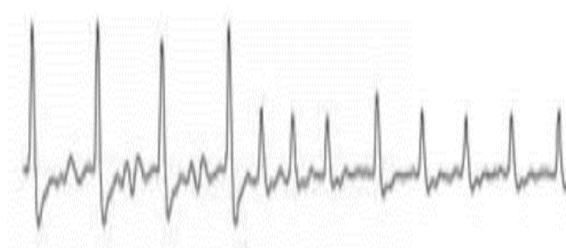


Figure 2.2: Real Signal

In this regard, the distribution of the detected fundamental waves on the time scale is then analyzed. If the distance between different adjacent teeth is greater than that of the cake (T_{avg} - the average duration of the period), then corrections (correction) are made for these areas.

The correction process is carried out as follows:

In non-periodic fields, the maximum amplitude is determined, and it is included in the list of main waves, after which the analysis of the distribution of their amplitudes on the time scale is repeated. This periodization algorithm is selected in almost all sampling periods of the studied pulsogram.

Minima in the basic quasi-cycle are analyzed in a similar scheme. The amplitude and time values of the main parameters are also evaluated. In this case, the amplitude prices are calculated taking into account the conditional zero, and the time parameters are calculated taking into account the time corresponding to the maximum value of the signal amplitude.

The obtained estimates of the main parameters of uniform oscillations are used to form the dynamic series. The generated time series is associated with subsequent statistical and structural analysis.

Variability is the variability of heart rate in response to the influence of various parameters, including any factors. Indicators of heart rate variability allow you to give a general assessment of



the patient's condition, reflect important indicators that control the physiological functions of the body. These indicators include functional reserves of control mechanisms and autonomic balance.

Analysis of heart rate variability

With the help of analysis, one can obtain information about the influence of the heart on the paper of the autonomic nervous system and about a number of humoral and reflex factors. A single-channel ECG recording is carried out. With the help of these records, using software, sequential RR-intervals are calculated and a rhythmogram is built, which is influenced by physiological processes.

Pulse signal processing

Primary signal processing is performed mechanically (manually). First of all, jumps with an amplitude of more than 300 mV and less than 25 mV and a time interval exceeding 0.9 seconds are eliminated (Figure 3.1).

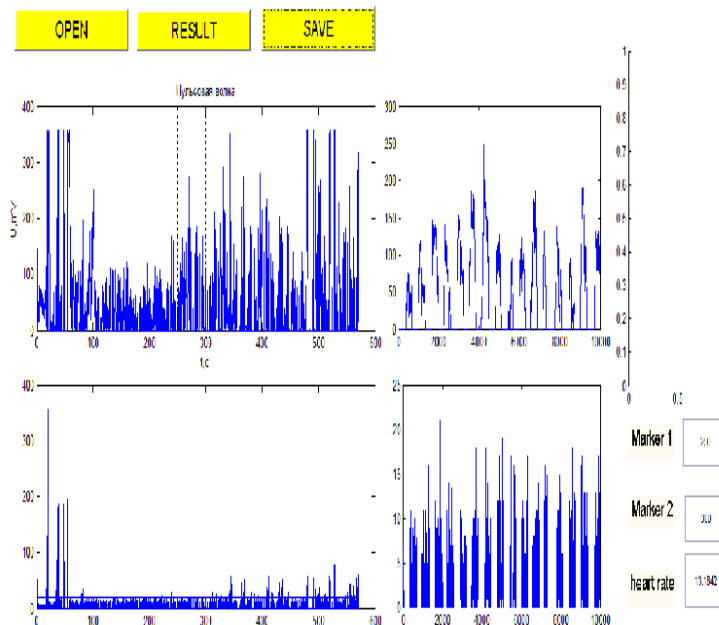


Figure 3.1. Initial Pulse

The differentiability of this signal is necessarily important in order to separate the spikes from the rest of the jumps in the signal. At this time, there is a problem with the fact that the jump does not occur instantly, but gradually.

Finally, before the differential, you need to reset the first 3 numbers before each bounce. The result is a signal about the occurrence of jumps at approximately equal time intervals [5].

This procedure takes a lot of time, and with a long registration it is quite difficult to carry out the primary processing manually. Therefore, there is a need to automate processing using the Matlab program.

It is necessary to bring the markers to the required amplitude and automatically eliminate the noisy part of the signal.

Programs are written like this:

1) to eliminate low-frequency noises that occur when the patient's body moves, it is necessary to replace the transmitter when the signal is removed. To do this, a trend is selected, which is separated from the initial signal. An example is shown in Figure 3.2

2) to clean up distortions, it is necessary to use small wavelength converters.

This signal differentiability is necessarily important for separating the peaks from the remaining jumps in the signal. The problem at this point is that the jump is gradual rather than instantaneous. Finally, before diffing, we need to reset the first three numbers before each bounce.

This step takes a lot of time and with long registrations it is very difficult to do it manually the first time.

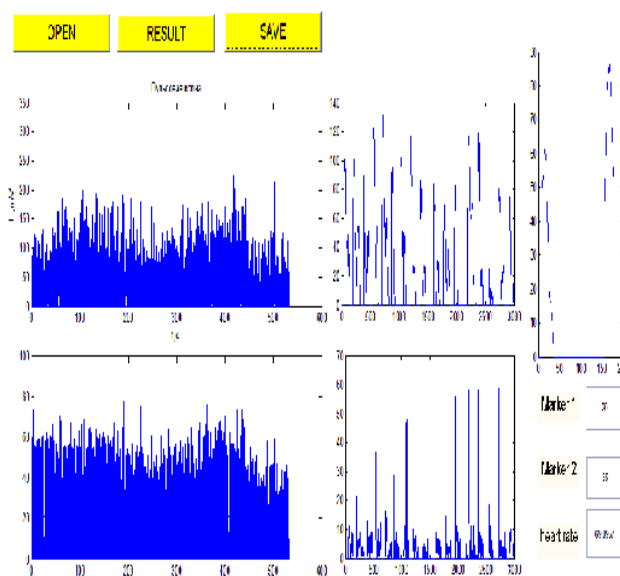


Figure 3.2: Pulse after manual treatment

Conclusion

In the final, methods for recording cardiac activity were analyzed: sphygmography, cardiography, echocardiography, phonocardiography, and the following results were obtained:

1. A comparative analysis of existing methods for processing pulsed wave signals has been carried out, and structural and principal electrical circuits of the heart rate monitor have been selected.
2. The technical characteristics of the functional elements included in the circuit diagram of the heart rate monitor are determined, the composition of the corresponding components is determined, and their modeling is performed.
3. An algorithm has been developed for processing impulse signals, determining their indicators and eliminating artifacts.
4. ECG signal processing in the Multisim13 software package, a model of the electrical circuit of the analog part of the processing device was built and the ECG signal was simulated.

The results obtained at this article can be used in the educational process, in the design of heart rate monitors and electrocardiographs.

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THE IMPORTANCE OF CHOOSING EFFECTIVE ADVERTISING IN THE PREVENTION AND PREDICTION OF HARMFUL HABITS AND SUICIDAL PROBLEMS IN THE EDUCATIONAL ENVIRONMENT

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ABSTRACT

Harmful habits are behaviors that are considered to have a negative impact on many people's health and prevent them from getting the benefit of their opportunities to achieve their goals throughout their life. There is a plethora of data about the most well-known individuals around the world who later died as a consequence of drug addiction. It is essential that those who end their lives by giving up a healthy lifestyle and accepting harmful habits realize the physical differences among health and illness in order to stop young people from taking this path. Obviously, those who elect this path do not read understanding and knowledge articles or watch commercials on suicide issues, but others who wish to assist such victims should be aware of them. The instructional model needs considerable support for young people who are prone to destructive habits and suicidal expressions since the sufferers of bad behaviors are serious patients. It's necessary to remain far from the surroundings wherever these tools are used, and if necessary, contact a specialist. It's necessary to not enable these deadly suggestions to destroy human life before the method has concentrated and addiction has begun. These habits not solely damage a human health, however conjointly stop them from achieving their goals and victimization their opportunities.

Keywords: Harmful habits, suicide, prevention, advertising, social networks, anonymous qualified helpers, individual characteristics, psychological services, gender, religion.

Introduction

Health is a condition that ensures normal functioning of a person in physical, psychological and social life. Health is a harmonious combination of physical, psychological and mental state. Every person who wants to live a healthy lifestyle should follow many steps. These rules include proper nutrition, constant strengthening of the body, compliance with hygiene rules, proper regulation of work and rest, and avoidance of harmful habits. A healthy person can give appropriate responses to environmental reactions. Unlike other living beings, man has the ability to change the environment around him and live according to this environment.

Diseases and effects caused by bad habits disrupt the internal environment of the body and create conditions for the development of various diseases. At this time, the body's resistance decreases, and the effect of psychogenic factors on the course of the disease increases. Harmful habits, which are the exact opposite of a healthy lifestyle and are the basis of an unhealthy lifestyle, seriously damage not only the person himself, but

also his family, the environment and the society in which he lives. The form and number of these habits are increasing and showing their negative effects on human society. Drinking alcohol and drugs, smoking are dangerous and widespread forms of harmful habits. These habits make a person's entire activity dependent on himself. The dangerous feature of harmful habits is that a



person becomes dependent on these tools, and a person cannot live without them. It is very difficult to get rid of these means and return to normal life. More dangerous are alcoholic beverages, drugs, toxic and psychotropic substances that have a lethal effect on the human body. A person who takes these drugs for fun does not realize that he is ultimately destroying his life.

Drug use destroys not only a person's health, but also his social and financial life. Psychotropic drugs, along with creating addiction in the body, damage individual organs, and then it is impossible to restore these organs with treatment. After a long time of use, a person becomes addicted to these tools without being dependent on himself. It should be noted that if harmful habits are cyclical, they eventually turn into diseases such as alcoholism, drug addiction, and drug addiction. The World Health Organization has compiled a list of dangerously addictive substances in the human body.

- alcohol-barbiturate-type substances - ethyl alcohol, barbiturates, sedative meprobamate, chloral hydrate, etc.;
- amphetamine-type substances - amphetamine, phenmetrazine;
- cocaine-type substances - cocaine and coca leaves;
- hallucinogenic substances - glyceride, mescaline;
- cat type substances - Catha ectulis Forsk;
- opiate-type substances - morphine, heroin, codeine, metan;
- ether type solvents - toluene, acetone, tetrachloromethane;

These substances, with the exception of ethereal solvents, are often used for therapeutic purposes and are addictive. In recent years, artificially produced drugs have become available, which have many times stronger effects than known drugs and are more unique [1].

Cigarette addiction also creates a serious addiction in the body. Nicotine and a number of toxic substances contained in cigarettes have a complex effect on the body and cause various diseases. Tobacco affects the central nervous system as a weak stimulant and antidepressant. 2-3 packs of cigarettes per day have a psychotic effect on the human body more than drugs. This effect is more dangerous at a young age, fogs the brain, and changes a person's behavior. Smoking addiction causes many diseases - lung cancer, gastric ulcer, myocardial infarction, hypertension, etc. causes diseases.

Actual statement of problem

Despite varied social advertisements concerning dangerous habits and their harmful finish, these habits have become a world unwellness of society. Degradation of temperament happens in those that area unit created sick by these habits. Drug use typically begins in adolescence. the explanations for victimization these tools area unit various:

- lack of sense of responsibility, internal discipline;
- the absence of a goal that someone has set for himself, the absence of a way of motivation;
- loss of certainty and confidence within the future;
- the teenager's lack of positive relationships together with his family, friends, schoolmates;
- basic cognitive process within the feeling of "forgetting" the issues of harmful substances.

Family and college should work along to stop these tools from getting into the lives of teenagers. it's necessary to create teenagers perceive however vital a healthy life-style is, taking into consideration their age characteristics and individual characteristics. As simple because it is to begin victimization harmful substances, it's terribly tough to cure addiction to those substances.

it's necessary to remain far from the surroundings wherever these tools area unit used, and if necessary, contact a specialist. it's necessary to not enable these deadly suggests that to destroy human life before the method has concentrated and addiction has begun. These habits not solely damage a human health, however conjointly stop them from achieving their goals and victimizationtheir opportunities [5].

Alcoholism happens once alcoholic drinks area unit taken for an extended time. Since alcohol-containing medication area unit neuro depressants, they weigh down the availability of atomic number 8 to the central systema nervosum. This, in turn, inhibits the activity of the brain, the coordination of movement and speech is disturbed. The brain ceases to perform logically, attention is distracted, and someone cannot be answerable for his actions. Alcoholism causes vas and canal diseases, particularly liver cirrhosis of the liver. Alcohol includes a venomous result on sex cells, disrupts the perform of endocrine glands. suprarenal gland pathology ends up in weakening of metabolism within the body and premature aging of the body. It has been scientifically established that the consumption of drinks with a little quantity of alcohol reduces the operating capability of someone by 5-10%. those that drink alcohol frequently on their days off have a 24-30% lower productivity. individuals engaged in mental work, World Health Organization have to be compelled to perform precise operations, seriously harm their work by drinking alcohol. It's known that the lifetime of alcoholics is 15-20 years but the lifetime of traditional individuals.

Hippocrates, the founding father of ancient drugs, noted that brain disorder, several medical specialty diseases, and schizophrenic psychosis occur thanks to the fault of oldsters World Health Organization took alcohol throughout the conception amount. The protection of human life isn't solely the task of life science, as a result of within the times their area unit several social and psychological reasons that directly have an effect on someone and that they area unit increasing. alland sundry ought to attempt to defend his health and observe preventive needs so as to take care of traditional life activities. For this, advertisements that cowl harmful habits and directly have an effect on the human brain ought to be enforced in universities.

One among the foremost serious issues facing human society is suicide. Suicide (Latin "sui cadre" to kill oneself) may be a deliberate act to finish one's own life severally and voluntarily. In fact, even considering death is tough for someone. Biologically, a healthy human brain doesn't settle for that it'll die someday. though he is aware of that everybody can die, together with himself, he doesn't deeply believe his own death. typically, there are cases of suicide over one thing that may be solved. Why do individuals kill and is it doable to stop these suicides? He sees that their area unit such a big amount of suicide cases around America, however by activity this subject and not giving it to the discussion of the society, we tend to do additional harm. Figure 1.

At present, suicide isn't a rare development in our life, it's been taking its place among the demographic events for an extended time. Contrary to the ostensibly innate instinct of saving all told living things, suicide has long occupied the thinking of the many researchers. Long before the science of suicide emerged as a life science, suicide was studied by philosophers, chroniclers, and historians [4].



Figure 1. Advertisements showing types of harmful habits and ways of getting rid of them

About one million suicides occur worldwide each year, and therefore the range of suicide tries has increased by concerning ten times in recent years. Suicides between the ages of fifteen and thirty-five area unit the second leading reason behind death once road accidents. Statistics show that the bulk of individuals World Health Organization die as a result of suicide failed to look for psychiatrically and psychological services for facilitate throughout their time period. Suicide, contrary to the saving instinct of all living things, has been studied by several researchers for an extended time. Long before suicidology emerged as a life science, suicide was studied by philosophers, chroniclers, and historians. From past to the current, philosophy has given nice importance to the matter of the acutely aware finish of life.

The subject "Suicide may be a social drawback of society" has relevancy, as a result of suicide is one among the eternal issues of humanity, it'll exist as a development throughout the time that man is on earth. the matter of suicide, in line with researchers, may be a utterly social science development. Suicide may be a advanced drawback, and therefore the study of this drawback began within the field of philosophy. Albert Camus believed that "there may be a extremely serious philosophical drawback, the matter of suicide. Deciding whether or not life is price living or not is respondent the basic question of philosophy. Everything else is secondary."

Suicides have taken their place among the events of the demographic chain for an extended time, however the matter of finding the optimum varieties of human behavior, the matter of suicide, is already within the minds of individuals. in line with social science studies, factors like climate, season, place of residence, age, gender, religion, economic normal of living, and political state of affairs have an effect on the entire range of suicide cases.

Since September ten, 2003, the globe Suicide bar Day has been celebrated so as to push suicide bar activities everywhere the globe. these days is widely known below the initiative of the International Association for the bar of Suicides, the support of the globe Health Organization and therefore the auspices of the international organization. in line with statistics provided by the globe Health Organization, within the third millennium, additional deaths were caused by suicide than by all wars and targeted killings. Taking into consideration the Covid nineteen pandemic,

studies area unit being conducted at the globe level to assume seriously concerning suicides and take necessary measures.

There are suicides all the time. There are a unit centers for obtaining out of important things in several countries of the globe. Suicides area unit most typical among adolescents and teenagers, thus it's acceptable to possess a district coping with these problems in youth organizations in faculties and universities.

Humanity doesn't gain something by activity the difficulties of life, in fact, the present issues ought to be investigated with full openness, then the responses ought to be shown. within the family, oldsters will share their kids' issues by establishing a friendly and trusting relationship with their children. Often, there's such advanced and tough surroundings within the family and society that someone doesn't have the physical and non-secular strength to face and fight. this can be the case all told countries of the globe, if their area unit individuals and life, there's conjointly competition and struggle. These problems ought to be seriously analyzed in social networks, the socio-psychological and social science basis of harmful habits and self-destructive events ought to be mentioned. Studies on the self-destructive behavior of adolescents in developed countries became a significant drawback. within the us and lots of European countries, adolescent suicide is one among the highest 5 causes of death among adolescents. in line with the results of studies, it's appalling that the present range of deaths among adolescents is second solely to suicide. As a rule, suicide tries begin at the age of thirteen. Suicides before the age of 12-13 area unit rare. From the age of 14-15, self-destructive activity will increase sharply and reaches a most at the age of 16-20. Suicidal behavior in adolescents is principally a transition amount drawback, that is caused by neuro-hormonal processes and body reaction states. Therefore, several suicides and suicide try area unit studied as "adolescence and youth crises". At this age, teenagers don't have the expertise to unravel the issues they face, they can't kindle facilitate from their families and relatives.

There is a unit terribly serious reason for this. Families themselves don't acumen to be friends with their kids, they are doing not have enough info for this. Education conjointly plays an enormous role here. If oldsters' area unit educated, they acumen to treat their kids on an individual basis. generally, we tend to bump into such cases that the precise suicide is beyond any doubt caused by the parent's treatment of the kid. in line with analysis, seventy fifth of individuals World Health Organization conceive to kill specific their self-destructive intentions in a way or another. Rarely, self-destructive intellection happens suddenly. nearly most of those individuals need to consult psychologists and doctors. generally, their opinions area unit unheeded, if they hear such individuals and share their pain, they most likely will not kill. Because, throughout a sincere language, the signs of planned suicide seem or the symptoms of depression seem. Such individuals board despair on the one hand, and hope for salvation on the opposite hand. it's doable to assist somebody World Health Organization needs to kill with straightforward words of support. If this can be not done, suicide won't be prevented. Therefore, it's important to grasp the signs of planned suicide. The fate of someone is said to the variability of events arising from the course of life. Every day, each second, we tend to create a selection in one direction or another, so leading the ways of our lives in one direction or another. It ought to be noted that their area unit parts of determinism in our life. we tend to cannot confirm ahead wherever, during which family and country we tend to area unit born, during which social level, during which health we tend to area unit born. Assessment of the role of biological factors in human life is additionally important. there's conjointly info concerning the role of heredity within the tendency to kill [3].



Suicidal behavior in kids and adolescents is one among the varieties of behavior and differs from the self-destructive behavior of adults by sure parts.

Description of suicide prevention among teenagers

A "call for help" is determined in ninetyeth of suicide cases in adolescence, solely 100% of adolescents need to commit real suicide.

The most typical causes of unsafe behavior in teenagers:

- feeling of not being understood, resentment, loneliness, feeling of alienation;
- feeling jealous of parental love, love towards different youngsters within the family;
- death of idolized ones, divorce, dangerous behavior of oldsters at home;
- guilt, shame, regret, pride hurt, ridicule, humiliation;
- worry of penalization, feeling of not apologizing;
- love failures, secretion sexual changes throughout puberty;
- feeling of revenge, anger, protest, threat, warning;
- the will to draw in attention, arouse sympathy, avoid unpleasant consequences and tough situations;
- sympathy or imitation of friends, book or moving picture heroes [1].

Suicidal behavior has modified thanks to the informatization of contemporary society. With the event of the net, the rise within the variety of individuals preferring virtual communication ends up in the disruption of human relationships in real world and therefore the emergence of depression. In times of crisis, a juvenile cannot satisfy the will to seek out associate interlocutor and discuss their issues, and that they will become victims of internet sites that promote suicide. It ought to be noted that "Suicide clubs" have existed since ancient times: in Ancient Egypt throughout the time of queen, in Federal Republic of Germany in 1819, in national capital in 1824, within the us at the start of the twentieth century, etc. however communities of virtual suicide supporters disagree from their ancient predecessors in their sizable amount and insufficiency. Geolocation and free access for individuals of any age on these sites is additionally a technique of attraction. the matter of virtual suicide exists everywhere the planet, beside the event of the net, the culture of virtual suicide has "emerged and formed". once learning the activities of those sites, it's determined that almost all of the guest's area unit children. Formally, these teams' area unit closed, however to induce info, you only ought to subscribe or write the cluster. the amount from the start of unsafe thoughts to the decide to carry them out is termed the presuicidal period; the individual is during a state of depressive have an effect on, his thoughts regarding suicide become stronger, his discontent with living conditions will increase.

This is often shown by the materials announce by the participants of virtual suicide clubs on their personal pages in social networks, they write that they're depressed and suffer from loneliness. Such a mood may be a fertile ground for a suicide proposal and offers a significant impetus to the event of a depressive mood, that is characteristic of the pre-suicide amount. Figure 2.



Figure 2. Advertisements promoting suicide prevention

Relatives or families of a depressed juvenile will browse this info on his personal page on the social network. In nowadays, voluntary organizations produce social networks and forestall suicide the maximum amount as attainable within the pre-suicide stage. The worst factor is that if the attractiveness is addressed to members of virtual suicide clubs, then the person doesn't suppose it: his alternative is confirmed and they begin to supply a fast and reliable technique of suicide. info regarding suicide ways and locations is straightforward to seek out on the net. All this makes it clear to the young man that society doesn't veto suicide, that he's superfluous. The content of virtual suicide clubs aims to draw in as several members as attainable. The danger of an individual's open access to such info is highlighted by the advice of the planet Health Organization. those who state the advantages of suicide within the virtual world increase the boundaries of non-public and public life and therefore the vulnerability of someone. Cyber mobbing, that facilitates the method of manipulation with the assistance of contemporary means that of communication, is strictly applied.

Cybermob Bing is dole out within the info house through info and communication channels and means that. as well as through e-mail, instant electronic communication programs on social networks (Instant Messenger), in addition as on video portals (YouTube, Vimeo, etc.) or through a portable. The perpetrators of those acts of bullying typically act anonymously so the victim doesn't apprehend UN agency the acts of violence area unit returning from.

Cybermob Bing or cyberbullying (Cyberbullying) characterizes actions or behaviors dole out by teams or people against a victim UN agency cannot defend himself. Defamation, insults, blackmail, and therefore the posting of obscene videos on the net haven't any geographical limits and may continue for a protracted time. it's unfeasible to forestall the dissemination of data during this content. At this point, crime is committed against someone, these days schoolchildren aged 11-16 area unit victims of crime, however adults may be victims of cyberbullying.

Cybercide is suicide iatrogenic by technology, like the synchronal suicide of many individuals when meeting on the net. victimization the net will result in suicide and, as a result, the amount of bierkellers. those who do not know one another get along and meet on the net and so get along

during a sure place and kill along. Additionally, to committing suicide on the net, there also are cases wherever users connected to the net kill through a digital camera in real time. In response to the mentioned and different similar cases, the question of the influence of the net on suicide has begun to be actively mentioned. On a sensible level, research project on cyberkillers remains in its infancy, and empirical proof that the net contributes to suicide rates is presently tokenish. One in all the primary cyber suicides began in 1997 in Israel, once 19-year-old soldier Eran Ateret expressed his need to kill on-line associated asked for elaborated directions on the way to bed with an M16 rifle. When receiving this instruction, he died. When this sensational event, SAHAR, a non-profit association was fashioned in Israel, whose goal is to forestall suicide by making associate anonymous, confidential on-line setting. Anonymous qualified helpers during this on-line setting provide support to individuals in crisis. In 2005, following a rise in cyber suicides, the police created a special unit of six cops to assist those who confessed on-line to kill. An infatuated section contacts forum moderators. UN agency area unit asked to follow informed reports of unsafe users. Regarding two hundred cases area unit detected per annum, that prevents dozens of suicides. World expertise shows that the foremost effective thanks to stop net-related suicides isn't to carry Internet suppliers and social network directors responsible, however to collaborate with them. This is often confirmed by the thriving implementation of the program developed in Israel in 2005. Volunteer teams of the SAHAR Foundation (SAHAR) try and hash out to assist those who state their issues on-line.

Within the 1st year of the program, quite 100 suicides have already been prevented. This effective technique has been studied and is presently utilized in Federal Republic of Germany, Scandinavian country and France.

The fight against cyber-suicides ought to begin from rising the standard of lifetime of the population, as a result of "cyber-suicide is simply one in all the symptoms of society's issues and it reflects its condition sort of a measuring system." Communication on the net will result in suicide, however the explanations for the increasing dynamics of the number of suicides among children ought to be wanted not within the virtual house, however within the globe.

Aid of this method, one is able to do their objectives. You ought to attempt to be a robust individual for this. Moreover, strength may be a quality that has to be attained, similar to the other. Suicide isn't associate option; instead, one ought to maximize use of their potential.

Conclusion

The Internet can serve two functions as a source of poorly managed information, including information that really is harmful and illegal. There are forums and groups on the Internet where young people become more and more popular in their suicides, and virtual reality enables supporters of youth culture who idealize death to come altogether. The ever-present lethal infection of suicide is disseminated by technological advances, as stated by psychologist Alexander Thostov [2, p. 64]. Cyberbullying and cybercide are activities that are spread through the Internet. It's critical to understand that using the Internet, a person's associated with depressive symptoms can be easily established and strengthened. Because the person who feels more alone in the virtual world than they do in fact. Because he will carry on playing the virtual game after committed suicide and become a hero online, for him, even death is merely some other episode in the game! Modern media, however, can have a positive impact on society and the individual, including decreasing suicidal ideation and preventing suicide (virtual psychological support services). The success of other societies in combat cyber suicides indicates that providing online

support to those contemplating suicide is more effective than using repressive methods to remove dangerous sites.

Since man is just so powerful, he can overcome anything. But confidence in one's own capabilities is essential. This can be done in a variety of ways utilizing psychology and psychoanalysis. Inoculation's healing benefits on patients (including healthy ones) were established by French psychiatrist Emile Kuye as early as 1921. Very few people are aware of the power of instillation in contemporary psychology. With the aid of this technique, one can achieve their objectives. You should strive to be a strong individual for this. Moreover, strength is a quality that must be earned, just like any other. Suicide is not an option; instead, one should maximize use of their potential.

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ISSUES OF TECHNOLOGICAL OPTIMIZATION OF CENTRALIZED COMBUSTION OF ASSOCIATED HYDROCARBON GAS FROM SOURCES WITH DIFFERENT CONCENTRATIONS OF METHANE

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ABSTRACT

A method for technological optimization of centralized combustion of associated hydrocarbon gas from sources with different methane concentrations is proposed. A technological scheme for the centralized combustion of hydrocarbon gas from sources with different concentrations of CH₄ has been drawn up. An optimization problem was formulated and solved, the solution of which, under a certain restrictive condition, made it possible to obtain the optimal relationship between the concentration of CH₄ in associated gas and wind speed. As a result of the optimization carried out, the optimal procedure for the functioning of the developed technological scheme for the centralized combustion of the associated gas was recommended. To determine the conditions for achieving the maximum functional efficiency of the proposed technological scheme, an optimization problem was compiled and solved, the solution of which, under a certain restrictive condition, made it possible to obtain the optimal relationship between the concentration of CH₄ in associated gas and wind speed. As a result of the optimization carried out, the optimal procedure for the functioning of the proposed technological scheme for the centralized combustion of associated gas from various sources was developed.

Keywords: Harmful habits, suicide, prevention, advertising, social networks, anonymous, qualified helpers, individual characteristics, psychological services, gender, religion.

Introduction

As noted in [1], due to the lack of detailed information on the combusted hydrocarbon gas volumes in the areas of production, storage and hydrocarbon processing, satellite tools are the most informative regarding the implementation of control over the global scale of gas flaring. According to the estimates of various international and governmental agencies, the Russian Federation is one of the main countries in terms of the amount of associated hydrocarbon gas flared. The total volume of flared gas in the Russian Federation according to [1] is 23 billion cubic meters, of which 19 billion cubic meters belong to the oil and gas industry, which is about 15% of the entire global scale of gas flaring on the planet.

Historically, the first work on satellite monitoring of gas flares was carried out on the basis of data obtained using the DMSP [2,3] and TIROS-N [4] programs. In the Russian Federation, similar studies were carried out on the basis of data obtained from spectroradiometers in MODIS [5].

According to NOAA (USA), in 2015, 13,605 gas flares located in 88 countries were detected by satellites [6]. According to the estimates given in [6], about 140 billion cubic meters of gas are burned per year, and as a result, 300 million tons of CO₂ are emitted into the atmosphere, as well as a large amount of aerosols and various small harmful gases, which generally stimulate the process of climate warming on the planet. In [7], a method for estimating the volume of

combusted hydrocarbon gas in flares was described, based on data obtained from the VIIRS spectroradiometer installed on the Suomi-NPP satellite [8, 9]. Let us briefly outline the theoretical foundations of this technique, which is based on the regression relationship between the flare power determined by satellite means and the volume of flared gas. This regression relationship looks like:

$$V=0.0247 \cdot W, \quad (1)$$

where: - volume of flared gas, in cubic meters; W is the power of the gas flare in megawatts.

According to Stefan Boltzmann's law

$$W=\sigma T^4 S, \quad (2)$$

where: - temperature in K; S is the surface area of the source; Stefan-Boltzmann σ -constant.

As was shown in [10], there is a non-linear relationship between the W and S indicators in the form

$$W=\sigma T^4 S^{0.7}. \quad (3)$$

It is well known that the completeness of combustion of hydrocarbon gas in flares is of particular importance, because, during incomplete combustion, a significant amount of such gases as CH_4 , NO_x , SO_4 , etc. is emitted into the atmosphere [11,12].

Issues of the negative impact of incomplete combustion of associated gas in flares were considered in [13-16]. According to [16], the efficiency of hydrocarbon gas combustion in flares can reach 98% or more. According to [17, 18], combustion efficiency depends on the stability of combustion conditions, which in turn depends on the energy content of the combusted gas and wind speed.

As indicated in [19], a technique and a corresponding special software tool were developed for calculating the efficiency of gas combustion, which was based on the results obtained in [17]. In this work, CO and NOx emission factors were calculated based on the UNIPCC [20] and USEPA [21] recommendations.

Summary of the current methodology for calculating the efficiency of hydrocarbon gas combustion.

Let us briefly outline the technique developed in [17].

According to [19], in order to accurately calculate the efficiency of hydrocarbon gas combustion, the moisture content in this gas should be taken into account. In this case, the concentration of water vapor formed during gas combustion is calculated by the Raolts formula

$$W = \frac{P_w}{P_0} \cdot \frac{H(\%) }{100}, \quad (1)$$

where P_w - is the water vapor pressure (kPa);

P_0 – barometric pressure (kPa);

H is humidity, in%.

Water vapor pressure according to [18] is defined as

$$P_w(kPa)=\exp\left[16.262-\frac{-3799.89}{T(^{\circ}C)+226.36}\right], \quad (2)$$

where $T(^{\circ}C)$ – is the temperature in Celsius.



After determining the concentration of water vapor, the moisture concentrations are calculated in such gas components as CH_4 , CO_2 , etc. Next, the molar mass of the gas mixture and the lower value of the heating index (LHV) are calculated. According to [19], methane

$$\text{LHV}_{\text{CH}_4} = 50.009 \frac{\text{MJ}}{\text{kg}} \cdot \quad (3)$$

where CH_4 is the concentration of CH_4 ; m are the molar masses of CH_4 and gas.

According to [17], taking into account (1)-(4), the overall efficiency of hydrocarbon gas combustion can be calculated by the formula

$$X = \frac{V_b \left(\frac{\text{m}}{\text{сек}} \right)}{V_{\text{gas}} \left(\frac{\text{m}}{\text{сек}} \right) \cdot g \left(\frac{\text{m}}{\text{сек}} \right) \cdot D(\text{m})^{\frac{1}{3}}} \cdot \quad (4)$$

where V_b is the wind speed; V_{gas} is the gas supply rate; D is the pipe diameter.

It was shown in [17] that on the basis of expression (5) it is possible to obtain the following expression for estimating the efficiency of hydrocarbon gas combustion.

$$E = 1 - \left(0.00166 \left[\exp(0.387 \cdot X_1) \right] \cdot \frac{\text{LHV}_{\text{CH}_4} \left(\frac{\text{MJ}}{\text{kg}} \right)}{\text{LHV}_{\text{нзлмг}} \left(\frac{\text{MJ}}{\text{кг}} \right)} \right) \cdot \quad (5)$$

Taking into account expressions (5) and (6), we have developed a special technique for optimizing gas combustion conditions to achieve the highest combustion efficiency.

Suggested method

Taking into account formulas (5) and (6), we obtain

$$E = 1 - \left(0.00166 \left[\exp \left[0.387 \cdot \frac{V_b \left(\frac{\text{m}}{\text{с}} \right)}{V_{\text{gas}} \left(\frac{\text{m}}{\text{с}} \right) \cdot g \left(\frac{\text{m}}{\text{с}^2} \right) \cdot D(\text{m})^{\frac{1}{3}}} \right] \right] \cdot \frac{\text{LHV}_{\text{CH}_4} \left(\frac{\text{MJ}}{\text{kg}} \right)}{\text{LHV}_{\text{gas}} \left(\frac{\text{MJ}}{\text{кг}} \right)} \right) \quad (6)$$

Taking the indicators in (4):

$$m(\text{CH}_4); \text{LHV}_{\text{CH}_4}; m_{\text{gas}} \quad (7)$$

as well as indicators in [17]:

V_{gas} , g , D , LHV_{CH_4} as constant values, expression (7), taking into account (4), we rewrite as

$$E = 1 - \frac{a_1}{C_{\text{CH}_4}} \left[\exp(a_2 V_b) \right], \quad (8)$$

where

$$a_1 = \frac{0.00166 \cdot \text{LHV}_{\text{CH}_4} \cdot m_{\text{gas}}}{m(\text{CH}_4) \cdot \text{LHV}_{\text{CH}_4}}, \quad (9)$$

$$a_2 = \frac{0.387}{V_{gas} \cdot g \cdot D^{\frac{1}{3}}} \cdot \quad (10)$$

According to the proposed method, the associated gas flaring facility under consideration serves several sources of such gas with different methane content. The technological scheme of the proposed method for organizing the centralized combustion of associated gas is shown in fig. 1.

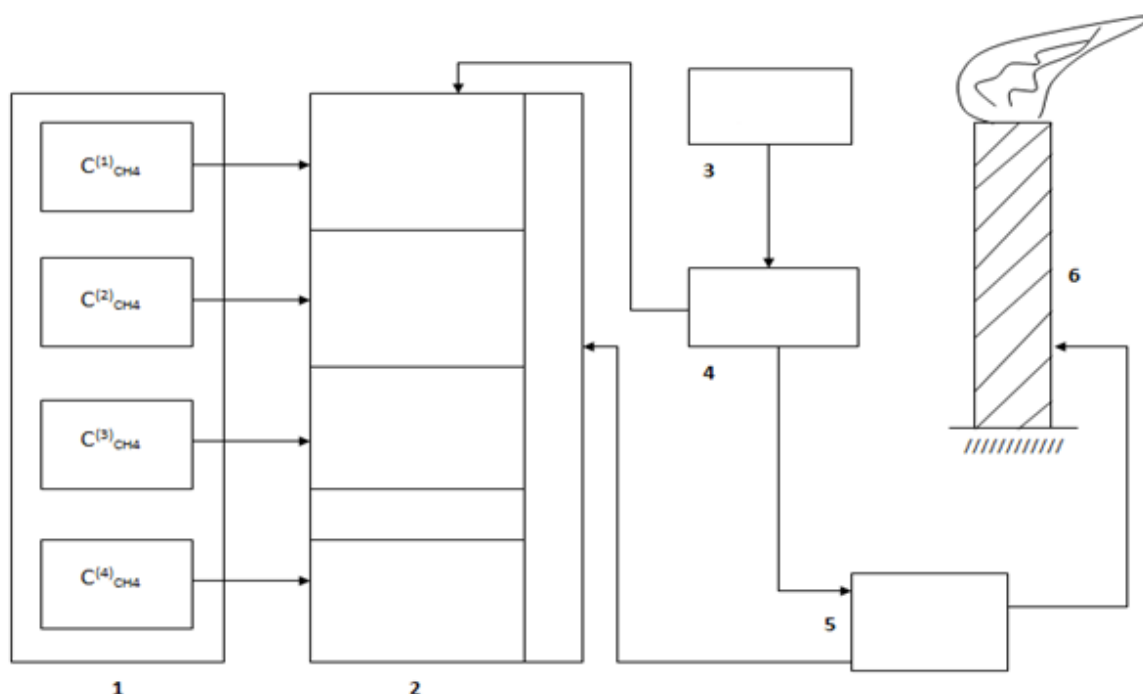


Figure 1. The proposed technological scheme for burning associated gas from different sources, taking into account the magnitude of the wind speed.

The numbers indicate: 1 - many sources of associated gas; 2 – associated gas accumulators with controlled output; 3 – wind speed meter; 4 - control system; 5 - block for supplying gas to the pipe; 6 – gas flaring pipe.

The general principle of the proposed methodology and the corresponding technological scheme of associated gas flaring is based on expression (8), according to which, in order to maintain an average high value of E , with an increase in V_b , compensatory control of the C_{CH_4} value should be carried out by supplying a mixture from one or another source of associated gas to the pipe. Therefore, it is important to find the optimal procedure for selecting associated gas sources, which achieve the maximum efficiency of gas combustion.

Sharing laser power and solar panels on drones Optimization of the proposed technological scheme for flaring associated gas from various sources.

Let us assume that for centralized combustion of associated gas produced in equal volumes at different sources, all sources are divided into n number of groups. CH_4 concentrations in associated gases included in these groups make up an ordered set



$$C_{CH_4} = \{C_{CH_4}^{(i)}\}, \quad i = \overline{1, n}. \quad (11)$$

where

$$C_{CH_4}^{(i)} = C_{CH_4}^{(i-1)} + \Delta C_{CH_4}; \quad \Delta C_{CH_4} = const, \quad C_{CH_4}^{(0)} = 0. \quad (12)$$

In this case, conditionally accepting, we compose the following optimization functional

$$F = \int_{CH_4(\min)}^{CH_4(\max)} \left[1 - \frac{a_1}{C_{CH_4}} \left[\exp(a_2 V_b(C_{CH_4})) \right] \right] dC_{CH_4} \quad (13)$$

where $V_b(C_{CH_4})$ is the input communication (control) function, the optimal form of which should provide maximum F .

In the general case, problem (13) does not have a general solution, and to calculate the solution, taking into account the narrowing of the class of possible solutions, we assume that the sought-for optimal function must satisfy the condition

$$\int_{CH_4(\min)}^{CH_4(\max)} V_b(C_{CH_4}) dC_{CH_4} = C; \quad C = const. \quad (14)$$

Taking into account expressions (13) and (14), we form the target functional of unconditional variational optimization

$$F_0 = \int_{CH_4(\min)}^{CH_4(\max)} \left[1 - \frac{a_1}{C_{CH_4}} \left[\exp(a_2 V_b(C_{CH_4})) \right] \right] dC_{CH_4} + \lambda \left[\int_{CH_4(\min)}^{CH_4(\max)} V_b(C_{CH_4}) dC_{CH_4} - C \right] \quad (15)$$

where λ is the Lagrange multiplier.

The solution to the optimization problem (15) according to [12] must satisfy the condition

$$\frac{d \left\{ \left[1 - \frac{a_1}{C_{CH_4}} \left[\exp(a_2 V_b(C_{CH_4})) \right] \right] + \lambda [V_b(C_{CH_4}) - C] \right\}}{d[V_b(C_{CH_4})]} = 0. \quad (16)$$

To simplify the mathematical calculations, we take

$$C_{CH_4}(\min) = 0. \quad (17)$$

Taking into account (16) and (17), the solution of the problem is obtained in the form

$$V_b(C_{CH_4}) = \frac{1}{a_2} \ln \frac{\lambda \cdot C_{CH_4}}{a_1 \cdot a_2}, \quad (18)$$

where λ - can be determined by substituting (18) into the integral (14) and calculating taking into account the given value C.

Thus, solution (18) provides the extremum of the objective functional (15). To determine the type of extremum, it suffices to take the second derivative of the integrand in (15) with respect to the desired function and make sure that it has a negative sign, i.e. extremum is the maximum. Therefore, in the optimal case, in the proposed centralized combustion process scheme, a logarithmic relationship between V_b and CCH_4 should be provided by measuring V_b and supplying gas from the corresponding source to the pipe.

Conclusions

Thus, based on the results of well-known studies of the dependence of the efficiency of burning associated hydrocarbon gas in flares on wind speed, methane concentration in associated gas, and other indicators. A technological scheme is proposed for centralized combustion of associated gas from various sources, where the concentration of CH_4 in them is different. To determine the conditions for achieving the maximum functional efficiency of the proposed technological scheme, an optimization problem was compiled and solved, the solution of which, under a certain restrictive condition, made it possible to obtain the optimal relationship between the concentration of CH_4 in associated gas and wind speed. As a result of the optimization carried out, the optimal procedure for the functioning of the proposed technological scheme for the centralized combustion of associated gas from various sources was developed.

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SURFACE TEMPERATURE REDUCTION METHODS BRAKE PAIR FRICTION

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ABSTRACT

One of the promising industries is oil engineering, the main task of which is the creation of drilling equipment of increased reliability and durability. A band- block brake (LKT) is one of the main units of hoisting and transport machines and equipment widely used in the oil, gas, mining industry, construction and transport. LCT, which has a number of advantages, differs sharply from other types of brakes. We have rich oil and gas deposits in the republic, which are located in deep and hard-to-reach places. During braking, all factors and parameter values, depending on their interconnected action on each other, change to a large extent, which further complicates the friction process. It is also known that, depending on the materials used, the design of the brake and the operating conditions, there is a sharp change in the friction parameters, especially in braking devices operating under heavy loads. Considering the complexity of the nature of the braking process, the deep analysis shows that, along with the interrelated action of various factors, depending on the design, materials of friction pairs and operating conditions of a given brake, the main dominant factor may be the temperature factor that occurs on the friction surface during the braking process.

Keywords: Thermal spots, nozzles, friction, retenax material, temperature, brake pairs, cooling, loading, band-block brake, brake pulley friction surface.

Introduction

The conducted experimental studies show that without forced cooling, high temperatures arise on the friction surface of brake pairs, which causes a sharp decrease in the quality of the friction surface and, in general, negatively affects the efficiency and reliability of the braking process. To reduce the temperature of the friction surface during braking and create a favorable working condition for the brake, researchers have proposed various methods and designs for forced cooling of the friction surface of brake pairs. In view of the imperfection and inefficiency of the proposed methods and structures for the full cooling of the friction surface of brake pairs, they have almost not found their application in a band- block brake to date. Therefore, it became necessary to develop a new method and design of a system for forced cooling of the friction surface of the brake pairs of a band-shoe brake, which, when used, would enable efficient cooling during braking. For this purpose, a new design of the forced cooling of the friction surface of the brake pairs of the band- block brake during braking was protected by a patent [1, 2, 4]. A technique has also been developed for testing a new design on a following test was carried out with the measurement of the temperature of the friction surface through the experimental

installation of a band- block brake. The proposed design of the cooling system for a band-shoe brake has an air-cooling device and is designed for uniform cooling around the entire perimeter of the friction surface of the brake pulley after each shoe during the braking process. To do this, compressed air is supplied to the slots formed between the pulley, the brake band and the pads from 2 sides along the width of the brake pulley, in a checkerboard pattern so that after cooling it is possible for air to escape in front of the nozzles. The proposed design is shown in (Fig. 1). It contains a brake pulley 1, a brake band 2, brake pads 3, mounted on carriages 4, an air-cooling device with a main pipeline 5, fixed clamps 6 on the brake housing from the side of the tape, with distributing nozzles 7 placed on them on both sides. The design of the cooling system of the band-shoe brake works as follows. Compressed air is supplied to the main pipeline, from here to the friction surface of the pulley, through dispensing nozzles placed along the width of the tape on both sides between the shoes in the slot on the pipeline.

Bodies of the brake pairs in the following order: on both sides of the brake pulley and in the middle part of the block without and with the use of cooling from one and 2- x sides.

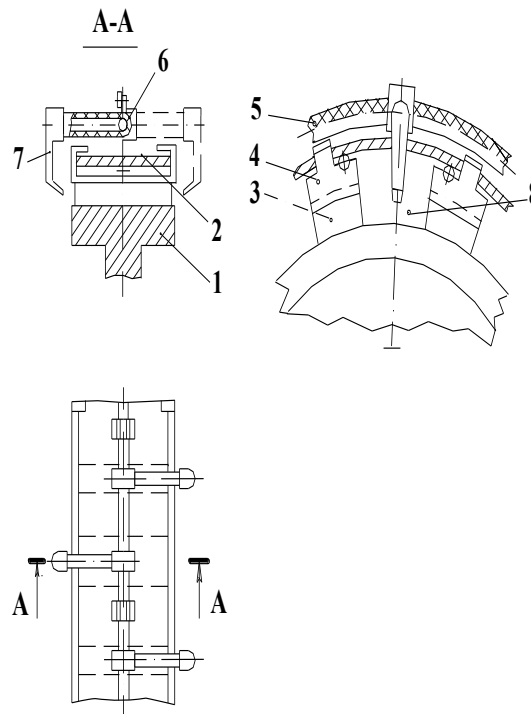


Figure 1: The device for cooling the friction surface is tape- block brake

When this compressed air is sent to the slot 8, with the possibility of exit after cooling in both ends of the tape 2 hot air. Slots for compressed air inlet and hot air outlet were formed between the pads around the brake pulley (1), created on both sides of the carriage (4) with pads (3), the surface of the pulley and the belt. In front of all nozzles, one side of the slots was left open [4, 10].

Tools to reduce friction surface temperature at local levels.

To install thermal sensors that determine the temperature of the friction surface of the band-shoe brake, on the brake pulley at the ends on both sides, at a distance of 0.5 mm from the friction surface, pre-drill o determine the effectiveness of the proposed cooling system on the installation of a band.

The measurement of the temperature of the friction surface during braking is carried out using temperature sensors that were prepared in advance. Then, using the calibration graph (Fig. 2), the value of the temperature of the friction surface of the rim of the brake pulley is determined along the width. For this, a certain cycle of operation was first chosen and its mode was worked out, which consists of the time spent on the braking process and the time between braking processes.

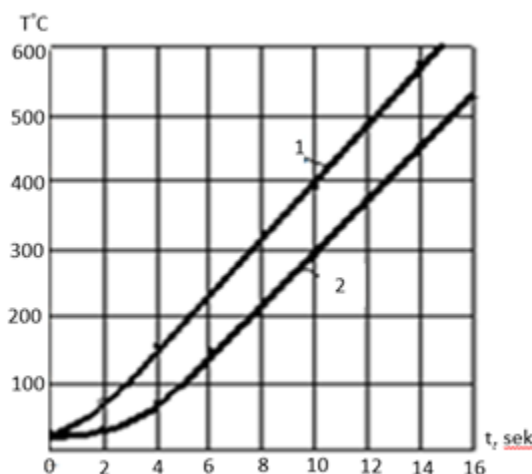


Figure 2. Calibration schedule brake pulley temperature depending on process time braking (1-on friction surface; 2-in depth)

The worked cycle of work was achieved by repeated repetition of braking and its values for all cases were taken to be the same. Measurement of the temperature of the friction surface is carried out according to the developed method, in the following three directions. 1. Measuring the friction surface temperature of the brake pulley without forced cooling. 2. Measurement of the temperature of the friction surface of the pulley with forced cooling on one side. 3. Measurement of the temperature of the friction surface of the pulley with forced cooling on both sides. During the experiment, the ambient temperature was 8-10° C. At the beginning, the friction surface temperature of the brake pulley in the selected mode was measured without cooling. Then, without changing the mode of operation of the brake, the temperature of the friction surface of the brake pulley was measured from both sides with cooling after each pad from one and both sides. To do this, compressed air is supplied to the pipeline, from there compressed air is directed to the dispensing nozzles placed on the pipeline and through them in a checkerboard pattern along the width of the tape, from one and both sides between the pads in the slot on the surface of the brake pulley after each pad. The slots are formed between the pulley, the belt and the blocks fixed on the carriages, and one side of the slot in front of each nozzles with the possibility of hot air outlet was left open [8, 12].

The results of the experiment, cooling the friction surface of brake pairs, are shown in (Fig. 3.). The nature of the temperature change during the braking process, depending on the time of increase, and cooling relative to the previous positions is shown by thin lines in (Fig. 3.).

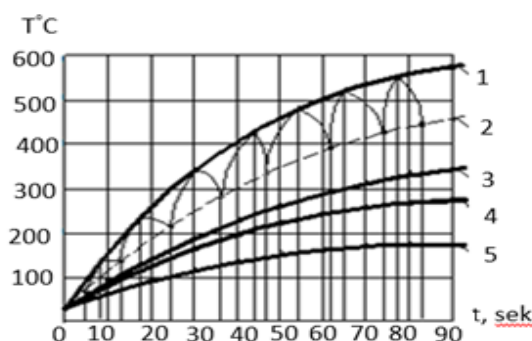


Figure 3. Graph of the dependence of the temperature of the friction surface of the pulley on time: 1 - during braking, without cooling of the friction surface; 2 - during cooling, without cooling the friction surface; 3 - at the outlet, with one side of the friction surface cooling; 4 - at the inlet, with one side of the friction surface cooling; 5 - with bilateral cooling of the friction surface

From these graphs it can be seen that with one-sided cooling of the friction surface of the brake pulley, the width at the inlet and outlet of the compressed air has a different temperature, and compared to without cooling, it turns out to be significantly lower. This is explained by the fact that with one-sided cooling of the friction surface of the brake pulley, compressed air removes heat from one side of the friction surface at the inlet, increases its value and displaces it in a warm form to the outlet in the other direction. With double-sided cooling, the friction surface of the brake pulley heats up much less than in previous cases and does not have a temperature gradient across the width, since the friction surface of the brake pulley is uniformly cooled around the entire perimeter after each pad in a checkerboard pattern. It should be noted that with this method of cooling, the friction surfaces of the brake pairs are simultaneously also cleaned of wear product [10].

The table shows that as the speed of the brake shaft and the load of the pulley increase, the temperature of the friction surface increases and reaches 630°C. Subsequently, with an increase in temperature, when it reaches the limit of 800-900°C, there is a significant change in the quality of the friction surface and, subsequently, the braking efficiency decreases sharply [10, 11].

Table 1. The results of measurements of the temperature of the friction surface through brake pulley body.

Flywheel load N,H	Brake shaft speed min, ⁻¹				
	20	40	63	80	100
	Brake pulley friction surface temperature, T ⁰ C				
20	52	110	170	190	210
30	70	130	210	270	370

40	85	165	270	350	450
50	95	190	350	480	530
60	105	315	380	520	630

Table 2. The results of measurements of the temperature of the friction surface through brake pad bodies.

Flywheel load N,H	Brake shaft speed min, $^{-1}$				
	20	40	63	80	100
	Friction surface temperature of brake pads, $T^{\circ}\text{C}$				
200	40	100	155	175	195
300	60	122	195	245	335
400	75	155	255	325	415
500	88	175	330	455	495
600	95	200	360	490	600

At the same time, it was found that the number of microcracks on the friction surface of the brake pulley increases, and the first signs of thermal spots appear. And on the surface of the block, cracks also increase and there are places where particles of retenax material are pulled out. On the friction surface of the brake pulley along the entire perimeter, especially in the middle part, the cracks were $\sim 1000\text{-}3000\ \mu\text{m}$ in length and $\sim 20\ \mu\text{m}$ in width (Fig. 3.4). On the surface of the pads, the sizes of cracks were large compared to the brake pulley and amounted to $\sim 3000\text{-}5000$ microns in length and $\sim 2000\text{-}3000$ microns in width. At high loads that occur in heavily loaded friction units, such as a draw works band-shoe brake, from the braking process, the temperature on the friction surface rises sharply, which leads to strong heating of the elements of the friction pair. And this affects the change in frictional properties, the quality of the friction surface: the geometric and physical-mechanical properties of the surface layer, and also creates the necessary conditions for the formation of micro and macrocracks, thermal spots on the working friction surface of the brake pulley. The presence of thermal spots on the friction surface of the brake pulley, due to their deepening, further increases the discreteness of the process of contacting the surfaces of brake pairs, which leads to a direct change in the actual contact area and the pressure of the pads on the brake pulley rim. As can be seen, at high speeds of the brake shaft and the presence of a large load, a high temperature can occur on the friction surface of the band-shoe brake, which, of course, has a significant impact on the parameters characterizing the quality of the friction surface: geometric and physical-mechanical properties of the surface layer. This creates conditions for changing the hardness of the surface layer of the brake pulley, which causes the formation of thermal spots and adversely affects the magnitude and stability of the coefficient of friction [8].



Figure 4. Brake pulley friction surface with microcracks and partial thermal spots.

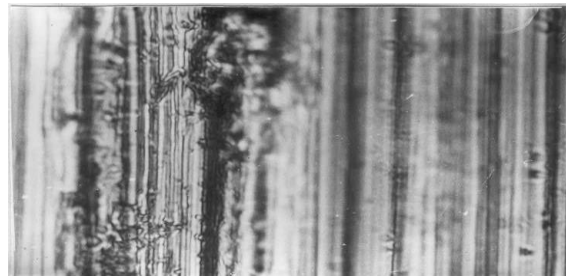


Figure 5. Brake pulley friction surface with adhering particles from the pad material Retenaks FK-24A.

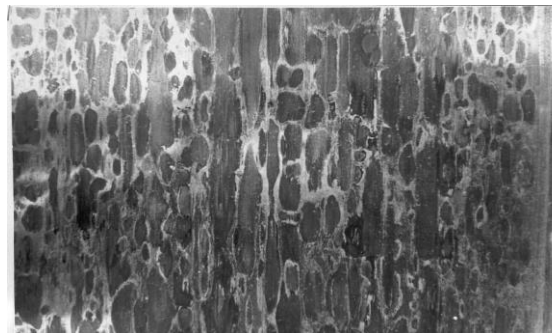


Figure 6. The surface of the brake pulley of the band-shoe brake of the draw works, worked out in severe conditions.

Conclusions

1. The review of the work shows that with the advent of the band-shoe brake in various industries, for a long time the main problem was to ensure the rational distribution of pad pressure on the pulley rim, to find ways to improve the efficiency and reliability of the braking process. One of the disadvantages of this design is the instability of existing and emerging parameters and changes in their values.
2. Direct fastening of the pads to the brake band leads to an uneven distribution of pad pressure on the pulley rim and creates additional problematic tasks. These important problems are solved with the use of forced cooling of the friction surface on the new design of the band-shoe brake, where the pressure of the shoes on the pulley rim is evenly distributed.

3. Comprehensive experimental studies carried out with different modes on a new constructions, under the action of interrelated basic parameters, show that this the design provides not only uniform distribution of temperature, pad pressure on the pulley rim, uniform wear of all pads; efficient and rational cooling friction surfaces, but also stripping
4. Guided by the results of the conducted research and the position of the theory of "dry" friction, theoretical foundations have been established on the mechanism of formation of thermal spots and cracks on friction surfaces of the brake pulley and pads. Consistently and in detail formation of thermal spots, the process of adhesion and setting of friction surfaces brake pairs. Their physical structure is explained.

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CALCULATING THE UNCERTAINTY OF MULTI-FUNCTIONAL EQUIPMENT AND PREPARATION OF THE UNCERTAINTY BUDGET

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ABSTRACT

Measuring uncertainty is not easy to calculate. Due to the large number of factors and parameters affecting the process during uncertainty assessment of complex objects, it is necessary to perform a correct assessment. In automated processes and automatically controlled systems, the factors affecting the measurement result are different. Engineers have trouble estimating uncertainty. Therefore, it is necessary to disclose an exclusive six-step process to calculate the measurement uncertainty and put together these instructions. Learn how to calculate measurement uncertainty in six easy-to-use steps. Also, what information is needed to calculate the uncertainty, how to obtain the uncertainty capability, and how to use calculations to obtain an overestimation or underestimation of the uncertainty. In addition, you can get some exclusive tips to help you calculate uncertainty like a pro with the help of the extract. Both production equipment and production systems can never be completely described or predicted. It is a contradiction for an engineer to get an accurate measurement and get the process right. Even if the engineer performs the measurement at a very high level, there will still be additional effects on the measurement result and the measurement process. Accordingly, this article can be used to estimate uncertainty.

Keywords: Uncertainty, uncertainty calculation, distribution, budget, standard deviation, A and B type of uncertainty, expanded and combined uncertainty.

Introduction

With scientific and technical progress in the field of measurement, the calculation of uncertainty, one of the new terms, added several innovations and advantages to the calculation results in the scientific field. Calculating errors and determining their impact on measurement results does not provide accurate results. For this reason, it is necessary to calculate the uncertainty in the measurement process and add (subtract) to the measurement result. In this section, let's clarify the nature of uncertainty and the issues of calculating its types. The term uncertainty should not be confused with error. As we know, the error is the difference between the measured quantity and the actual value. However, it can have both positive and negative effects on the measurement result under the guise of uncertainty.

The uncertainty is divided into 2 main types. Type A uncertainty and type B uncertainty. Let's look at the broad explanation of these types. A type of uncertainty is one that can be recognized by statistical analysis.

- Mean value of measurements;
- Standard Deviation;



- Distribution around the mean

There are different methods used to calculate A type uncertainty.

- Repeatability test (single);
- Repeatability test (multiple).

An example of a repeatability test can be performed by making repeated measurements at 10 points.

Type B uncertainty can be collected from the data statistically. It can be determined by means but the process is different from Type A uncertainty measurements.

- Type B uncertainty is related to the presence of systematics.

There is various source of data that you use to assess B Type uncertainty.

- Reports;
- Calibration certificates;
- Articles;
- Manuals;
- Engineers' notes;
- Datasheets;
- Excel files;
- Conference materials;
- Experimental results.

Since multiple sources of information are used throughout the measurement process, type B uncertainty can come from multiple datasheets. Thus, when assessing type B uncertainty, experts can use couple different methods

When type A uncertainty is calculated and added to the measurement result, it is possible to reduce the effect of random errors. Systematic errors can be avoided when type B uncertainty is calculated and added to the measurement result. When calculating the standard uncertainty, 67.8 percent and 95 percent when calculating the expanded uncertainty are obtained.

Normal distribution (also called Gaussian distribution) is used to evaluate uncertainty. Normal distribution is a symmetrical form around the mean value. Six main types of distribution are used in science. Normal distribution is preferred when estimating uncertainty.

- Normal;
- Uniform;
- U Shaped
- Log normal;
- Triangle;
- Quadratic.

The rectangular distribution is more commonly used by engineers to estimate uncertainty. Because all results have same probability to happen.

U shaped distribution means head points of the range are most likely to happen.

Triangular distribution is used when there is insufficient data, that's why it is called dangerous distribution. For example: As a result of experiment engineers get 3 different points of temperature. Which means high, low and average points. In this situation we must use Triangle distribution formula.

Log normal type of distribution has been created in the base of logarithmic functions

As a reference of ISO 17025 required to determine source of the uncertainty from the calibration and testing laboratories. All main source of uncertainty must take into account during the assessment of process. Laboratories which performing calibration and testing services must to evaluate uncertainty and add it to the result. If assessment of uncertainty is not available because of the testing methods then engineers must use practical principles and practical experience. The result of the uncertainty if is not required by the customer then the laboratory has an ability like to archive this material.

- Who needs measurement uncertainty?

The customer needs this value, together with the measurement result, to make the right decision.

- Why should the laboratory report the uncertainty of measurement?

Customers need this value to make the legal decision. When examining compliance with limits, the uncertainty of the outcome is important.

The requirements define the highest allowable uncertainty.

- How is measurement uncertainty used?

Results from different laboratories or at different times in the same laboratory decide whether there is a difference (variance over time) between the obtained results.

Uncertainty is mainly characterized by the concept of risk. From the point of view of probability, the uncertainty of calculations is divided into 3 places.

- Complete uncertainty;
- Complete certainty;
- Partial uncertainty.

As a result of non-calculation of uncertainty, we can show the following negative effects:

- Financial expenses;
- Time Wasting;
- Low accuracy;
- Negative feedback;
- Wrong result;
- Unavailable reputation;
- Low reproductivity.

The following are the unintended effects that affect the operation of the laboratory.

- Different types of accident;
- The equipment failure;
- Hazardous area;
- Unsafe work space;
- Dangerous data;
- Injured workers;

Uncertainty should be calculated to reduce and eliminate such effects.

Calculation of the uncertainty for the multi-functional equipment.

As a first step, average evaluation should be carried out. The method (Multiple repeatability) used when determining type, A uncertainty is based on 10 different measurement points and the average is calculated. By the given below formula (1):



$$\sigma = \frac{(x_1 + x_2 + x_n)}{n}, \quad (1)$$

where ...

σ – Mean (average)

x_n – Reading number n

n – Total number of data

Standard deviation formula is utilized for to find out data that is collapsed. Standard deviation generally is calculated for the determine A type uncertainty in the result of this process we can get approximately 68 percent probability (2):

$$SD = \sqrt{\frac{(x_1 - x_n)^2}{n}}, \quad (2)$$

where ...

SD – Standard Deviation

x_1 – 1st reading

x_n – Mean

n – Total number of data

After the estimating standard deviation, it is possible to get uncertainty by given formula. (3)

$$u = \sqrt{\frac{(x_i - \mu)^2}{n * (n - 1)}}, \quad (3)$$

where ...

u – A type uncertainty

x_i – Reading number i

μ - Standard deviation

Once all types uncertainties are determined, the combined uncertainty can be calculated. (4)

$$u_c = \sqrt{u_A^2 + u_B^2 + u_C^2 \dots}, \quad (4)$$

where ...

u_c – combined uncertainty

u_A – A type

u_B – B type

As a final part, expanded uncertainty can be calculated by simple mathematical form. (5)

$$u_e = u_c * k \quad (5)$$

k Coverage factor: The main purpose of the Engineer's Student Table is used to determine the relationship between the number of measurements and measurement errors.

The number of measurements is different, the factor is set according to infinite measurements from the table. When $k = 1.98$ is set, this is suitable for 95% confidence interval (Fig. 1).

Most of the time, $k=2$ is used by engineers, which gives a confidence ratio of 95.45%.

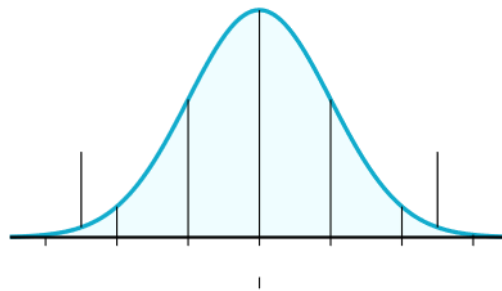


Figure 1. Normal distribution

When $k=3$ is accepted, the confidence coefficient is used as 99.78%. When $k=2.58$, 99% high result can be obtained. The uncertainty meets with a confidence ratio of 68%, where is $k=1$.

When the coverage factor is 3, it means a very high confidence interval. Accordingly, coverage factor 2 is accepted because our equipment does not work without errors.

On the base of JSGM 100:2008 the explanation of uncertainty has been proved. According to the documents uncertainty means doubt to measurements and it is named as the uncertainty of measurement.

At this point the main issue is defined like the comparison between the measuring uncertainty and measurement conception and they should not mix each other.

For example: Sometimes the concepts of standard deviation and uncertainty can be equated.

- Uncertainty is the measurement variance and can be added directly to the measurement result.
- Standard deviation, which is one of the parameters, is an interval with a confidence level. GUM specifies the steps for calculating uncertainty.

Budget for uncertainty.

6 easy steps should be preferred when you want to go into processing uncertainty assessment.

- Learn the measurement;
- Determine source of uncertainty;
- Find out Standard Deviation;
- Combined Uncertainty;
- Expanded Uncertainty;
- Budget for uncertainty (Excel version).

First of all, it is necessary to have enough information about the measurement. Measurements made by experts are less likely to cause errors. Resources must be available and properly selected during the process.

Secondly, sources that will cause uncertainty should be identified and evaluated. After determining the standard deviations, the Gaussian distribution should be constructed.

Excel, one of the Microsoft office programs, can be used to prepare the uncertainty budget. The wide range of functions in the Excel program will help engineers in all calculations. Before creating the budget, all the data should be collected and the measurement methodology should be



selected. The engineer must control the resources and then prepare the equipment, manuals and engineering records. Unlike single-function equipment, the uncertainty is calculated separately for each function of multi-function equipment. According to the standard and methodology, 10 times measurement is performed at 1 point. Readings of UUT from ten tests are recorded in Table 1.

Table 1. Readings of Unit Under Test (UUT).

Voltage DC		
Points	Reference Standard	UUT
1	5.0000	5.000
2	5.0000	4.999
3	5.0000	5.000
4	5.0000	4.999
5	5.0000	5.000
6	5.0000	5.000
7	5.0000	4.999
8	5.0000	5.000
9	5.0000	5.000
10	5.0000	4.999

A formula is used to determine the difference. (6)

$$D = RS(readings) - UUT(readings), \quad (6)$$

where ...

D - Difference

RS – Reference Standard

UUT – Unit Under Test

The obtained results are entered into Excel Table 2.

Table 2. Results of Difference for each point.

Difference
0.000
0.001
0.000
0.001
0.000
0.000
0.001
0.000

0.000
0.001

Standard deviation and uncertainty are pointed by using the mean, showed in Table 3.

Table 3. UN and SD.

Uncertainty	Standard Deviation
0.20000000	0.000516398
0.20004001	
0.20000000	
0.20004001	
0.20000000	
0.20000000	
0.20004001	
0.20000000	
0.20000000	
0.20004001	

In the result of calculation of A and B type engineers can get combined uncertainty, in Table 4.

Table 4. Types of uncertainty.

U _a	U _B	U _c
0.00016330	0.044741	0.001001

As a Final we can use all results and by using the we can find out expanded uncertainty, Table 5.

Table 5. Expanded uncertainty.

U _{exp}
0.00200179

Steps, that we used, can apply to all different functions of multi-function equipment. Result of uncertainty can be added and minuses from main results of equipment. Detailed template for the assessment of measurement uncertainty, Table 6.

Table 6. Quality control and data for measurement uncertainty.

Analytical procedure:	
Measurement interval and analytical.	
Measurement range:	Uncertainty accumulation Essential



1st	Percent
2nd	
3rd	
Short explanation of Analytical procedure.	
Related standard/ method.	
Customer demands for uncertainty?	

How to calculate the measurement uncertainty in the analytical report with the value. The logo of the company and the accreditation institution has been removed from template and the report does not contain the information normally requested by accreditation institutions.

Engineers must give relative or absolute values according to the client's needs that are recommended.

Conclusions

As a brand-new term uncertainty is applied to all field of measurement. Though there are a few methods which is used to get uncertainty, in this article is decided to create 6 easy step to calculate it. by using available program, the budget of uncertainty can be created.

Article makes it clear that what type of distribution is sufficient for evaluating uncertainty. Also, there are given formulas that are used to get result.

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MATHEMATICAL MODELING OF THE METEOROLOGICAL FACTORS IMPACT ASSESSMENT ON RELAY SCATTERING OF ELECTROMAGNETIC WAVES IN THE ATMOSPHERE

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ABSTRACT

In the article, the problem relevance of solving many methodological issues by means of mathematical modeling is due to the fact that the technological possibilities of controlling remote sensing signals with the necessary accuracy are limited, and considering that the main type of scattering of electromagnetic waves during remote sensing with the help of artificial Earth satellites is Relay scattering and the issue of mathematical modeling of the evaluation of the impact of meteorological factors on this process of electromagnetic waves in the atmosphere was solved. For this purpose, the structure of the mathematical model was selected and its adequacy was checked and For a more detailed investigation of the capabilities of the mathematical model, computational experiments were conducted. In order to verify the adequacy of the mathematical model of the assessment of the influence of meteorological factors on the Rayleigh (molecular) scattering of electromagnetic waves in the atmosphere, the values of the molecular scattering coefficient calculated using the appropriate formula and were reconciled with the data provided in the relevant literature sources. The obtained results show the adequacy of the model. For a more detailed study of the capabilities of the mathematical model, computational experiments were conducted. The obtained results showed that the proposed mathematical model can be successfully used in solving a number of practical problems.

Keywords: Remote sensing, electromagnetic waves, Relay scattering, mathematical modeling, meteorological parameters.

Introduction

It is known that the presence of the atmosphere between the observed object and the optical-electronic systems in remote sensing is the cause of the main distortions. The energy of the rays from the object weakens when passing through the atmosphere, and the spectral composition of the rays undergoes transformation. In addition, the temperature gradient in the atmosphere causes turbulence, which in its turn affects the parameters of the measuring device and deteriorates the image signals quality [4. 10]. To eliminate the atmospheric effects, it is necessary to know the atmospheric model, aerosol model (type and concentration), optical thickness of the atmosphere, surface reflection coefficient, and a number of other parameters for gaseous components. Since it is very difficult to measure such characteristics of the atmosphere directly, methods are being developed to obtain them from the spectral values of sounding data. As a result, the received data is used to develop high-precision models of atmospheric correction.



For example, in solving the issues of remote sensing of the earth's surface, data from the EOS MODIS (Earth Observing System, MODerate Resolution Imaging Spectroradiometer) and NOAA POES (National Oceanic and Atmospheric Administration, Polar Operational Environmental Satellite) satellites of the global earth surface monitoring system are used. However, this data processing is efficient for "standard atmosphere" or weakly cloudy atmospheric conditions, and large distortions are allowed in other cases. One of the main reasons for this is that the optical-meteorological conditions of the atmosphere are not taken into account during satellite observations. However, relevant studies have been started to overcome such difficulties. One of them was the solution of the issues of restoring the temperature field of the surface coating based on the physical models of the transport of heat radiation. To this and, the distorting effect of the atmosphere on the results of surface temperature monitoring was directly taken into account by using a priori optical-meteorological information (satellite observation data, prognostic data, radiozonde data, AERONET network data). Later, according to the data of EOS MODIS and NOAA POES systems, based on the RTM-method (Radiative Transfer Model), researches were conducted on the development of algorithms and software tools for operational atmospheric correction of satellite infrared measurements of the earth's surface temperature [8], some results of the various algorithms development for performing atmospheric correction [11, 14, 15] are given in the article.

A brief analysis of the characteristics of the influence of the atmosphere on electromagnetic signals in the real conditions of aerospace observations shows that for the atmospheric correction of remote sensing data, the issues of mathematical modeling of the main characteristics of the Earth's atmosphere must be solved and their adequacy must be checked in different time intervals for specific areas [9].

Mathematical modeling

It is known that depending on the ratio of the sizes of the particles in the atmosphere and the wavelength of the incoming rays three types of scattering are distinguished in the atmosphere: Rayleigh scattering or molecular scattering (while the sizes of the atmospheric particles are smaller than the wavelength); - Mie scattering or aerosol scattering (the sizes of particles in the atmosphere are comparable to the wavelengths of the visible, near-infrared and thermal infrared regions; - non-selective scattering (independent of wavelength, scattering occurs by particles with a radius of more than 10 μm) A review of studies on the determination of Rayleigh dispersion [10] shows that there are certain difficulties in the of Rayleigh dispersion value calculating.

The basis of the mathematical model for influence evaluating of meteorological factors on Rayleigh scattering evaluation -;of electromagnetic waves in the atmosphere is the following expression [10]:

$$\alpha_m = \frac{3}{8 \cdot \pi} \cdot \beta_m, \quad (1)$$

β_m is determined by the Rayleigh formula [2, 7, 13]:

$$\beta_m = \frac{8}{3} \pi^3 \frac{(n^2 - 1)^2}{N \cdot \lambda^4} \cdot \frac{6 + 3\delta}{6 - 7\delta}. \quad (2)$$

The calculated concentration of molecules in the air can be determined as follows [7]:

$$N = \frac{P}{k \cdot T}, \quad (3)$$

It can be noted that in standard atmospheric conditions ($T=273.1\text{K}$, $P=1013.25\text{ hPa}=101325\text{ Pa}$) the value of $N=2.686763 \cdot 10^{25}\text{ m}^{-3}$ is called Loschmidt constant. The change of the calculated concentration of air molecules depending on the height above the earth's surface (H , km, up to 50 km) can be calculated by the following formula obtained by us using literature data [5]:

$$N = -5 \cdot 10^{-5} \cdot H^3 + 0.006 \cdot H^2 - 0.2143 \cdot H + 2.4883, \quad r = 1.00. \quad (4)$$

The degree of depolarization (δ , dimensionless quantity) of the main atmospheric gases and mixtures is as follows [3, 13]: - air – 0.035; H_2O – 0.020; N_2 – 0.036; O_2 – 0.065; CO_2 – 0.097; SO_2 – 0.031; H_2S – 0.003; CH_4 – 0.000; Cl_2 – 0.041; HCl – 0.007; CO – 0.013.

$$n = 1 + 10^{-6} \left(b(\lambda) \frac{P(1+10^{-6}P(1.049-0.0157T))}{720.833 \cdot (1+0.003661T)} - P_w \frac{0.0624-0.00068\lambda^{-2}}{1+0.003661T} \right), \quad (5)$$

$$b(\lambda) = 64.328 + \frac{29498.1}{146-\lambda^{-2}} + \frac{255.4}{41-\lambda^{-2}}, \quad (6)$$

where β_m is molecular scattering coefficient; N – the calculated concentration of molecules in the air; δ – degree of depolarization of scattered radiation; P – atmospheric pressure, Pa; T – air temperature, K; $\kappa = 1.380658 \cdot 10^{-23} \frac{\text{Coul}}{\text{K}}$ – Boltzman's constant; P_w – partial pressure of water vapor, hPa; λ – length of the wave, μm .

In order to verify the adequacy of the mathematical model of the assessment of the influence of meteorological factors on the Rayleigh scattering of electromagnetic waves in the atmosphere, the values of the molecular scattering coefficient calculated using the formula (1) with the data for the range of 0.2-0.4 μm given in the relevant literature sources (for standard conditions in the near-earth layer of the atmosphere) [1, 6] is reconciled. The obtained results show the adequacy of the model (Figure 1) and it can be successfully used to solve relevant problems.

As can be seen from Figure 1, the values of the Rayleigh scattering coefficient calculated by the model and the values given in the literature sources are very close to each other, and this is confirmed by the very high correlation coefficient between them ($r=0.9999$). These data show the adequacy of the model and it can be successfully used to solve relevant problems.

Then, computational experiments were conducted for a more detailed investigation of the model capabilities. Meanwhile, different values of air temperature were used, the calculation was made for two options. In these options, $P=101325\text{ Pa}$ was taken, and the air temperature was changed from 0°C to 45°C every 5°C . Air and carbon dioxide environments are considered as atmospheric environments. The degree of depolarization (δ) for air is 0.035 and for carbon dioxide is 0.097

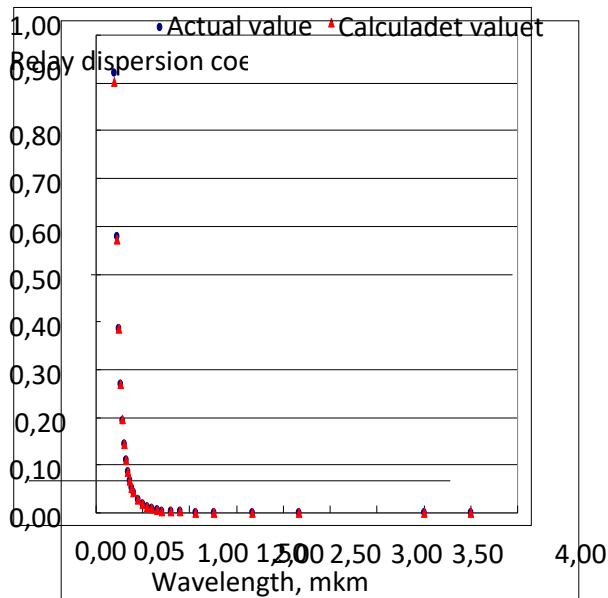


Figure 1. The value comparing results of the values of the molecular scattering coefficient in theory and the values calculated by the formula (1).

In the 1st option, $\lambda=0.20 \mu\text{m}$ was adopted. The results of calculations are given in figure 2. It can be seen from here that the effect of air temperature on the relay coefficient is linear and as the temperature increases, the coefficient also increases. These changes range from 1.00 1/km (0°C) to 1.60 1/km (45°C) for air, and 0.90 1/km (0°C) to 1.40 1/km (45°C) for carbon dioxide. is in the interval. The relay dispersion coefficient increases by ≈ 0.05 1/km for every 5°C increase in temperature for both environments.

In the 2-nd option, $\lambda=0.55 \mu\text{m}$ was adopted. The calculation results are shown in figure 3.

It can be seen from Figure 3 that the effect of air temperature on the relay coefficient is linear and as the temperature increases, the coefficient also increases. These changes are in the range of 0.013 1/km (0°C) – 0.090 1/km (45°C) for the air environment, and 0.0115 1/km (0°C) – 0.0185 1/km (45°C) for the carbon dioxide environment. For both environments, the relay dispersion coefficient increases by ≈ 0.00062 1/km for every 5°C increase in temperature.

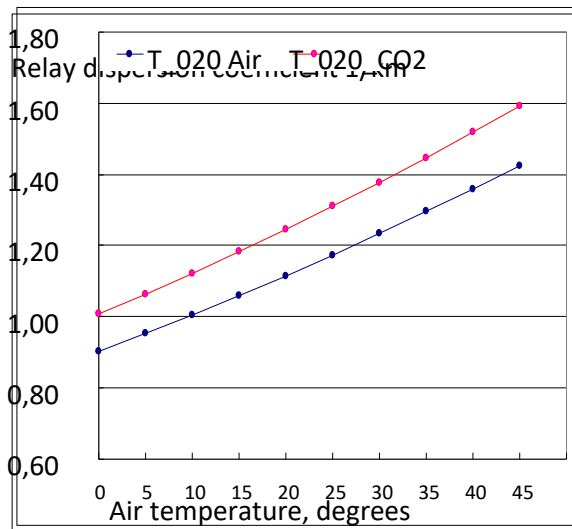


Figure 2. Variation of Relay scattering coefficients in air (T_020_air) and carbon dioxide (T_020_CO2) environments as an air temperature change function.

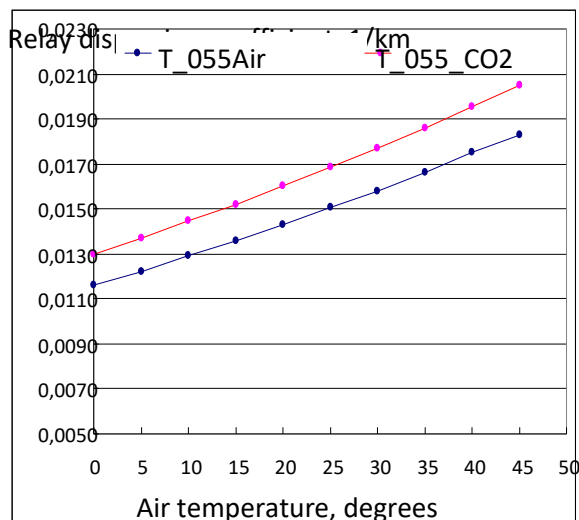


Figure 3. Variation of Relay scattering coefficients in air (T_020_air) and carbon dioxide (T_020_CO2) environments as a function of air temperature change.

At the next stage, the air temperature is $T=00^{\circ}\text{C}$; $p=760$ mm Hg, and the values of partial pressure of water vapor (P_w) were assumed to vary from 0 to 27 hPa every 3 hPa. Again, the environment of air and carbon dioxide was considered. Calculations were made for $\lambda=0.20$ and 0.55 mkm. The results of the calculations for the option $\lambda=0.20$ mkm are given in figure 2.7.

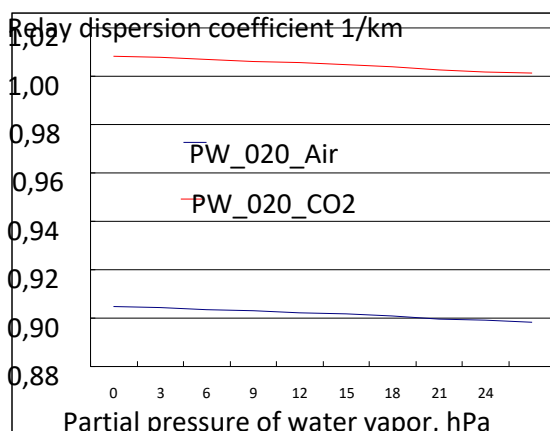


Figure 4. $\lambda=0.20$ mkm, depending on the change in the partial pressure of water vapor, the change in values of the relay scattering coefficient in air and carbon dioxide.

Conclusions

The article analyzes the effects of electromagnetic signals of the atmosphere in real conditions of aerospace observations, considers the problems of mathematical modeling of the main characteristics of the Earth's atmosphere for Atmospheric correction of remote sensing data and their adequacy in different time intervals on Con-Cretaceous areas.

In order to verify the adequacy of the mathematical model for assessing the influence of meteorological factors on the relay scattering of electromagnetic waves in the atmosphere, the calculated values of the molecular scattering coefficient were compared with the data for the 0.2-0.4 mm range given in the relevant literature sources, and the adequacy of the model was confirmed based on

In order to study the detailed model possibilities, two variants of computational experiments were carried out, graphs of dependence of relay scattering coefficients on changes in air temperature were established using different values of the air temperature. The graphs show that the influence of air temperature on the relay coefficient is linear, and as the temperature increases, the coefficient increases.

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IMPROVEMENT OF INTELLIGENT INTERNAL COMBUSTION ENGINES

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ABSTRACT

Research investigations of the solutions of internal combustion engine control problems based on artificial intelligence systems are quite relevant. The power of ship devices and mechanisms is increasing, the requirements for accuracy, reliability, speed and other indicators of the quality of control processes are increasing, increased operational requirements related to economy and efficiency of ship systems and equipment.

Currently, there are a lot of studies which are successfully performed to create the installations with a higher degree of automation – adaptive (intelligent) internal combustion engines, including a class of marine diesel installations. This term means the Engine controlled by adaptive automatic control systems with elements of artificial intelligence that can apprehend and analyses quite complicated and changeable ambient and take a decision. However, the problematic issues of adapting a piston engine in operating conditions are still under study and theoretical conceptualization.

In this article, a study of the scientific and technical problem of improving the operational qualities of intelligent marine diesel installations is carried out. The problem has a great technical importance and requires scientific substantiation of the directions of both improving the operational qualities and reliability of existing models, and identifying ways to modernize existing structures of marine diesel installations.

Keywords: internal combustion engines, marine diesel, intelligent engine, adaptive systems, adaptive motors, microprocessor controls, controlling algorithm, neural networks.

Introduction

At the end of the XX century, the world marine diesel industry, following the automobile industry, started attempts to create adaptive marine diesel installations. Marine engines are a special class of power plants that differ from industrial analogues, they have different operating modes and loading cycles, as well as increased requirements for reliability, durability, and safety. All this determines the design and automation features of the ship's power plant.

The appearance of microprocessors in 1972 led to a qualitative change in the element base of shipboard automated control systems of the shipboard power plants. The first implemented microprocessor-based automatic control system of a ship's power plant (SPP) performed the following functions: control of the parameters of the technological processes of SPP, warning and emergency alarms; the automatic control of the ship's power plant; the automatic control of the start-ups and operation of the main engines and other auxiliary mechanisms of SPP. The system was divided into several subsystems, for each microprocessor was provided. All microprocessors were integrated into a common network.

The modern electronic control system, in addition to monitoring the parameters of the main engine systems, includes a microprocessor with software that solves a wide range of engine management tasks.

The purpose of microprocessor control of internal combustion engines is to improve their ecological and economic characteristics due to a high level of individual optimization of the workflow in each cycle of each cylinder. It is achieved by automatic selection and setting a set of values of the working process parameters in the engine cylinders and by controlling algorithms that are optimal in terms of fuel consumption and the quality of transients, while fulfilling environmental and technical parameters restrictions.

It should be noted that since the development of engine control systems, the computers controlling the engines have been improved. So, the first computers equipped with Caterpillar engines had an 8-bit processor, then a 16-bit processor. Currently, ECM ADEM-III (Advanced Diesel Engine Management) has a 32-bit processor. At the same time, the number of inputs/outputs also changed due to the need to increase the number of sensors and controlled quantities to take into account a large list of operating parameters and external conditions. The newest ECM ADEM-IV has 170 inputs and communication lines with the engine [1].

In addition to the main tasks for controlling the workflow of a diesel engine, ECM provides solutions to a number of other tasks, including:

- monitoring of sensor readings with a control of their serviceability;
- self-diagnosis of the electronic control system with the output of active codes-notifications of malfunctions of their components (modules);
- storing fault notification codes in memory;
- storing in memory of the operating parameters that have occurred beyond the set limits (overheating, exceeding the set speed limits, low oil pressure, etc.);
- performing tests and calibrations of some elements by commands of a special program.

The achievements listed above, applied in electronic engine control systems, allow us to draw conclusions about the absence of constraining factors for the integration of the internal combustion engine into a single target control system of marine power plant, which allows to implement control scenarios depending on the external operating conditions of the vessel.

One of the most important ways to develop modern internal combustion engines and units based on them is to equip them with intelligent systems that perform the functions of automated or automatic control, regulation, control, maintenance and protection, automatic diagnostics, adaptation of the engine to changing operating conditions. The adaptive motors, which have a large number of controllable parameters and allow adjustment to each operating options, are called intelligent motors. These engines are controlled by adaptive automatic control systems with elements of artificial intelligence in the form of the ability to perceive and analyze a rather complex and changing external environment and make appropriate decisions.

An important factor determining the quality of microprocessor engine control is the controlling algorithm. The use of "intelligent" control algorithms allows you to achieve the maximum possible best indicators of the workflow's quality. This applies, first of all, to the accuracy of maintaining the engine crankshaft speed when operating in steady-state loading modes, limiting the maximum deviation of parameters and duration of transient start-ups, acceleration, loading and tracking loading changes.

The complex of control algorithms generally includes algorithms for adaptive control of fuel supply advance, pressure, the number of injection stages, the form of fuel injection characteristics,



fuel supply restriction, exclusion of fuel supply under conditions that do not ensure its ignition and effective combustion, gas distribution phases, boost pressure, etc. It is important that for the implementation of control algorithms, information received from sensors of regulated parameters is collected and processed, which also allows the implementation of algorithms for automatic technical diagnostics.

Taking into account the tightening of environmental standards, the problems of saving fuel and energy resources, as well as transport safety problems related to the fault tolerance of marine internal combustion engines and especially their control systems, it is obvious that the task of intelligent control of this object is relevant.

Development of intelligent engines.

An American company Caterpillar was the first who mastered the industrial production of electronically controlled diesels. Most of the engines of this company are now produced with electronic control. The microprocessor installed on the engine performs the following functions:

- an electronic speed controller that supports a given speed and a loading mode;
- fuel supply control according to the set mode;
- recording and monitoring of the main parameters of the engine and its maintenance systems;
- the implementation of an emergency warning alarm when the parameters go beyond the setpoint and the engine resets or stops when the setpoint is significantly exceeded;
- the implementation of an emergency warning alarm when the parameters go beyond the setpoint and the engine resets or stops when the setpoint is significantly exceeded;
- fixing in the processor memory of all violations in the operation of the engine and regardless of the term of limitations of their issuance on the screen of the computer connected to the microprocessor.
- the implementation of these functions significantly increases the level of control and technical operation, prolongs the life of the engine.

In the field of marine engine building, the first steps were taken by "MAN & BW", "Wartsila" and "Sulzer".

The use of technical solutions with electronic control by MAN-B&W corporation was introduced in 2001 in the engines of the ME series [2]. The company has developed and laid the foundation of the electronic system software. In recent years, this company has achieved a very high degree of reliability of electronic control circuits and they have replaced mechanical devices in many installations that perform the functions of supplying fuel into diesel cylinders.

In the fuel injection control scheme developed by MAN (Fig.1), several sections of a high-pressure fuel pump (HPFP) are used to pump fuel from a fuel tank (FT) into a special battery tank (BT). The pressure in the accumulator tank is regulated by acting on the fuel injection pump spool, as well as using a high-speed discharge valve (V), which, if the pressure increases excessively, discharges part of the fuel back into the tank (FT). Diesel injectors (I) are equipped with a special hydro- locking system where the pumps (P) maintain a constant oil pressure of 20 MPa.

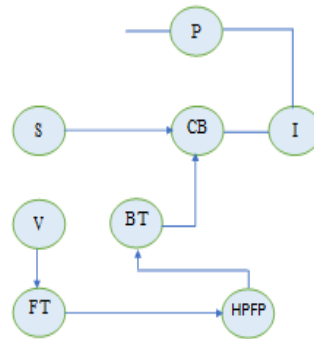


Figure 1. Electronic fuel injection system diagram.

Fuel is supplied to the nozzle sprayers by commands generated by the control unit (control unit), the input of which receives signals from sensors (S) injection pressure, gas pressure in the cylinder, charge air pressure, shaft speed and other measuring devices. The control unit compares these signals with the preset ones, and, in case of their inequality, changes the fuel supply and charge air pressure accordingly. Commands are given at certain positions of the crankshaft. The timing of the command signals determines both the moment of the start of injection, as well as its duration and the amount of fuel supplied. Electromagnetic high-speed valves are installed on the pipeline connecting the battery tank with the injectors, when triggered, the fuel supply to the injectors stops and at the same time the cavity of the injectors in front of the sprayers communicates with the drain line.

The control unit of the system is made with a wide use of digital integrated microchips. The basis of the control unit is a microprocessor, whose programs are implemented into permanent storage devices to which are connected: sensors (E) of injection pressure, gas pressure in cylinders, air pressure, shaft speed sensor. The microprocessor evaluates all incoming signals; performs appropriate calculations according to the specified programs; generates the necessary commands that control fuel injection, the processes of start-ups, reversing the diesel engine, as well as the operation of various information display devices.

To achieve high quality engine management, it is necessary to provide flexibility in the management of the fuel supply and exhaust valve. Ensuring the flexibility of engine control with the fuel pump and exhaust valve driven from the camshaft will require the creation of a complex mechanical complex, which will greatly affect the reliability of the engine.

All this led to the creation by MAN corporation of an intelligent engine with a new type of drive for high-pressure fuel pumps and exhaust valves, which would be controlled by electronic controls under the control of an engine condition monitoring system.

The block diagram of the intelligent motor control is shown in Fig. 2. The engine operation programs can be set from the control panel or by the intelligent engine's own control system.

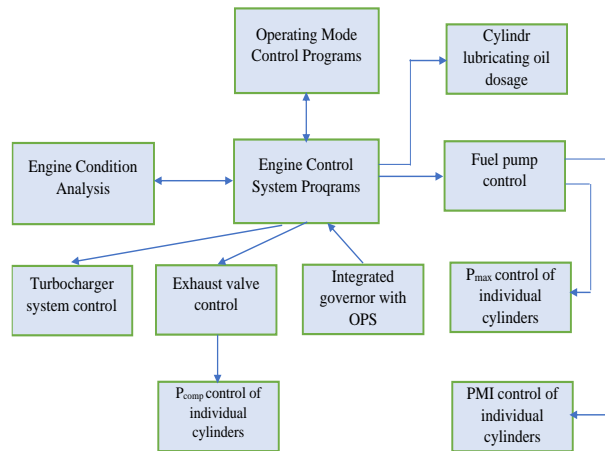


Figure 2. Block diagram of intelligent motor control

The control system contains data for optimal control in these programs, which consist of separate modes corresponding, for example, to different engine loads or limits on emissions into the atmosphere.

The fuel economy and atmospheric emission limits options are set from the engine control panel, and the reverse and emergency stop mode is selected by the control system when the maneuvering system requests the execution of the appropriate command.

The engine damage warning mode is set exclusively by the engine condition analysis system, regardless of the current operating mode.

The electronic control system analyzes the condition of the engine and controls the operation of the following systems: fuel injection, exhaust valves, cylinder lubrication and turbocharging.

The main advantages of the "intelligent engine" are: reduction of fuel consumption; reliability and flexibility of management; flexibility in managing exhaust gas emissions.

In the Wartsila-Sulzer RT-flex/X engine, all functions in the system are operated and controlled through the WECS-9520 engine management system [3]. It is a modular electronic system with separate microprocessor control units for each cylinder and common control and supervision by duplicated microprocessor control units. They provide interconnection with an electronic controller, a remote automatic control system and an alarm system. Microprocessor control units, or electronic control units, are installed directly on the engine, either on the front of the battery pack, or next to it.

- One of the most important changes in the engine was the introduction of a battery fuel supply system consisting of a fuel injection pump that creates a pressure of 1000 bar, a fuel accumulator and electronically controlled valves that distribute fuel through the injectors (Fig. 3) [3].
- From the battery, fuel is supplied to standard injectors, the opening and closing of their needles occurs in the usual way under the pressure of fuel entering each of them from the control valve. The latter sets the moment of needle opening - the advance angle, the amount of fuel injected and the shape of the fuel supply curve (Fig. 4) [4].

- The three nozzles in each cylinder are controlled independently of each other - programmed to work individually or as needed in unison.

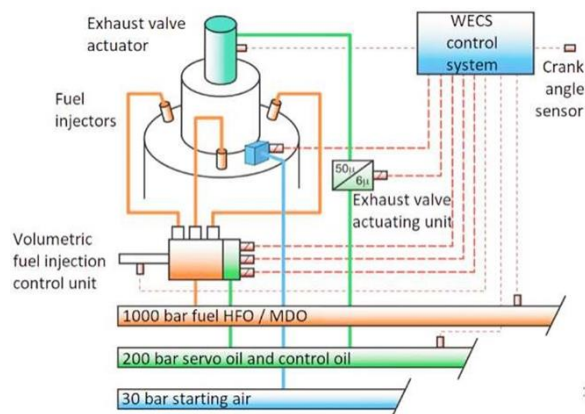


Figure 3. Battery fuel supply control system.

The valve is controlled by a microprocessor-based electronic control system WECS 9500, which has a modular design with a separate microprocessor for each cylinder. The same system is responsible for monitoring the entire engine.

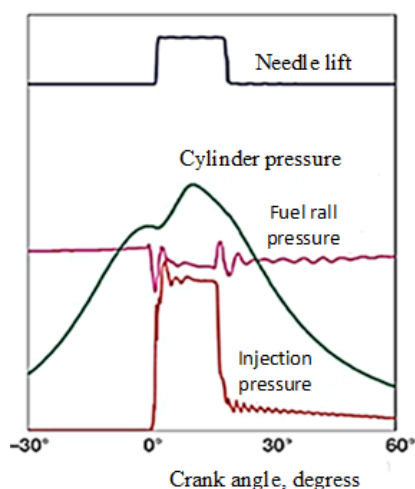


Figure 4. RT-flex/X engine injection scheme

RT-flex/X engines have standardized interfaces (DENIS) for remote control and safety systems. Remote control and safety systems are supplied to the vessel by various approved manufacturers, and DENIS determines the interaction between the equipment installed on the engine and remote automatic control systems, emergency warning alarm and security system.

The main advantages of RT-flex/X engines with their electronically controlled systems are:

- Reduced specific fuel consumption in partial modes.
- Smokeless operation at all speed modes.

- Very low, stable rotation speed at a value of about 10% of the nominal.
- Easy engine setup for less maintenance.

Increased time between major repairs, primarily due to a better load balance between the cylinders and cleaner combustion at all loads.

From the above mentioned it follows that on all engines with electronic control systems, a significant reduction in operational fuel consumption has been achieved, starting and braking characteristics have been improved, and the reliability of engine components and parts has been increased. Microprocessor systems are increasingly being used for information processing and decision-making in the automation of SEU. One of the problems of using diagnostic systems in the process of adaptive management is the large amount of information processed, which is not always possible to perform in real time.

Currently, fuzzy neural networks (FNS) are used for more accurate, perfect control and monitoring with internal combustion engines [5]. The most important advantage of the FNS is the ability to build a single network to calculate multiple output values from multiple inputs. Hardware implementations of the FNS are ideal for solving identification and control tasks, as they provide, thanks to the parallel structure, extremely high speed of operations.

With the advent of new technologies in the marine industry, management systems are being improved every year. With the support of the European Commission, the "Auto-ship" project has been developed, which includes the construction and operation of unmanned and autonomous vessels. The era of marine robotics has begun.

Conclusion.

The safety of navigation is the most important requirement for the exploitation of the vessel. Ensuring the safety of navigation is more related to the reliability of working with internal combustion engines, which in turn depends on their technical condition. Modern automated control system by ship technological processes is implemented in the form of a three-level system. The first levels sensors and measuring transducers for collecting information, acting technologies for controlling the working parts of control objects. The second level is programmable microcontrollers. The third level consists of hubs, multiplexers, switches, and "intelligent" microcontrollers that ensure the execution of the control algorithm.

The use of artificial intelligence elements allows you to automatically configure a computer program to solve a specific task. The operator's participation is reduced only to the formation of a database of source data and the choice of the purpose of finding a solution.

The largest manufacturer of marine diesel engines MAN B&W is developing a package of computer diagnostics CCS EDS (Computer Controlled Surveillance Engine Diagnostic). The software package allows you to integrate it with the system of centralized control and monitoring of the main diesel engine through a standard interface. Thus, the system acquires data on the operation of the diesel engine, analyzes them and gives an assessment of the technical condition. The system can store data of normal operation mode of the diesel engine and a database of expert data, allowing you to give a conclusion about the deviation from normal operation and recommendations for the operation of the diesel engine.

Experts predict that the development of artificial intelligence will occur exponentially, which will allow computers to be used to analyze the future course and maneuvers of the vessel, increasing situational awareness of the crew and reducing accidents.

The development of piston engine building has entered a new phase – the creation, production and operation of super-intelligent engines of new generations. On this path, we are waiting for impressive scientific and technical ideas that will extend the life cycle of modern internal combustion engines for the foreseeable future, increase their importance in the global energy sector.

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THE ROLE OF METROLOGICAL SUPPORT IN INNOVATIVE ACTIVITIES

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ABSTRACT

The transition to new technologies sets a number of new specific tasks determined by the parameters and structure of innovative products to science and technology. Both the technological process of creating innovative products and the measurement of parameters, processing of measurement information, and ensuring the credibility and metrological reliability of measurements need metrological support. The functioning of modern measuring instruments is connected not only with the possibility of a purposeful choice of a rational measurement algorithm in a fixed situation but also with the procedure for making decisions about the nature of further actions. Therefore, fundamental research concerning the design of intelligent measuring instruments is currently being actively conducted in mathematical metrology.

The development of an electronic information and analytical system for measuring equipment will ensure the installation of the optimal range of quantitative target indicators and the formation of metrological measures of priority programs and projects.

The article considers the possibilities of successfully solving the problems of metrological support for the implementation of innovative technologies. The solution of such problems depends on the completeness, validity, and feasibility of metrological measures.

The expediency and necessity of the formation and implementation of metrological measures of innovative technologies are shown.

Keywords: Metrology, metrological support, quality, innovative activity, infrastructure, metrological measures, measuring indicators.

Introduction

Currently, in the Republic of Azerbaijan, the processes of modernization and the formation of an innovative economy are highlighted, they are implemented through a set of legislative and organizational measures, including the formation and development of an innovative infrastructure. A number of state programs and normative-legal documents contain provisions related to innovations. First of all, the Law of the Republic of Azerbaijan "On Science" (14.06.2016) [1] defines the main principles of the state policy in the field of organization, management and development of scientific activity in Azerbaijan, the goals of science and scientific-innovation activities, the mechanisms of financing science, and the stimulation of scientific achievements. The role of metrology, standardization and conformity assessment as a quality infrastructure is emphasized in Decrees, Orders of the President on innovation activities in the Republic. In recent years, special attention has been paid to considering organizations and institutions as part of the innovation infrastructure that provide services and perform work in the field of metrology,

standardization and certification, which contributes to the development of the metrological infrastructure.

A Memorandum of Understanding on cooperation was signed between the Institute of Standardization and Certification at the State Committee for Standardization, Metrology and Patent and the "Innovations Center" of the State Agency for Service to Citizens and Social Innovations under the President of Azerbaijan. The Institute of Metrology was transferred to the State Service of Antimonopoly and Consumer Market Control under the Ministry of Economy.

The effectiveness and efficiency of priority programs and projects is determined by a set of economic-static, technical, metrological and other indicators, the requirements for which are established by regulatory legal acts and technical documents acting in Azerbaijan Republic. One of the conditions for the effectiveness and efficiency of priority programs and projects involving the development of innovative technologies is their metrological security. Insufficient metrological security is the reason for the duplication of previously completed developments or the adoption of unreasonable decisions on the development of non-promising measuring technologies, the technical level of which does not meet the requirements of international and national standards. The use of modern national standards and measuring instruments contributes to better competitiveness of domestic products and the promotion of innovative products and technologies to the world markets.

Metrological services play an important role in ensuring the priority directions of the development of science, technology and engineering, one of the main mechanisms of the state innovation policy. The analysis of the data base of state standards showed that the standards satisfy the needs of the economy in the measurement capabilities of all priority directions of the development of science, technology and technique, as well as in the metrological provision of new technologies corresponding to these directions. Taking into account the importance of these technologies and the priority directions of the development of science, technology and technology for the implementation of the scientific and technical policy of the state and the formation of an innovative economy, all types of subjects of innovative infrastructure, which are necessary for any country, including such a subject as metrology, should receive timely support and development. That is why mandatory official registration is required as part of the innovation infrastructure of organizations and institutions providing services and performing work in the field of standardization, metrology and conformity assessment, i.e. quality infrastructure. This will contribute, in accordance with the requirements of the innovative economy, to the development of metrological infrastructure and increase the innovative activity of the domestic industry.

Metrological support – endurance of innovative processes

The measurement aspect of the theory of innovation lies in the need to develop and implement procedures for extracting and managing measurement information at various stages of the life cycle of innovation processes. Measurement information about the complex dynamic systems of modern industries is equally important for improving the management of technical systems and socio-economic ones. Technological innovation management is associated with the management of measuring information of various enterprise resources in the context of a process controlling model. A modern digital enterprise, as a complex dynamic system, operates with measuring information that is characteristic of both technical systems and socio-economic ones (measuring information about the business processes of an enterprise). Measuring information about business process indicators serves as the initial information for the formation of a business decision.



Directed adjustment of the measurement results will allow to manage the key performance indicators of the enterprise.

The main trends in the construction of metrological measures and the evaluation of quantitative indicators and indicators of innovative programs are shown in Fig. 1 [2]:

Scientific and technical innovations cause the need to develop new types and units of measurements, which stimulates the development of fundamental and applied metrology, and this, in turn, allows the introduction of new instruments and devices for any field of technology. In other words, metrology supports research and development and other innovative processes in enterprises and organizations that lead to innovation.

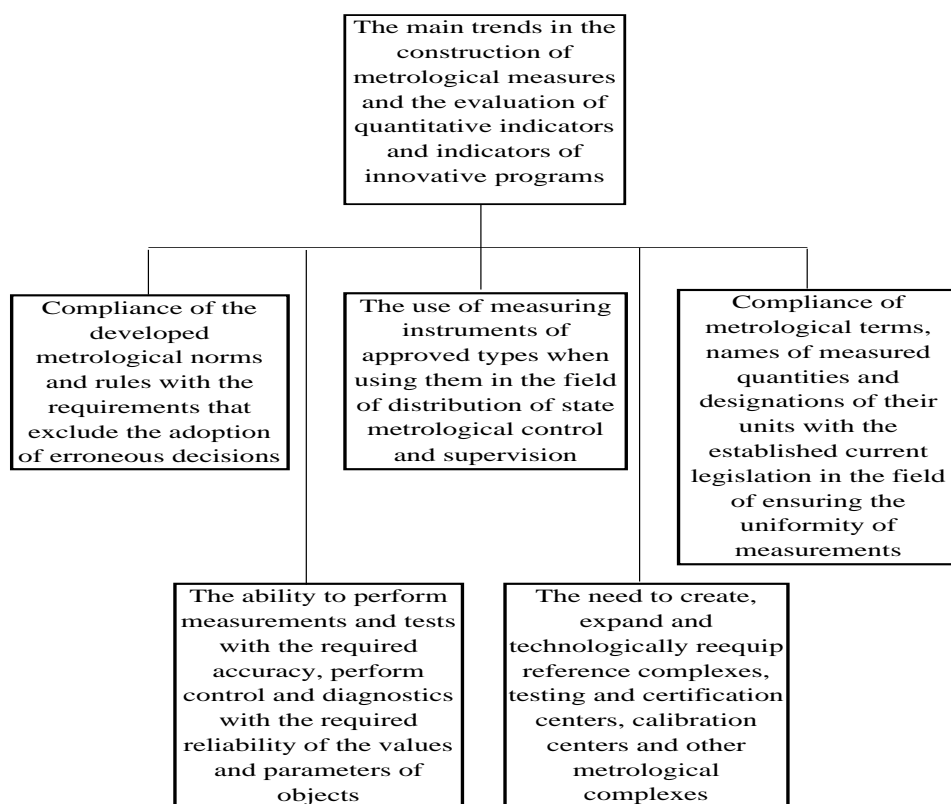


Figure 1. The main trends in the construction of metrological events.

metrology supports research and development and other innovative processes in enterprises and organizations that lead to innovation. Thus, we can talk about a kind of “self-reinforcing mechanism” that links metrology, operational measurements, research and development and innovation (Fig. 2).

Numerous studies confirm the positive impact of metrology not only on the economy, but also on the activities of people and society as a whole. The most significant areas can be identified.

1. Metrology improves the quality of production processes, labor productivity.

2. Measurements contribute to the development of an innovative culture of society, its readiness for new quality, since they provide objective evidence that an innovative product is actually the best.
3. Improvement of metrological support contributes to the improvement of the quality of commodity-money relations in a market economy due to the reduction of transaction costs between suppliers and consumers.
4. The development of metrology has a multiplicative effect, as it contributes to improving the quality of not only industrial goods, but also services (for example, the development of the educational sphere is also associated with the ability to assess the quality of student training, the work of educational institutions).

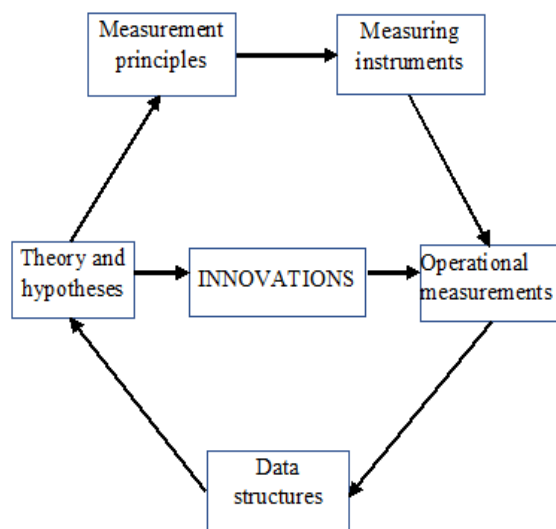


Figure 2. Self-reinforcing mechanism [3].

The functioning of modern measuring instruments is connected not only with the possibility of a purposeful choice of a rational measurement algorithm in a fixed situation, but also with the procedure for making decisions about the nature of further actions, therefore, fundamental research in mathematical metrology is currently being actively conducted, concerning the design of intelligent measuring instruments.

The introduction of the concept of virtual measuring circuits as an innovation in assessing the reliability of metrological analysis makes it possible to implement the analysis and synthesis of measuring circuits in the presence of the necessary composition of a priori knowledge about the measurement procedure.

Measurements of tactical and strategic levels of management are determined to a greater extent by economic measurements, which are the values of business process indicators. Economic measurements are represented by a set of values of business process indicators. For each indicator of the business process, its own series of sample data is accumulated. However, such an indicator as the economic situation must be assessed using a set of indicators - a set of sample data series.

For the analysis of sample data, methods of statistical analysis, fuzzy logic, neural networks, expert assessment methods.

The system of metrological support of programs, innovative projects development and modernization of the economy [2], consisting of scientific-educational, informative- analytical and regulatory-technical modules, which all together allow you to create a mechanism that let us solve the following tasks:

- monitoring, analysis and selection of measuring technologies developed or used in innovative programs and projects, assessment the level of their metrological support;
- training and advanced training in the field of metrological and regulatory support of programs for employees involved in the development, examination and implementation of innovative programs and projects, in order to acquire the necessary and sufficient level of qualification to perform work on the formation, examination and implementation of metrological measures;
- development of standard- regulatory and standard -technical documents that establish and ensure the procedure for the formation, examination and implementation of metrological measures of innovative programs and projects, the complexity, completeness and sufficiency of metrological indicators, as well as the reliability of metrological indicators.

The main goal of the integrated metrological support system is to increase the targeted effectiveness and economic efficiency of innovative programs and large high-tech projects implemented within their framework. This goal is achieved through the development and use of competitive and perspective measurement technologies, confirmation of compliance with mandatory metrological requirements and the implementation of planned metrological measures, obtaining reliable and comparable measurement results, monitoring and diagnostics and, accordingly, excluding the adoption of unreasonable decisions and erroneous actions based on unreliable measurement information.

One of the main tasks to be solved in the implementation of the informative-management system of metrological support of innovative technologies is to make a rational decision on the development of a new measuring technology or the use of already used measuring technologies. The complexity of solving this problem lies on the fact that it is quite difficult to choose the most effective solution, since a huge fleet of measuring instruments and at the same time the lack of reliable and up-to-date information about specific samples of measuring equipment makes it much more difficult to choose the optimal solution. Innovative products require special approaches to determining their characteristics, since they may have unique values. Precision techniques and measuring instruments should be used to determine these values.

Metrological activities are formed taking into account the system of quantitative indicators that provide the ability to verify and confirm the achievement of the intended goals and solve problems implemented by innovative technologies. The values of most indicators have metrological roots and their evaluation is associated with the measurement of physical quantities with established accuracy and reliability. In this case, only the use of an innovative system for metrological support of innovative technologies becomes an effective tool that allows developing and implementing the intended goals and solving the tasks set.

An approximate list of measures for the metrological and regulatory support of innovative programs and their metrological and regulatory expertise is determined by the State Programs. The need for a mandatory examination of the requirements for measurements, standard samples and measuring instruments contained in the draft regulatory legal acts of the Republic is

determined in the Law of the Republic of Azerbaijan "On ensuring the uniformity of measurements" [4]. But despite the significance of the steps taken, the task of creating a unified integrated system of metrological support for state technological, product and environmental programs for innovative development of the economy has become more relevant in the implementation of innovative programs. The programs lack indicators of adequacy, accuracy, reliability, reproducibility of the planned indicators, which is a consequence of the lack of unified legal and intersectoral scientific and methodological mechanisms that determine the procedure for the development and examination of metrological measures and quantitative indicators, as well as an insufficiently high level of competence of the management implementing and guiding practice in this area.

The effectiveness of the developed innovative technologies can be assessed by the level and completeness of metrological support, including metrological indicators and measures that must meet the mandatory metrological requirements and characteristics of measurements, measurement standards, standard samples, measuring instruments and the conditions under which these characteristics must be provided.

The fulfillment of these requirements encounters significant difficulties due to the huge amount of data on the developed, operated and supplied measuring instruments, information-measuring systems and test equipment. Therefore, there is a need to search for a qualitatively new approach to solving the metrological support of innovative technologies. Providing developers and performers with operational information about competitive tools for metrological support of innovative technologies will allow to make the optimal choice of quantitative values of indicators and form the metrological measures necessary to achieve them. The development of an electronic information and analytical system for measuring equipment will ensure the installation of the optimal range of quantitative target indicators and the formation of metrological measures of priority programs and projects.

Conclusion

Today, in the context of the globalization of the world economic and socio-cultural space, the solution of quality issues is becoming the most important component of the success of socio-economic development. And since mankind is unlikely to turn off the path of globalization, the solution of quality issues in all its diversity of manifestations is becoming more and more relevant.

As it is known, quality is achieved through innovation. However, in order to consolidate an innovation, it is necessary to learn how to measure its parameters and characteristics. This is the main task of metrology. Therefore, today, when knowledge in any field is rapidly updated, refined, new data and facts appear that require evaluation and scientific understanding, metrology is becoming an increasingly popular science. Correct and accurate measurements create a solid foundation for making effective management decisions, reduce the risk of error, and therefore improve quality. Metrology, standardization and certification are types of quality control, now they belong to the quite common category - "quality infrastructure" [5].

Beginning of the 21st century coincided with the formation of the sixth technological order as a set of technologies characteristic of a new level of production development and capable of giving mankind an increase in labor productivity and an improvement in the quality of life. These are bio- and nanotechnologies, means of production with artificial intelligence, new medicine, "smart" energy supply networks, including alternative ones, etc. At the same time, the state



scientific and technical policy is practically implemented through the growth of innovative activity.

Scientific and technical innovations cause the need to develop new types and units of measurement, which stimulates the development of fundamental and applied metrology, and this, in turn, allows the introduction of new instruments and devices for any field of technology. In other words, metrology supports research and development and other innovative processes in enterprises and organizations that lead to innovation.

Creation of a unified integrated system of metrological support for state technological, product and environmental programs for innovative development of the economy

Providing developers and performers with operational information about competitive tools for metrological support of innovative technologies will allow to make the optimal choice of quantitative values of indicators and form the metrological measures necessary to achieve them.

The development of an electronic information and analytical system for measuring equipment will ensure the installation of the optimal range of quantitative target indicators and the formation of metrological measures of priority programs and projects.

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INTELLIGENT CONTROL SYSTEMS IN OIL REFINING PROCESS

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ABSTRACT

The oil refining industry is an industry with high requirements for process control. Nowadays, an important problem is the creation of the concept of control systems for oil companies and enterprises. Oil is one of the Earth's most important resources. Its extraction and processing have become relevant for mankind. However, in the modern environment, the tasks of extracting oil with the latest equipment, as well as the use of cleaning and processing with minimal losses, have become important. This paper discusses intelligent control systems and their use in the oil refining industry. The purpose of the abstract is to create a structure that will be useful in the respective enterprises. But in order to achieve the goal of the work, it will be necessary to take into account such common problems as the instability of demand; restrictions imposed by the state and many others. That is why the features of each enterprise, which may bring various risks in the future, are considered at the design stage. Also, (it is necessary to indicate that,) the implementation of intelligent control systems in various industries is a time-consuming process. In these situations, the heads of enterprises need to take into account the human factor and help their employees adapt to new systems in every possible way. Among these methods, there are incentives with awards, the introduction of a team to train how to work with intelligent systems, and others. To delve into this topic, it is initially necessary to consider intelligent control systems separately from the oil refining industry.

Keywords: automated control systems, deposits, oil refineries, quality of intelligent systems.

Introduction

Accurate reporting on the production resources of many sectors of the national economy (energy, water supply, gas supply, heat supply, supply of petroleum products and many other sectors) always leads to an intersectoral problem consisting in the uneven differences between the results of measuring resource producers and the results of multiple measurements in the distribution of these resources to consumers. An accurate report is based on the results of measurements of various physical quantities carried out by modern automated information-measuring control systems (IMCS). Currently, due to the rapid development of digital computing technology, there are practically unlimited opportunities to create modern automated IMCS of various classes. Minimization of measurement errors in the construction of automated IMCS, delivery of oil products to numerous consumers is an interdisciplinary problem.

Intelligent control systems (ICS) are the ultimate in complexity class of automated control systems (ACS), focused on the acquisition, processing and use of some additional information, understood as "knowledge". These systems are made to work with uncertain information about the various qualities of objects and their functioning. If the level of data inaccuracy is very high, then



it is necessary to apply new information technologies, that is, to develop new principles for building intelligent control [5].

Intelligent control occurs where information is considered to be a collection of data and relationships between them in the current interpretation. For meaningful management, you need a database if the context and relationships of the data are constant. If the essence of the information is quite complex, and the purpose of the work and the context are adjusted over time, then the database needs to restructure internal relationships. A distinctive feature of intelligent management is just these requirements for restructuring, which allows you to actively interact with information. Intelligence characterizes how the system relates to the outside world. Intelligence helps to form an image that affects the reaction to external stimuli. It is used during interaction with other complex systems and reorganization of internal communications. The main factor in the operation of intelligent systems is related to knowledge. Classical control does not require such a configuration, since it cannot be broken down into these structures. Management through the "image" needs to take into account the specifically accumulated knowledge and more critically reacts to changes in information in the process of work. The intellectual properties of the "object - control" system have a discrete manifestation [7].

Given the database definitions of intelligence, a system can only have these properties at certain times. To be more precise, intellectual characteristics appear at the moments of modification of the knowledge base, which essentially gives a new context. With a stable structure, these properties are not necessary on a permanent basis [2].

The apparatus for restructuring knowledge bases is based on mechanisms similar to the "arrangement function". For the legitimate use of a finite automaton (computer) as part of an intelligent system, the theory should consider the possibility of constructing abstract structures that implement objects that are not computable in the usual sense. The oil refining industry is a branch of heavy industry covering the refining of oil and the production of petroleum products [4].

An increased interest in oil deposits and its distillation in order to obtain more valuable products began in the first half of the 19th century. In pre-revolutionary Russia, oil refining was carried out according to primitive technology; kerosene was the main processed product that was marketed. Oil refineries were concentrated mainly in the Caucasus (in Baku and Grozny). The share of foreign capital accounted for 56% of all capital investments in the oil industry (1917) [1].

Now the main direction of development of oil refining is the modernization and reconstruction of existing oil refineries with the advanced construction of capacities to deepen oil refining, improve the quality of petroleum products and produce catalysts. Such results can be achieved precisely through the use of intelligent control systems in production processes [3].

The creation of intelligent systems is a very complex process, which includes such items as inspection of production facilities, development of an automation concept, design of control systems, technical support, consulting and many others. The concepts should contain the structure of the entire intelligent control system, all kinds of applications and suppliers of software and hardware systems. Also, there should be decisions on building a network structure, a schedule for the implementation of work and their stages. Development and coordination of design solutions take place at the stage of technical design. This approach allows you to create intelligent control systems with minimal resources. To implement this idea, it is necessary to solve the following set of tasks in laboratory business processes: reducing the time of analysis using equipment, standardizing and systematizing information, ensuring confidentiality, reducing labor costs for

document management, maximizing throughput, monitoring the adequacy of instruments, reducing the input of errors, etc.

Laboratory information management systems should cover all enterprise structures and provide for comprehensive automation of quality management [9].

Disadvantages of Existing Automation Techniques.

The unstable economic situation, the lack of stable development in the field of oil refining and other problems create obstacles for the growth of this industry and the introduction of information technologies into it. The main external disadvantage is fluctuations in demand, which affect the use of production capacities. Also harmful is the instability of supply, which depends on price, quality, availability and profitability. In addition, government regulations also impose restrictions on the supply of products.

Awareness of all these facts leads oil refineries to the use of hardware and software systems to support management decisions. They apply to information process modeling technologies, design tools, simulation optimization methods, performance monitoring, energy management, and more [8].

Another major disadvantage of automation concerns the recycling of production waste. In the oil industry, they are called oil sludge. These products are very dangerous for people and the environment. The composition of oil sludge may vary depending on the production. However, these wastes are often stored in the same way - in worn-out and overcrowded storage facilities, which may be located near water bodies. The lack of desire to allocate the necessary funds for recycling leads to the fact that in this area it becomes practically unmanageable and cannot be automated. This can be solved by including in the technological series of management and the creation of reports on this activity in the information branch. The ideal model of an intelligent control system, of course, implies ideal situations in production processes. However, the desire for this contributes to any changes for the better [12].

The need to create an intelligent development management system hydrocarbon deposit was determined considering the following circumstances: [3].

1. Increasing uncertainties and associated risks of natural (for example, during the development of deep deposits of hydrocarbon deposits raw materials or with hard-to-recover oil reserves) and market (change demand/supply and various price fluctuations for hydrocarbon resources) nature and risks caused by the human factor.
2. The emergence of new, innovative technologies and equipment for mining hydrocarbon raw materials, as well as systems for providing comprehensive monitoring development of oil and gas fields.
3. A significant increase in the volume of geological and field information and application different types of software and hardware systems for its collection, transmission, processing, analysis and storage.

With the help of a digital (virtual) permanent geological and technological oil field model it is possible to provide an effective solution to the following tasks: [10].

- a. clarification of the geological structure of deposits (deposits) in the process drilling new wells;
- b. calculation of various development technology options: determining the nature and the degree of development of explored reserves (when analyzing the distribution fields saturation of various fluids and specific residual reserves hydrocarbons), as well as

- identifying the features and conditions for promoting process waters injected into the reservoir;
- c. forecast of optimal rates of fluid (oil, gas and water) withdrawal in production wells;
- d. improving the efficiency of operating modes of production wells;
- e. planning of various geological and technical measures (GTM) and calculation economic efficiency of their implementation;
- f. forecast of the state of development of a hydrocarbon deposit (in the course of purposeful change in the conditions for the development of productive formations in within the planned GTM).

The essence of the concept of "smart" oil fields is to ensure transparency and instant availability of any required production parameters and performance indicators of an oil production enterprise: technological, technical, geological, ecological and economic. This availability of constantly growing production data (and necessarily in real time) allows you not to simple to organize remote control of oil production facilities, but also significantly improve their existing energy efficiency, as well as ensure significant growth almost all performance indicators of equipment operation, and besides this - optimize staff performance. The core of an intelligent oil and gas development management system deposits of hydrocarbon raw materials is a software and hardware complex, capable of providing a real-time analysis of a rather voluminous fishery information, and as a result of which the prompt identification of any deviations from the design (set) parameters, the formation of effective options control actions and the development for them of optimal technical, technological and logistics solutions, and in some cases the independent implementation of these solutions (still with permission from the operator).

In accordance with this approach, the "smart" oil field is a system for operational management of oil production processes, which includes a set of specific business processes aimed at optimizing production and reduce financial costs through the timely identification of emerging problems and quickly making optimal decisions, based on the received real-time production data [11].

Development of an ideal model of an intelligent system.

Over the past decades, there has been a great leap in the development of information technology. Legacy oil refining systems face many challenges. Old technologies reduce productivity and slow down reorganization. For this reason, modern enterprises compete in the use of the latest scientific achievements, which increases competitiveness and positively affects production. Each enterprise has its own individual situation, which makes the development of any ideal model abstract without taking into account the particular. However, this quotient must be calculated at the design stage. In production, there should be a desire to maximize the use of analytical data in order to minimize all risks. In this way, problems can be avoided in technological, economic, and other terms. In some situations, a phased introduction of reconstruction is possible. Failure to take these measures will result in greater losses due to maintenance costs and lower revenues. The main thing is to reflect the real amount of work for such an update. The final choice of software and technical means of automation systems, control and security systems is always with the consumer, considering the following requirements: reliability, guarantee of technical support, full integration of technical solutions. At the same time, the software, which is one of the most important elements of the automated management and control system, must be original and approved by the relevant government agencies to protect against malfunctions, various types of freezes and unauthorized access. Currently, in practice, the volume-mass dynamics method and direct mass

flow measurement systems are widely used. Measuring devices for liquid volume consumption are divided into two types: absolute compaction (volume) meters and indirect measuring meters. Volumetric meters measure flow directly by dividing the flow into specific volume fractions and calculating these fractions. In indirect meters (primarily turbine meters), the flow rate is determined based on the measurement of some dynamic characteristics of the fluid flow [6].

As a rule, the value measured by the meter is converted into electrical impulses that are proportional to the volume of fluid passing through the meter. The most important characteristics of the meter for practical application are as follows: [12].

- a. Coefficient k is the number of pulses that occur when a volume of liquid passes through the meter;
- b. the characteristic of the meter is the dependence of the coefficient K on the flow rate;
- c. linear-maximum sharpness in the range of processing consumption between the actual value of the coefficient K and the accepted fixed value;
- d. dynamic range is the interaction of the maximum possible and minimum costs for certain characteristics.
- e. reproduction (reproduction) – the ability of the measured system to reproduce the output signal during a series of calibration tests under stable operating conditions.

Turbine flowmeters. It is achieved at the expense of high accuracy and repetition of the statements of the calculators:

- optimal constructive solutions;
- high class of processing and manufacturing accuracy of details;
- properly selected high-quality materials;
- high balancing level of rotor;
- the use of filters that eliminate large solid particles in the liquid;
- application of plates in front of the turbine flowmeter, which level the surface of the flow rate;
- application of modern electronics and microprocessors as secondary equipment;
- testing of each meter at the factory-manufacturer;
- high accuracy of Assembly;
- regular individual calibration of flow meters under operating conditions over the entire flow range using high-precision calibration tools (fuses).

Volume counters. Volumetric meters have been used for decades, have significant dimensions and are more expensive than turbine meters of the same consumption, have a more complex interior design, more moving parts. The advantages of these meters should include:

- can be installed close to other fixtures and fittings without dividing directly into sections and without flow aligners;
- lower pressure loss on the meter itself and reduced overall losses due to lack of flow rectifiers;
- high release viscosity unlike turbine meters;
- a wider permissible range for measuring viscosity without taking into account the K -factor of the meter.

Mass flowmeter. Recently, vibration Coriolis flowmeter devices have been used to calculate mass flow, this flowmeter provides direct measurement of mass flow. In these flowmeters, the Coriolis effect is applied, the Coriolis effect consists in the fact that a body moving at a certain linear speed in a rotating coordinate system is affected by the force of inertia (Coriolis), which is in the



ratio of speed and mass. Mass flowmeters are produced by most traditional flowmeters manufacturers. The advantages of mass flowmeters are as follows:

- direct measure of mass;
- large dynamic range;
- non-dependence of flowmeter properties on liquid properties (density, viscosity, presence of gas);
- there is no need for direct sections before and after flowmeters;
- lack of moving parts;
- the ability to measure density.

There are following parameters of intelligent systems.

Table 1. Parameters of intelligent systems.

Internal	External
structural	load
functional	environment parameters
x_i	particular performance indicators
a_i	weight indicator coefficient of x_i

In general terms, the system design problem is formulated in the following way. The purpose of the intelligent system is set, determined by: [11]

- a list of functions assigned to the system;
- a list and values of load parameters that describe;
- the interaction of the system with the external environment and the need for resources;
- systems for the implementation of specified functions;
- requirements for the characteristics of the system - power, temporary, reliable, economic, limiting admissible values of characteristics.

It is required to determine:

- structural organization of the system, i.e. nomenclature and composition elements, as well as the configuration of links between them;
- functional organization of the system, i.e. mode system functioning, satisfying the given requirements and maximizing (minimizing) direct (inverse) efficiency criterion.

Requirements for the quality of the functioning of the intellectual systems in the form of restrictions on characteristics and efficiency criteria are formulated on the basis of the analysis of the results of model experiments. [9]

The formation of an efficiency criterion involves the construction a generalized performance indicator based on a set of private indicators based on one of the following approaches:

- construction of a composite efficiency criterion in the form of an additive F1 or multiplicative F2 functional;

$$F_1 = \sum_{i=1}^k a_i x_i;$$

$$F_2 = \frac{\prod_{i=1}^k x_i}{\prod_{i=k+1}^k x_i}.$$

choice as an efficiency criterion F of one quotient indicator with restrictions imposed on other indicators efficiency:

$F = x_j$ under restrictions $x_i < x_j$ or $x_i > x_j$

for all $x_i \neq x_j$.

Solution of the problem of design (synthesis) of a new or modernization existing intelligent system with specified properties is to determine the parameters of the structure and functioning systems that provide specified restrictions on characteristics systems. [1]

The ideal model should combine a complex of rapid response to non-standard situations and an adapted base for the coordinated action of all services. The main difference between an abstract system and a traditional one is a significant increase in productivity while reducing costs. New intelligent technologies help to increase the efficiency of the work of console operators, control engineers and maintenance specialists.

Conclusions

This article shows the impact of intelligent systems in the modernization of management in the oil refining industry. The possibilities and features of the production of petroleum products are disclosed. The industry has been looked at from different angles, which helped to make an assumption about which direction it is worth going in order to succeed. The main conclusion is that technology and scientific progress are only aids to production. However, in the implementation process, you need to take into account all the risks and deal with possible problems so that the enterprise reveals its full potential.

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THE USE OF "SOFT COMPUTING" FOR THE DIFFERENTIAL DIAGNOSIS OF THE FUNCTIONAL STATE OF THE CARDIOVASCULAR SYSTEM

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ABSTRACT

The application of soft computing technology for diagnosing the functional state of the cardiovascular system is considered. Soft computing technology uses fuzzy sets, fuzzy logic, fuzzy neural networks, genetic algorithms and evolutionary modeling as tools. Various methods of soft computing technology in solving various problems often complement each other when used in various combinations. This technology is focused on solving control problems with semi-structured control objects. The main informative indicators (indicator variables) characterizing the functional state of the cardiovascular system and obtained on the basis of statistical information are identified. These informative indicators include the tension index, the vegetative rhythm index, the indicator of the adequacy of regulatory processes, the tension index of regulatory systems, and also special indicators that are derivatives of classical statistical indicators: respiratory modulation index, functional arrhythmia index, cardiorespiratory synchrony index, parasympathetic control destabilization index. The quality of the classification of possible diseases is determined by indicators such as sensitivity, specificity, predictive value and diagnostic efficiency.

Keywords: Neural networks, fuzzy inferences, diagnostic conclusion, confidence coefficient.

Introduction

Cardiovascular diseases of various etiologies are one of the key problems of modern medicine. Despite significant advances in the diagnosis and treatment of cardiovascular diseases in recent decades, the number of patients with this type of pathology continues to increase. Due to the fact that the effectiveness of the treatment of cardiovascular diseases largely depends on the accuracy of prognosis, diagnosis of stages and their severity, one of the main directions in choosing a rational strategy for managing patients with this pathology is to improve classification methods, including predicting the onset of diseases, prenosophical and differential diagnostics. Known methods of examining patients with cardiovascular pathology, as a rule, provide their accurate nosological interpretation. However, in a number of cardiovascular diseases, known approaches require significant costs, sometimes using very painful invasive procedures. In this regard, the task of finding methods that facilitate and accelerate the procedures for predicting and diagnosing various types of cardiovascular pathologies becomes relevant. It is possible to improve the quality of solving the studied class of problems using the methods of fuzzy set theory in combination with exploratory analysis, and reflexology with the addition of modern information technologies. Existing methods and tools for diagnosing cardiovascular concerns do not provide the required quality of classification under the given restrictions on decision-making time and technical and economic costs, and a high percentage of these diseases require solving the problems of improving the quality of diagnosis and treatment, the problem of increasing the efficiency of

decision support systems that allow to study various manifestations of cardiovascular disease is very relevant. An analysis of the literature data and our own research led to the conclusion that the tasks of predicting and diagnosing an early stage of cardiovascular diseases in conditions of a shortage of expensive non-invasive equipment are characterized by the fact that the signs used (data from a survey, examination, instrumental and laboratory studies) are heterogeneous, and often fuzzy and incomplete, and the distinguished classes have a complex, intersecting structure. Under these conditions, it is most expedient to use the theory of fuzzy decision-making logic based on exploratory analysis data. The tasks of diagnosing and predicting cardiovascular pathology, as well as other tasks of medical forecasting, can be considered as determining the answers to one of the following questions: a) to determine with what confidence, in the presence of certain risk factors, the subject can develop the selected cardiovascular pathology within a fixed time interval? b) determine after what time and with what certainty the subject may develop a particular cardiovascular disease, taking into account possible concomitant diseases with certain sets of risk factors with a given time limit?

A natural limitation on the tasks of medical forecasting in the conditions of observation of a large contingent of subjects are temporal and technical and economic constraints. These limitations, as well as the real state of affairs with monitoring the health status of the population of the regions, lead to the fact that the informative signs used for forecasting, and in particular risk factors, are most often collected in insufficient volume (incompleteness of the characteristic description). Used signs are measured in various quantitative and qualitative scales (heterogeneity of the structure of signs). Often, experts find it difficult, and sometimes they cannot express in clear terms what the expected prognosis for a particular class of diseases is for the selected, given and (or) obtained by available methods values of informative features [1, 11].

When solving classification problems in the case of fuzzy logical inference, it is proposed to use a medical application based on the use of confidence coefficients in the used giontheses. The possibility of using artificial neural networks for the analysis of electric cars is shown. diographysical signals, where the measured and calculated informative features were used as input parameters.

The decision recommendation system in this study aims to determine the amount of building materials that must be available to meet the construction needs of a residential project. Calculating the right amount of building materials is very important for the project as it determines the amount of budget the construction company has to allocate. This decision uses a Tsukamoto fuzzy inference system to help determine the quantity of building materials needed based on inventory data and number of requests. Decision making in this study was modeled with three variables. Each variable consists of her 3 fuzzy sets. Inventory levels in this system are determined by the concentrated average de-fuzzification method. The proposed method can accurately predict the amount of building materials. The test data accuracy is displayed based on the MSE obtained from the prediction results. From the error calculation, we can conclude that the actual orders placed with the company had an error of 0.11505 compared to the Tsukamoto FIS calculation. From this we can conclude that the method works well in this system and has a high level of accuracy.

Diagnostic conclusions are routine in clinical practice, have great implications for patients, and determine subsequent treatment. However, many patients rarely understand the complexities of this process and are often misunderstood by their physicians.

The confidence factor is the percentage of samples of a given size expected to contain the true mean. This means that given 95% confidence intervals, if many samples are collected and confidence intervals are calculated, about 95% of those intervals will contain the true mean over time. increase.

Soft computing technology is focused on solving control problems with semi-structured control objects. This technology uses fuzzy sets, fuzzy logic, fuzzy neural networks, genetic algorithms and evolutionary modeling as tools. Various methods of soft computing technology in solving various problems often complement each other when used in various combinations.

A characteristic feature of the functioning of complex objects (including living organisms) is that the information available for measurement is incomplete and fuzzy, and the classes of their states are not amenable to a strict analytical description and are evaluated by a set of fuzzy judgments. Inference mechanisms are based on fuzzy decision logic [1].

Statement of the problem

Consider the application of soft computing technology for diagnosing the functional state of the cardiovascular system. To do this, first of all, we select informative indicators (indicator variables) that characterize the functional state of the cardiovascular system and are derivatives of classical statistical indicators [2]:

- stress index

$$SI = \frac{AM_0}{2XM_0}, \quad (1)$$

where M0 is the mode determined by the number of the most frequently occurring RR intervals; AM0 is the mode amplitude, defined as the proportion of RR intervals corresponding to the mode value; X is the variation range, calculated as the difference between the duration of the largest and smallest RR intervals.

- index of vegetative balance

$$IVB = \frac{AM_0}{X}; \quad (2)$$

- vegetative rhythm indicator

$$VRI = \frac{1}{M_0} X; \quad (3)$$

- indicator of the adequacy of regulation processes

$$IARP = \frac{AM_0}{M_0}; \quad (4)$$

- index of tension of regulatory systems

$$ITRS = \frac{AM_0}{2 \cdot X \cdot M_0}. \quad (5)$$

Special indicators:

- respiratory modulation index

$$RM = \sqrt{\Sigma \left(\frac{R_{i+1} - R_i}{2} \right) \cdot \frac{2}{N_1} \cdot 100\%}, \quad (6)$$

where N1 is the number of half differences of RR intervals (-25÷+25 ms);

- functional arrhythmia index

$$FA = (1 - DM/RR_{\text{variation}}) \cdot 100\% - 30 \quad (7)$$

- average SI interval;

-index of cardiorespiratory synchrony



$$CS = SI/RR_{average}; \quad (8)$$

- destabilization index of parasympathetic control.

The spectral relative index is the most informative

$$SI = \frac{LF}{HF}, \quad (9)$$

where LF is the low-frequency component of the heart rhythm, the main spectral power of which falls on the frequency range $0.04 \div 0.15$ Hz; HF is the high-frequency component of the heart rhythm, the spectral power of which lies in the range of $0.15 \div 0.4$ Hz. The SI index characterizes the balance of influence on the work of the heart of parasympathetic and sympathetic departments.

International Indices:

- standard deviation - SDANN;
- root-mean-square deviation of differences between adjacent cardiointervals - RMSSD;
- percentage of adjacent cardiointervals that differ from each other by more than 50ms - pNNSO.

Solution of the problem

The level of functioning of the cardiovascular system is the most important indicator that reflects the level of harmonious interaction between a person and the environment and the adaptive capabilities of the body. To assess the functioning of the cardiovascular system and assess its adaptive potential, the index of functional changes (health index) is also determined according to the formula

$$IFI = 0,011 \cdot css + 0,014 \cdot SBP + 0,008 \cdot DBP + 0,014V + 0,009m - 0,009R - 0,27,$$

where IFI is the index of functional changes, HR is heart rate, SBP is systolic blood pressure, DBP is diastolic blood pressure, P-growth; m is body weight, B is age, 0.027 is an independent coefficient.

Depending on the value of the IFI according to table 1 find the appropriate level of functioning of the cardiovascular system (CVS).

Table 1. Depending on the value of the FFI - the corresponding level of functioning of the CCC.

Group	Performance level (adaptive potential)	FFI values (points)
one	Satisfactory	less than 2.60
2	Tension mechanisms of adaptation	2.60-3.09
3	Unsatisfactory adaptation	3.10-3.49
four	Disruption of adaptation	3.5 and above

Pre-hospital screening based on the coefficient of health is based on the position of the state of the circulatory system as an indicator of the whole organism. The range of changes in the other indicated indicators in normal and pathological conditions is given in [3]. To objectify the results obtained, statistical tests of fuzzy decision rules are carried out on representative control samples.

The sample size is determined in accordance with the recommendations [4] and is selected in such a way that the number of not sick and sick patients remains constant and amounts to 100 people for each class. This made it possible at each stage of the research not to violate the estimate of the probability of correct classification chosen as the standard at the level of 0.95.

The quality of classification is determined by such indicators as sensitivity, specificity, predictive value and diagnostic efficiency [5]. The distribution of observational results is shown in Table 2.

Table 2. Distribution of observation results.

Subjects	Research results		Total
	positive	negative	
Number of surveyed classes $\omega_1 - n_{\omega_1}$	True (IP)	False (LO)	IP+LO
Number of surveyed classes $\omega_0 - n_{\omega_0}$	False (LP)	True (IR)	LP+IO
Total	IP+LP	LO+IO	IP+LO+LP+IO
*- classes for comparison change depending on the pair being checked.			

LP is a false positive result, numerically equal to the number of healthy people classified by the decision rule as patients with a predictable (diagnosable) disease.

LO - false negative result, numerically equal to the number of people in the class ω_1 , classified by the decision rule as healthy people.

IP is a true positive result, numerically equal to the quality of people of the class, correctly classified by the decision rule. ω_1

AI is a true negative result, numerically equal to the number of sick people classified by the decision rule as healthy people. ω_0

The diagnostic sensitivity (DS) of the decision rule in relation to the class is determined by the ratio of the frequency of true positive results to the number of patients, i.e.

$$DS = \frac{IP}{n_{\omega_1}}. \quad (10)$$

Diagnostic specificity (DS) of the decision rule in relation to the class ω_0 represents the ratio of true negative results to the number of healthy people, i.e.

$$DS = \frac{IO}{n_{\omega_0}}. \quad (11)$$

The predictive value of positive results of PZ+ is determined by the expression

$$PZ^+ = \frac{IP}{IP+LP}. \quad (12)$$

The prognostic significance of negative results PZ- is determined by the expression



$$PZ^- = \frac{IO}{IO+LO}. \quad (13)$$

Diagnostic efficiency (DE) is determined from the expression.

$$DE = \frac{IP+IO}{IP+LP+LO+IO}. \quad (14)$$

When solving classification problems using the theory of fuzzy logic, it is necessary to calculate the membership functions, which is determined in relation to the elements (points) of the sets. However, when solving the classification problem to process each individual point, as it is implemented in set theory, the general properties that form the basis of classification are easily lost. This may lead to incorrect results.

Another approach to fuzzy inference is proposed specifically for medical applications and is based on the use of confidence coefficients in the hypotheses used ω_f [6]. This approach is based on the assumption that two mutually reinforcing evidence (signs, indicators) should increase confidence in the conclusion (prognosis, diagnosis), possibly giving a higher degree of truth than the average or even the maximum. On the other hand, a few pieces of evidence pointing in one direction cannot be fully offset by evidence pointing in the opposite direction. This logic of reasoning is implemented by the formula for calculating the confidence in the decision being made, which is determined through the corresponding coefficient of confidence CG_{ω_f} :

$$KU_{\omega_f} = MD_{\omega_f} - MND_{\omega_f}. \quad (15)$$

where MD_{ω_f} - measure of confidence in the decision (to the classification) ω_f , MND_{ω_f} - an appropriate measure of distrust.

In turn, each of the components is determined by iterative expressions of the form:

$$\begin{aligned} MD_{\omega_f}(j+1) &= MD_{\omega_f}(j) + MD(Y_i) \cdot [1 - MD_{\omega_f}(j)]; \\ MND_{\omega_f}(j+1) &= MND_{\omega_f}(j) + MND^*_{\omega_f}(Y_q) \cdot [1 - MND_{\omega_f}(j)] \end{aligned} \quad (16)$$

where j is the iteration number, often coinciding with the numbers of features and (or) frequency (intermediate) confidence factors; - measure of confidence k from the newly received evidence (feature, combined indicator, etc.) to the moment when it has already been determined for all previous evidence; - a measure of distrust to from the newly received evidence.

$$MD^*_{\omega_f}(U_i)_{\omega_f} Y_i MD_{\omega_f}(j) MND^*_{\omega_f}(U_q)_{\omega_f} U_q. \quad (17)$$

As the results of using fuzzy decision-making logic have shown, in medical practice, experts often use only those signs and (or) combined indicators as signs and (or) combined indicators, the analysis of which testifies in favor of the class. For example, a blood pressure scale can be used to indicate the degree of hypertension or hypotension. ω_f

Then, if there are no informative features that disprove the version , then , and the CG formula is modified to the expression: $\omega_f MD_{\omega_f} = 0 \omega_f$

$$KU_{\omega_f}(j+1) = KU_{\omega_f}(j) + KU_{\omega_f}^*(U_i) \cdot [1 - KU_{\omega_f}(j)];$$

where is the coefficient of confidence in from one evidence (factor) $.KU_{\omega_f}^*(U_i) \omega_f U_i$

The meaning of the last formula is that the effect of new evidence in favor of the hypothesis with already known evidence affects the shift of CG towards complete certainty by a distance depending on the new evidence. Important properties of the above formula is its symmetry in the sense that the order of succession does not matter, and the movement towards the certainty of CG (MD or MND) is carried out as supporting evidence is accumulated. $(Y_i) \omega_f \omega_f Y_i \omega_f$.

Conclusions

The increase in the measure of confidence in the combined accounting of evidence, compared with the confidence in each of them taken separately, is consistent with the intuitive notion that several evidence pointing in the same direction should reinforce each other. There is no theoretical justification for these rules. MD and MSD are not probabilistic measures, although they obey some axioms of probability theory. They are not samples from any population and therefore cannot be given a statistical interpretation. However, they allow you to order hypotheses according to the measure of validity that they have.

One of the ways to increase the efficiency of diagnostic conclusions and classification of diseases is the addition of a decision support system to the software of computerized medical devices. The use of artificial neural networks is associated with pattern recognition, optimization, and data analysis [7]. Neural networks are widely used in medical diagnostics and treatment prognosis. Neural networks can also be successfully used to analyze electrocardiographic signals. Of the structures of neural networks under consideration, the three-layer perceptron can be considered the most acceptable, in which the measured and calculated above informative features (indicators) were used as input parameters of the initial data. At the output of the neural network, a diagnostic conclusion is formed.

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CRYSTAL STRUCTURE AND SURFACE MORPHOLOGY OF CD_{1-X}FE_XS SOLID SOLUTION-BASED THIN FILMS

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ABSTRACT

Cd_{1-x}Fe_xS ($x = 0.03$) solid solutions were synthesized and thin films were obtained on their base by molecular beam condensation method. It was studied the effect of γ - irradiation on surface morphology, growth properties and crystal structure of obtained thin films. The characteristics of Cd_{1-x}Fe_xS ($x = 0.03$) solid solutions exposed to γ -rays at doses of 50, 100 and 150 kGy from ⁶⁰Co source were characterized by XRD, SEM, EDX methods. XRD analysis showed that the orientation of crystal planes changes after γ -exposure. It was determined that the peak intensity of the (101) plane of Cd_{1-x}Fe_xS solid solutions increased with the radiation dose. Sizes of crystallites increased after γ -irradiation. Thus it is possible to manage some crystal properties with γ -irradiation. XRD investigations demonstrates, that thin films grown on glass substrates at substrate temperature $T_{sub}=470$ K were polycrystalline structure and thin films grown at substrate temperature $T_{sub}=670$ K were monocrystalline structure.

Keywords: Solid Solution, Semimagnetic Semiconductor, SEM, XRD, EDX, γ -radiation

Introduction

Cadmium sulfide (CdS) with a bandgap of 2.44 eV is considered to be one of the semiconductor compounds of II-VI group, and useful in solar cell devices, thin film transistors, optoelectronic devices, etc. making interesting material for application purposes. Thin films of CdS are more focused in the production of electronic devices, photovoltaic cells and optical detectors. In recent years, some research in the field of magnetic materials has been directed to obtain semiconductors with ferromagnetic properties at room temperature. Semiconductor compounds II-VI group containing Mn, Fe, and Co ions have been extensively studied for their properties as dilute magnetic semiconductors or semimagnetic semiconductors.

New class materials in which semiconductors are doped with magnetic impurities are II-VI semiconductors. Semimagnetic semiconductors (SMSC) is critical to the future of electronic science because it combines elements of semiconductors (charge) and magnetism (spin) into a single material known as spintronics [1, 2].

Nowadays, it is impossible to imagine modern electronics without thin films. Since devices are created on the surface of crystals, including all structural changes reflected in the parameters of devices, it is necessary to obtain thin films with perfect crystal structure and clean smooth surface. Meanwhile, one of the urgent problems of modern physics is to obtain radiation-resistant and radiation-sensitive materials with stable physical properties. It should be noted that due to the formation of radiation defects, changes in the physical properties of materials that are most strongly affected by ionizing radiation under certain conditions are observed. For this reason, it is



important to study the effect of ionizing radiation on the physical properties of semiconductor materials. These materials have many promising applications in solar cells, optoelectronics, light amplifiers, light-emitting diodes, laser diodes, photoelectrochemical cells, nanosensing, and biomedical imaging [3-8].

$\text{Cd}_{1-x}\text{Fe}_x\text{S}$ thin films are of particular significance in actual application and basic research. Some works have been dedicated to the problem of physical properties of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) thin films. The current paper is about the investigation of the effect of γ -irradiation on the crystal structure and surface morphology of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) thin films.

Material and method

$\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) SMSC thin films of $1.5 \mu\text{m}$ thickness were deposited on cleaned glass substrates at the rate of $v=18\text{-}20 \text{ \AA/s}$ by molecular beam condensation technique in a vacuum of $(1\div 2)10^{-4} \text{ Pa}$. All technical details and preparation methodology are reflected in our previous works [9,10].

Synthesis of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ solid solutions was obtained, therefore treatment of primary components: cadmium, sulfur, iron. In order to clean electrolytic iron covered with an oxide layer, we etch it in a solution of distilled water and nitric acid (HNO_3) taken in a ratio of 1:1, and then wash it in distilled water. We accurately weigh the primary components on the VLA-200 analytical scale. The following formula is used to calculate the amount of substances:

$$P_{\text{Cd}} = P \cdot A_{\text{Cd}} \cdot x / (A_{\text{Cd}} \cdot x + A_{\text{Fe}} \cdot y + A_{\text{S}} \cdot z); \quad (1)$$

$$P_{\text{Fe}} = P \cdot A_{\text{Fe}} \cdot y / (A_{\text{Cd}} \cdot x + A_{\text{Fe}} \cdot y + A_{\text{S}} \cdot z); \quad (2)$$

$$P_{\text{S}} = P \cdot A_{\text{S}} \cdot z / (A_{\text{Cd}} \cdot x + A_{\text{Fe}} \cdot y + A_{\text{S}} \cdot z), \quad (3)$$

where, P – total weight of charging, P_{Cd} – cadmium weight, P_{Fe} – Fe weight, P_{S} – sulfur weight, A – atomic weight of element, x, y, z – atomic share of Cd, Fe, S respectively [11].

It is noteworthy, which filling of drawn components into recycled and thermally treated ampoules is carried out in the same order. After creating a vacuum of $1 \cdot 10^{-4} \text{ Pa}$ in the ampoules, its mouth is separated from the absorption system by melting and soldering, and then the process of synthesis of the materials to be processed is carried out. The ampoule set down in the horizontal furnace is heated to the melting temperature of the solid solution at 100 degrees/hour, and the temperature increases by 50 degrees after keeping for 3 hours. When the required temperature is obtained, the mixing mechanism is periodically changed for 2 hours. Then the temperature is reduced to T_{fus} . The bulb is kept at this temperature for 24 hours and the entire system is rotated periodically to mix the alloy well. After the synthesized samples undergo a homogeneous thermal treatment at a temperature of $873\div 973 \text{ K}$ for a week, the substance quantity of 10 g of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions is calculated using the above formula.

The rate of condensation is controlled by the temperature of the primary source. We can note that additional S source evaporation was used in order to obtain perfect film surface morphology without using any samples. It can be seen from the XRD studies that $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ thin films develop in glass substrates at $T=470 \text{ K}$ have a polycrystalline structure, and at the substrate temperature $T=670 \text{ K}$ they have a monocrystalline structure.

$\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions were irradiated with γ - rays obtained from ^{60}Co source of $E=1.17 \text{ MeV}$, $E=1.33 \text{ MeV}$ energies.

The structure and phase purity of the γ -irradiated these films were examined by X-ray diffraction (XRD) at room temperature using a BRUKER XRD D8 ADVANCE. The studies of surface morphology of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions were carried out the scan electron microscope (SEM) JEOL/ JSM-6610. According to the Energy Dispersive X-Ray Analysis (EDX) technique, the chemical structure of these films was analyzed using standard energy dispersive analysis.

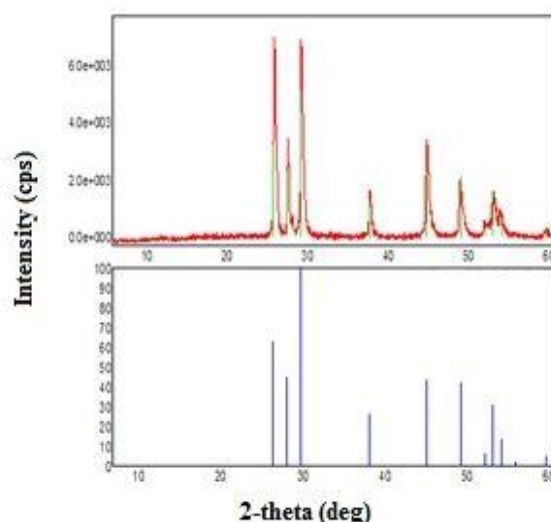
Experimental

On the characteristics of electronic devices are relatively related to the surface morphology of crystals, the study of external effects (temperature, pressure, lighting, radiation, etc.) occupies the significant place in diagnosing their surface. It is clear that radiation technology is more dominant favorable methods for the modification of semiconductor materials. Thus, by irradiating the material, it is possible to control the physical feature of these materials, as well as to predict the properties of devices based on them. In this regard, it is of great interest to study the changes in the surface of the $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions, therefore the effects of γ -irradiation. The results of SEM and XRD studies of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions exposed to γ -irradiation ($D_\gamma=10\div100$ kGy) are presented in this study.

X-ray diffraction pattern of as-prepared $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions appears in figure 1. High intensity peaks of sample is given using Debye Scherrer equation. According to the table 1, the XRD measurement reveals that all the sharp diffraction peaks (100), (002), (101), (102), (110), (103), (200), (112), (201) and (202) confirmed face centered cubic structure of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ with crystal lattice parameter of $a = b=4.1002$ Å, $c=6.6568$ Å, $\gamma=120^\circ$. The crystallite size (figure 1) of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions may be estimated from the width of the XRD peak using Debye–Scherrer’s formula [12] given by

$$D = (0.9 \lambda)/(\beta \cos \theta), \quad (4)$$

where, D - is crystallite size, β - is full width at half maxima (FWHM) of the peak intensity, θ - is diffraction angle in degrees and λ - is the wavelength of X-ray used (table 1).



**Figure 1.** X-ray diffraction patterns of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x=0.03$) thin films.**Table 1.** The XRD measurements.

№	2θ (deg)	Crystal system (hkl)	FWHM, β (deg)
1	27	100	0.15
2	28.2	002	0.15
3	30	101	0.15
4	38.4	102	0.1
5	45	110	0.25
6	50	103	0.25
7	52.7	200	0.2

It was studied effect of γ -irradiation on crystal structure of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) thin films. XRD patterns of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions on glass substrate and irradiated by γ - quanta ($E=1.17\text{MeV}$, $E=1.33\text{MeV}$) with different doses ($D_\gamma=10+100$ kGy) are shown in fig1. The diffraction pattern of γ -irradiated thin films with different doses 10, 50 and 100 kGy revealed that the peak intensity of (101) plane of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ increased with dose.

It can be seen that the number of planes aligned along the (101) direction increased with γ -irradiation. The reason for this is that ^{60}Co γ -rays are high-energy electromagnetic waves. When the radiation dose $D_\gamma = 50$ kGy \div 100 kGy, the surface energy becomes important in the process of crystal growth. During the process, atoms are easily attracted by the high surface energy (101) crystal face and condense there, which can lead to the predominance of the (101) plane [13,14]. XRD analysis confirmed the change in orientation of the planes after γ -irradiation exposure.

The SEM method was used to study the effect of γ -irradiation on the surface morphology of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) thin films. The morphology of the $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ thin films before and after γ -irradiation was analyzed by SEM method. $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions were irradiated with γ -quanta at a dose of $D_\gamma=100$ kGy, which is caused by the interaction of γ -quanta with atoms in their paths during irradiation. It was revealed, that after γ - irradiation, the $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ crystallite size increased, which is in profitable consent with the XRD results. The compositional analysis of the pure $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ solid solution was carried out using EDX shown in table 2.

Table 2. EDX analysis of pristine $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions.

Element	Weight %	Atom%
Cd L	79.38	52.71
S L	19.91	46.34
Total	100.00	100.00

Elemental chemical composition was investigated by means of EDX analysis. The results did not deviate much from the structure of starting precursor alloys (figure 2).

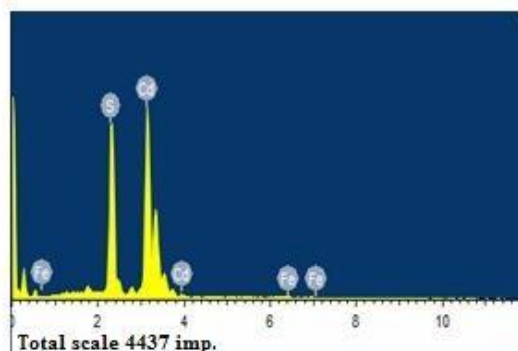


Figure 2. Energy-dispersive X-ray spectrum of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions

Results

In the current research, $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions were synthesized and thin films were obtained on their basis by molecular beam condensation method. We studied the effect of γ -irradiation on growth properties of obtained thin films. Properties of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ ($x = 0.03$) solid solutions exposed to 50, 100 and 150 kGy doses of γ -rays from ^{60}Co source were characterized by XRD, SEM, EDX methods.

XRD analysis revealed that the peak intensity of the (101) plane of $\text{Cd}_{1-x}\text{Fe}_x\text{S}$ increased with dose. Crystallite size increased after γ -irradiation. Finally, it was realized, which is possible to control some crystal properties with γ -irradiation. The results obtained from XRD investigation demonstrates, that thin films with polycrystalline structure grow on glass substrates at substrate temperature $T_{\text{sub}} = 470$ K, and monocrystalline structure grow at substrate temperature $T_{\text{sub}} = 670\text{K}$.

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REMOTE MEASUREMENTS OF WATER SURFACE POLLUTION BY THE METHOD OF LASER LOCATION

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ABSTRACT

As it was shown in the nature investigations, the most area of water in the Azerbaijan shore of Caspian Sea is covered by oil film, the square of which depends on direction of wind.

The research of pollution's of environment by the mean of optical apparatus of remote sounding, mounted on the board of flying apparatus or space satellites is one of intensely developing directions.

The theory of measuring of oil film's thickens by the help of laser location in detail described. The principles of straight-line spreading of electromagnetic waves, reflecting of electromagnetic energy by objects and constant speed of their propagation are laid in the basic of location.

We have developed lidar for controlling of pollutions of water surface, where helium-neon laser "LGI-102" having power 3mW working in the pulse regime is used as beam radiator. During the experiment the laser was mounted on the plain ground on the distance 1-meter from water surface. The prism was placed in the road of propagation of laser beam and used for direction of radiation under the angle 45 on water surface. Integral photo transducer on the base of local mono-and polycrystalline silicon films with linear output was used in the photo detector device. Photo transducer was made in hybrid form on the base of two crystals: photo sensitive poly-silicon film and unpack operational amplifier 740UD4.

Keywords: Pollution, water surface, oil film, laser location, lidar, photo detector.

Introduction

Oil and product of its processing are most spread substances, which harmfully effects to the sea's flora and fauna, what is especially important for Azerbaijan, which is sea and oil producing state.

As it was shown in the nature investigations, the most area of water in the Azerbaijan shore of Caspian Sea is covered by oil film, the square of which depends on direction of wind and for example, equals in the region named as Oil Stones, to 240km², in the region of island named Bulla-11km² and in the region of bank named after Mackarov-8km² [1].

The existence of oil film in the surface of water changes the proceeding on physical-chemical processes in the border "Water-air", substantially effects to the amount of dissolved oxygen in the water, which could bring to decrease and disaster of fish resources of sea.

The solving of problems of protection of environment and rational using of natural resources in signification level depends on development and applying of technical means of control of parameters of ecological media.

The research of pollutions of environment by the mean of optical apparatus of remote sounding, mounted on the board of flying apparatus or space satellites is one of intensely developing directions.



In compare with traditional contact methods of obtaining of information, the remote sounding provides the broad possibilities of operative collection of data with high spatial, spectral and time solution and also with high speed of transferring of information to the processing centres. Prognosis shows, that the volume of information transferred via space satellites will achieves such values in the near future, that the super high-speed operating system would be needed for transferring of them. For example, during remote sounding of Earth from space satellite flying on low orbit; to transfer the image with solution 10m in the ten spectral bands with solution equal to 8bits, the system with the speed of transferring no less than 1Gbit/s is needed.

The development of systems with such speeds of transferring of information by the mean of radio apparatus is a problematical task. This task can be solved by using of optical band of electromagnetic waves. Besides, the optical link is not sensitive to the ionization of atmosphere and has higher protection from interference and higher directivity of radiation. Indeed, in the circular antenna with diameter 3m in the SHF-system of 3cm band, the angle of beam's divergence is equal to 10 mrad, which is considered as sufficiently low for SHF band.

General part

In the optical band, if the wavelength is equal to $0,5\mu$, diameter of receiving antenna is equal to 10cm, the theoretical value of divergence angle $\gamma=5\text{mrad}$ and in order to provide the same level of received powers it is sufficient to use the transmitter having power of radiance less than 66dB in comparison with power of SHF transmitter [2].

The theory of measuring of oil film's thickness by the help of laser location in detail described in [3]. The principles of straight-line spreading of electromagnetic waves, reflecting of electromagnetic energy by objects and constant speed of their propagation are laid in the basic of location. The capability of ecological objects to diffuse the electromagnetic wave fallen to them is estimated by effective square of scattering, (ESS), which should be considered as factor of proportionality between power of wave P_D , diffused by object of locational observation and density of power stream P_S , of wave fallen to it [3].

$$P_D = \text{ESS} \frac{P_S}{4\pi L^2}; \quad (1)$$

where L- the distance between receiving antenna and ecological object. While using the non-directed antenna, the density of power stream on the distance L from station could be found by dividing the radiated power P_1 to the square surface of sphere.

$$P_S = \frac{P_1}{4\pi L^2}; \quad (2)$$

For directed antenna the density of power stream in the direction of maximal pulse radiation P_1 should be multiplied to the factor of directed effect G of transmitting antenna.

$$P_S = \frac{G \cdot P_1}{4\pi L^2} \quad (3)$$

If the ecological object is situated in the direction of maximal radiation of antenna, the diffused by object power should be determined by formula: π^2

$$P_D = \text{ESS} \frac{G \cdot P_1}{16\pi^2 L^4}; \quad (4)$$

Indicated the effective square of receiving antenna as S_a , we find the power of reflected signal, which received by antenna of locational station.

$$P_R = \text{ESS} \frac{G \cdot P_1 \cdot S_a}{16\pi^2 L^4}; \quad (5)$$

The main equation of location shows the dependence of power of reflected signal from parameters of station, character of ecological object and distance up to it.

Among the active methods of control of ecological media's parameters, the widely used one is method of laser location, where the information about the distance up to investigated object is contained in the parameters of reflected(diffused) optical radiance.

The magnitude of signal while reflected from oil film on the water surface is determined by equation (5) which taking into account the feature of laser beam's propagation is transformed as(4):

$$P_R = ESS \cdot G \cdot P_I \cdot S_a \cdot K_{opt} \cdot T_{atm}^2 \cdot T_C / 16\pi^2 L^4 \quad (6)$$

The fading of radiance in the receiving optical device is taken into account by factor k_{opt} and the square meaning of factor T_{atm} denote the equal spectral admission of optical radiance for direct and reverse pulses and T_C is the factor of fading of reflected radiance by corrugated water surface,

$$T_C = 1 - \exp(-\theta^2 / 4a_\Delta^2) \quad (7)$$

where a_Δ -parameter of corrugation. According to(5) the sea surface is characterized with following values of parameter of corrugation: $a_\Delta^2 = 0,02$ while the speed of wind 5m/s, $a_\Delta^2 = 0,04$ while $v=10$ m/s.

To optimise the performance of a lidar system in terms of sensitivity, reliability, portability and costeffectiveness, a judicious choice of the laser and the photodetector must be made. In addition, the selection of an optimum laser wavelength must be based on the wavelength-dependent trade-offs between the scattering cross-section and the atmospheric transmittance. However, in the final analysis, the minimum detectable power is governed by the required S/N (signal-to-noise) ratio and this, in turn, depends on the signal averaging time. For weak signals, buried in background optical and electronic noises, encountered in remote sensing application, the required signal averaging time may restrict the range of application of this technique.

Present status of remote sensing of water pollutants

Experimental work on the use of laser scattering in remote probing of water pollution started in earnest following the initial feasibility studies on the detection and identification of oil spills nearly two decades ago (Measures and Bristow, 1971; Horvath et al, 1971). However, the unknown variability of fluorescence characteristics of oil (Abroskin et al, 1988) due to contact with water and exposure to weather (ageing) and its presence in a variety of forms (films, emulsion, dissolved petroleum products, etc) resulted in a lack of progress in the implementation of a useful remote laser fluorosensor system. A fully operational fluorescence lidar was demonstrated in 1979 in Canada (O'Neil et al, 1980). Using correlation analysis of the fluorescence data obtained by the airborne lidar and those taken in the laboratory, unambiguous identification of the grade of oil (crude, light, refined, etc) and the type of dye was possible. The same system was later used to monitor dissolved organic carbon and chlorophyll (Bristow et al, 1985) in surface waters. An airborne fluorescence lidar system has also been developed and tested in North America (Franks et al, 1983). Although this was capable of detecting strong fluorescence from surface oils and dyes, it lacked spectral information. Very recently the successful operation of an airborne fluorosensor system in Germany has been reported (Hengstermann and Reuter,



1990). The system is capable of classifying small discharges of mineral oils and measuring film thickness in the submicrometre region from a detection range of 245 m. No such operational remote sensing system exists in the UK. The possibility of using fibre optics for the remote detection of ground-water pollution has been reported by several workers (Hersefeld et al, 1983; Chudyk et al, 1987). Fibreoptics are used purely to transmit both the laser light and the fluorescence scatter to and from locations normally inaccessible to light. Very recently a shipborne prototype laser-fluorosensor system using fibre optics has demonstrated the feasibility of depth profiling (Cowles et al, 1989) (up to 20m) of chlorophyll and natural pigments in water. Conventional Raman scattering has been used in the past for the detection and identification of some molecular (Bradley and Frenzel, 1970) and ionic (Baldwin and Brown, 1972) pollutants in water. Under ideal experimental conditions and in pure waters, detection sensitivities of a few parts in 10⁶ were achieved. In real-world samples, the sensitivity of detection of, for example, sulphate ions (Cunningham et al, 1977) were too poor to be of any practical use. However, using resonance excitation a few parts in 10⁹ level of sensitivity, for the detection of industrial fabric dyes in natural waters, has been demonstrated (Haverbeke et al, 1978). The feasibility of Raman scattering for remote sensing of water pollution (Ahmadjian and Brown, 1973) has been investigated as early as in 1973, but no practical Raman lidar for this purpose exists at present.

Future prospects

The fluorescence lidar, based on a nitrogen laser (1 mJ/pulse), developed in Canada (Barringer system) (O'Neil et al, 1980) in the early 1980s remains the only effective operational system to date. The complexity, cost effectiveness and portability of the system are the main factors which inhibit its wider application. It has been suggested (Bristow et al, 1989) that the scope of such a system could be vastly enhanced by the use of an excimer laser (>100 mJ/pulse) and a gateable intensified diode-array detector, controlled by a dedicated optical multichannel analyser (OMA). Despite all the sophistications, the identification and classification of pollutants (eg, spilled oils, dyes, chlorophyll, etc) spread homogeneously over a large area of surface water, rely on correlation of the lidar data with that from the laboratory. Therefore there is a need for a database both on the fluorescence quantum yield and Raman cross-section under specific environmental conditions. The spectral signature and its dependence on excitation wavelength, is also a prerequisite for the application of a lidar system in remote water-pollution measurements. Owing to the unknown quenching factor, the fluorescence quantum yield of x pollutant species in a real-world situation remains unpredictable. This will make evaluation of the detection sensitivity of a fluorosensor impossible. However, since the quenched fluorescence cross-sections of some molecules - eg, OH, NO₂, SO₂, etc - are still several orders of magnitude higher than that of their Raman crosssections, the fluorescence will provide a better SIN for a lidar signal and unambiguous detection and identification of highly chromophoric pollutants. For quantitative estimation of concentration of a species, particularly those which are weakly fluorescent and present in a mixture of other species, Raman lidar, utilising resonance excitation, holds the only promise as a versatile remote sensing tool for water pollution monitoring both for local and field application. To apply Raman scattering for remote sensing, various parameters and requirements (see Eqn (1)) have to be considered. For a particular atmospheric model and known Raman excitation profile (wavelength dependence of the cross-section), an optimum excitation wavelength can be located for a particular detection range. Since the sensitivity will, at the same time, depend on transmitted power, this needs to be optimised. While frequency-doubled dye

lasers can produce the output at a desired wavelength, the requirement of higher output power will dictate the use of a discrete output from the excimer laser (191 nm, 248 nm, 308 nm, 337 nm or 351 nm). The trade-offs between the enhanced background fluorescence, atmospheric attenuation and the increase in Raman cross-section will dictate the use of 308 nm or 248 nm output, particularly for remote application. The detection sensitivity can be increased (lower $N_{m;n}$) by lowering the minimum detectable power (P_{min}). For a particular photodetector this, in turn, is governed by the required S/N and the data-averaging time. The sensitivity of an optical remote-sensing system for the detection of a molecular species is estimated with the following considerations:

1. The field of view of the receiver telescope or the divergence of the laser beam is adjusted so that the effective area, viewed, coincides with the total irradiated area.
2. Signal-averaging time is selected to achieve the required minimum detectable power.
3. Raman/quenched fluorescence cross-section and the atmospheric attenuation coefficient at the relevant wavelengths are known.

The calculation must be based on lidar parameters achievable by the present state-of-the-art electro-optics technology. Accordingly, the following parameters are assumed:

$$P_{rmin} = 10^{-13} \text{ W}; P_i = 100 \text{ W (248 nm output of an excimer laser)}$$

$$\eta_s = 0,5 \text{ and } r = 0,3 \text{ nm.}$$

For the detection of pollutants in the bulk of the water, we choose arbitrarily an effective sampling depth $l = 1 \text{ m}$. We define the effective sampling depth such that it takes account of the two-way attenuation by the water and the uniformly distributed pollutants. For near UV and visible wavelengths, penetration depth of a few meters can be achieved in most natural waters. Therefore, $l = 1 \text{ m}$ is a reasonable approximation in the estimation of a lidar sensitivity for uniformly dissolved organic compounds, and uniformly suspended emulsified oil and other Raman-active pollutants. The Raman cross-section of S04- at 248 nm excitation is $\sim 3 \times 10^{-28} \text{ cm}^2/\text{sr}$. At this wavelength, the lidar detection sensitivity is estimated to be 6 mg/l at a range of 100 m (with $T = 0.75$). For some molecules such as 12. $\text{C}_6\text{H}_5\text{NO}_2$, NO_3 , etc, the crosssections are much higher than that for S04- at resonance excitation. Therefore higher-sensitivity or longer-range capability can be achieved for the detection of these species. Oil pollution manifests itself as films on water surface of sub-millimetre thickness. At ultraviolet wavelengths these films are practically opaque, and the fluorescence and Raman scattering are confined to the surface layers of these films. Since there are a host of Raman-active species in crude oils. Raman lines from such samples will neither be specific nor separable. Moreover, the strong fluorescence may submerge any specific Raman line irretrievably. However, characteristic fluorescence from such samples render these detectable from long ranges. For laser fluorosensors to be cost-effective and versatile, further research on the optimisation of the lidar system parameters and on the fundamental interaction process are needed.

Conclusions

We have developed lidar for controlling of chemical pollutions of water surface, where helium-neon type laser "LGI-102" having power 3 Mw working in the pulse regime is used as beam



radiator [6]. During the experiment the laser was mounted on the plain ground on the distance 1 meter from water surface. The prism was placed in the road of propagation of laser beam and used for direction of radiation under the angle 45° on water surface. Integral phototransduced on the basis of local films of mono-and polycrystalline silicon with linear output was used in the photo-receiving device [7]. Photo transducer was made in hybrid-film form on the basis of two crystals: photo sensitive poly-silicon film and unframed operational amplifier 740UD4. The minimal level of radiance power, detected in the spectral band $0,5 \div 1\mu$ was equal to $10\text{W}/\text{cm}$. The dependence of output voltage from illumination was of linear type till values of 6000lx , with sensitivity no less than $10\text{mV}/\text{lx}$.

Table 1. Results of lidar on the basis of laser “LGI-102”

Type of water surface's pollution	The voltage of registered signal, mV
Clean water	200
Condenser oil	300
Machine oil	420
Benzine	550
Oil film	570
Diesel fuel	800
Bitumen varnish	960

The signal from output of photo transducer was transferred to the input of processing device and then was registered by analyzer of high-speed processes, including oscillograph, millivoltmeter and indicator. The results of measuring of various types of water surface's pollution have been shown in the table 1, from which it is clear, that reflectional capabilities of polluted and clean water differ 2-4 times.

The presence of film of oil product in the surface of water increases the reflected signal due to two reasons. Firstly, the oil film increases the reflecting capability of water surface. Secondary, the oil pollutions stabilize the seaways and accordingly decreases the corrugation 2-4 times.

The results of estimation of effects of seaways to the value of reflected signal of lidar are shown in the table 2.

Table 2. The factors of decreasing of reflected radiance from water surface by seaways.

θ, mrad	$V_{\text{wind}} = 5\text{m/s}$		$V_{\text{wind}} = 10\text{m/s}$	
	absence of film	presence of film	absence of film	presence of film
3	0,11	0,34	0,05	0,16
6	0,45	1,36	0,23	0,67
52	33,6	98,6	17,0	50,2
100	117,5	315,3	60,5	171,3

The data shown in the table 2 indicate that seaways brings to significant decreasing of reflected signal. From another side, on account of smoothing of seaways the signal, reflected from corrugated water surface covered by film, approximately 3 time more, than signal reflected from clean water. The tests had shown the possibility of using of lidar to identify the water surface pollutions in principle.

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PRESSURE SENSORS WITH METROLOGICAL SELF-CONTROL FUNCTION

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ABSTRACT

The paper considers the advantages of using smart pressure sensors in systems for measuring and controlling technological objects. Modern intelligent sensors that, in addition to the measurement process, convert the measured signals into typical analog and digital values, perform self-diagnosis of their work, remotely adjust the measurement range, pre-process measurement information, and sometimes a number of fairly simple, typical control and management algorithms. They have interfaces to standard / typical field digital networks, which makes them compatible with almost any modern automation equipment, and allows you to communicate with these tools and receive power from the power supplies of these tools. The technical features of the use of modern intelligent pressure sensors are considered. The functions implemented by intelligent sensors, their structural features and characteristics of the main data transfer protocols used in automation systems where these sensors are used are analyzed. The correction of temperature errors of the pressure sensor, which works according to the scheme of the tensor-resistive bridge, with the use of the capabilities of the LabVIEW software environment, is considered.

Keywords: Smart pressure sensors, data transfer protocols, sensing element, LabVIEW software.

Introduction

Gauge, absolute, differential, and hydrostatic pressure sensors covering a wide range of measurements are an integral part of modern measuring systems and complexes. They are in demand in monitoring various technological processes, energy, oil and gas industries and other areas of life such as medicine, food industry, heat and water supply, engineering industry, automotive industry, electronics industry, robotics, etc. It is obvious that the control of the metrological serviceability of sensors during operation in difficult working conditions is a very urgent problem. Currently, to solve this problem, preference is given to the intensive introduction of smart pressure sensors (SPS) in monitoring and control systems. In accordance with [1], an intelligent sensor is understood as an adaptive sensor with the function of metrological self-control. Self-checking of the sensor involves automatic verification of the metrological serviceability of the measuring instrument during its operation with the determination of the status of the measurement result. Metrological self-control should be based on additional data obtained due to the spatial (structural), temporal, informational (functional) redundancy available or formed in the sensor. As indicated in [2], metrological self-control reduces the likelihood of

obtaining insufficiently accurate measurement information during the calibration interval, to justify changing the calibration interval depending on the residual metrological life of the sensor, to reduce operating costs by reducing the number of verifications and calibrations, and also when eliminating the consequences of malfunctioning sensors caused by metrological failures. In addition to the usual functions of perception of the desired value and signal conversion, modern intelligent sensors perform a number of other functions that significantly expand their capabilities and improve technical characteristics.

Structure of smart pressure sensors

Modern PDAs have a block structure, the main blocks of which are a sensitive element (sensor), a conditioning unit, an analog-to-digital converter, a local user interface, an application algorithm, a memory, a communication unit. The structure of an intelligent pressure sensor is shown in Fig. 1.

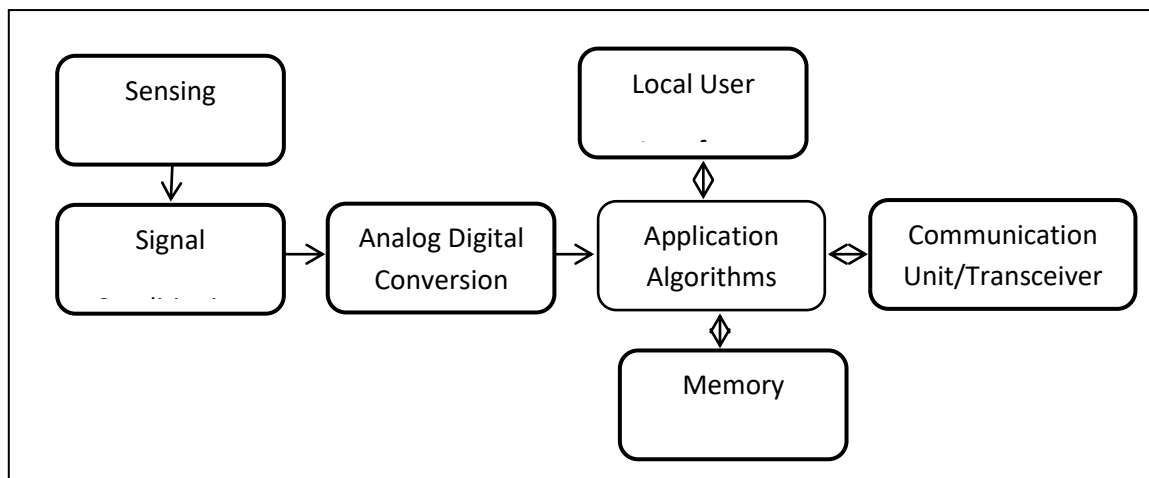


Figure1. Structure of intelligent pressure sensor

The sensing unit of the SPS usually has many versions designed for different properties of the measured and the environment and different design of the measurement object.

The basic pressure sensing element may be a C-shaped Bourdon tube; spiral Bourdon tube; flat diaphragm; curved diaphragm; capsule; or a set of bellows. Figure 2 shows different versions of the main sensing elements of SPSs.

The signal conditioning unit converts the signal received from the sensing element into a usable form to meet the needs of next-level operations without data loss.

Analog to Digital Converter (ADC) converts the signal from analog to digital format & sends it to the microprocessor.

The Local User Interface (LUI) is a panel-mounted device that allows building operators to monitor and control system equipment. Application algorithm. This block is a microcontroller that receives signals from smart sensors. The microcontroller processes the received data based on the application programs previously loaded here and generates output signals. The choice of a microcontroller is based on the nature of the parameters of the measured signals, the required measurement accuracy, the dynamic characteristics of the measurement object, and the information saturation of the communication channels.



The Memory Block is designed to store media to save received and processed data. The communication unit is designed to transmit output signals microprocessor to the main station. This device also receives command requests from the key station to perform certain tasks. The method of representing, encoding and transmitting data is called a protocol.

At the field level, the currently dominant protocols for measurement systems are FOUNDATION Fieldbus, HART and PROFIBUS PA.

Foundation Fieldbus is an all-digital two-way serial communication system that serves as the base layer network in an automation environment. The FOUNDATION Fieldbus specification is clearly different from other network technologies. FOUNDATION Fieldbus is not only a communication protocol, but also a programming language for building control strategies.

One feature of FOUNDATION Fieldbus,

provided by a standard programming language and powerful communication features, is the ability to perform control distributed among field devices rather than a central controller. The HART protocol allows multiple devices to be connected to a single pair of wires, but in the vast majority of installations, HART devices are connected point-to-point, i.e. one pair of wires for each device and a portable device that is occasionally connected temporarily for configuration and maintenance [3, 4].

Both FOUNDATION Fieldbus H1 and PROFIBUS PA are fully digital and even use the same wiring according to IEC 61158-2 [5]. HART and PROFIBUS technologies do not have a control strategy programming language. FOUNDATION Fieldbus has a standard function block language and communications between publisher and subscriber [4].

Table 1 shows the characteristics of the main data transfer protocols used in automation systems.

Table 2. Characteristics of the main data transfer protocols.

Charac-teristics	Protocols			
	Profibus	Modbus	HART	Foundation Fieldbus
Maxim-um data transfer rate	1.5 Mbit/s	115.2 kbit/s	1.2 kbit/s	312.5 kbit/s
Maxim-um nu-mber of connec-ted dev-ices	126	247	15 slaves and 2 masters	240
Maximum cable length (with repeater/without repeater)	10 km / 1.2 km	10 km / 1.2 km	9.5 km/ 1.9 km	3 km
Compatible protocols	DP-V0 DP-V1 DP-V2	Modbus RTU	HART	FF-H1

To control the parameters of modern SPS, different software is used. As a rule, software for working with smart sensors is either universal or available for free download from websites of smart sensor manufacturers.

Functions implemented by smart sensors.

The trend in the development of SPS, associated with the ever-expanding capabilities of microprocessors built into them, is to transfer them from controllers of an increasing number of the simplest typical control and management functions. In addition, modern smart sensors are

increasingly using the capabilities of their microprocessor converter to improve the measurement process: improve accuracy, increase reliability, select the measurement range, eliminate erroneous output data, expand the functions of remote control of the sensor.

To the complex of functions that is implemented in the most advanced smart sensors manufactured by leading manufacturers such as Endress & Hauser, Valcom, Honeywell, Yokogawa, Fisher-Rosemount, Metran (Emerson Process Management), you can include the following functions: information functions, configuration functions, formatting functions, self-diagnosis functions, conversion functions, control functions.

The SPS information functions include the following actions: the sensors store in their memory and, at the remote request of the user, issue all data that determines the properties, characteristics, parameters of this particular device: its type, serial number, technical indicators, possible measurement ranges, the established scale, the specified settings sensor, a working version of the software, an archive of performed metrological checks, the date of the next sensor check, etc. Sensors can also have an archive of current measured and calculated values for a specified time interval.

The setup function includes remote formation or change by the user of the main sensor settings: setting the device to zero, calibration, selection of a given measurement range, filtering current values, selection of the name of the units of measurement in which the sensor should provide information, etc. actions.

The formatting functions include automatic analysis of changes in the measured value and the current state of the measurement environment: determining the output of the values of the measured value beyond the specified norms, issuing various messages about changes in the values of the measured value, checking whether the parameters of the measured medium are within the allowable ranges. All these functions can be configured remotely by the user. In the process of operation, the sensors perform an analysis of their work and perform the following diagnostic functions: in the event of various failures, violations and malfunctions, they fix their place of occurrence and cause, determine if the instrument error exceeds the passport standard, analyze the operation of the sensor database, consider the correctness of taking into account factors that correct the output sensor readings. The sensor can issue up to 30 different messages to the operator, specifying the current features of its operation and greatly facilitating and speeding up its maintenance. Usually, the information given by the sensor about its individual malfunctions is divided into two types:

- non-critical information, when the sensor requires some maintenance, but the values measured by it can be used for control;
- critical information when the sensor output data is incorrect and either immediate operator intervention is required to suspend the use of its readings, or the sensor itself transfers its output to a constant safe value for process control and reports the need for urgent instrument maintenance.

The following functions are performed in SPSs, the necessary transformations of measuring information: amplification of sensor signals, linearization and filtering of measured values, standardization of output analog signal ranges, calculation of output values according to specified algorithms, analog-to-digital conversion of measured values.

Recently, an increasing number of additional functions directly related to process control have been assigned to smart sensors (especially when used with a Foundation Fieldbus network). To implement these functions, an appropriate set of standard software modules is flashed into the sensor's microprocessor memory, and their initiation and parameterization is carried out remotely



by the operator using a simple graphical configurator. As typical software modules, the simplest arithmetic and logical operations, a timer, a pure delay element, an integrator, controller options are used: P, I, PI, PD, PID, etc. functions from which specific control algorithms of various types are easily typed, blocking dependencies, mixing algorithms and other process control algorithms.

Correction of the temperature error of the intelligent pressure sensor.

Depending on the particular application, the requirements for pressure sensors also vary, and often include accuracy, output stability, reliability, durability, and low cost. In most cases, the main requirement is to improve accuracy by minimizing measurement errors. When measuring pressure, the influence of other extraneous factors on the sensing element, especially temperature, causes measurement errors. To correct the temperature errors of pressure sensors, two methods are mainly used: the first method consists in constructive-technological and circuitry methods for minimizing the distortion of the conversion function of the converter or the output signal depending on temperature; and the second method is to introduce corrections by making certain calculated corrections to the output signal during the measurement process by approximating the conversion function according to the results of experiments carried out at different temperatures [7]. The second method also includes the application to the problems of correcting the results of modeling a priori created and adequate models that take into account the effect of temperature on the output signal.

It is more expedient to use microprocessor converters (intelligent converters) using programming tools to take into account the temperature factor and ensure higher accuracy.

We considered the correction of temperature errors in pressure sensors based on a strain gauge bridge formed from an epitaxial silicon layer on a sapphire substrate by the second method mentioned. For this, experimental results [8] on the study of pressure sensors in the pressure range of 0...4 MPa and temperatures of $-40...+80^{\circ}\text{C}$ were used. Polynomial approximation of the transducer transfer function for various temperatures was performed using the General Polynomial Fit function in the LabVIEW software environment. The front panel of the program is shown in Fig. 2. The transformation function, approximated by the second-order polynomial of the sensor at a temperature of $20\pm 5^{\circ}\text{C}$ (graph of the output voltage depending on the pressure), and the approximation error depending on the pressure are described here. Experimental data taken from [9]. The figure also shows the array of data (Data), the array of approximations (Fitted Data) and the value of the root mean square error (mse).

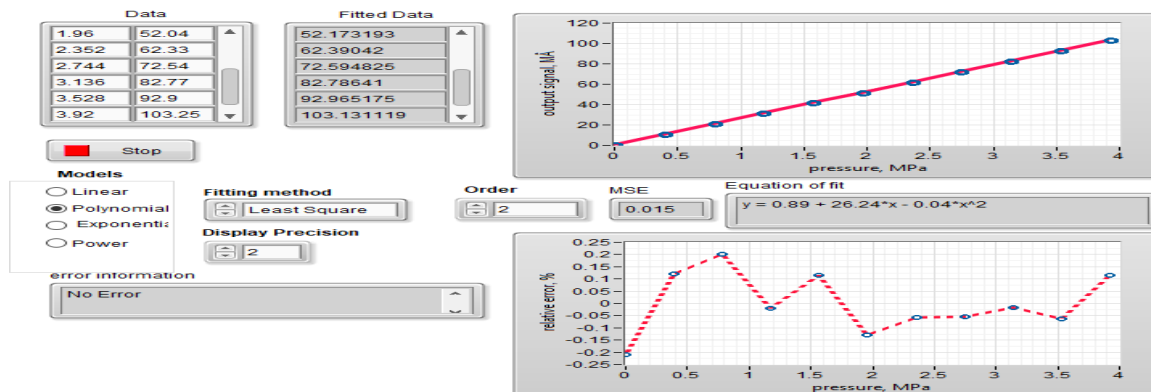


Figure 2. Results of the polynomial approximation of the transfer function of the pressure transducer in the LabVIEW software environment.

Conclusions

It is intelligent sensors that meet the ever-increasing requirements for quality and reliability of process control. Simultaneously with the measurement process, modern intelligent sensors also perform conversions of measured signals into typical analog and digital values, self-diagnosis of their work, remote adjustment of the measurement range, primary processing of measurement information, and sometimes a number of quite simple, typical control and management algorithms. They have interfaces to standard / typical field digital networks, which makes them compatible with almost any modern automation equipment, and allows you to communicate with these tools and receive power from the power supplies of these tools. In fact, modern smart sensors combine sensor functions and a number of controller functions and change the entire structure of the lower level of industrial automation systems. The program for correcting the output function of the pressure transducer, developed using experimental data in the LabVIEW environment, allows you to increase the accuracy of the measurement process, control the measurement errors in accordance with the requirements, automate the measurement process and display the measurement results in real time.

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USE OF NEW INFORMATION TECHNOLOGIES IN THE OIL-REFINING INDUSTRY

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ABSTRACT

The application of new information technologies in the field of automation of oil refining and petrochemistry has not yet been carried out at the proper level. At modern oil refineries, big data technologies are being introduced. Big Data is one of the key areas of digital production and can serve as a tool for integrating technological installations and equipment that have a wide range of information about the technological process and the main production as a whole. The fourth industrial revolution, which is based on the global "internetization" of technological installations and equipment, is closely related to the use of the Internet of things and cloud storage. The transition to Industry 4.0 in the refinery implies the ability of the refinery to integrate digital and physical technologies to improve operation and increase productivity. But, unfortunately, the oil refining industry has a low activity in the implementation of digital technologies. The emergence of new cyber-physical production systems will radically change the traditional logic of oil production.

The work is devoted to the use of information technologies of the oil refining industry in the field of integrated automation of the refinery as a whole, and individual technological processes, including for the production of polypropylene, by leaching, washing and drying, which is part of the refinery, these issues are almost not considered.

Keywords: big data, industry 4.0, security, information technologies.

Introduction

In nature of production, the oil-refining industry (ORI) is a complex and large-scale facility. ORI is characterized by many factors: a variety of products, a high degree of concentration of production, a diversity of technological processes and a large interchangeability of installations, the complexity of technological processes and production, a high degree of automation of production, continuity of production, etc. ORI products are consumed by almost all industries, that emphasizes its influence on the development of the economy [1].

Taking into account these factors, it is necessary to introduce new information technologies which will increase labor productivity and efficiency of managing the mainline production, in order to increase the profitability of ORI.

ORI produces and uses a huge amount of data:

- Equipment data;
- Data on the frequency of services;
- Data characterizing the parameters of technological installations, production and costs; and
- Data and standards of other ORIs.

Big Data technologies are being introduced both at modern corporate industrial enterprises and oil refineries. Big Data is one of the key areas of digital production and can serve as a tool for integrating technological installations and equipment that have a wide range of information about the technological process and the mainline production as a whole [2]. BigData is characterized through 7Vs now (Figure: 1). BigData technologies make it possible to automate technological processes and industrial production in general, which leads to an increase in the quality and speed of managerial decision-making. It is this time that a quick response to external and internal disturbances is ensured. The definition of "big data" can be formulated as "next-generation technologies and architectures for economical extracting value from large volumes of multi-format data by capturing, processing and analyzing them quickly" [3].



Figure 1. Characteristics of BigData

Currently, there are products designed for processing big data [4, 5]:

- Electron Data Solutions system;
- Electron Community Solutions system;
- MapReduce model;
- A set of HADOOP programs;
- MPP technologies;
- NoSQL databases;
- DataDiscovery class tools;
- A set of ApacheSpark libraries, etc.

These tools provide:

- Other applications with the necessary data at the right time
 - Distributed data processing on computer clusters;
 - Development and implementation of various programs;
 - Transforms the data distributing them over knot sets;
 - Using the collection and storage of information in social networks and projects, etc.
- Figure: 2 presents the future development of BigData in many respects.

These and other platforms are developing software for management and decision-making both for ORI as a whole and for individual industries.

Now, not only individual operations, but entire technological installations and their complexes are being automated at the refinery. In view of this, the refinery accumulates a very large amount of information, normative-reference and operational data. At the same time, the processing of a large amount of information requires a quick response to emerging technological situations in production. That is, it is necessary to increase the speed and efficiency of decision-making by using the competencies of managerial personnel, as well as by applying Industry 4.0 technologies to get out of critical production situations.



Figure 2. Future development of BigData

The fourth industrial revolution (Industry 4.0), which is based on the global "internetization" of technological installations and equipment, is closely related to the use of the internet of things (IoT) and cloud storage.

Industry 4.0 is the development of digital industrial technologies (Figure: 3).

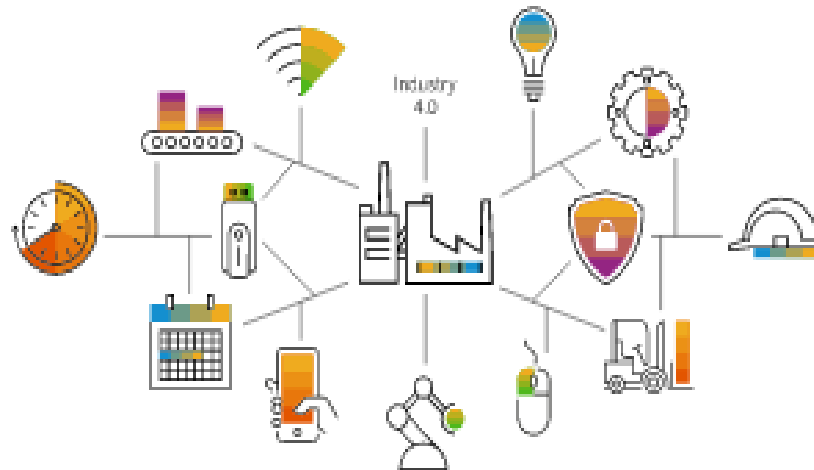


Figure 3. Industry 4.0

Transition to Industry 4.0 in the refinery implies the ability of the enterprise to integrate digital and physical technologies to improve operations and increase productivity. Unfortunately, the oil-refining industry is conservative and least subject to change, and we can talk about a rather low activity in implementation of digital technologies in this area. One example of the application of

Industry 4.0 technologies is Honeywell Connected Plant Services or CPS for smart plant control. To date, support for technological installations using Honeywell UOP technology [9] is provided in oil refining, petrochemistry and gas processing. Before transferring data to the cloud, they are structured and verified, further processing by using models takes place in the cloud; about 200 special key indicators and symptoms developed by the expert planners of UOP licensor are calculated for each type of plant. In parallel, negotiations with other licensors, as well as with manufacturers of equipment and diagnostic systems, such as SKF, Flowserve, and Dover are underway. Technically, the CPS service is built according to general principles.

A significant part of Industry 4.0 technologies is already available in the market and has been tested in real production facilities. Based on this experience, the following recommendations can be made to companies considering implementation of these technologies. Start with what you already have. Go beyond a simple replacement of basic automatization systems and measuring tools whenever possible, motivating it by the need to prepare the "foundation" for further transformations. Certainly, such a foundation is necessary and often it is the replacement of problematic elements of a controlling and measuring device (CMD) that gives a significant effect. But the principle of "replace all CMDs first" only delays the introduction of new technologies, increases the cost of entering Industry 4.0 and devalues the benefits of introducing new technologies. As a rule, advanced companies build projects as a chain of benefits in order to skim the "cream" off first of all, thereby demonstrating, at each step, a positive effect which will be the rationale and motivation for the following steps:

1. Choose from a wide range of secure, IoT-ready technologies. They already exist and have been tested in practice.
2. Leverage the expertise of major developers to realize meaningful business performance improvements. Large solution providers already have the necessary industry expertise.

Emergence of new cyber-physical production systems will fundamentally change the traditional logic of oil production. It will become decentralized, and each element of the production system will determine for itself what work needs to be done. At the same time, this transition can be carried out in stages through the gradual digitization of existing production facilities simultaneously with the use of new technologies at newly commissioned enterprises.

To simulate the technological process, a digital model of installation, for example, AVT is created. With its help, the original installation is studied, and the behavior of installation in certain technological conditions is predicted. At the same time, without touching the original itself, they gain experience in managing a technological installation. But, it should be remembered that the digital model of installation cannot fully correspond to the original, that is, it carries a system error. Thus, the experience of managing a digitized installation does not allow one to fully become a specialist in managing the original model.

The following requirements are imposed on the digital model of installation: it must be cheaper than the original installation, and the results obtained on the digitized model must be transferred to the original installation with great accuracy.

Increase in refinery profitability is associated with introduction of new technologies that will allow modeling technological processes and increase labor productivity, management efficiency, energy efficiency, and the speed of response to changes in market conditions.

To play different options for operation of mainline production, it is required to create a simulation model of an oil refinery (refinery). We have created a simulation model of mainline production

[6], and also developed a database for certain processes [7], which can be used during the reconstruction of refinery and management.

Using simulation methods for studying systems, it is possible to specify and establish the expected patterns, identify specific interrelations and relationships, for example, between the degree of loading of a production site, the average tracking time of workpieces, and the required average duration of technological operation. In those cases where the average regularities can be formulated analytically (or graphically), and for known values of the parameters of the studied laws, simulation creates opportunities for calculating the ordered relationships between these parameters.

Refinery simulation software is provided through the use of specially developed software which can exist both as a standalone product and enter into the composition of another software product as a subsystem.

The simulation model of the mainline refinery production that we developed was implemented by the SIMULINK subsystem of the MATLAB environment. The decision to use this package was dictated by simplicity and efficiency of the package, presence of built-in nodes for simulating the manufacturing units, and a debugger for more thorough control of the results. In this case, the production output is simulated on a certain accepted time scale which provides quasi-experimental conditions for studying processes. The values of the variables characterizing the state of the system are recorded step by step in time and processed. Thus, when simulating, it is only necessary to ensure the similarity between the processes observed in practice and the processes reproduced in computer experiments with models as accurately as possible.

Designing of new technological lines and production processes of an oil refinery (refinery) is one of the most important tasks of machine simulation. To ensure the continuous growth of production productivity, it is necessary to constantly improve its technology, organization, planning, and management. An interesting point to be noted is that the products remain the same, but the system that produces them is continuously improved. Let's call this the law of continuous rationalization. Not only new methods and new equipment, but also new forms of organizing the processes, new ways of their control and management are usually considered as a means of rationalization. Simulation is successfully used to solve rationalization problems. When using simulation methods, as accurate as possible reproduction of real-life processes is achieved first of all, after which the bottlenecks and shortcomings of the systems under study are determined. A purposeful change in the parameters of models within the boundaries of the areas of permissible variations in the parameters of real systems is used to find reserves of working time, material and other resources at various sections and stages of processes. Initially, the possibilities of rationalization are carefully studied on the basis of simulation experiments with models of production systems and only then are recommended for practical implementation.

Database tables are created in SQL ServerManagementStudio 2012 [8]. A database has been created for operational management of the alkalization section of the propane-propylene fraction, washing and construction of a catalytic cracking unit in order to obtain polypropylene [7]. The database consists of four tables: K-303 absorption-desorption calorific value, K-304 stabilization calorific value, K-306 propane calorific value, and values of the determined limit of parameters.

We have also developed a dynamic expert system to control the technological processes of polypropylene production by leaching, rinsing and dehumidification in an oil refinery.

Today, the main technologies that lead to shifts in the economy are cloud solutions and maximum use of the Internet of Things.

The refinery is a large-scale production facility, where small regular savings of resources, time, energy, money, ultimately gives a powerful cumulative effect.

Refineries in the US and Europe have already begun to switch to new technologies. One of the significant indicators of such a transition is reduction in the number of employees.

An important strategic direction in the development of refineries is to improve reliability, safety, energy efficiency and environmental friendliness of equipment.

The main problems of introducing the new technologies at refineries are the lack of personnel who have competencies in operational technologies and cybersecurity, justification of investments in new technologies and their payback, and interaction between IT specialists and production specialists.

Conclusions

The refinery of the future should be:

- Environmentally friendly production;
- Energy efficient;
- Integrated with petrochemical production;
- Respond quickly to requests;
- Switch from production of one type of fuel to another;
- The safety of the probability of emergency situations in production and in the field of IT work is ensured;
- Consist of replaceable units with their own software (SW), etc.

To achieve these goals, it is necessary to use new technological processes and information technologies, as well as personnel training.

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PROGRAM FOR DETERMINING THE INFORMATIVE PARAMETERS OF SURFACE ELECTROMYOGRAPHIC SIGNALS

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ABSTRACT

The article analyzes and calculates informative parameters of surface electromyographic signals (sEMS), which can be used to control biotechnical systems, as well as to diagnose the state of the musculoskeletal system. The analysis parameters in the time and frequency-time domains of the signal are considered. A program has been developed for calculating the informative indicators of the signal in the indicated areas. The program is implemented in the LabVIEW environment. To analyze the sEMG signal in the time domain, using the developed program, such indicators as Integral EMG, Average amplitude change, Wavelength, Simple quadratic integral, Absolute value of the 3rd time moment, and others were calculated; and to describe the signal spectrum by methods of time-frequency analysis, the average frequency of the spectrum (mean power frequency-MPF), the median frequency of the spectrum (median Frequency-MF), root mean square (RMS), power density spectrum (PDS), half width - the width of the spectrum at half maximum amplitude (HW). To test the program, files of real sEMG signals were used. The calculated parameters of the sEMG analysis in the time and frequency-time domains make it possible to non-invasively and objectively assess the state of the musculoskeletal system.

Keywords: Surface electromyographic signals, biotechnical systems, time-frequency analysis, Labview software.

Introduction

Electromyography is one of the methods of medical clinical diagnosis based on the measurement of bioelectric potentials generated in skeletal muscles during the excitation of their fibers. The non-invasive method of electromyography is widely used in the study of electrical activity of muscles for the diagnosis of the neuromuscular system. This method is based on measuring and recording the difference in superficial electrical potentials through electrodes placed on the surface of the human body skin.

The information carried by the electromyographic signal is used not only in the examination of the neuromuscular system, but also in biotechnical systems, such as the creation of active prostheses, exoskeletons and other technical devices, which are controlled by measuring the bioelectrical potentials of muscles. Objective analysis of electromyographic signals can determine a person's planned actions and thus activate the executive mechanism in the way he wishes.

The current high level of development of cybernetics, robotics and bioengineering, actualizes the purposeful use of electromyographic signals in these scientific and technical directions. However, the implementation of electromyographic signals (EMG) in these areas requires the solution of a number of issues, including the analysis of the characteristics of time, frequency and time-frequency characteristics of EMG signals, statistical processing, determination of informative parameters, motion recognition and classification, etc. An important obstacle in the creation of



prostheses of the upper extremities, which are controlled by EMG signals and have several degrees of freedom, is the complexity of management. The limitation of the functionality of such prostheses is the limited number of EMG-independent components taken from the area left after amputation [1]. For example, in the case of amputation of the forearm, as a rule, it is possible to identify the location of the electrodes in only two places - in the projection of the flexor and extensor forearm muscles, i.e. to reliably distinguish signals corresponding to the compression and opening movements of the hand. Disabled people who have lost their upper limbs prefer non-invasive prosthesis management and are primarily interested in not high opportunities and the sense of touch, but in ease of use and training, longevity, weight, value, and reliable performance of the prosthesis's two main functions - grip and rotation[2].

Recently, machine learning methods have been used to make decisions about the nature and parameters of movement (the movement of limbs). In this case, for the correct operation of algorithms, there is a need to measure the informative parameters of the signal, on the basis of which the model is taught. Distinguishing the semantic parameters of the signal is important in obtaining useful information in the surface EMG signal, determining the nature and type of movement. EMG signal analysis parameters are divided into three groups: analysis parameters in time, frequency and frequency-time ranges. In the presented work the methods of determination of informative parameters of electromyographic signal in *time* and *frequency-time* ranges are explained and the program of determination of these parameters in LabvieW environment is presented.

Analysis parameters in time range of EMG signals

The parameters of the analysis of the EMG signal in the time range, which can be used in the management of biotechnical systems, include the following [1-10]:

1. Absolute integral value of EMG signal - IEMG (Integrated EMG). The IEMG parameter is defined as the sum of the absolute values of the EMG signal reports:

$$IEMG = \sum_{k=1}^N |x_k|. \quad (1)$$

Here x_k is the k^{th} report of EMG signal, N – is the length of the EMG signal.

2. EMG signal amplitude change [3]. WL amplitude changes are set on the characteristic points of the signal. This parameter is also called wave length (Waveform length-WL) and this parameter is determined as cumulative wave length of EMG signal in time range:

$$WL = \sum_{k=1}^{N-1} |x_{k+1} - x_k|. \quad (2)$$

Here x_{k+1} and x_k is the characteristic points of EMG signal, N - is the length is the signal.

3. Average amplitude change - AAC [4]. This parameter is characterizes the complexity level of EMG signal and preserves the information about amplitude, frequency and the length of the signal and is defines as follows:

$$AAC = \frac{1}{N} \sum_{k=1}^{N-1} |x_{k+1} - x_k|. \quad (3)$$

4. Mean average value -MAV. This parameter is determined as follows:

$$MA = \frac{1}{N} \sum_{k=1}^N |x_k|. \quad (4)$$

5. Root mean squared value - *RMS* [5]. This parameter is defined as follows for the N length signal:

$$RMS = \sqrt{\frac{1}{N-1} \sum_{k=1}^N (x_k - \bar{x})^2}. \quad (5)$$

6. Zero crossings [6, 7]. The zero line crossing frequency indicates how many times the signal crosses the zero level line inside a given window and is defined as follows:

$$ZC = \frac{1}{N} \sum_{k=1}^{N-1} f_k. \quad (6)$$

$$f_k = \begin{cases} 1, & x_k x_{k+1} < 0 \\ 0, & \text{in the other cases} \end{cases}. \quad (7)$$

7. Slope sign change -SSC [8, 9]. It means the number of peak points for the given N length of the signal and this SSC parameter is defined as follows:

$$SSC = \frac{1}{N} \sum_{k=1}^{N-1} f_k \quad (8)$$

$$f_k = \begin{cases} 1, & (x_k - x_{k-1})(x_{k+1} - x_k) < 0 \\ 0, & \text{in the other cases} \end{cases}. \quad (9)$$

8. Difference absolute standard deviation value - DASDV [10]. This parameter identifies the value of average-quadratic inclinations of amplitude of signal surrounding and is defined as follows:

$$DASDV = \sqrt{\frac{1}{N-1} \sum_{k=1}^{N-1} (x_{k+1} - x_k)^2}. \quad (10)$$

9. Simple square integral -SSI (Simple square integral). This parameter characterizes the energy of the EMG signal and is expressed as the sum of the squares of the amplitude values of the signal:

$$SSI = \sum_{k=1}^N x_k^2. \quad (11)$$

10. Absolute value of the 3rd temporal moment -TM3. TM3 parameters are used when getting results with the low-compiled moments is impossible and are defined as follows:

$$TM3 = \left| \frac{1}{N} \sum_{k=1}^N x_k^3 \right|. \quad (12)$$

The block diagram of the program developed in LabviewW environment to calculate the above-mentioned analysis parameters in the time range of the EMG signal is shown in Figure 1 and the face panel in Figure 2. The information parameters are specifically defined for the EMG_Data_1.tdms data file taken from the LabVIEW 2014 environment database - C: \ Program Files (x86) \ National Instruments \ LabVIEW 2014 \ examples \ Biomedical \ Data folder, and the calculated values of these parameters are shown on the face panel in Figure 2. The file is read using the Read Biosignal virtual device (VC).



Time-frequency analysis of surface EMG signal

The surface EMG signal consists of the sum (interference) of bioelectric potentials generated by all muscle fibers located in the projection area of the superficial electrode. Because muscle movement units are controlled by independent motoneurons (independent channels), the concentrated signals (pulse sequences) differ in phase (asynchronous), and the complexity of the surface EMG (sEMG) signal is explained by this asynchrony of the interfering signals.

The surface EMG signal is a non-stationary signal, the frequency and amplitude of which vary chaotically and depend on the number of active motor units that make up the composition and their synchrony. The mathematical model $s(t)$ of the sEMG signal (excluding noise) can be described as follows [11, 12]:

$$s(t) = \sum_{i=1}^M \sum_{j=-\infty}^{+\infty} \varphi_i(t) \delta(t - t_{ij}). \quad (13)$$

Here M - is the number of active moving units, $\varphi_i(t)$ - impact potential function of i^{th} moving unit, $\delta(t - t_{ij})$ - delta function and shows its attachment given to $s(t)$ during t_{ij} - moment of i^{th} moving unit.

Since the sEMG signal is a non-stationary signal, it is more appropriate to use time-frequency analysis methods in its analysis [12-14]. The following methods can be used for time-frequency analysis:

a) The most popular method of analyzing the frequency composition of $s(t)$ sEMG signal is the Fourier transform:

$$S(\omega) = \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt. \quad (14)$$

Fourier transformation shows the presence of harmonics of one or another frequency in the signal under study, but does not allow us to judge at what instant they are formed.

b) Gabor transformation expands the application of the Fourier transformation method by dividing the input signal into segments. Gabor conversion is performed with basic functions consisting of Gaussian windows modulated by complex exponents

$$G(\tau, \omega) = \int_{-\infty}^{\infty} s(t) W(t - \tau) e^{-j\omega t} dt. \quad (15)$$

Gabor transformation allows you to determine the instantaneous average value of the frequency of the signal for each given t moment of time, as well as the frequency distribution of the signal energy.

c) Wigner-Ville Distribution — WVD used as the following:

$$WVD(t, \omega) = \int_{-\infty}^{\infty} x(t + \frac{\tau}{2}) x^*(t - \frac{\tau}{2}) e^{-j\omega \tau} d\tau \quad (16)$$

And here $x(t)$ is an analytical complex signal of a real entrance of $s(t)$ signal:

$$x(t) \equiv s(t) + iH[s(t)]. \quad (17)$$

$H[s(t)]$ - is a Hilbert transformation of $s(t)$ signal. Although WVD conversion has a high resolution in time and frequency, it can also generate extraneous frequency components that complicate signal analysis.

There are a number of methods that work using certain averaging procedures to reduce the intensity of these extraneous components.

One of them is based on the use of the $h(t)$ window in the time range and is called the pseudo-Wigner-Ville transformation (PWVD).

d) The Pseudo-Wigner-Ville (PWVD) transformation is mathematically described as follows:

$$PWVD(t, \omega) = \int_{-\infty}^{\infty} h(\tau) x(t + \frac{\tau}{2}) x^*(t - \frac{\tau}{2}) e^{-j\omega\tau} d\tau. \quad (18)$$

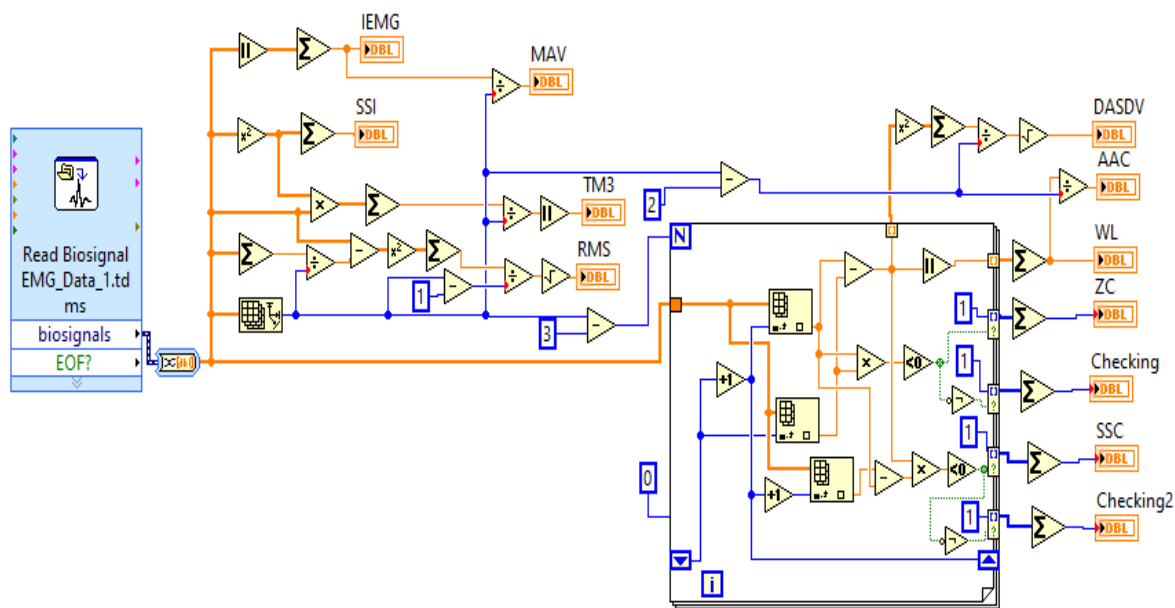


Figure 1. Block diagram of the program for determining the informative parameters of the electromyographic signal in the time domain in the *LabVIEW* software environment.

The following indicators are used to describe the spectrum of the SEMQ signal by time-frequency analysis methods: mean power frequency-MPF, median frequency of the spectrum (median frequency-MF), root mean square (RMS), spectral power density (power density spectrum-PDS), spectral width corresponding to half of the maximum amplitude (half width - spectral width at half maximum amplitude-HW).

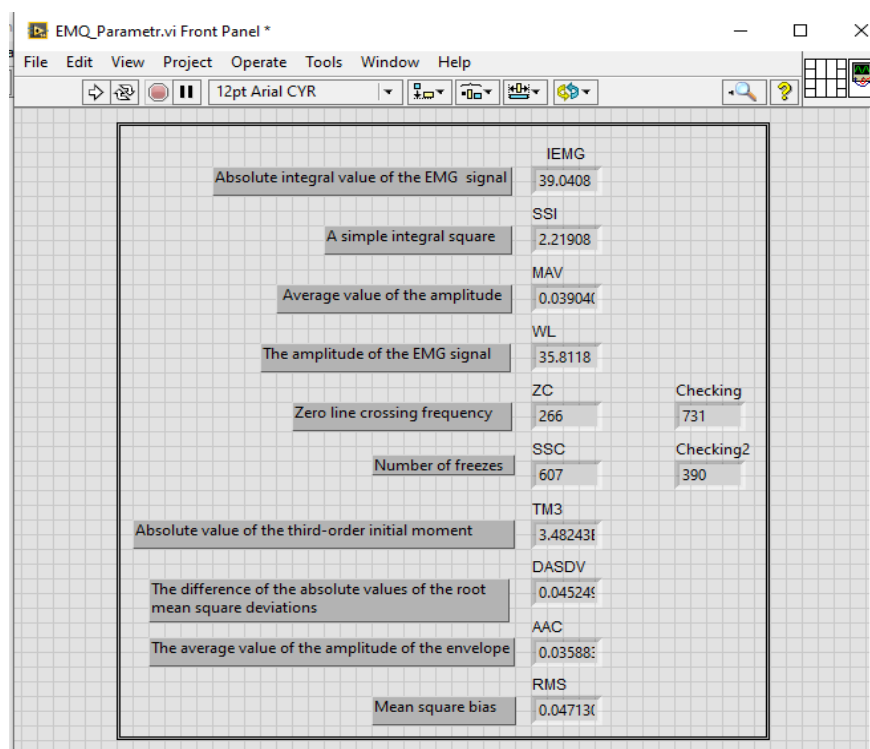


Figure 2. The front panel of the program for determining the informative parameters of the electromyographic signal in the time zone in the Labview software environment.

During time-frequency analysis, the initial SEMQ signal is performed separately for each segment, sequentially divided into segments according to short time intervals. The median frequencies are calculated for all segments and recorded in the “time-median frequency” plane (Figure 3). By approximating the obtained points in a straight line, we obtain the regression line of median frequencies (MTRX). The point of intersection of the regression line with the ordinate axis characterizes the initial tension state of the muscle fibers and is called the initial median frequency (IMF).

The point on the graph corresponding to the last moment is called the last median frequency. The angle of inclination of the regression line reflects the degree of muscle fatigue. Time-frequency methods of sEMQ signal allow to assess the condition of the musculoskeletal system non-invasively and objectively. The median frequency is considered an indicator of muscle fatigue, and the more individual indicators are the starting median frequency and the spectral width corresponding to half of the maximum amplitude.

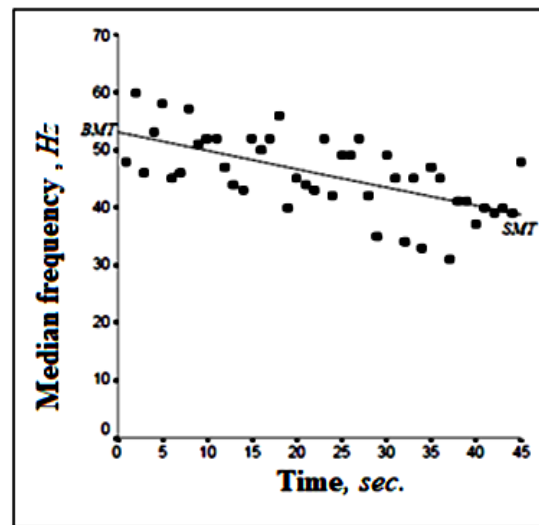


Figure 3. Dynamics of the median frequency of the SEMQ signal, which reflects muscle tension.

The block diagram described in Figure 4 can be used to perform time-frequency analysis of the EMG signal in the Labview software environment [5]. Here, the Read Biosignal Express VI virtual device reads the stored EMQ signal in the form of a file, the Filter Express VI virtual device allows you to filter the signal (you can select the type and topology of the filter), and Spectral Measurements Express VI allows you to capture amplitude, power, phase spectra. In addition, the appropriate frequency-time analysis of the EMG signal can be performed using the virtual devices of LabVIEW program TFA Wigner-Ville Distribution VI, TFA Fast Gabor Spectrogram VI.

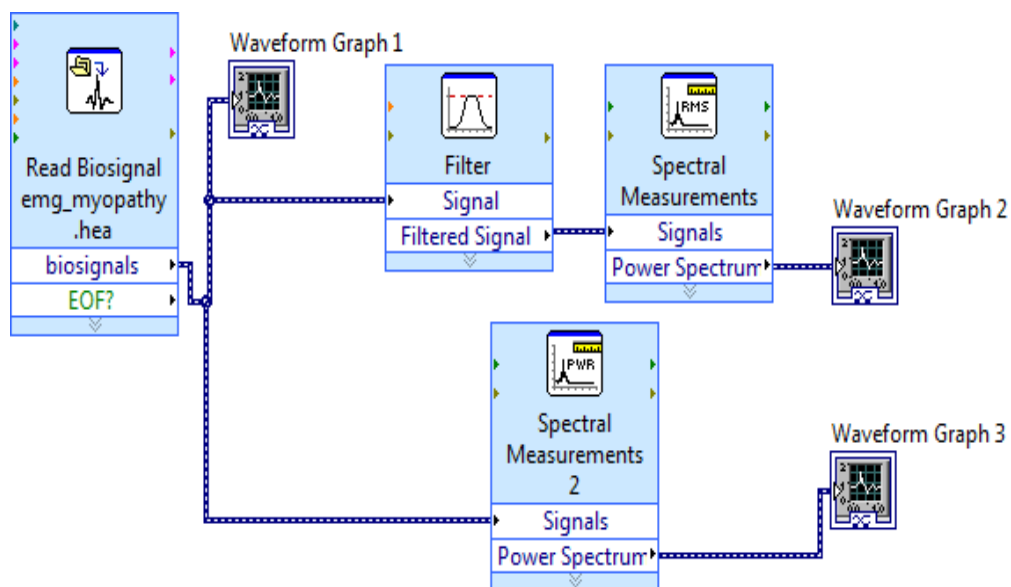


Figure 4. Time-frequency analysis of EMQ signal in Labview software environment.

Conclusions

In the Labview environment, a program was developed to calculate the informative parameters determined by the analysis of the measurement results of EMG signals in time and time-frequency ranges, and the values of these parameters were determined for a real sEMG signal. The results obtained confirm the adequacy of the program. The parameters of the time-frequency processing of the surface EMG signal make it possible to fully evaluate its frequency content and the effective width of its spectrum. It should be noted about the informational significance and expediency of using spectrograms in the qualitative assessment of the functional state of the neuromuscular apparatus. The frequency parameters are determined based on the results of the calculation of the EMG signal spectrogram. The median frequency divides the area under the spectral energy density curve into two equal parts. In contrast to the arithmetic mean frequency, the concept of median frequency refers to robust statistics and is not affected by large deviations and makes it possible to better describe the central trend of the studied series of surface EMG signal values.

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BENEFITS OF USING A FID TO MEASURE THE MULTICOMPONENT GAS MIXTURES

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ABSTRACT

The development of the oil and gas complex is one of the priority areas of the Azerbaijan economy. Oil and gas are among the most competitive Azerbaijan goods and are in high and stable demand from global consumers. Therefore, increased attention is paid to product quality. One of the methods for quality control of petroleum products is gas chromatography. Today it is a widely used physical and chemical research method.

The capabilities of a gas chromatography are mainly determined by the enormous separating power of the chromatographic columns and the characteristics of the detectors. If the chromatographic column is sometimes called the heart of the chromatograph, then the detector can be called the brain of the chromatograph [1,2]. Effective development of an analysis technique, its successful implementation, troubleshooting of a chromatograph, and metrological certification are impossible without the ability to make the right choice of a detector, operate it competently, and correctly interpret the detector signal.

About 50 detectors have been proposed for gas chromatography, but only a few of them are used in practice. The most used are the flame ionization detector and the thermal conductivity detector. The article shows the advantage of using a flame ionization detector to measure important physical and chemical properties, such as density, caloric content, the ratio of the number of carbon atoms to the number of hydrogen atoms C/H.

Keywords: Chromatography, gas-mixture, density, hydrocarbon, heat of combustion, calorific value, flame ionization detector, number of carbon atoms, sensitivity, quality.

Introduction

The most important technological parameter of the processes of the oil refining and petrochemical industries is the quality of the processed raw materials and the resulting products. Therefore, analytical control is an indispensable element of any process control system. Chromatographic methods are used for qualitative and quantitative analysis of the composition of multicomponent mixtures. In gas chromatography, there are a large number of different detection devices like flame-ionization detector (FID), the thermal conductivity detector (TCD), the electron capture detector (ECD), thermionic detector (TID), flame photometric detector (FPD), selective photoionization (PID), thermochemical (TCD), and universal helium ionization (HID) detectors.

A special place in chromatography is occupied by a mass spectrometric detector (MSD), which makes it possible to carry out fairly reliable identification of a peak using the mass spectrum obtained in the process of detection [3].

All of this detectors have their own advantages and disadvantages. Detectors are distinguished by their versatility due to their good characteristics and high performance.

The main characteristics of the detectors are:

Sensitivity - is the ratio of the output signal to the amount of substance in the sample. This parameter determines the analytical capabilities of the chromatograph as a whole. The more

sensitive the detector, the better. The value that evaluates the sensitivity is the limit of detection. The detection limit is the minimum concentration of an analyte in a carrier gas stream that can be detected. The minimum measurable signal is considered to be a signal whose amplitude is twice the noise level.

Linearity - is the proportionality between the concentration of the analyte in the carrier gas flow at the outlet of the column and the detector signal. If we remove the dependence of the signal on the concentration, then its straight section determines the linear region of detection.

Within the range of linearity, the sensitivity of the detector is independent of concentration. The linearity range is the range from the limit of detection to concentrations at which there is a significant deviation from proportionality (3 - 5%).

Quantitative analysis under non-linearity conditions requires more detailed calibration in the range of working concentrations of analytes.

Selectivity - is the ratio of the detector response for a particular substance to the detector response for another substance when the same amount is detected. For example, the PPD detector is considered selective, since its sensitivity to sulfur-containing or phosphorus-containing substances is orders of magnitude higher than to hydrocarbons. Selective detectors greatly simplify the identification of components and are indispensable in many analyses.

At present, flame ionization detectors have found wide application in gas chromatography due to the fact that they have the highest sensitivity of all detecting devices. In addition to its high sensitivity, the flame ionization detector has another important property. It has been experimentally established that for individual hydrocarbons of some homologous series there is a linear relationship between the detector signal and the number of carbon atoms in a substance molecule [1,2,3]. This interesting feature of the flame ionization detector can be used to measure some of the physicochemical properties of gases, since knowing the number of carbon atoms in a hydrocarbon molecule, in many cases one can judge its structure and physicochemical parameters.

Determination of the number of carbon atoms in gas mixtures.

To study the possibility of measuring the number of carbon elements both in individual gases and in their mixtures, the installation was assembled, the diagram of which is shown in Fig. 1.

The installation consists of the following units: gas preparation unit 1, sensor 2, electrometric amplifier PV-3, flame control circuit 3 and recorder EPP-09.

The sensor 2 of the installation consists of a flame ionization cell *FID*, a hydraulic resistance *C_v*, a throttle divider of the carrier gas flow *D_c* and a dispenser *D*. The hydraulic resistance *C* - is a copper tube 0.5 m long and 4 mm in diameter, filled with quartz sand. The measuring cell and column are thermostatted.

An automatic sampling valve from the PX-1 chromatograph was used as a dispenser, and it was also possible to inject a dose using a syringe through the *S*.

This setup allows for a pulse injection of the analyzed gas into the detector with all the advantages inherent in this method [4]. In addition, as shown by preliminary measurements, with a continuous supply of the analyte to the flame ionization cell, it is practically impossible to ensure the stability of the flame and, as a consequence, the stability of the signal.

Measurements were carried out on the experimental setup in the linear region of the detector, the essence of which was that doses constant in volume and pressure, equal to 0.001 mg of hydrocarbon gases and their mixtures, were entered into the detector through the column.

The operating parameters of the installation were as follows: hydrogen consumption - 3 l/h, air consumption - 25 l/h, carrier gas consumption (nitrogen or hydrogen) 3 l/h, detector column temperature - 250C, voltage across the detector collector 150 V.

The results of the experiment are shown in the table 1. In this table comparison of the results of calculations of the hydrocarbon number n for individual substances and their mixtures are given according to the formula

$$n = \sum x_i \cdot n_i, \quad (1)$$

where x_i - is the volume concentration of the i component; n_i - is the number of carbon atoms in the molecule of the i -th component.

It is assumed that h_i is the average of 3 measurements, the height of the methane peak corresponding to $n = 1$.

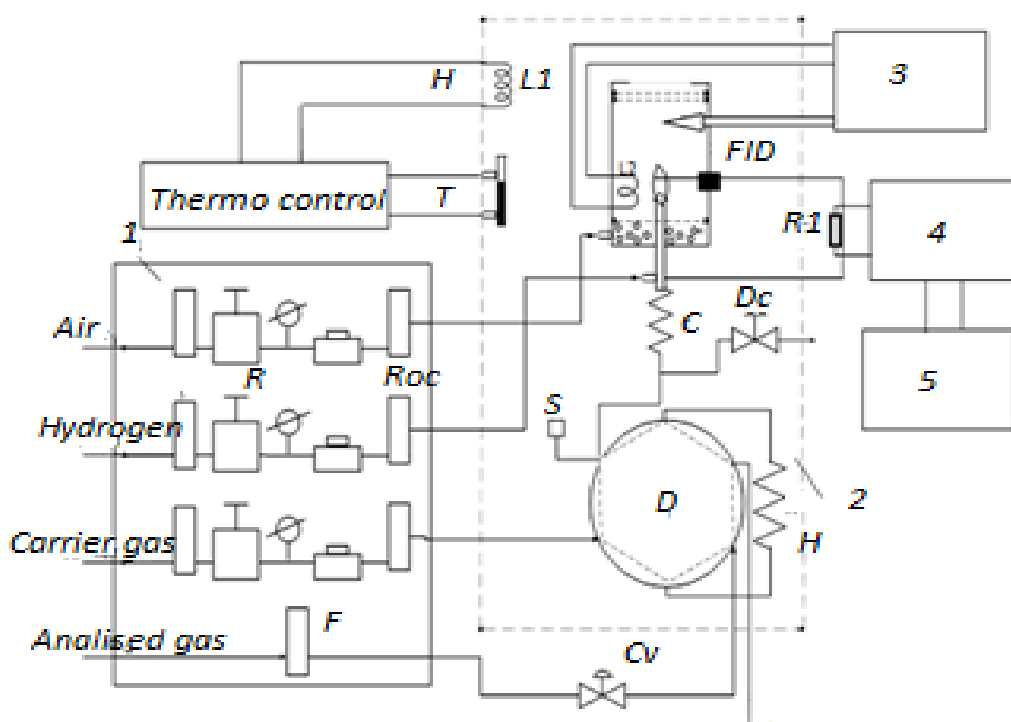


Figure 1. Installation for measuring the number of carbon atoms in gas mixtures

F - Filter; R - Reducer; M - Manometer; Rt – rotameter; Cv - cut-off valve; FID-flame ionization detector; C - Coloumn ; D - dispenser; H - spiral heater; T - contact thermometer; S - fitting for injecting the analyzed gas with a syringe; Dc- flow divider throttle

Gas mixture components	Composition of the mixture, ratio	Peak heights h_i , M_v			Relative error, % to the calculated value
			Calculated n	Experimental n	
CH ₄	1,0	211	1,0	1,0	0
C ₂ H ₄	1,0	436	2,0	2,07	+3,5
C ₃ H ₆	1,0	618	3,0	2,93	-2,3
C ₄ H ₁₀	1,0	873	4,0	4,13	+3,25
C ₂ H ₄	0,486	473	2,42	2,24	-7,4
C ₃ H ₆	0,514				
C ₂ H ₄	0,737	509	2,5	2,41	-3,6
C ₄ H ₁₀	0,263				
C ₃ H ₆	0,6	705	3,4	3,34	-1,76
C ₄ H ₁₀	0,4				
CH ₄	0,128	462	2,3	2,19	-4,78
C ₂ H ₄	0,405				
C ₃ H ₆	0,467				
CH ₄	0,096	38 2	1,95	1,81	-7,17
C ₂ H ₄	0,89				
C ₄ H ₁₀	0,014				
CH ₄	0,46	473	2,12	2,24	+5,6
C ₃ H ₆	0,50				
C ₄ H ₁₀	0,04				

Table 1. Comparison of readings of the number of carbon atoms.

Analysis of experimental and calculated data shows that the flame ionization detector can be used to measure the carbon number of gas mixtures, which makes it possible to determine for individual homologous series such important physicochemical properties as density, calorific value, the ratio of the number of carbon atoms to the number of hydrogen atoms C/H.

Measurement of density of hydrocarbon gas mixtures

Densities of undiluted gas mixtures derived from conventional liquid petroleum products are always higher than those of air. Therefore, layering effects appear during transshipment operations, which can lead to hazardous situations.

The table 2 shows the density values relative to air of three pure gases: propane, butane and pentane, which together are approximately the gas mixtures emitted respectively by crude oils, motor or aviation kerosene and natural gasoline. These values will change slightly if the inert gas is replaced by air.

**Table 2.** Density values relative to air.

Gases	Density relative to air		
	Pure hydro-carbon	50% hydro-carbon content by volume	Lower flammable limit of the mixture
Propane	1.55	1.25	1.0
Butane	2.0	1.5	1.0
Pentane	2.5	1.8	1.0

According to the data in the table, it follows that the density of the undiluted gas released from a product such as motor gasoline is likely to be approximately 2 times the density of air, and the density of the gas released from ordinary crude oil is approximately 1.5 times. The values of these densities are high, and the manifestation of layering effects is significant only when the given gas remains in a concentrated state. When diluted with air, the density of the gas-air mixture of all three types released from the cargo approaches the density of air, and at the lower ignition limit does not differ from it.

The density of gases in the methane series decreases with increasing temperature due to thermal expansion of the gas. This character of the dependence of density on temperature is also characteristic of many other gases. It should also be noted that the density of gases of the methane series increases as the number of carbon and hydrogen atoms in the gas molecule increases (numbers n in the formula C_nH_{2n+2}).

For hydrocarbons, the molecular formula is C_nH_{2n+2a} , where a takes on different values (1, 0, -2, -3). It follows that, for example, for methane hydrocarbons having the molecular formula C_nH_{2n+2a} , the molecular weight is (the atomic weights of carbon and hydrogen are taken to be 12 and 1, respectively)

$$\mu = 12 \cdot n + n + 2 = 14 \cdot n + 2. \quad (2)$$

The density ρ under normal conditions for any of the gaseous terms of this series can be determined with sufficient accuracy by the formula

$$\rho = \frac{\mu}{22,41} = \frac{14 \cdot n + 2}{22,41}. \quad (3)$$

When we obtain the dependence for the methane series

$$99999\rho = 0,625 \cdot n + 0,09. \quad (4)$$

Similarly, for other homologous series, you can get:

- a) for ethylene $\rho = 0.625 \cdot n$
- b) for acetylene $\rho = 0.625 \cdot n - 0.09$

As follows from the table of experimental data, the accuracy of determining the density from the carbon number measured by the flame ionization detector is low. Therefore, the use of such a method for measuring the density of gases is advisable only in cases where it is impossible to use a gas density meter for this [5], for example, for micro-amounts of the analyte.

Measurement of the heat of combustion of gases

The heat of combustion of gases is the most important heat engineering characteristic.

Calorific value - the main indicator of fuel shown in Fig.2, characterizes the amount of heat released during the complete combustion of fuel with a mass of 1 kg or a volume of 1 m³ (1 l). The heat of combustion is determined by the chemical composition of the combustible substance. It depends on:

- combustible fuel components (carbon, hydrogen, volatile combustible sulfur, etc.);
- humidity and ash content of the fuel.

The higher the specific heat of combustion of fuel, the lower its consumption.

Therefore, the calorific value is one of the most significant characteristics of the fuel shown in Fig.2.

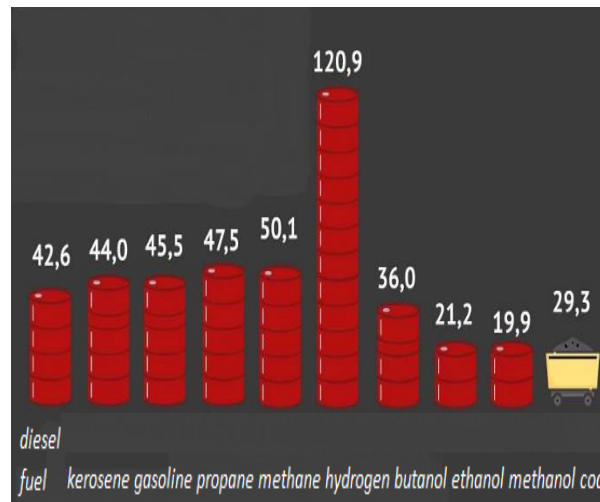


Figure 2. Calorific value of various fuels

In the analysis of fuel and in thermal calculations, such concepts as "gross calorific value" and "lower calorific value" are used.

Gross calorific value (gross calorific value) - the amount of heat released during complete combustion of fuel, cooling of combustion products to fuel temperature and condensation of water vapor formed during the oxidation of hydrogen, which is part of the fuel.

In those cases when the heat of combustion is determined on the basis of the component composition of the gas, expressed in units of a mole fraction, it is denoted as $\overline{H}_S(t_1, p_1)$;

when the composition is expressed in units of mass fraction, the heat of combustion is denoted as $\widetilde{H}_S(t_1, p_1)$.

When the calorific value is determined on the basis of the component composition of the gas, expressed in units of volume fraction, it is denoted as $\widetilde{H}_S[(t_1, p_1), V(t_2, p_2)]$, where t_2 and p_2 are

(measured) standard conditions for the volume of gas (Fig.3).

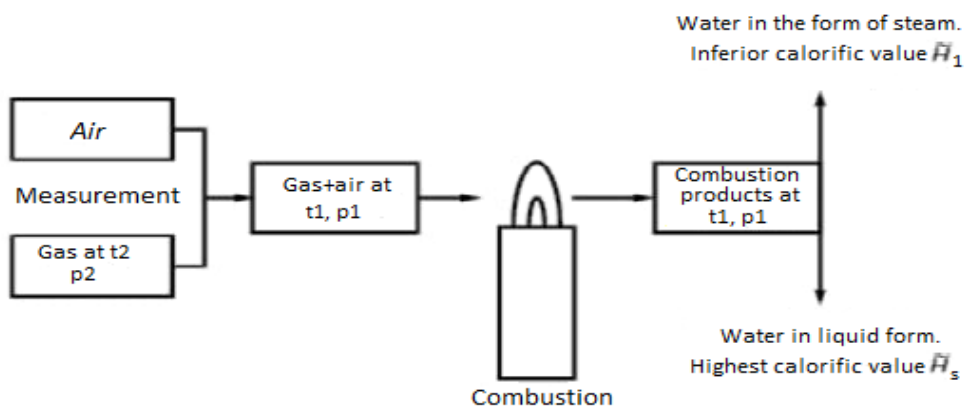


Figure 3. Volumetric calorific value. Standard measurement and combustion conditions.

Inferior calorific value (lower calorific value) - the amount of heat released during complete combustion of fuel without condensation of water vapor.

This characteristic is especially important for gases used as fuel. In engineering practice, there is a distinction between the concept of the highest Q^h and the lowest Q^l heat of combustion of gases. From a technical point of view, Q^l is a more convenient characteristic of the heat value of the fuel than Q^h , since the combustion products of gas fuels in various heating devices I usually have a temperature above 100°C .

There are the following relationships between the heat of combustion and the carbon number [2]. for the methane series:

$$Q^h = 7050 \cdot n + 2500 \text{ kcal/m}^3$$

$$Q^l = 6560 \cdot n + 2000 \text{ kcal/m}^3$$

a) for the ethylene series:

$$Q^h = 7050 \cdot n + 900 \text{ kcal/m}^3$$

$$Q^l = 6560 \cdot n + 900 \text{ kcal/m}^3$$

Measurement of the C/H ratio

Thus, by measuring the number n , you can calculate the heat of combustion of the gas mixture. Most often, methane hydrocarbons are used as fuel gas - natural or associated gases mixed with air. To find out whether the signal of the flame ionization detector is affected by air impurity in the hydrocarbon gas, gases mixed with air were fed into the cell. As a result, it was found that air impurity in the volume of the injected dose does not affect the detector signal, but it is only related to the amount of combustible substance.

The ratio of the carbon content to the hydrogen ratio for hydrocarbons in many cases makes it possible to determine the belonging of a given hydrocarbon to one or another homologous series. For some petrochemical processes, for example, for the process of thermal destruction of hydrocarbons, the C/H ratio characterizes the quality of the feedstock. Therefore, the rapid measurement of C/H allows more efficient control of the modes of technological units.

The C/H measurement can be carried out using a flame ionization detector and a gas density meter [5, 9].

If we take the general formula for hydrocarbon gases in the form of C_nC_m , then the C/H ratio is determined by the expression:

$$\frac{C}{H} = \frac{12 \cdot n}{1 \cdot m}, \quad (5)$$

where **m** is the number of hydrogen atoms in the molecule.

Molecular weight and density in this case can be represented by the expression

$$\mu = 12 \cdot n + 1 \cdot m, \quad (6)$$

$$\rho = \frac{\mu}{22,41} = \frac{12 \cdot n + 1 \cdot m}{22,41}. \quad (7)$$

From formula (7), the average number of hydrogen atoms is

$$m = 22,41\rho - 12 \cdot n. \quad (8)$$

Then expression (5) can be represented

$$\frac{C}{H} = \frac{12 \cdot n}{22,41\rho - 12 \cdot n}. \quad (9)$$

Thus, from formula (9) it can be seen that to measure the C/H ratio, it is sufficient to measure the value n with a flame ionization detector, and the density of the gas mixture with a gas balance.

Considering that when using a gas density meter in a pulsed measurement mode, its signal is proportional to the difference, density of the analyzed gas mixture and the carrier gas [4], it is convenient to represent expression (9) in the form

$$\frac{C}{H} = \frac{k_1 \cdot 12 \cdot n}{k_2(\rho_{c-g} + \Delta\rho_{mix}) - k_1 \cdot 12 \cdot n}, \quad (10)$$

where k_1 - is the sensitivity of the flame ionization cell; k_2 - is the sensitivity of the gas density meter; ρ_{c-g} - density of the carrier gas under normal conditions; $\Delta\rho_{mix}$ - the difference between the

densities of the analyzed gas and the carrier gas under normal conditions.

If the combination of a density meter and a flame ionization cell makes it possible to measure C/H for any gases, then for individual homologous series it is possible to determine C/H from the results of measuring the value of n , only with the help of a flame ionization cell. For example, for the methane series (the need for such measurements is most common), the C/H ratio is calculated using the formula

$$\frac{C}{H} = 6 \cdot \frac{n}{n+1}. \quad (11)$$

Conclusion

The measurement methods considered in the article can be used both in laboratory practice and in the creation of automatic gas analyzers that measure the number of carbon atoms of hydrocarbon substances, the density of calories and the C/H ratio.

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THE STUDY OF LAMINAR AND TURBULENT FLOW IN TURBINE TYPE OF FLOW METERS

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ABSTRACT

The paper studies the operation of a turbine-type flow meter under various operating modes. In the industry, flow measuring devices are widely used on oil and gas platforms and terminals. In the processes of production, processing and transportation of oil and gas, which is a strategic raw material, strict state control of its consumption is carried out precisely by means of consumption measurement. A performance study has been carried out for turbine - type gas flow meters under laminar and turbulent gas flow conditions .. One of the main factors that cause damage to the mechanical parts of turbine and rotor type gas flow meters during operation was the study of flow changes. The proposed method to prevent flow changes was considered. The principle of work of the proposed scheme is based on the connection of a flow regulator before the flow meter being tested to the same gas line. In this case, the transition of the flow from the laminar regime to the turbulent regime is prevented, as well as the rotating mechanical parts are protected from sudden rotation and damage. In ideal rotation, it is assumed that the flow through the turbine meter is uniform, incompressible, and steady, and the turbine blade rotates without friction. Under these conditions, the speed of rotation of the impeller is determined by the pitch of the turbine impeller.

Keywords: turbine-type flow meter, ideal rotation, turbulent flow, laminar flow, Reynolds number.

Introduction

The section on measuring devices is currently one of the most relevant sections of device manufacturing. In the industry, flow measuring devices are widely used on oil and gas platforms and terminals. In the processes of production, processing and transportation of oil and gas, which is a strategic raw material, strict state control of its consumption is carried out precisely by means of consumption measurement. Gas consumption and quantity measurement in gas industry facilities is mainly performed by the method of changing the pressure drop in the narrowing device, with tachometric flow meters and counters, and recently also with the use of ultrasonic flow meters. Of course, since the accuracy of this type of devices is always in the foreground, great steps have been taken in the direction of increasing the accuracy and bringing the errors closer to zero.

One of the main factors that cause damage to the mechanical parts of turbine and rotor type gas flow meters during operation was the study of flow changes. The proposed method to prevent flow changes was considered. The principle of work of the proposed scheme is based on the connection of a flow regulator before the flow meter being tested to the same gas line. In this case, the transition of the flow from the laminar regime to the turbulent regime is prevented, as well as the rotating mechanical parts are protected from sudden rotation and damage.

Turbine-type flow measuring device

In the industry, axial turbine (Figure 1) devices are made use of to measure the consumption of gases and liquids. These devices differ in their reliability and can increase the accuracy of measuring the consumption of 0.1% liquids and 0.25% gases under normal conditions. In ideal conditions, they have the ability to measure with an accuracy of 0.02%. Turbine flow meters of various designs are used in a wide range of applications in the chemical, petrochemical, food and aerospace industries. The internal diameter of this type of flow meter can vary from 0.6 mm to 760 mm.

A schematic diagram of a turbine-type flow meter is shown in Figure 2. This drawing shows the most important elements of a turbine flow meter. Turbine-type flow meters are mounted in the flow direction. Typically, the flow first enters through a flow straightener or flow conditioning plate (A) to eliminate swirl and create a uniform flow. Then, the flow penetrates through the annular channel and the turbine (B),

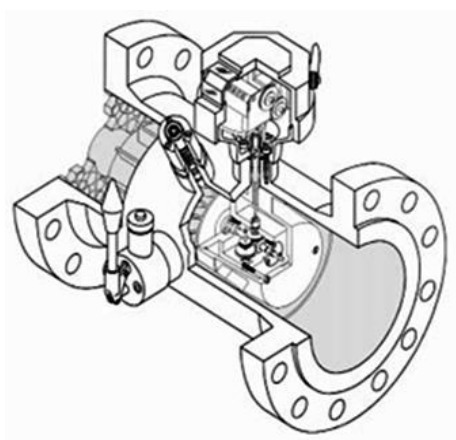


Figure 1. Schematic diagram of a turbine type flow meter

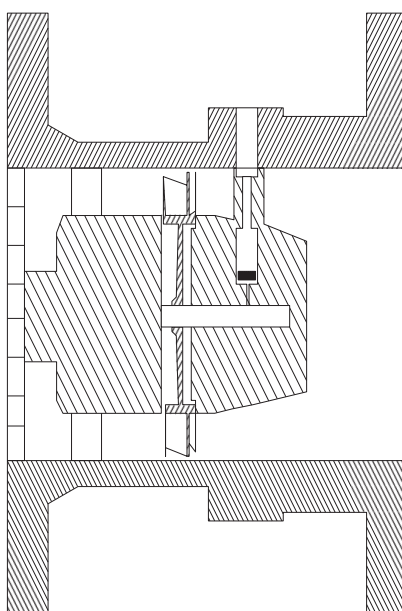


Figure 2. Schematic diagram of a turbine-type flow meter with flow regulator and turbine nozzle, mechanical meter drive mechanism.

The blades of a turbine blade (Figure 3) often have flat plates or a spiral shape. Spindle and roller bearings are placed inside the core. There are several ways to detect the rotating velocity of a turbine blade. The most common detection methods are mechanical detection and magnetic detection.

Mechanical detection of turbine blade speed is measured by transmitting the blade speed to a mechanical counter through the rotor shaft and gears. The method of magnetic detection can be measured by breaking the magnetic field, so that any point is marked on the coil, and the number of cycles of that point is directly proportional to the count of pulses. Those pulses can be counted by electronic methods.

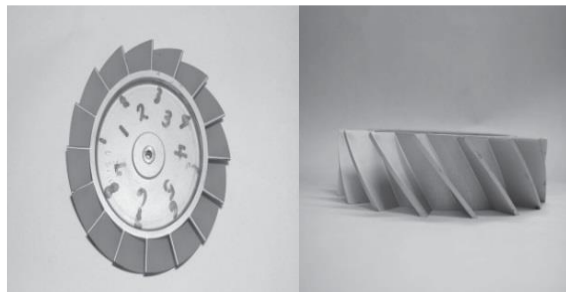


Figure 3. Photo of turbine fairing of Elster G250 turbine flow meter

In this thesis, the experiments were carried out with the SM-RI-X G250 type gas turbine meter in gas turbine flow meters of Elster-Instromet, (Figure 4). The internal pipe diameter of this meter is 100 mm. The relative error accuracy is 0.1% for volume flows in the range of 20 to 400 m³/h. The meter is capable of working at an pressure of 0-20 bar (this type of meter is also available for working pressures up to 0-100 bar). The turbine blade is made of aluminum and has spiral-shaped blades (Figure 4).



Figure 4. Photograph of the turbine flow meter
Ideal rotation

By ideal rotation, it is assumed that the flow through the turbine meter is uniform, incompressible and steady, and the turbine blade rotates without friction. Under these conditions, the impeller rotation speed is definite by the pitch of the turbine impeller [1-5],

$$S = \frac{2\pi r}{\tan \beta}. \quad (1)$$

r is the radius of the turbine blade and β is the angle of the blades relative to the blade axis. (see figure 5).

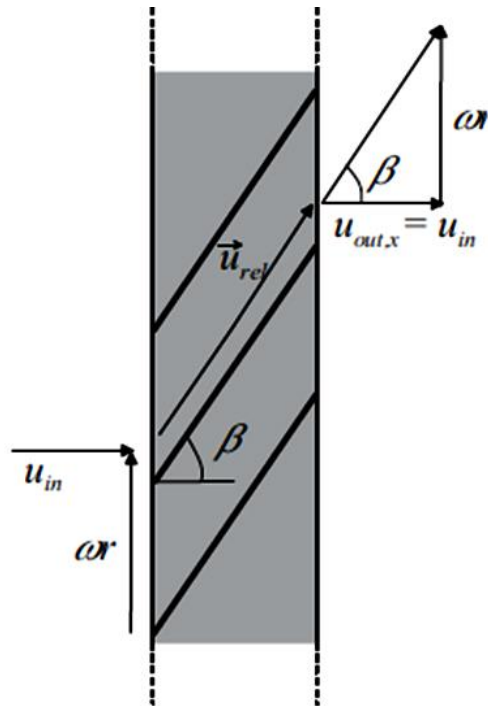


Figure 5. Stationary flow for an ideal rotor[1]

Ideally, the turbine corresponds to the displacement of natural gas during one revolution of the turbine. For a perfect helicoidal turbine blade, S is constant over the entire radius of the rotor, while the vane angle β varies. Since friction is neglected, the flow entering and exiting the turbine is parallel to the propeller blades. This means that the inlet velocity and the rotational speed are related to the angle of the turbine blades, β :

$$\frac{\omega_{id} r}{u_{in}} = \tan \beta. \quad (2)$$

For the ideal case considered with ω_{id} , π is the angular velocity and u_{in} is the speed of the flow entering the turbine. In this ideal case, the angular velocity:

$$\omega_{id} = \frac{U_{in} \tan b}{r} = \frac{2\pi u_{in}}{s}. \quad (3)$$

Laminar flow

Natural gas flowing through a pipe or between two flat plates is either laminar flow or turbulent flow, depending on the velocity, pipe size (or Reynolds number), and fluid viscosity (Figure 6).

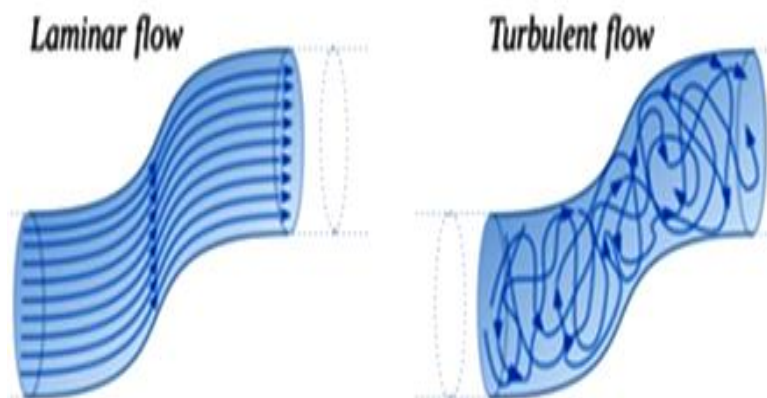


Figure 6. Laminar flow and turbulent flow

Laminar flow is the movement of gas particles along defined flow lines in which all flow lines are straight and parallel. Thus, the particles move in laminar or layered form and slide smoothly over the adjacent layer. This smooth and streamlined nature of flow is considered laminar flow. Generally observed in viscous or low-velocity fluids, laminar flows, at each point in the flow, the properties of the fluid remain constant, including velocity and pressure. If the flow path is divided into several infinite layers, the liquid layers in laminar flow remain parallel without mixing with each other or disrupting the path of neighboring layers. This kind of flow is known as aerodynamic flow or viscosity flow. Figure 9 is a graph showing flow versus pressure for laminar and turbulent flows.

Unidirectional laminar flow

Pulsatile laminar flow. Wavy Laminar [5-9]. Flow Characteristic instance of laminar flow are the flow of oil through a subtle pipe, the flow of blood via capillaries, and fume increasing straight from a steam wand. However, the smoke deviates from its normal path and becomes a turbulent flow after rising to a small height.

Laminar flow is divided into 3 parts:

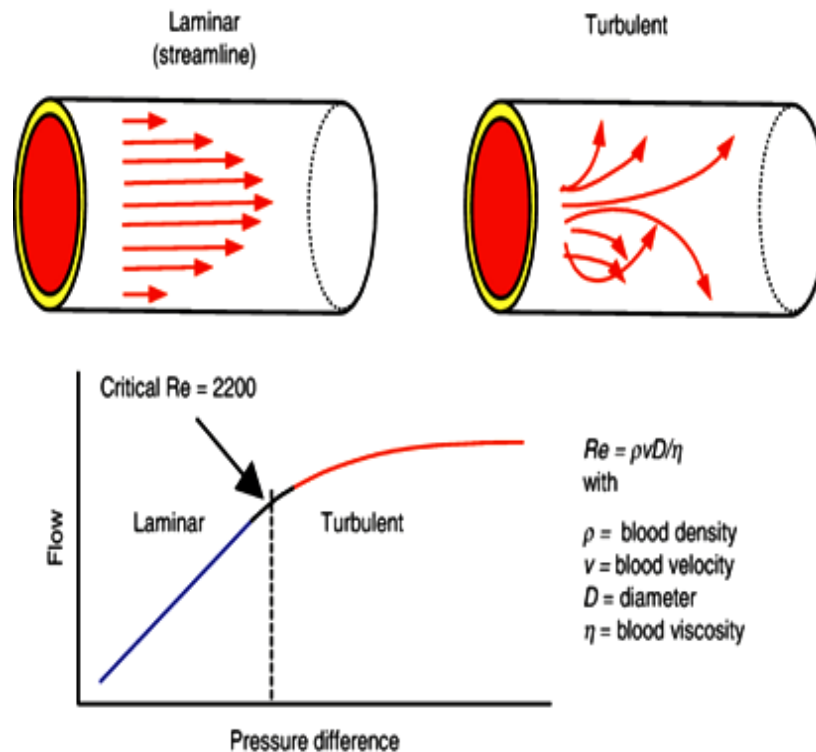


Figure 7. Flow versus pressure for laminar and turbulent flows

Turbulent flux

Turbulent flux is characterized as flow in which liquid and gas particles move chaotically. Due to the chaotic flow of fluid particles, the formation of whirlpools occurs due to high energy loss. During turbulent flow, the velocity of the fluid at one point changes continuously both numerically and in direction. Turbulent flow occurs in huge size pipelines where the liquid flows at high speed.

Differently from the laminar axis, the turbulent axis may cut their line by reason of the constant change of the flow and stability of the axis. Tors may be observed in turbulent axes, and the behavior of the apparent non-steady axis complicates the analysis of the turbulent axis. With this, the hardness of the turbulent axis is important for the industry, because most of the observed axes are turbulent. It is used for sharing of turbulent materials or in the effective design of mixing systems. Turbulent prognosis can be appraised with the help of Reynolds number. Accordingly, the value of the Reynolds number (Re) can be expressed as:

$$Re = \rho v D / \mu \quad (4)$$

Note that:

1. ρ is the density of the fluid
2. V is the velocity of the fluid
3. D is the hydraulic diameter
4. μ is the viscosity of the liquid

Important results from Reynolds number calculations include:

- As the Reynolds count is up to 2300, the flow is considered laminar. Viscous force is more noticeable due to slower flow rate.
- As the Reynolds count is greater than 3500, the flow is considered turbulent. A faster and more irregular flow path maximizes the inertial force in the system.
- For a Reynolds number between 2300 and 3500, the flow regime is considered transitional flow.

Methods of preventing turbulent flow

There are several effective methods to prevent turbulent flow. One of them is to install a flow regulator before the flow meter. The flow straightener (Figure 8) significantly reduces the disturbances in the flow, and also allows the correct redistribution of the velocity profile at each point of the pipe section [10-12].



Figure 8. Stream straightener

Thus, these devices allow reducing high flow lengths during flow measurement and improving measurement accuracy. Therefore, they must be placed between the pipe fitting (elbow, reducer, etc.) and the flow measuring element, observing the distances specified in the standard.

Identifying Different Flow Regimes for Efficient Computational Fluid Dynamics (CFD) Analysis

Most real industrial systems are designed for laminar or turbulent flows, so predicting the flow regime is critical to effective CFD analysis and system design. The analytical study of laminar and turbulent fluid flux regimes can be difficult, especially for scheme with geometric designs. This may require modeling over a range of Reynolds numbers and vorticities at the fluid interface. One solution is to use a CFD interface that let you to characterize and select the correct flow regime. The modeling capabilities of the Omnis platform make it easy to perform CFD modeling on complex systems. This flexible and robust tool makes it easy to simulate all flow regimes with the required levels of speed and accuracy. 3 main ways to simulate "Turbulent Flows" in CFD.

Turbulent flows are characterized by the three-dimensional movement of fluid on a large scale, the pair of in time and space. Mathematically, this means that a very small distance between the discretized points is required, which makes the computations longer and more expensive. Therefore, a number of approximations are introduced to represent the turbulence and make the simulation more feasible.

The various approaches developed to calculate turbulent flows can be broadly divided into the following three groups:

- 1) Direct numerical simulations, 'DNS',

2) Large Eddy Simulations, 'LES' and

3) Reynolds-Averaged Navier-Stokes, 'RANS'. B

In appendix to these methods, for instance, LES and RANS, etc. There are also hybrid methods that combine A) Birbaşa Rəqəm Simulyasiyası (DNS).

In the first-ever simultaneous world (DNS), the entire mineral mix of the movement is completed by Navier-Stokes and its persistence. DNS requires a very thin network range, as all media scales must be taken into account. DNS provides detailed information about the network, but requires super computational materials. As the count of Reynolds increases, the calculation request becomes more rapid because the tuning fork of the turbulent torsion dimensions grows rapidly. The second degree of finite volume scales is not very timely and other methods can be used quickly. These generalize the usage of the general public. While useful for fundamental axis solutions, DNS is accordingly not suitable for ordinary engineering calculations and not of choice for ink axis problems. B) Böyük Eddy Simulyasiyası (LES)

Large Eddy Simulation (LES) is another technique for computing turbulent flows where large scales are determined and small scales are modeled/estimated. LES appeared more than 40 years ago, initially for meteorological applications. The idea behind the LES technique is that large scales in a flow are anisotropic (i.e. directional) and therefore not universal and must be resolved, while small scales are isotropic (i.e. non-directional), dissipative and more universal so can be approximated. . By applying a filter to the velocity field and decomposing it into filtered (resolved) and modeled (subgrid) components, large scales can be separated from small scales. The size of this filter is defined by the resolution of the grid. Although LES has proven accurate in a number of industrial and non-industrial applications and requires less computational resources than DNS, the worth of LES still exceeds that of RANS simulation (presented below) by at least several orders of magnitude. It is therefore predicted that LES calculations for complex geometries, especially at high Reynolds number, may not be feasible for several decades.

In most engineering situations, average velocity, pressure, etc. of interest and fine details of all turbulent eddies are not required. Therefore, if instantaneous flow parameters are not required, a more practical alternative to DNS and LES is the Reynolds-Averaged Navier-Stokes (RANS) technique. As suggested by Reynolds, the velocity and pressure fields can be separated into the variable part (Figure 9):

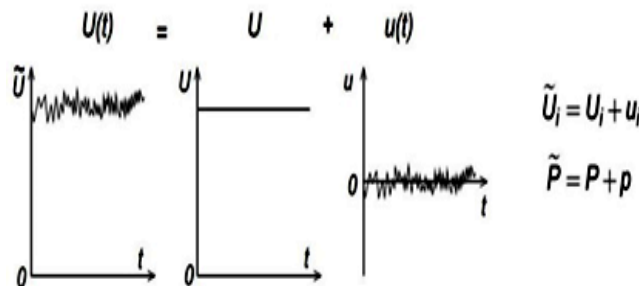


Figure 9. Velocity and pressure fields

In many cases the flow field may be constant on average, in which case the decomposition of the variables can be easily done by definition.

$$U_i = \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T \tilde{U}_i dt. \quad (5)$$

Decomposed velocities, pressures, etc. It can be restored by the Navier-Stokes equations. This is the basis of the RANS approach.

$$\frac{\partial U_i}{\partial t} + \frac{\partial (U_i U_j)}{\partial x_j} = -\frac{1}{\rho} \frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j} \left(\nu \frac{\partial U_i}{\partial x_j} - \overline{U_i U_j} \right). \quad (6)$$

RANS is at the present time the most economical and thus the most accepted approach for forecasting turbulent flows, and although its accuracy is highly dependent on the choice of turbulence model, it is widely used in industry for the design and analysis of various flow problems. Since it is impossible to have a universal turbulence model, it is very important for CFD users to be savvy which turbulence models are more accurate and thus reliable for use in different flow problems. This need has resulted in extensive CFD verification and validation evaluations and is still the subject of research and debate in the international community.

Conclusion

In the work, the principle of operation of the turbine-type flow meter device was considered, the flow passing through that device is in the laminar or turbulent phase. Also, the proposed method to prevent sudden changes in the flow was investigated. The types of effective CFD flow research methods were analyzed. As the analysis suggests, each of the three methods has its own advantages and disadvantages.

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A FUZZY CONTROLLER FOR A MOBILE ROBOT WITH OBSTACLE AVOIDANCE

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ABSTRACT

This research paper presents a mobile robot based on the MAMDANI fuzzy inference system. The mobile robot is equipped with three pairs of HC-SR04 ultrasonic sensors to detect the distance between the robot and obstacles. A fuzzy logic controller is built into the STM32F4 microcontroller platform to generate the actuation signal for the DC motor mounted on each robot wheel. To perform obstacle avoidance, a sensor capable of detecting the distance between the robot and the obstacle must be installed so that the controller can calculate and determine the appropriate control signal to send to the robot's actuator. In achieving this goal, the robot can perform movements at a constant speed or at a variable speed. When the distance between the robot and the obstacle is too far, the speed is too fast. Then, as the distance to the obstacle increases, the speed decreases. Such a control mechanism can be implemented with certain control methods installed in the controller. The data obtained from the ultrasonic sensors are expressed as linguistic variables that indicate the speed of movement of each wheel in fuzzy sets. A robot with a fuzzy logic controller based on a rule table is designed to achieve uninterrupted motion with obstacle avoidance capability.

Keywords: STM32F4 microcontroller, Fuzzy logic, Fuzzy inference system, mobile robot, obstacle avoidance.

Introduction

A mobile robot is designed to move along a given trajectory. One of the goals of the control is to maintain a distance between the robot and the obstacle so that the robot does not hit the obstacle. This ability is known as obstacle avoidance. It needs a sensor capable of detecting the distance between the robot and the obstacle must be installed so that the controller can calculate and determine the appropriate control signal to send to the robot's actuator. In accomplishing this objective, the robot can perform movements at a constant speed or at a variable speed. When the distance between the robot and the obstacle is too far, the speed is too fast. Then, as the distance to the obstacle rises, the speed falls. Such a control mechanism can be implemented with certain mechanism installed in the controller.

In practice, the above-mentioned abilities are fuzzy logic, artificial neural networks, genetic algorithms, etc. are achieved by applying certain control methods included in the category of artificial intelligence. Currently, artificial intelligence and robotics are intertwined in robotics research [1]. It was predicted to affect future economic growth and the labour market, as well as have important consequences for social welfare [2]. This paper describes a wheeled mobile robot whose actions are regulated based on fuzzy logic.

With this principle, both process variables and processed output variables are expressed as fuzzy sets. In fuzzy sets, the degree of membership of each member of the fuzzy set is characterized by linguistic variables. For example, the input variable to control the movement of a mobile robot was the distance between the robot and the obstacle. Consider this input variable as very close, close, far, very far, etc. in the fuzzy set. We denote by linguistic variables. At the same time, fuzzy sets can be developed for the output variables, such as slow, fast, very fast, etc. By adopting the principle of fuzzy logic, the robot's movement becomes more natural because it adapts to the distance between the robot and the obstacle.

The purpose is to be more efficient and save the resources used. This fuzzy logic is used in [3] to determine the apparent uncertainty function in designing an adaptive controller for mobile robots. [5] Fuzzy methods were used to optimize the motion of self-balancing mobile robots. In practice, the application of the fuzzy logic principle in system design requires three steps, including fuzzification, inference, and defuzzification.

Fuzzification is the process of transforming real data into fuzzy sets, while inference is making decisions in a certain way. Meanwhile, defuzzification returns the fuzzy value to its true value. An inference mechanism is an expert decision mechanism in the form of a set of statements based on "if/then" rules. Regarding the inference system, there are two popular methods used in the implementation of fuzzy logic controllers, which are the MAMDANI inference system and the Takagi-Sugeno-Kang (abbreviated by TSK) inference system. The first method is more widely used because it is more natural in representing fuzzy sets for all input and output variables.

MAMDANI fuzzy control design is model-free and essentially heuristic, which must incorporate expert skill and experience through a set of rule bases [6-13]. MAMDANI extraction (decision-making) system can be applied in temperature control, aerodynamic modeling of fixed-wing aircraft, classification features of mental disorders, six-legged robot, etc.

System design and equipment implementation

The mechanical structure of the wheeled mobile robot used in this work is shown in Figure 1. The main components of the wheeled robot are ultrasonic sensors, STM32F4 microcontroller and DC motors. Three pairs of ultrasonic sensors are used to detect obstacles in front, left and right of the robot. The input variable is the distance between the robot and the obstacle. A value of the distance is obtained by such sensors. Such values will be adjusted to the degree of membership of the corresponding fuzzy set for each sensor.

These processes are carried out by the fuzzifier. In addition, the inference system processes the fuzzy data from each sensor and converts it into an output in the form of adjusting the speed of the wheels on the left and right of the robot according to the rule table.

A rule table is a collection of statements that link the previous and final results in the form of If Then rules. The fuzzy data will be further processed by the fuzzifier to obtain the corresponding velocity value. The fuzzy inference system is implemented in a programming code built into the STM32F4 microcontroller and compiled. A value of speed is then sent to the motor driver to start the DC motor mounted on the wheels.

The schematic diagram of the wheeled mobile robot is given in Figure 3. Three pairs of HC-SR04 ultrasonic sensors are connected to the input data ports of STM32F4 microcontrollers. Such an ultrasonic sensor is used in distance detection because it has relevant specifications, that is, the range of measurable distances is from 2 cm to 400 cm, the resolution is around 3 mm, the measuring angle can reach 30 degrees, the dimensions are relatively small. Meanwhile, the output

data ports of the STM32F4 microcontroller will feed the signal to the L298N DC motor driver. An LCD display was developed to display the speed value of the left and right wheels of the mobile robot.

For fuzzy systems, the input variable is the distance between the robot and the obstacle obtained from three pairs of ultrasonic sensors, and the output variable is the speed of the wheels. Fuzzy sets for distance consist of three fuzzy sets near, middle and far with triangular and trapezoidal membership function as shown in Figure 2-3.

At the same time, the fuzzy sets for wheel speed consist of three fuzzy sets including slow, medium and fast with triangular and trapezoidal membership function. As you can see from these figures, the entire distance is measured in cm (centimeter) units, and the wheel speed is given in RPM (revolutions per minute) units. In fact, the RPM value will be converted into a pulse width modulation signal to drive the wheels.

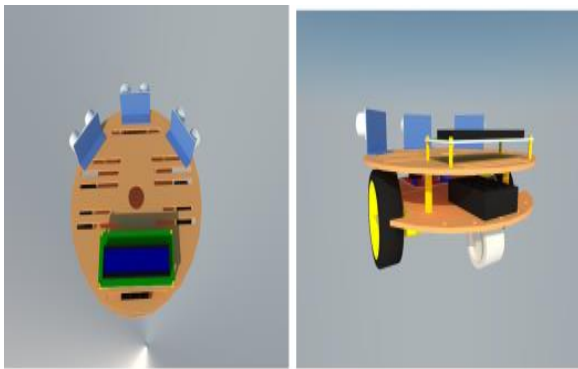


Figure 1. Mechanical structure and components layout of the wheeled mobile robot; top view (left) and side view (right).

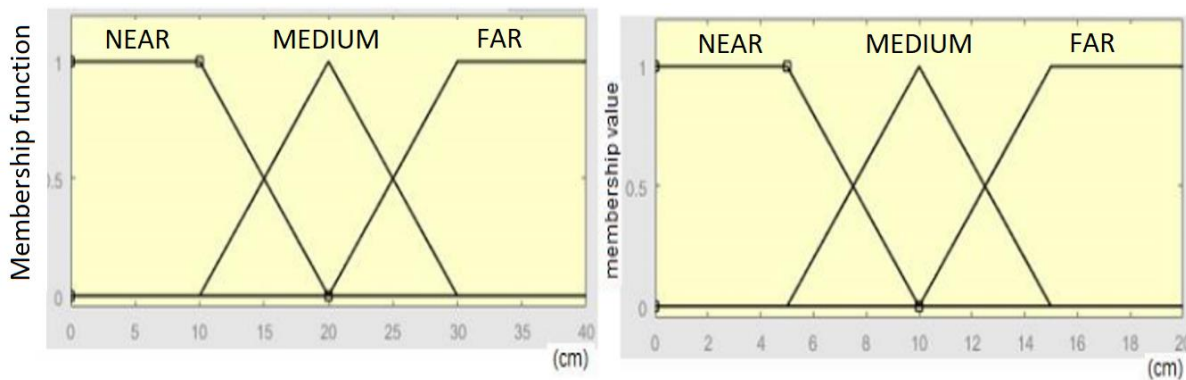
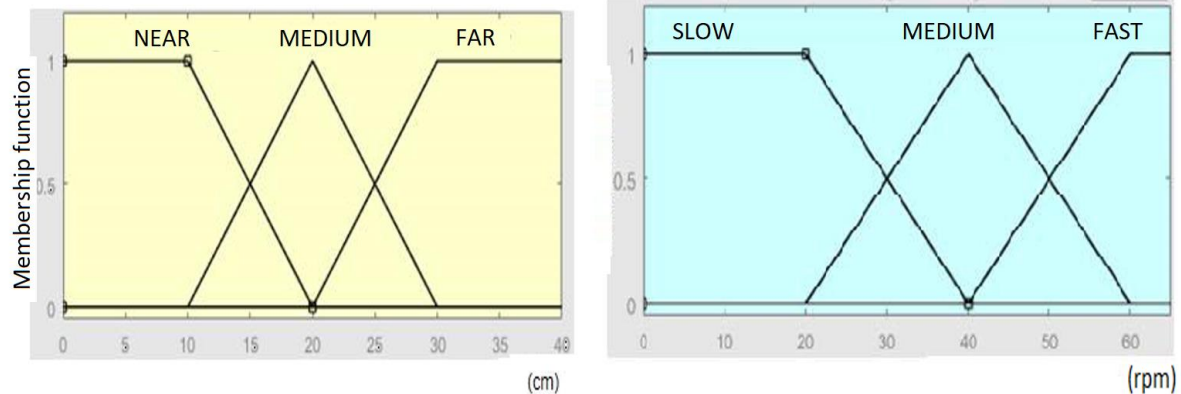


Figure 2. Left, Right, fuzzy sets for distance acquired by ultrasonic sensor.

Figure 3. Fuzzy sets for the distance obtained by the front ultrasonic sensor and the speed.



Figures 2 and 3 show the fuzzy sets for the distance shown by the left, forward and right ultrasound sensors. The hardware implementation of the wheeled mobile robot is shown in Figure 4. Three pairs of HC-SR04 ultrasonic sensors are positioned to indicate the distance between the robot and obstacles on the left, front and right sides.

In this case, the wheeled mobile robot can move in a corridor closed by walls to the left and right, and the trajectory is not very straight.

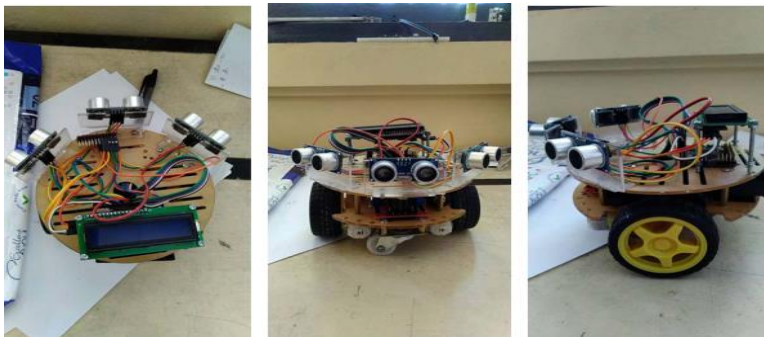


Figure 4. Realization of wheeled mobile robot with equipment; top view (left), front view (center), and side view (right)



Figure 5. The wheeled mobile robot runs slower when it is close to the wall. It shows the speed value plotted by the fuzzy inference system built for the STM32F4 microcontroller.

Experimental results

The wheeled mobile robot runs slower when it is close to the wall. It shows the speed value plotted by the fuzzy inference system built in STM32F4 microcontroller. First, an experimental test is conducted to obtain the results of the fuzzy inference system embedded in the STM32F4 microcontroller.

The speed value is also measured by a tachometer connected to the DC motor. From these results, the accuracy of the speed value given by the fuzzy inference system built into the STM32F4 microcontroller is about 96%. Second, the experimental test is performed by placing the wheeled mobile robot at the initial point and observing the movement along the trajectory given by the left and right bounded by the wall. Figure 5 shows that the wheeled mobile robot can move forward and avoid obstacles. The robot runs away without hitting the wall. We observe the evasion performed by a wheeled mobile robot. When the wheeled mobile robot approaches the wall, it moves slowly so that the robot does not hit the left and right walls.

Conclusions

The design and application of fuzzy logic controllers to regulate the motion of a wheeled mobile robot is presented. The wheeled mobile robot has the ability to run by implementing the MAMDANI decision-making system embedded in the STM32F4 microcontroller. A comparison of the hardware implementation with the compilation in the Matlab program shows that the accuracy of the hardware implementation is quite high. Experimental results show that the wheeled mobile robot equipped with a MAMDANI-based fuzzy logic controller performs well along the trajectory. The wheeled mobile robot avoids hitting the wall when it approaches the wall. For some experimental data, the accuracy of the speed value given by the fuzzy inference system installed on the STM32F4 microcontroller is about 96%.

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DYNAMIC EXPERT SYSTEM INFERENTIAL MECHANISM FOR POLYPROPYLENE PRODUCTION PROCESS

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ABSTRACT

The oil refining industry is one of the most important industries in our country, a kind of locomotive for economic development. Automation issues in the field of oil refining and petrochemistry are not at the proper level yet. Therefore, the topic can be considered an urgent research problem. This paper is devoted to the development of an inferential mechanism of dynamic expert system for managing the technological processes of polypropylene production by leaching, washing, and drying an oil refinery, which can be considered a scientific novelty.

At the beginning, an enlarged structure of the created dynamic expert system is given and their contents are revealed. Then the general structure of the inferential mechanism is given. A special place is allocated to building a knowledge base. The knowledge base consists of products in the form of "if-then". They were divided into two groups: products for emergency situations and products of a technological nature. Specific products are given.

To organize a logical conclusion, the apparatus of the theory of fuzzy sets was used and a mathematical description of the scheme developed by us for making a decision from a situation that arose in production was given.

Keywords: expert system, inferential mechanism.

Introduction

An important reserve for improving the efficiency of the functioning of a modern oil refinery (OR), which makes it possible to significantly increase its qualitative and quantitative indicators, is the creation of a decision support system for management of an oil refinery. Specifics of OR, continuous and multi-product nature of production, complex interconnections of process installations and tanks for storing oil products of the enterprise - all this causes a significant impact on the smooth production flow.

It is considered expedient to use expert systems for managing various industries, including for managing technological processes for producing polypropylene by leaching, washing and drying.

The importance of expert systems is as follows:

- expert system technology significantly expands the range of practically significant tasks solved on computers, the solution of which brings a significant economic effect;
- ES technology is the most important tool in solving the global problems of traditional programming: the duration and, consequently, the high cost of developing complex applications;
- high cost of maintenance of complex systems, which often exceeds the cost of their development by several times; low level of program reusability, etc.;
- the combination of ES technology with traditional programming technology adds new qualities to software products due to: providing dynamic modification of applications by the user, not by the programmer; greater "transparency" of the application (for example, knowledge is stored in a



limited natural language, which does not require comments on knowledge, simplifies training and maintenance); better graphics; interface and interaction.

ES are designed for so-called non-formalized tasks, i.e. ECs do not reject or replace the traditional approach to program development focused on solving formalized problems.

Non-formalized tasks usually have the following features:

- fallacy, ambiguity, incompleteness and inconsistency of the source data;
- fallacy, ambiguity, incompleteness and inconsistency of knowledge about the problem area and the problem being solved;
- large dimension of the solution space, i.e. the search for a solution is very large;
- dynamically changing data and knowledge.

Expert systems are used to solve only difficult practical (not toy) problems (Figure 1). In terms of the quality and efficiency of the solution, expert systems are not inferior to the solutions of a human expert. Solutions of expert systems have "transparency", i.e. can be explained to the user at a qualitative level. This quality of expert systems is ensured by their ability to reason about their knowledge and conclusions. Expert systems are able to replenish their knowledge in the course of interaction with an expert. It should be noted that at present the technology of expert systems is used to solve various types of problems (interpretation, prediction, diagnostics, planning, design, control, debugging, instruction, management) in a wide variety of problem areas, such as finance, oil and gas industry, energy, transport, pharmaceutical production, space, metallurgy, mining, chemistry, education, pulp and paper industry, telecommunications and communications, etc. asks this or that question?", "how was the answer collected by the system received?".

Creation of a dynamic expert system (one of the areas of artificial intelligence) remains an urgent task in the management of production with a continuous nature [1, 2].

The scientific novelty of this paper can be considered the development of an inferential mechanism for a specific production. That is for the control of technological processes for polypropylene production by leaching, washing and drying.

A static expert system is a software tool that uses the knowledge of experts for highly effective solution of problems in a subject area of interest to the user. It is called a system, and not just a program, because it contains a knowledge base, a problem solver, and a support component. ESs of this type are used in those applications where it is possible not to take into account changes in the surrounding world that occur during the solution of the problem.

Like all other expert systems, the dynamic expert system we have created for managing the technological processes of polypropylene production by leaching, washing and drying (POLYPROPYLENE TP ES) consists of the following main components, the enlarged structure of which is shown in Figure 1:

- Solver (interpreter);
- Working memory (WP), also called a database (DB);
- Knowledge base (KB);
- Components of knowledge acquisition;
- Explanatory component; and
- Dialog component.

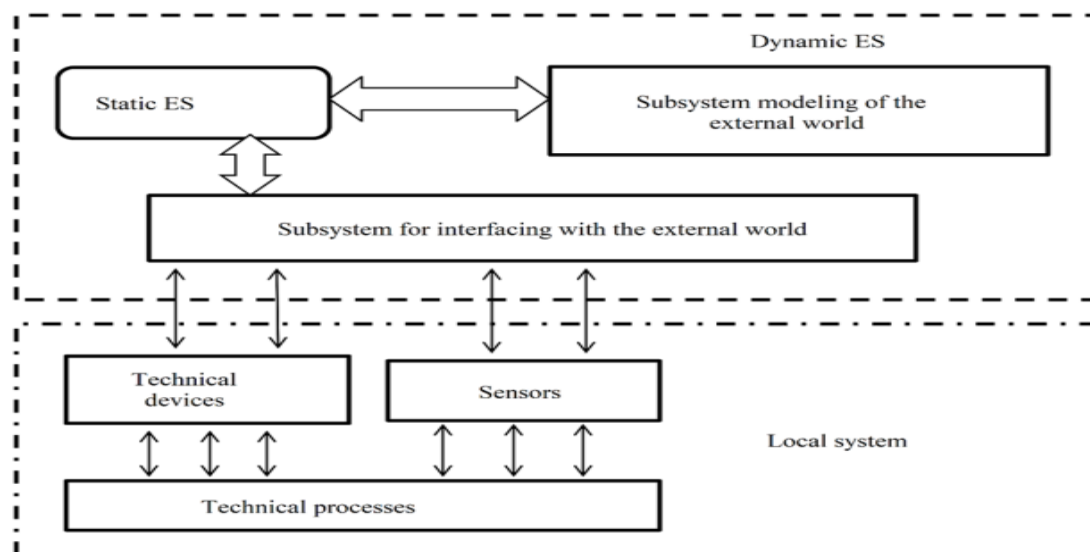


Figure: 1. A dynamic POLYPROPYLENE TP ES

The knowledge base is designed to store long-term data describing situations in the process installations of the main OR production, and rules describing appropriate data transformations. The inference subsystem (a solver) of a dynamic expert system for managing the technological processes of polypropylene production by leaching, washing and drying an oil refinery consists of a knowledge base (KB), a database (DB) and the inferential mechanism (Figure: 2.)

Using the initial data from the working memory and knowledge from the KB, the solver forms a sequence of rules which lead to the solution of the problem, when applied to the initial data.

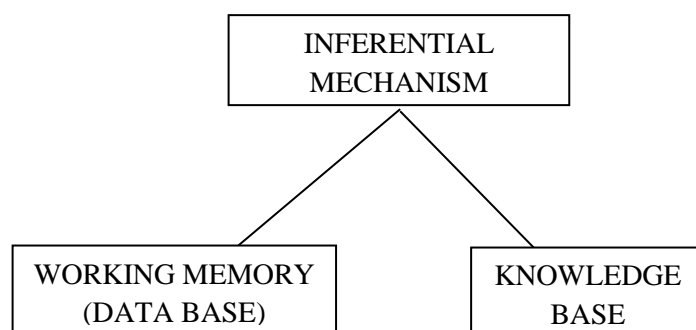


Figure 2: General structure of the inferential mechanism

The working memory (or memory for short-term storage) stores prerequisites, initial and intermediate factual data used in solving specific problems that characterize this process, for analyzing and making decisions on operational management of the main production of OR and the results of conclusions.

The knowledge acquisition component automates the process of filling the ES with knowledge, carried out by an expert user.



The explanatory component explains how the system got the solution to the problem and what knowledge it used in doing so, which makes it easier for the expert to test the system and increases the user's confidence in the result.

The dialog component is focused on organizing friendly communication with the user, both in the course of solving problems and in the process of acquiring knowledge and explaining the results of work.

Collection of data from technological installations and tank farms is carried out mainly automatically with the help of technical devices and sensors.

The modeling engine of the external world and the subsystem for interfacing with the external world provide an imitation of the current production situation with planned production indicators.

The knowledge base (or rule base) is designed to store long-term data describing situations in the process units of the main OR production, and rules describing appropriate data transformations. This includes a set of descriptions of cause-effect relationships in the form of productions.

The KB consists of productions in the form of "if-then". They can be divided into two groups: productions for emergencies and productions of technological nature.

Here are some of them:

1. Productions for emergency situations:

- 1.1. If oil products are not replaced during the insulation impregnation, then the insulating materials ignite spontaneously.
- 1.2. If a fire occurs at the plant, then the direct supply of raw materials to the plant must be stopped.

2. Productions of technological nature:

- 2.1. If preventive inspection of equipment is carried out irregularly, this can lead to failure of both the equipment and certain components and devices.
- 2.2. If the pumps are not cooled during operation, this can lead to the pump malfunction.

There are a number of methods for organizing inference based on the use of various approaches (production, frame, semantic networks, etc.)

The inference engine performs interference from a pre-built fact base (true statements) and rules in accordance with the laws of formal logic [3, 4]. Inference can occur both in direct order (inference from facts) and in reverse inference order.

A fairly adequate approach to organize interference in the conditions of a complex oil refinery is to use the apparatus of the theory of fuzzy sets [5, 6]. This is due to availability of the following factors in such industries:

- The complexity of the utility, therefore, the complexity of cause-effect relationships: cause - situation - action;
- Fuzzy priorities of actions corresponding to the arisen situation and chosen by the operator;
- The need to take into account experience and intuition, on the basis of which the operator makes a decision in this situation;
- A linguistic form of describing situations, the causes that cause them, and actions taken to eliminate them and etc.

Let a set of situations occur in the facility:

$$S = \{S_z\}, z = 1, 2, \dots, m. \quad (1)$$

Each S_z situation is characterized by a set of features:

$$P_{S_z} = \{P_i S_z\}, i = 1, 2, \dots, n. \quad (2)$$

Availability of $P_i S_z$ actions causes a fuzzy set of actions $D_{P_i S_z}$ with $\mu_{D_{P_i S_z}}$ membership function.

Construction of $\mu_{D_{P_i S_z}}$ membership function is based on the study of the expert's opinion on correspondence of a certain set of actions to the situation under consideration. At the same time, the expert evaluates the degree of correspondence in the form of linguistic expressions.

Then, the fuzzy set of actions corresponding to S_z situation with a set of features $P_i S_z$ is defined as:

$$D_{S_z} = \bigwedge_{i=1}^n D_{P_i S_z}, \quad (3)$$

Or passing to the membership function (here $\bigwedge_{i=1}^n$ – conjunct):

$$\mu_{D_{S_z}}(d) = \min_i \mu_{D_{P_i S_z}}(d). \quad (4)$$

The best action in this case will be the action, the value of $\mu_{D_{S_z}}$ membership function (d) of which will be maximum, i.e.

$$d^* = \sup (\bigwedge_{i=1}^n D_{P_i S_z}) \quad (5)$$

or

$$d^* = \operatorname{argmax} \mu_{D_{S_z}}(d) = \operatorname{argmax} [\min_i \mu_{D_{P_i S_z}}(d)].$$

The expert system developed by us operates in two modes: knowledge acquisition mode and problem solving mode (also called consultation mode or ES usage mode).

In the mode of acquiring knowledge, communication with the ES is carried out (through the mediation of a knowledge engineer) by an expert. In this mode, the expert, using the knowledge acquisition component, fills the system with knowledge that allows the ES in the solution mode to independently (without an expert) solve problems from the problem area. The expert describes the problem area as a set of data and rules. Data defines the objects, their characteristics and meanings that exist in the field of expertise. Rules define the ways in which data is manipulated that is specific to the domain in question.

Note that the knowledge acquisition mode in the traditional approach to program development corresponds to the stages of algorithmization, programming, and debugging performed by the programmer. Thus, in contrast to the traditional approach, in the case of ES, the development of programs is carried out not by a programmer, but by an expert (with the help of ES), who does not know programming.

In the consultation mode, communication with the ES is carried out by the end user, who is interested in the result and (or) the method of obtaining it. It should be noted that, depending on the purpose of the ES, the user may not be a specialist in this problem area (in this case, he turns to the ES for the result, not being able to get it himself), or be a specialist (in this case, the user can get the result himself, but he turns to the ES with the aim of either speeding up the process of obtaining the result, or entrusting the ES with routine work). In consultation mode, data about the user's task, after being processed by the dialog component, enters the working memory. The solver, based on input data from the working memory, general data about the problem area and rules from the knowledge base, forms a solution to the problem. When solving a problem, the ES

not only executes the prescribed sequence of operations, but also preliminarily forms it. If the system response is not clear to the user, then he may require an explanation.

Conclusion

This research paper of theoretical and applied character is intended to create an expert system, in particular, to create a component of the inferential mechanism. Use of the apparatus of the theory of fuzzy sets for organizing a logical inference is substantiated and a mathematical description of the developed scheme is given, which provides a decision to get out of the situation that has arisen in production. The best action to get out of a critical situation is proved.

The proposed method for the inferential mechanism is one of the applications in continuous production management and can be applied in other industries by updating the knowledge base products.

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DESIGN OF CONTROL SYSTEM FOR MANUFACTURING OF PERIODICAL MULTILAYER X-RAY MIRRORS

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ABSTRACT

Periodical multilayer mirrors (PMMs) are coatings used in various industrial and scientific applications for the manipulation of X-Rays. PMMs consist of periodically repeated stacks; every stack comprises nanolayers of several different materials. The number of stacks may vary from 50 to 500. Manufacturing such coatings, consisting of hundreds of nanolayers, needs precise sputtering deposition systems. A deposition system must provide a stable deposition rate and accurate deposition time control. This paper developed a new process control system to satisfy these requirements. Before running the deposition process, the final script is saved automatically to a backup folder; the file name is created automatically and includes the date and time that is why every deposition can be repeated with the same parameters. Multithreading and precise microcontrollers allowed real-time management of the deposition process and increased user interface responsiveness. System architecture and hardware structure schemes for robust PMMs manufacturing were designed. Corresponding operator software having custom script language was developed to provide flexibility and simplicity of operation. The architecture of the software allowed high responsiveness of the user interfaces. The system was tested to verify the reliability of the deposition process and the high quality of PMMs.

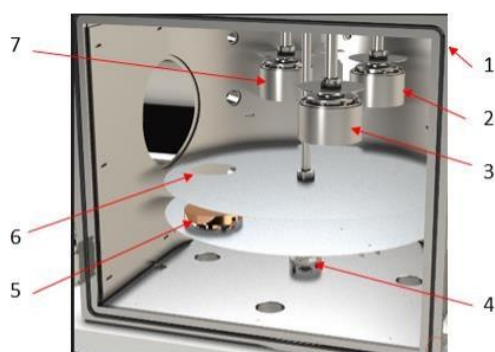
Keywords: Process control, vacuum, sputtering, automation, SCADA, user interface.

Introduction

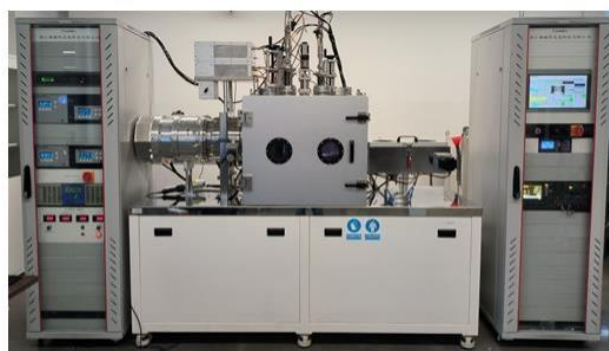
X-ray optics is one of the key technologies in various scientific, engineering, and industrial applications, such as EUV lithography, high-resolution microscopy, X-ray fluorescence analysis, synchrotrons, free-electron lasers, and space astronomy [1]. Because the refractive index of all materials is very close to 1, manipulation of soft X-ray radiation demands advanced reflective optical devices [2], [3]. Such optical devices consist of shape-forming glass substrates (flat, spherical, parabolical, elliptical, etc.) covered by a special artificial multilayer coating that can reflect x-rays. Such periodical structures are called periodical multilayer X-ray mirrors (PMMs) [4]. PMMs are synthetic Bragg crystals consisting of tens or hundreds of alternated layers of "light" and "heavy" materials. The sum of the thicknesses of the light and heavy layers is called the periodicity parameter d . For PMMs designed for near-normal incidence, d is around half the working wavelength. In some cases, a skinny layer of a third material (diffusion barrier) can be deposited between primary light and heavy layers [5], [6]. The schematic of the deposition system is shown in Fig. 1a. The deposition system consisted of a vertical cylindrical vacuum chamber with magnetrons mounted on the top. A, B, and C targets are

installed on the magnetrons. A substrate holder was mounted below the magnetrons and was moved from one magnetron to another by a robotic arm to deposit alternate layers of A, B, and C. A shutter with a window is used to control the deposition time [7]. The whole system is shown in Fig. 1b. Generally, the manufacturing of first-class PMM is far beyond just alternating stacking of two materials [1]. It requires control of the structure and composition of layers, interface roughness, spatial uniformity, and time stability of the deposition rate [8 - 10]. The time stability of the deposition rate directly affects the uniformity of d across the whole multilayer stack. Time stability has two aspects. First, it should be stable during the single manufacturing cycle, which could take up to 3-5 hours for a PMM with several hundred pairs. Variation of d in a PMM led to broadening, splitting, and shifting of the diffraction peak due to a violation of Braggs law [3]. The second aspect is the stability between several manufacturing cycles. Each PPM is designed for specific geometry (incidence angle) and given wavelength. The deviation of d should be within 1% to satisfy manufacturing requirements. Assuming the typical layers thicknesses of 2-4 nm, we must control the periodicity within ~ 0.02 nm. Besides pure periodical PMMs, there are so-called "aperiodic" broadband PMMs. In their case, parameter d gradually changes from the bottom to the top of the PMM by a given law (liner, parabolic, etc.). In this case, the d parameter should follow the law with the same precision (below %1).

Precise control of the d parameter is possible due to maintaining stable conditions and accurate control of the exposition time. The constant conditions, first of all, means the pressure of the working gas, the composition of the atmosphere in a deposition chamber, and the temperature. Solving these technological issues needs careful design of the controlling system, which is the topic of this work.



a)



b)

Figure 1: a) Schematic of the deposition system for manufacturing of PMMs.

1 – vacuum chamber; 2, 3 – magnetrons A and B; 4 – robotic arm; 5 – substrate holder; 6 – shutter's window; 7 – magnetron C. b) Image of the whole deposition system.

Architecture of the control system

The overall controlling system architecture is shown in Fig. 2. The system's components can be divided into the following groups: vacuumcreation and control, chamber atmosphere control (composition and pressure), sputtering management (power), mechanics, data acquisition, and communication systems. The vacuum subsystem includes pumps, valves, gauges, sensors, etc. The atmosphere control consists of a primary throttle valve, gas mass flow controllers (MFCs), and gas valves. The mechanical part includes two precise programmable stepping motor controllers (PSMCs) and stepping motors with encoders and home sensors used to move the shutter and the robotic arm (substrate holder). Power control includes power sources for magnetrons and the ion gun. The acquisition system comprises a multichannel signal analyzer, a residual gas analyzer, and emperature sensors. The communication subsystem consists of an industrial LAN controller and industrial RS-232 to USB / LAN adapters. The relation between the components of the system is shown in Fig. 3.

An industrial PLC directly controls vacuum and gas composition in the working atmosphere. A real-time operating system controls PLC through the HMI interface. The workstation is disabled to manipulate the vacuum components but can read their state, e.g., pressure and chamber temperature. The atmosphere subsystem can be controlled in both ways. For example, it is directly connected to PLC, but the PLC can also pass through the corresponding commands from the workstation and return the status information. The operator's workstation controls all other components. The workstation is operated under MS Windows, and pre-compiled GUI control software was created using Embarcadero Delphi RAD.

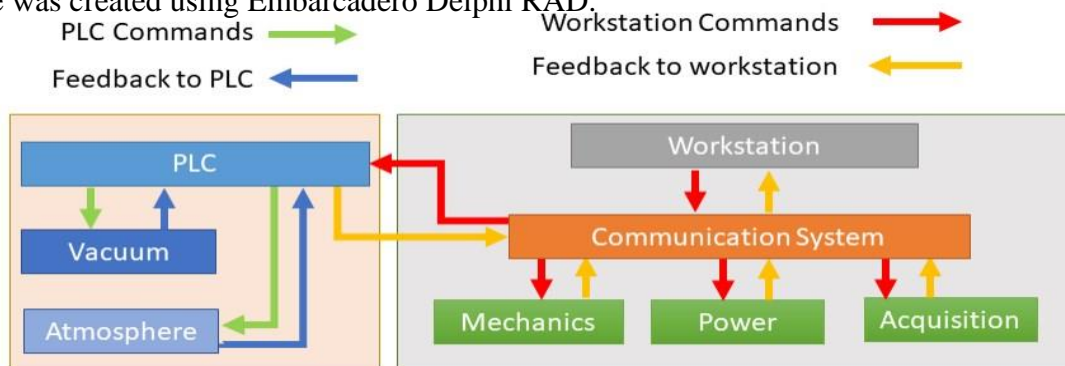
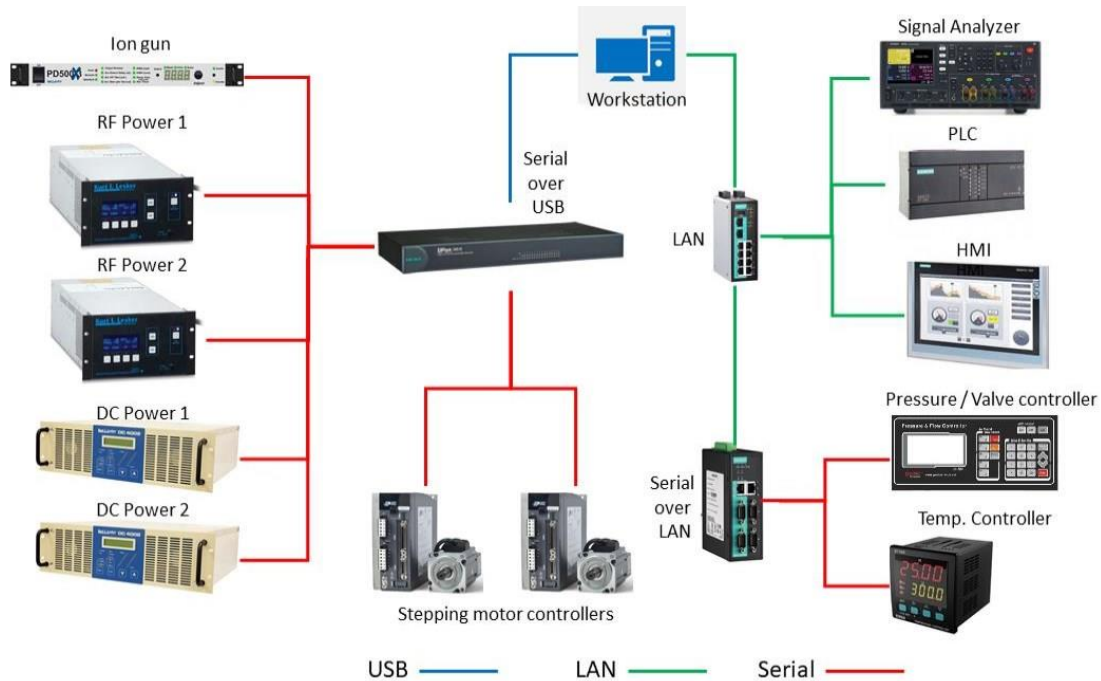


Figure 2: Controlling system architecture and commands/feedback flow.

Figure 3: System components and their physical communication

**Table 1.** Communication protocols and interfaces.

Component	Interface	Protocol
Valve controller	RS-322	Custom ASCII
Temp. Controller	RS-232	MODBUS RTU
Signal Analyzer	100BASE-TX	Custom ASCII over TCP/IP
Stepping Motor Controller	RS-232	Custom ASCII
RF Power Source	RS-232	Custom ASCII
DC Power Source (A)	RS-232	Custom MODBUS RTU
DC Power Source (B)	RS-485	MODBUS RTU

Design of the system**Communication protocols and interfaces**

The variety of protocols and interfaces used in the system is defined by the assortment of components provided by different vendors, as shown in Table 1. PLC is connected to the system using the LAN interface. The communication is executed by the SNAP7 library performing direct data read/write operations into PLC's memory [11]. The rest of the units are operated using Modbus or custom ASCII command protocols.

System Control

The desired degree of stability of the deposition process is warranted by the automatic throttle valve controller and PSMC. Since GUI is run under Windows, it cannot perform accurate time control. Instead, critical timings, such as the exposition time of the shutter, are performed by PSMCs. GUI interpreters a deposition script and sends short program sequences to PSMCs. Such a sequence forces PSMCs to perform simple "atomic" actions. Examples of such activities are moving the substrate holder to a given position, opening the shutter at a specific place for a given time, and closing the shutter. Such an approach provides the best flexibility and high precision.

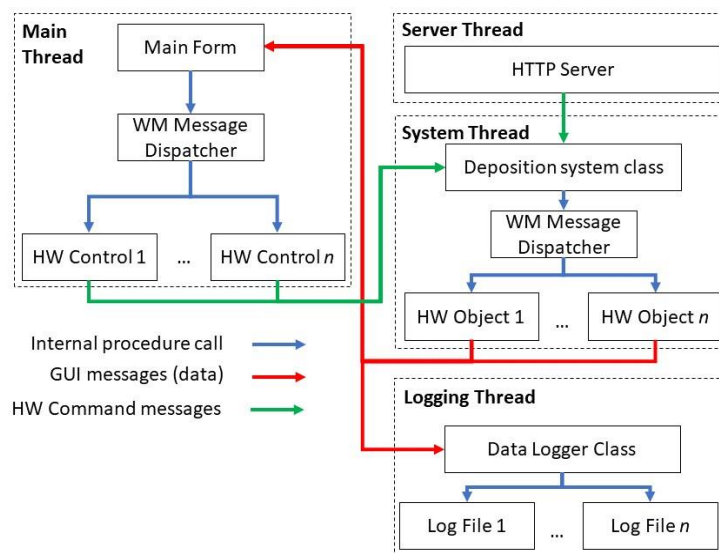


Figure 4: Structure of the control software.

Control Software

The software uses multithreading to aim for a better user experience and quicker reaction time. Communication between the threads is performed using the Windows Messaging (WM) mechanism. Fig. 4 shows the relation between threads and directions of the communication. Every hardware component shown in Fig. 3 is presented in the code as an independent object (HW Objects 1..n). GUI includes corresponding controls (HW Controls 1..n) to represent the state and manipulate hardware objects.



Figure 5: Main window of the control software.

The recipe editor window is divided into several sections for configuring deposition conditions. The top section, 'Deposition conditions', includes fields for 'CleaningTime (sec)' (10), 'Pressure (mTorr)' (2.00), 'Warm-UpTime (min)' (60), 'MFC Ar1 (sccm)' (40), and 'MFC Ar2 (sccm)' (40). Below this is the 'Layer B' section, which has fields for 'Power (W)' (300), 'Time Middle (sec)' (4000), and 'Time Top (sec)' (200). The bottom section, 'Layer Mo', includes fields for 'Current (mA)' (50), 'Freq (kHz)' (20), 'Pulse Time (us)' (10), and 'Time (sec)' (200). Each field is represented by a text input box with its current value displayed.

Figure 6: Recipe editor window.

The HTTP server accepts commands from an additional keyboard with 15 LCD keys. This keyboard is used as a remote control. The message dispatcher processes WMs addresses to the system thread and passes commands to corresponding hardware objects. Every hardware object performs physical communication with related hardware, as listed in Table 1. The system thread uses an infinite loop polling the state of devices. Then hardware objects request

to update the main interface by sending WMs to the main window. The logging thread also uses an infinite loop to read the state of all hardware objects and save results into several log files. The main window of the control software is shown in Fig. 5. The main window provides status information and fast access to controls of power sources, atmosphere, and mechanics. The deposition process can be controlled manually, but it usually is defined in the script files. The software uses custom-designed script language. The language is system-specific and includes commands for the operation of all hardware. Because the deposition process is quite sophisticated, a typical script describing the manufacturing of PMM can contain up to 60-70 lines. The script language also supports specific programming structures like variables, loops, and functions. The software also supports recipe files to simplify routine operations. The recipe is an XML file. The recipe includes the script file and describes the GUI window's layout, allowing easy change of the script's parameters. Fig. 6 shows an example of Recipe selector windows with the parameter's editor. Fig. 7 c shows the final script generated before running the deposition. Before running the deposition process, the final script is saved automatically to a backup folder; the file name is created automatically and includes the date and time. Thus, every deposition can be repeated with the same parameters.

```

1 var CleaningTime 60
2 var P 2.00
3 var WarmUpTime 60
4 var N 40
5 var powerB 300
6 var timeB 283
7 var currentMo 100
8 var timeMo 22
9 var DCFreq 40
10 var DCPulseTime 70
11 start
12   valve 5 open; valve 10 open
13   wait 0.5 "Pipe cleaning..."
14   valve 2 open; valve 3 open
15   MFC 2 40; MFC 3 40
16   pressure P
17
18   message "Set Ion current to 0.1A. Ready for cleaning"
19
20   holder Ion
21   deposit Ion CleaningTime 1
22   holder 1
23
24   message "Set Ion Current to 0.<br>Main phase"
25   valve 7 close; valve 9 open
26   pressure P
27
28   shutter B
29   set RF_A Ramp 60
30   set RF_A Power powerB
31   wait 65 "B Ramping"
32   shutter 1
33
34   message "Start DC Source (100 mA)"
35   wait WarmUpTime "Warm-Up"
36

```

Figure 7: Fragment of the deposition script generated for the recipe shown in Fig. 6



Performance evaluation

To assess the stability of the deposition process, W/B4C PMM was manufactured. Respectively, pulse DC and RF power sources were used for W and B4C. The layer thickness was 2.4 nm for W and 6.1 nm for B4C. The total number of W/B4C pairs was 50. The entire deposition time was 3 hours, including the preparation.

The structure of the PMM was evaluated using low-angle XRD with computer modeling (Fig. 8) [4]. The deviation of the d parameter was calculated based on HWFM of the 6th diffraction order. It was concluded that the Δd is below 5%.

Conclusions

System architecture and hardware structure schemes for robust PMMs manufacturing were designed. Corresponding operator software having custom script language was developed to provide flexibility and simplicity of operation. The architecture of the software allowed high responsiveness of the user interfaces. The overall system performance and stability of the deposition process were demonstrated in the experiment.

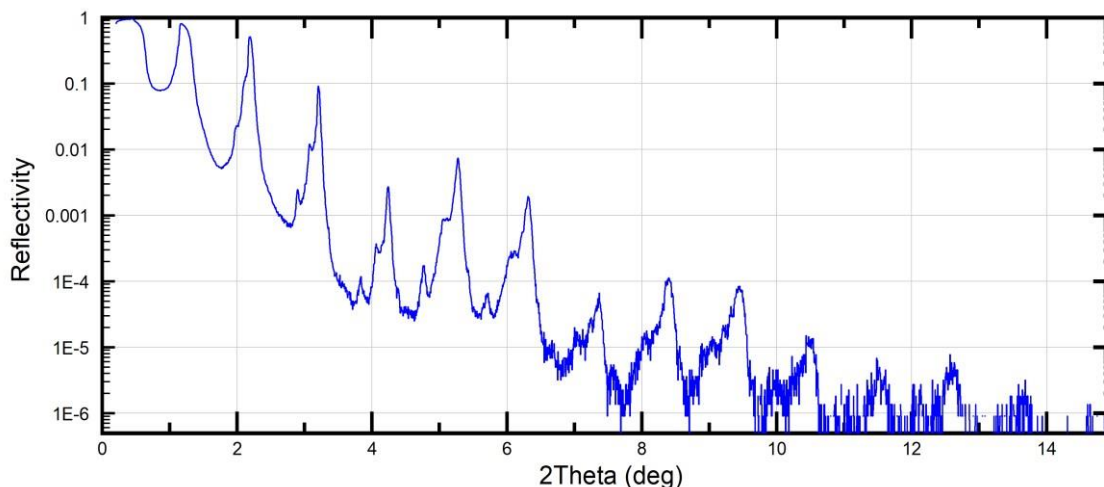


Figure 8: XRR Curve at $\lambda = 0.154$ nm of W/B4C PMM manufactured by the deposition system

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ELECTROPHYSIOLOGICAL METHODS FOR ASSESSING THE FUNCTIONAL STATE OF THE GASTROINTESTINAL TRACT

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ABSTRACT

According to the criteria of prevalence and loss of working capacity, diseases of the gastrointestinal tract (GIT) occupy one of the leading places. Disorders of the functional state of the gastrointestinal tract, which are accompanied by violations of its motor-evacuation functions, are considered. To identify gastrointestinal motility disorders, it is necessary to conduct studies that are invasive, or are accompanied by radiation exposure and are difficult to analyze. In this regard, simple non-invasive methods of functional diagnostics, such as peripheral electrogastroenterography (EGEG), are of particular importance.

Electrogastroenterography has no contraindications and is well tolerated by all patients. This allows you to examine even extremely severe patients, both before surgery and from the first hours of the postoperative period. Given the simplicity and accessibility of the technique, it is possible to conduct multiple repeated studies to assess the dynamics of indicators in the course of treatment. The data obtained with electrogastroenterography do not contradict and often outstrip the results of X-ray and endoscopic examination, which indicates a higher sensitivity of the method for diagnosing motor disorders of the motor-evacuation functions of the gastrointestinal tract,

Significantly improving the timeliness and quality of diagnosis to expert doctors allows the use of modern computer technology.

Keywords: neural network, gastrointestinal tract, parasites, disease symptoms, diagnostics, electrogastroenterography.

Introduction

Promotion of food through the digestive tract, its mechanical processing, mixing with digestive juices is one of the important functions of the gastrointestinal tract. Doctors call it the motor-evacuation function (MER) of the gastrointestinal tract (GI).

The development of new technologies in medicine has made it possible to introduce electrophysiological methods for studying the motor-evacuation function of the gastrointestinal tract (GIT) into clinical practice.

Conventionally, they can be divided into two main groups [1];

- methods that allow you to directly register the contractile activity of the gastrointestinal tract;
- methods for assessing the motor function of organs based on data characterizing their electrical activity.

The first group includes methods based on direct measurement of intraluminal pressure of the gastrointestinal tract using balloons, microsensors, radiocapsules, open catheters. The disadvantage of these methods is the introduction of a foreign body - a balloon or a catheter - directly into the lumen of the organ, which leads to irritation of the mucosal mechanoreceptors

and changes its motor activity. These methods are also laborious, invasive and in some cases expensive, making them difficult to apply in everyday clinical practice.

The second group includes electrophysiological methods based on the study of the electrical activity of the gastrointestinal tract. They are based on the data of numerous studies proving the close relationship between the electrical and contractile activity of the gastrointestinal tract, and include the direct registration of the biopotentials of the smooth muscle walls of organs from electrodes fixed on them (direct electrogastroenterography), as well as their registration from the surface of the body abdominal wall or limbs (peripheral electrogastroenterography) [2, 3].

Electrophysiological parameters of the motor-evacuation function can be describe using the three main indicators of peripheral electrogastroenterography (Table 1).

Electrical activity (P; / P.) - the percentage contribution of each of the sections of the digestive tract to the overall frequency spectrum, the amplitude characteristic indicates the strength of contractions of each section of the gastrointestinal tract. This indicator is calculated as a percentage (%). We moved away from the analysis of absolute values, since the percentage is a constant value and more accurately characterizes the electrical activity of various parts of the gastrointestinal tract.

Coefficient of rhythm (K) - the frequency response indicates the rhythm of contractions of various sections of the gastrointestinal tract.

Ratio coefficient (P; π +1) - ratio of electrical activity of the overlying department to the underlying – says $\left[\frac{L}{SEP} \right]$ about coordination of reductions of various departments. GIT. measured in millivolts (mV).

Table 1. Indicators of electrogastroenterography of various parts of the gastrointestinal tract in healthy patients.

Department of the gastrointestinal tract	electrical activity	Rhythm factor	ratio ratio
stomach	22.4 \pm 11.2	4.85 \pm 2.1	10.4 \pm 5.7
dpk(12 stopped gut)	2.1 \pm 1.2	0.9 \pm 0.5	0.6 \pm 0.3
Jejunum	3.35 \pm 1.65	3.43 \pm 1.5	0.4 \pm 0.2
Ileum	8.08 \pm 4.01	4.99 \pm 2.5	0.13 \pm 0.08
Colon	64.04 \pm 32.01	22.85 \pm 9.8	-

Thus, at present, a set of these parameters for all parts of the gastrointestinal tract is used to decipher the data of peripheral computerized electrogastrography.

The contraction frequencies of various parts of the gastrointestinal tract, as shown in a number of studies, are a stable parameter. Knowledge of these frequencies makes it possible to process the electrogastroenterographic signal in such a way (spectral analysis, digital filtering, etc.) in order to isolate and separately analyze the motility of various parts of the gastrointestinal tract [4].

The presence of certain diseases is reflected in the electrogastrographic signals of each of the sections of the gastrointestinal tract.

When considering long-term recordings of these signals, one should take



in taking out the non-stationarity of the recorded signals. At the same time, their spectral composition and oscillations can change significantly even in the course of a single measurement session. In addition, the considered signals, as a rule, contain artifacts, the origin of which is not associated with the contractile activity of organs.

Gastrointestinal tract (for example, motion artifacts). Also of particular interest is information concentrated in "bursts of organ activity.

Therefore, for differential diagnostics of the functional state of the organs of the gastrointestinal tract, modern methods of spectral analysis (wavelet analysis) of multifractal analysis of electrogastrographic signals are used [5,6.]

Often, a violation of the functioning of the gastrointestinal tract is associated with the influence of parasites. Parasites have a more complex structure and have well-established defense mechanisms directed against the human immune system (encapsulation, antigenic mimicry, antigenic "drift", inactivation of enzymes and biologically active substances, etc.), which allows them to exist for a long time in various organs and tissues of man. In addition, there are objective difficulties in identifying, isolating and obtaining immunoreagent specific antigens of parasites.

The World Health Organization has proven that 95% of humanity has a variety of parasites in its body. These living organisms are not as harmless and safe as it might seem at first glance. Most of them are localized in the organs of the gastrointestinal tract (worm eggs get here along with contaminated water and food). but there are also so-called extraintestinal forms of invasions - parasites can live in the lungs, heart, and even the human brain [7].

However, the establishment of the influence of parasites on the properties of the electrical signals of the gastrointestinal tract is a rather complicated task; in medical clinical practice, methods of serological diagnosis of many infectious diseases are widely used.

In addition, microscopic diagnostic methods, biopsy methods, laboratory tests are generally accepted, allowing it is enough to accurately detect the types and location of parasites.

Computer support of medical activity. which can be applied at all stages of the treatment and diagnostic process, introduces new possibilities into the medical technological process. Computer biotechnical complexes for electrogastrographic studies are characterized by the presence of a large number of factors that affect the formation of a reliable diagnosis[3]

In this case, it is necessary to take into account many different factors determined by the risk factor, the peculiarity of the course of the disease, the individual characteristics of the organism, the stages of localization, the severity, etc. When constructing the corresponding algorithm, depending on the conditions for triggering the prognostic and diagnostic rules, control is transferred to rational diagnostic schemes [4].

The diagnostic process control algorithm is presented of the Figure 1.

The algorithm provides for the implementation of a mechanism for determining the degree of risk (prognosis) of the appearance of peptic ulcer of the gastrointestinal tract and establishing the presence of pre-illness. If the patient has not been diagnosed with a predisease condition (gastritis, erosion of the walls of the stomach) and if peptic ulcer disease has not been recorded, then if there is a reason for treatment, an analysis of the need for an electrogastrographic examination is performed.

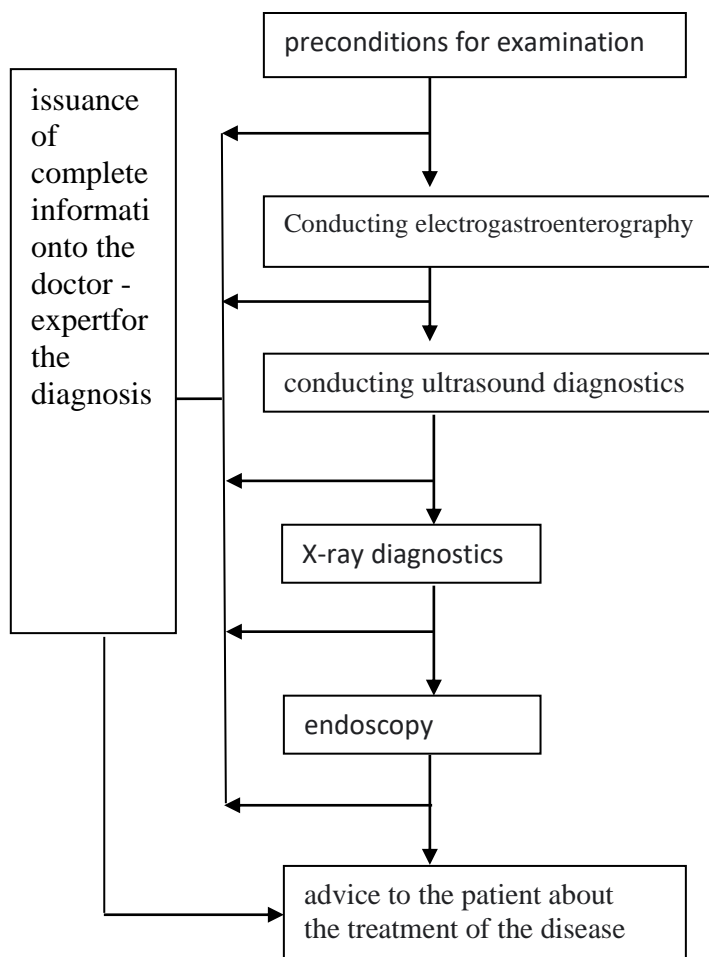


Figure 1: The diagnostic process control algorithm is presented.

The choice at the initial stage of the electrogastrographic method is associated with the advantages that have been indicated. If during the implementation of the Considered algorithm a sufficiently high RISK of the disease is determined, then, depending on the available medical and technical capabilities and individual indications, the issue of introscopic examination is decided: ultrasound diagnostics, X-ray diagnostics and endoscopy. If introscopic diagnostic methods are not used, then, based on the results of an electrogastrographic examination, recommendations can be given to reduce the risk of peptic ulcer disease or prescribe treatment based on risk factors. When using introscopic methods research, using signs of visual images, the belonging of the subject to the classes is determined: relatively healthy, pre-disease, peptic ulcer of the stomach (GU) and other organs of the gastrointestinal tract. At this stage, standard software packages for processing medical introscopy images can be used.

Computer-aided medical systems are being developed and deployed for identifying parasitic diseases. For example, the Mekos company was the first to develop and put into practice a software module



"Parasitology", which allows you to automatically screen microscopic preparations in order to search for and identify pathogens of intestinal parasitosis in biological material, followed by saving images of detected pathogens, the possibility of remote control of research results, archiving of research protocols with an image atlas and, more importantly, the possibility of their representations at the remote expert estimation. The robotic model MEKOS-12 uses original detection and recognition methods parasitological objects, original data collection system of functioning of automatic functions using the features of the architecture of the apparatus and intermediate fixed models of preparations of each level of biomaterial recognition [8]. Very promising for solving diagnostic problems in the differential diagnosis and classification of parasitic diseases of the gastrointestinal tract is the use of artificial neural networks and the fuzzy inference apparatus.

Conclusions

Currently, to diagnose diseases of the digestive system, expert doctors conduct examinations according to a certain scheme, which consists of a mandatory diagnostic minimum and a set of additional examinations.

1. Mandatory Diagnostic Minimum

Mandatory diagnostic minimum means that if a patient does not meet the criteria listed below, then he/she cannot receive treatment.

- a) A minimum of two symptoms should be present.
- b) Symptoms should last at least three months.
- c) Symptoms should be severe enough to interfere with daily activities.
- d) Symptoms should be accompanied by abnormal laboratory findings.
- e) Patients who do not have any of these conditions may still receive treatment if they have a history of chronic disease or if their condition worsens.

2. Additional Examinations

Additional examinations are performed to determine whether the patient's condition is caused by a specific disease. These examinations are optional and depend on the doctor's discretion.

a) Blood tests

Blood tests are conducted to check the levels of various substances in the blood.

b) Stool test

Stool tests are conducted to identify bacteria, parasites, viruses, and fungi.

c) X-ray examination.

This diagnostic minimum usually includes several or even all of the following types of examinations: questioning, palpation of the abdominal organs, complete blood and urine analysis, biochemical blood test, fecal occult blood test, ECG, ultrasound, X-ray examination of the stomach, gastroscopy with biopsy, determination of acidity gastric juice. All information on these examinations is placed in the medical history, which is further a source of information about the course of the disease and the history of its development (etiology).

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THE DEVELOPMENT AND TREND OF URBAN SMART TOURISM

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ABSTRACT

Technological developments, which are closely related to the tourism sector, have led to the concepts of “smart tourism”. The smart city approach is the basis of smart concepts for tourism. For this reason, in order to realize “smart tourism” applications in a tourism destination, it is necessary to develop “smart city” infrastructure for that city first. Therefore, it would be a correct approach to evaluate “smart city” and “smart tourism” applications as integrated with each other, enhancing and enriching the quality of life of the local people in that city, and enriching the experiences of those who temporarily visit that city, supported by advanced internet technologies. When we look at the current “smart tourism” objects, it is seen that internet-supported applications have been developed in important tourism destinations, which especially regulate the tourist's use of time, make use of transportation services, obtain information about tourist attractions, and facilitate their use. These are the practices that contribute significantly to the quality of the touristic experience of the tourist at the destination. Thus, it is very important to develop applications related to “smart tourism”, primarily in destinations that have worldwide awareness and significant touristic attractions.

Keywords: “Smart city”, “smart tourism”, information technologies, modernization, urban planning.

Introduction

The last decade is characterized by the rapid growth of high technologies, electronics, instrumentation, which have found their wide application in all sectors of our daily life. The use of such technologies in urban planning, including tourism, has led to the creation of “smart tourism”, which is a new approach.

At present, the modernization, informatization, and internationalization brings opportunities for the traditional tourism, at the same time “smart tourism” is developing [1]. “Smart tourism” satisfies the needs of tourists, allows tourists feel convenient, and leads to the modernization of tourist complexes [2]. Of course, the rapid development of science and technology, and the application of the Internet, take an important place in the development of tourism, including intellectual tourism.

Today tourism vigorously develops, but there are problems in this area. Therefore many scientists study the problems and engage solutions of these problems in tourism. On the other hand, the development problems of smart tourism are at the center of the attention of many scientific centers, and specialists. They have searched the ways of smart tourism development and have investigated innovation in tourism [3-7].

The authors of [3] show the importance of analyzing information from social networks to develop “smart tourism”. Their models could be used as input data for the creation of “smart urban tourism”.



The authors [4] conducted an analysis of urban attractiveness taking into account the residential population and demand of international tourism. They revealed a balance between environment, population, tourists, and visitor numbers. Although their study analyzes the development of tourism in complex with the city's attractions, but real data is not given.

The authors in the work [5] combine the information on initiatives and works from the documents of public tourism planning. They defined that a growing number of destinations require the generation of knowledge useful for managing of tourism. Although their research has practical significance, but it has no connection with the transformation and upgrading of tourism.

The main characteristics of smart tourism development were studied in the work [6]. It is possible to use these results in planning the further development of smart tourism and in the application of tourism innovation policies. These results have only certain reference value for the modernization of traditional tourism and the long-term and sustainable development of "smart tourism", but the authors have not widely analyzed the development of "smart tourism".

The paper [7] deeply analyzed the problems connected with the development of the tourism industry today and providing information technology for tourists during travel.

The purpose of our study is to study the literature on the topic of "smart tourism" and its applications in the planning of urban development of tourist complexes. In the work, the literature data was studied in detail, various definitions of "smart tourism" were identified, and the concept of "smart hotel" was considered. It is determined that in "smart tourism", which is assessed in the framework of information and communication technologies, the main place is occupied by mobile applications, smartphones social networks, the Internet, but no attention is paid to environmental issues.

We think that new advances in technology will change tourism planning and that this will subsequently help cities work towards implementing sustainable urban planning practices. Considering how destinations can be "smart" and jointly plan tourism?

"Smart City", "Smart Village" and "Smart Tourism"

"Smart city" is an urban planning concept for integrating a variety of information and communication technologies (ICT), including Internet of Things (IT) systems for managing urban infrastructure: transport, education, healthcare, housing and communal services, security, etc. The goal of creating a "smart city" is to improve the resident's life using urban informatics technology to improve service efficiency and meet the needs of residents (fig.1) [8].

ICT allows the city government to contact communities and the infrastructure of the city, monitor processes in the city, develop the city, and find ways can improve the quality of life. The use of sensors integrated in real time, the accumulated data from urban residents and devices is processed and analyzed. The collected information is the key to solving problems of inefficiency. It was used ICT to improve the quality, productivity, and interactivity of city services, consumption of resource consumption and reduce costs, and improve communication between city dwellers and the state. The application of smart city technology is being developed to improve the management of city flows and respond quickly to complex challenges. Therefore, a "smart city" is more prepared to solve problems than with a simple "operational" relationship with its citizens. However, the term itself remains obscure in its specificity, and hence is subject to many interpretations and discussions.

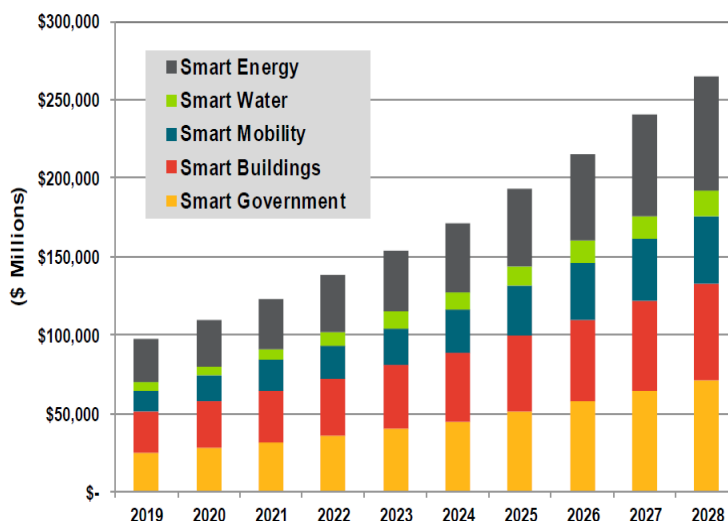


Figure1. “Smart City” evolution white paper [9]

The global smart cities market size consisted of 1,090.64 billion USD in 2021. It is expected to expand at a compound annual growth rate of 24.2% from 2022 to 2030 [10]. The major growth drivers are increasing urbanization, the need for efficient management of resource utilization, public safety concerns, and growing demand for an environment with efficient energy utilization (fig.2).



Figure 2. US smart cities market size, 2020-2030.

The market growth is explained by the increase in the use of nanotechnology, artificial intelligence, machine learning, cloud computing, intelligence of things, cognitive computing, big data analytics, and open data.

Technological innovations are on the ground of new approaches and innovative business models also in the tourism. The tourism industry, which has a great place in the development of countries,



is experiencing significant changes with the developing technology, like all other sectors. One of the latest concepts related to tourism brought with technological innovations and developments is the concept of "smart tourism". Unlike the "smart city", "smart tourism" focuses not only on the local people, but also on the tourist experiences, and the life of the local people, as well as the life of the tourists, their mobility, ease of access to resources, and sustainability, are also important. "Smart city" and "smart tourism" are two strictly connected concepts in the framework of technological component.

Smart cities have overlapping and interacting concerns, including tourism. The aspects shown in fig.1 are only an example of the many different aspects. For example, big data, artificial intelligence, and intellectual technology can be used to improve transportation efficiency, health services, sustainability, and tourist experience (fig.3) [11].

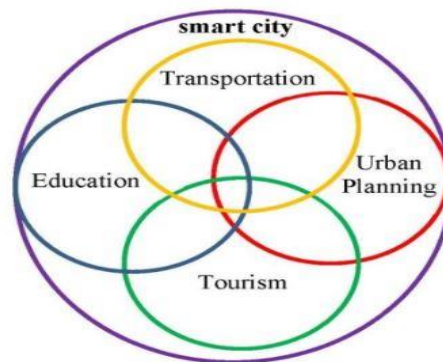


Figure 3. Aspects of the smart city that are relevant to tourism

We can understand it as clean, green, ethical and quality at all levels of the service. "Smart tourism" is tourism where technology is applied and preference is given to the number and maybe to the quality of apps available for the tourist use of the city. Today, "smart tourism" technologies are given priority as the tool in the tourism planning processes of destinations, projects for smart airports, smart hotels, and smart transportation systems are on the agenda and are being implemented. states that smart destinations as places and "smart tourism" are closely related concepts. Therefore, the "smart destination" has a meaning that includes regions with touristic attractions where smart tourism technologies are used effectively. It is seen that the "smart tourism destination" is considered as a concept that emerged together with the concepts of "smart tourism" and "smart city" in the related literature.

It is seen that the "smart tourism" has emerged as a new approach sensitive to technology, quality and environment and finally the widespread use of technology in the field of tourism.

Integrating smart technologies into tourism destinations is a process that requires takes place stakeholders in a technological platform that allows instant information sharing between people involved in tourism activities. This platform consists of tools that have multiple connection points, support and facilitate the creation of instant tourist experiences, and increase the tourism resources at the micro and macro level. The main motivation in the creation of "smart tourism destinations" is to make the most of technology to increase tourist experiences and resource management efficiency in order to maximize consumer satisfaction and destination competitiveness along with sustainability.

“Smart City” and “Smart Village” Concept in Azerbaijan

"Smart village" and "smart city" are areas where various electronic and digital methods and sensors are used to collect data. The information gained from the collected data is directed toward the efficient use of assets and resources. This concept includes the internet, artificial intelligence, blockchain, etc. technologies. Certain components are formed based on these technologies. For example, the electronification and collection of electricity and water consumption in specified places can be shown. The population can see their utility history and make payments using certain software.

The difference between the "smart city" from other cities is the electronification of the entire infrastructure and the creation of a large database. On the data set, the efficiency of spending and life of the population is increased throughout the city.

"Smart city" and "smart village" technologies have the power to improve the health and well-being of citizens while providing new ways for economic development. The application of cloud-based technologies in regenerating areas accelerates the recovery process of the region and makes the region interesting for techno-investors.

In addition, the relevant state institutions gain the opportunity to carry out optimization work based on the information gathered in the entire database. All these applications of electronification are also valid for the field of medicine and transport. In addition, it is possible to monitor pollution in the city area on an electronic map through wireless sensor networks for air monitoring in environmental protection.

On the "smart village" platform, it is possible to observe the implementation of sustainable development goals in remote areas through technology. Through this model, governments aim to increase the efficiency and safety of public services, reduce financial costs, and ensure transparency and good governance (fig.4).

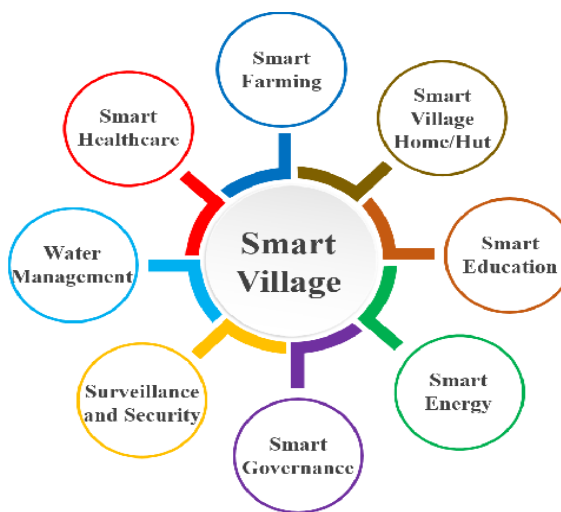


Figure 4. Proposed “Smart village” Model [12,13]

As we mentioned, "smart village" projects are implemented in different countries of the world. One of this project's main objectives is to prevent people's flow from rural to urban areas. The second goal of the "smart village" project is to create an opportunity for people to earn money in



the village. The third point is that rural residents should have access to public services, just like every citizen of the country.

The "Smart village" concept was realized with the support of "Vodafone" in Turkey, the "Village Kazakhstan" project in Kazakhstan, the "Smart Village" project in Rwanda, the "Autonomous Smart Village" project in Ukraine, and the "Smart Village" project in Germany have been implemented and the smart trade and logistics have been implemented in these places, smart energy methods are used.

The "smart city" and "smart village" projects are among the main priorities of sustainable development in increasing the quality, safety, and efficiency of services provided in the cities and villages of Azerbaijan, applying information technologies in their provision, as well as ensuring the effective use and management of existing resources for those services. With the implementation of this project in cities and villages of Karabakh region of Azerbaijan, freed from occupation, the foundation is created for the transition of the works to be provided there to the next stage of development.

The creation of "smart cities" in the modern world can also eliminate many problems caused by globalization and the 4th industrial revolution. Also, making cities more sustainable, inclusive, and safe is one of the Sustainable Development Goals of the United Nations.

The Smart City project launched in Azerbaijan in 2017. Azerbaijan has developed the Development Concept "Azerbaijan - 2020: a look into the future" and a strategic direction for the development of telecommunications and information technologies.

Thus, the "Public Wi-Fi" project already launched in the capital of Azerbaijan was the beginning stage of the implementation of the "smart city". In subsequent stages, such components as "smart transport", "smart port", "smart trade", etc. were implemented. "Smart cities" and green energy are the focus of the National Priorities of the Azerbaijan Republic.

In order, effectively use information technology and renewable energy potential the "State Program on the use of alternative and renewable energy sources, information technology in the Republic of Azerbaijan" was adopted in 2004. Concept №5 of the document "Azerbaijan 2030: National Priorities for Socio-Economic Development" (clean environment, "green growth" country and "smart village") approved by the Decree of the President of the Azerbaijan Republic dated February 2, 2021, in the direction of climate change and its fight against, the application of renewable energy in all sectors of the economy based on the principles of green energy space and smart city in the country is also reflected. The mentioned National Priorities are also of special importance in the realization of the commitments arising from the UN "Transformation of our World: Agenda for Sustainable Development until 2030."

The mentioned concept of "smart city", "smart village" and "green energy" will, first of all, respond to global challenges in the world. Especially, the Karabakh region has become a center of interest for technological investments, and it will also serve as an experiment for the application of smart urban-rural technologies in other regions of the republic, such as the Sheki Zagatala region. This region is a well-known region of Azerbaijan because of its tourism abilities [14-19]. Every year the number of tourists visiting the Sheki-Zagatala region of Azerbaijan is growing. This region is rich in ancient natural, historical, and cultural tourism potential. Various types of tourism are developing because of the expansion of the areas serving tourism in the region (accommodation, food, transport, excursions). Statistics and marketing research of recent years give grounds to assert that every year more foreign guests wish to spend their holidays in the Sheki-Zagatala region and get to know the region. The use of "smart city" and "green energy"

concepts in this region is considered very perspective and will lead to the development of tourism potential in this region.

In order to make the "smart city" concept a reality in the territories, it is necessary to study sustainable international practices first, apply and promote them at the next stage, and make extensive use of ICT.

By implementing "smart city" solutions, we can change the quality of life indicators such as health, safety, time, environmental quality, convenience, social connectivity, civic participation, jobs, and cost of living.

The information technology will allow to improve the distribution of energy in the region, facilitate the collection of waste, reduce traffic congestion, and improve air quality (fig.5). For example, the installation of smart bins that automatically send information to waste management companies and have a pre-planned schedule for removal when necessary can turn the region into a waste-free recycling center in Azerbaijan.

From the point of saving water resources that is important for the economy of the country as a whole, the smart city concept to be realized in the liberated territories will play a significant role in reducing water consumption. Such smart technologies as intelligent irrigation systems and water leakage, water quality and consumption monitoring can save between 25-80 liters of water consumption per person in a day.



Figure 5. Smart Village projects in Azerbaijan

Cloud technology applications can facilitate not only human lives but also territorial management. For better decision-making, increasing the quality of their work and life, local government structures, municipalities, private enterprises, and citizens may use these applications to receive, analyze, and manage information in a real-time manner.

As 5 cities applying smart-city solutions the most, Singapore, London, Amsterdam, Hong-Kong, and New York are also the world's main tourism centers. It means that smart city technologies may lead to new opportunities for developing tour

Conclusions

In order to realize "smart tourism" applications in a tourism destination, it is required to develop "smart city" infrastructure for that city first. It is a correct approach to evaluate "smart city" and "smart tourism" applications as integrated with each other, enhancing and enriching the life of the local people in that city, and enriching the experiences of those who temporarily visit that city,



supported by advanced internet technologies. It was considered “smart city” opportunities of Sheki Zagatala region of Azerbaijan.

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PROSPECTS FOR THE USE OF ACTIVE ASPIRATION ALARM SYSTEMS IN FIRE SAFETY SYSTEMS OF MANY-STOREYED HIGH BUILDINGS

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ABSTRACT

At present, multi-story high-rise buildings are becoming one of the most widely used buildings in cities. Now it is very difficult to imagine urban architecture without them. The increase in the urban population in cities is the result of an increase in the level of urbanization. As a result, the price of land increases due to the lack of free land in cities. Thus, the construction of multi-story buildings has become an inevitable solution to this issue, but this, in turn, has led to new problems.

Depending on the purpose, composition, and number of technical systems, multi-story buildings are complex engineering and technical objects. On the one hand, the use of engineering and technical systems leads to an increase in the standard of living of people living standards, but they are also the main causes of new problems. For example, high-rise buildings are quite large consumers of electrical energy, both as objects and as subjects of these buildings, and this, in turn, leads to an increase in the likelihood of a fire in them.

To prevent such undesirable cases, one has to use fire safety systems, one of the components of building automation. One of the main responsibilities of fire safety systems is to determine the initial stage of ignition and quickly detect its source, only, in this case, it can be eliminated or at least localized. The life and property of people can be protected.

The main purpose of this article is to consider the currently unused active aspiration system in multi-story high-rise buildings as an alternative to currently used systems to improve efficiency in terms of fire safety. The article includes the appointment of an active aspiration system, the principle of operation, and the main characteristics, and functions of those designed for early fire detection. In addition, several options and a comparative analysis of an active aspiration system are considered to create a highly efficient fire safety system for high-rise buildings.

Keywords: fire protection systems, smoke exhaust systems, fire protection sensors, aspirator alarm systems, automatic building systems.

INTRODUCTION

As it is known, many-storeyed high buildings are high-tech facilities consuming a lot of electricity. The use of various types of technological systems requiring large energy consumption in these buildings and the existence of human factor being specific for the consumers of this system lead to an increase in the risk of fire. Fire safety is an important field of activity for both fire fighting services and apartment owners. Uncontrolled fire is a process that leads to great consequences. Most of the fire incidents resulting in fatalities occur due to direct entry of combustion products into tracheas, that is, smoke is one of the main fire factors which concerns

the most hazardous factors. Another dangerous factor is the high temperature generated during the fire, which can seriously injure or even kill people as a result of high temperature effect. Besides, the generated high temperature can seriously damage the structural elements of buildings. As a result of failure of structural elements of buildings, complete or partial collapse of building elements results in mechanical damage to people, which in turn leads to fatalities [1].

In addition, the gas factor should not be omitted, as the presence of garage spaces in many-storeyed high buildings and the large indoor concentration of the two most common air pollutants such as CO and NO₂ during the operation of vehicles there are also a source of hazard to human life. Natural gas leaks inside apartments are also hazardous because they are a source of explosion [2].

Thus, from a technological point of view, the features of the use of complex systems and residential premises require a special approach to fire detection. Thus, in buildings where strong air currents are unavoidable, the efficiency of conventional fire detectors to detect smoke or heat radiation is very low or they are not effective at all under such conditions. In areas with air currents, smoke may not enter the chamber of ceiling-installed smoke sensors, or by the time smoke enters the chamber, the concentration of smoke in the room will have reached the maximum level, so that the spread of fire is already inevitable when the sensor is activated. Therefore, in our opinion, despite the fact that active aspirating fire alarm systems are not currently used in many-storeyed high buildings, their use will become inevitable in the near future [1,2].

Active aspirating systems are a complex of innovative devices that provide the early detection of fire. As a rule, they have a modular architecture, which enables the system to be adjusted to specific working conditions and building design [3]. The major components of such a system contain a pipeline for air intake from the monitored area and one or another sensor or sensors (Fig. 1) that can be placed anywhere inside or outside the protected area.



Figure 1: Aspiration system with two sensors

The system has a number of advantages, the most important of which is a wide range of sensor sensitivity to the changes in the environment [4]. In addition, sensors are able to record fire signs in facilities with any complexity.



Also, the system can be installed inside the ceilings, walls and interior parts of the apartment or house. As it is seen, the scope of wide use of the product is quite large.

Pastic PVC pipes are usually used as a pipeline. By means of various types of accessories, it is possible to develop flexible networks of pipelines for air intake by taking into account the properties of each individual area (residential and non-residential). Also, the aspiration sensor itself provides a vacuum in the pipeline to ensure continuous air inflow from the area under study through specially designed holes. These actively obtained air samples pass through a detection chamber where smoke particles are checked. Moreover, in some systems, dust and impurities are first removed from the air sample using an internal filter, and then the sample is fed to the chamber of the aspiration sensor. This prevents contamination of the optical surfaces of the chamber.

The air sample enters the calibrated chamber of the sensor, through which laser beam passes. When there are smoke particles in the air, light scattering is observed inside the chamber, which is immediately detected by highly sensitive receiver system. The signal is then processed and its state is displayed in various techniques (bar graph display, alarm threshold indicators and/or graphic display). Sensor sensitivity can be adjusted and airflow is continuously monitored to detect pipeline damage [5].

Aspiration sensors are conventionally divided into two categories. The first of these are PIB (Point in the box) type of sensors, which are used as detection chambers of conventional smoke sensors increasing sensitivity, for example, ASD-Pro or LASD by Sistem Sensor company with sensitivity of 0,03 to 3,33%/m. The second group is aspiration sensors by VESDA company, such as Icam or Titanus, which have their own internal smoke detection chambers with sensitivity range of 0,005-20%/m for VESDA, 0.001 to 20%/m and 0,05 for Icam. In Titanus it is up to 10%/m [6].

Applying active aspiration systems as a component of fire safety systems contributes significantly better results than conventional passive detectors. First of all, these are enterprises and companies where the continuity of production or working processes is of great importance, and interruptions are unacceptable. These are, for example, telecommunication systems and server rooms of financial institutions, utility facilities and medical sterile rooms (operating theatre), energy and transport systems. Aspiration systems are also useful when it is necessary to exclude the malfunction of the active fire extinguishing system, which leads to large time and money costs for the restoration of the facility. These systems have a wide range of usage opportunities and can be installed in the following facilities:

- Mines, power plants (increase in the air pollution level, existence of hazardous equipment);
- Elevators, communication lines (inaccessible places);
- Sports fields, warehouses (large facilities);
- Power plants, switches (a large number of electronic devices);
- School, cinema, market (places with many people);
- Airports, bus stations (transport systems);
- Plants, factories, enterprises (industrial facilities);
- Many-storeyed high residential buildings.

There is only one category of facilities where the installation of sensors is banned or not recommended, and they include areas containing large amounts of explosives [7].

Aspiration systems are preferred in rooms where smoke detection is challenging, such as high airflows or high atrium locations (shopping malls, gyms, theaters, museums, etc.). They are also applied in rooms where access for maintenance is impossible or difficult, however they are ideal for protecting suspended ceilings and high floors, hoistway, industrial areas, air ducts, as well as prisons and other places of detention. Another field of their application is in extreme environmental conditions: heavy dust, gas pollution, humidity, very high or very low temperatures (for example, in power plants, paper or furniture factories, car workshops, mines). And finally, aspiration systems are applied in case it is necessary to preserve the design of the room and hide the means of smoke detection [8].

Materials and methods

Aspirator smoke sensor is one of the tools that can be used to prevent fires. Its main functionality is to analyze residential and non-residential areas in terms of detecting fire signs. As soon as such a sign is detected, the fire alarm should be immediately delivered to the required place.

Air ducts 3 with a small number of 2 air intake holes is attached directly to the sensor unit 4. The distance between pipes is small. An electronic receiver is placed inside the device to check air samples 1 from the environment (Fig. 2).

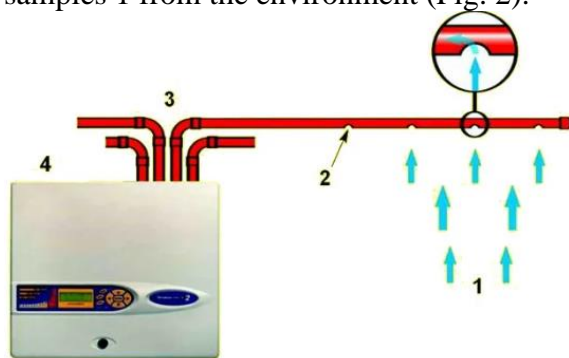


Figure 2: Aspirator smoke sensor

The size of air intake pipes directly depends on the area and volume of the area under study. Their length can range from a few centimeters to hundreds of meters.

Different types of materials can be used for the production of pipes. Their diameter usually does not exceed 10-25 mm. When selecting pipes, the properties of the facility they serve are taken into account. Heat-resistant metallic pipes are used for areas with high temperature environment. In cases where the facility has non-standard, multi-level ceilings, flexible and plastic pipes are used, which are cheaper than metal pipes, their installation works are very simple and they are resistant to bending.

The most common type of aspiration fire sensors are smoke devices. There are combination model types with several control types and they have different degrees of sensitivity.

Aspiration sensor has the following types:

- High precision type is for environment density lower than 0,035 dBm;
- The type with increased accuracy if for environment density starting from 0,035 dBm;
- Standard type is for environment density starting from 0,088 dBm.

When it is started, the device takes air samples from the environment. The conductance of this procedure is mandatory. The used fan allows constant flow of air to enter the system. Air enters the exhaust pipes of the aspiration system thanks to special holes in these pipes. After entering the system, the air is processed after passing through the air filter. Then, some fresh air is added to it. This procedure is carried out to prevent device calibration violation by the samples with ignition elements.

The aspiration fire alarm system is considered as more innovative direction of fire protection and this system has the following advantages:

- Devices use the principle of active detection as a working principle;
- Air testing is carried out in various sites;
- Ventilation and air conditioners do not interfere with the operation of devices;
- Aspiration does not depend on the structural stratification of the facility;
- Innovative smoke chamber immediately detects all changes in the environment;
- Devices can be used anywhere.

The main advantage of aspiration sensors is their practical use. They are ideal options for high ceilings. The following model classes can be selected on the basis of certain height criteria:

- Class A, for high ceilings;
- Class B, for medium ceilings;
- Class C, for standard ceilings.

The basis for this division is their efficiency, their performance indicators in specific conditions, and non-compliance with these recommendations reduces the efficiency of the sensors.

The length of the air intake pipes varies depending on the properties of the served buildings. Their sizes can vary from a few centimeters to hundreds of meters. They have holes through which air enters. As a rule, the interval between them is 9 meters, and the distance from the walls is 4,5 meters.

Pipes can be installed in various sites. In the case of areas without a ceiling, it is possible to use alternative installation options. Such an alternative option can be their installation in metal constructions. It is also possible to use structural gaps of the areas, provided that small holes are released for additional capillary tubes (Fig. 3).



Figure 3: Capillary tubes of aspiration pipeline systems.

The absence of bends in the pipeline will reduce the number of false alarms. This will also provide an opportunity to increase the area of the service zone. Another protective measure is that the pipes can be installed vertically in the walls, which is a positive case to analyze the fire area. These methods of installing pipes allow aspiration detectors to have many advantages that distinguish them from other methods of fire prevention.

When the trajectory of the pipe is required to be changed, it is necessary to follow bending radius of about 90 mm. Installing straight pipes is better because it does not obstruct the airway. The standard ratio is as follows: 2 meters of straight pipe is equal to one turning point.

If the facility has a high level of air pollution, supplementary filters are required to be installed in addition to the standard installation. They are supplementary elements of the pipe system. A system of returning air through pipe is applied for better performance and elimination of contamination.

As an additional measure, it is recommended to install a moisture collector device in areas where there is a possibility of temperature fluctuations resulting in condensation in the system.

Constructing an aspiration system in the protected areas is the most effective solution to protect these areas by taking air samples from closed apartments, corridors in common use, garage areas, cable shafts, etc. Pipes of the aspiration system are installed in the protected areas. The pipe system enables to take samples from the required sites using air aspirators and provides the most reliable smoke detection in building areas.

Active air absorption for the analysis of the composition of smoke particles and its subsequent analysis in the aspiration chamber allows to construct the system in such a way that the air currents in the studied areas cannot impact on the process of smoke detection.

The main task of the aspiration system is not only to determine the early detection of fires, but also it includes determination of the fire source. It is possible to protect large areas preserved by aspiration pipes through a sensor module.

Active aspiration systems can be installed in various configurations, but the basis of all of them will be air pipes. The differences will be determined by the structural features of the protected areas and the selected sensor module.

In one option of the process for determining the source of fire through an aspiration system, a procedure containing four phases is carried out:

- in phase 1 (common mode), the pipeline takes air samples for research from several protected areas where it is constructed;
- in phase 2 (early detection of fire), the analysis of the absorbed air is performed. In case of smoke detection, the alarm signal is immediately transmitted to the required location for early reaction;
- in phase 3 (reverse circulation), after receiving the alarm signal, the exhaust fan is turned off and venting fan is turned on and expels all the smoke particles in the pipe in the opposite direction.
- in phase 4 (source determination), the cleaning fan is stopped after cleaning the pipeline and the direction of air movement is changed again through the first fan. Based on the time when smoke particles reach the sensor module again, the system detects the fire source.

It should be noted that it is possible to construct the system using another method. For this, the corresponding valves monitored by the controller are attached to the pipes in each protected area. They are all initially attached in the open position and transfer the intake air mass to the sensor module. In case of smoke is detected, an alarm signal is transmitted immediately for early



reaction. The exhaust fan is then turned off and smoke particles in the pipe are returned by turning on the second fan. Then the second fan is turned off. After that, all the valves are closed, and then they are attached to the sensor module one by one, and through the first fan, they determine the source of the fire by studying the air in the areas.

The two options mentioned have common and different aspects. Despite the fact that the working principle of both options is identical, their work algorithms will certainly differ. Depending on the demand, one of these two methods or their combined options can be used in the fire safety system of many-storeyed high buildings.

Conclusions

After analyzing Active Aspiration Systems that can be used to ensure fire safety in many-storeyed high buildings, the following results were obtained:

1. The application of commonly used sensors, smoke, heat, flame sensors, is not effective, because the effectiveness of these types of sensors decrease in some types of fire, including in case of fires accompanied by incandescence, as well as in the presence of air currents in the protected facility during the fire spreading along the surface of the earth. In addition, they do not determine gas factors, i.e. natural gas leaks, air pollution by gas in the garage.
2. The use of Active Aspiration Systems is considered a very promising, innovative solution with wide range of possibilities. Their use has great advantages: the construction of the system is not so expensive, it allows to detect the fire incident at the first moment, and the exact determination of the area of fire and other hazardous sources. Eliminating the installation of a large number of sensors by applying one sensor module, simplicity of maintenance, etc., also concern these advantages.
3. The positive feature of Active Aspiration Systems is being capable to use one or more sensors of various purposes in the sensor module, as well as being able to use other types of universal sensors that work on other physical bases instead of these sensors.

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DEVELOPMENT, INSTRUMENTATION, AND ANALYSIS OF RECOIL THROUGH A RIFLESCOPE

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ABSTRACT

The research and development of new technologies to incorporate in the sport optics field have orientated the design, development, and construction of new riflescopes with state-of-the-art materials, processes, and technology. With each evolution, the riflescope should be evaluated to observe and acquire data on how the riflescope behaves during recoil. For this, the data acquisition and test setup should be easy to maintain, portable, and fast setup addition, measurements should be repeatable and low-cost. A literature review was conducted to check what has been done, what sensors and data acquisition controllers were used, the setup type, and the results. The sensor selection process required numerous specifications to filter the possible sensors for the ideal selection. The main factors and basis for the appointment were weight, G force, frequency, and price. The calculated theoretical max acceleration suffered by the rifle setup is 114g. The sensor also must be easily mounted/unmounted to/from the riflescope body. Furthermore, the sensor should be rigidly fixed not to suffer any unnecessary vibration from the interface and interfere with the measured data. Finally, the data acquisition should be accomplished relatively quickly to measure all the necessary data points. Sensors and accessories from various manufacturers were researched that fit the requirements. However, due to cost limitations, the selected sensor was the ADXL372. The testing setup includes a rifle and riflescope assembly on a stand. The sensor is guided and fixed on the riflescope, and a microcontroller reads and stores the acquired values. As a result, the testing setup is easy to transport and has a quick and repeatable structure. The measured acceleration values can calculate acceleration curves, displacement, velocity, and forces. The setup is ideal as it can be used to monitor the riflescope reaction on each test point, and results can have many uses, such as validating a numerical model FEA simulation. This paper will present and discuss the instrumentation and setup needed to read acceleration values on a riflescope from the firearm recoil and analyze the data for further use and interpretation.

Keywords: Rifle scope, Recoil, accelerometer, MEMS, ICP, Arduino, ADXL372.

Introduction

For any data acquisition application, it is critical to dimension the sensor and controller to the application correctly. Otherwise, the setup could be over-dimensioned, meaning it would be more expensive than necessary. Alternatively, it may be under-dimensioned, meaning that the setup will not be able to characterize the application correctly. It is essential to analyze the equipment

specifications used in other works for a similar application. A rough calculation may also help to define relative sensor working values.

Using kinematic equations with Newton's second and third laws, it is possible to give a rough estimate of the rifle recoil. For example, solving with projectile and rifle assembly parameters would give a rifle acceleration of $1,119.8 \text{ m/s}^2$ or 114.1 G .

Although more rifle and bullet variations need to be used in these calculations to verify if this value has drastic changes from one possible setup to another, it is a rough estimate and will be used for the sensor selection. For example, Mathilda Liennard et al. [1] measured a projectile's acceleration directly and performed a simulation of the same setup. This author concluded that the two curves matched quite well. Although in her findings, the projectile reached an acceleration of around $6.5 \times 10^4 \text{ G}$, this value is approximate to the calculated projectile acceleration value of $5.8 \times 10^5 \text{ m/s}^2$ or approximately $5.8 \times 10^4 \text{ G}$ used to calculate the rifle recoil.

Elizabeth Brueck [2] also performed various recoil measurements at the stock of a rifle to see if adding a moderator to the rifle would attenuate the felt recoil by the shooter. From this author's ten tests with different rifles and different ammunition, the highest read value was 760 m/s^2 or approximately 76 G .

B. Lonzi et al. [3] also measured a rifle's recoil using an accelerometer and a load cell. In the presented work, the maximum recoil force measured was 1241.3 N , i.e., well below our recoil force.

The sensors that make the most sense for the required measurements are accelerometers. The sensors must be lightweight and easily mounted/unmounted to/from the riflescope body. The sensors should be rigidly fixed not to suffer any unnecessary vibration from the interface and interfere with the measured data.

Finally, the data acquisition should be accomplished relatively quickly to measure all the necessary data points. According to other works, it should be at least 200 kHz . Also, from a theoretical max acceleration calculation, the required G value is around 114 Gs , which is almost double the value other researchers have obtained.

There are three different main types of accelerometers. These are piezoelectric, piezoresistive, and capacitive accelerometers.

Piezoelectric accelerometers use a quartz crystal or a lead zirconate titanate (PZT) to produce a small electrical charge proportional to the acceleration disturbance [4–6]. These are AC response accelerometers and can be of two types, charge output, and voltage output.

The charge output accelerometers generally require a charge amplifier and a low-noise shielded cable due to their high impedance characteristics. These sensors are considered the most durable due to their ability to tolerate aggressive environmental conditions when hermetically sealed in a welded metal housing. Such conditions include harsh temperatures from -200°C to $+640^\circ\text{C}$ [7].

Conversely, a voltage mode piezoelectric accelerometer includes an onboard charge amplifier to output the voltage. These are also known as ICP types from PCBPIEZOTRONICS. These accelerometers tend to be more sensitive to harsh environments due to their onboard amplifier and have a limited working range for the same reason [7-8].

Piezoresistive accelerometers are in a way similar to a stress gauges. The piezoresistive material changes its resistance when a force is applied. This change in resistance is then converted to an acceleration measurement [4], [9], the output of piezoresistive sensors tends to be sensitive to temperature changes. Therefore, most have an onboard ASIC chip for signal conditioning and temperature compensation. These are also either gas (MEMs) or fluid (strain gauge) damped to



prevent sensor resonance and improve dynamic range in high input frequencies. Some can handle frequencies up to 10,000 g making them well-suitable for impulse and impact measurements in automotive or weapons testing [7].

Capacitive accelerometers use MEMs or Micro-Electro-Mechanical systems to operate. MEMS accelerometers are known to be small, lightweight, and relatively cheap [5], [7], [10–12]. Alternatively, they tend to have a poor signal-to-noise ratio (SNR) and a reduced dynamic range. The maximum range is usually less than 200. These sensors contain an onboard amplifier and are relatively easy to interface with while requiring a stable DC power source [7]. Due to the many works involving MEMs accelerometers, these are the most mature among inertial MEMs [13].

Various manufacturers have been searched for sensors and accessories that fit the requirements, such as PCB Piezotronics [8], Kistler [14]–[16], and DEWESoft [17]. Unfortunately, such sensors, DAQ systems, and accessories do not qualify as a "low-cost system" the end cost would be in the several thousands of dollars range. For a low-cost budget, a MEMs accelerometer would have to be acquired.

As with any input or sensor device, noise is always an issue. Noise sources may include mechanical noise, thermal noise, amplifier noise, sensor-charging reference voltage noise, clock jitter noise, and quantization noise [18–19]. MEMs sensor manufacturers reduce unwanted noise is to add a low-pass or anti-aliasing filter before passing data through the ADC [19]. The ADC may be the most prominent noise contributor to the entire system if not correctly dimensioned by the manufacturer [20]. Leslie Pupo [21] suggests using the Allan Variance method for identifying and characterizing noise in inertial sensors.

Although, in general, low-noise accelerometers have integrated electronics to reduce the distance from the sensor to the amplifier, thus reducing the capacitance and eliminating the noise source [22].

There are numerous ways to reduce noise in accelerometer data. The most common ways include a low pass filter [23], averaging data, and sometimes oversampling and averaging [24]. In any case, it is essential to know how much noise a sensor has. Each sensor has a noise specification described in $\mu\text{g}/\sqrt{\text{Hz}}$ on its datasheet. This specification transforms the noise at a given frequency into g terms [25].

In addition, some datasheets have the noise value described in LSB or the least significant bits. These are the number of bits that may have noise, and when subtracted from the sensor's bit resolution, can be used to calculate the minimum detected acceleration (MDA) for the sensor, as shown in the equation 1 [26].

$$\text{MDA} = r/2N_e \quad (1)$$

where r is the total sensor measurement range, and N_e is the number of effective bits, or total bits minus LSB.

Methodology

There are numerous MEMs accelerometers manufacturers available on the market. But most source their ICs from Analog Devices. Table 1 shows a filtered selection of accelerometers available from Analog Devices and their biggest differentiators. The initial filter required that the accelerometers measure at least $\pm 200\text{g}$ and be triaxial. Triaxial accelerometers offer simultaneous

measurements in three orthogonal directions enabling the entire movement being suffered by a structure to be analyzed [8], [27].

All table values are for the IC itself except for the cost; this is in reference to the evaluation board.

Table 1. Accelerometer sensors available from Analog Devices.

Model	ADXL371 [28]	ADXL372 [29]	ADXL375 [30]
Type	Mems	Mems	Mems
# axis	3	3	3
G rating	±200	±200	±200
Weight [mg]	18	18	30
Dimensions [mm]	3 x 3.25	3 x 3.25	5x 3
ODR (Output data rate) [Hz]	320-5120	400-6400	0.1-3200
Resolution [Bits]	12	12	16
Noise [$\mu\text{g}/\sqrt{\text{Hz}}$]	6.5	4	5
Bandwidth [kHz]	3.2	3.2	1.6
Price [€]	30.72	33.51	38.52

All table values are for the IC itself except for the cost; this is in reference to the evaluation board. The chosen accelerometer was the ADXL372 due to its higher ODR to read more and higher frequencies. The ADXL372 also comes with an Arduino shield for easy setup and integration. Sample code has also been made available from Analog Devices. The Arduino Uno microcontroller was a good fit since it can communicate easily with the ADXL 372 accelerometer through SPI using the sample code. In addition, the processor was fast enough for the sensor's maximum data output, and gathering all the data through the serial port would be easy. The sensor has a calculated minimum detected acceleration of 1.1 g.

The sample code consists of many adjustable sensor parameters such as ODR, bandwidth, operating mode, wake-up rate, set activity and inactivity threshold and time, and FIFO operation. Initially, the Arduino was programmed to fetch the accelerometer values one by one and write them each time to the serial monitor. However, this proved insufficient due to the considerable time delay in reading and writing the data. The code was then adjusted to save all the values in local memory and dump all values to the serial monitor simultaneously. This change significantly improved the ODR to the desired values.

The Arduino Uno board could read up to 100 data points for each axis before filling the internal memory. Through trial and error, it was verified that the Arduino UNO's available memory was insufficient to gather all the required data. An upgrade to the Arduino Mega would be necessary.

The Arduino documentation indicates that the Slave Select (SS), also known as the Chip Select (CS), is different for the Arduino UNO and the Arduino MEGA. The CS pins for the Arduino UNO and Arduino MEGA are pins 10 and 53, respectively. Once the shield correctly worked with the Arduino Mega board, it was possible to print 450 data points for each axis.

For attaching the ADXL 372 to the riflescope, a support guide was manufactured and glued precisely onto the riflescope objective with epoxy. The support contains a hole and slot with tight tolerances to position the accelerometer and two screw holes to hold it. So, a couple of calibrated pins were secured to the PCB with epoxy to precise position the accelerometer sensor. This setup

facilitates mounting and systematically unmounting the sensor when needed. This setup also allows for more support structures on different riflescope areas and precisely moves the sensor from one support to another and back again to gather more data.

The ADXL372 evaluation board is meant to be placed directly on the Arduino shield. Therefore, extension wires were connected to the shield and board headers to minimize the weight of the whole assembly on the riflescope. The extension wires and assembly are pictured in Figure 1.



Figure 1. ADXL372 assembled on the riflescope

A more precise image of the sensor assembly and orientation is represented in Figure 2.

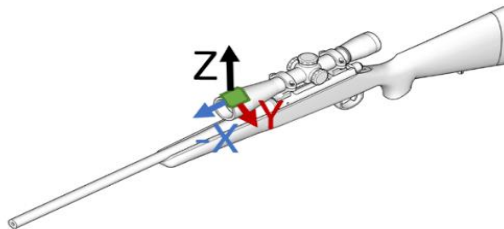


Figure 2. ADXL 372 position and orientation

Results

While reading the sensor data, the ADXL372 post processes the acquired data with a low pass filter to enforce the Nyquist law. The following images will show the acquired accelerometer data over the three axes processed through a low pass filter.

Figure 3 below shows the accelerometer data for the x-axis. It is noticeable that the acquired data contains high frequencies by not having any data points between the peak and the consecutive data point being the local low, as shown in Figure 3.

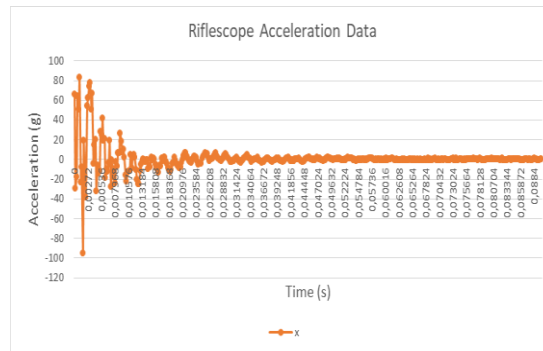


Figure 3. Riflescope acceleration x-axis

Figure 4 shows the y-axis acceleration data similar in behavior to the x-axis data above.

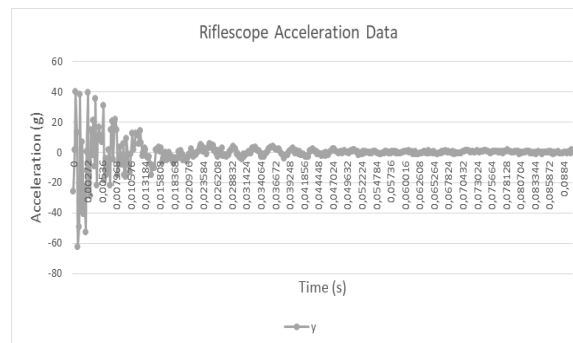


Figure 4. Riflescope acceleration y-axis

Figure 5 shows the z-axis accelerometer data. Contrary to what was measured for the x and y axes, the z-axis acceleration data clearly shows a well-defined sinusoidal wave attenuating over time and converging to zero. In addition, each half wave is distinctly defined by multiple points, indicating a lower frequency vibration.

Figure 6 shows the velocity magnitude calculated by integrating the accelerometer data for the three axes.

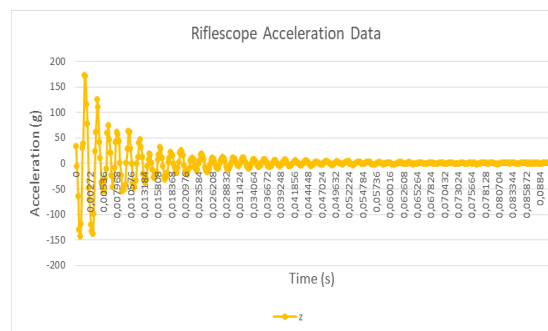


Figure 5. Riflescope acceleration z-axis

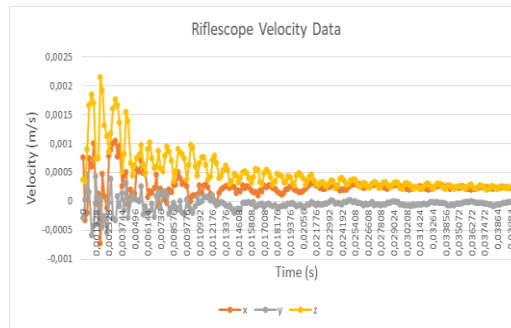


Figure 6. Riflescope velocity

Figure 7 shows the displacement calculated from double integrating the accelerometer data for the three axes.

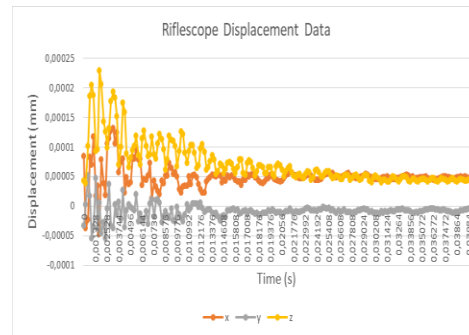


Figure 7: Riflescope displacement

Figure 8 shows the calculated three-axis displacement in 3D space. The color-code scale is defined as time in seconds, which makes interpreting the data more accessible. This graph represents the riflescope movement in 3d space and shows how it not only vibrates but also shifts locations from the start time (blue) to the end time (red).

Figures 9, 10 and 11 show the calculated FFT data for the x, y, and z axes, respectively. The FFT was calculated in excel using 2^5 data points.

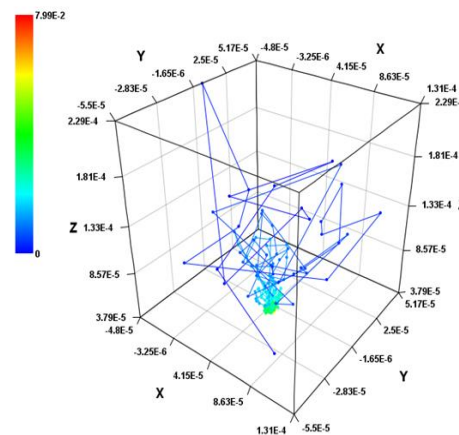


Figure 8: Riflescope 3D displacement

Figure 9 shows dominant data frequencies at 60Hz, 400 Hz, and 500 Hz on the x-axis. Other higher frequencies are also present in the data, with about half the magnitude of the dominant frequencies. Having such higher frequencies closer to the Nyquist limit implies having jagged or sharp data curves making the data difficult to analyze and interpret.

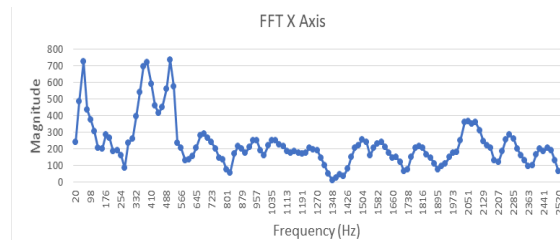


Figure 9: FFT on the x-axis

Figure 10 shows dominant data frequencies at 260Hz, 1400 Hz, and 2200 Hz in the y-axis. Here the higher frequencies closer to the Nyquist limit are also more dominant and have similar magnitudes to the harmonic frequency. Similarly to the x-axis and even more exaggerated, these frequency magnitudes imply having jagged or sharp data curves making the data difficult to analyze and interpret.

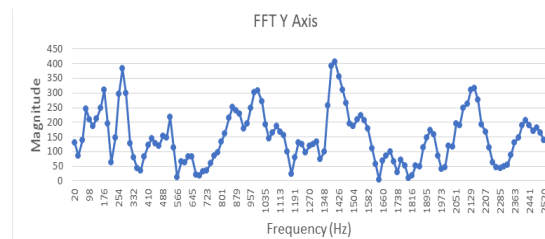


Figure 10: FFT on the y axis

Figure 11 shows a harmonic frequency at around 500 Hz on the z-axis. Few higher frequencies are present in the data with relevant magnitudes to the harmonic frequency. This harmonic is most relevant when interpreting the post-processed acceleration data in the z-axis. The acceleration data curves are well-defined by multiple points and can be directly used to compare and validate analytical data.

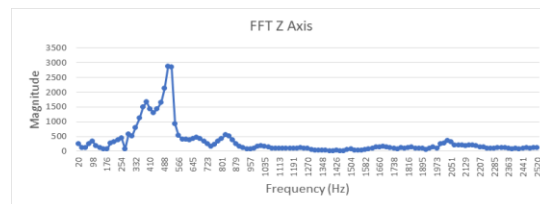


Figure 11: FFT on the z axis

Conclusions

Experimental data is crucial to characterize the riflescope movement during a shot. Therefore, various accelerometers were researched and compared between working principles, specifications, and prices. Based on the selection criteria, the ADXL372 was selected. The shield was connected to the Arduino Mega due to its higher internal memory to save all the necessary data points.

The sensor must be mounted onto the riflescope without interfering too much with the function and recoil wave propagation. Therefore, a 3D support was manufactured, and epoxy was glued onto the riflescope objective using an alignment tool. The support will systematically align the ADXL 372 sensor using two tightly tolerance pins. Thus, making it ideal for easy assembly and testing.

Considering that the acquired accelerometer data has a low pass filter to enforce the Nyquist law, the accelerometer data showed that the maximum recoil on the z-axis is close to the sensor's specified measuring range. The x and y axis are below even the 100 g mark. Also, the z-axis seems to form a clean curve. A periodic sinusoid with multiple data points defining each half sinusoid is depicted in the data. On the other hand, the x and y axis do seem to jump between extremes. One way to make the data more consistent would be to have a low pass filter at 1000 Hz to have multiple data points describing each sinusoid leg.

The acceleration data was once integrated to generate a velocity graph and twice integrated for the displacement graph. Observing the graphs, the z and x axes had a larger movement than the y axes. Also, from the x and z axes dataset, there was vibration and displacement. In other words, there was movement in the x and z axis that once the riflescope came to rest, the accelerometer was no longer at the origin.

The accelerometer data was also used in an FFT analysis. This analysis helped to discover the more dominant frequencies in the dataset and to justify why the acceleration in the z axis is of higher magnitude but more periodic than the x and y axes. The z-axis has a dominant frequency at around 500 Hz, meaning that the sensor picked up on slower-moving frequencies that, in turn, have larger amplitudes. In contrast, the x and y axes have harmonic frequencies present over the entire range meaning more fast-moving waves with smaller amplitudes.

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COMFORT ANALYSIS COMPARISON BETWEEN ALFAPENDULAR AND INTERCITY PORTUGUESE TRAINS AT THE NORTH RAIL

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ABSTRACT

Nowadays, trains are one of the most used public transportation modes. Comfort is the key to keeping and attracting new users. Vibration highly influences comfort levels and, once it is derived from the train motion it is stated as a primary concern. Due to contact with the seat and floor, passengers are subjected to whole-body vibration. ISO 2631 standard is fully dedicated to the evaluation of this type of vibration. Following its approach, the present research evaluates the comfort levels of Alfapendular and Intercity trains operating in Portugal at the Porto Campanhã – Lisbon Oriente connection. Measurements were performed at the beginning, middle, and end of the train, allowing a comparison between seat types within the same train and the same types from different trains. Results showed higher comfort levels for the Alfapendular trains, while for the Intercity train, both middle and end of train locations were ranked as “Little uncomfortable”. As a complementary analysis, it was observed the vibration transmission of the seat based on the Seat Effective Amplitude Transmissibility (SEAT). Results were above 100%, showing vibration amplification by all tested seats. Higher SEAT values were found for the Intercity train seat. This was the first study conducted on Portuguese trains regarding comfort analysis and vibration transmission.

Keywords: Railways, Whole-body vibration, Vibration transmission, SEAT.

Introduction

Trains are becoming competitive transportation over air travel. Its low environmental impact and high transportation capacity took governments to incite its use for connecting distances up to 850 km [1]. Comfort, safety, and user conditions are the key to keeping customers satisfied and attracting new ones. These parameters are influenced by vibration. Once it is derived from the train motion, passengers are subjected to it throughout the entire journey especially due to the contact with the floor and the seat. Vibration types are characterized depending on the transmission path as whole-body vibration (WBV) or hand-arm vibration. If the vibration transmission into the body occurs through a supporting surface, then it is classified as WBV. In opposition, hand-arm vibration is defined by a localized transmission to the hands and arms. Once vibration transmission happens mostly due to the contact of the user with the floor, seat surface, and seatback, this is classified as WBV. This type of vibration can cause discomfort, fatigue, and, in some extreme cases diseases. The human body possesses its natural vibration mode; when these modes coincide with an externally induced vibration, resonance may occur, which, if absorbed, can lead to tissue and organs' physical stress. This way, studying the vibration



transmission in a rail environment is crucial not only to quantify the passenger's comfort levels but also to assess the harmful consequences of vibration on users. ISO 2631 standard is fully dedicated to the WBV evaluation related to comfort, health, and motion sickness, and, thus, its methodology will be followed in the present study [2–9].

A seat can also mitigate or amplify the vibration transmission and, this way, decrease or increase discomfort caused by vibration. Seat Effective Amplitude Transmissibility (SEAT) is a method dedicated to evaluating this dynamic discomfort caused by vertical vibration. Therefore, this method will be used as a complement vibration analysis to ISO 2631 [10].

The objectives of this study are (1) to evaluate the vibration discomfort levels, concerning the comfort approach, on the Alfapendular and Intercity trains on the same track, (2) to evaluate the vibration transmission on different seat types (comfort and standard classes) within the same train and (3) compare the WBV levels on the same trains as (1).

Materials and Methods

The present study was conducted on 2 different types of trains, the Alfapendular tilting train, and the Intercity train. Both trains were running at the North line connecting Porto Campanhã and Lisbon Oriente train stations. Vibration measurements were executed at 3 different train locations (beginning, middle, and end) within 3 different measurement places (floor, seat surface, and seatback) following the ISO 2631 standard specification.

ISO 2631

ISO 2631 is a standard specially designed to quantify WBV about comfort, human health, and motion sickness. Concerning motion sickness, it is defined as an interest in the frequencies comprehended within the range of 0.1 – 0.5 Hz. Once comfort and health are related in many ways, the analysis should consider the frequencies between 0.5 – 80 Hz as the interesting ones. At this specific range, vibration affects the body as a whole, causing WBV which can lead to discomfort and fatigue.

Measurements should take place at the interface surfaces between the user and the vibration source, particularly the floor, seat surface, and seatback. The method consists of taking 3-axial acceleration measurements and calculating the root mean square (RMS) acceleration for each axis. Since the human body has its natural vibration mode, vibrations with identical intensities but different spectral content will induce different dynamic responses, thus, this effect needs to be quantified. To do it, the standard stated the application of weighting curves, that, depending on the impact of the RMS acceleration assign different weights to it. Depending on the measurement place and purpose different weighting curves are applied [9, 11]. The weighting process is calculated according to Equation (1)

$$a_w = [\sum (W_i a_i)^2]^{1/2}, \quad (1)$$

where W_i represents the weighting frequencies and a_i the RMS accelerations.

The measurement position defines the application of multiplying factors, k . Weighting curves and multiplying factors concerning comfort analysis can be found in table 1.

Table 1. Frequency weighting curves and multiplying factors defined by ISO 2631 for comfort analysis of a seated passenger.

	X - axis	Y - axis	Z - axis
Floor	Wk and kx = 0.25	Wk and ky = 0.25	Wk and kz = 0.40
Seat surface	Wd and kx = 1.0	Wd and ky = 1.0	Wk and kz = 1.0
Seatback	Wc and kx = 0.80	Wd and ky = 0.50	Wd and kz = 0.40

Lastly, the total vibration (a_v) is obtained following the Equation (2)

$$a_v = (k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2)^{1/2}, \quad (2)$$

where a_w are the RMS accelerations for each axis. The comfort level is evaluated based on a defined scale, table 2.

ISO 2631 also suggests the use of the Vibration Dose Value (VDV), calculated as follows at Equation (3)

$$VDV = \left[\int_{t_1}^{t_2} [a_w(t)]^4 dt \right]^{1/4} \quad (3)$$

This parameter uses the fourth power of acceleration instead of the second power, this way it is used when the goal is to emphasize acceleration peaks [11].

Table 2. ISO 2631 comfort evaluation scale. Adapted from [11]

$a_v (m/s^2)$	Ride comfort
≤ 0.315	Not uncomfortable
0.5 – 0.63	Little uncomfortable
0.63 – 0.8	Little uncomfortable to fairly uncomfortable
0.8 – 1.0	Fairly uncomfortable to uncomfortable
1.0 – 1.25	Uncomfortable
1.25 – 1.6	Uncomfortable to very uncomfortable
1.6 – 2.0	Very uncomfortable
2.0 – 2.5	Very uncomfortable to extremely uncomfortable
≥ 2.5	Extremely uncomfortable

SEAT

SEAT value is a complementary method to evaluate comfort that shows the extent to which a seat is increasing or decreasing vibration transmission; thus, this is an indicator of seat isolation efficiency. To do it, the SEAT compares the vibration discomfort when sitting on a rigid seat to the discomfort feeling on a non-rigid seat [10]. Thus, the SEAT is calculated as the ratio between the VDV measured on the seat and the VDV measured on a rigid support beneath the seat surface, Equation 4

$$SEAT \% = \frac{VDV_{seat}}{VDV_{floor}} \times 100. \quad (4)$$

If the SEAT result is equal to 100% the seat does not influence the vibration transmission. In opposition, if this value is higher than 100% the seat is amplifying the vibration transmission and,

thus, the seat is increasing discomfort levels, on the other side, for SEAT values lower than 100% the seat is mitigating the vibration transmission to the passenger.

SEAT can also be calculated with the a_{RMS} , however, once the considered journeys are long and the VDV calculation takes more into consideration the acceleration peaks than the RMS acceleration, it was decided to use the VDV to perform the SEAT calculations.

Concerning the rail environment, the vertical SEAT is expected to be greater than 100% because seat foams cannot mitigate the low frequencies vibration dominant in the vertical direction [12].

Alfapendular train

The Alfapendular (AP) tilting train of the 4000 series, was introduced in 1999 in Portugal and it was renovated in 2017. This electric train has a total length of 159m, is operated as a single unit, and is a train with an active tilting system consisting of 6 cars, where four are engines and two are trailers. The cars are classified based on two classes and bar facilities; the 1st and 2nd cars are designated as comfort class, figure 1a, on the 3rd car is placed the bar and, the 4th, 5th, and 6th cars are categorized as the standard class, figure 1b. Following the train motion, the 1st car corresponds to the begging of the train while the 6th car, located at the opposite end, matches the end of the train [13].



Figure 1: a) Comfort class seat; b) Standard class seat

As noted in figure 1, the seats from the comfort and standard class are different, being the seat of the former larger and with higher foam thickness.

Intercity train

Intercity (IC) train service, introduced in 1980 in Portugal, is currently run by 5600 series locomotives with Corail coaches which, were renovated in 2002. The electric locomotive trails 5 coaches, the 1st and 2nd representing the comfort class and the bar, and the 3rd, 4th, and 5th classified as a standard class. As on the Alfapendular train, according to the train motion, the 1st car corresponds to the start of the train and, consequently, the 6th car, placed at the opposite extremity, means the end of the train [14].

Corail coaches are characterized by having 2 seats per row. However, for the comfort class, besides matching this parameter the seats are arranged individually and, thus, the seat support frame is not shared by 2 seats. In opposition, the touristic seat frame is shared by 2 seats,

representing a more similar structure to Alfapendular seats. Depending on the class, the seats show different dimensions and foam thicknesses. Figure 2 illustrates the seats from both classes.



Figure 2: Intercity train seats: a) Comfort class; b) Standard class

Procedures and equipment

The experimental procedure consisted in taking 15 full journeys for the trains (9 for the Alfapendular and 6 for the Intercity train). Measurements occurred at the beginning of the train (1st coach), middle of the train (4th car for the Alfapendular train and 3rd coach for the Intercity), and end of the train (last car).

Table 3. Experimental testes results.

Results for the beginning of the train								
Measurement position	$a_{RMS} (m/s^2)$		$a_v (m/s^2)$		$VDV_z (m/s^{1.75})$		SEAT %	
	IC	AP	IC	AP	IC	AP	IC	AP
Floor	0.19	0.18	0.06	0.06	3.49	3.50		
Seat Surface	0.27	0.27	0.27	0.27	4.47	4.08	128.19	116.41
Seatback	0.26	0.26	0.18	0.17	3.85	3.85		
Results for the middle of the train								
Floor	0.21	0.15	0.07	0.05	3.87	3.43		
Seat Surface	0.34	0.26	0.34	0.26	5.65	4.30	145.96	125.25
Seatback	0.28	0.25	0.19	0.16	4.04	4.03		
Results for the end of the train								
Floor	0.18	0.17	0.06	0.06	3.50	3.47		
Seat Surface	0.34	0.28	0.34	0.28	5.55	4.40	158.54	126.81
Seatback	0.27	0.25	0.18	0.16	4.12	4.06		
Results for the beginning of the train								
Measurement position	$a_{RMS} (m/s^2)$		$a_v (m/s^2)$		$VDV_z (m/s^{1.75})$		SEAT %	
	IC	AP	IC	AP	IC	AP	IC	AP
Floor	0.19	0.18	0.06	0.06	3.49	3.50	128.19	116.41

Seat Surface	0.27	0.27	0.27	0.27	4.47	4.08		
Seatback	0.26	0.26	0.18	0.17	3.85	3.85		
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Seat Surface	0.34	0.26	0.34	0.26	5.65	4.30	145.96	125.25
Seatback	0.28	0.25	0.19	0.16	4.04	4.03		
Results for the end of the train								
Floor	0.18	0.17	0.06	0.06	3.50	3.47		
Seat Surface	0.34	0.28	0.34	0.28	5.55	4.40	158.54	126.81
Seatback	0.27	0.25	0.18	0.16	4.12	4.06		

For each location, following ISO 2631 standard, 3 measurement places were considered, namely the floor, seat surface, and seat back. Vibration measurements were realized using 3-axial accelerometers (PCE-VDL-24I $\pm 16g$) fixed into a disc format, flexible, silicone seat pad attached to the vibration transmission source [15].

Matlab scripts, following ISO 2631 guidelines, were developed, and validated, in order to calculate the RMS acceleration, total acceleration, VDV and SEAT %.

The track presents a total length of 275 km, divided into 5 stations and 2h50m to complete for the Alapendular journey and 12 stops and 3h15m to complete for the Intercity trip. It should be noted that a maximum velocity of 220km/h is achieved by the Alapendular train, while the Intercity achieves a lower maximum speed, around 200km/h. The journeys run under regular operation conditions and passenger transportation [13, 14].

Results

Following ISO 2631 the a_{RMS} , a_v , and VDVZ were calculated, additionally, the SEAT % was obtained based on VDV values. This way, the journeys were ranked according to their ride comfort and complementary with the seat vibration transmission. The results concerning the full experimental campaign can be observed in table 3.

The AP trips were all ranked as “Not uncomfortable”. However, for the IC train, only the journey at the beginning of the train (comfort class) presented this rank. For the middle and end of the train journeys, the ride comfort was classified as “Little uncomfortable”. Regarding SEAT %, the results also found the same trend, as the ones for the AP were lower than the ones for the IC train. This parameter was expected once the seats from the AP train are newer than the IC seats.

Furthermore, concerning the middle and end of the train measurements for the AP train, similar results were obtained for the ISO 2631 and SEAT % analysis. The same did not occur for the IC trains, besides the ride comfort values were similar, the SEAT values increased by 12.58% in the last car.

As anticipated, the SEAT values are higher than 100% for all journeys on both types of trains.

Discussion

To the authors' knowledge, this is the first test conducted in Portuguese trains during regular service conditions, examining the WBV parameters and vibration transmission.

Concerning the beginning of the train, results were equal or quite similar (0.01 m/s² difference) for AP and IC on both RMS and total acceleration. It should be highlighted that the highest total

acceleration value (0.27 m/s^2) was found for both trains on the seat surface measuring location, still 14.3% under the reference value for the “Not uncomfortable” level. SEAT results show an approximately 12% higher value for the IC train (128.19%) than the one for the AP (116.41%). These results are justified based on the higher VDV value presented by the IC seat surface, which traduces its increased susceptibility to transmit and amplify vertical vibration when compared with the AP. As expected, the SEAT values are above 100%, which complies with findings from Gong and Griffin [12].

While seats for the begging of the train are classified as comfort seats, the seats from the middle and end train measurement locations are touristic seats. As evidenced in sections 2.3 and 2.4, this type of seat presents different dimensions and characteristics, so it is expected that this seat does not perform dynamically as well as the comfort ones but present similar results for both locations. Relatively to the middle of train results, in opposition to what was expected, the AP results for a_{RMS} and a_v decreased when compared with the comfort class, keeping the “Not uncomfortable” level. However, the same did not occur for the IC results as this increased and, the seat surface achieved the “Little uncomfortable” rank. As the seat structure (and dimensions) are different from the first class, dynamic comfort is expected to be different. This is evidenced by the VDV value, which increases at the seat surface and, consequently, leads to an increase of the SEAT in relation to the comfort seats.

For the last car of the train, measurements show similar RMS and total acceleration results with the ones for the middle of the train for both AP and IC trains. It was observed that the worst a_{RMS} result (0.21 m/s^2) for the IC train on the floor measurements was 155% lower than the one presented by Indian IC trains, which is also an indicator of the comfort at the Portuguese IC train [16]. Regarding the AP train, comparing the a_v values found for the seat and backrest with those obtained, in the same locations, in Chinese high-speed trains (0.12 m/s^2), the Portuguese trains show 116.67% more total acceleration in the seat and, 33% more in the backrest [17]. However, it should be pointed out that AP passengers do not experience discomfort in any carriage and, all journeys are ranked as “Not uncomfortable”. Regarding the VDV and SEAT for the AP train, these remained close to the values of the middle carriage. Since the seats in these locations are equal, these would be the expected results as equal seats should present the same dynamic comfort. The same did not happen for the IC train where, despite the seats being the same as in the previous location, the VDV values increased and consequently the SEAT increased by 12.58%. Thus, this proved to be the worst location to travel and the most susceptible to acceleration peaks and vibration transmission/amplification.

Conclusion

Multiple interactions between rails, wheels, acceleration, braking, and seats made the vibrating environment of trains very complex. Due to the contact with the seat and floor, vibration is transmitted to the passengers. This can affect not only the ride comfort by also the dynamic seat comfort. To evaluate these parameters, ISO 2631 and the SEAT method were applied to AP and IC Portuguese trains on the Porto Campanhã – Lisbon Oriente connection.

Measurements took place at the beginning, middle, and end of the trains. Results demonstrated the comfort presented in all trains and locations. Different seat types were also evaluated and, as expected, the comfort class seats performed better relative to the dynamic comfort. For the IC train, the worst travelling location was obtained at the end of the train. However, for the AP train, the middle and end of the train presented similar results.

This is a pioneer study in Portugal, once, to the authors' knowledge, it is the first study to evaluate passengers' ride and dynamic comfort. The present results can provide precious feedback for the operator to improve the passenger's comfort.

Finally, the present study concluded that the passengers of the Alfapendular and Intercity trains are travelling in a comfortable situation considering vibration, with some space for improvements in dynamic comfort, regarding the Porto Campanhã – Lisbon Oriente connection.

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HAND EXOSKELETON FOR REHABILITATION AND FUNCTIONALIZATION

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ABSTRACT

Many diseases and injuries of the hand require rehabilitation to restore function. However, the high human, financial, spatial, and temporal costs associated with rehabilitation often mean that the population in need does not have access to optimal rehabilitative care. Therefore, devices that complement the therapist are a possible solution, as they make rehabilitation more independent and frequent, and save healthcare facilities the aforementioned resources. Nevertheless, these devices are not widely distributed in the market, mainly due to their poor accessibility. The newly designed exoskeleton has four motors and a redundant transmission system that allows independent flexion and extension of each finger, except the thumb. Kinematics were analyzed with motion studies and loads were evaluated with static studies and structural analysis using motion loads. In the simulations, both flexion and extension were achieved in four seconds. A prototype transmission system was built and its kinematics matched that of the simulation and corresponded to the biomechanics of the fingers. At maximum flexion, the exoskeleton would be able to hold small objects and exert a normal force of up to 20 N with structural integrity.

Keywords: Engineering design, exoskeleton, hand rehabilitation, hand functionalization.

Introduction

The hand played a prominent role in human evolution. Through anatomical changes, the main function of the hand shifted from locomotion to object handling, communication, and sociocultural interactions. Most of our daily activities depend on the hand, which means that quality of life declines when this complex and versatile organ is impaired.

According to the American Society of Plastic Surgeons, hand surgery was among the top five reconstructive procedures performed in 2020 [1], and this number is predicted to increase in the future [2]. It could be concluded that the need for hand rehabilitation after surgery will follow this trend. In addition, other conditions such as strokes and spinal cord injuries further increase the need for rehabilitation and functionalization of the hand.

Hand exoskeletons offer rehabilitation that focuses on repeatability and automation, allowing data collection and gamification, among others. This saves healthcare resources while improving patient management and monitoring, which is critical given the increasing pressure on healthcare facilities and professionals [3]. The use of exoskeletons provides the potential for independent and remote rehabilitation where patients are only monitored by healthcare professionals. The same caregiver could monitor multiple patients simultaneously or prescribe a plan with a series of programmed movements.

Although research on hand exoskeletons continues to advance, few are marketed, and even these are intended for use in clinical settings [4] and are prohibitively expensive for most people. On

this basis, the need for wearable exoskeletons at moderate prices and that allow independent rehabilitation becomes apparent.

Biomechanical overview

The hand and wrist consist of the radius and ulna, eight carpals (divided into two rows), five metacarpals, and 14 phalanges (three in each finger, except the thumb with only two).

The muscles of the hand are divided into extrinsic and intrinsic. The former are located outside the hand and insert into it, while the latter are located inside the hand. This division places the contractile part of some muscles, which have a greater volume, outside the hand, allowing finer movements. Both muscle groups together are responsible for actuating all degrees of freedom of the hand. The most important movements of the hand and wrist are [5]:

- supination, pronation, abduction, adduction, flexion, and extension of the wrist;
- flexion, extension, abduction, adduction, opposition, and reposition of the thumb;
- flexion, extension, abduction, and adduction of the index, middle, ring, and little fingers;
- minor movements of the carpometacarpal and intermetacarpal joints.

Hand Exoskeleton Modules

Hand exoskeletons can be divided into several modules. Following Bos et al. (2016) [4], the modules actuation, motion transmission, and control have been defined.

Most exoskeletons use electric motors, such as linear actuators and servo motors. However, other options are less commonly used: pneumatic (pneumatic muscles or pistons) and hydraulic actuators, shape memory alloys, active polymers, body-driven actuation, and others [4,6].

Motion can be transmitted directly through the actuators (e.g., pneumatic muscles), through tendon-like systems (e.g., with cables), and through rigid mechanisms (matched-axis, remote centers of rotation, redundant linkage, and base-to-distal). This module is often used as a strategy for underactuation, reducing overall cost, volume, and weight. The rigid mechanisms provide better trajectory control and lower variability but are usually larger than non-rigid transmission [4,7].

Finally, as far as finger control is concerned, it can range from fully passive (the movement is performed entirely by the exoskeleton) to fully active (the movement is performed exclusively by the user, but the exoskeleton defines the trajectory and has mainly a monitoring function). The trigger for the movements can be done in many ways, highlighting EMG and EEG in more complex systems or buttons and pre-programmed movement plans in simpler systems [8].

Exoskeleton Design

Initially, a hand model was developed based on average male measurements from an anthropometric study of 2307 US Army personnel [9].

Although the kinematics of the model are much simpler than those of a real hand, the model provides a basis for testing the exoskeleton and for articulating the degrees of freedom of flexion and extension of each of the phalangeal joints.

The next step was to design the attachments to the fingers and dorsal region (Figure 1). These elements can be 3D printed and attached to the hand with hook and loop straps, resulting in low overall production costs.

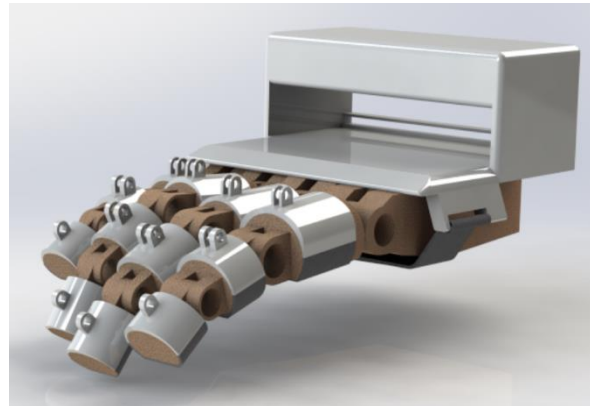


Figure 1. 3D model of the hand, the supports, and the straps

The motion transmission was achieved using a newly developed redundant bar linkage (Figure 2). This type of linkage offers a certain degree of adaptability to different hand sizes and still manages not to lose much control over the trajectory. The linkage has ambiguous degrees of freedom that are limited when the exoskeleton is attached to the hand, matching the user's natural finger movement. Because the relative proportion of each hand varies significantly less than the absolute proportions, the linkage of each finger was personalized, optimizing the adaptability of the transmission system.

The linkage consists of six bars, with the most proximal bar being a rack that slides on a rail and is also part of the actuation module.

Similar to the attachments, the bars could also be 3D printed. However, the connections of the bars could be made of rivets or strap screws, as these are a cost-effective and resistant solution.



Figure 2. Bar linkage of the transmission module

In terms of adaptability, it is also necessary to adjust the linkage laterally and match it to the central axis of the fingers. Mismatching the transmission module with the fingers would cause deviations from the natural flexion and extension biomechanics and possibly cause discomfort or injury. For this purpose, an adjustable support with a rail (Figure 3) was developed for the rack. The support slides laterally and can be easily fixed and unfixed by tightening and loosening a nut.

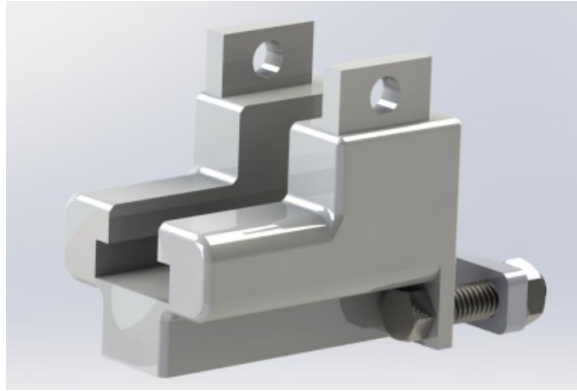


Figure 3. 3D model of the support for the rack and the motor

In addition, the support holds the actuation module. This module consists of a worm mounted on the shaft of a "380:1 Pololu Micro Metal Gearmotor HP 6 V", which transmits rotation to the rack converting it into linear motion. Table 1 shows the technical data of the selected motor.

This mechanical system (Figure 4) provides a compact and less expensive alternative to linear actuators small enough to fit the current application. The worm and rack were resized and modified from a model available online at

<https://www.mediafire.com/download/lh4zsb1229kf5dq/WormRack2STEP.zip>.

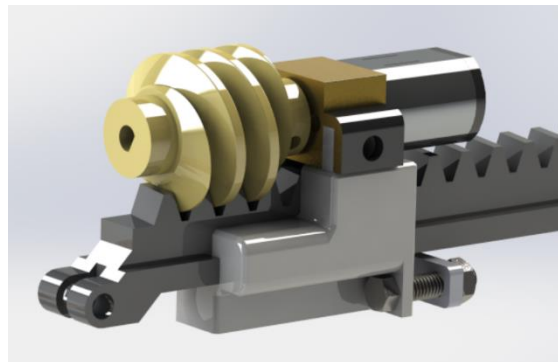


Figure 4. Full actuation module, with support, rack, worm and motor

Table 3. Specifications of the motor at 6V

Specification	Value
No load speed	84 RPM
No load current	0.1 A
Stall Current	1.6 V
Stall Torque	0.54 N.m
Max Output Power	1.1 W

The entire actuation system is encapsulated by the dorsal attachment to prevent injury to the user. Nevertheless, the capsule allows the detachment of the actuation module and the transmission

module (through the back) so that the exoskeleton can be adapted and used on either hand by simply reversing the order of these modules.

A set of two 3.7 V (7.4 V total) and 5000 mAh ("radiomaster 5000 mAh 2s li-ion battery pack") batteries power the exoskeleton for a reasonable amount of time, between 5-7 hours of continuous use. A case for the batteries was modeled, which can be attached to the forearm.

Although the control system has not been designed, a basic list of components is proposed for future work and a case for those components has been modeled for visualization purposes:

- arduino Uno
- two "Motoron M3S256 Triple Motor Controller Shield Kits"
- four "Polulu Magnetic Encoder Kits for Metal Gearmotors"

The controllers are stackable and allow a total of six separate motors to be controlled. In addition, the encoders provide position feedback to the controllers. The entire system would be implemented on an Arduino board and powered by the batteries as an external power supply. Alternatively, a custom circuit board could be designed.

Figure 5 shows the overall design of the hand exoskeleton.

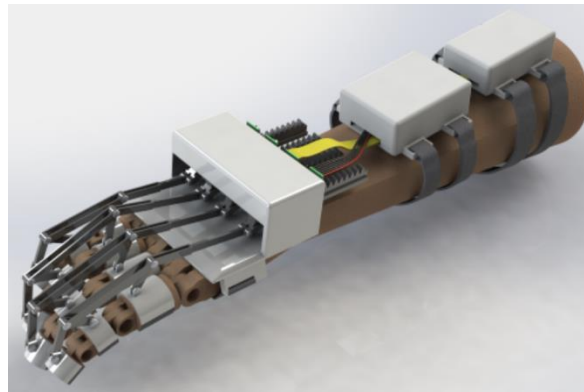


Figure 5. Complete 3D model, with the batteries, control, actuation, and transmission modules.

Kinematic analysis

The kinematics of the fingers were validated using the Motion Study feature of Solidworks®, with the Motion Analysis option selected. Contacts were set between the bars, supports and fingers. The motion of the actuation module comes only from mates and no contacts were set. No friction was considered for the contacts and the contact properties were defined as nylon-nylon contact between the bars, nylon-steel(greasy) between the supports and the bars, and steel(greasy)-steel(greasy) between the fingers. Finally, a rotary motion of 80 RPM was set on the worm.

Figure 6 shows the motion of the index finger. The motion of all other fingers was also analyzed, with satisfactory results.

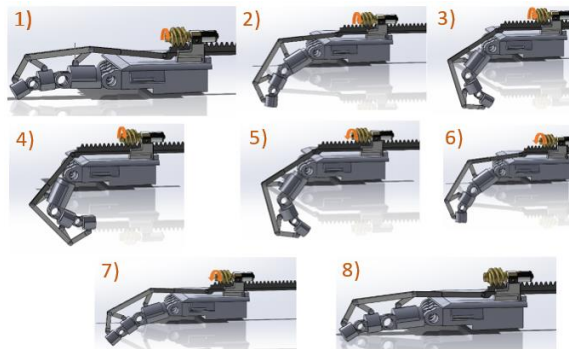


Figure 6. Simulation of the index finger motion, flexion is shown from 1) to 4) and extension from 5) to 8)

A prototype was built with the same bar dimensions as the model. Even in a situation with different hand sizes, the prototype and the simulation showed similar trajectories (Figure 7), which speaks to both the adaptability of the transmission module and the validity of the simulation.

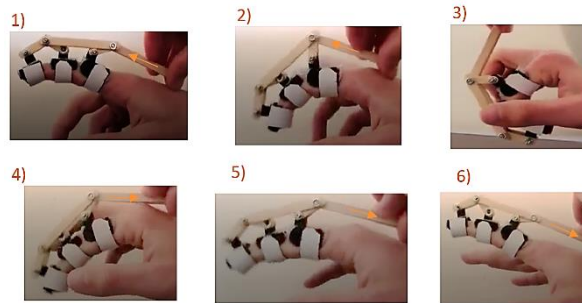


Figure 7. Motion of the index finger with the prototype, flexion is shown from 1) to 3) and extension from 4) to 6)

The torque required to perform the movement (free movement, unconstrained) never exceeds 0.17 N.mm during flexion (Figure 8-a).

Since gravity acts against the motor during extension, it was included in the study. In extension (Figure 8-b), the effect of gravity can be seen as the finger approaches the plane of action of the rack, as the torque increases with the momentum on the metacarpophalangeal joint. At the maximum extension of the exoskeleton, where the momentum is also maximum, the torque is 0.0009 N.m. (significantly lower than the stall torque of the motor (0.54 N.m)).

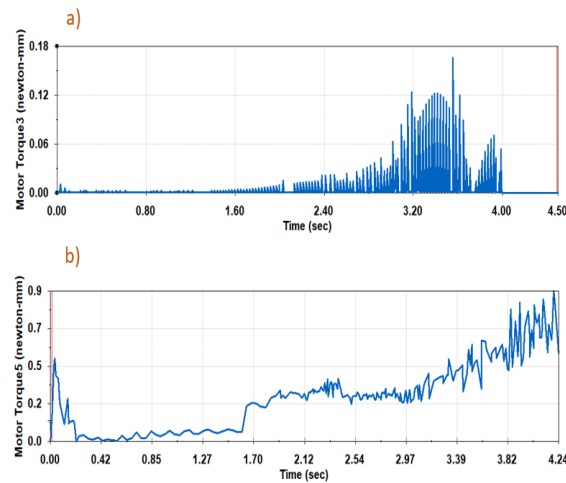


Figure 8: Motor torque during flexion (a) and extension (b)

These results indicate the motor is adequate. Nevertheless, the hand and fingers have a complex force system that was not defined in this simulation and should be gauged with a prototype in the future.

Stress Analysis

To find a critical configuration that can be further analyzed with a static study, a structural analysis using motion loads was performed for every bar of the transmission mechanism.

The static study is used to evaluate the stresses when the movement of the hand is hindered by an object in the most critical configuration.

The materials used in the analysis were extruded ABS for the bars (with the average properties from a MatWeb.com database [10], which summarizes all the extruded ABS entries on the website) and Nylon 101 for the rack and worm (with the properties available in Solidworks®).

The properties of ABS and Nylon 101 are listed in Tables 2 and 3, respectively.

Table 2. Properties of ABS.

Property	Value
Elastic Modulus	2.06 GPa
Poisson's Ratio	0.393
Mass Density	1080 Kg/m ³
Tensile Strength	38.7 MPa
Yield Strength	40.7 MPa

Table 3. Properties of Nylon

Property	Value
Elastic Modulus	1 GPa
Poisson's Ratio	0.3
Mass Density	1150 Kg/m ³
Tensile Strength	79.29 MPa
Yield Strength	60 MPa

Structural analysis using motion loads.

Following the kinematics analysis, the loads and stresses were evaluated at discrete time steps, to save computational time. There was a time step for every second of the motion, comprising full flexion and extension.

In general, the fourth and eighth configurations, corresponding to maximum flexion and extension, were those in which the factor was lower. Nevertheless, in each configuration and for each bar, the factor of safety was always greater than 10^2 , thus ensuring the structural integrity of the bars. It is still necessary to evaluate this integrity in a locked configuration and with the motor stall torque acting on the bars.

Since the hand won't be "holding" any object at maximum extension, the fourth configuration was selected for a static study.

Static analysis

The component interactions between the motor's body and its support and between the worm and the motor's shaft were set to "bonded". In contrast, the interactions between the worm and the rack and between the rack and the support were defined as "contact" (previously "no penetration").

"Pin connectors" with no translation were attached to the finger joints and the bars.

The purpose of the selected component interactions is to evaluate in detail the bars and the rack and the worm, since this are the most critical elements.

Figure 9 shows the four fixtures set on the simulation.

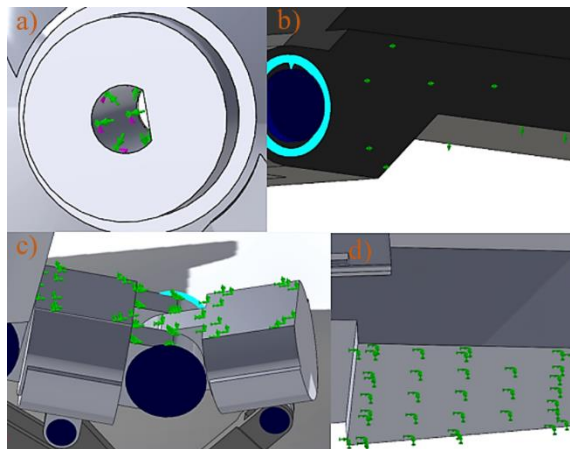


Figure 9: Representation of the fixtures: **a)** a “fixed hinge” fixture in the interior face of the worm. In this type of fixture translational displacement is eliminated and only rotation is

considered; **b)** two “roller/slider” fixtures, one on the bottom face of the rack and the other on one of its side faces. This way only displacement along the axis of the rack is allowed, simulating its linear movement; **c)** and **d)** “fixed geometry” fixtures on the volar faces of the intermediate and distal phalanges and on the palm of the hand (as if an object was blocking the movement). These fixtures remove translational displacement.

A high-quality mesh of 3D tetrahedral solid elements was created with a mesher from Solidworks®.

Table 4 lists the mesh properties and Figure 10 shows the graphic representation of the mesh.

Table 4. Mesh properties.

Property	Value
Mesh type	Solid mesh
Mesher	Blended curvature-based
Jacobian points	16
Max element size	12.0408 mm
Min element size	0.602042 mm
Total nodes	89976
Total elements	51501
% element's aspect ratio < 3	92.9%

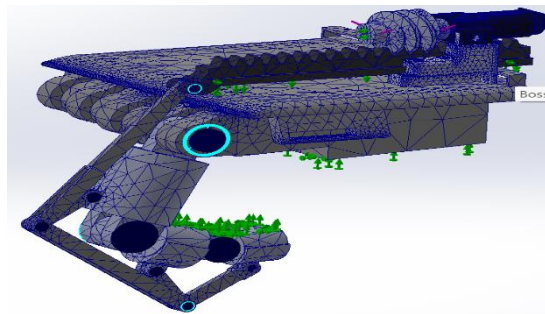


Figure 10: Graphic representation of the high-quality mesh

The factor of safety plot (Figure 11) shows a minimum value of 1.839 occurring on the teeth of the rack. This confirms the need to use Nylon 101, which has a higher yield strength, for the rack and the worm.

The bars have a safety factor always greater than 10. Even though it could be concluded that the transmission mechanism is oversized, unpredictable loads due to accidents or improper use are bound to occur. Therefore, it was considered that the dimensions are feasible and even preferable. Figure 12 shows the distribution of von Mises stresses along the actuation and transmission modules.

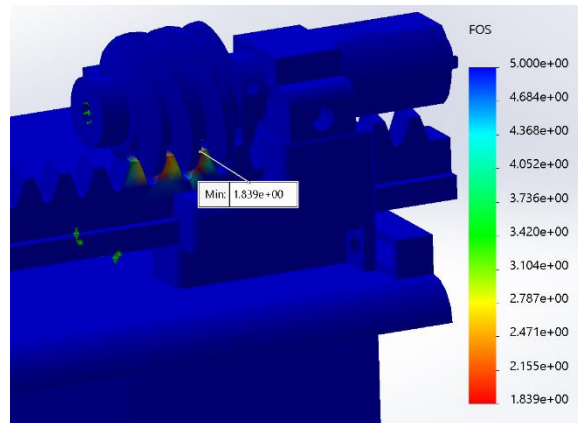


Figure 11. Factor of Safety plot. The minimum factor of safety is located at the teeth contacting the worm.

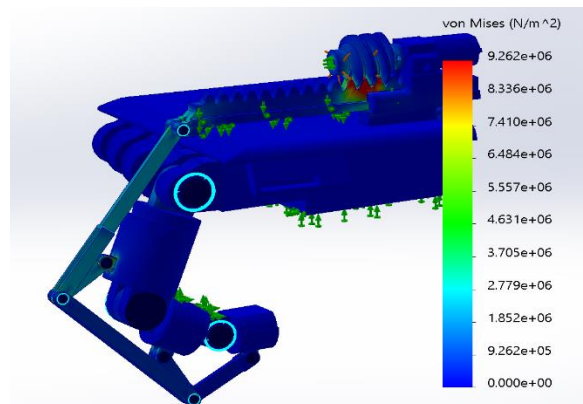


Figure 12: Distribution of von Mises stresses. The biggest stresses happen at the points of contact between the worm and the rack, and, in the bars, they decrease from proximal to distal

Finally, the normal forces on the volar surfaces of the fingers show that they can hold objects up to 20 N (Figure 13). The distal phalanx, however, has normal forces opposite to what is expected. This occurs because the mechanism tends to make the distal and intermediate phalanges parallel when flexion continues beyond the maximum point.

This means that when an object rests only on the distal phalanx, the distal phalanx becomes parallel to the intermediate phalanx. However, the hyperextension of the distal phalanx is intentionally limited by the morphology of the bars, and it locks at maximum extension. Consequently, the load on the object is still indirectly exerted by the intermediate phalanx.

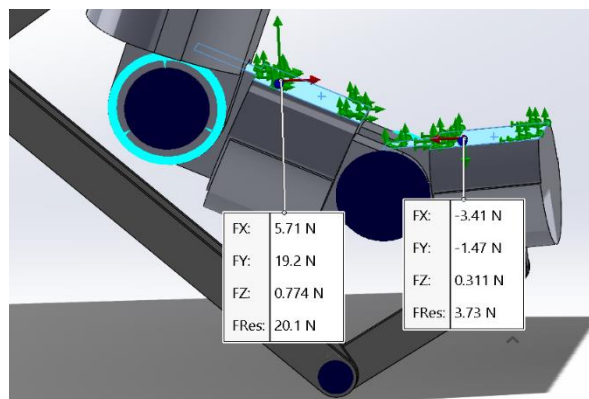


Figure 13: Normal forces on the intermediate and distal phalanges.

Conclusions

The simulations demonstrate the potential of the exoskeleton as a viable and accessible solution for hand rehabilitation and functionalization. Flexion and extension were achieved in four seconds with a normal force of 20 N at maximum flexion. The trajectory respects the biomechanics of the fingers, which was confirmed with a prototype. When the exoskeleton is maximally flexed in a static study simulating the hand holding an object, the factor of safety is, at its lowest, 1.822.

Future Work

In the future, fatigue studies should be performed, especially for the rack and worm. Also, other grips (with different exoskeleton configurations) should be tested in static studies and eventually with a prototype.

The control system will be designed thoroughly and in detail, as will the programming of the exoskeleton. The proposed control elements can manage up to six motors, so a thumb module could be designed and actuated with the remaining two motors.

Force sensors could also be attached to the distal phalanges of the prototype to measure and monitor the progress of the rehabilitation.

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TECHNOLOGICAL MODELLING OF SMART PACKAGING BASED ON INTERNATIONAL PACKAGING STANDARDS

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ABSTRACT

As the end result of the overall process, improperly packaged product and packaging containers with low quality can lead to risks and high damage. One of the current problems is the lack of packaging containers that meet the high requirements for the successful delivery of specific products. A number of internal and external influences and risks occur throughout the whole process, and a brand-new packaging model is needed to minimize and eliminate those factors. Requirements and instructions for the packaging process are completely recorded in ISO international standards. In this article, the technical model of the new intelligent packaging containers is drawn up in AutoCAD (following the requirements of the standards), and an explanation of each specification is included. The structure of the model, the layers of protection and the used equipment and their functions are shown. Traceability can also be achieved through the application of navigation systems, and thanks to this, it can be determined where the packaging containers are and at what time intervals they will be delivered. The application of the live location system will provide the user with a wide range of opportunities. With drone technology, which is one of the new generation technologies, the delivery process can be carried out over long distances. Application will be used to constantly inform the user and monitor the system. Risk assessment, marketing and financial values should be considered.

Keywords: Packaging, packaging container, delivery process, SMART packaging, international standard (ISO).

Introduction

As an inner part of development in scientific and technical progress, those packaging and delivery processes are one of the important issues which remain actual. Packaging and delivery are the last and most significant steps of the main process, which includes specific requirements. Although there are international standards for packaging, we still need a brand-new smart model to meet modern changes.

According to fact, focusing on the point of impact is the first attempt to eliminate risks of packaging therefore assessment of international standards is necessary. Though the application of ISO international standards to the internal packaging process of Azerbaijan is at a high level, there is a need for new applications in a number of special areas (medical, chemical, etc.). Management of packaging is a wide concept from the beginning to the final product and all companies face new obstacles in this section. ISO 15378-2015 “Primary packaging materials for medicinal products” is an international standard that facilitates the identification of filters. Filters use to mitigate risks that are taken from the reference standard are listed below.

- Specifications of product

- Information and communication
- Validation of packaging
- System control

The initial method is defining product specifications such as low and high limits of temperature, acceptable humidity, and inner and outer effects for each product. Sensitive handling and conditions are needed during the packaging and transportation of medicines and chemicals as well as these specifications are not constant during the process. Insufficient information can cause confusion between the user and the consumer and packaging boxes without sufficient data can be dangerous. Communication is the next step and it is not only for trade, it must be created between product and user.

Validation is a phrase familiar to ISO 17025:2017, although the meaning of the phrase here is slightly different. In the packaging sector, two different validation schemes are applied; Process and product validation.

Process validation is a number of methods that compare the results of process under the normal condition, via additional tests, and during routine production.

Product validation is a line that our product meets specific requirements at the end of the packaging process.

Control system: A special management system is needed to achieve a successful result. In order to reduce 50 percent of the challenges which companies face in the field of packaging; it is necessary to pay special attention to the management system. Based on the ISO 9001: 2015 standard, it is possible to organize the control system and manage the packaging process according to the general requirements.

ISO 13127:2012 provides many options for test methods, selection of methods, composition verification, sample selection, and testing.

The most important characteristics of packaging containers are listed below:

- Critical dimension
- Material
- Shape and structure
- Handling
- Rigidity

Smart packaging

In terms of quality and safety, SMART packaging is very useful to provide industry and consumers with timely information about the condition of the product through a change in the package system.

This type of packaging communicates the quality of the packaged product to its processors or users by sensing, recording, and notifying users of the characteristics of the packaged product or its environment in the form of messages about spoilage or deterioration.

SMART packaging of products.

- Extension of product life;
- Quality and safe packaging;
- Interaction with products;
- Contact with the consumer.

SMART packaging boxes were monitored and the following results were obtained. In accordance with the requirements of ISO 9000 quality standards, this packaging method combines several pieces of equipment.

With the application of new technology, it will be possible to achieve the following goals.

- Quality and safety
- Constant composition
- Sufficient information

These are the main issues we should focus on in the modelling of packaging:

Model structure:

- Withstands impact
- Inner stability
- Protection
- Freshness
- Shape and easy-handling

Data:

- Logo
- Label and Barcodes
- Monitor
- RFID

Communication:

- Mobile application

Technological modelling

In the packaging sector, importance is attached to the application of smart technologies during the modeling of containers.

Considering the general requirements, smart packaging containers should not have a negative impact on human health and the environment and should be the fruition of scientific progress with a user-friendly interface and multiple functions.

Containers should consist of two layers to withstand external influences: internal and external layers. (Figure 1)

- External layer (strong plastic material)
- Internal layer (for extra protection)

Equipment will be placed between internal and external layers at the back side of the packaging container. The third par layer will be used for easy placement of various compositions.

Internal stability can be ensured by keeping the given indicators stable.

- Microbiological variables
- Increases and decreases in gas level
- Gas leak
- Temperature fluctuations



Figure 1. Technological Model of Packaging Container (AutoCAD version)

Sensors:

A type of sensor is used to measure the temperature of containers and products.

B type sensor is a sensing technology such as microbiological sensing technology. This device is utilized to find out the occurrence of microbiological changes.

Detectors:

Via detectors can detect gases, gas leaks and oxygen depletion.

The equipment helps us to keep the products fresh inside the container for a long time.

For temperature stability, the cooler is placed behind the packaging box (Figure 2). Airflow is provided by the outlet on the back of the device.



Figure 2. Back Profile

The determination of the temperature range and the upper and lower temperature limits depends on the characteristic indicators of the object. A regulated complex cooling system should be created by taking inspiration from several reference equipment.

Barcode and RFID technology should be used to establish a communication loop between the user and the packaging object (Figure 3).



Figure 3. Top Profile

By means of a navigation system, it will be possible to find out where the package is during long-distance delivery.

By using the application, the user will get a wide range of opportunities with a simpler interface. All the tracking information and also factors like the live location of the packaging can be managed through this application.

A number of results can be obtained during risk assessment.

- Weather condition
- Duration of delay
- Internal microbiological environment
- Compatibility

Offers:

Before starting the application of packaging containers in any country, the degree of compatibility should be determined by PESTEL analysis.

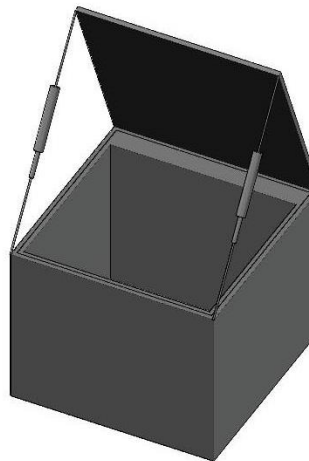
It is possible to protect the internal microbiological environment with infrared lamps. (It should not directly affect the internal environment)

Packaging for distances that cannot be delivered by land can be delivered by drone technology. (Risks must be assessed in advance).

Handles are placed on the left and right sides of the container, as well as they, are very convenient for easy handling (Figure 4). Hand dimensions are fully taken into account and via material, it does not hurt the inside part of the hand.

**Figure 4.** Side Profile

As an opening and closing function, an automatic controllable circuit should be designed. Security will be provided by placing restrictions on the opening of the container with the lock system. (Figure 5).

**Figure 5.** Visual Model

Conclusions

With the introduction of new technology, it will be possible to transport specific unique objects. From the beginning of the packaging period until the end of the delivery process, indicators of the internal environment will be kept within normal limits and protected.

With the inner and outer layers, you can protect yourself from external influences and cut off the connection between the inner and outer environment. It is possible to perform a number of functions and extend the life of the object through the equipment listed in the upper part.

Users can find out the live location of packaging containers, at what time they will be delivered, and what are the limits of the parameters of the product by using the navigator and application.

Taking into account the special opportunities and risks, drone technology can be applied and the process of long-distance delivery can be implemented.

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APPLICATION OF ARTIFICIAL NEURON NETWORKS AND FUZZY LOGIC IN DIAGNOSTIC AND FORECASTING THE TECHNICAL CONDITION OF TRACTION MOTORS

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ABSTRACT

The article is devoted to the application of artificial intelligence in diagnosing and predicting the technical condition of electric motors. Currently, a number of traditional and modern methods are used to perform diagnostic monitoring of electric motors, and research is being conducted in this field. The application of traditional diagnostic monitoring systems in the diagnosis of motors faces problems in determining the normal and threshold values of the diagnostic parameters that cannot be measured in the working condition due to the lack of uncertain information. Various traditional methods are applied to partially overcome these problems and increase the effectiveness of diagnostic control in working conditions.

The development of computer technology and its application in technology paved the way for the creation of more modern diagnostic monitoring systems. Modern diagnostic monitoring methods based on Soft Computing play an important role in optimizing the working condition of motors and increasing their stability. As a result of the research, it was found that the application of artificial neural networks and fuzzy logic-based diagnostic systems, which are pioneers of these methods, together with traditional methods in monitoring the technical condition of motors, will lead to the creation of new hybrid and complex systems.

Keywords: Traction motor, fuzzy logic, neural networks, diagnostic monitoring.

Introduction

As we know, all electric motors lose their stable working mode due to a number of failures and abnormal modes in the working process. Some failures directly cause the motor to stop. In order to detect such abnormal conditions and defects, a number of important parameters of motors should be monitored in working condition.

In particular, the development of railway transport is the focus of attention of several countries of the world. Traction electric motors are the important and main executive equipment of locomotives operated in railway transport. A number of railway vehicle manufacturing companies around the world apply various methods to increase the effectiveness of diagnostic monitoring of traction electric motors, and research is being conducted in this field.

Statement of the problem

Faults in electric motors are caused by mechanical and electrical reasons. Failure to prevent failures and defects in time leads to loss of motor performance. This is unacceptable in a number of production areas, as well as in transport. Corrosion and wear, severe operating conditions of

motors lead to abnormal operating modes and emergency situations. In order to reduce the number of accidents that lead to long downtimes and high costs of overhauling motors, real-time automatic diagnostics of motors is required for timely detection and prediction of failures. The main difficulty in creating an adequate diagnostic system is the variable loading of the traction electric motors in operation. The wide variation of the main operating parameters depending on the motor load and operating mode directly affects the accuracy of diagnostics.

Modern adaptive systems based on artificial intelligence, such as artificial neural networks and fuzzy logic, can solve these problems, as well as the problems of predicting output parameters in a small time interval, thanks to the learning, memorization and approximation capabilities of input data. So, to solve diagnostic and forecasting problems, it is necessary to investigate the possibilities of using artificial intelligence, study and compare different architectures of neural networks, fuzzy logic system, as well as their hybrid neuro-fuzzy networks.

Application of neural networks and fuzzy logic the application of neural networks and fuzzy logic It is possible to create a model of the system by selecting the best options as a result of the research for diagnosis and forecasting of the technical condition of the traction electric motor. This system should diagnose the following defects:

- inter-phase short-circuits in the stator windings of the motor, including short-circuits between turns of the windings, insulation breakdown and overheating of the windings;
- in the case of overloading (especially on steep slopes), the electrical strength of the insulation decreases with the increase of the current;
- cracks and breaks in hard joints (motor -wheel block) due to excessive mechanical vibrations caused by the road;
- shocks and temperature changes in the pads during changing work modes, etc.

After the normal and threshold values of the informative parameters received from the motor through various sensors are analyzed by the expert, they are applied to the Master-SCADA system for integration into the control system. The system is created using specialized packages (FuzzyLogic Toolbox, ANFIS Toolbox, Neural Network Toolbox, NNstart) with wide possibilities for solving tasks in the MATLAB programming environment.

The first step is to create a mathematical model of the traction electric motor in MATLAB Simulink and to model all the faults that will be diagnosed by the system. As a result of modeling, it is necessary to obtain the training sample of the traction electric motor - the time series of the values of the parameters in different modes. The adequacy of the system's work depends on the completeness of the training sample, because its data form the basis of the rule base of the fuzzy output system and serve to train the artificial neural network.

The scheme (Fig. 1) has the following designations: GV, CV, SV – transmitters for voltage, armature circuit current and angular velocity, respectively, located in the traction electric motor; I_t , U_t , R_t , M_t , ω – traction electric motor current, voltage and armature circuit resistance, torque and angular speed; PLC – programmable logic controller; PC - computer.

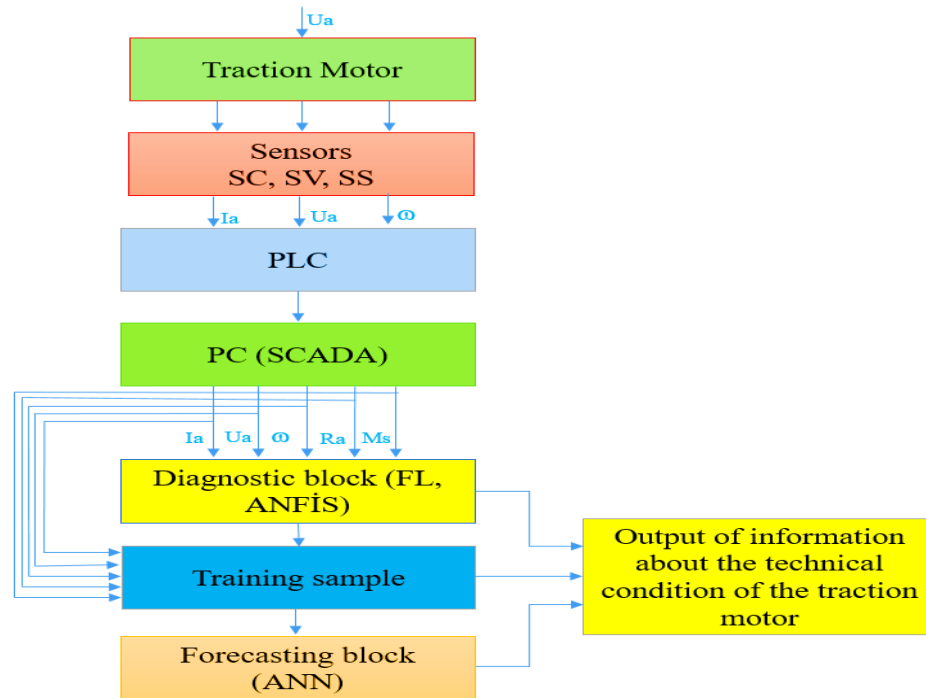


Figure 1. Diagram of the traction electric motor diagnosis and technical condition prediction system based on artificial intelligence.

The data from the transmitters is sent to the PLC, and then to the SCADA system through the OPC (Open Platform Communications) server. The OPC server indirectly calculates uncertain parameters (R_l , M_t) that cannot be measured directly and transfers them to the diagnostics and prediction system. The diagnostic block is a fuzzy inference system (fuzzy inference system) built on the basis of fuzzy logic or neuro-fuzzy networks (ANFIS). The advantage of neural fuzzy networks is that artificial neural networks are part of a fuzzy decision-making system. The following figure shows an example of the architecture of fuzzy neural networks in the MATLAB package (Fig. 2).

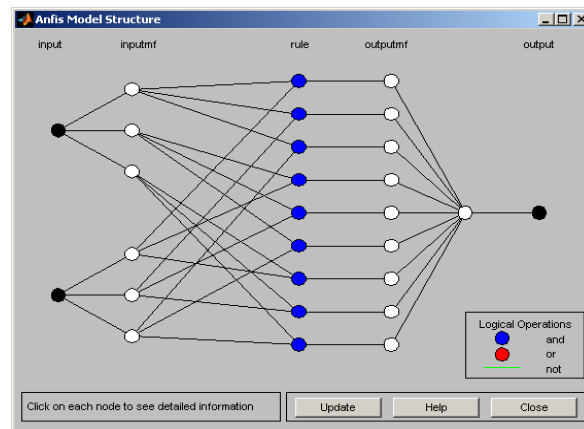


Figure 2. An example of the architecture of neural fuzzy networks in the MATLAB package.

Which independently creates a rule base for the fuzzifier based on the choice of training and given parameters (type of membership function, number of hidden layers in artificial neural networks, etc.). Accordingly, these steps are given in the following pictures (Fig. 3, 4, 5).

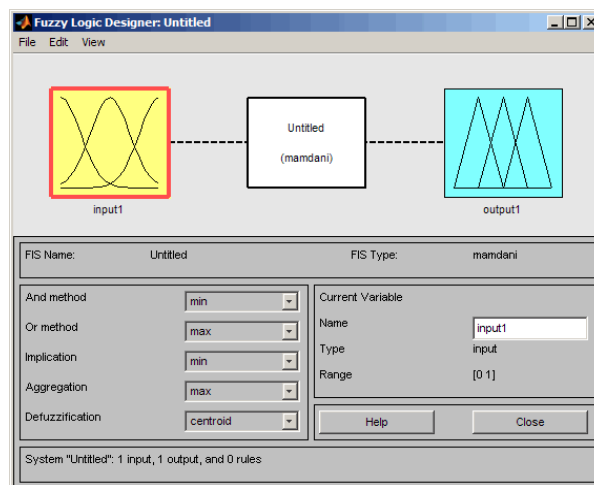


Figure 3. Membership Function Editor of the Fuzzy Toolbox.

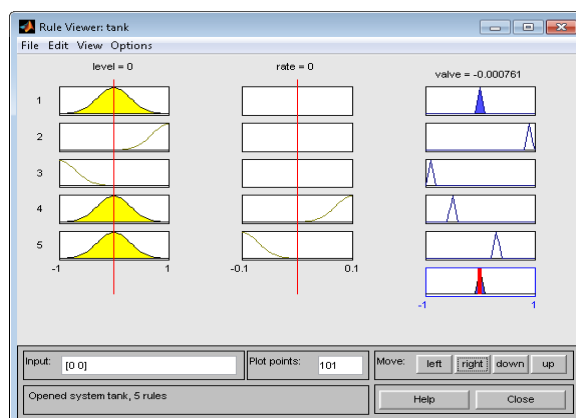


Figure 4. Rule Viewer of the MATLAB Fuzzy Logic Toolbox.

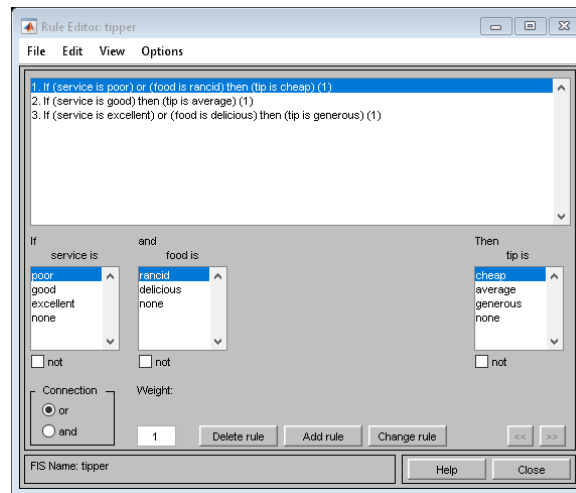


Figure 5. Rule editor in MATLAB/Fuzzy logic toolkit

The accuracy of fault diagnosis depends on the number of rules and the absence of contradictions between them. Specialized tools of MATLAB packages allow obtaining interactive surfaces of technical condition degrees (Fig. 6) for the convenience of tuning the fuzzy inference system.

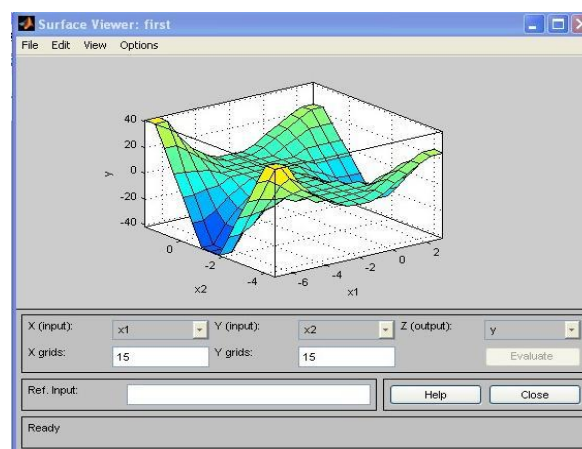
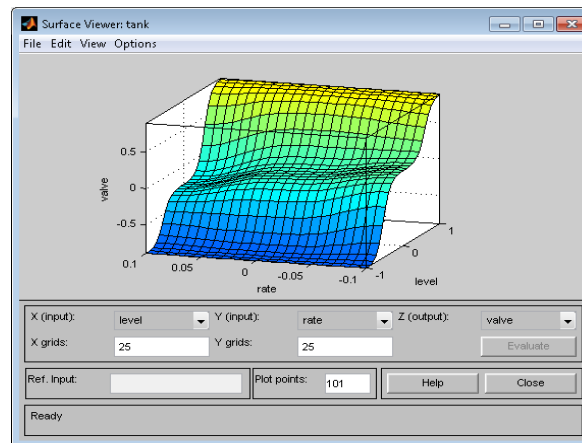


Figure 6. Level surfaces of technical different condition in Fuzzy-Logic Toolbox

The accident prediction block is based on the NARX recurrent neural network, the accuracy of the prediction depends on the training speed of the neural network and its architecture. Artificial neural networks perform the prediction in the following way: the input and output are given the training option (sample) from which the network is learned, together with the parameters that determine the technical condition of the traction electric motor. At the output, the values of the parameters at the moment of real time are compared with the values of the sample, and as a result, the prediction of the change of the parameter with step $t+1$ is given. All the data from the diagnostic and forecasting blocks are displayed on the screen of the SCADA system, the degree of technical condition of the motor (faulty, faulty, operational, short-circuited, broken, etc.), graphs of changes in parameters in real time and forecasting graphs are shown in the following figure (Fig. 7).

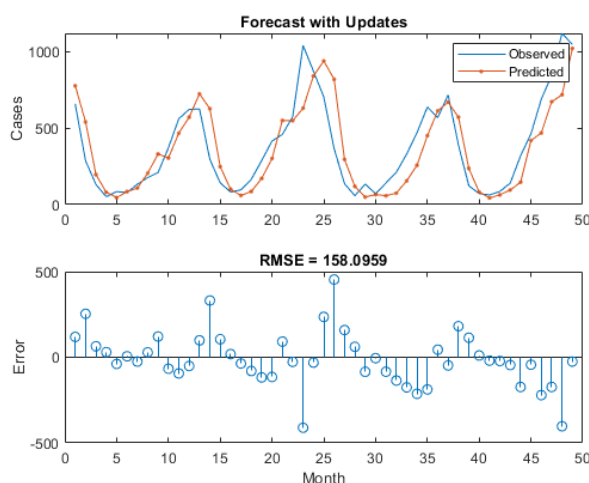


Figure 7: Graph of anchor current change prediction in NNstart package

Conclusions

The use of a diagnosis and prediction system based on artificial intelligence will allow to diagnose the technical condition of the traction electric motor with high accuracy in real time, to predict and prevent the occurrence of accidents, thereby increasing the life of the motor and avoiding additional costs for overhauling the motor.

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QUESTIONS OF SELF-CALIBRATION OF SATELLITE TOOLS FOR DETERMINING THE VOLUME OF BURNED ASSOCIATED GAS IN FLARE

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ABSTRACT

The possibility of carrying out mutual calibration of satellite means for determining the volume of associated gas burned in flares was analyzed. Existing satellite methods for estimating the total amount of associated hydrocarbon gas flared, implemented on the basis of MODIS and VIIRS data, are considered. Methods have been developed for inter sensor calibration of satellite meters, implemented by introducing an additive calibration correction for the measured temperature of objects outside the plume in the first case, when the MODIS data are calibrated according to the VIIRS readings and for the plume emissivity, in the case when the VIIRS readings are calibrated according to the MODIS readings. The problem of the optimal choice of the temperature of the gas torches, at which the emission of an aerosol such as elemental carbon (BC) can be reduced in comparison with the maximum generation level, is considered and solved. With the full knowledge of the frequency statistics of the appearance of low-temperature flares and the appearance of high-temperature flares, the proposed mathematical model allows us to estimate the maximum formation of a dangerous aerosol to prevent the formation of a hazard and allows us to calculate the remaining quantities if the values of five quantities are known from the set of variables participating in the model. The proposed model makes it possible to determine the maximum emission and its average temperature expectation.

Keywords: Associated gas, calibration, satellite measurements, flame, temperature.

Introduction

Combustion of associated gas that appears during oil production or natural gas flaring is a technological operation for high-temperature oxidation of this product in flare installations. The combustion of hydrocarbon gases in flares inevitably leads to the release of CO₂ into the atmosphere, which is the main factor in global warming [1, 2]. According to World Bank estimates, about 150 billion cubic meters of natural gas are flared every year, which is equivalent to 30% of the total gas consumed in the European Union. The annual combustion of gas in the amount of 400 million tons per year leads to the emission of such a volume of CO₂ into the atmosphere, which is equivalent to 1.2% of all annual emissions of this gas on the planet [3]. The first works on satellite monitoring of the volumes of gas burned in flares appeared in the 70s and 80s of the last century [4,5]. The principle of such control was to register the light radiation of the torches entering the input of the photosensitive onboard equipment. The first practical work was carried out under the GGFR program of the World Bank using NOAA satellites in 2002. The onboard equipment installed on these satellites recorded a light signal in the spectral range of 0.5-0.9 μm with a spatial resolution of 2.7 km. At the same time, an individual model for calibrating



measurement data was developed for each country. To eliminate such shortcomings as low spatial resolution, lack of calibration on board, and impossibility to take into account some countries, it was proposed to use the data of the MODIS spectro-radiometer for this purpose [6]. A measurement technique was developed that used both mid-infrared (MIR) and thermal infrared (TIR) data [7,8]. The National Geophysical Data Center (NGDC) has also developed a methodology based on information obtained only from MIR channels [1,6]. Since 2011, NGDC has been using data from the VIIRS spectroradiometers, radiometers, which have a high spatial resolution, high sensitivity, and calibration tools that have made it possible to distinguish gas flares from biomass burning and volcanoes.

Analysis of the methods used for satellite estimation of the volume of flared gas

One of the most practical methods for determining the power of optical radiation from plumes based on the MODIS database was proposed in [9]. According to this technique, the radiation power of a gas torch can be determined by the formula.

$$FRP = 4,34 \cdot 10^{-19} (T_4^8 - T_{4b}^8) \left(\frac{B_M}{m^2} \right) \quad (1)$$

where: T_4 -brightness temperature, measured at a wavelength of 4 μm (MIR), torch; T_{4b} -brightness temperature, measured at the same wavelength of objects surrounding the torch.

According to [10], formula (1) is valid for flames in the temperature range (600–1500 K).

According to [11], a regression model has been developed between the volume of gas burned and FRP in the form

$$GFV_1 = 2442,7 \cdot FRP \quad (2)$$

where GFV_1 - the volume of gas burned in cm^3 .

The accuracy of GFV estimation by formula (2) does not exceed 2%. The corresponding regression curve is shown in Figure 1.

At the same time, there is a methodology for determining the volume of flared gas under the GGFR program of the World Bank in cooperation with NOAA applied to satellites launched in 2012 and 2017, which use VIIRS spectroradiometers. According to [12], these satellites carry out night measurements several times a night and operate at the wavelength at which the emission is maximum. VIIRS detectors make it possible to detect more than 10,000 gas flares annually [13].

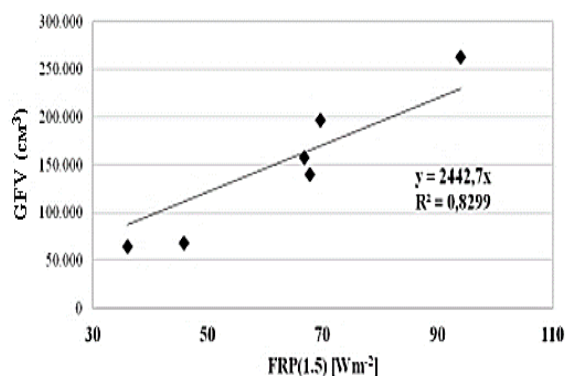


Figure 1. Regression relationship between GFV and FRP

According to [13], there is also a linear regression relationship between the VIIRS radiative heat estimates and the estimates of the volume of combusted gas (Figure 2).

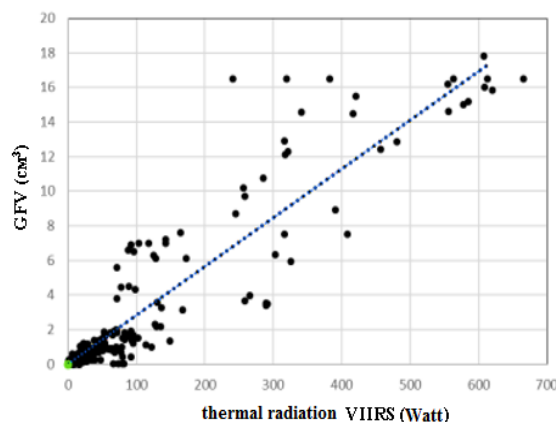


Figure 2: Regression Relationship Between Indicators Estimated Thermal Radiation VIIRS and GFV

The methodology for estimating GFV based on the VIIRS database is as follows [13]. Flame temperature is determined by the formula:

$$T = b / \lambda_{max} \quad (3)$$

where: T is measured in K;

b – constant guilt;

λ_{max} – the wavelength at which the Planck curve reaches its maximum.

Radiative heat per unit area J is defined as

$$J = \sigma \cdot \varepsilon \cdot T^4 \quad (4)$$

where: J is measured in (Watt/m²); ε – radiance; σ – constant of Stefan-Boltzmann.

Torch surface area (m²), S is determined by the formula

$$S = \frac{h_0}{h_d} \cdot S_0 \quad (5)$$

where: h_0 – the height of the Planck curve for the current radiation measurement;

h_d – the maximum possible height of the Planck curve during measurements;

S_0 – area of the sensitive surface of the photodetector.

The total radiant heat RH is defined in Watts as

$$RH = J \cdot S. \quad (6)$$



The volume of gas flared in m^3 is defined as

$$GFV_2 = RH \cdot J \cdot 0,0281. \quad (7)$$

Suggested method

Taking into account the above methods for determining the GFV index according to the MODIS and VIIRS readings, the following methods of intersensor calibration of these instruments can be proposed.

Calibration of MODIS according to the indications of VIIRS. Taking into account (1), (2) and (7), we write:

$$GFV_1 = GFV_2,$$

or

$$2442,7 \cdot 4,34 \cdot 10^{-19} [T_4^8 - (T_{4b} \pm \Delta T_{4b})^8] = \frac{RH \cdot J \cdot 0,0281}{10^6}. \quad (8)$$

As can be seen from (8), the calibration additive component is used here in relation to T_{4b} . From (8) we get

$$[T_4^8 - (T_{4b} \pm \Delta T_{4b})^8] = 0,0264 \cdot 10^8 \cdot J \cdot RH. \quad (9)$$

From (9) we get

$$(T_{4b} \pm \Delta T_{4b})^8 = T_4^8 - 0,0264 \cdot 10^8 \cdot J \cdot RH. \quad (10)$$

or

$$T_{4b} \pm \Delta T_{4b} = \sqrt[8]{T_4^8 - 0,0264 \cdot 10^8 \cdot J \cdot RH}. \quad (11)$$

Thus, after measuring T_{4b} , T_4 , J and RH the calibration correction ΔT_{4b} can be calculated.

Calibration of VIIRS according to MODIS readings. Taking into account (2), (4) and (7), we obtain

$$2442,7 \cdot FRP = \sigma(\varepsilon \pm \Delta\varepsilon) T^4 \cdot RH \cdot 2,81 \cdot 10^4. \quad (12)$$

From (12) we find

$$(\varepsilon \pm \Delta\varepsilon) = 8,66 \cdot 10^2 \frac{FRP}{\sigma \cdot T^4 \cdot RH}. \quad (13)$$

Thus, with known values of ε , FRP , σ , T and RH , the calibration correction $\pm\Delta\varepsilon$ can be determined.

Therefore, the proposed methods of intersensory calibration can be implemented according to the following unified algorithm:

Determination of the values of GFV_1 and GFV_2 according to formulas (2) and (7), drawing up an equation

$$GFV_1 = GFV_2. \quad (14)$$

1. Determination of the calibrated indicator by adding a calibration additive correction to its value.
2. Determination of the calibration correction based on equality (14).

In general, according to [14], the higher the flame temperature, the more complete the hydrocarbon gas burns and the less aerosol are generated. In this work, the concept of the emission factor BC, which depends on the temperature of the torch, is introduced. The corresponding plot of the dependence of the emission factor $\omega(x)$ is shown in Figure 3, where on the axis is the temperature in K.

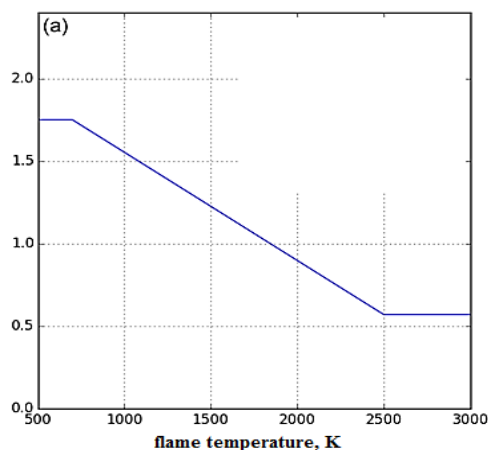


Figure 3. Plot of emission factor BC versus flame temperature.

At the same time, the flaring temperature statistics compiled according to the SLSTR and VIIRS data are almost the same [14].

On Figure 4 a histogram of the temperature distribution of gas combustion in flares is given [14].

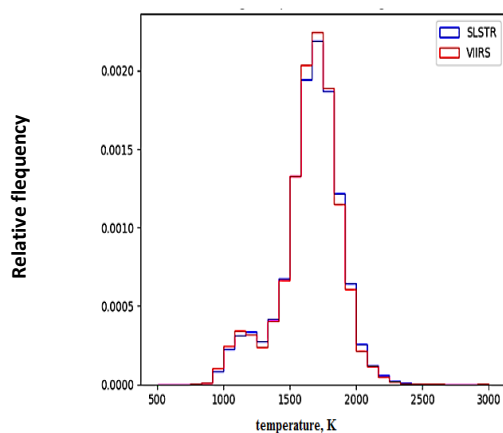


Figure 4. Histogram of distribution of gas combustion temperatures in flares.



As can be seen from the histogram shown in Fig. 4, the general view of this curve resembles the addition of two Gaussian curves centered at the points $T=1200$ K and $T=1700$ K.

This raises the following research problem: It should be determined at what average temperature the maximum BC emission should be expected if the plume frequency statistics are fully known.

Further, for the analysis, we will take the following initial assumptions:

Flame temperature is considered a random variable which is the sum of two independent random variables x_1, x_2 . Here we mean not algebraic summation, but statistical summation, i.e. the occurrence frequencies of these two random flame temperatures are summarized.

The above two random variables are the appearance of low-temperature flames and the appearance of high-temperature flames.

Random variables are introduced

$$z_1 = \omega(x_1) \cdot x_1; \quad (15)$$

$$z_2 = \omega(x_2) \cdot x_2. \quad (16)$$

where: x_1 -is a random variable indicating the appearance of a low-temperature torch; $\omega(x_1)$ -frequency of occurrence of a low-temperature torch; x_2 -is a random variable indicating the appearance of a high-temperature torch; $\omega(x_2)$ - frequency of occurrence of a high-temperature torch.

It is well known that the probability distribution density of two independent random variables is determined by the product of the corresponding densities, i.e.

$$f_0(z_1, z_2) = f_1(z_1) \cdot f_2(z_2) \quad (17)$$

where f_1, f_2 -re the corresponding probability densities of z_1 and z_2 .

Taking into account (15) and (16), we rewrite expression (17) as

$$f_0(z_1, z_2) = f_1(\omega(x_1) \cdot x_1) \cdot f_2(\omega(x_2) \cdot x_2). \quad (18)$$

The purpose of the study is to determine such a relationship between f_1 and f_2 in which $f(z_1, z_2)$ would reach an extreme value. Taking the derivative of f_1 and f_2 with respect to z_1 and z_2 respectively, and equating the result to zero, we get

$$\frac{\partial f_0}{\partial f_1} \cdot \frac{df_1}{dz_1} + \frac{\partial f_0}{\partial f_2} \cdot \frac{df_2}{dz_2} = 0. \quad (19)$$

Taking into account

$$\frac{\partial f_0}{\partial f_1} = f_2; \quad \frac{\partial f_0}{\partial f_2} = f_1. \quad (20)$$

From (19) and (20) we get

$$f_2 \cdot \frac{df_1}{dz_1} + f_1 \cdot \frac{df_2}{dz_2} = 0. \quad (21)$$

From (21) we can write

$$\frac{f_1'}{f_1} = -\frac{f_2'}{f_2}. \quad (22)$$

Integrating the left and right sides of (22) we obtain

$$\ln f_1 + \ln f_2 = C; \quad C = \text{const} \quad (23)$$

where: C-constant of integration.

From expression (23) we finally obtain:

$$f_1 \cdot f_2 = C_1; \quad C_1 = \text{const} \quad (24)$$

or

$$f_1 = \frac{C_1}{f_2}. \quad (25)$$

Therefore, when condition (25) is met, f_0 reaches an extremum, the type of which (minimum or maximum) can be determined when considering specific types of distributions.

Consider an example. Let's say f_1 and f_2 are Gaussian functions:

$$f_1 = \frac{1}{\sqrt{2\pi\sigma_{z_1}^2}} \exp\left[-\left(\frac{z_1 - m(z_1)}{2\sigma_{z_1}}\right)^2\right]; \quad (26)$$

$$f_2 = \frac{1}{\sqrt{2\pi\sigma_{z_2}^2}} \exp\left[-\left(\frac{z_2 - m(z_2)}{2\sigma_{z_2}}\right)^2\right]. \quad (27)$$

Obviously, in (19) $\frac{\partial f_0}{\partial f_1}$ and $\frac{\partial f_0}{\partial f_2}$ are positive values. Let's calculate derivatives $\frac{df_1}{dz_1}$ and $\frac{df_2}{dz_2}$. We have:

$$\frac{df_1}{dz_1} = \frac{-2}{\sqrt{2\pi\sigma_{z_1}^2}} \exp\left[-\left(\frac{z_1 - m(z_1)}{2\sigma_{z_1}}\right)^2\right] \cdot \frac{(z_1 - m(z_1))}{2\sigma_{z_1}^2}; \quad (28)$$

$$\frac{df_1^2}{dz_1^2} = \frac{-2 \cdot 2}{\sqrt{2\pi\sigma_{z_1}^2}} \left[\exp\left[-\left(\frac{z_1 - m(z_1)}{2\sigma_{z_1}}\right)^2\right] \cdot \left[\frac{(z_1 - m(z_1))}{2\sigma_{z_1}}\right]^2 + \frac{\exp\left[-\left(\frac{z_1 - m(z_1)}{2\sigma_{z_1}}\right)^2\right]}{2\sigma_{z_1}^2} \right] \quad (29)$$

As can be seen from $\frac{df_1^2}{dz_1^2}$ is always negative. Similarly, to (28), one can show that $\frac{df_2^2}{dz_2^2}$ is also always negative.

Therefore, when solving (25), functional (18) reaches its maximum. This means that the values of z at which the BC emission would be maximum can be calculated taking into account (25), (26) and (27) from the condition.



$$\sqrt{\frac{2\pi\sigma_{z_2}^2}{2\pi\sigma_{z_1}^2} \exp\left[-\left(\frac{z_1-m(z_1)}{2\pi\sigma_{z_1}}\right)^2 + \left(\frac{z_2-m(z_2)}{2\pi\sigma_{z_2}}\right)^2\right]} = C_1. \quad (30)$$

Thus, according to (30), if there are values of five quantities from the set $\{\sigma_{z_1}, \sigma_{z_2}, m(z_1), m(z_2), z_1, z_2\}$ we can calculate the rest of the sixth, at which f_0 will reach the maximum, those. BC generation will reach its maximum value. It is heuristically clear that in practice this calculated value of the desired indicator should be avoided in order to prevent the maximum generation of aerosol type BC.

Conclusions

The existing satellite methods for estimating the total amount of associated hydrocarbon gas flared, implemented on the basis of the MODIS and VIIRS data, are analyzed. Methods for the intersensor calibration of satellite indicators are proposed, which provide for the introduction of an additive calibration correction for the measured temperature of objects outside the plume in the first case, when the MODIS data are calibrated according to the VIIRS readings and for the plume emissivity, in the case when the VIIRS readings are calibrated according to the MODIS data. The problem of the optimal choice of the temperature of the gas torches, at which the emission of an aerosol such as elemental carbon (BC) can be reduced in comparison with the maximum generation level, is considered and solved. An analytical expression has been obtained that makes it possible to calculate such values of the main indicators of the torch, at which the level of aerosol emission could reach a maximum value.

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$$f(x) = a_0 + \sum_{n=1}^{\infty} \left(a_n \cos \frac{n\pi x}{L} + b_n \sin \frac{n\pi x}{L} \right) \quad (1)$$

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Font	Article Title	Headings	Subheadings	Reference list	Text
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Line Spacing	1.15	1.15	1.15	1.15	1.15
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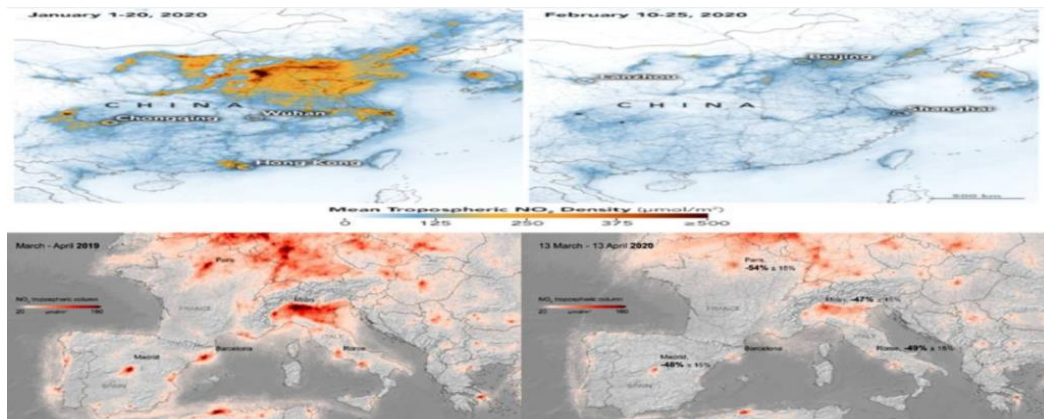


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1. W. S. Author, "Title of paper," Name of Journal in italic, vol. x, no. x, pp. xxx-xxx, Abbrev. Month, year. <https://doi.org/10.21467/ajgr>
2. Bahishti, "Peer Review; Critical Process of a Scholarly Publication", J. Mod. Mater., vol. 2, no. 1, pp. 1.1-1.2, Oct. 2016. <https://doi.org/10.21467/jmm.2.1.1.1-1.2>
3. Bahishti, "A New Multidisciplinary Journal; International Annals of Science", Int. Ann. Sci., vol. 1, no. 1, pp. 1.1-1.2, Feb. 2017. <https://journals.aijr.in/index.php/ias/article/view/163>
4. W. S. Author, "Title of paper," Name of Journal in italic, vol. x, no. x, pp. xxx-xxx, Abbrev. Month, year. Access online on 20 March 2018 at <https://www.aijr.in/journal-list/advanced-journal-graduate-research/>
5. W. S. Author, "Title of paper," Name of Journal in italic, vol. x, no. x, pp. xxx-xxx, Abbrev. Month, year. Access online on 5 March 2018 at <https://www.aijr.in/about/publication-ethics/>
6. M. Ahmad, "Importance of Modeling and Simulation of Materials in Research", J. Mod. Sim. Mater., vol. 1, no. 1, pp. 1-2, Jan. 2018. DOI: <https://doi.org/10.21467/jmsm.1.1.1-2>

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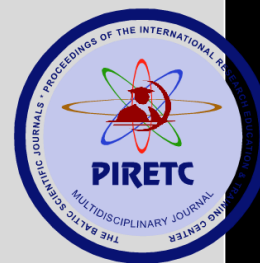
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