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ANALYSIS OF THE MEASUREMENT METHOD AND MODEL CREATED IN THE RESEARCH AND IMPROVEMENT OF ACCURACY OF ELECTRONIC TACHYOMETERS IN FIELD CONDITIONS

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Abstract. *The article presents the results of studies of the errors of electronic tacheometers in field conditions and improvement of their accuracy. In modern metrology of geodetic instruments, a pressing issue is the research and development of new methods for calibrating inclinometers or calibration stands. Since the unit for measuring angles in electronic tacheometers is a separate working part, a regulatory document has been developed for this purpose for specialists and organizations working in the field of geodesy, cartography and cadastre, developing methods and improving activities related to their research. Attention is focused on the need to perform high-precision geodetic measurements of horizontal angles, taking into account the study of tools and equipment.*

Keywords: *electronic total station, dial, alidade, accuracy, measurement of angles and distances, research, monitoring.*

АНАЛИЗ МЕТОДА ИЗМЕРЕНИЙ И МОДЕЛИ, СОЗДАННОЙ ПРИ ИССЛЕДОВАНИИ И ПОВЫШЕНИИ ТОЧНОСТИ ЭЛЕКТРОННЫХ ТАХИОМЕТРОВ В ПОЛЕВЫХ УСЛОВИЯХ.

Аннотация. *В статье приведены результаты исследований погрешностей электронных тахеометров в полевых условиях и улучшение их точности. В современной метрологии геодезических приборов актуальным вопросом является исследование и разработка новых методов калибровки угломеров или калибровочных стендов. Так как блок измерения углов у электронных тахеометров является отдельной рабочей частью, для этого разработан нормативный документ для специалистов и организatsiй, работающих в области геодезии, картографии и кадастра, разрабатывающий методику и совершенствование мероприятий, связанных с их исследованиями. Акцентируется внимание на необходимости выполнения высокоточных геодезических измерений горизонтальных углов с учетом исследования инструментов и оборудования.*

Ключевые слова: *электронный тахеометр, лимб, алидада, точность, измерение углов и расстояний, исследование, мониторинг*

I. INTRODUCTION

Metrological control of measuring systems of electronic tachyometers, angle and laser distance measuring devices is an urgent task. When measuring an angle, high accuracy is required, which in turn places excessive demands on angle measuring instruments. Among the angular measuring devices, the important features and defects of electronic tachymeters are determined accurately and if they are corrected in time, it can be effective in performing geodetic work, i.e. angle measurements, and obtain a reliable amount as a result of the measurement. measurement results are reliable [1]. Solving these important issues can be done as a result of accurate testing of all geodetic instruments, including electronic tacheometers [3].

Modern geodetic instruments must meet the following requirements:

1. Sufficient measurement accuracy and high labor productivity are necessary;
2. High reliability during measurement and no damage during transportation in extreme conditions;
3. It is necessary to be simple and convenient in dealings.

General technical requirements for geodetic instruments are set on the basis of special standards. It is necessary to repair the construction of geodetic instruments from a technological point of view, to ensure that their technical characteristics and main parameters are controlled[2].

To date, any electronic tacheometer remains a "mystery device" for all surveyors. The reason for this is that special algorithmic software, metrological stand, improved collimators or laboratories are not enough. In modern electronic theodolites and tachyometers, the position of the limb is not changed, any angle of the limb can be displayed on the screen by imitation. Researching and improving the accuracy of electronic tacheometers is important not only for manufacturers, instrument maintenance centers, research institutes, but also for the user who can determine which electronic tacheometers will allow for more accurate measurements when needed[2].

II. OBJECTIVE OF THE RESEARCH

The purpose of this control is to check their performance and to determine the error values during measurements. Interference comparators were used for the research of high-precision angle measuring devices, the principle of their operation is based on the physical phenomenon of interference of light waves [4].

In research works and literature, the impact of the horizontal circle eccentricity on the values of angle measurement errors, the size of the battery of geodetic instruments, the position of the geometric axes of electronic tachyometers is described. All sought-after experts do not recommend studying electronic total stations unless you have a stand consisting of 2 theodolites with a professional autocollimator focused on continuity and the ability to change the position of the base between runs. The method developed by the author is intended for large-scale users and allows to study the errors of measuring horizontal angles using electronic tachymeters in non-laboratory conditions [5].

III. RESEARCH METHODOLOGY

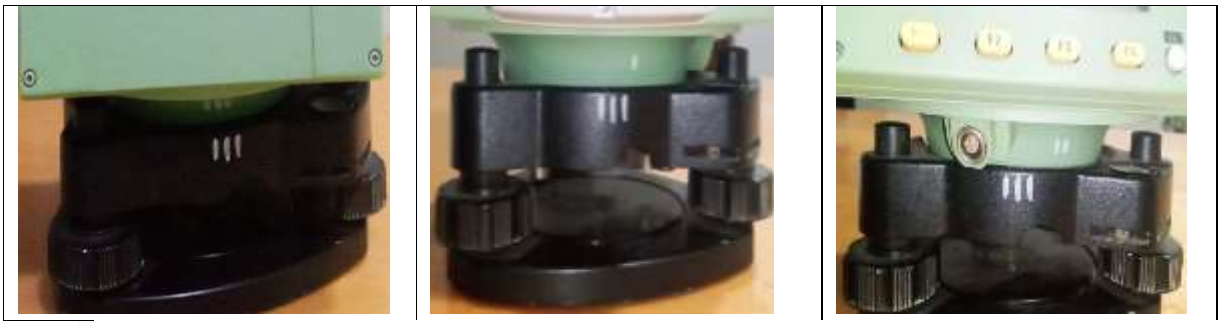
In order to confirm the proposed method, the experiments in the scientific research were conducted directly in the field conditions on the standard geodetic base. The above theoretical and scientific studies proved the need for additional research to investigate the errors of electronic tachyometers in field conditions and to improve their accuracy [3].

For this purpose, it was carried out at 187-type points where a mandatory centering device was installed. A high-precision TS-11 electronic tachymeter was used to calibrate the angle. Researches were carried out using 5 different types of electronic tachyometers. The results of the measurement were equalized using the Fure series using the Excel program and diagrams were made. As a result, the azimuthal deformation of electronic tachyometers, which is formed as a result of the rotation of the alidade, was studied [5].

Due to the imbalance of the electronic tachymeter alidade, the moments of harmful forces cause not only azimuthal deformations, but also alidade bends. The azimuth tilt causes a larger error than the azimuthal deformation. They appear when they rotate in the form of variable elastic deformations [7].

In any study of the angle measurement error of the horizontal circle, it is required that the errors occurring in the coded circle are clearly related. The connections presented in the study were performed by setting the zero calculation on the circle in a certain direction of alidade with respect to the base (see Fig. 1). It is almost impossible to make this direction more accurate than 1-2'. This situation is an obstacle that is difficult to overcome for more specific (small) studies. It is almost impossible to make this assumption more accurate. This situation can create great difficulties for the identified studies. It is necessary to study errors not only every 30°, but also in smaller values, including short-term errors. However, the excellence of the study is that not all tachyometers known to us have the function of a primary device for calculating the horizontal circle attached to the limb. Due to this situation, it is proposed to provide the possibility to display the starting orientation of the horizontal circle (GDBO), calculation on the scale in electronic tachyometers. In practice, it means digitizing the coded limb bars and knowing what limb bars are currently being used to measure. The implementation of the GDBO function allows the universal program to enter the parameters of the studies of angular measurement errors, to place the exposure equipment and to change it when a change occurs [3].

Scheme of the structure of the combination of replacing the base of electronic tachyometers		
I-I	I-II	I-III
		
II-II	II-I	II-III
		
III-III	III-I	III-II

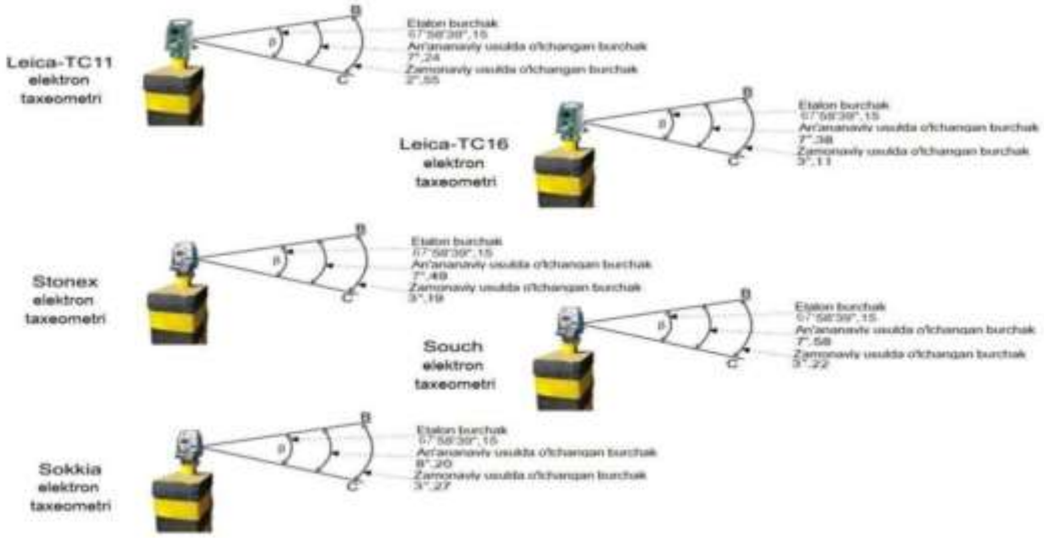


1 – picture. The structural scheme of the combination of replacing the base of electronic tachyometers

IV. RESEARCH RESULTS

This program is very descriptive with features such as robust control of error parameters, correct introduction of corrections, evaluation of the target of studies for this equipment. For this purpose, after conducting research, re-research is carried out in "high accuracy" mode. In this mode, the error parameter and overall precision estimation should be better compared to the initial studies in the "normal precision" mode.

In July 2021 and September 2022, angles were measured and studied by the author at the Bulungur reference base with 5 types of electronic tachyometers (Fig. 2 [3].



2 – picture. Scheme of angles measured on the standard by methods

(Leica TS11, Stonex, Sokkia, Leica TC16 and Souch electronic total stations were measured between July 15, 2021 and September 20, 2022, according to the instructions in the manual, at the most convenient times for measurement).

Elektron taxeometrlarni tagligini mexanik almashtirish kombinasiyasining tuzilish sxemasi

№	According to the initial orientation of the horizontal circle	Measured angle	Standard angle	The difference between the reference angle and the measured angle
1	I-I (Ч 0°)	67°58’41”,26	67°58’39”,15	2”,09

2	I-II (Ч 120°)	67°58’42”,16	67°58’39”,15	3”,31
3	I-III (Ч 240°)	67°58’37”,01	67°58’39”,15	2”,14
4	II-I (Ч 0°)	67°58’36”,04	67°58’39”,15	3”,11
5	II-II (Ч 120°)	67°58’36”,44	67°58’39”,15	2”,31
6	II-III (Ч 240°)	67°58’42”,17	67°58’39”,15	3”,02
7	III-I(Ў 0°)	67°58’41”,40	67°58’39”,15	2”,25
8	III-II (Ў 120°)	67°58’37”,11	67°58’39”,15	2”,04
9	III-III (Ў 240°)	67°58’36”,48	67°58’39”,15	2”,27
10	I-I (Ў 0°)	67°58’41”,08	67°58’39”,15	1”,53
11	II-I (Ў 0°)	67°58’41”,53	67°58’39”,15	2”,37
12	III-I(Ў 0°)	67°58’36”,34	67°58’39”,15	2”,41

It is necessary to determine the standard angle for surveying geodetic instruments. To measure the standard angle, a high-precision electronic tachymeter of the brand "Leica" TS 11 (m_v = 0.2") was used.

V. CONCLUSION

By comparing the results of similar studies performed by Alidada in different installations, it is possible to draw a conclusion about the stability of the metrological characteristics of the interpolator over the entire range of the device. After detecting the systematic errors by means of complete error analysis using the autocorrelation function, the periods of the individual additive sinusoids are found (the skewness of the errors is distributed). In order to provide metrological support for checking all types of electronic tachyometers, it is necessary to develop a comprehensive program for checking angle and distance measurement blocks in the reference geodetic network in field conditions[1,2,4].

It is recommended to use the methods developed by the author for studying electronic tachyometers in field conditions and the general principles formulated by him to evaluate the accuracy of measuring horizontal angles and calculating corrections.

As a result of the analysis of the general structure of the errors of modern geodetic angle measuring instruments, the general structure of the error of electronic tachyometers was established. Its constituent errors are random, systematic, correlated, and unstable over time, and must be quickly detected and accounted for in surveying and calibrating geodetic instruments[2].

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