AN EXAMPLE OF EQUIPMENT SUBSYSTEM FOR AIRCRAFT LIFE EXTENDING MODEL

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***Abstract:** This paper describes the steps and procedures necessary to achieve an acceptable level of aviation safety for military aviation with low time resources and a modern concept of Aircraft Life Extending (ALF) is presented. The concept of ALF is employed to extend the life of the aircraft taking into consideration relevant and critical flight parameters on the aircrafts structure and engine. ALF is incorporated in key flight monitoring operations including: aircraft life prediction models, structural and operational loads models, engine operation models, stress and thermal analysis tools, control schemes, and intelligent acquisition systems. The overall goal of this paper is to define an Intelligent Health and Usage Monitoring System (IHUMS), with which the user can determine the aircrafts life resources.*

***Key words**: aircraft life extending, structure, engine, operational services, health usage monitoring system, resources.*

1. INTRODUCTION

Sustaining the aircraft structure is one of the main challenges in extending use of old aircraft. As aircraft age and as their use increases, damage accumulates in their structures and various subsystems. Aging is understood as a process, where the structural and/or functional integrity of equipment components will be continuously degraded by the exposure to environmental conditions, under which the equipment is operated. Many older aircraft are facing these aging issues, and many more aircraft are expected to encounter them as the Air Force keeps them in service for many years. [1]

The maintenance of the aircraft produced in early 1980's has been performed with the concept of a prescribed fixed number of working hours. The prescribed preventive procedure does not take into account real operational loads of aircraft structure and real thermal loads of engine during service. In the recent years a lot of number of users of this old aircraft have been changed the maintenance philosophy from preventive to corrective procedures with goal to extend the aircraft operational services. [2]
The approach and methods to extend the aircraft life can be very different in dependence of designer team. This various possibilities are effects of new technologies, which are available in nowadays. Possibilities to develop the software, possession of faults data base from previously period of aircraft services, accessibilities of probes (sensors) with acquisition equipments and different sophisticate maintenance equipment are the excellent base for improving the maintenance procedures.

The objectives of this paper are to define the architecture of a dynamic prognostic Intelligent Health and Usage Monitoring System (IHUMS) system for enhancing the aircraft life and to develop a generalized methodology for predicting the remaining useful life of systems.

2. PROBLEMATIC OF AGING AIRCRAFT

When aircraft are getting older operators are increasingly confronted with problems, which are caused by the aging process to which the aircraft are exposed. Aging could degrade the integrity of structures, equipment and other components to such an extend that the consequences of failures could be catastrophic.

To operate flight systems safely within their certified life, maintenance procedures have been defined taking into account their fail-safe design philosophy. This means that any failure within the subsystem, which could lead to a safety critical hazard, would be extremely improbable and fly to failure is the prevailing philosophy. This is a major reason why the On-condition Maintenance Concept (OCM) is applied to the majority of subsystem components. The second reason for changing maintenance concept is the economics aspect. The budget for old aircraft is decreasing from year to year, but operational request remaining the same. With this trend aircraft availability and mission success will be increasingly impaired due to unscheduled maintenance actions required and created Intelligent Health and Usage Monitoring System for every aircraft system and subsystem.

The aging process is irreversible and a lot of factors have been affected for aircraft aging:

- atmnosferic conditions (exposure to normal or salty atmosphere, heat, water, oil, grease, fuel, ultraviolet light, etc., which could lead to corrosion, embrittlement, swelling, overheating, melting or other material degradation, electrical interruptions, short circuits, etc.
- exposure to vibration and acoustic environment, which could lead to fatigue damages, wear and tear, etc.
- envelope and conditions of flight, load and velocity, etc.
- storage, which means exposure to storage conditions, specified by the equipment supplier or in-service practice,
- maintenance activities, which can induce accidental damages, etc.

It is important to recognize, that the aging process of any component cannot be prevented but the velocity of aging can significantly be reduced by:

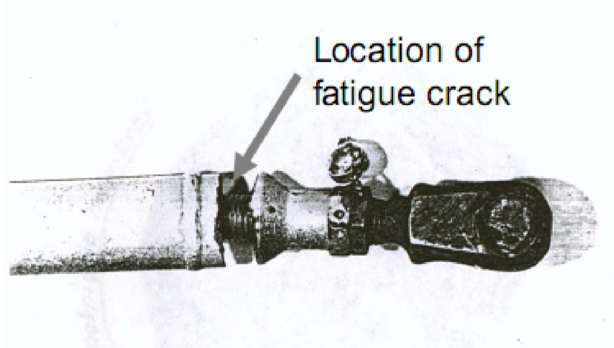
- identifying critical areas and components where aging could have serious consequences,
- reviewing the current aging process of subsystem components in high aged aircraft or of high aged components,
- reviewing the current maintenance procedures and policy regarding the aging problematic,
- defining the Health and Usage Monitoring System for the most critical components for all system and subsystem,
- development the new data-base softwer, which will be consisted from previously maintenance data and data from flight. [3]

As already mentioned, the main goal of this paper is created the model of IHUMS for aircraft life extending on the basis of previously aircraft maintenance data, flight envelope and flight parameters request.

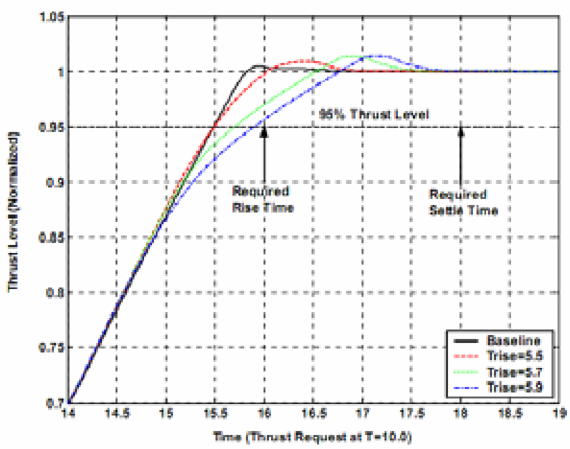
3. APPROACH OF DEFINING THE IHUMS

To create an IHUMS, it is typically necessary to do a three things: first, analysis a previously fault in all system and subsystem of aircraft, to identify the critical positions of structure and system in all life cycle. The example of failure on command lever is given on Picture 1.

Second, all operational flight parameters of engine, controls, hydraulic, electric and other subsystem with tolerance values must be defined, measured and recorded on HUMS. The aim of this stage is defined the representative number of parameters. One parameter must define the foul of system, before full failure. The example of this parameter is the thrust response curves of the selected optimized acceleration schedules during the take-off acceleration process (Picture 2). [4]



Picture 1: The failure of command lever



Picture 2: Response curves of thrust in accelerations

Third, on basic of all selected critical components and operational parameters will be created the airborne aquisition system with apropriate software configuration.

The example of ALE with IHUMS create with described steps is given for helicopter configuration.

4. AN EXEMPLE OF AIRBORNE ALF EQUIPMENT SYSTEM

The ALF monitoring systems typically consist of a variety of onboard sensors and data acquisition system. The main function of the of the airborne ALF equipment system (Data Acquisition System-DAS) is to monitor sensors and provide measurement data over a vehicle's life span to allow the maintenance organization to monitor the vehicle's health and determine when action is necessary to either perform equipment repair or retire the vehicle. This part of system provides extremely flexible, high-performance digital data acquisition systems supporting advanced signal conditioning, integrated data logging, and multiple output types. The data may be processed onboard the vehicle or on a ground station (or a combination of both). System encoders are designed to provide maximum accuracy of test results in the most severe environments [5], [6].

A simple block diagram of the DAS is shown below in Picture 3 using point-to-point wiring between analog transducers and signal conditioners installed within centralized data acquisition units throughout the vehicle. The typical IHUMS system consisted of a PCM (Pulse Code Modulation), DAS and recorder.

Picture 3: Stress analysis of fuselage-absorber connection

The aircraft are usually instrumented with a number of sensors (strain, voltage, acceleration, charge, power, vibration, position, pressure, rate, rotation, speed or temperature). While strain gauges, accelerometers and thermocouples are well known sensors used in existing fatigue monitoring programs, fiber-optics and acoustic emission sensors have found recent application in research programs for health monitoring of structures. Sensors used must have the capability to detect the type, extent and location of the damage within the component without being disturbed by the in flight environment (noise, vibration, temperatures, etc). For example, a number of different types of sensors use during the OLM (Operational Loads Monitoring) program, but the predominant type are strain gauges. These were primarily measure the loading on the airframe, landing gear and flight surfaces, but also included accelerometers and position (synchro) sensors.

The airborne DAS provided excitation for all same implemented sensors. Signals were also acquired directly from the aircraft itself in the form of voltages, discrete signals, or from avionics buses.

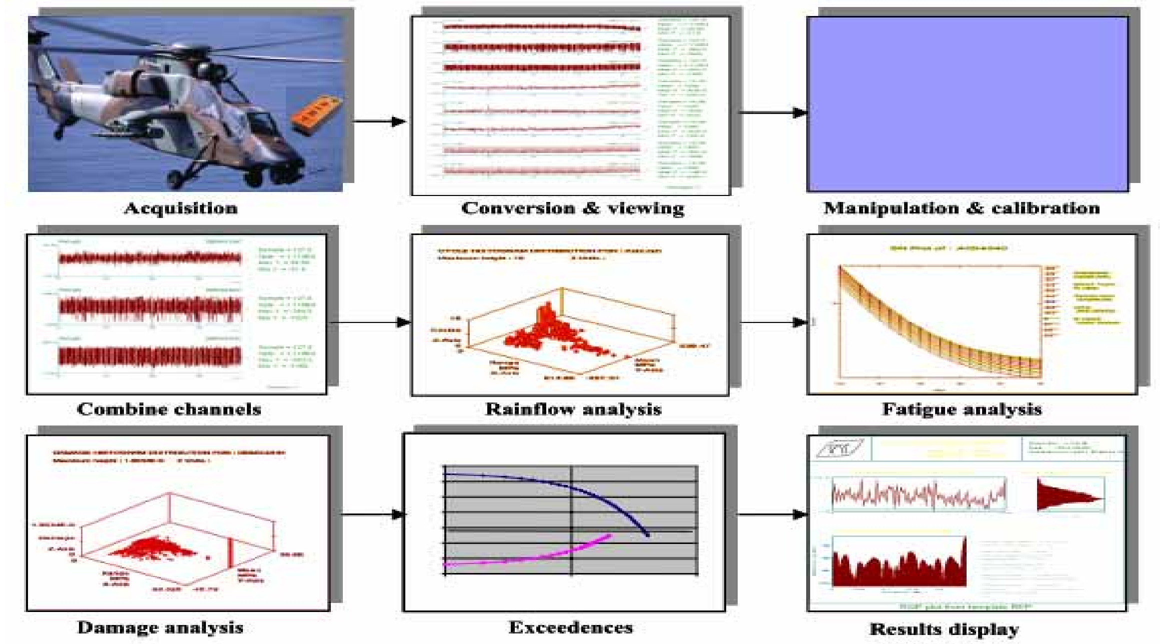
All operational parameters are programmed at the system, card, and frame level using easy to follow menus and familiar Windows commands. Software includes menu selections for file maintenance, calibration and on-line help. A portable laptop computer can be used in the field during system installation for downloading PCM formats and monitoring system operation. Real-time data is monitored without the use of a decommutator.

Samples rates for the parameters were typically set at between 16 and 256 Hz with the measurement bandwidth dictated by the expected frequency range expected for a given signal, and the analysis requirements e.g. For the strain gauges, 256 Hz was typically used, giving a bandwidth of 64 Hz for the acquired signal due to the DAS used.

The sampled data was then stored on solid-state flash memory that formed part of the DAS system itself. The amount of memory required was dictated by complexity of airborne configuration including a variety of sensors, sample rates and duration of flight mission. Once an DAS System is installed, you never have to access the system again, except to change the programming parameters or run a calibration mode. Real-time data is monitored without the use of a decommutator.[7].

5. SOFTWARE FOR ALF APPLICATION

Software includes data collection, analysis algorithm and expert systems to initiate the “decision making process” provides limit of exceeding alerts and supports detailed data analysis and trending.



Picture 4: Typical Data Processing Flow [7]

The key elements of any IHUMS are the real time diagnostic of the structural status of the aircraft using a sensor, linked to a processor and display unit and an intelligent software to compare actual events or accumulation of damage/wear with predefined limits, evaluate the criticality and provide information to other systems like pilot alert or maintenance recording units for later retrieval.

Programs such as LabView, MatLab, MathCAD, Eurilogic Magali and nCode Glyphworks are commonly in use around the world for aerospace data processing applications. Programs such as Magali and Glyphworks provide access to many of the algorithms that are commonly used for flight and fatigue data analysis.

All these software systems allow the user to define and design data processing functions and displays to suit their own application in an automated manner include many features specifically designed for multi channel and multi function processing of fatigue and critical type data (Picture 4):

- Stress-life/strain-life calculations, uniaxial/ multiaxial/ frequency loadings,
- Access to materials data, fracture mechanics,
- Strain-life (EN) method to predict crack initiation, the stress-life (SN) method for total life prediction, and fracture mechanics for crack growth,
- Constant amplitude loads, product duty cycle or design spectra, and variable time histories from sensors,
- Uniaxial and non-proportional multiaxial load cases,
- Frequency response analysis (cross-spectrum, gain, phase and coherence),
- Octave analysis and auto and cross-correlation functions,
- Remez filter algorithm for user-defined time domain filtering, and a user-defined fast Fourier filter,
- Time series created from a rainflow histogram or a Markov matrix,
- Formula processing, peak counting, advanced statistics, range-mean analysis and simultaneous maximum/minimum output,
- A large number of potential thresholds for each aircraft could be generated,
- Automation method could be targeted at setting and updating thresholds using statistics of previous data sets,
- Acumulated time of aircraft operation above threshold level. [7].

6. MONITORING CAPABILITY OF RELEVANT HELICOPTER PARAMETERS

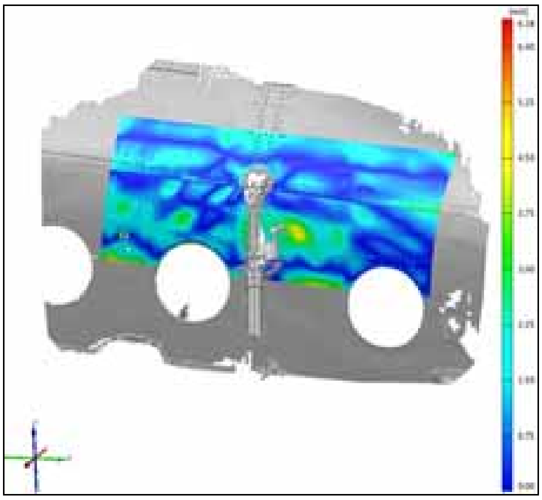
Helicopter health and usage management systems (HUMS) must generate large amounts of data, which are downloaded to ground-based systems. The data are automatically examined on download for damage indications, which provide the immediate go/no-go response required by the aircraft operations management [8]. This level of reactive fault detection and diagnosis is possible in the case of monitoring the relevant number of parameters.

To choose the relevant number of parameters, first the designer must know the general trends of helicopter failures. In this trends must be recognized the elements which damaged go to catastrophic aftermath. On helicopter that elements are structure elements, rotating parts in power distributions and hydraulic systems.

All this parameters can be monitored with different type of sensors. Usually on helicopter structures is used the next types of sensors:

- strain gauges, (load or displacement, wire and wireless), and
- sensors for acceleration, velocty or displacement.

The structure elements will be defined from structures stress analysis and previous operational data. The example of stress analysis and choice of monitoring shock absorbers joint is shown on Picture 5.



Picture 5: Stress analysis of fuselage-absorber connection

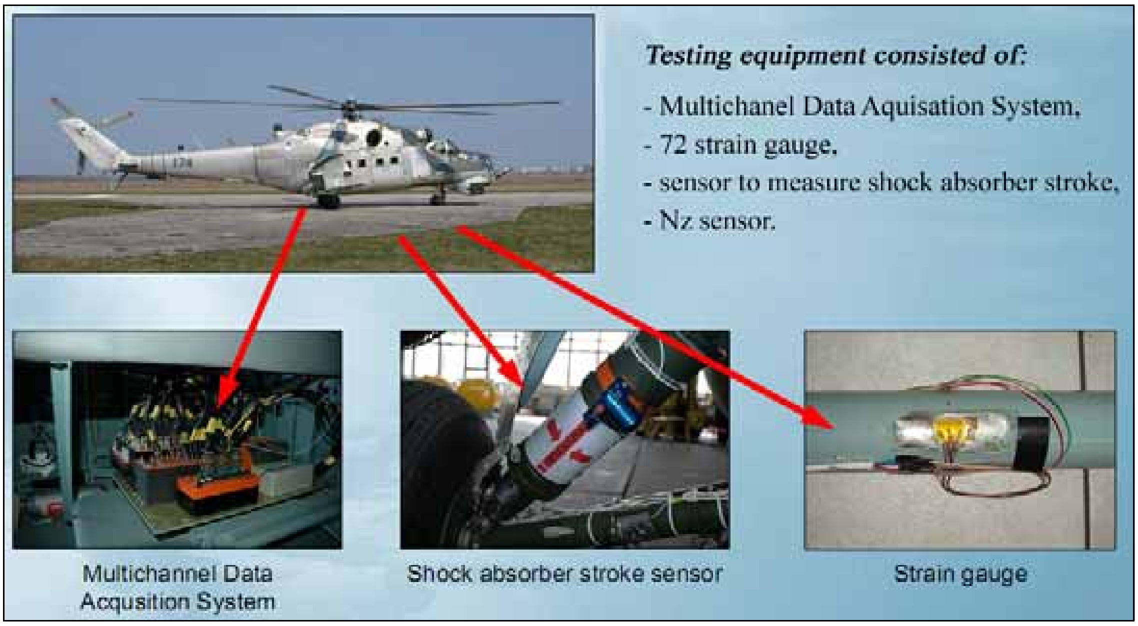
With the same methodology, the strain gauges for monitoring the loads and displacement of structure can be chosen for non-rotating elements (all joint elements, fuel tank-structure connection, elements of tail cone, hydraulic cylinders etc…). These sensors present the Operational Loads Monitoring (OLM) program.

The position of vibration sensor is usually on covers of rotating elements (main and tail rotor, shaft bearing, engine and redactor components). These sensors are primary in structure monitoring system. The higher level of vibration given the first signal of potentially failure of system. Vibration data analysis techniques are investigated for fault diagnosis of helicopter rotating elements (planetary gears, bearing, rotors, etc…). This techniques is the primary elements of IHUMS for helicopters structure.

On Picture 6 is shown an example of configuration acquisition system for ALE program with aim of monitoring vibration and loads state on primary elements of helicopter structure. The sensors are used as inputs to fault classifiers and are shown to detect the fault successfully based on the test data that is available.

The second set of parameters are flights and operational working parameters. This parameters can be divided in few groups:

- flights parameters (airspeed, altitude, normal acceleration, angle of atack, angular velocity and accelerations in helicopter coordinate system, etc...)
- engine working parameters (rpm, exhaust gas temperature, inlet air temperature, pressure before and after compressor, fuel flow, pressure in fuel pipe, pressure in tank, etc...). The number of engine working parameters are depending on complexicity of manufacturer applied solutions.
- hydraulic working parameters (the pressures and flow sensors on different position). The measuring position dependt of previously failure detection. Usually the primary controls of rotors must be covered with sensors, and
- avionics working parameters must be recorded. Usually this parameters are communication between pilot and air traffic control, ON/OFF signals of different instruments (navigation, lighting system, electrical power system, etc...)



Picture 6: A part of acquisition system for monitoring vibration and loads state whole structures

From privously exposure is evidence that for creating one IHUMS is needed to involve a large number of different types of sensors. The large number of parameters are increased the finance resources, and can not authorize the whole ALE programs. The really knowledge is optimisation the large number of needed parameters and select the number which will represent the propriety state of helicopter. Select the adequate number of parameters (sensors) is the fundamental step for creating the IHUMS, select the aquisation system, integate the sensors and creating the appropriate softwer are the final steps.

On Picture 6 is shown a example of configuration acquisition system for ALE program with aim of monitoring vibration and loads state on primary elements of helicopter structure. The sensors are used as inputs to fault classifiers and are shown to detect the fault successfully based on the test data that is available.

7. CONCLUSION

This paper presented the example of IHUMS system for enhancing the aircraft life and to develop a generalized methodology for predicting the remaining useful life of systems. The IHUMS consists of an airborne system, a ground base system and open architecture software. The airborne system acquires and processes data from different sensors and aircraft buses. Measurement data can be selectively displayed in the cockpit and recorded on compact flesh memory. It is easily removable from the aircraft for data transfer to the ground station. The majority of the raw data and processed information is exported to the ground base station after landing. The software enables efficient data and information exchange between the two systems and among other ground base stations.

The approach and methods to extend the aircraft life can be very different in dependence of designer team. This various possibilities are effects of new technologies, which are available in nowadays. The system provides access to a larger data set for trending, prognostics and planning. The ground software is responsible for logging and maintaining all flight and maintenance data, performing aircraft configuration and parts tracking, supporting maintenance and engineering analysis of the flight data, generating engineering and management reports, and archiving data. Users can generate maintenance forecast and maintenance history reports for any collection of aircraft or assemblies, providing for timely and opportunistic scheduling of maintenance activities. The final resultant of implementation IHUMS is:

- Improving preventative maintenance with reducing maintenance costs,
- Increasing aircraft availability, and
- Improved aircraft life.

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