INTRODUCTION OF A STRUCTURE INTEGRITY PROGRAM FOR A MILITARY TRAINER AIRCRAFT

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Abstract

This paper presents introduction of a structure integrity program, called SEWST, developed by Airbus Military with cooperation with Air Force Institute of Technology (AFIT) for PZL-130 Orlik TC-II military trainer aircraft operated in Polish Air Force (PAF). The idea of the program is to thoroughly modernize operation procedure of the aircraft in order to achieve higher reliability and availability of the airplane. The program is similar to Aircraft Structural Integrity Program (ASIP) and benefits from its history. The ASIP addresses many complex aspects of aircraft operation which couldn't be all incorporated within polish program. This article outlines the basic concept and tasks already fulfilled during implementation of the SEWST program.

1 SEWST program genesis

PZL-130 Orlik aircraft was developed by PZL Okęcie (currently Airbus Military – PZL Warszawa Okęcie) in the 1980s and was introduced to service as TC-I version in 1994. Due to constant improvement a TC-II version was designed, which can be mainly characterized by modernized wings (larger wing area and wing span), overhauled and strengthened fuselage with larger empennage and modernized avionics. Since the new version of the aircraft is to be operated for a prolonged time (expected service life of order of 12 000 flight hours) a modern structural integrity program was proposed based on ASIP and MIL-STD-1530C [1]. The general idea and definition of tasks within the SEWST program are presented in following chapters.

2 Preliminary preparations

The first part was an introductory stage focused on data gathering, personnel training and preparation of necessary bulletins for program initialization. Although not much interesting from the engineering point of view it was a crucial stage for program fulfillment since all further modifications had to be approved and concluded with appropriate documents.

3 Units and sets

The second part was focused on the aircraft units and sets. The basic task was to determine which units are crucial for reliability of the whole system (and need to be operated using design life) and which are less significant from the safety point of view (and can be operated by monitoring their actual condition) both according to MIL-STD-1629A standard [2]. One of the concerns was, that the units design life estimated by producers differ much one from another and also did not correspond to the scheduled structural repair scheme, hence resulting in additional unnecessary downtimes.

In order to check possibility of correlating service procedures a detailed examination of unit's reliability had to be carried out. Since some of the units were common with the previous version TC-I as well as other aircrafts operated in Polish Army (jet trainer TS-11, helicopters Mi-2 and W-3) the available historical service data, provided both by producers and depots, has been very helpful in reliability analysis.

4 Aircraft structure durability test

The third task, most laborious and crucial from the point of view of the whole program, was related with integrity of aircraft structure. The main goal of this task was to verify and define total service life of the structure while detecting critical points and developing mitigation techniques which would prevent occurrence of critical structural damage prior to estimated service life. Hence a Full Scale Fatigue Test (FSFT) has been designed during which a specially prepared structure was subjected to characteristic loads for TC-II trainer aircrafts operated in PAF.

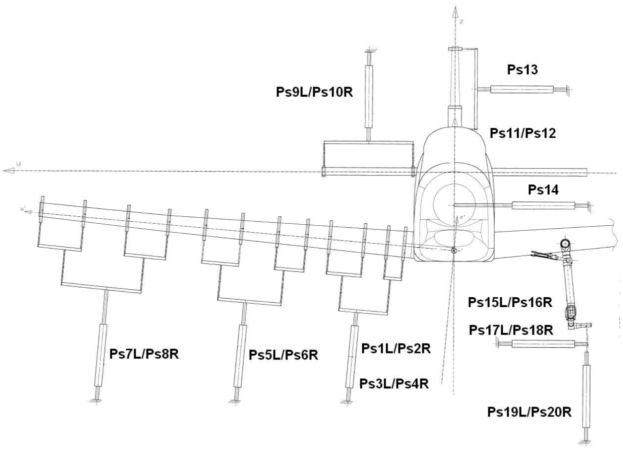

Fig.1 Configuration of the FSFT loading system.

In order to be able to carry out such test and obtain adequate results it was necessary to fulfill several sub tasks [3-4]. First of all a mean flight profile characteristic for Polish Air Force PZL-130 TC-I/TC-II aircraft had to be determined [4] using data registered from Flight Data Recorders (FDR), available thanks to previous AFIT arrangements. The profile was based on the Nz exceedances per flight hour. Moreover it was investigated which exercises and how often had been performed during pilot trainings as well as the number of landing and spins per hour of flight. Second subtask was to determine actual loads acting on the aircraft structure during flight [5]. Basing on the gathered mean profile data a set of experimental flights has been designed, during which loads were measured by means of foil strain gauges. Overall the strain gauge measuring array consisted of 86 different measurement points (Fig.2) recording coherently load signals in 13 different locations.

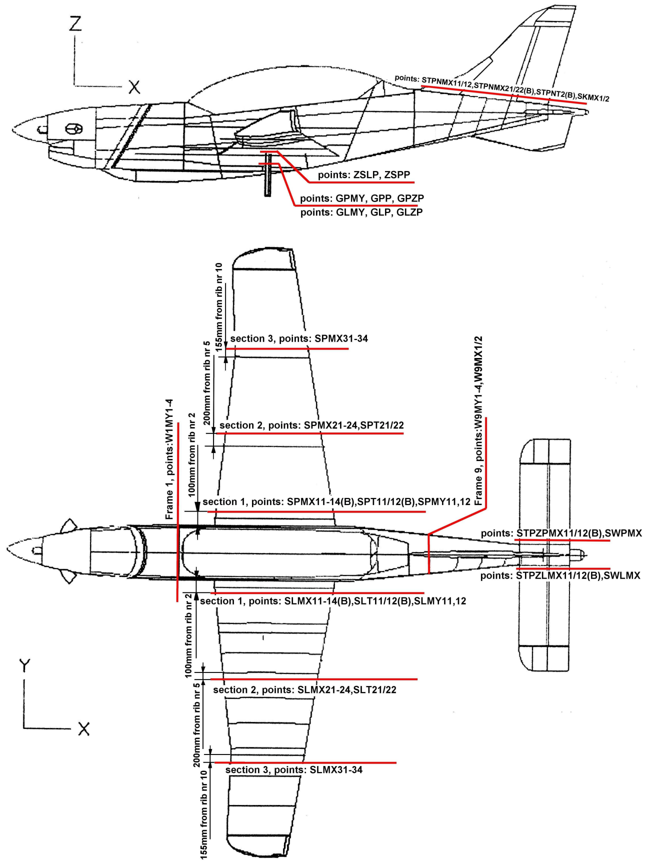

Fig.2 Location of measurement sections.

The obtained data was used to develop a load spectrum for FSFT purpose which consisted of load lines for 20 jacks (Fig. 1) which were used for exerting loads on the test specimen. The load spectrum corresponded to about 200 Simulated Flight Hours (SFH) and represented flight, ground, landing loads as well as buffeting of the empennage.

The fatigue test itself has been designed to be fulfilled within three years considering technical breaks and scheduled Non Destructive Inspections (NDI). The tests are meant to detect cracks occurring during the test in order to determine the Critical Points (CP) [6] in the structure before critical damage occurs as well as to evaluate the crack propagation rate and future operation service intervals. The tests will be divided into three levels:

- Level 1 – conducted every 1000 SFH,
- Level 2 – every 5000 (3000) SFH,
- Level 3 – every 10 000 SFH.

Levels differ by methods used, from basic visual inspection (level 1) through simple eddy current and ultrasonic inspection (level 2) up to automated hybrid structural scans (level 3). Each level also demands different preparation and access to the tested structure from simple stopping of the test, through dismounting of the loading system up to disassembling of wings and fuselage. The general outline of NDI tests is presented on Fig. 3.

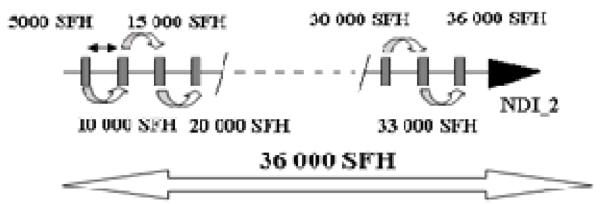

Fig.3 Scheme of the planned NDI inspections intervals.

At the time of publishing of this article the test has reached 10 000 SFH and already some minor structural damage has been found. Most of the findings concern the overhauled fuselage although some cracks were found in secondary structural elements of the wings. According to the manufacturer these damages do not influence the structural integrity of the whole aircraft and the test continues and no repairs were conducted up to this point.

At the end of the fatigue test, achieving 36 000 SFH in April 2014, a Teardown Inspection (TI) is scheduled, during which the structure is going to be taken apart piece by piece according to instructions included in TR-AER-1-2005 document [7]. This will allow conducting detailed NDI of the elements which were not accessible during the fatigue test. The results of TI will grant thorough knowledge of structure's durability and allow to develop appropriate modifications as well as to design repair routines.

Simultaneously to the conducted structural test a global FEM model of the structure was developed which will be used to assess the structural integrity of the aircraft due to damage found during the fatigue test. Additionally a series of detailed submodels will be defined for the particular locations where cracks were found. The global model was validated using actual loads from the fatigue test. Strain determined within the model in locations corresponding to locations of strain gauges during the flight tests were compared in order to check correlation. After some minor corrections satisfactory similarity was reached.

Moreover detailed crack propagation analyses using da/dN method and AFGROW software are planned. Spectra for the calculations will be developed basing on the load spectrum prepared for the FSFT. Results of the analyses in comparison with the propagation of the actual damage will be used to determine inspection intervals for the aircrafts operated according to SEWST program.

Another aspect of the structural part of the program is the corrosion prevention and control program (integral part of the MIL-STD-1530C) which goals are to evaluate corrosion susceptibility and assess corrosion influence on the structural integrity. Within this part of the program a database will be created which will gather all the currently available corrosion data and available mitigation techniques. The influence of the corrosion onset on the residual structure strength will be determined using FEM models.

5 Individual Aircraft Tracking

Structural data gathered during the Full Scale Fatigue Test, numerical analyses as well as the final teardown inspection will be used to determine Critical Points, predict occurrence of damage and propagation of fatigue damage in the structure. These data will allow to predict inspection intervals and overall structural health of an individual aircraft thanks to developed crack propagation curves and uploading of flight data from FDR.

According to SEWST program a Data Center (DC) for gathering and post processing operational data will be created. The DC is supposed to deliver tools for automatic report, estimating intervals between NDI inspections as well as determining detected crack propagation rate. Due to the stochastic nature of the factors affecting the risk of damage occurrence in the aircraft structure, such as dispersion in operating loads or scatter of material properties it is necessary to perform some probabilistic analysis damage risk to structures. Results of these analyses will be included within automated raporting routines of the DC which will allow to operate the whole fleet of PZL-130 TC-II aircrafts more efficiently and with higher reliability.

The final goal of the SEWST program is to develop an Individual Aircraft Tracking system which will allow operating each of the PZL-130 "Orlik" TC-II aircraft individually basing on the collected flight history and developed analyses determining possible occurrence of damage in critical locations. Data recorded during operation will be gathered and stored within the DC which will allow automated estimation of possible damage and schedule necessary inspections and repairs.

6 Summary

SEWST program is already in an advanced stage while the FSFT is being carried out and parallel analyses are developed. Although much work has already been done much has to be accomplished until the program reaches it's designed full functionality. Nevertheless at current state it can be claimed that, after polish F-16 ASIP, SEWST is the most complex and comprehensive aircraft structural program in PAF. Estimated savings achieved by the introduction of SEWST program and abandonment of main overhauls reach the costs of retrofitting the entire fleet of PZL-130 TC-II airplanes.

References

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[7] TR-AER-1-2005

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