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RECENT PROGRESS IN FULL SCALE FATIGUE TEST OF PZL-130 "ORLIK" TC-II STRUCTURE

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Abstract

This article presents preparation of the Full Scale Fatigue Test of the PZL-130 "Orlik" TC-II. After completing the flight load acquisition stage [1] a load block representing 200 Simulated Flight Hours in 194 flights was developed. This load block was further modified in order to introduce fatigue markers on the crack surface [2] visible during Quantitative Fractography, planned to take place during the Teardown Inspection of the structure after completion of the test. Meanwhile, the test rig along with the loading system and the test specimen were prepared at Výzkumný a Zkušební Letecký Ústav (VZLU, Prague, Czech Republic). The test specimen, consisting of the overhauled fuselage, modernized wings and the landing gear, was instrumented with the identical strain gauge measuring system as presented in [3], which was calibrated before the commencement of fatigue testing. Finally, some preliminary issues encountered during the fatigue test startup were highlighted and the outline for future work was described.

Keywords: Full Scale Fatigue Test, Non Destructive Inspection, Teardown Inspection, Quantitative Fractography

1. INTRODUCTION

In 2009 the Polish Ministry of Defence contracted a modernization program for PZL-130 Orlik aircraft to convert it to the TC-II version. The modernization is accompanied by a research program to establish a new maintenance principle. The research program is called "SEWST" (*System Eksploatacji Według Stanu Technicznego*). The program consists of many different tasks but its main objectives concerning the service life assessment include flight tests, Full Scale Fatigue Test (FSFT), determination of Non Destructive Inspection technology routine and Teardown Inspection (TI).

The paper presents a review of the recent progress in Full Scale Fatigue Test. The FSFT is currently being carried out at VZLU Praha in Czech Republic. The test article is a structure consisting of a retired fuselage after some modifications and a brand new wing, characteristic for the TC-II version, assembled by EADS PZL-Okęcie. The structure is loaded in a specially designed test rig by means of 20 actuators. Before the beginning of the test a calibration procedure was performed. Calibration results were compared and validated against the flight test results.

An intensive NDI program is planed to support the FSFT. There are three distinguishable levels of inspection accuracy. In the paper, brief information about the planned NDI activity is given including a description of each inspection level. The main deliverables of the project, the AFIT's work results and staff contribution to the project is highlighted in the following chapters.

2. DEVELOPMENT OF LOAD SPECTRUM

According to the SEWST program assumptions, the load block for the test was developed based on the flight loads measured during experimental flights, which were designed to represent the pilot training program for the PZL-130 airplane [1]. This assured that the obtained loads were consistent with the mean flight profile for the PZL-130 "Orlik" TC-II in Polish Armed Forces (PAF). Measurements were carried out with an array of foil strain gauges described in [1].

According to the program assumptions the load block was to represent four main flight components: taxing, flight, landing and buffeting. Flight and buffeting loads were developed directly using strain data gathered during flights. Since landings performed during the experimental flight program were, untypically, very smooth, the decision was made to develop landing loads separately according to the literature sources [4] and the previously performed drop tests [5]. Similarly, taxing loads showed very low amplitudes and, due to limitations in the number of load lines within the load block, discussed in the following paragraph, couldn't be introduced directly. Instead, three types of artificial taxing loads were developed: full stop, left and right turn; and were randomly placed within the load block. The level of loads was chosen based on the actual loads measured during experimental flights.

Time schedule of the FSFT and technical capabilities of the loading system imposed some limitations for the load block. Preliminary estimations showed that a ratio of about 120 load lines per flight hour (which gives 24 000 load lines in one block for planned 200 SFH) had to be achieved in order to finish the test on schedule. Since the sampling frequency of measured data was in the order of 100 Hz (400 Hz for buffeting loads), the amount of collected data was tremendous. In order to achieve the estimated ratio the gathered data had to be filtered.

The level of filtration was chosen using interactive methods. Based on the preliminary assumptions resulting from the flight profile defined by the Polish Armed Forces, representing 194 flights within the load block, flights were filtered and put together to achieve the number of lines close to the estimated. Since a further reduction was planned and it was necessary to increase the loading frequency for buffeting loads when only empennage actuators operate, the preliminary load block consisted of about 30 000 load lines.

The load block contained 194 flights with each flight involving the following components: taxing, flight with or without buffeting, landing and final taxing. The components were filtered and prepared separately and this is why it was necessary to verify load sequences after assembly in order to eliminate the load lines for which load levels for all 20 actuators differed by less than 5% or for which three subsequent loads for all actuators were either ascending or descending.

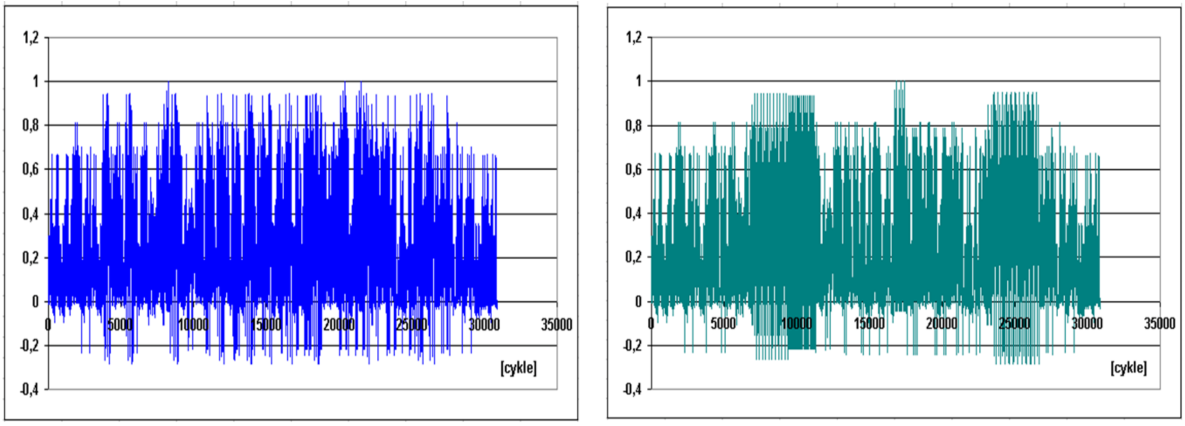
Since the test specimen was not fully constrained within the test rig it was necessary to assure that for all load lines the resultant forces would be in static balance. Additionally, loads acting on the structure were checked along with the N_z factor to make sure that the resultant mass of the aircraft was within a reasonable range (empty airplane and with fuel). After performing all the above steps, the final load block consisted of about 26 000 load lines, which was acceptable due to the possibility of the simulation of buffeting loads.

3. INTRODUCTION OF FATIGUE MARKERS

Since Teardown Inspection is planned after the completion of the fatigue testing it would be most beneficial to be able to determine the growth rate of expected cracks by means of Quantitative Fractography. There are several known techniques of introducing fatigue markers e.g. adding under/overloads or reordering loads within a load block [2,3]. Since the main objective of the preparation of the load block was its correspondence to the actual PAF flight profile, introducing any artificial loads could change the block leading to false outcomes of the whole test.

The prepared load block, shown in Fig. 1a, exhibits local maxima due to significantly different severity of individual flights, which is consistent with the actual flight profile where aircraft is used both in training and display flying. Hence individual flights could be rearranged in such a manner that highly maneuverable flights were gathered in several groups of different lengths (Fig.1b) resulting in distinguishable markers on the crack surface (Fig.2).

The influence of original and modified load blocks were tested using specially prepared Wedge Opening Load samples Fig. 3, manufactured from 2024-T3 aluminum alloy identical with the material used in PZL-130 "Orlik" TC-II.



a) b)

Fig. 1. Tested load blocks: a) before reordering, b) after reordering

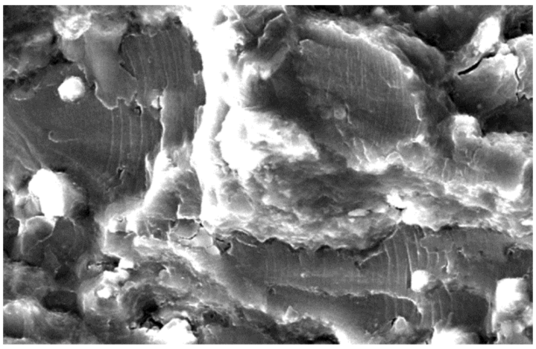


Fig. 2. Visible markers on the crack surface

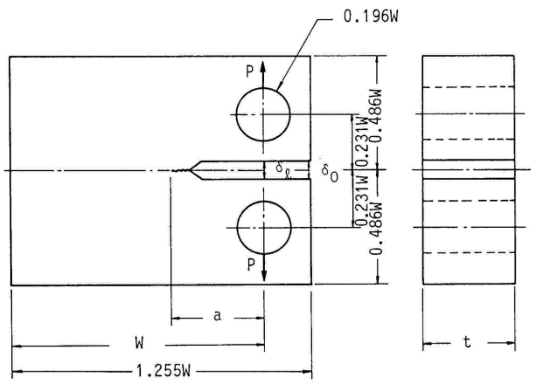


Fig. 3. Wedge Opening Load sample used in tests

4. FULL SCALE FATIGUE TEST STARTUP

The Full Scale Fatigue Test of PZL-130 "Orlik" TC-II is being conducted at Výzkumný a Zkušební Letecký Ústav. A PZL-130 "Orlik" TC-I aircraft was specially selected for the test purposes and modified according to bulletins to the TC-II version. The modernization consisted of overhauling the fuselage and assembling a new set of wings. The completed specimen consists of the fuselage, wings, landing gear and the engine mount. It was instrumented with the identical set of strain gauges as the specimen used previously by the AFIT during Operational Load Monitoring. The measuring system has two main objectives: validation of loads prepared for the purposes of fatigue testing and monitoring strain levels of crucial structural elements throughout the whole test.

Prior to the commencement of the test the strain gauge array was calibrated in a two-stage process. Firstly, loads used during the pre-flight calibration were used in order to verify the correlation between two installations. Secondly, actual load lines taken out from the prepared load block were tested in order to check the strain levels and stability of the specimen when extreme loads are applied.

Since the load block consists of over 24 000 lines that were directly calculated from flight loads, it was not possible to test all of them during calibration. Hence the first full load block was carried out at 30% of the total range in order to verify the stability of the specimen throughout the whole sequence.

After some minor modifications, e.g. caused by of some actuators reaching the end of the range, the setup was approved and the test was ready to start.

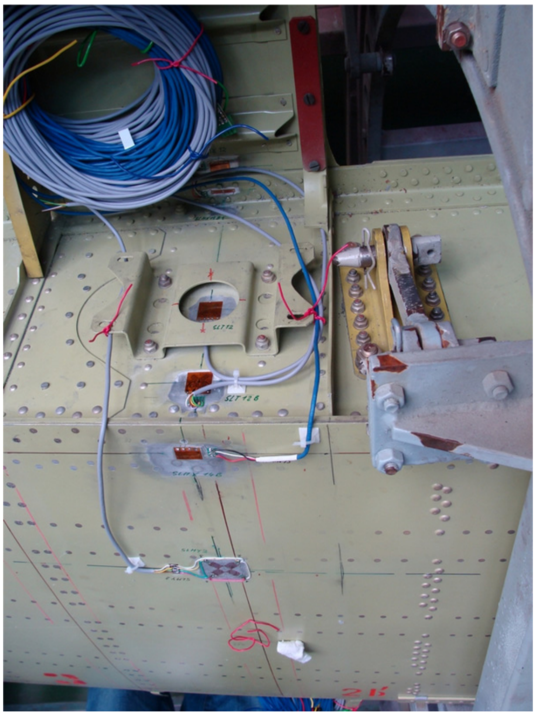


Fig. 4. Strain gauges installed on the test specimen

Fig. 5. Completion of loading system

Fig. 6. Test specimen mounted in test rig

5. NON DESTRUCTIVE INVESTIGATION PROGRAM

During the whole test the structure will be monitored using various methods from simple visual inspection to eddy current or ultrasonic testing. According to the tripartite consultations between EADS, AFIT and VZLU the Non-Destructive Tests will be divided into three levels.

Level 1 is based on simple NDI techniques and will be carried out every 1000 ± 50 SFH. This inspection will be executed by VZLU in accordance with the NDI instructions delivered by AFIT. Estimated time for inspection is about 2 man-hours. No modifications to the test specimen or the test rig will be necessary.

Level 2 - inspection will require using advanced NDI equipment, so additional access to the structure will be needed. This level will necessitate a removal of clamps to grant access to aircraft structure. The inspection will be conducted every 5000 ± 1500 SFH for between 0 and 30000 SFH and the time interval will be shortened to 3000 SFH ± 1500 SFH for 30000 ÷ 36000 SFH. VZLU will also conduct this level of inspection in accordance with the NDI instructions delivered by the AFIT although first inspections will be conducted in presence of the AFIT qualified personnel. Estimated time for this inspection is 2 working days.

Level 3 − detailed NDI inspection including dismounting the wings and the fuselage. Four major inspections are planned throughout the test every 10 000 ± 2500 SFH:

- 12 000 SFH ± 2000 SFH;
- 20 000 SFH ± 2000 SFH;
- 26 000 SFH ± 2000 SFH;
- 33 000 SFH ± 2000 SFH.

The AFIT will be responsible for this level of inspection. Estimated time for inspection is 5 working days.

A reporting routine valid for all levels of inspection has been developed. It includes detailed documentation of detected damage including photographic documentation and detailed definition of damage location as well as methods used to find and verify it. It will allow for a precise identification of damage and its location and enable tracking it throughout the test to verify its severity with relation to structural integrity. Reports will be developed by VZLU and delivered to the AFIT for interpretation and storage.

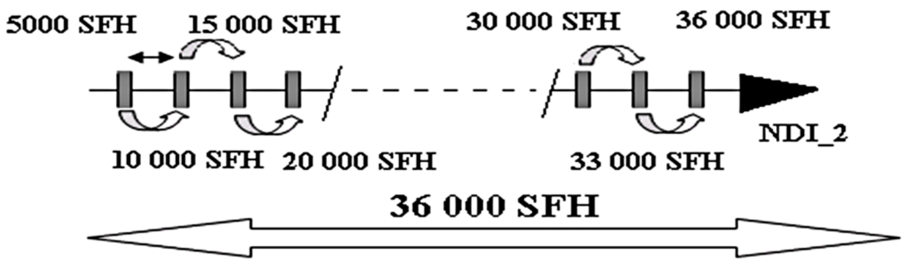


Fig. 7 General schedule of Non Destructive Inspections throughout the test

6. TROUBLESHOOTING AND CONCLUSIONS

In the preliminary stage of the test some minor problems occurred which were indentified by alarming noises. In the first case there was a clear sound of the upper wing skin's buckling. After detailed examination it was decided that since this phenomenon appeared only for high levels of N_z the test will be carried out as planned but with special care taken during inspection of the wing's upper skin. The latter case was identified in the main landing gear region. In this case it appeared that the noise was caused by friction between the landing gear and the wing structure due to lack of grease between these two components. After supplying additional grease the alarming noise stopped.

The test is scheduled for 36 000 SFH. During the first three level 1 inspections, after 1000, 2000 and 3000 SFH, no damage in the structure was found. The first level 2 inspection planned after 5000 SFH is due in early March 2012. Conclusions from these investigations along with further conduct of the fatigue test will be presented.

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