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THE VERIFICATION OF THE TECHNICAL CONDITIONS OF A COMBAT-TRAINER JET`S AIRFRAME

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Abstract

The combat-trainer jet aircraft is an important element in the process of fighter pilot training. This type of aircraft provides a means of transition from basic training on low-speed propeller trainers to piloting high-speed and highly maneuverable fighter aircraft. Nowadays, in Poland, the PZL TS-11 "ISKRA" jet trainers, designed in 1960s, are employed for training purposes. Because of financial considerations this trainer hasn't been yet replaced by modern aircraft that conforms to current specifications and needs.

As is the case with other aircraft in service of the PLAF, the TS-11 fleet has a large reserve of remaining Hourly Service Life (HSL). This opens an opportunity to extend the Calendar Service Life (CSL), so as it matches the HSL. To this end, a series of technical and research activities needed to be undertaken. The Air Force Institute of Technology is conducting the necessary verification of airframe structural conditions in cooperation with the Military Aviation Works No. 1 J.S.C. (branch in Dęblin) responsible for the overhaul and repair operations.

The AFIT's activities in this program include:

- *deformation analysis of the selected surface areas of the wing and the fuselage;*
- *assessment of hidden corrosion in riveted joints;*
- *non-destructive testing of selected riveted joints.*

This paper describes the deformation analysis. As of today, the first stage of the deformation inspection has been completed. At this stage, baseline surface measurements were obtained. Further inspections shall be performed cyclically. The future measurements will be used to establish the areas that deform due to the aircraft operation.

Keywords: Ageing fleet, Extension of Service Life, deformation analysis.

INTRODUCTION

The PZL TS-11 ISKRA, a two-seat jet trainer, was the first jet aircraft designed and manufactured in Poland (at the WSK PZL Mielec, 1963 – 1987). It was operated mainly by the Polish Air Force and the Indian Air Force. Many variants of the TS-11 were available, including reconnaissance, trainer-attack and civilian (modernized ex-military) versions.

In the Polish Air Force the aircraft is currently mainly used in its trainer capacity while its aerobatics variant is utilized by the Polish Air Force Aerobatics Team. In Poland 38 aircraft remain in service, while the Indian Air Force decommissioned all of their TS-11s.

There were several attempts at replacing the TS-11 in the Polish military. The PZL I-22 IRYDA was one of the proposed designs, however this aircraft was never introduced into service due to several difficulties (including two fatal crashes). Although several other foreign trainers were taken into consideration, none of them was accepted. Finally, it was Alenia Aermacchi M-346 MASTER that was chosen as AJT (Advanced Jet Trainer) for Polish Air Force. It will be introduced to service in 2016.

Figure 1. PZL TS-11 Iskra aircraft

MAINTENANCE SYSTEM

Maintaining an aircraft's airworthiness throughout its many-years' service requires a number of overhauls and inspections as well as research support. The aim of research programmes is to indicate factors that may affect service life and durability of the structure, and to mitigate their negative impact. It is of vital importance for aircraft that have particularly reached or exceeded the designed service life.

The PZL TS-11 Iskra, in accordance with the latest maintenance bulletins (airworthiness directives), has a calendar service life (CSL) of 35 years and an hourly service life (HSL) of 3500 flight hours. Reaching any of these limits should result in decommissioning a particular aircraft. The described difficulties in introduction of a new trainer require the operator to fully and optimally utilize the remaining HSL. Table 1. shows exemplary utilization of the hourly service life for selected TS-11s.

Table 1. Illustration of Hourly Service Life utilization

ID	Type	Year of Manufacture	Operator	No. of Flight Hours	No. of Landings	HSL (FH)	CSL (years)
1	TS-11	1976	41. BLSz Dęblin	2723	4741	3500	35
2				1532	2304		
3				2515	4453		
4				2799	4982		
5				2699	5016		
6				2344	3933		
7				1677	2495		
8		1977		2629	4623		
9				1518	2385		
10				2493	4099		
11				2681	4833		
12				1703	3143		
13				3163	5555		
14				2646	4910		

Based on the experience in TS-11 maintenance, the HSL use analysis as well as the technical condition analysis, a new maintenance bulletin [1] has been devised. This bulletin recommends the extension of CSL to 40 years as well as the extension of the CSL between overhauls to 15 years. Both these extensions are conditional on not exceeding HSL as well as on performing a number of activities (specified in the bulletin) on the aircraft.

SHAPE MEASUREMENTS OF SELECTED REGIONS

Geometry measurement of selected airframe regions is one of the activities required by the bulletin. The mid-fuselage and wing surfaces regions were taken into consideration. The Polish Air Force Institute of Technology was appointed to perform this task.

The following regions have been selected for inspection:
- Wing, left side, top surface
- Wing, left side, bottom surface
- Wing, right side, top surface
- Wing, right side, bottom surface

The regions were shown in Figures 2 and 3.

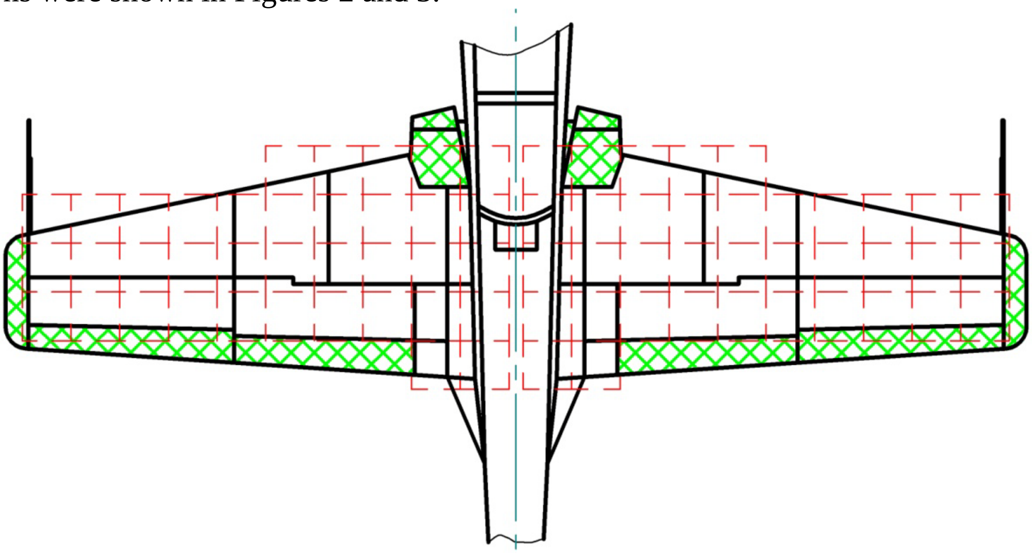

Figure 2. Measurement diagram for the upper side of the wing

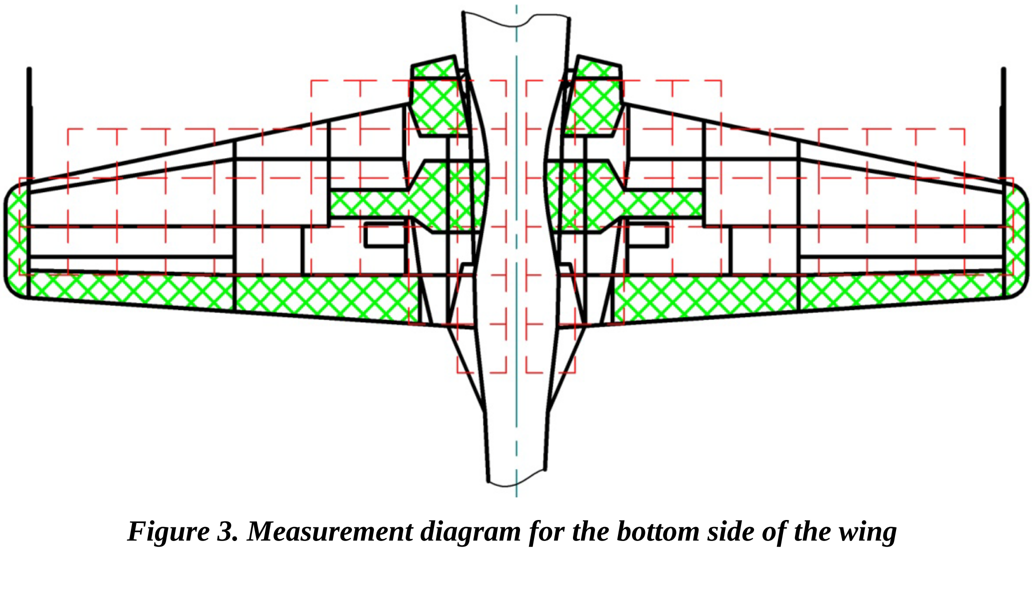

Figure 3. Measurement diagram for the bottom side of the wing

For the fuselage section, the measurement area was limited to the upper surface of the fuselage (above the wing fitting regions) between the frame ribs 12 and 15a. This region is indicated in Figure 4.

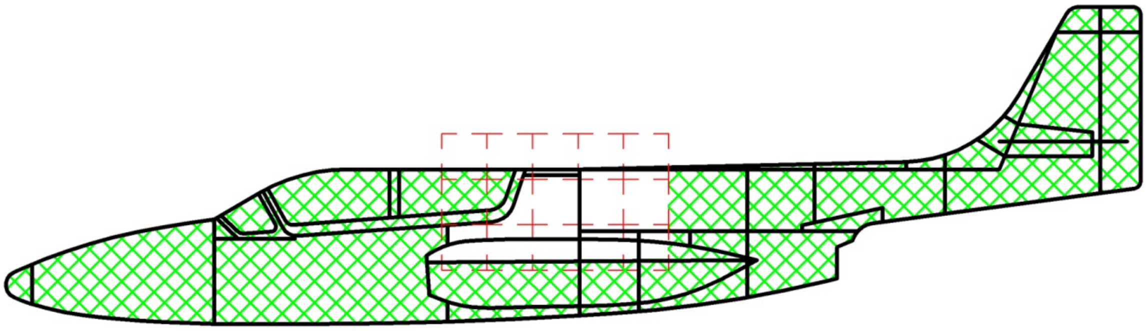

Figure 4. Measurement diagram for the left side of the fuselage

The ATOS III optical scanning system, produced by GOM mbH, was used for the measurements. In the measurements, a series of special line patterns was projected onto the measured surface and the line shapes were analyzed by the system to produce a digital 3D representation of the geometry.

The measurements involved taking snaps of the measured surface until the complete structure was scanned. The resulting multiple scanned patches were sewn together automatically by the ATOS software with the use of markers randomly placed on the measured surface. Markers were placed randomly because the system relied on the pattern recognition to orient the scans in the reference system so that the marker pattern should be different for each scanned patch.

Figure 5. ATOS III is an industrial optical 3D scanner

The scans were taken with the use of a 500x500mm measurement field. This size enabled a sufficient scan resolution, with a low overall number of scans. The surface area of the TS-11 was 17,5 m^2. The overall scan surface was 34 m^2, including the fuselage. This area corresponded to around 136 patches. But this number neither reflected the additional overlapping scans the system needed to connect the patches properly nor it reflected the fact that some of the regions needed several additional scans due to noise, artifacts and surface imperfections.

Depending on the personnel experience and the environmental factors, the number of scans varied, however it can be assumed that the average number of snaps was 340. This gave a multiplication factor of around 2,5. The total measurement time amounted to around 10÷12 hours.

MEASUREMENT RESULTS

As a result of the described measurement procedure 6 digitized surfaces were obtained, which are subregions of the scanned area. These segments are shown in figs 6 and 7. The digital surfaces are made of triangle meshes. Triangle edge length was approx. 1,5 mm in areas of low curvature and approx. 0,3 mm in the areas of high curvature.

Depending on the region this results in:

- 4,5÷4,7 mln nodes – upper wing surface
- 3,7÷4,1 mln nodes – lower wing surface
- 1 mln nodes – fuselage (single side)

The total number of nodes was around 19 million, which corresponded to around 1.5 GB of disk space. The *.stl (STereoLitography) file format was used for storage.

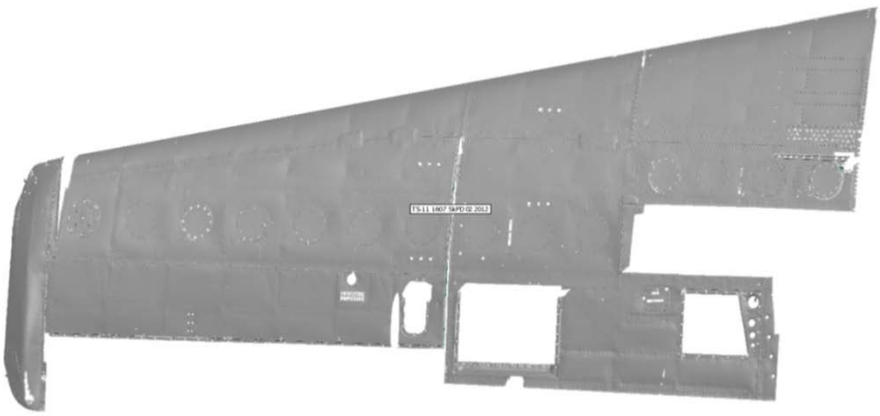

Figure 6. Example scan result – wing, right side, bottom

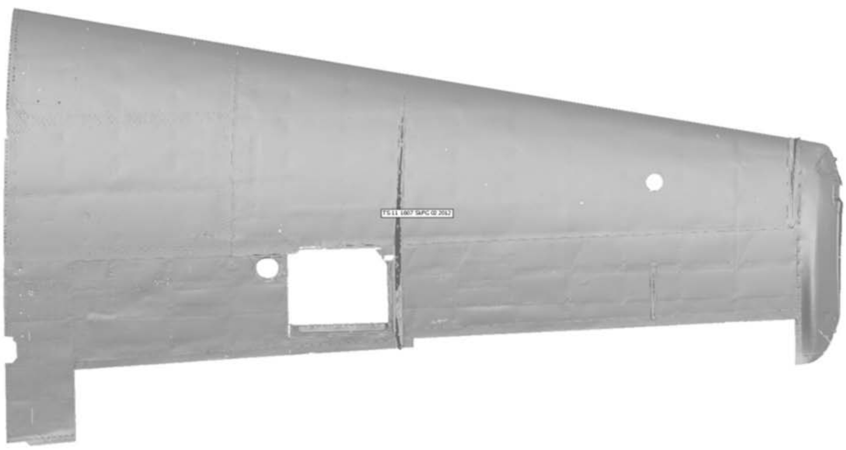

Figure 7. Example scan result – wing, right side, top

The resulting digital models require some processing after scanning. In essence, the holes left by the orientation markers have to be filled – for the most of the circular markers the automatic procedure performed by the system is sufficient. However, several markers and artifacts may be left by the automatic procedure and those have to be addressed manually. Special care must be taken in the high curvature areas, as removing measurement flaws there may lead to unacceptable distortion of the digitized surface. This would introduce large errors at the shape analysis stage.

SHAPE DEFORMATION ANALYSIS

The main goal of the periodical shape measurements is to perform an incremental analysis of the changes in geometry. The surface changes (deformations) occur as a result of structural defects (e.g. caused by runway debris or maneuver strains). The digitized geometry collected in the course of the measurement program will serve as a basis for future shape analyses.

An example shape analysis is shown in Figure 8. Here, shape representations were taken from two different TS-11s. The analysis showcases a plot of differences in the shapes, and serves only as an illustration of the methodology. The deformation baseline can be taken from other similar aircraft, from an earlier snapshot of the same aircraft or from an idealized CAD geometry. In the methodology described in the present paper, the digital representation taken in the first round of measurements will serve as a baseline for all of the subsequent analyses.

In Figure 8 color maps represent the deviation of the analyzed shape from the baseline. The redder regions correspond to convexity, while greener bluer regions correspond to cavities. A proper selection of the surface normal is crucial for the analysis results to be interpreted correctly.

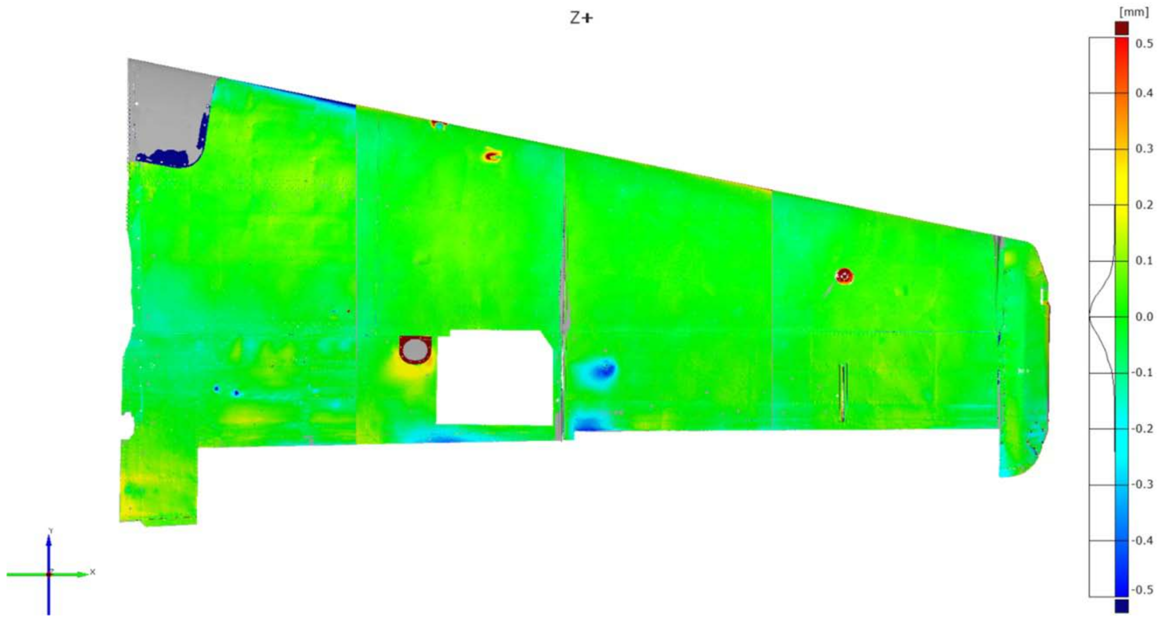

Figure 8. Example of shape analysis

SUMMARY

The deformation analysis is one of the tasks needed for structural monitoring of aging aircraft. The aim of this activity is to indicate the regions of greatest structural concern to the non-destructive inspection personnel. The validity of the method will be confirmed after the second round of surface measurements has been completed. The experience obtained in the course of a similar measurement program for the Mi-8 family helicopters suggests that the method is effective for detection of harmful deformations induced by a prolonged and aggressive operation.

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