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THE DEFINITION OF THE LOAD SPECTRUM FOR SU-22 FIGHTER-BOMBER FULL SCALE FATIGUE TEST

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Abstract

The Su-22 fighter-bomber is a military aircraft used in the Polish Air Force since the mid 1980's. By the decision of the Polish Ministry of Defense the predicted service life for this type of aircraft will be extended to 3200 flight hours. Due to the fact that some aircraft were nearing the end of the service life guaranteed by the manufacturer, the actual service life, determined based on the flight profile in the Polish Air Force, had to be validated. Consequently, the Full Scale Fatigue Test (FSFT) had to be carried out in order to verify that the required service life was attainable.

This article describes the process of preparation of the load spectra used in the Su-22 FSFT. Due to the fact that the Su-22 has a variable sweep wing the whole test was divided into three Stages (landing, flight and flap loads) carried out at different wing sweep angles (30°/45°/30°).

The spectra were developed using the historical data gathered from Flight Data Recorders (FDR), strain signals acquired during the Operational Load Monitoring program (OLM) and aerodynamic calculations.

Keywords: Full Scale Fatigue Test, Su-22 fighter-bomber, load spectrum.

INTRODUCTION

The Su-22 is a variable wing sweep angle fighter- bomber aircraft which has been operated by the Polish Armed Forces (PLAF) since mid-1980's. There are two versions of the aircraft: a single-seated combat version M4 and a two-seated trainer UM3K. The total length of the aircraft is 19 m and the Take-Off Gross Weight (TOGW) is 19 500 kg. The outer wing sweep angle can be changed from 30° for take-off and landings through 45° for subsonic flights up to 63° for supersonic flights. The wing sweep angle affects the wing span, which ranges from 10 to 13.7 m, as well as the wing area, which ranges from 34.15 to 38.49 m^2. The range of vertical overload approved by the manufacturer is between -2 and 6.

As specified by the technical requirements [1, 2], the main goal of the Su-22 FSFT was to confirm the aircraft's structure durability by carrying out a total number of 6000 landings and a total number of 3200 flight hours without damaging the primary structural components. Due to both the limited time to perform the test and the complications with changing the wing sweep angle it was decided to divide the test into three stages including: landing loads, flight loads and flap loads.

The FSFT was carried out on a taken out of service aircraft which had already performed 3127 landings and 1583 flight hours. Before the test, the aircraft was carefully tested using visual, eddy current and ultrasonic Non Destructive Inspections (NDI) during which only some corrosion and minor damages in non-flight critical structural components were found.

OPERATIONAL LOAD MONITORING PROGRAM

One of the milestones in defining the loads acting on the Su-22 structure during operation was the Operational Load Monitoring program (OLM). During the program, 40 strain gauges [3] were installed on the aircraft to measure the wing root rib and main pivot joint bending moments, fuselage bending in five sections and Main Landing Gear (MLG) vertical load as well as bending moments along two axes (Fig. 1). The SSR airborne multi-role recorder from ACRA was installed for data capturing purposes. Moreover, the flight parameters such as velocity, overloads, altitude and angular position were captured for the analysis purposes.

The test flights involved different mission types characteristic for the Su-22 operated by the PLAF. A total of 10 flights were accomplished during which 25 landings (15 x touch&go) were carried out. The flights involved basic, intermediate and high maneuver flights. The most important characteristics captured during flights was the relation between vertical overload and strains both for flight conditions as well as landings with different mass due to different amount of fuel.

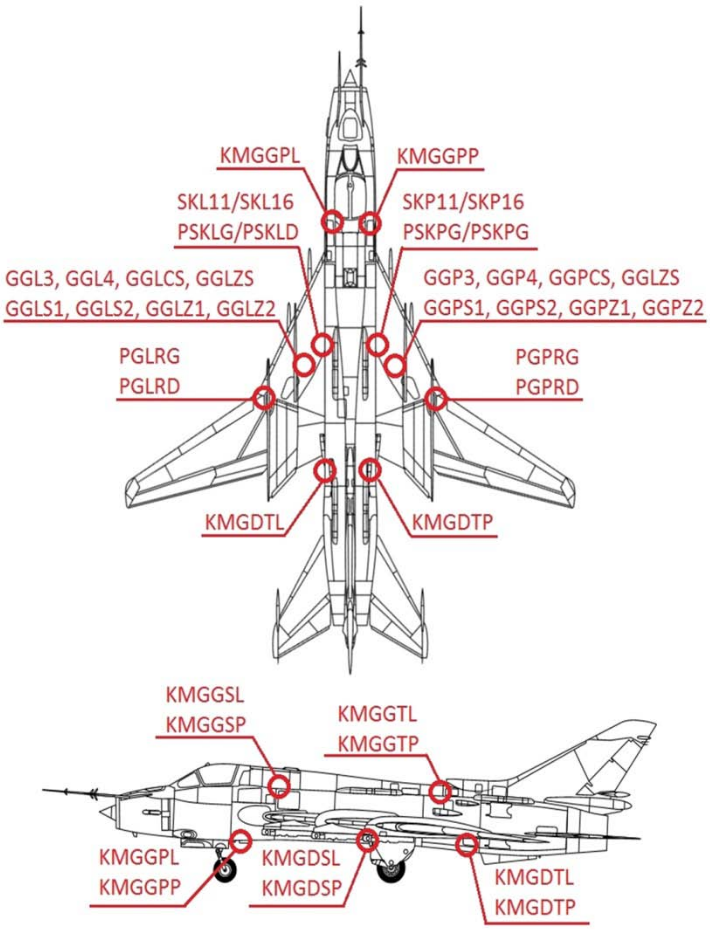

Figure 1. Location of measurement points during the Operational Load Monitoring Program

In order to define the forces acting on the structure during operation it was crucial to determine the relation between forces acting on the aircraft and the resulting strains in the structural components. Therefore a detailed physical calibration was carried out [4] involving loading the structure with a known force and measuring the difference in strains. The calibration was carried out after the test flights in order to set the strain gauges and to minimize the hysteresis loop effect.

DEFINITION OF LANDING LOADS SPECTRUM

According to the technical requirements [1, 2] during Stage I of the FSFT the aircraft with the wing sweep angle set at 30° was placed in the test rig and loaded by means of 16 hydraulic actuators (Fig. 2).

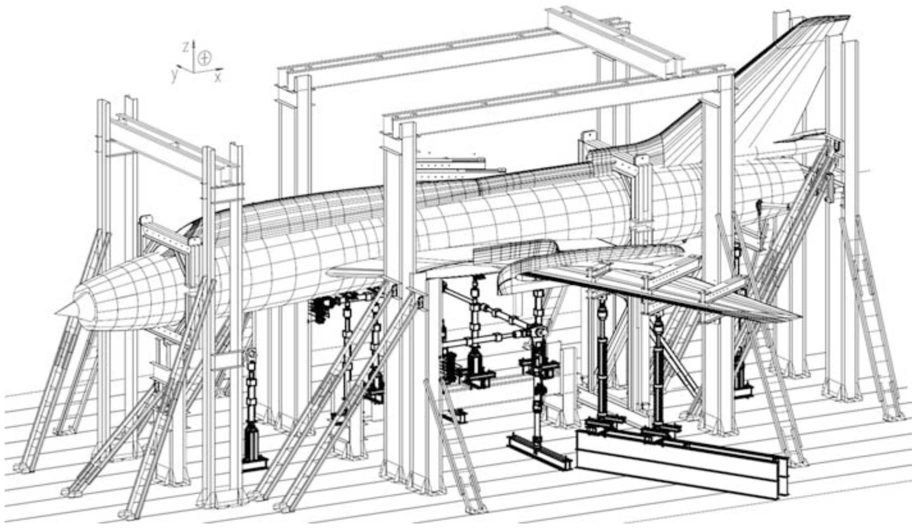

Figure 2. Test stand configuration during Stage I – Landing Loads

It was decided to divide the landings into two categories (full stop and touch&go) and to further, divide each category into eight levels. These levels were defined by dividing the allowed ranges of mass and the vertical overload product into eight subdomains. Then the product of mass and vertical overload for each landing was defined and each load was assigned to the adequate level. This allowed researchers to use the strains measured during each landing to define the relationship between the level of landing and forces acting on the structure. Similarly, the loads acting on the MLG during taxing, braking etc. were defined using the strains measured and force-strain relations defined during calibration. The historical data recorded with the TESTER U3Ł flight recorders throughout the Su-22's operation by the PLAF were analyzed in a similar manner [5], which made it possible to define the landing level histograms for both full stop and touch&go landings. Based on these histograms, the total numbers of full stop and touch&go landings were defined (Table 1).

Table 1. Number of landings carried out during Stage I of the Su-22 FSFT

Full Stop Landings		Touch&Go Landings	
Level	**Occurrences**	**Level**	**Occurrences**
1	1 926	1	92
2	5 603	2	619
3	1 849	3	435
4	589	4	128
5	157	5	42
6	36	6	12
7	9	7	1
8	1	8	1
Sum	**10 170**	**Sum**	**1 330**

The touch&go landings consisted of five load lines: level flight, first touchdown, level flight, second touchdown and final level flight. The full stop landings consisted of thirteen load lines of which first four were identical as in the case of touch&go landings and the remaining nine represented the aircraft in full stop, breaking and turn loads.

DEFINITION OF FLIGHT LOADS SPECTRUM

According to the technical requirements [1, 2] for the Stage II of the FSFT the test specimen's wing sweep angle was set at 45° and the whole structure loaded by means of 15 hydraulic actuators (Fig. 3).

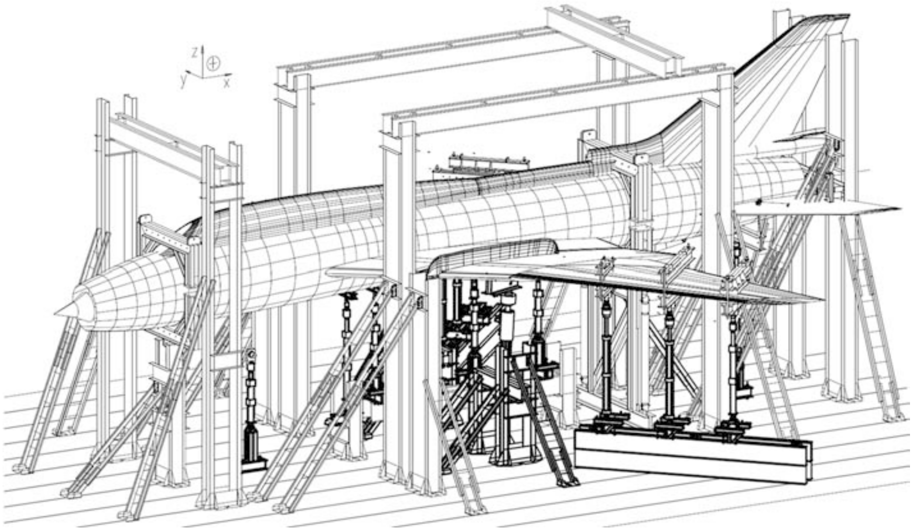

Figure 3. Test stand configuration during Stage II – Flight Loads

The flight load spectrum was defined as a blocked spectrum using the historical data analysis [5], which resulted in the from-to table including the numbers of load cycles (described as mean value and amplitude of vertical overload) per 500 Flight Hours (FH) averaged for the whole fleet of Su-22 aircrafts operated by the PLAF. The from-to table consisted of the total of 26 different load cycles and in order to fulfill the technical requirements had to be carried out 13 times. Using the OLM measurements and the results of the physical calibration [4] the loads distribution (values of forces to be executed by each of the 15 hydraulic actuators) for vertical overload values was defined.

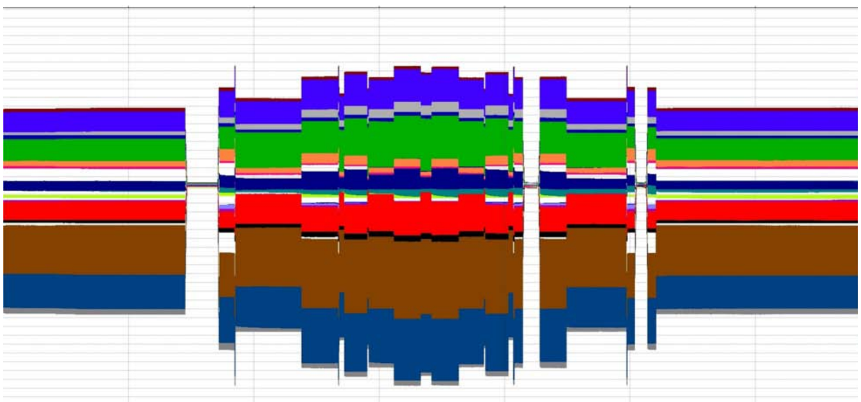

Figure 4. Graphic representation of a single pass (500 SFH) of the Flight Loads Spectrum

In order to initiate the test with a characteristic load block, which would potentially allow to define the test start on the surface of a crack not detected prior to the FSFT, the load spectrum started with an initiation phase consisting of a single load block including a load cycle with the highest mean value and lowest amplitude. Moreover, the load cycles for which the maximum value of vertical overload exceeded 5 were compiled into a finalization phase block carried out at the end of Stage II. The remaining cycles were used in the main phase and ordered ascending, firstly by the amplitude and secondly by the mean value. The initiation phase, one pass of the main phase and the finalization phase are shown in Figure 4.

DEFINITION OF FLAP LOADS SPECTRUM

According to the technical requirements [1, 2] for the Stage III of the FSFT the test specimen's wing sweep angle was set back at 30° while the extended and blocked, both left and right, inner and outer flaps were loaded by means of four hydraulic actuators (Fig. 5).

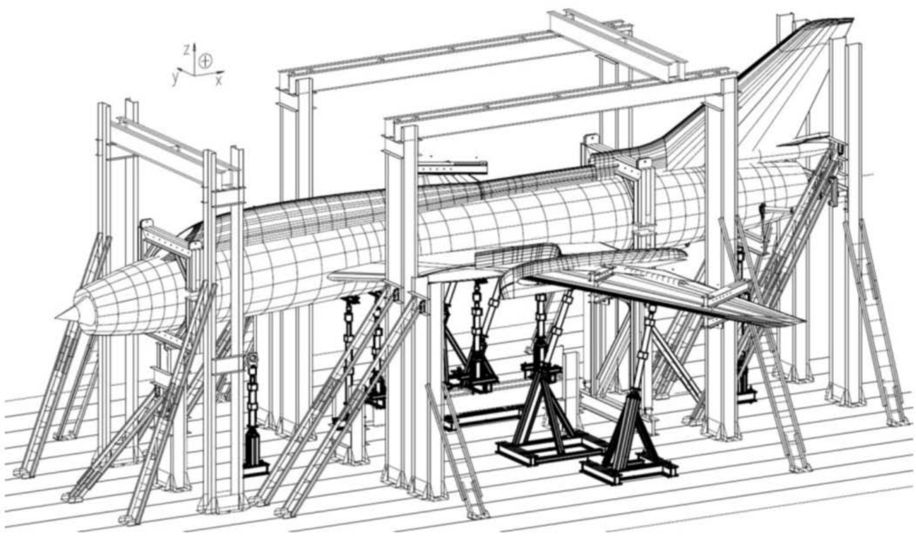

Figure 5. Test stand configuration during Stage III - Flap Loads

Since at this stage the whole aircraft's structure was to be used only as an interface for the flaps, the load spectrum consisted only of loads to be exerted on the flaps by four actuators. The values of forces were defined using flight mechanics in Advanced Aircraft Analysis 3.2 and the XFOIL software by defining the increase in lift force due to flap extension [6]. Two conditions were taken into account: take-off and landing. During take-off only the inner flaps were loaded whereas during landing both inner and outer flaps were loaded. Therefore, one load block consisted of a total of four load lines: zero load, take-off condition, zero load and landing condition. The total load spectrum consisted of 11 500 repetitions of the load block.

SUMMARY

The authors presented the process of defining three load spectra for the Su-22 FSFT. The prepared spectra were based both on historical data as well as on the results obtained in the OLM program carried out on an in-service aircraft.

During FSFT the test specimen was instrumented with a set of strain gauges identical to those used on the OLM aircraft [2]. Due to the complexity of the loading system during the FSFT the values of forces used during the actual FSFT had to be adjusted based on the results of the load system calibrations carried out before each stage of the test during which the measured strain signals were compared with strain signals measured during the OLM program.

The test specimen withstood the test according to requirements [1, 2]. NDI carried out after the test revealed minor structural damages, among which none were in the primary structure [7].

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