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MI-24 HELICOPTER FULL SCALE FATIGUE TEST CONCEPT

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ABSTRACT

This paper presents a general concept of the Full Scale Fatigue Test of the Mi-24 helicopter including the test layout and load distribution, as well as describes the milestones to be achieved. Additionally, some initial work conducted in order to determine both the mass and load distribution in the structure is described. The main goal of the test is to verify the low cycle fatigue life of the helicopter structure (fuselage, tail boom, wings and landing gear). The test will be divided into two main stages at which flight and landing loads will be applied. The authors demonstrate the general test concept, the helicopter's structure fixture and the arrangement of the hydraulic actuators at both stages in order to achieve representative loads during the test. The proposed concept is based on AFIT's previous experience in full scale structural testing, available literature and the experience of the test staff.

Keywords: Full Scale Fatigue Test, Mi-24 helicopter.

INTRODUCTION

Mi-24 helicopters were introduced to the Polish Army in late 1970s. In view of the need to extend their service life and the planned modernization, the Ministry of Defence ordered preparation and execution of the complex Service Life Extension Program for these helicopters.

Based on the previous experience [1-3], the Air Force Institute of Technology (AFIT) proposed the Full Scale Fatigue Test (FSFT) concept of the Mi-24 helicopter structure as well as the implementation of the onboard loads and vibration monitoring system (SMST) in order to extend the service life and Structural Health Monitoring at the same time.

The FSFT will be carried out by the PZL-Świdnik (a LEONARDO HELICOPTERS company) according to the technical requirements developed by AFIT. The structure will be tested both in terms of flight loads and in terms of landing loads. The test rig and the hydraulic actuators load system will be designed (by PZL-Świdnik) to allow for monitoring the reaction forces and moments in the main gearbox fixture. The test will cover only low cycle fatigue loads. The vibration loads, which are crucial for rotorcrafts and their power transmission, will be monitored by the SMST.

The SMST will be a system incorporating classic strain measurements in selected regions (for operational load monitoring), as well as vibration sensors monitoring the power transmission system. The strain measuring system has been already installed on one Mi-24 helicopter designated for flight tests. It will provide load data for the FSFT load spectrum definition. The FSFT specimen will be instrumented with a strain measurement setup identical to that used for flight tests, with additional strain gauges defined for the purposes of load monitoring during the test.

The following chapters present the general outline of the FSFT concept and define the tasks necessary to gather all the data crucial for the execution of the test.

FULL SCALE FATIGUE TEST GOALS

The main goal of the proposed FSFT is to verify the total service life of the helicopter's structure beyond the 4 000 Flight Hours (up to 5 500 FH) and up to 14 000 landings. However, once these goals have been accomplished, a further testing of the structure with inflicted damages is planned (see Table 1). The assumed safety factor of the FSFT is 3, which means that the goal service life of the test structure is 16 500 FH and 42 000 landings. The tested structure will be a taken out of service Mi-24 helicopter which has accomplished 3 250 flight hours and 6 500 landings. The numbers of flight hours and landings at each FSFT stage are shown in Table 1.

Table 1. Assumed goals for the individual FSFT stages

	Current	Stage I (flight loads)	Stage II (landing loads)	Stage III	Final
Flight Hours	3250	2x3250+3x2250		3x500	critical
Landings	6500		2x6500+3x7500	3x1000	critical

The tested structure will be composed of the fuselage, tail boom, wings, landing gear and the main gearbox, which will be used as the fixture for the whole structure. In order to monitor the reaction forces in the fixture, a special adapter will be designed. The adapter will allow researchers to transfer all these six loads (pitch, roll and yaw moments as well as vertical, longitudinal and transverse forces) and to monitor them throughout the test in order to avoid the overloading of the tested structure.

The results of the test will allow the definition of the service criteria after 4 000 flight hours. It is assumed that no significant damages will occur in the primary structure (main load distribution paths), while some minor damages may be found in the secondary structure and therefore these areas will be monitored during operation.

The load spectrum for the FSFT will be defined based on the Operational Loads Monitoring Program (OLM) during which the planned test flights will be executed as well as on the analysis of the current flight program. The measurements during the flight tests will be carried out by 65 strain gauges and additional vibration sensors (Figure 1).

As shown in Figure 1, the strain gauges will be located in the fuselage, tail boom, landing gear, wings, and main gearbox support structure. Strain gauges and vibration sensors will be installed during overhaul allowing access to primary structural elements that are normally inaccessible during operation. In these areas, two or more sensors measuring the same loads will be applied, which will result in a higher reliability of the test.

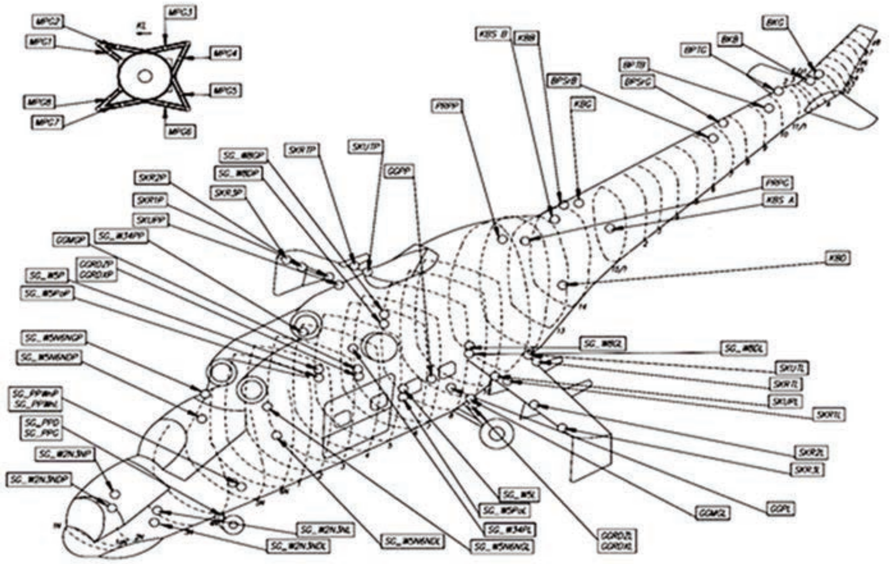

Figure 1. Location of measurement points during the Operational Load Monitoring Program

TEST STAGES DEFINITION

As shown in Table 1, the whole test will be divided into several stages at which loads will be applied to the structure. The two test configurations are listed below:

- Flight loads configuration;
- Landing and Ground Air Ground (GAG) loads configuration.

A crucial task in any FSFT preparation is to achieve a load distribution similar to those occurring in the operational conditions. The loads acting on the structure during operation are evenly distributed throughout the volume (inertial loads) and the surface (aerodynamic loads). The only exception are the landing loads acting on the landing gear.

Using a set of hydraulic actuators in order to represent the actual load distribution it is a compromise between the resulting load distribution and the final number of actuators.

The configuration of the actuators at the first stage aims at representing all the inflight loads resulting from maneuvers (therefore aerodynamic and inertia forces). The structure will be fixed by the main gear box frame and loads will be exerted by means of 39 hydraulic actuators representing the fuselage bending in two directions, tail rotor thrust, fuselage drag, inertia forces and armament deployment loads. The general outline of the actuators' array at that load stage is shown in Figures 2 and 3.

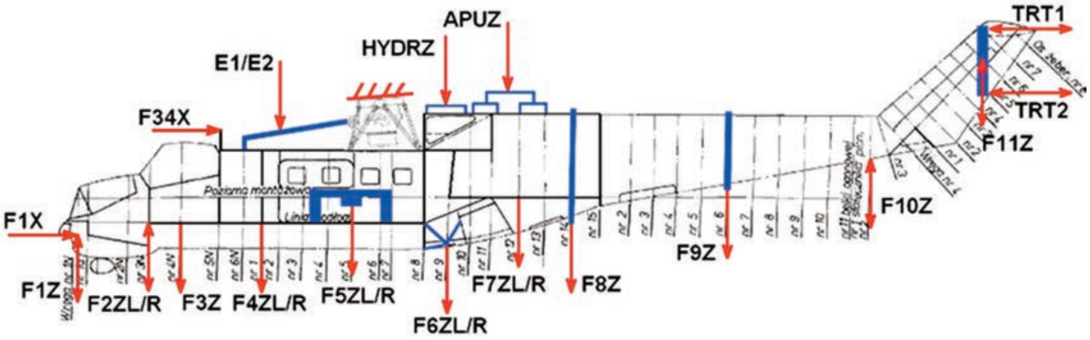

Figure 2. Flight loads stage load introduction scheme – side view [8]

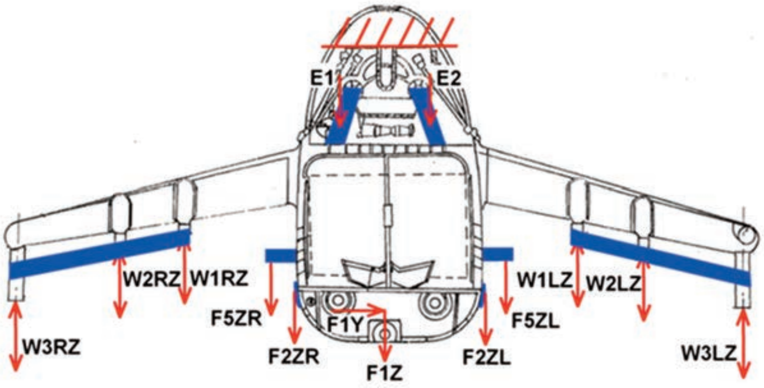

Figure 3. Flight loads stage load introduction scheme – front view [8]

In order to distribute the inertia loads throughout the length of the fuselage, an additional adapter will be put inside the transport cabin protruding through the windows in the closed cabin doors, allowing attaching one actuator on each side (F5ZL/F5ZR). The vertically loading actuators on the fuselage will be placed in pairs underneath the fuselage allowing for the introduction of torque. The wings will be loaded through the three pylons symmetrically and additional actuators will load the wings in longitudinal direction according to the loads due to the armament deployment.

Inertial loads coming from the two disassembled engines, hydraulic block and an APU unit will be also applied by separate actuators.

The proposed concept is based on AFIT's previous experience [1-3] as well as the experience of the test staff.

The second stage will be focused on landing loads and GAG loads, which are load cycles between on ground condition and the most severe in-flight condition. The structure will be fixed by the main gear box and loaded by 35 hydraulic actuators. The main difference in the actuators' layout compared to stage 1 is the introduction of main and front landing gear actuators acting on the actual landing gear structure and the disassembly of the transverse loading fuselage actuators. The general outline of the flight load stage is shown in Figures 4 and 5.

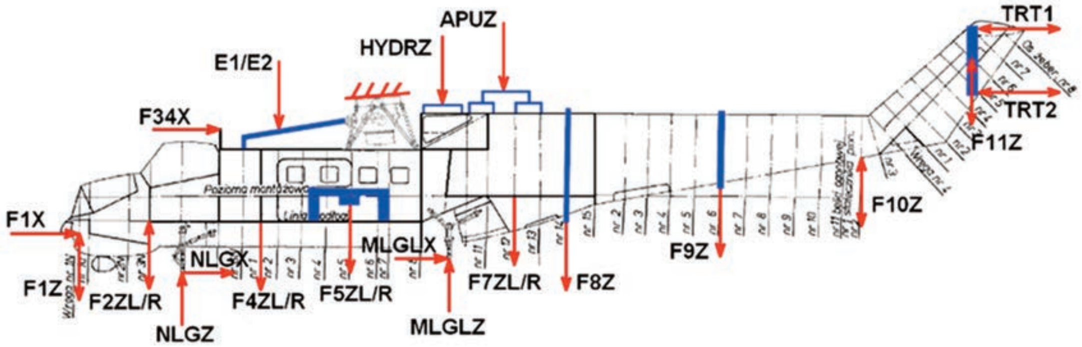

Figure 4. Landing loads stage load introduction scheme – side view [8]

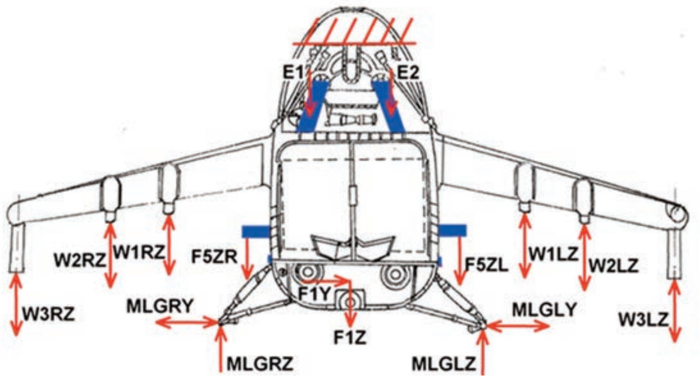

Figure 5. Landing loads stage load introduction scheme – front view [8]

The tested structure will be instrumented with the identical array of 65 strain gauges and 26 additional sensors, which will be redundant in the least accessible locations during the test as well as monitor load distribution paths in some additional structural elements. The sensors will allow both for calibration of the loading system before launching of the test and for monitoring loads during test execution [4-6].

Figure 6 shows the test rig concept allowing for the hydraulic actuators' arrangement according to schemes shown in Figures 2-5. The helicopter's structure will be placed in the test rig and mounted to it by the main gearbox frame through a specially designed adapter. The purpose of the adapter will be both to fix the structure and to measure all the six components of reaction forces and moments. The assumed maximum loads on the fixture are:

- Roll moment - 50 000 to 50 000 Nm;

- Pitch moment: -50 000 to 50 000 Nm;
- Yaw moment: -25 000 to 25 000 Nm;
- Longitudinal force: -50 000 to 50 000 N;
- Transverse force: -50 000 to 50 000 N;
- Vertical force: -50 000 to 250 000 N.

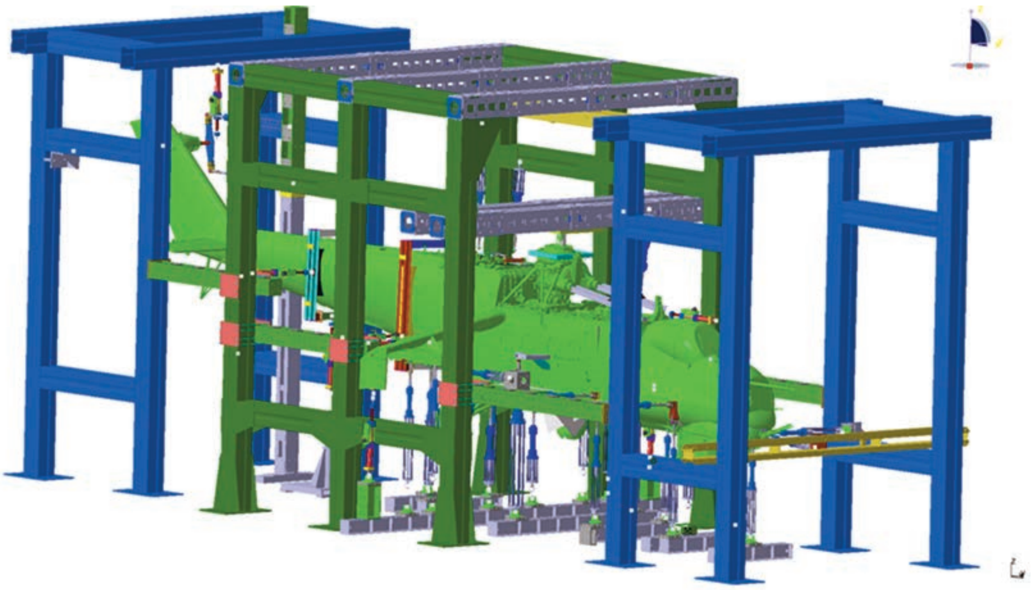

Figure 6. Test rig concept based on the assumed hydraulic actuators layout

PRELIMINARY WORK

In order to estimate the initial conditions for the test, some preliminary tasks had to be accomplished at the initial preparation stage. Given a lack of detailed information about the structure (geometry and mass distribution [7]), major work was done to obtain these data.

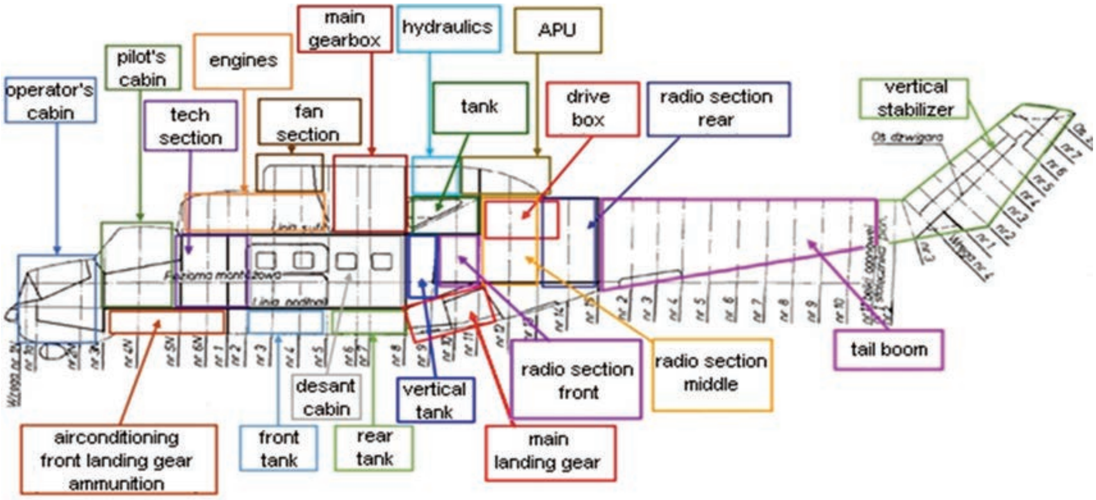

Figure 7. Division of the structure according to main mass components

Firstly, a detailed geometry of the Mi-24 helicopter structure was obtained by means of three-dimensional laser scanning and reversed engineering of the test object (Figure 8). At the initial stage, the outer structure was thoroughly scanned. Secondly, the disassembly took place during which all the significant components were taken out one by one, listed and carefully weighed in order to enable the structure to be divided into several sections corresponding to their function (Figure 7). During this process the location of the center of mass was defined by measuring the weight exerted by each landing gear in a series of weight distribution measurements.

After the disassembly it was possible to scan the inner structure and combine the two measurements in order to obtain a detailed geometry of the helicopter structure for 3D modelling. The scanning process as well as the result of reversed engineering are shown in Figure 8.

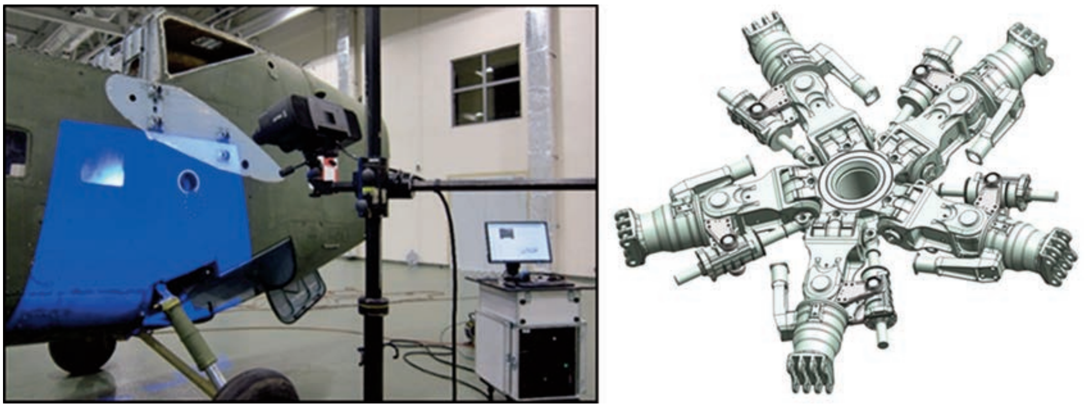

Figure 8. 3D laser scanning in progress and obtained helicopter hub model

SUMMARY

The presented FSFT concept will be used to verify the total service life of Mi-24 helicopter beyond 4 000 FH. The results obtained from the test will allow for the definition of operation routines necessary not only to achieve the desired service life (if confirmed during the test) but also to do so with a low level of risk.

The article defines the concept as well as describes some preliminary tasks already accomplished. However, many more tasks need to be finished in order to prepare the test.

Further work in preparation of the test will include the installation of strain gauges on both flight and fatigue test helicopters, designing and manufacturing of the test fixture adapter including other interfaces, the execution of the flight test campaign and the definition of load spectrum.

Besides enabling the preparation of the detailed geometry model of the whole helicopter structure (crucial for designing all the interfaces and actuators' placement), the reverse engineering methods also made it possible to define the geometry of the aerodynamic surfaces as well as the geometry of the main rotor hub to be used for the aerodynamic loads verification during the preparation of the load spectrum.

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