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Non-destructive inspection of L410 NG aircraft structure during full-scale fatigue tests

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Abstract. A fatigue test is one of the most important steps in the long and demanding way to obtain airworthiness certification of every new aircraft structure. A new type of aircraft structure usually starts with the development and testing a new material, elements, then sub-component and components such as wing or fuselage. A full-scale fatigue test is carried out to prove the design and verify the predicted lifetime and detect damage which can occur during service. Non-destructive inspections are used to detect any damage during the fatigue test. The inspections are divided into the General Visual Inspection, Detailed Visual Inspection or Special Detailed Inspection according to MSG-3 standard. NDT methods such as visual, eddy current and ultrasonic testing are used for the inspections. Also, it is important to determine the schedule of inspections and personnel requirements.

Introduction

Certification of any airframe structure can be performed by numerical or experimental methodology in compliance with airworthiness requirements. Although advanced numerical methods are very sophisticated, experimental verification of any primary airframe structure through full-scale testing is still necessary [1].

The main aim of the full-scale fatigue test is to find out how the aircraft is able to sustain real conditions that will be encountered in-service. A full-scale fatigue testing of airframes and components is carried out to prove the design, to verify the predicted or design life and to reveal structural defects that may appear during service. In generally the full-scale test is an experimental test based on the simulation of flight hours (SFH), which should simulate the real operating condition according to relevant standard [2]. The very important part of any full-scale test is continuous non-destructive inspection (NDI) of the structure. NDI is conducted at different levels and by using different equipment. It is a very time consuming and costly activity. The aim of the paper is to show basic NDI principles and methodologies applied during the fatigue test of L410 NG commuter aircraft.

Full – Scale Fatigue Test of the L410 NG

The structure of L410 NG is designed for 30 000 flight hours (FH). Applied fatigue loading includes all phases of the flight (taxiing, takeoff, cruise including aerodynamic gusts and landing). The set-up of the full-scale test includes many hydraulic cylinders, loads are applied into the structure through the complex whiffle three systems and additionally many gauges and additional measurement systems are installed to the tested structure. The test set-up of the wing together with the middle section of the fuselage is shown in Fig. 1. All the systems are necessary for the test conduction in compliance with the test plan and designer requirements but at the same time all systems make the requested inspections of principal critical parts of the structure more difficult. All these issues must be taking into account during inspection plan development [3, 4].

Fig. 1: Full-scale fatigue test of the wing and fuselage middle section of the L410 NG

Non-Destructive Inspection

The non-destructive inspection plan was created in cooperation with Aircraft Industries, a.s. There are several issues which had to be defined before the start of the experiment:

- inspection areas,
- type of inspection,
- schedule of inspections,
- NDT methods and equipment,
- qualified personnel.

Inspection Areas

Based on the experience and numerical simulations, the critical areas and important parts of the structure were determined and must be inspected. These are some parts of the wing, fuselage, landing gear and tailplane such as spar caps, shear webs, splice and stringer joints, flap hinges, frame segments and bottom skin panels.

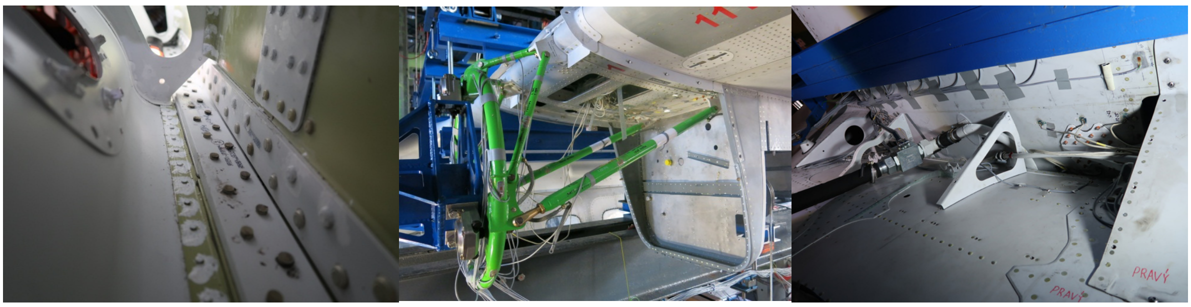

Fig. 2: Inspection areas on L410 NG

Type of inspections

NDT inspections performed during full-scale fatigue tests are divided into three types of inspection in accordance with MSG-3 standard:

1. General Visual Inspection (GVI) – this type of visual inspection detects obvious unsatisfactory conditions or discrepancies, including removal of aircraft parts e.g. fairings, access panels, doors etc. due to get close to the inspected area. The inspection is made under normally available lighting condition such as daylight, hangar lighting etc. [5]
2. Detailed Visual Inspection (DET) – this is an intensive visual inspection of a special detail, assembly or installation. Artificial lighting is required if necessary. Aids to inspection such as mirrors, magnifying glasses can be used [5].
3. Special Detailed Inspection (SDET) – the inspection is similar to the DET except that other NDT methods are used, especially eddy current testing or ultrasonic testing depending on the geometry, location, surface condition etc. [5]

The first step is the selection of the inspection method according to MSG-3. The first option is GVI. The general direct visual method enables the inspector to get the overall view of the condition of a structure to be tested. The method focuses mainly on servicing the external areas. If GVI is not able to meet some of the detection requirements, then DET type inspection has to be used.

A DET inspection is a detailed local visual inspection which is able to detect smaller size damage (cracks) than GVI. Both internal and external areas are inspected during the DET.

A SDET inspection is only considered when neither GVI nor DET inspections are able to detect some hardly detectable damage. This more intensive inspection level is achieved through the use of specialized inspection techniques and equipment which go beyond the ability of human sight. A SDET may use other NDT methods to detect small size damage with using special equipment such as endoscopes or flaw detector devices.

Schedule of Inspections

The schedule defines the inspection intervals depending on the simulated flying hours and determines what types of inspection are to be performed [2].

NDT methods

NDT is a wide group of methods, which are used for testing materials, components, parts or the whole assembly such as an aircraft. Basic methods used for the NDT inspections are visual testing, eddy current testing and ultrasonic testing.

Visual Testing (VT)

VT is the basic, oldest and most common NDT method. It is typically the first step of inspection to detect surface discontinuities or defects by human eyes, which use the visible electromagnetic spectrum of radiation. VT is divided according to EN 13018 into direct (uninterrupted optical path of light) or remote (interrupted optical path light) visual testing, which is performed with special equipment (e.g. boroscope, videoscope etc.). The method depends on the following basic conditions:

- visual ability of the performing worker,
- sufficient lighting of the tested surface,

- capability – the knowledge and practical abilities of the worker who is performing VT.

The visual inspection of the L410 NG must be performed precisely either directly by the eyes or with equipment as magnifying glasses, mirrors, etc. eventually remotely with usage of the endoscopes, especially videoscope.

The inspection is performed by ten (full inspection) or six (partial inspection) certified personnel. Each inspector has an assigned section to be inspected. To ensure a high probability of defect detection, inspection of some critical areas is performed by two inspectors.

Some areas are not possible to inspect directly by eyesight, e.g. FWD or AFT spar area. That is why the videoscope must be used for remote visual inspection. For the activities, the videoscope Olympus IPLEX UltraLite is used.

Fig. 3: Remote visual inspection using videoscope

Eddy Current Testing (ECT)

Eddy current testing (ECT) is one of the most extensively used non-destructive techniques for inspecting electrically conductive materials [6]. ECT method employs alternating currents applied to a conducting coil held close to the test piece. The primary alternating magnetic field generated in this way penetrates the inspected material and generates continuous circular eddy currents in it. The induced currents flowing within the test piece generate a secondary magnetic field that tends to oppose the primary magnetic field. Changes in the induced eddy currents may be caused by changes to a material's electromagnetic properties or changes in geometry, including cracks. After the coil passes over a crack, the impedance of the coil changes and this impedance variation is directly illustrated on the screen of the flaw detector in a view called the impedance plane.

The biggest advantage of ECT is that it is a clean NDT method which does not require any couplant. It is extremely sensitive to flaws, very accurate for dimensional analysis, very repeatable and it is able to give an instantaneous response. On the other hand, it has also some disadvantages and limitations. The method is very sensitive to surface variations and therefore requires a good surface. It is applicable only to conducting materials and the depth of penetration is limited.

During a full-scale fatigue test of L410 NG, the ECT methods are used mainly in the frame of SDET inspections of critical areas identified by the manufacturer. For example, they are used for second layer type inspections of the main splice joint in the middle of the wing, inspection of the bottom panel under the engine nacelle cover, bottom spar cap joints inspection, etc.

Along with the conventional ECT techniques, there is used also Eddy Current Array (ECA) technology in some problematic areas. ECA probes use several individual coils grouped together in one probe. Data acquisition is performed by multiplexing the EC sensors. Measured data is referenced to an encoded position and time and represented graphically as a C-scan image. ECA NDT technology has big potential to considerably reduce the duration of the inspections and increase detection probability.

Fig. 4: ECT flaw detectors, probes and calibration standards

Ultrasonic Testing (UT)

Ultrasonic testing is able to detect the presence of internal material discontinuities. Ultrasound, as well as sound and noise, is the mechanical vibration spreading in the environment due to its elastic properties. The frequency range of ultrasonic vibration is out of audible spectrum, i.e. more than 20 kHz. The range of frequencies between 1 MHz and 20 MHz are used for the conventional ultrasonic testing. Ultrasound waves spread into the material by ultrasonic probe transducers which are different due to used angles and frequencies. The wave spread through the part as a sound wave which is reflected at the interface (imperfection) and may be received back by the probe. The received signal appears on the ultrasonic device display in the form of an echo [7].

Ultrasonic testing is performed only in a few locations of the aircraft structure during the fatigue test. There are some areas where there is no access to use either a visual inspection or eddy current testing.

Qualified personnel

The inspections must be performed by qualified personnel. Personnel must be qualified and certified in the appropriate NDT methods according to the relevant standards. Personnel must have satisfactory physical abilities, which means satisfactory vision, especially near vision (Jaeger test no. 1 or Tumbling E in accordance with ISO 18490 from the distance of at least 30,5 cm) and colour vision (Ishihara test). Vision shall be checked at least every 12 months.

Damage

The inspection plan describes specific damage types that may be found on the structure during the fatigue test. Typical damage is e.g. crack, corrosion, loose or broken rivet etc.

Any damage, which is found, has to be written to the summary list of NDI. Each damage is assigned a number. There is also written the location, type of the damage, size, used NDT method and actual number of simulation flight hours. The found damage is monitored due to its propagation.

Some of the damage can be repaired, especially if the damage achieves the critical size or it is a critical point of the structure.

Conclusions

Aviation is an advanced and important field of NDT application. Along with NDT inspections during production or maintenance, NDI is also an integral part of the fatigue test of the new aircraft structure.

The basic principle of NDT inspection during the fatigue test is to find any damage to the structure, where there are always several critical areas. Therefore, the effort to perform the NDI as detailed as possible. Three types of inspection in accordance with MSG-3 standard are used. GVI inspection is used to get the overall view of the structure without using any special equipment. For DET and SDET inspections aids or special equipment to improve damage detection probability are used. The full-scale fatigue test provides also an opportunity to try new NDI techniques such as ECA technology or some developed special equipment for the limited access areas inspections.

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