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SPECIFICS OF AEROSTRUCTURES EXPERIMENTAL TESTING

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Abstract: *The article provides information about ground tests of aircraft structures at Institute of Aerospace Engineering, Brno University of Technology. The paper presents some of the specifics of the testing.*

Keywords: Aircraft, Structure, Testing.

1. Introduction

Generally, the experimental verification of aircraft structures is similar to other engineering works, nevertheless it has some specifics, which are described in this paper. Essentially, the tests are divided into the ground (laboratory) tests and flight tests. Other division defines the tests for the development and certification, i.e. they are proving the entire set of requirements of aeronautical standards defined the aviation authority, which confirms individual requests with their methods of proof.

Fig. 1: Composite wing structure test.

2. Load definition and conditions

The first steps for the structures testing is its definition and design of arrangement. Based on the geometry and weight, where the aircraft take-off weight is significantly dominating, there are defined the aerodynamic and inertial forces acting on the structure during the flight and each of the maneuvers. Subsequently these forces are expressed in the form of normal and shear forces and bending and torsional

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moments along the construction of the wing, tail and fuselage. There is also defined the maximum load for each load cases and it is declared as the **limit load**.

Subsequently, with regard to the type of construction, there is defined the **ultimate load**, i.e., limit load multiplied by the safety factor that is at least 1.5 and it is properly increased if all "normal conditions" are not fully complied, or there is a certain doubts level about the quality of production technology (e.g. castings, etc.)

From this perspective, it can be pointed out, for example, the influence of temperature and dispersion of production quality for composite structures that may cause a further increase of the required safety factor about 1.5 times.

Similarly, as in other branches, there are also significantly evaluated the fatigue characteristics of the structure, where it is also necessary to define the loading. It is prepared on the basis of a long-term collection of spectrum data about the particular amplitudes of load and their cumulative frequency and on the basis of the typical flight profile. Then the defined spectrum is ready for the planned life-time of the structure, based on the range of the test sample multiplied by the safety factor (3 for complete part), and subsequently it is applied to the structure.

3. Slim composite wing tests

A special chapter of the tests is to prove the static strength of composite wing structure. The wings are tested by application of local forces into collets for reaching of prescribed shear force, bending moment and torque moment. Unlike the metal structures, however, a significant deflection of the structure (see Fig. 1) has to be reflected, and it brings a significant accumulated energy, which is released during structure fail, and it destroyed the whole structure significantly. Another phenomenon of large deflection is the displacement of loading forces compared to the unloaded condition, i.e. thanks to the deformation, the resultant total force distributed over load system moves closer to the root of the wing, and it causes the necessity to shift this total force during the test procedure. The distance of the loading tree arms is also changing by the deformation of structure. Therefore, this phenomenon requires a special process in the design of the loading tree system, using the expected deformation and imaginary location of forces on the radials of circumscribing circle. By this step the result forces have got effect of perpendicular acting on the wing plane during the ultimate load.

Another specification of composites is the impact of the requirements of the regulations, which require "normal operating conditions". While, in case of the metal structures increased temperature due to surface coating is not considered significantly, in case of composite structures it is necessary to demonstrate ultimate strength according to the expected temperature. The regulation condition requires a hot summer day when the aircraft is exposed to direct sunlight. According to the surface color, the tests are realized in the temperature range from 54 Celsius degrees (for white surfaces) up to 90 Celsius degrees (for black or dark blue colors). This temperature difference is very important because the polymer resins with enhanced temperature can be getting close of the glass transition temperature, and it is significant for the technological process and the types of matrix. When approaching this temperature there are changes of viscosity and creep of structure. Generally, it can be said that each temperature increase compared to the room temperature during tests, means the higher structure deformation.

For conclusive tests at higher temperatures is a specific test of aircraft structures, where is the necessity of construction of the "heating boxes" that allow maintaining the temperature and heating of structure. For these cases, the Institute of Aerospace Engineering developed the Heating Chamber of Polystyrene, which was protected as the utility model.

Another phenomenon is also the effect of humidity, which requires a considerable number of validation tests of the material due to moisture.

4. Fatigue tests

Part of the aircraft structures proving is also proving of the operational reliability, which covers the effects of operational damage (impacts) and fatigue life (durability). In the context of aviation, first the safe life philosophy was applied, which required proof of ability to carry all the load cycles throughout life without any fault. Here are applied appropriate safety factors in accordance to the range of the specimen. Nowadays applied approach is the philosophy of Damage tolerance, which assumes potential defect of the structure, and together with maintenance system and structure design there is secure the timely detection before it reaches a critical size. These approaches are of course linked to the NDT methods and inspection systems. The optical methods are used in many cases, but there are also used more advanced methods, for example, the acoustic emission (Cejpek et al., 2015, Juračka et al., 2011) (see Fig. 2) or surface waves.

The significant proportion of aeronautical testing is also partial development tests, where dominate tests for the determination of growth curves of cracks (Klement et al., 2015), strain energy release rate (Matejak et al., 2012), etc.

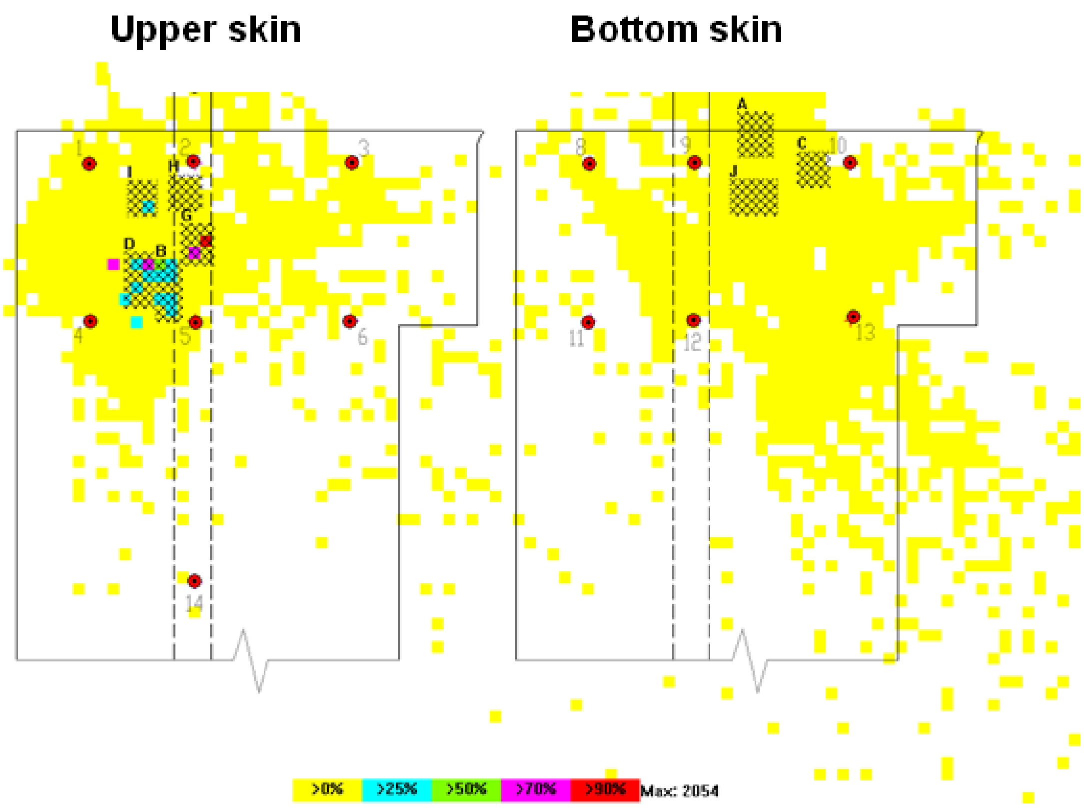

Fig. 2: Structure diagnostic during fatigue test by acoustic emission.

5. Dynamic tests

The last chapter of tests are tests of structures under dynamic load. A typical example is the resistance of the dynamic impact of small particles (stones), but also resistance, for example, the impact of the bird. In the framework of the development tests it may be, for example, impact of dynamic load on the panel (Splichal et al., 2015) with the evaluation of buckling or integrity (separation or delamination of the reinforcements from the skin).

Specific tests are drop tests of undercarriage (see Fig. 3), where the behavior of landing gear during the landing impact (Jebacek et al., 2015) is evaluated. Requirement is to absorb the energy of dynamic impact and minimally springing-back, which is given the aircraft mass and descending speed. Here are successfully used the drop test on the measuring platform with the evaluation of forces, acceleration and landing gear compression. In the case of tests of larger aircraft, it is necessary to simulate also the forward speed of the aircraft, mainly by using impact of the spinning wheel on hard surface.

The last mentioned type of dynamic tests are cockpit tests that prove the emergency load cases. There are either the direct impact of the glider to the Earth's surface at an angle of 45 (which can be simulated as well as quasi-static) or dynamic tests of seats of the larger aircraft.

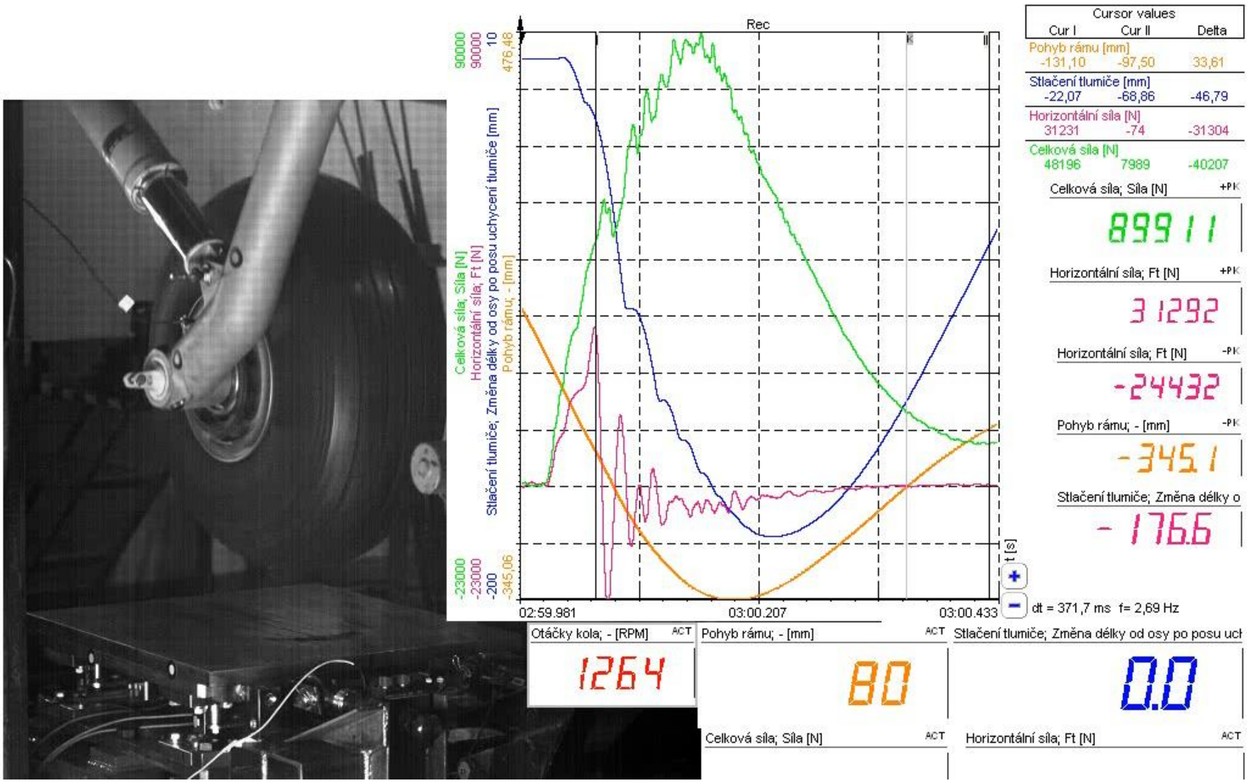

Fig. 3: Landing gear drop test.

6. Conclusion

The article mentions limited extend of some tests of aircraft technology, that were realized by the Institute of Aerospace Engineering, Brno University of Technology, and assist in the development or certification of a number of domestic and foreign aircrafts. The article does not mention any flight tests, which are also carried out to demonstrate the aircraft that are mentioned by my colleagues in another paper.

Dedication (Acknowledgement)

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