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Original Research Article

Experimental tests concerning the impact resistance of a tailplane

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ABSTRACT

The article presents impact tests carried out for the elements of a tailplane. The author describes the experiments in which a head-on and an off-centre collision of a bird-imitating object with the leading edge of the tailplane were recreated. The tests were performed with the use of an impact system with a projectile thrower in form of a 250 mm pneumatic gun. Objects made of gelatine and imitating birds were used in the tests. The collision was recorded by two high-speed cameras positioned at different angles to the axis of movement of a thrown projectile. The article presents the test system, test procedures and the results of the experiments available in form of a recorded image of the collision. Additionally, the effects the head-on and off-centre collisions have on the tested aircraft structures are shown.

1. Introduction

Aircraft structures and elements of aircraft engines are prone to damage during everyday exploitation, which can be caused by the collision of a plane with any foreign body [1–3]. The phenomenon known in aviation as a 'foreign object damage' is behind numerous plane crashes that are fatal for plane passengers and crew. External structures of aircraft are particularly exposed to being struck by hard chips of the runway, rubber fragments of tires, or collisions with animals [2–6]. Such natural meteorological phenomena as hail for instance can also be dangerous and cause damage to the aircraft [7–9]. Furthermore, the transverse impact on the surface of aircraft wings or fuselage (caused, for example by the dropping of a tool) can also lead to severe internal damage in the vicinity of the point of impact, particularly in the case of composite elements [10–13].

Despite the diversity of the causes of collisions, their characteristic feature is the fact that about 90% of such aircraft damage is directly caused by birds [14–16].

According to current standards, any new structural element of an aircraft needs to undergo impact resistance tests. A huge increase in the processing power of modern computers has significantly expanded the capabilities of simulation tests [17–19]; however, a final verification is always carried out with the use of experimental methods. The kind of test to be applied depends on the phenomena it has to recreate and is also closely connected to the type of test instruments used. According to a general division, which is inherently not very precise, two types of tests can be distinguished, i.e. test conducted for small and high impact velocities, and for low and high energies.

Low-energy damage, also referred to as barely visible impact damage (BVID), corresponds to low energies of an impulse resulting from low impact velocities [20–22].

High-energy damage in a macro scale is connected with significant damage and deformation of the structure and corresponds to collisions occurring when the aircraft is moving at high speeds.

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Low-energy tests are conducted with the use of a Charpy's hammer or a triphammer. These tests are carried out only with reference to specially prepared samples adjusted to the used test instrumentation. The impact energy does not exceed 20 J and a maximum speed 5 m/s [23–25].

In high-energy tests, because velocities of 350 m/s (or more) are achieved, the impact energy can even reach the level of 150 kJ [26]. The objective of high-energy tests is to recreate the moment of the collision of a foreign body with an element of the structure or a complex unit in full scale. In high-energy tests, only cases of collisions with a fast moving aircraft are considered. Essential elements of test devices used in this type of tests are ballistic projectile throwing systems in the form of pneumatic guns. In high-energy tests, aircraft structures are bombarded with objects that move at the speed resembling the actual speed at the time of collision [27]. In ballistic tests, the natural set of velocities is therefore reversed; instead of a fast moving plane, a fast moving bird or a foreign object is used.

Originally, real birds killed immediately before throwing were used in impact tests. However, due to hygienic and environmental reasons, tests with real birds have almost completely been abandoned. This has also contributed to the establishment of standards concerning the construction of a bird-imitating substitute. Studies showed that, during the collision, a bird behaves similarly to liquid or gel, and the adoption of such a model brings good results corresponding to the process in which a real object is involved [21–30]. Therefore, projectiles made of gel or gelatine with the addition of solidification accelerators are now commonly used.

Since 1970s, impact tests are dominated by head-on collision tests. This means that the bird-imitating object strikes the central area of the exposure of the test structure. Such tests are usually conducted for windshields [27–32], fairings [33], the leading edges of wings [34–39] and tail elements [18,40]. Only a few studies deal with cases in which the direction of impact is not perpendicular to the surface of the test structure [40–42]. There is no information on how an off-centre collision, in which the axis of the movement of the projectile is displaced in parallel with respect to the median plane of the test object, affects the test structure.

The measurement of elastic deformations occurring at the time of collision in impact tests is an extremely difficult issue. Strain gauge measurements enable only a limited range of measurements [43]. Strain gauges are difficult to apply and can be used only once. The application of moiré patterns [44,45] is very helpful; however, their applicability is limited to small areas of specially prepared samples. In the case of large objects, i.e. full-scale real components, the best results can be achieved when high-speed high-resolution cameras are used, because they enable even long objects to be recorded with an ensured high accuracy of analysis.

The objective of the study was to obtain information using high-speed video recording techniques on how the off-centre collision affects the leading edge of a wing or a tailplane and what significant differences there are between the off-centre and the head-on collisions.

2. Test object and stand

The tests were carried out for a PZL M28 vertical tailplane (Fig. 1a). In the impact test, a collision of a gel projectile weighing 3.6 kg with the leading edge of the tailplane was examined.

During the tests, the tailplane was vertically mounted onto the tripod (Fig. 1b), which was fixed to the ground with a set of brackets enabling the proper positioning of the test object with reference to the barrel of the pneumatic gun.

The experiments were carried out on a test stand developed at the Institute for Sustainable Technologies – National Research Institute (ITeE-PIB) and composed of a projectile throwing system, two high-speed digital cameras, halogen lights, a length model and white background making the analysis of the image recorded by the camera much easier [47]. The camera for speed measurement was positioned perpendicularly to the axis of the barrel. The other camera, intended for the observation of the collision, was placed directly in front of the test object at an angle of 30° to the axis of the barrel (Fig. 2). The cameras can be placed on the left or the right side of the barrel, depending on the location of the impact zone.

The collision was recorded with the use of a Phantom V 710 monochromatic, high-speed camera enabling the recording of an image at a speed of 7500 frames per second and an resolution of 1208×800 pixels. The speed of the impact was also recorded with the use of a monochromatic high-speed camera. However,

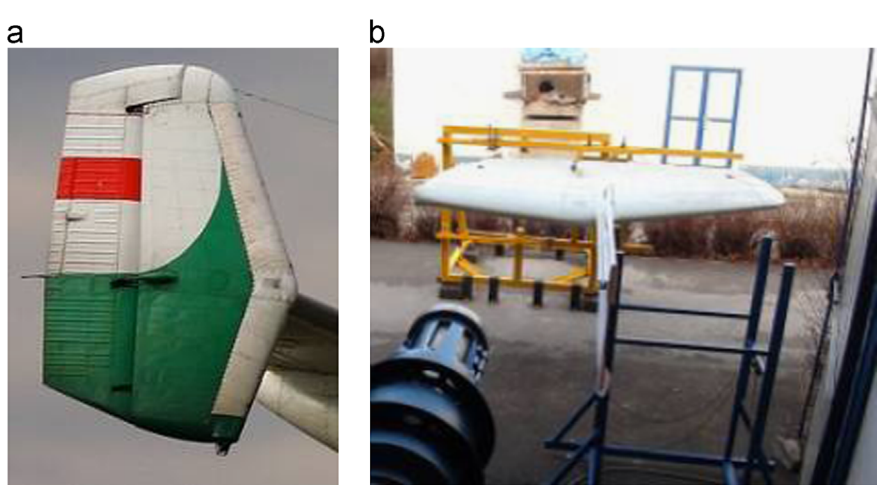

Fig. 1 – Real test object (a) PZL M28 vertical tailplane, (b) test object mounted on a tripod.