PRELIMINARY INVESTIGATION INTO THE DAMAGE OF THE HORIZONTAL STABILIZER OF MOTOR GLIDER DUE TO LOW ENERGY IMPACT

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Abstract. The investigation presented focuses horizontal stabilizer of AOS 71 electric engine powered motor-glider. Preliminary loading cases analysis indicated that the stresses due to the anticipated flight loads acting on the stabilizer will be low and therefore the load caring skin can be made with a hybrid glass/carbon fiber fabric of 200g area weight only. A typical tail lay out chosen for AOS 71 results in a low placement of the horizontal stabilizer which makes it very vulnerable to an accidental low energy impacts. First, to estimate the extend of such a damage drop tests were carried out. The results provided input data for the FE analysis carried out to estimate how much such a damage can decrease stiffness and strength of the stabilizer.

Keywords. Low energy impact, sandwich structure

1 Introduction

Sandwich structures have found broad application in various structural parts of modern airframes. Such structures consist of thin facesheets supported by honeycomb or foam core. While the facesheets are to carry in plane loads, a foam core is to support the facesheets in out of plane direction and prevent premature local buckling in case of shear or compressive loading. Design of sandwich structure is a well known procedure and advantage of such a structure over laminates when structure weight saving is one of the major goals is well documented, however there is a major drawback resulting from application of such structures. They are very vulnerable to low energy impacts, and furthermore, the effects of such impacts are difficult for detection and assessment. Impacts can produce local facesheet-core delaminations as well as local damage to both the facesheets, (fiber breaking and resin cracking), and core, (crash, dents). Under tension lading such a damage may result in catastrophic crack propagation. Uunder compressive loading it may enhanced premature local buckling of facesheeds.

In the case of AOS 71 motor glider, Fig.1, weight reduction of the tail section was of particular importance. It was done by keeping weight of the horizontal stabilizer as low as possible. Stress analysis indicated that the skin of torsion box could be made with just one layer of carbon fabric of 200 g/m^2 area weight. However such a structure was not appropriate because of buckling threat and the only solution to the problem was a sandwich structure. It prevented buckling but did not remove vulnerability of the stabilizer to impact damage. Because of the tail configuration and resulting from this low placement of the stabilizer as well as possible operating from ground airfields low energy impact damages, (up to 20J) can be of real threat. For this reason a test program had been designated. The purpose of it was to asses extend of such a damage, its severity and reduction in stiffness of the stabilizer.

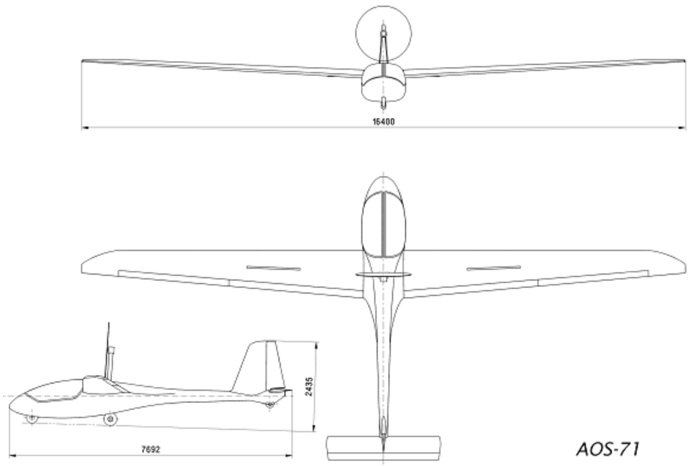

Figure 1: AOS 71 lay out

2 Structure and manufacturing of the stabilizer

2.1 Structure

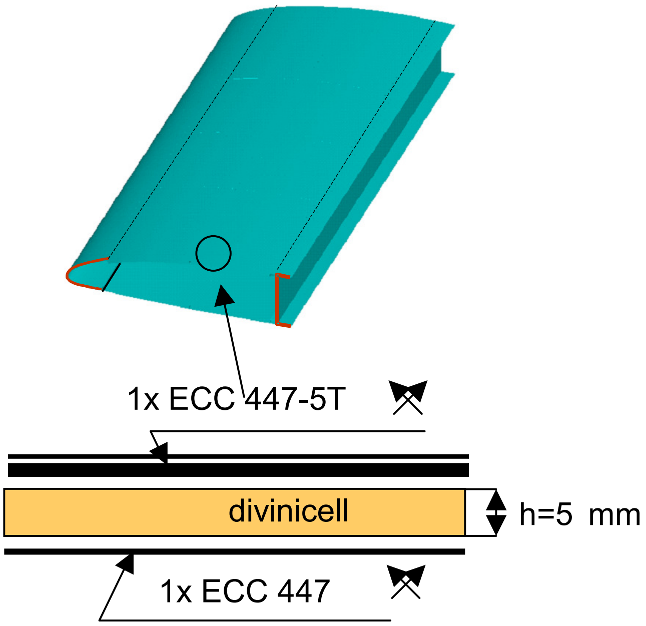

Figure 2: Structure of the stabilizer.

Structure of the stabilizer section under consideration is shown in Fig.2. The section forms a torsion box and is composed of a spar and an upper and lower sandwich skins. The outer facesheet of each sandwich skin is made of a hybrid glass-carbon two part fabric ECC 447-5T, (initially the fabric parts adhere to each other but can be easily separated after impregnation). The area weight of the carbon one was 160g/m^2 and the glass one was 40 g/m^2. Each of the inner facesheet was made with carbon fabric ECC 447 of 160 g/m^2 area weight.

2.2 Manufacturing

The stabilizer section and specimens for the drop tests were fabricated with the use of the wet lay-up and vacuum bagging assisted technique. The upper and lower skins and spar were formed and initialy cured at room temperature in a separated molds. Next, they were assembled and glued together with the same epoxy resin that was used for impregnation of the fabrics. Next, the final curing was applied.. For fixing and loading purposes two external ribs made of 15 mm thick playwood were glued at the sablizer section ends.

The sandwich plates designed for the drop test are shown in Fig.3. The structure of the snadwich plates and the curing process were the same as those of the stabilizer skins.

3 Experimental procedure

3.1 Test procedure

All the tests were carried out at room temperature

3.1.1. Drop tests

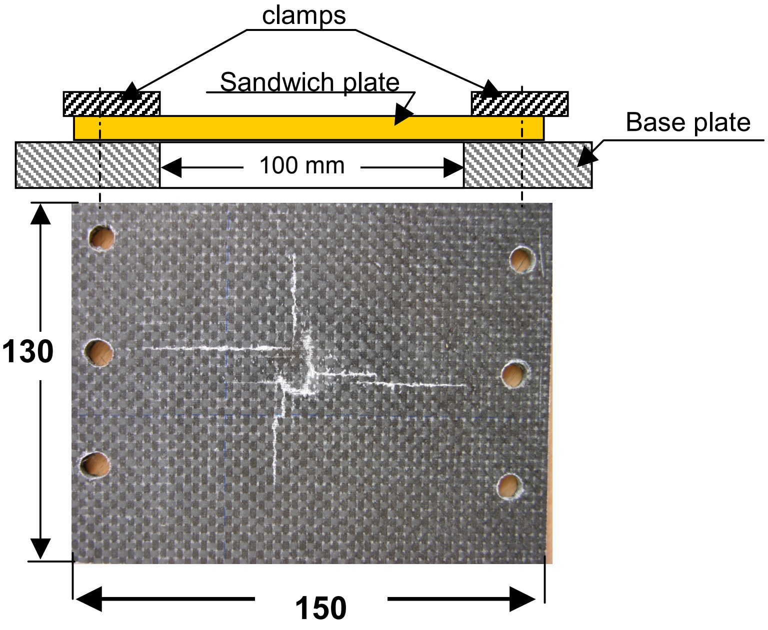

Figure 3: Sandwich plates designed for the drop test

The flat tests coupons were clamped at their edges to the 50 mm thick base steel plate, as shown in Fig3. The test section was confined to a 100mm x 100mm square. Each impact was made at the plate center at the approximate velocity 6m/s. A steel 1000g projectile used was ended with 20 mm diameter hemisphere The corresponding energy of each impact was about 18 J.

3.1.2. Component stiffness test

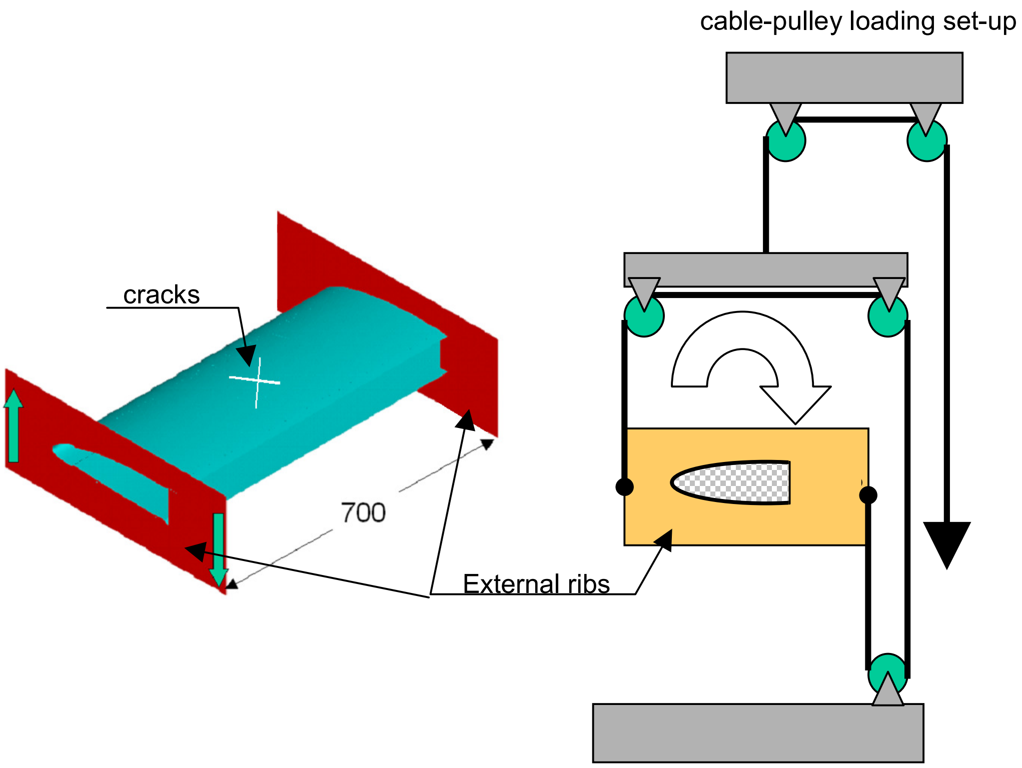

Figure 4: Stiffness test. Experimental setup

To determine the torsion stiffness of the stabilizer section pure torque was applied to the one of the external ribs with the help of the cable-pulley loading set-up, Fig.4, while the second rib was fixed. Displacements were measured with dial gauges at corners of the rib.

4 Numerical analysis

4.1 FE model

Numerical modeling was carried out with the use of FEM. For this purpose ANSYS v.11 code was used. SHELL91 type elements were used to model facesheets and SOLID95 type elements to model the core. Since the purpose of the FE modeling was to analyze global impact effects not the crack propagation phenomenon, the cracks were modeled with the use of the "element kill" technique and the stress singularities at crack tips were neglected. The FE mash is shown in Fig.5. Each crack was 100 mm long.

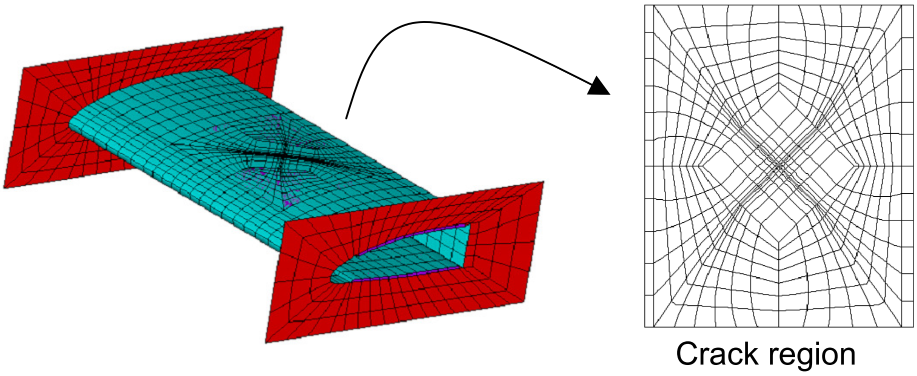

Figure 5: Finite element model

5 Results

5.1. Impact damage observation

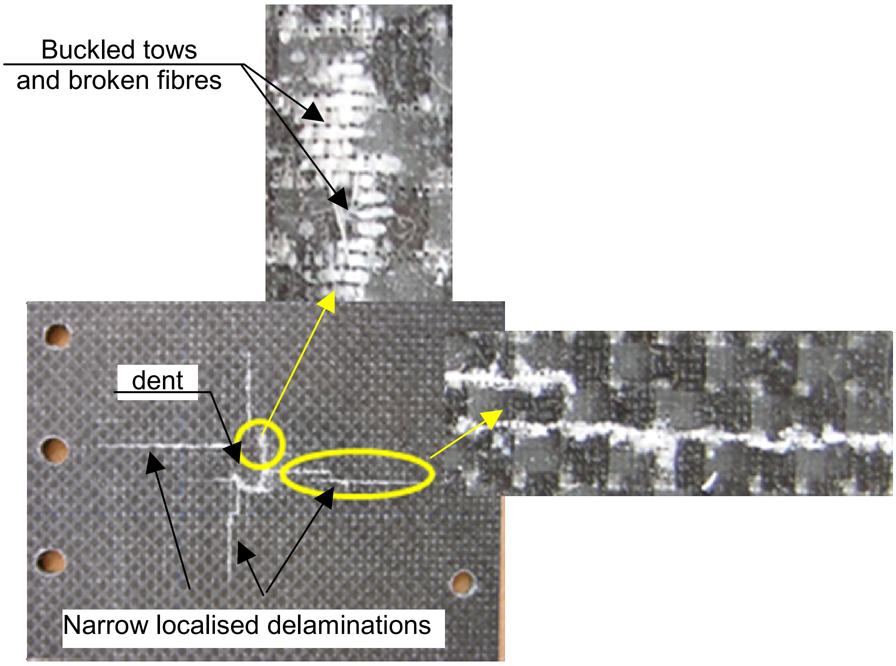

Figure 6: Damage pattern

There is pronounce difference between an impact damage of the sandwich structure under consideration, Fig.6, and that of solid laminate. Extensive description of the latter can be found in [1]. The damage produced included fracture of glass and carbon reinforcements of the outer facesheet, partially crushed core and a dent. No extensive delamination was found. The delaminations were very narrow and parallel to warp and perpendicular to weft tows. Some fibers of the tows perpendicular to the delamination paths were broken. Probabely, the fibre brackage resulted from the localized bending of reinforcement which was possible due to its prior disbonding and buckling. The core did not fracture, however local dent of outer face was visible as well as small bump at the inner face surface, below the impact point.

5.2. Stiffness changes

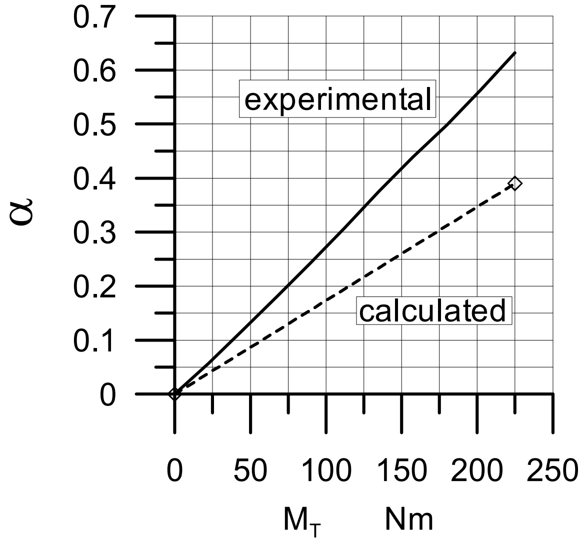

Figure 7: Stiffness of stabilizer section. Numerical and experimental estimation.

Results of the numerical analysis showed that the stiffness change due to crack formation is about 0.1% of the initial one and is meaningless. Comparison of the experimental and numerical results indicate that the FE model is too stiff and needs improvement.

The following general conclusions can be drown:

- Impact damage of sandwich structure of extremely thin facesheets noticeably differs from that of solid laminate and is not well understood
- Mechanisms of such a damage formation must be investigated
- To estimate impact damage severity the fracture mechanics tools should be used

The presented research was financially supported under grant IT1:514R11325420000

References

[1] Gao S-L, Kim J-K, Three-dimensional Characterization of Impact Damage in CRRPs, 1998, Key Engineering Materials, Vols. 141-143, pp.35-54.