

The composite material used in manufacturing the wing boxes was prepregged by Hexcell Belgium, aiming at a cured fibre volume content of 60 percent.

An epoxy resin system designed for autoclave curing at 120°C was used to impregnate the graphite (T300) and aramide (Kevlar 49) fibres.

The pre-pregs used in the first wing box (graphite tape (T3T 145/F550 - graphite fabric W3T 282/F550 - Aramide Fabric Kevlar 49-285/F550) had an excess resin content (Tape: 41% - Fabric: 37,5% - Kevlar 60%). In the vacuum bagging the stacking sequence was: one ply nylon-peel ply on top of layup - one ply of perforated release film - one ply of fibreglass type 181 as surface bleeder - release film and pressure plate - breather - vacuum bag.

The pre-pregs used in the second wing box (graphite tape T3T 145/F155 - graphite fabric W3T 282/F155) had a net resin content (Tape: 35% - Fabric 34%), simplifying in this way the vacuum bagging sequence only to: release film on top of layup - pressure plate - breather - vacuum bag.

The cure cycle was: Heat up, under vacuum, to 120°C at 2°C per minute - Apply 0,7 MPa pressure - Hold 90 minutes - Cool down to 50°C at 2-3°C per minute.

Each wing box was 920 mm long. At the end of the specimens each panel is reinforced by glass/epoxy for a length of 140 mm; suitable fittings are bolted in order to fix them to the bending machine. The specimens are bolted to the machine by two clamps hinged to the frame by four rods. On the other side of each clamp a hydraulic jack is hinged, by which the bending moment is applied.

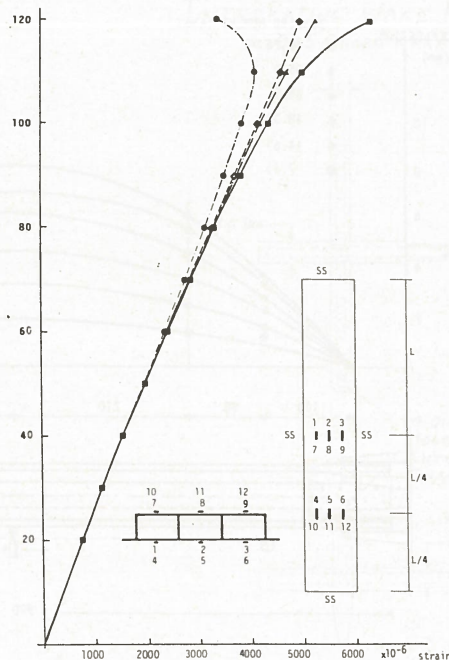


Fig. 3: Load versus longitudinal strains of compression test.

Experimental results

First a compression test was carried out on a small panel to check the capability of the cellular panel to withstand the design compression stress without local buckling failure. The panel was 730 mm long and 103 mm wide (only 3 cells); T300/5208 NARMCO graphite/epoxy material has been used to manufacture this panel and cured at 175°C.

The panel was simply-supported on four sides; failure occurred at a load of 125 KN (corresponding to an index load N_x of 1213 N/mm) by local buckling of the laminates between the bridges and followed by an explosive delamination of the skin. In Figure 3 longitudinal strains are reported versus compression load. Although the ultimate compression index load ($N_x = 1190$ N/mm) was achieved, the failure load was 30% lower than the theoretical one calculated by using the orthotropic plate theory of compression panels. Simple compression tests, indeed, cannot represent properly the load condition of a wing box compressed panel because of the constraints and deformations induced by the edges and because of the effects of the bending curvature. Furthermore one of the main objectives of the program is to check the capability of the webs to withstand the crushing loads introduced by the bending curvature.

For these reasons compression tests have been set aside and bending tests were planned.

Deflection curves at different load levels are taken by means of 3 dial deflectometers; the central one runs on a guide for a length of 420 mm and is connected to an x-y recorder.

Longitudinal stresses are determined by linear strain-gauges placed on the outer and inner laminate of the upper and lower wing panels and on the four halfwebs. The applied bending moment has been increased step by step to record the deflection curves and to make the strain measurements at constant loads. For the first specimen under bending load failure occurred at a bending moment of 33 KNm (corresponding to an index load of 1070 N/mm) by local buckling of the laminates between the bridges and followed by an explosive delamination of the skin. In Fig. 4 longitudinal strains versus bending moments are reported; it is very clear that the inner laminate of the compressed panel, beginning from low loads, has a reduced stiffness and at about the half failure load does not increase its deformation; it then seems that failure occurred in this laminate, although stresses are lower than in the outer laminate. The behaviour of tensioned panels has been quite linear and like it was expected; indeed the failure load has been 40% lower than the theoretical one. In the second bending test failure occurred at a bending moment of 43 KNm in the same way of the first-

one. Deflection curves at different values of the bending moment are reported in Figure 5; very small deflections have been recorded up to highest loads proving the very high flexural stiffness of graphite composites. The same behaviour of the first test was recorded for longitudinal strains (Figure 6).

Although the ultimate bending moment (35 KNm) was widely exceeded, the results of this test were not completely satisfactory, because of the differences between theoretical and experimental results.

The main reason for this difference is, in my opinion, a few defects in the cured panels; infact, there are, especially in the corners, resin pockets, with cracks, fibres bunched up, distortion of fibres at intersection of the webs with the panels; pinching over compaction etc. The defects can, in particular, give rise to the delamination of the outer laminate from the inner laminate of the cells reducing the theoretical critical load.

A second reason is that in wing boxes subjected to bending, the curvature of the box has a remarkable effect on the deformation of compression panels reducing the critical load. The theoretical analysis has then to take into account this effect (Ref. 4).

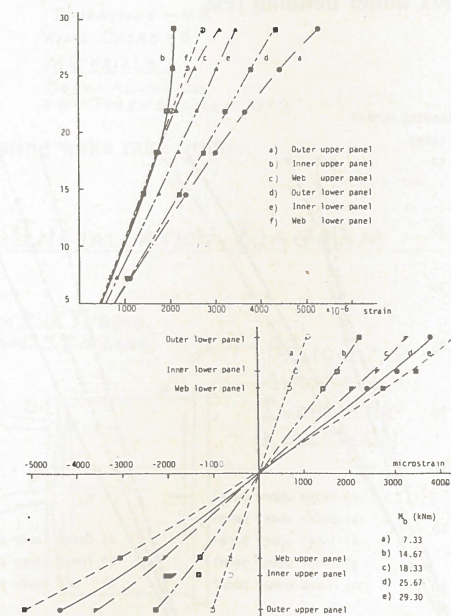


Fig. 4: Longitudinal strains versus bending moments.

Fuselage production process

In the construction of the composite fuselage a simpler production process was used, avoiding the most expensive mould; a PVC foam core, called AIREX (Ref. 5), was used for a sandwich construction. At first a wooden building frame was constructed and planked with AIREX; the outer skin (Kevlar 49/epoxy) was then laid up by hand; after the hardening a cradle was built on top of the hull prior to turn over; at the end the

inner skin was laid up completing the half hull. The construction process seemed to be quite easy and a good hull came out; some problems arose in bending the foam to conform to the curvature of the frame; it will be easier warming the AIREX in an oven at 40-50°C. A torsion test is planned for the near future.

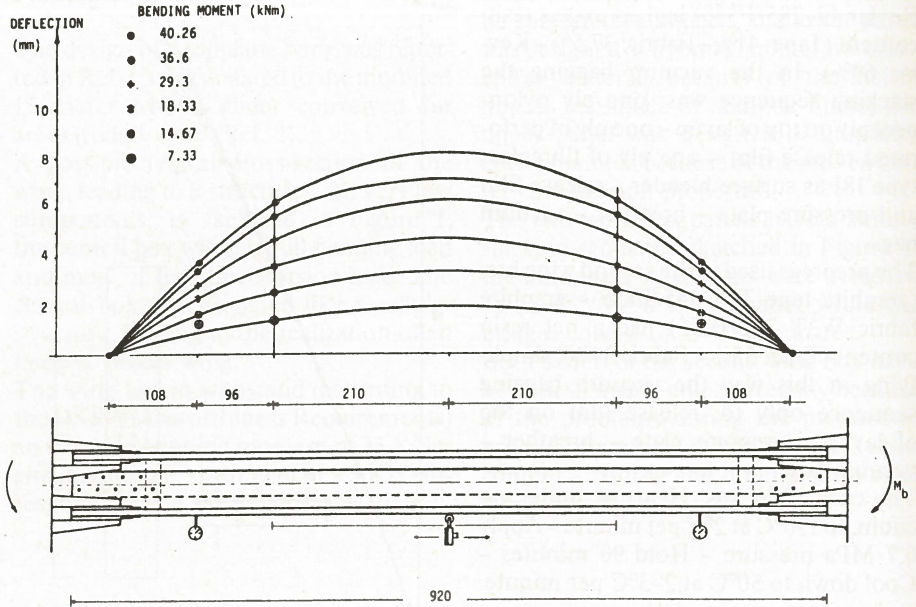
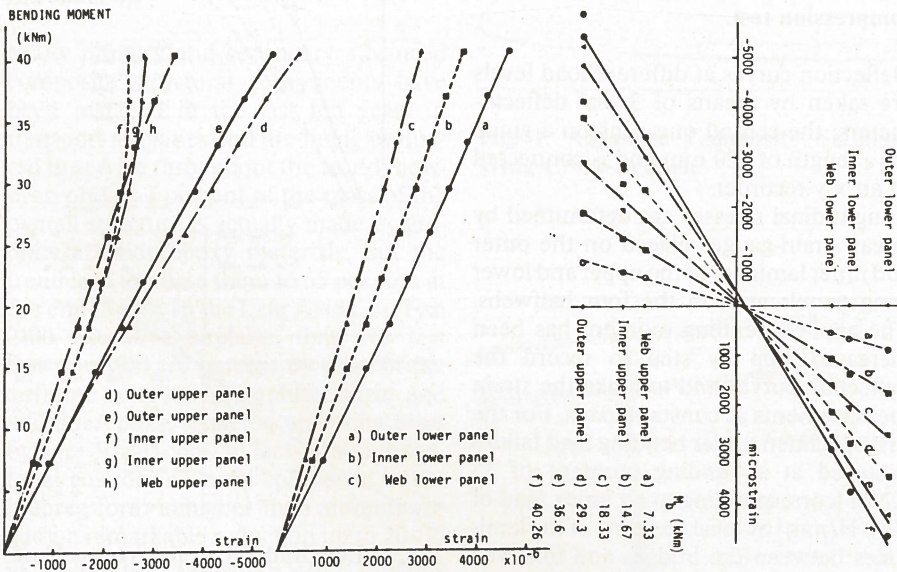


Fig. 5: Deflection curves of second wing box under bending test.



References

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Fig. 6: Bending moment versus longitudinal strain of second wing box.