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THE ADVANCED TECHNOLOGY FUSELAGE RESEARCH PROGRAMME

by

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ABSTRACT

The Advanced Technology Fuselage (ATF) Programme is one of a number of structural technology activities currently being undertaken at Westland Helicopters. This programme involves the design, manufacture and test of two centre section fuselages which are representative of a medium transport helicopter design. Extensive use has been made of titanium alloy and carbon reinforced plastic materials in their construction.

Tests have concentrated on establishing the engineering performance and potential of the advanced concept structures in terms of weight and cost, as well as addressing acoustic, electromagnetic compatibility, dynamic and strength issues.

This paper outlines the objectives of the ATF programme, gives details of the design and manufacturing undertaken, discusses the tests completed and the results obtained and outlines the conclusions regarding the application of the technology.

1. INTRODUCTION

Westland's Advanced Technology Fuselage (ATF) Research Programme is jointly funded by the UK MOD(RAE) and Westland. It involves the design, manufacture, test and evaluation of two, 2-bay centre fuselage structures at full-scale, comprising:

Structure 1: Ti 6Al-4V (Electron-Beam welded) frames and carbon/epoxy skinned honeycomb sandwich panels.

Structure 2: Carbon/epoxy frames and carbon/epoxy skinned honeycomb sandwich panels.

The primary objective of the programme is to compare the engineering performance and potential of these advanced structural concepts with conventional constructions.

Advanced structural concepts - employing new materials - promise substantial improvements to the helicopter's overall efficiency through, particularly:

i) Reduced empty weight fraction

ii) Reduced first and operating costs

The aim of the ATF programme is to provide engineering data in respect of both weight and costs together with engineering data on:

i) Structural design (strength, modes of failure, load/deformation behaviour) and manufacture (process development and automation)

ii) Electrical/electromagnetic (EMC) issues

iii) Acoustics

iv) Structural Dynamics

v) Crashworthiness

The comparison of the two advanced structures with a structure of conventional design is of fundamental importance. A medium transport helicopter design was used as a basis for comparison (Figure 1).

2. MATERIALS AND CONFIGURATION SELECTION

The choice of materials used in the construction of the ATF structures was determined by results of a study into the potential benefits of a number of structural materials which were becoming available in the late 1970's.

For the frame application, two materials offered the most potential in terms of specific properties - the Titanium alloy Ti 6Al-4V and carbon/epoxy composite. Ti 6Al-4V offers good corrosion and fatigue properties especially, although its cost and its lack of cold forming capability have reduced its potential in this application.

The selection of carbon/epoxy for the frames and panels was due principally to the potential structural weight benefits and cost savings in the manufacture of the structures.

The choice of the configuration (Figure 2) was also driven by cost. The component parts count has a very important effect on manufacturing cost. To this end the ATF structures were designed with widely spaced frames to which were adhesively bonded the carbon/epoxy skinned honeycomb sandwich panels.

3. DESIGN

The design, manufacture and test of the two structures has been completed to aircraft standards. The design is based on a medium transport helicopter design with an all up weight (AUW) of 10,886 kg (24,000 lb).

There are two load cases:

i) Vertical up-load. This is based on a checked descent case with maximum thrust and a maximum aft cyclic pitch giving a total vertical load of 21,892 daN (ultimate) (49,215 lbf). In addition an effective freight loading of 9.3911×10^{-4} kg/mm^2 (200 lb/ft^2) at 4.5g ultimate acceleration vertically is applied to the floor.

ii) Vertical down-load. This load was determined as the down load to produce the minimum reserve factor on the structure. This load was calculated to be -16,083 daN (36,156 lbf). In addition, a ditching pressuring (ultimate) of 0.03447 N/mm^2 (5 lb/ft^2) is applied to the undersurface of the structure to represent the water pressure in an emergency ditching.

4. MANUFACTURE

The titanium alloy (Ti 6Al-4V) frames are of I-section, electron-beam welded together from four flange parts and one web. All components for these frames were manufactured at British Aerospace (Filton). Component assembly was completed at Westland.

The carbon/epoxy frames (XAS/Fibredux 913, 120°C curing epoxy) have top-hat section side frames and back-to-back channel roof and floor members (Figure 3) all components are adhesively bonded (BSL 312/5, 120°C curing) together. Fabrication and assembly of these frames was completed at Westland.

The composite panels which are both flat and curved, were manufactured at Bristol Composite Materials Engineering Ltd (Avonmouth), with final assembly of the ATF structures at Westland. The panels are both adhesively bonded (room temperature curing) and sparse-fastened to the frames. The panels employ Hyfil/Torayca 130 fibre in Hyfil R7H epoxy resin for the skins and a Hexcel 16 honeycomb core.

The floor panels are of similar construction.

5. TESTING

5.1 Acoustic Investigations

A series of acoustic investigations have been completed on both ATF structures to assess the implications for the acoustic characteristics of a helicopter fuselage incorporating lightweight, stiff, sandwich panels and widely-spaced frames.

An important aspect of these investigations is the application of information derived from simple laboratory panel tests to full-scale structural components.

Tests conducted on the ATF structures included acoustic transmission loss measurements and radiation efficiency measurements. For the transmission loss measurements good agreement was found throughout the frequency range investigated, for both ATF structures and the laboratory panels (Figure 4). The transmission loss of the ATF structures was found to be panel dominated with the frames and stiffeners having no effect. Compared to typical (0.7mm) aluminium skin/stringer panels, the ATF panels provide 5-6 dB less attenuation over the frequency range of interest.

The measured radiation efficiency of the ATF structure did not provide such good agreement with the laboratory panel measurements (Figure 5). It was found that the fuselage measurements were dominated by different parts of the structure, dependent on the frequency. However, the degree of correlation obtained over a significant proportion of the total frequency was such that, it is considered that to a first approximation, the radiation efficiency of the structures can be determined from simple laboratory panel tests.

The acoustic investigations have also included the development of a statistical energy analysis theory for the prediction of the noise field and vibration response of the ATF structures. Good agreement has been found particularly in the noise field survey.

The overall effect of cabin noise comparing the ATF-type structure with conventional is estimated to be an increase of about 6 dB in noise level. However no attempt has been made to acoustically optimise the ATF panels. This would have a significant effect on the cabin noise level.

5.2 Electrical/EMC Investigations

The large scale use of composite materials in structural applications has signficant implications for all EMC considerations. The carbon composite framed ATF structure has been used to investigate the installation issues and performance of an HF band (2-30 MHz) communications system. This is considered to be the most critical of the frequency bands.

Considerable effort was devoted to ensure adequate electrical conductivity throughout the structure since the ground plane of an HF system usually covers the majority of a metallic fuselage.

Tests completed on the composite structure were also conducted on an equivalent metal box for comparison.

Whilst the power output was lower from the HF system on the composite structure, over parts of the band it was found to be easier to tune.

This work is covered fully in a previous paper by Boughton and Heseltine (Ref. 1).

5.3 Dynamics Study

There is little information available on the dynamic characteristics of complex composite structures. The all-composite ATF structure has been used to compare experimental and theoretical analyses of the dynamic response of a full-scale helicopter centre section fuselage.

Single-point excitation was used to determine experimentally the normal modes and frequencies of the ATF structure.

Seventeen modes (modes shapes and frequencies) and their corresponding damping factors were calculated for the frequency range 0-150 Hz using a NASTRAN model (Figure 6).

Comparison of test and NASTRAN modes showed a good agreement for approximately half of them. It was found that many of the other modes were similar in shape causing inaccuracies to occur. These modes were dominated by panel motion.

5.4 Strength Tests

A major objective of the ATF programme is the validation of the stress analysis used in the design of the structures. The finite element model ASAS (Atkins Structural Analysis System) (Figure 7) was used with a good agreement between the model's predicted stress levels and those found on the (Ti-framed) structure.

To support the design calculations for the carbon composite frame, a number of top and bottom corner joint specimens were tested.

The ATF (Ti-framed) structure has been tested to failure. Two static cases were applied to the structure: flight with freight load and a crash/ditching load (see Section 2). The input loads (from 2 jacks) are applied to attachments at the top corners of the centre lift frame. The loads exit the structure via metal (Al alloy) extensions attached to the fore and aft frames.

The Ti-ATF structure has cleared both load cases and failed at 150% of the design ultimate compressive load (crash/ditching).

The strength testing of the carbon framed ATF is underway.

5.5 Crush Tests

The Ti-ATF structure has been subjected to a crushing test to give information on the post ultimate load/deflection behaviour. The underside of the structure was supported by a flat continuous surface. The load was applied via the two attachment points in the top corners of the centre lift frames.

The structure reacted a total load of approximately 600 kN (60.2 tonf.) before initial failure and continued to support useful load for a significant deflection after this, (Figure 8). From a simple assessment of the load/deflection behaviour, the energy absorbed by the structure was predicted to be equivalent to a 3.9 m/s (12.8 ft/s) vertical velocity impact condition. Several failure mechanisms were observed throughout the structure, including plastic hinges in the frames. This information will subsequently be used for analysis by the KRASH program to predict the potential crashworthiness properties of this type of configuration.

The carbon framed ATF will also be tested in this way.

6. COST AND WEIGHT STUDIES

To provide a direct comparator for the ATF structures an equivalent light alloy structure has been designed. Based on this and an extensive survey of the manufacturing options available using the ATF materials and configuration, estimated cost and weight savings have been derived for the centre fuselage section application (Figure 9). The apparently low cost savings figure for the Ti-ATF is attributable to the high cost of the titanium alloy.

7. CONCLUSIONS

The ATF programme has provided valuable information and experience in the design and manufacture of advanced structures for the centre fuselage section application. It has also provided much useful data on several structural issues including acoustic, EMC and dynamic characteristics and has been used to further develop a number of analytic techniques in these areas.

The cost and weight studies completed to date indicate significant savings particularly for the carbon framed structure over that of a conventional (metallic) type.

The ATF programme has provided a valuable basis for further structural technology development activities which are addressing other major structural issues such as battlefield survivability, repairability and durability as well as a number of new materials which are serious contenders for primary structural applications such as the aluminium- lithium alloys and the high performance reinforced thermoplastics.

8. ACKNOWLEDGEMENT

Acknowledgement is due for the support given to the ATF programme by the Royal Aircraft Establishment, Farnborough; British Aerospace, Filton; and Bristol Composite Materials, Avonmouth.

9. REFERENCE

1. Heseltine M J & Boughton W G — "Electrical Connections and Antenna Performance of a Large Composite Fuselage Module in the High Frequency Range", Presented at 10th European Rotorcraft Forum, The Hague, (Paper 86), August 1984.

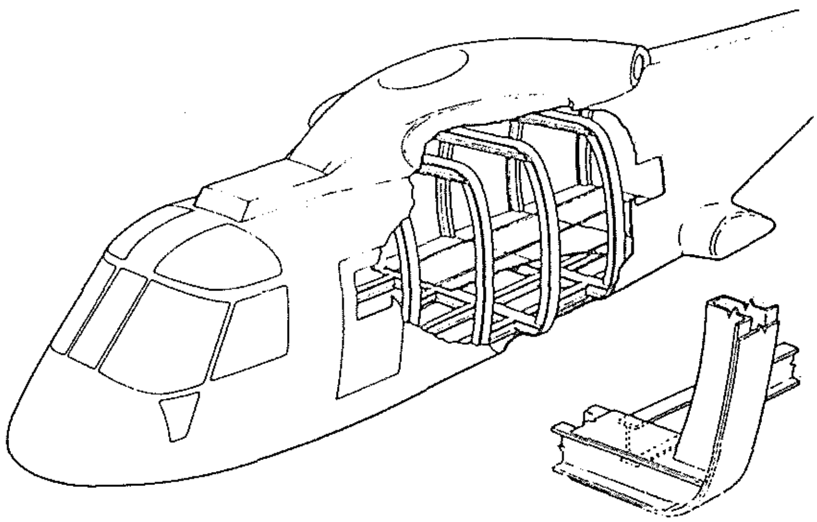

Figure 1. Transport helicopter with ATF-type centre structure

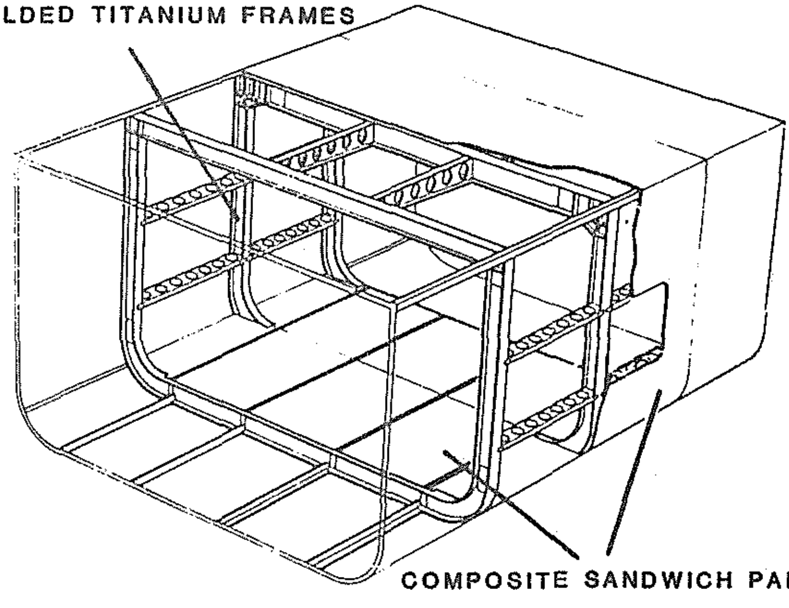

Figure 2. Configuration of Ti-framed ATF structure

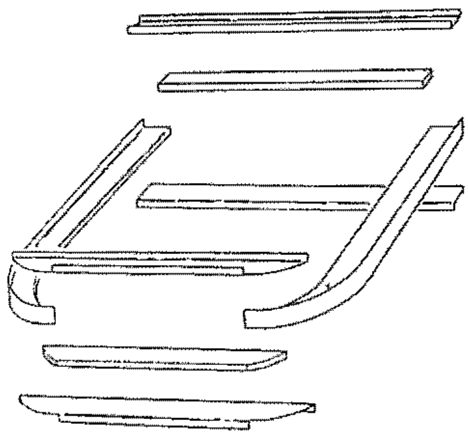

Figure 3. Components of ATF carbon frame

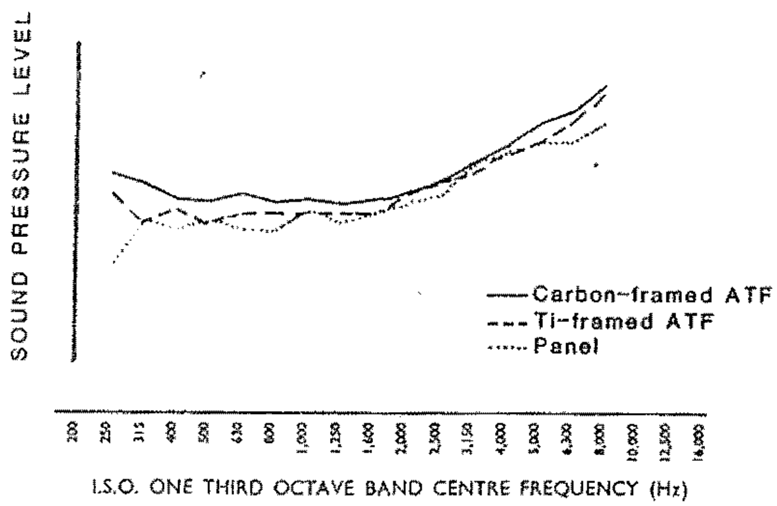

Figure 4. Acoustic Transmission Measurements

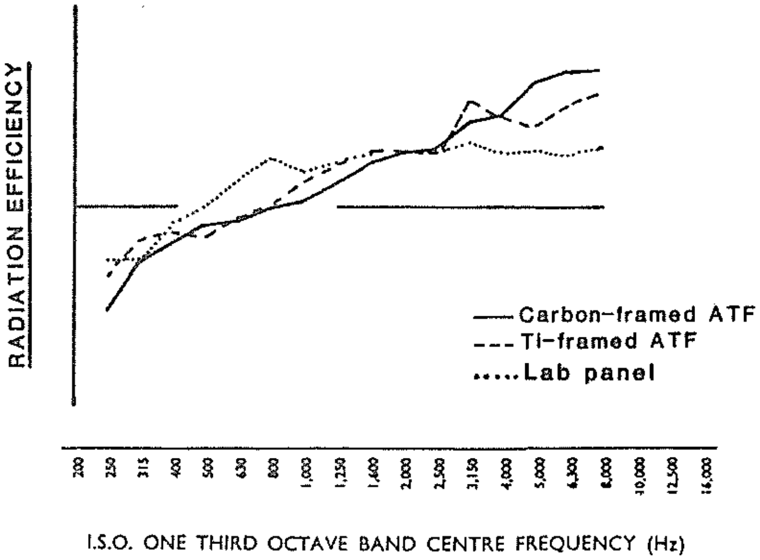

Figure 5. Radiation efficiency measurements

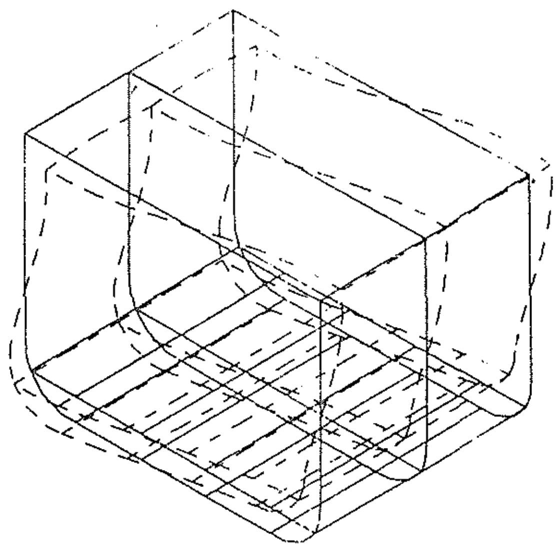

Figure 6. ATF model mode at 36.95 Hz

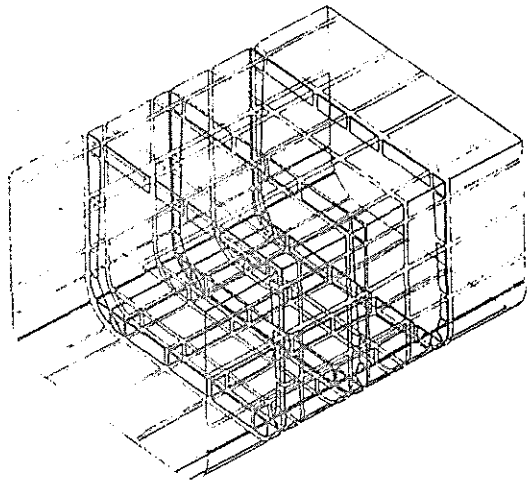

Figure 7. ASAS model of carbon framed ATF structure

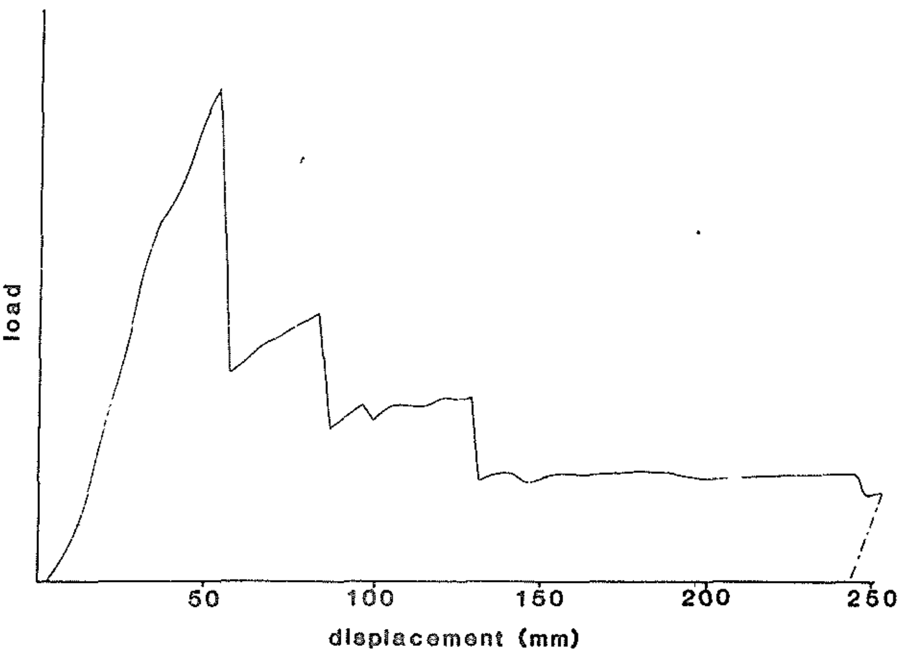

Figure 8. ATF crush test load/displacement curve

	Cost	Weight
Ti ATF	5%	10%
Carbon ATF	18%	16%

Figure 9. Estimated cost and weight savings