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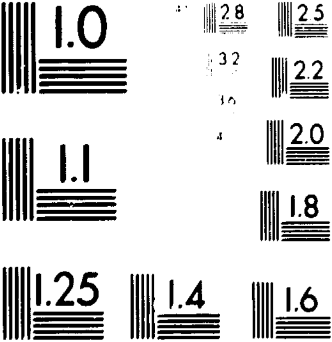

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APPLICATION OF CARBON FIBRE REINFORCED POLYMERS IN AEROSPACE

SPECIAL EXPERIENCES IN THE UNITED KINGDOM*

by

Barry J. Hayes**

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HISTORY

The first consciously produced, high performance, semi synthetic composites were manufactured from unidirectional prepreg at Duxford, near Cambridge, England in 1941-2.

These were developed as a safeguard against the non availability of aluminium and although very advanced materials at that time, were never put into full production.

SLIDES (30), (31)

Some 25 years later high performance carbon fibre was becoming available for evaluation and by the late 1960's the U.K. had three production plants in operation, all licensees of the process developed at the Royal Aircraft Establishment near London.

By far the largest production capability was at the Rolls Royce plant. This had been constructed to yield up to 60 tonnes per year; principally aimed at providing carbon fibre for their own project the RB211 engine fan blade.

This fan blade programme was also very advanced for its time but unfortunately failed due to inadequate impact performance. Many trial blades were produced, including the rather smaller Conway blade.

SLIDE (32)

Other projects were less ambitious but for one reason or another were not put into series production, although all were technically successful.

SLIDE (33) HARRIER ferry wing tip demonstrating very complicated ply orientation.

SLIDE (34) WESTLAND torque tube produced from prepreg as a demonstrator along with other ambitious items such as a tail boom.

SLIDE (35) I.M.I. early demonstrator ESRO 2 satellite. One of the first carbon fibre structures employing aluminium honeycomb for increased stiffness. The structure was fully fatigue and strength tested and easily met all design requirements, although its construction was expensive and time consuming.

DEMONSTRATORS

After the demise of the RB211 project the prospects for CFRP looked doubtful and for some two to three years activity was at a very low level.

From 1972 work increased again and there was a gradual progression from making small non critical parts in carbon fibre which were already designed for metals (access doors etc.) to making larger structures in which a portion of a metal part was replaced by composite. Most of these structures were given practical flying trials.

SLIDE (36) V.C.10 centre rudder section showing partial replacement of metal with CFRP. Three of these were produced and two are still in service.

Gradually this approach gave way as confidence was gained to redesigning some aspects of existing metal parts for composites and then to designing, producing and testing a much wider range of items as initial composite concepts.

SLIDE (37) BAC 1-11 engine stub wing panels. 5 sets produced from woven carbon fibre FIBREDUX 914 prepreg and directly co-cured with REDUX 319A film adhesive to AEROWEB NOMEX honeycomb core. All five sets are successfully in service with British Airways.

MILITARY DEMONSTRATORS

As various parts were made in CFRP and proved to be satisfactory so some of them were put into limited production. The French Aerospace industry was probably rather advanced in this approach and have a good success record in their early production use of CFRP.

SLIDE (38) MIRAGE F-1 aileron - in production since 1975

In the U.K. more and more parts were produced and tested for the JAGUAR and TORNADO aircraft.

SLIDE (39) Showing schematic representation of the parts manufactured for evaluation in CFRP on JAGUAR.

SLIDE (40) JAGUAR shroud panels showing complex skin shape with honeycomb insets. Produced entirely from undirectional tape.

SLIDE (41) JAGUAR spine panels demonstrating aluminium honeycomb core. Many of these have been made and flown with good service experience.

SLIDES (42), (43) JAGUAR wing skin after removal from autoclave and upright to show general dimensions.

SLIDE (44) TORNADO front fuselage demonstrator clearly showing rivetted assembly. A later version was entirely adhesive bonded.

SLIDE (45) Showing full JAGUAR wing assembly: the bonded TORNADO front fuselage and the TORNADO taileron - one half of which is made by BAe and the other by MBB. Top right is the automated tape laying head and the revolving laying table designed for large relatively flat areas such as wing skins.

SLIDE (46) TORNADO in flight showing the size of the taileron.

Meanwhile Dassault in France have been demonstrating their skill in the production of some outstanding integrally stiffened panels.

SLIDE (47) MIRAGE 4000 fin skin.

EARLY CIVIL PRODUCTION

Rolls Royce having suffered the early set-back of the fan blade problem had continued to study the weight saving possibilities of carbon fibre and took the decision to subcontract the manufacture of the main RB211 engine pod doors in a carbon/honeycomb sandwich construction to British Aerospace. Some fifty sets of these were made and they have been flying now for many years on Lockheed L1011 aircraft with complete success. The first of these were the largest carbon composite structures flying in regular commercial operation: weight saving was 40kg per set.

SLIDE (48) Showing one door after removal from the mould tool.

SLIDE (49) A pair of doors painted for protection

SLIDE (50) Full engine pod/door assembly installed on a 1011.

Another successful application has been the use of carbon skinned NOMEX honeycomb floor panels for many civil airlines. These represent the minimum weight construction for this use but are rather expensive and less impact resistant than the equivalent glass skinned panels. Nevertheless, they have flown many millions of miles with few problems.

SLIDE (50A) A fully fabricated FIBRELAM 2000 carbon fibre floor panel ready for fitting to a SHORT 360 aircraft.

HELICOPTERS

Whilst much work was being carried out on this range of airframe and subsidiary components the helicopter industry had a ready made application for composites - rotor blades.

Early rivetted metal blades had a very short life, suffering very badly from fatigue and mechanical damage problems. The introduction of metal bonding greatly improved this situation but the advent of composites, initially as glass but more recently as hybrids, has improved the situation still further. Modern composite blades possess very long lives and are outstanding in fatigue resistance. The Anglo-French programmes have produced some very interesting and successful composite blade designs.

SLIDE (51) Shows the construction of the PUMA blade, which consists largely of low density NOMEX honeycomb skinned directly with ± 45° high modulus graphite fibre impregnated with high toughness self-adhesive FIBREDUX 920 resin.

In the centre is the SEA KING composite blade which contains a unidirectional glass spar overlaid with woven glass and a carbon fibre trailing edge skin. The NOMEX honeycomb is coated with a specially compatible epoxy resin.

At the bottom is the LYNX tail rotor where the NOMEX is replaced by a high temperature resistant foam core.

SLIDE (52) A PUMA helicopter with carbon blades in service.

SLIDE (53) A SEA KING helicopter refitted with all composite rotor blades.

As well as rotor blades more and more structural fuselage and ancilliary parts are being put into production in helicopters to reduce weight and improve performance.

SLIDE (54) This trend is exemplified by the DAUPHIN Fenestron, tail rotor and fin which is largely constructed from unidirectional and woven carbon prepreg.

ANCILLIARY APPLICATIONS

The use of CFRP has not been restricted to standard airframes and components. Many other ancilliary applications and structures have been pursued.

SLIDE (55) SYLDA (Systems Lanceur Double Ariane)

This is essentially a large protective container for the second of the two satellites that Ariane can carry. It is one of the largest European carbon fibre structures measuring some four metres in height and 3 metres in diameter. The weight saving over the equivalent metallic structure was 43%.

SLIDE (56) Illustrates the important application of carbon reinforced carbon matrix composites in brakes for aircraft. Shown is a Brake assembly for the A310 which has a thermal capacity three times that of the equivalent steel structure, exhibits low wear and high friction characteristics and saves a total of 400 kg per aircraft.

SLIDE (57) Depicts the latest technology carbon/glass propeller blades manufactured by Dowty Rotol using resin injection techniques. These blades are in series production and will shortly be used in the new SAAB-FAIRCHILD SD340 commuter plane.

MODERN CIVIL PRODUCTION

The latest civil aircraft composite parts are being designed specifically for these materials. An interesting example is the fixed trailing edge structure for the AIRBUS A300-600. Initially it was designed in metal and the first attempt to convert it to composite construction resulted in a part that contained hundreds of mechanical fasteners and was heavier and more expensive than its metal counterpart.

British Aerospace - Weybridge Division then redesigned it as a composite part from the outset and the result was a structure essentially free of mechanical fasteners which is lighter and cheaper than the metal one. A good way to ensure the spread of composite usage.

SLIDE (58) Shows the carbon fabric flanged ribs produced from four plies of FIBREDUX 6268 prepreg.

SLIDE (59) Illustrates the completed parts almost 5 metres long and 1.5 metres wide. The construction is of two carbon fabric/ NOMEX honeycomb skins bonded either side of the ribs shown previously. This part is now in series production - to be followed by an equivalent structure for the A310 as well as many other new composite items.

Finally we move on to the future generation of aircraft which will contain much larger quantities of carbon in their construction.

American designed but built in Northern Ireland is the very 'avant garde' LEARFAN 2100. Constructed principally from carbon fibre it has suffered from being the "first in the field" and all the problems that usually entails. Nevertheless it is hoped to obtain FAA Certificaion in 1984 followed by full production.

SLIDE (60) LEARFAN 2100 in natural carbon fibre colouring.

SLIDE (61) LEARFAN 2100 fully painted and in flight over Nevada.

There are three military aircraft now being designed in Europe which have much higher levels of carbon fibre composite in them than anything before on that side of the Atlanic Ocean.

These are the SAAB GRIPPEN, for which the first five sets of wings are being manufactured by British Aerospace (38% CFRP).

SLIDE (62) The DASSAULT ACX with approximately 40% CFRP

SLIDE (63) and the joint Anglo/German/Italian Agile Combat Aircraft (ACA) with 38% CFRP

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It is now very likely that use of carbon fibre composites in Europe will show a fairly rapid increase in the Aerospace sector. This being due to the replacement of metals rather than any great increase in aircraft numbers or volume.

Nevertheless, the threat of a challenge by lithium/aluminium alloys will be taken seriously. A big opportunity now rests with the fibre and resin manufactures to produce systems which can be used to greater design strains. It has been suggested that if carbon composites can be designed to a safe strain limit of 0.6% instead of the current 0.35 - 0.4% then they will find much wider use in aerospace and their performance will be significantly beyond the range of the new aluminium alloy challenge.