The particular construction described is merely one approach to the problem, but it may be of interest to see how far the system satisfies the more important design requirements

(1) By making the main spar a tube and using it for supplying air to the jet, additional air conduits are avoided and a reasonably smooth passage is provided

NOTE —This arrangement may, under certain conditions force a compromise between chord and thickness of blade

(2) The system permits differential thermal expansion between spar, superstructure and fuel pipe

(3) Flexibility in both vertical and horizontal planes is provided, thus avoiding buckling of the underskin and trailing edges This feaure is also being incorporated in shaft-driven rotor blades In this design the oval tube provides good torsional stiffness

(4) As a result of flexibility of the superstructure, the flexural axis approximates to the spar axis and longitudinal axis of inertia, whereas with a rigid skin the flexural axis is offset and torsional loads are introduced whenever the blade bends in a vertical plane

(5) By pressing out the blade elements in a die, close conformity to the required aerofoil section is obtained

(6) Whenever the blade has to be stripped for inspection or repair the rivets can be drilled out and the same elements used for the re-build, or new elements inserted for repair

(7) Once the jigs are made the blades can be built by semi-skilled labour

(8) With the exception of the trailing edge, the skin is free from rivet heads or blemishes such as over-countersinking

(9) By making the elements of stainless steel, no protection is required except for the spar itself, and the blade can be fully ventilated

(10) Automatic de-icing is provided by the heat radiated and conducted from the spar

(11) The skin does not have to rely on bonding or rivetting to the ribs and therefore can be made of very thin steel , the construction also permits of the use of strip steel which is readily obtainable

(12) As a result of using very thin steel (in the example 010′) in narrow strips, the gap between each element will be very small, and, even under maximum thermal and stress differentials, the gap will increase by a dimension of the order of only 004″

(13) Having no external paint or fabric covering, the blade can fly through all types of weather without fear of leading edge erosion This in turn reduces the amount of maintenance required

I must thank the Fairey Aviation Company for permission to read the paper, but I should point out that the opinions expressed are my own and not necessarily those of the Company

REFERENCES

LOCKING WEDGE	PAT No 28045/50
OVERLAPPING SECTIONS	PAT No 21563/51

(FOURTH PAPER)

The CHAIRMAN, introducing Mr O L L FITZWILLIAMS, said Mr Fitzwilliams has had a long connection with development work dating back to his period of service with the Autogiro Department of G & J. Weir Ltd He later joined the Airborne Forces Experimental Establishment and, on leaving in 1946 to take up an appointment with the Westland Company, he was in charge of the Rotary Wing Aircraft Section Mr Fitzwilliam's work as Helicopter Engineer with the Westland Company is widely known, as are his contributions to the Association as a lecturer and Member of Council

Blade Construction Processes

By O L L FITZWILLIAMS, B A

This short talk describes the manufacture of the metal rotor blades now going into quantity production for the S 51 and S 55 Helicopters at the Westland Aircraft Works These blades are a Sikorsky development so that there are many details both of design and construction which I am not at liberty to discuss On the other hand I hope to give a general indication of the way in which they are made, and of the scale of facilities which are available They are the first all metal helicopter main rotor blades to go into quantity production outside the United States

The backbone of the blade is an extruded light alloy spar which begins life as a billet in the extrusion presses at Messrs Birmetals Since the blades of the S 55 Helicopter use the same type of extrusion as the smaller S 51 blades, in future all extrusions will be delivered to us in the longer length and will be cut down for the manufacture of S 51 spars Each extrusion contains two shear webs inside the main contour and these run the entire length of the spars

Extrusions of this kind are produced by bridge type dies in which, at one point during its passage through the die, the metal is divided into a number of streams which are welded together in emerging from the die while still in the plastic state The light alloy is chosen mainly for its good extruding qualities and has not a particularly high tensile strength, but it is fortunately very resistant to corrosion and has good fatigue properties It will be seen from Fig 1 that what we purchase from Messrs Birmetals is essentially a series of accurately formed holes surrounded by an adequate quantity of light alloy which we subsequently machine to the correct contour

The raw extrusions are anodized since the chromic acid anodic process is an excellent aid to crack detection On receipt at the factory they are carefully inspected externally for crack indications and the three longitudinal passages in each extrusion are given a rigorous inspection with the aid of a boroscope, both for crack indications in the anodic film and for a variety of small blisters and other defects which occasionally

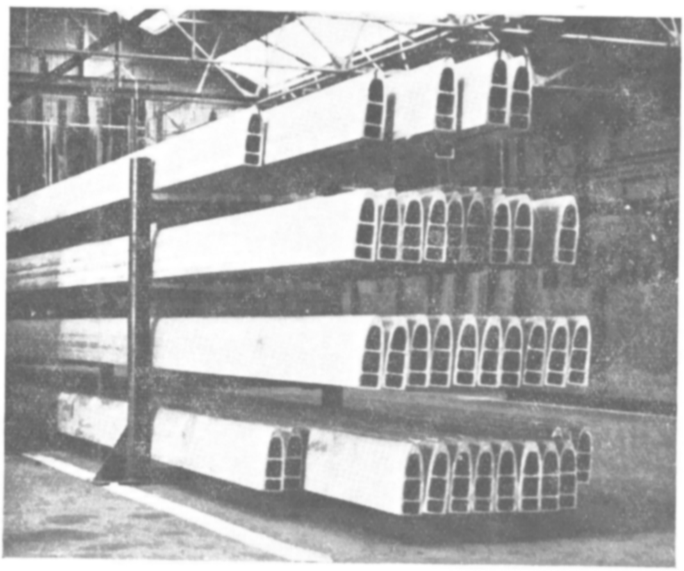

Fig 1

call for rejection The boroscope, which is a tubular assembly of lenses with a small light and periscope at the far end, is passed at least four times along the length of each longitudinal passage in the extrusion and the angle of vision provided by the small periscope at the end is such that this procedure gives a complete coverage of the internal surfaces

In the contour cutting operations the spar rests on supporting rollers on either side of the machining table and is drawn past the cutter and guide rollers by means of a cable and winch arrangement The cuts are generally small and the spar is machined on alternate faces, making sometimes as many as eight or nine passes through the contouring machine The same set-up is used, with other cutters installed, for rebating the rear surfaces of the spar to provide a location for the light gauge fabricated metal trailing edge sections

After machining, the entire spar is inspected by means of a Magnaflux Sonizon instrument as a check on wall thickness This instrument is surprisingly accurate as we were able to demonstrate some time ago on cutting up a rejected spar Some 30 readings taken by the Sonizon were subsequently checked with a micrometer and in no case was the error found to be more than 3 thou I believe that this type of measuring apparatus will be found increasingly valuable, not only as an inspection means but also as a guide to the final machining of the spars

After the machining and hand finishing operations have been completed the spar is checked for twist and rectified to angular limits of plus or minus ten minutes Immediately after extrusion it is in any case necessary to adjust the twist and straightness, and the raw extrusion when delivered to us is already twisted in very close approximation to the final requirement

The spar is then anodized and subjected to further external and internal inspection In the interval between anodizing and the various bonding operations which follow, the spar is subject to very careful cleanliness precautions, also the large room in which all subsequent operations are carried out is kept at a suitable even temperature

The first bonding operation concerns the attachment of the root adaptor plates which are essentially a means of adapting the curved surfaces of the spar root to the flat surfaces of the steel root fitting These adaptor plates extend for a considerable distance outboard and are an effective means of evenly spreading into the spar the loads arising from the root attachment The use of Redux cement in this bonding operation constitutes the main change between our production and that carried out in America where Scotchweld is used Scotchweld can give very good results under ideal conditions but some of our early tests indicated that we might have had to expect frequent disappointment unless some improved method of bonding were found Our Metallurgical Engineer has in consequence completed a very large volume of test work with both Redux and Scotchweld bonds, with results entirely favourable to Redux, with which we have obtained really very excellent results Redux has a considerable advantage, from the manufacturing point of view, in that its gap-filling qualities permit us to eliminate the elaborate scraping and fitting operations necessary to obtain the near perfect mating required by the thin Scotchweld film adhesive

The bonding operation is aided by the special preloaded spring clamps seen in Fig 2 Our bonding oven was originally designed to handle the high temperatures appropriate to the Scotchweld cement, and the lower temperatures and longer periods used in the Redux bonding permit a much easier and more accurately controlled technique A recording thermometer is connected to thermo-couples on the spar and on test pieces which are bonded at the same time The temperature recordings are kept for reference and inspection purposes

The aft two thirds of the blade aerodynamic shape is completed by fabricated light alloy sections or pockets, each extending over a spanwise distance of about one foot There are twenty two pockets in the S 51 blade, each separately cemented to the spar The thin light alloy skin of each pocket is supported by five ribs The cement used here is a special rubber based type supplied by Messrs Bostik and is substantially identical with the cements used in the American manufacture The bonding procedure involves several applications of cement with varying time intervals between each application

When the cements are ready for bonding, the ribs are inserted in a jig where they are supported and separated by wood blocks The jig assembly is then clamped up, using the wood separator blocks as wedges to ensure the application of adequate

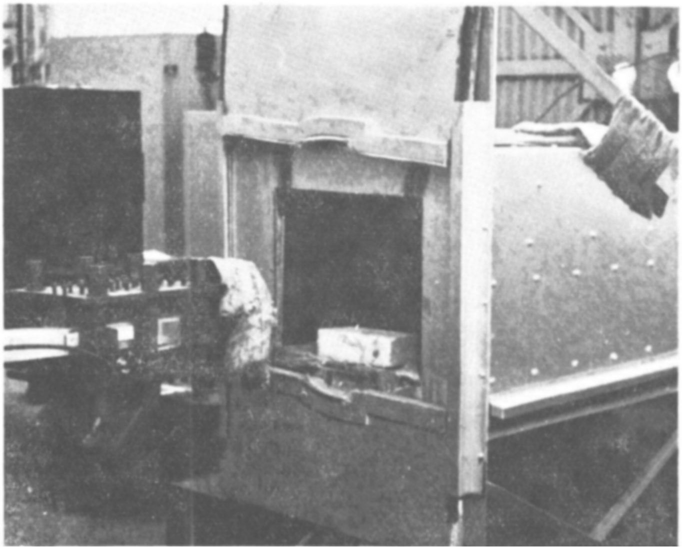

Fig 2

pressures to the bonding surfaces The jig is left for 48 hours before removal of the pocket, which is aged for several days before assembly to the spar, with which the final curing is completed

When the trailing edge pockets are sufficiently aged they are mounted together with the spar in another assembly jig In this jig the pocket assemblies are fitted

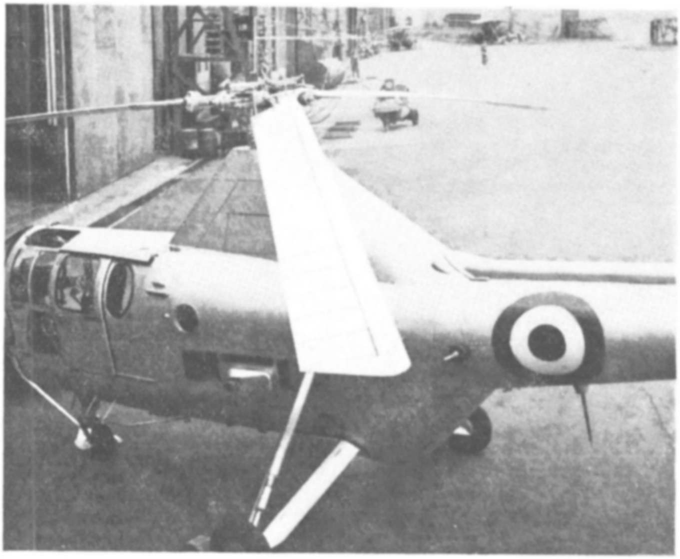

Fig 3

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together and the final positions which they will occupy are marked The pockets are then removed and the spar and pocket surfaces to be bonded are given the appropriate coatings of cement When the cement is ready for bonding the pockets are sprung over the spar into their previously marked positions and the jig is clamped up for an initial period of air curing of the cement

After removal from the assembly jig the blade is placed in a low temperature oven, heated by the steam pipes The blade is cured in this oven for approximately 16 hours at a moderately low temperature

We could use Redux for all bonding operations on the blade including the pocket assemblies but the rubber cements, although not as strong as Redux, have given results well above the desired minimum The rubber cement is easy to apply and also has the very useful property of air curing, so that should a trailing edge pocket be damaged in the field it can be removed and a new pocket cemented in its place, provided reasonable cleanliness precautions are taken, and thereafter left to air cure The desired minimum strength is in such cases reached after approximately 10 days in normal storage although the bond does not reach its full strength for 3 weeks

The trailing edge of the pockets forms a natural kind of tab which is useful in the final matching of the blades, carried out with special instrumentation either on a helicopter or on a test tower The blade tip assembly incorporates a weight which is movable chordwise, the position of this weight also being finally determined as a result of whirl tests During these tests a temporary tip cover is used, but when they are completed the production tip cover is riveted and cemented in place When the blade has been finally checked out it will, when we have fully developed our matching technique, be interchangeable with any other blade so that it can be supplied individually as a spare

Fig 3 shows the first set of metal helicopter rotor blades built at Yeovil and the photograph was taken during the course of the Type Test These blades have completed some 60 hours ground running and over 60 hours of flying, all of which has been concluded without incident This is the first set of all metal rotor blades to be built and flown in this country and the first to have successfully concluded a Type Test outside the United States

I hope that this short description has indicated the scale of the production which we are undertaking on metal rotor blades and the care in manufacture and inspection which is being devoted to this effort Although the blades appear superficially to be simple to build, in fact a great deal of painstaking work is necessary to obtain the high standard required In the course of our efforts we have received invaluable assistance from Messrs Sikorsky, but even so have met a number of interesting and sometimes difficult problems mainly concerned with the methods and facilities available to us The experience gained with the first few sets of blades has removed a great many of our earlier worries so that we are in a position to undertake with confidence the quantity production which is now commencing

The metal blades have proved very smooth in flight and almost immune from the random variations in day-to-day behaviour which have been a typical feature of many previous types of helicopter rotor blades All our helicopter production will from now on be based on these blades and from our experience with both American and British sets we know that when they come into service they will be recognised as a very considerable advance in helicopter construction technique

For the facilities which I have been given in preparing this talk I am indebted to the Management of Westland Aircraft Limited, and to Mr Worsdale of the Birmetals Company who kindly lent the first two slides

Mr Fitzwilliams talk was illustrated by 19 slides

(FIFTH PAPER)

The CHAIRMAN Our next speaker is Mr K W TURNER, who joined the Bristol Aeroplane Company in 1937 During the War Mr Turner served for a time with the Airborne Forces Experimental Establishment, and later in India as Chief Technical Officer at the Airborne Forces Research Centre At present he is Deputy Flight Research Engineer at the Bristol Company

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