CONSTRUCTIONAL DESIGN OF AEROPLANES

SECTION III.

Abstract of Paper read by Mr. C. W. Tinson, A.F.R.Ae.S., Member, at a meeting of the Institution held at the Engineers' Club, W.1., on December 1st, 1922. Mr. H. B. Molesworth in the Chair.

MR. C. W. TINSON said:

To ensure ease of engagement folders should be rigged with the front joints gaping a little. If the planes are trued up with the front pins in place the wings are almost certain to jump a bit when folded, and will not spread without easing the front spar home.

AILERONS.—Ailerons do not present any great difficulty in design except as regards torsion. When an aileron is heavily loaded, as in a dive, the support is virtually a triangle, with the hinges as base and the cable connection as apex. The load then deflects the extremities if there is no provision against it.

Diagonal members running from the lever to points on the trailing edge, where maximum deflection would occur, are generally employed to limit this deflection and stiffen the aileron up.

In calculating the strength the normal average surface loading may be taken as for the wing.

TAIL PLANE.—The majority of tail planes are symmetrical in cross section, but in special cases a tail of wing section, but inverted, is employed when there is a minus moment about the centre of gravity throughout the speed range, such as in a flying boat.

Normally the tail must depress through the greater portion of the speed range, but at minimum speed it must lift to hold the speed of the machine, and because then there is very little moment of the centre of pressure of the wings about the centre of gravity of the machine.

For detachability the tail should be a unit bolted on top of the fuselage, but when adjustable considerable air leaks occur through the gap, which must be left between it and the fin, reducing the efficiency of both fin and rudder.

A one-piece tail located between the fuselage longerons has to be more or less built in position, or the end of the fuselage put together after the tail is in place, and is bad for rapid production and for detachability. The alternative is to have the tail in halves, and attach them like wings, and this is preferable aerodynamically and from a production point of view.

As has been noted, the elevator cables must pass through the axis, about which the tail swivels, to avoid tightening and slackening.

Elevators should be designed like ailerons, but the loading on them will not exceed that which can be imposed through the controls. The torsion in them can generally be taken up by wires running out diagonally from the lever, as their span is small, or it can be provided for as in ailerons by an internal diagonal spar.

Fin and Rudder.—The aspect ratio of the rudder is important, and it is not easy to obtain a high value unless the fuselage is raked up at the rear end to give a good angle to the wings when at rest.

This seems desirable, as it would certainly appear that a symmetrical empennage is nicer in the air than one in which the majority of the vertical area is above the fuselage. Care must be taken to get sound fixings for the rudder ribs on the vertical member, generally a tube, which, of course, cannot be drilled for pins, and to get the lever as near the middle as possible, at the same time having a convenient run in for the operating cables.

Undercarriages.—When the undercarriage is of the rubber-sprung type the common method of determining the amount of rubber seems to be to call for so many yards per thousand pounds weight. This method is altogether wrong. A test should be made on the rubber cord or rings used, and a curve plotted of extension against stress in pounds per square inch.

It will then be found that 100 per cent. extension corresponds to from 700 to 900 lbs. per square inch, and clearly the unit stress should be one-third of this, or whatever figure corresponds to the factor of safety used in the design of the undercarriage.

Say it is one-third, then this will correspond to about 30 per cent. extension under unit load, and the dimensions of the rubber ring arranged accordingly, so that there is actually no initial deflection of the axle.

The number of cross sections of rubber carrying the load will be such that the unit stress does not exceed the figure selected, and the other dimensions of

https://doi.org/10.1017/S2976690700000115 Published online by Cambridge University Press

the ring, namely, its length or diameter, depends entirely on the amount of travel of the axle required.

If four inches deflection is required, for example, the free length of the ring being L, it will be 1.3 L long when in position under unit load (30 per cent. extension), and 2 L long when "home" (100 per cent. extension).

The difference, 0.7 L, is the effective extension, or deflection of the axle, and equals four inches, from which L can be determined.

TAIL SKIDS.—It is very desirable that the tail skid should be steerable, and there are not many ways of effecting this if head resistance is to be avoided.

The most satisfactory system appears to be that used in the S.E.5 and Gloucester machines, in which the skid is an arm articulated on the bottom of the stern-post, and held down by a shock absorber strut formed of spring-loaded telescopic tubes. If rubber be used a really good steerable tail skid can be designed for quite a reasonable weight, but, of course, is inevitably heavier than the usual pivotted lever type.

FLOAT CHASSIS.—Floats are the least satisfactory port of a modern aeroplane, both on account of their weight and resistance and because of the obstruction to view from the cockpits.

Disregarding the central float system float chassis fall into two classes: (a) the Short type; and (b) the White type.

In the former three-point support on the water is provided, and in the latter the main floats are very long, so that the machine floats level. Neither type appears to be definitely superior.

The employment of a tail float allows an effective water rudder to be used, and this is essential, and gives fin service aft, which is necessary. The tail float must be close up to the fuselage, and this gives a big angle to the machine when at rest, with the result that it is more easily blown over.

With the White type the water rudder has no purchase, and in a wind the machine can only be partly turned round on the water, the air pressure on the vertical surface aft overpowering the water rudder control. If the rudder be increased in size under the float bottom it is so easily damaged on the beach or slipway.

Float chassis are bound to be heavy, apart from the floats, because of greater propeller clearance, involving heavier struts, duplicate axles and bracing, and heavy side loads in taxi-ing.

FLOATS.—Floats of flexible construction are superior to the rigid type, but are more expensive to manufacture.

Flexible floats embrace the Linton-Hope type, and that type of rectangular section float virtually consisting of a thin skin box, reinforced by a number of ribs of small section like a rowing boat. The skin is also reinforced by longitudinals of light section, and the whole is flexible enough to prevent high local stresses.

In the rigid type buckling of the sides at the step is a common fault, and to avoid it there should be ample bearing area at the ends of the frame members abutting on the longerons.

If the sides are planked gaps should be left to allow for expansion on immersion. A float will absorb anything from 25 to 50 lbs. of water, in spite of varnish and paint.

The loading on the bottom varies from 4 lbs. to 8.7 lbs. per square inch, and the planing surface should not be loaded more heavily than 100 lbs. per square foot.

The float must be strong enough to permit prising the machine about the heel of the float to get the beach trolley under, and this also applies to the fuselage, a condition which does not arise with land machines.

Slinging shackles should always be provided on the centre section of a seaplane.

The total displacement of the floats should be from 1.85 to twice the weight of the machine; the planing surface should be straight from the step for a distance, giving the necessary area (100 lbs. per square foot or less); the step should be at about 0.6 of the chord; and to prevent the machine getting off before the wings are properly loaded, the planing surface should be not more than one or two degrees to the wing chord. This, of course, depends on the planing surface loading, plane loading, and other factors.

The rear axle, at any rate, should be sprung, the simplest way being to bind the axle with rubber cord to members in the float structure; but the deflection of the axle is, of course, very limited. In this case the initial tension in the rubbers is very high, to prevent deflection under unit load, and the forces tending to close the slot in which the axle rises are high, necessitating special care in design to get these forces properly transmitted to the longerons.

Rebound dampers must be fixed to the bottom of the slot, and allowance must be made for movement of the float in every direction by placing rubber rings between the sides and the locating flanges on the axles.

Amphibians.—The principal essentials of an amphibian undercarriage are: (1) the efficiency of the float, both as regards structure and operation, must not be impaired by the land gear; (2) the concentrated loads on the wheels and the distributed loads on the float bottoms must, as far as possible, be transmitted through the same structure to avoid duplication of highly stressed members.

The shock absorbers should be arranged so that they serve either when landing on ground or water.

The bottom of the float should not be recessed to accommodate the wheels, as they would very easily spring leaks through wracking, but the wheels should

https://doi.org/10.1017/S2976690700000115 Published online by Cambridge University Press

be swung on radius rods clear of the water, or into a part of the float aft, in which a hole may be made to receive them.

WINGS.—The position of interplane and internal struts having been fixed, a setting-out of the wing must be made to fix up the rib positions.

Until quite large chords are dealt with, the design of ribs is largely a matter of the minimum sizes of stuff that can be used rather than the cross sections theoretically required, so that rib spacing will not depend on their strength so much as preserving the form of the wing section.

The spacing for a normal wing should be from 10 to 13 inches, and the portion from the front spar to the leading edge should have intermediate nose ribs, or be covered with thin plywood to maintain the wing section where the curvature is sharp.

Where the chord exceeds 9 or 10 feet the ribs may be stressed out as a girder, and members of appropriate cross section employed.

As regards design, ribs usually fall into three main classes. There is the type in which a sheet of 3-ply forms the web, lightened out with lozenge-shaped or oval holes; the open panel type, in which a narrow web member runs continuously top and bottom, strutted at intervals by little uprights, as in the S.E. 5 rib; and the lattice type, in which there are diagonal bracing strips.

The first two are more suitable for small machines, in which the minimum workable size of stuff governs the design, and the last, where scientific treatment is possible.

Failure of ribs under test generally takes place in shear across the tie behind the rear spar, C.P. back, or in tension plus crushing where the flange crosses the rear spar. A little reinforcement here will make the rib carry much more, and will limit the deflection under load, which is greater than many imagine.

The flanges should never be screwed to the spar.

Ribs should be located on one side of one spar only to facilitate erection, and is all that is necessary.

In staggered machines box ribs are preferable to drift struts, as they take up torsion in the spars due to offset wire loads. At the hinges duplicate drift struts should be used for the same reason to keep the hinges plomb. These should, of course, be one above the other, as near the top and bottom edges of the spar as practicable. Similar provision should be made in way of slinging shackles on the top plane.

Spar fittings generally fall into two classes: (1) when the spar is flitched on its sides, extensions through the fabric being provided for wiring shackles; and (2) top and bottom plates bolted through the spars, with wiring lugs bent up out of them.

The latter has some advantages in staggered machines, as it tends to reduce the torsion offset.

Spar joints to fuselage and top centre section are either plain butt joints or socketted, and present no difficulty except perhaps in providing sufficient bearing area for the bolts taking tension through the joint.

FOLDING WING JOINTS.—The design of joints for folding wings presents any amount of scope for ingenuity in order to keep the weight down. Compared to a non-folding job, the joints come out very heavy, owing to the whole weight of the machine having to be carried over the joint, and tensions and compressions of great magnitude also pass through, necessitating a good hold on the spar and an all-round robustness which is not called for when the inner lift wires are attached to the fuselage direct.

Ingenuity can be displayed in making the upper and lower joint parts as nearly similar as possible for economy in production, without wasting weight, and this is not simple, as the character of the forces present is quite dissimilar.

Joint fittings complete will weigh about 0.02 of the total weight of the machine per set, unless the interplane struts can be arranged to seat on the hinge pin, when a considerable saving can be effected, as then there is practically no bending moment to be taken over the hinge fittings.

It is difficult in a folder to arrange the inner end ribs to butt, and they must usually be placed clear of the main wiring lugs on the joint fittings, and the intervening gap covered by aluminium.

DISCUSSION.

The Paper was discussed by MR. W. O. MANNING, who touched upon the following points :—

Location of ribs, and attachment of fabric; deflection of ribs under unit load; wing hinge bending moment; possibility of fouling of elevator rudder; loading on bottom of hull; water absorption; invertion of empennage.

MR. TINSON'S reply to Mr. Manning :

I am afraid that my remarks re the location of ribs on one side of one spar were dictated more by practical than theoretical considerations. Some