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174

TECHNICAL MEMORANDUM 174

COMMERCIAL AIRPLANES AND SEAPLANES.

THICK WINGS OR THIN WINGS. ALL METAL OR MIXED CONSTRUCTION.

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THICK WINGS OR THIN WINGS. ALL METAL OR MIXED CONSTRUCTION.*

By Point.

Before comparing the various solutions of the problem of commercial aviation already adopted or under consideration, it is well to establish a basis of comparison. We would, moreover, call attention to the insufficiency of having only one such basis, since the object aimed at, the commercial utilization of airplanes, may be affected by circumstances. In fact, we may consider, as the dominating characteristic, either the load carried, the speed, the radius of action, the fuel consumption, the activity of transport, or, lastly, the qualities of comfort and safety. The first four factors (weight carried, speed, radius of action and fuel consumption) determine the theoretical efficiency of the airplane, while the others (activity of transport, comfort and safety) determine its practical efficiency.

Commercial efficiency includes both of these efficiencies and it may be said that, in the most general sense, the perfect commercial airplane is a swift airplane with a large carrying capacity, a large radius of action and a small fuel consumption. It must also be strong and stable, able to fly in bad weather, capable of finding its way and landing by night, and also be able to maintain stable flight with half its engine power.

* From "Premier Congres International de la Navigation Aerienne, Paris, November, 1921, Vol. IV, pp. 475-479.

Such an ideal is too complex to be analyzed mathematically. It is possible, however, by direct calculation and by experience acquired, both in aerodynamics (by laboratory and flight tests) and in construction, to estimate the influence of these different factors.

We do not pretend to solve completely such a complex problem, but will confine our analysis to the influence of airfoils and to the structure entailed. The employment of thick wings seems bound to become general, by reason of their many aerodynamic and structural advantages, of which the following are the principal ones:

1. The high lift coefficient of thick wings at large angles of attack, which, moreover, does not exclude, for certain wing actions, a small drag at small angles of attack. One result of this property is the great range of speeds possible. Another result is the high unit load, which enables a reduction of the lifting surface, causing an increase in the maximum landing speed.

2. The "fineness" of good wing sections at the angles of minimum drag and minimum power.

The practical results of these properties are evidenced in the small fuel consumption and the possibility of flight at reduced power, or, otherwise expressed, in an increase in the radius of action and in security.

3. The thickness of the wing enables placing the structural members necessary for its strength, inside. The wing then constitutes a braced girder, which can, according to circumstances, eit

er completely do away with exterior struts and stays or at least reduce their number and size. These exterior members produce, in addition to their drag proper, parasitic drags due to their relation to the wings and their interaction with the latter, thus exacting heavy toll aerodynamically and therefore economically in return for the indispensable aid they give the thin wing.

The fineness of a thick-winged airplane is increased by this fact, as also its speed. An airplane with a mediocre thick wing (and there are excellent ones) may exhibit aerodynamic properties superior to those of an airplane with the best thin wing. Another advantage of the thick wing is the possibility of placing inside the wings bulky and dangerous accessories, such as gasoline tanks and even baggage and merchandise.

There is one other very important characteristic, which it is well to consider, namely, the weight of the airfoil. It is indisputable that a thick wing without exterior members is heavier per square meter than a thin wing with such members, but the total weight of the thick wing of an airplane of a certain weight and landing at a certain speed, is about the same as the total weight of a thin wing (including supports) adapted to an airplane having the same characteristics. In the former case, the surface area of the airfoil is reduced in nearly the same proportion as the weight per unit area in the latter case. For example, a thick-winged airplane will carry 60 kg per square meter (12.29 lbs/sq.ft) and the airfoil will weigh 9 kg per sq. (1.84 lbs/sq.ft) for a safety factor of 8. The corresponding thin-winged airplane will carry 40 kg per sq.m (8.2 lbs/sq.ft) and its airfoil will weigh 6 kg per sq.m (1.23 lbs/sq.ft) for the same resistance.

From the point of view of the weight of the airfoil, the thick-winged airplane has the further advantage of a smaller span, in comparison with a thin-winged airplane, since, with the same chord, the former will support a load per running meter inversely proportional to its span. In the flexure formula, however, the load per sq.m is in the first power and the span in the second power.

To sum up, we may affirm that a thick-winged airplane, with the same carrying capacity and landing at the same speed as a thin-winged airplane of the same strength, will have smaller wings than the latter, rendering it more maneuverable and giving it a greater speed and a smaller fuel consumption. Lastly, it will almost necessarily be a metal airplane, which is of less expensive upkeep and more durable than a wooden airplane. The commercial efficiency of such an airplane is considerably greater than that of a thin-winged airplane.

A few figures will clarify these statements. A very good thin-winged monoplane driven by a 300 HP engine, weighs 1000 kg (2204.6 lbs) in flying order. Its wing area is 15 sq.m (161.46 sq.ft) and consequently its weight per sq.m is about 66.6 kg (or 13.63 lbs/sq.ft). This all-wood airplane has two wing struts and the lines of its fuselage are perfect. Its speed is about 320 km (200 miles) per hour.

A thick-winged all-metal monoplane, of the same power and safety factor and landing at the same speed, weighs 800 kg (1763.7 lbs) in flying order and has a wing area of 7.5 sq.m (80.73 sq.ft) and a weight of 106.7 kg per sq.m (21.84 lbs/sq.ft).

The latter airplane has the advantage over the former, both in the matter of weight and also of drag, due to the absence of exterior struts and to its airfoil being only half as large. Although its wing section offers a little more resistance than the excellent biconvex wing section of the former airplane, its total drag is much less and the airplane flies 30 kilometers (18.64 mi.) faster than the former. On the other hand, the thick-winged airplane is smaller and consequently more maneuverable. Being metal, its upkeep is easy and its wing truss cannot warp. This airplane now costs more than the wooden one, but the time will soon come when aluminum will be as cheap as the wood from our impoverished forests.

Another question is whether the commercial airplane is to be a monoplane or a multiplane. This problem, the subject of numerous controversies, is more difficult to solve. We believe that either the monoplane, the biplane, or even the multiplane may be the best solution, according to circumstances.

Doubtless the monoplane without exterior stays constitutes aerodynamically the best glider, but it cannot always be employed. The structural difficulties increase with its size. Beyond a certain length, it becomes impossible to construct a purely cantilever wing. It is then better to renounce the monoplane or add exterior struts.

A strutless biplane of large aspect ratio and large gap may have a greater aerodynamic efficiency than a monoplane of small aspect ratio, with struts. As to practical efficiency, it may differ according to the importance attached to this or that quality considered preponderant.

When confronted by two solutions which seem equally acceptable, the engineer, in making his choice, must depend on calculations of the interactions of the wings, in order to determine the aerodynamic losses due to the mutual action of the wings of a multiplane, and see whether these losses are offset by the gain due to the aspect ratio. He must also investigate, in the laboratory, the interaction of the parasite members on each other and on the wing surfaces. Furthermore, he must make weight estimates based on strength calculations. He must give special consideration to the needs of the aerial navigation company. Only after building several complete airplanes, will he be able to choose the best solution.

Let us now consider what means have been employed for making thick-winged airplanes. We have already mentioned that the thick-winged airplane is necessarily a metal airplane. We will now add that its wings must be made of light alloys. The strength of the materials teaches us that the deflection of a part loaded in flexure (like a wing) is inversely proportional to the product of the coefficient of elasticity times the moment of inertia: Experience teaches us, on the other hand, that the requisite strength and durability of an airplane forbid going under certain practical thicknesses, lest the component parts, fastened together by the crude method (and yet the only method now known) of riveting, undergo local deformation, thus weakening the whole structure. Rivet heads, in assembling, and afterwards as a result of vibrations, penetrate the metal of the parts assembled, which, on account of their thinness, are no longer held firmly together, thereby causing a general dislocation of the whole structure.

The use of wood in long cantilever wings is possible only for wings of considerable thickness, since a large moment of inertia, necessitating a very deep girder, is required, in order to make up for the small coefficient of elasticity of the material.

The use of high-tensile steels is not possible in the construction of thick wings, because the high coefficient of elasticity of the steel diminishes the moment of inertia, while the requisite thickness of the material renders it impossible to profit by a great depth of girder. Even the strongest steel would therefore be too heavy.

Light alloys, on the contrary, are suitable for thick wings and the very lightest alloys with a small coefficient of elasticity (containing considerable magnesium) are the best for very thick wings.

The structural principle for cantilever wings is the same as for metal bridges and buildings. It should be noted, however, that the formulas employed in metal construction are semiempirical formulas, which are generally very broad. In other words, the engineer who employs them, must provide against the possibility of unforeseen stresses.

On the other hand, certain formulas employed in metal construction are applicable only within limits dètermined by the experience of the builders. It would be imprudent to transfer blindly all these formulas to the metal construction of airplanes. The engineer must make a detailed analysis, going back to the basis of the establishment of the formulas he employs. In doubtful cases, tests must be made. Often it is only after many tests that he can determine just how to apply his personal experience, together with the general information he has previously acquired.

Aside from this restriction, metal construction does not present the mysteries often ascribed to it. Though it has led to disappointments, the latter have only served as lessons for the future. Relying on ous small experience in one year of metal construction, we do not hesitate to state that we prefer this method to wood construction.

Much has been said about metal wing coverings. The Germans have used them and some have claimed that the covering increases the strength of the wing truss by taking the place of spars. This is surely going a little too far, since such a covering is too thin to prevent compression on top. The metal covering has the advantage of preserving the shape of the wing section. At the present time, its employment seems premature, because riveting necessitates a thickness which renders the duralumin covering too heavy and this increase in weight is not compensated by any sufficient gain in strength. Perhaps extremely light alloys will yet solve the problem of metal covering. For the interior framework of the wing, either tubes or other shaped beams mav be used.

An interesting solution of the cantilever wing is the wing of uniform strength, of which there are two conceptions:

1. The wing of variable thickness and chord. This is evidently the more logical. It has, however, the disadvantage of complexity. The ribs being all different, interchangeability is impossible and practical efficiency in production is reduced.

2. The wing of constant thickness and length and of uniform strength, consisting of ribs all alike, on spars of uniform size, the ribs and stays being placed nearer together toward the axis of the airplane. This latter method greatly facilitates construction, especially in quantity production.

We will conclude with a few words on raw materials. We would recommend the remarkable works of Colonel Grard to those desiring information on this subject. We will limit ourselves to the expression of two wishes, namely, to have at our command a metal on whose homogeneity we can always rely and a sufficient assortment of shapes to draw from. Henceforth, the manufacture of metal airplanes will constitute an industry of sufficient importance to demand the undivided attention of the metallurgist. On him will depend the progress of this industry, which, we are convinced, will soon be one of the factors of national prosperity.

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