TECHNICAL MEMORANDUMS

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# TAIL PLANES

By L. Constantin

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# T A I L   P L A N E S.*

By L. Constantin.

I am here to present to the constructors of large airplanes the possibility of an improvement in the cells. My remarks will doubtless be received at first only with indifference, but I consider it my duty to present the following facts.

In the course of a very interesting lecture, Mr. Verdurand, Director of the "Air Union," made the following surprising statement to the "Société Francaise de Navigation Aérienne": "A lightening of 1 kg (2.2 lb.) in the cell of a commercial airplane may result in a saving of 4620 francs, if the airplane is in actual use for 1500 hours; or, of more than 12,000 francs, if the cell should last 4000 hours."

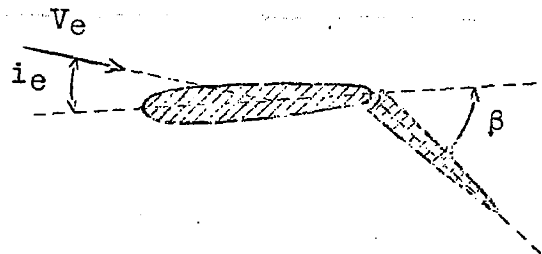
In the same order of ideas, Mr. Stout, the American constructor, declares: "A saving of 100 lb. in the weight of an airplane means a saving of $20 per hour, or $200 per day, of 10 hours of flight."

In the face of such astonishing but indisputable figures, why do not the bureaus of research, instead of giving so much attention to the cost of production, investigate the matter of reducing the weight of the cells to the extreme limit compatible with safety?

*"Les Empennages," from "L'Aérophile," May 1-15, 1926, pp. 140, 141.

There is one portion of an airplane, namely, the tail group, which seems to have received no real attention in the matter of lightening, although a considerable weight reduction could be effected without entailing any increase in cost. The reason for this neglect doubtless resides in an almost superstitious belief which, although supported neither by experience nor by any of the existing theories (of Joukowski or Witoszynski), is nevertheless very widely diffused, namely that $\frac{d\ C_z}{d\ i}$ is constant for all profiles of airplane wings having the same aspect ratio. In other words, all curves representing the lifts of the various profiles of wings (having the same aspect ratio) in terms of the angle of attack are, within the utilizable limits, straight lines of constant angular coefficient. Nearly all constructors have accordingly adopted symmetrical profiles for their stabilizing planes because they have the least drag, without considering the effect on the lift.

On the other hand, and especially for large units such as are required both to give the airplane a suitable stability and reduce to a minimum the hinge moment of the elevator (i.e., the effort of the pilot on the control stick), the bureaus of research have adopted, more and more generally, a very forward location of the center of gravity, a large stabilizer attacked negatively and an elevator somewhat sheltered behind the stabilizer.




This arrangement has obvious disadvantages. The polar curve of the kind of angle thus formed is very poor for negative angles of attack. The aerodynamic efficiency of the whole is therefore low and its weight considerable. In the second place, since the static-test loads are (according to the stipulations for the acceptance of airplanes) proportional to the areas, the mechanical strength of the fuselage must be larger, which further increases the weight. In the third place, since the longitudinal moment of inertia of the airplane is composed largely of the moment of inertia of the tail, all these weight increments augment this moment of inertia to such an extent as to impair the maneuverability and dynamic stability of the airplane. Lastly, if it is true that the static lift produced by the hinge moment of the elevator is small, it must not be forgotten that the moment of inertia of this movable part is large and that the rapid manœuvers, necessary for protection against sudden wind gusts demand great muscular efforts.

It is possible, however, to improve all this. A stabilizer of total area $S_e$, must perform three main functions.

1. To make the centering possible, i.e., to furnish a sufficient negative lift to insure static equilibrium, when the center of gravity of the airplane is located far forward, as it has an increasing tendency to be.

2. To produce automatically, in case of static instability (caused, for example, by a wind gust) correcting moments capable of providing a certain inherent stability, both static and dynamic.

3. To render the control of the airplane possible. If the first two functions are fulfilled, an appropriate movable flap will always render it possible to assure the third.

If it be assumed, as is generally done, that all the profiles of the same aspect ratio have the same $\frac{d\,C_z}{d\,i}$, it is evident that, for a given centering, all the profiles can be utilized to fulfill the functions 1 and 2. It will, in fact, suffice to dimension suitably the total area $S_e$ and to set the stabilizer at the angle corresponding to the desired lift. This operation will be facilitated, moreover, by the possibility of changing $\frac{d\,C_z}{d\,i}$ by modifying the aspect ratio. The final choice will be determined by considerations of another order, such as the minimum drag or the maximum facility of manufacture. All the elevators thus established will have proportionate weights.

This does not hold true, however, for profiles of very large $\frac{d\ C_z}{d\ i}$, for which these weights can be appreciably reduced. Probably there is a very large number of profiles possessing this property, and the aerodynamic laboratories can doubtless perform a useful service by making a thorough investigation of them. One of these is the Eiffel profile No. 4, a circular profile of constant thickness, with a camber equal to 1/7 of the radius. For this profile, between $-3^\circ$ and $3^\circ$, $d\ C_z$ attains a mean of more than 0.12 per degree of increase of the angle of attack, for an aspect ratio of 6, when this increase does not exceed 0.07 under the same conditions as for the present profiles. Between $0^\circ$ and $3^\circ$, $d\ C_z$ even reaches 0.15; and between $0^\circ$ and $2^\circ$, 0.17. These remarkable properties certainly merit the attention of constructors.

In a pamphlet published by the S.T.Aé. ("Le centrage de la stabilité des avions") and which is a mine of valuable information, Mr. Toussaint, Director of the "Institut Aérotechnique de Saint Cyr," shows how, in a biplane of 100 m² (about 1076 sq.ft.) wing area, the angle of attack of the stabilizer varies only $5.35^\circ$, while the angle of attack of the principal surfaces varies about $20^\circ$. This is due first to the deflection of the air filaments by the cell and second to the deflection caused by the propeller slip stream. It follows that we can, in most cases, utilize the Eiffel profile No. 4 in the portion of the curve corresponding to large values of $\frac{d\ C_z}{d\ i}$.

Thus, in the example given by Mr. Toussaint, on p. 20, if, instead of a surface $S_e$ with a symmetrical profile, with an aspect ratio of 3.15, set at $-5.55^o$ to the wing chord, we employ a surface $S_e/3$, with 1/3 the area, but with the Eiffel profile No. 4 and an aspect ratio of 6, set at $3.9^o$, with its concavity upward, the airplane would still be in static equilibrium for $100\ C_z = 40$. The static stability for this lift would be the same $\frac{d\ C_{ze}}{d\ i}$ and, due to the smaller inertia, the dynamic stability would be perceptibly improved. The same would doubtless be true of the drag. We may sometimes be disturbed by the very great lift of the Eiffel profile No. 4 and it may be difficult to determine a good angle of setting.

Still less has it been demonstrated that the very forward centering is the best. In fact, it has the disadvantage of diminishing the aerodynamic efficiency of the cell and amounts to a useless increase in the dead weight, which we are trying to reduce. The stability of shape is thus obtained at the expense of the maneuverability.

Moreover, it is possible to anticipate the time when all large airplanes will be piloted through the intermediation of stabilizing wind vanes, when it will probably be advantageous to reduce the inherent stability of these airplanes to zero.

The Eiffel profile No. 4 will still be employed, however, either with a diminution of the aspect ratio or, as I suggested a long time ago, by the structure of the tail planes formed by two surfaces symmetrical to a median plane (See "L'Aérophile," May, 1924). We can thus simultaneously obtain perfect aerodynamic symmetry and minimum drag.

The advantage thus obtained may be important, but it is difficult to evaluate it now with exactitude, for the lack of a few laboratory experiments. It will bring about a considerable saving in the operation of air traffic lines.

Translation by Dwight M. Miner,
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