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TREND TO BE GIVEN AERODYNAMICAL RESEARCH AND EXPERIMENT.

By M. Lèpere.

From L'Aérophile, March 1-15, 1923.

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By M. Lepere.

Progress in aeronautical construction depends upon improvements effected in the methods of design and construction available. These fall under three heads:

1st. Theoretical data,

2nd. Experimental data,

3rd. Materials and methods of construction.

We must confess that, of the three, the section dealing with experimental work is the least satisfactory. We believe that this is due to the fact that there is too much optimism with regard to wind tunnel tests. It has been too easily taken for granted that results obtained on small models could be directly applied to full-size airplanes.

The main causes of error were:

1st. Neglect of the laws of dynamic similitude (Reynolds Law vl = constant). The law of mechanical similitude was applied, the formula for which is $\frac{v}{\sqrt{l}}$ = constant.

2nd. Interference between the support and the model.

3rd. Nature of air stream: open or closed tunnel; turbulent or smooth flow.

4th. Influence of the walls of the tunnel.

* From L'Aérophile, March 1-15, 1923, pp. 70 and 71.

Since the armistice two objects have been kept in view; one was to check by experiment certain mathematical theories, and the other was to reconcile with each other the results obtained in different tunnels in France and other countries. It would appear that this latter object has been attained, as regards the tests made at the laboratories of St. Cyr, Eiffel, and Göttingen, on a simple monoplane wing, allowing for the necessary corrections.

But even admitting that this agreement has been reached, there is none the less a good deal of uncertainty as regards the correlation between large and small models. We may indicate, roughly, the chief points on which accuracy should be sought, taking as our standpoint the practical application of laboratory tests, rather than scientific considerations.

I. Results Concerning Separate Parts.

a) WINGS.- The coefficients of lift K_y appear to be little affected by the law of similitude (vl) in thin wings. Recent experiments made in England, however, seem to indicate that in thick wings the influence of this law on K_y is very great (compare results of the Pulitzer Cup Contest: thick-wing monoplanes). The K_x obtained in the different laboratories are far from agreeing in value and seem clearly affected by the law of similitude. The variations of K_x are relatively unimportant, considering their very low value in the drag of a complete airplane. With C_m (coefficient of moment) the case is different. As a matter of fact, the correctness of the position of the center of gravity and the stability of the airplane depend on the accuracy of C_m. Thick wings of the Joukowsky type must be employed very carefully until the values of the C_m have been verified on full-scale airplanes. It would seem that the instability of some airplanes having wings of this type is due to errors in the computation of the C_m.

Another interesting point to be studied is the effect of the shape of a monoplane wing, of its gradual reduction in thickness, and of the distribution of lift along the span (elliptic distribution). All this is of great importance in computing the resistance of cantilever wings, the use of which has given interesting results.

b) AILERONS.- Aileron action is still far from being thoroughly understood, nor is the moment about the hings well understood, so that it is difficult to compute beforehand the force required for their operation. It would be well, if aileron action could be increased at low speeds and while landing. On these lines the English have obtained interesting results with the Handley Page slotted ailerons. Such ailerons have been mounted on an experimental airplane. They have also the advantage of partially balancing the stresses. Almost all other forms of balancing hitherto tried had to be given up, as they gave rise to vibration.

c) TAIL SURFACES.-

<u>1st. Horizontal</u>.- The proportions to be given to the sta-

bilizer depend directly on the shape of the C_m curve relative to the lifting surfaces.

Even when the C_m curve is well-defined, we have still to design a stabilizer which will act satisfactorily under varied and opposite conditions (climb at the take-off, horizontal flight at full throttle, gliding flight with engine shut off; stability and absorption of shocks). Both the total reaction on the stabilizer and the reaction on the elevators must be known.

2nd. Vertical.- What we have just said concerning the horizontal tail surfaces applies equally to the vertical tail surfaces. These consist of a fixed fin and a movable rudder. On a single-engine airplane the arrangement of the fin and rudder is not very important, but with a multi-engine airplane badly placed vertical surfaces may lead to a catastrophe should one of the engines stop. Generally, the fin and rudder are determined on purely empirical data and little account is taken of reactions on the controls. But if we possessed reliable data enabling us to choose a good general contour, right proportions of fin and rudder and the best section for each part, we might be able to arrive at a satisfactory solution of the problem. We should do well to study the numerous tests made on this point by the English and Germans.

d) STREAMLINE PARTS.- Streamline bodies, such as fuselage and struts, introduce purely passive resistances which are so greatly affected by similitude that it has been found necessary, in testing small models, to do away with all the bracing wires and most of the struts. It would be very interesting to know what strut sections give the least resistance at the high speeds now made. It is by no means sure that the best form for a speed of 200 km/h (124.3 mi/hr) is also the best for a speed of 350 km/h (217.5 mi/hr).

II.- THE PARTS AS A WHOLE.- We have just shown the great uncertainty which prevails in applying test results to separate parts. We shall now show that the uncertainty is still greater when we consider the parts as a whole. In point of fact, when any two parts are connected they no longer behave as when they were separate units. The interferences thus set up may be divided into three main categories:

1st. Interference of two or more lifting surfaces (biplanes, multiplanes, etc.).

2nd. Interference of lifting with non-lifting parts, (wings, struts, fuselage, radiators).

3rd. Interference of lifting elements and controls resulting in downwash.

Of the three categories, the first has been most studied. The interference of lifting surfaces with each other has been well worked out from a mathematical standpoint and many tests have been made. This interference can now be determined pretty accurately in simple cases, though recent tests made at St. Cyr seem to throw a doubt on the fundamental theorems of Munk on the interference of lifting surfaces.

We have scarcely any data on the interferences of the second class. Prof. Ursinus, however, indicates that, in order to allow for the interference of a wing with the end of a strut, we must add to the end of the strut an imaginary length equal to 30 cm (11.8 in).

For the third sort of interferences, we possess experimental results and practical formulas, but unfortunately, they are not in complete agreement. It is a pity that the effect of downwash has not been studied in France.

III.- PROPELLER INFLUENCE.- The airflow about the different parts of an airplane is further troubled by the propeller or propellers. It is almost impossible to forecast the disturbance thus caused, even if we consider only the propeller itself, for the characteristic curves applicable to full-scale airplanes have not yet been accurately defined. For testing a propeller alone we must have two conditions (VD = constant and v/nD = constant) and it is often difficult to reconcile the two. We have no exact data on the relative efficiency of a three- or four-bladed propeller. Moreover, blade deformation always causes considerable error.

If it is difficult to forecast the functioning of a propeller considered alone, the problem becomes much more difficult when the propeller is mounted on an airplane and we have multiple interferences to consider. These are:

1st. The effect of the propeller on the wings (before or aft).

2nd. The effect of the propeller on the fuselage (decrease of propeller efficiency and increase of fuselage drag), whence the advantage of reducing gear to increase the ratio of propeller diameter to fuselage diameter.

3rd. The effect of the propeller slipstream on tail unit.

The above considerations apply only to a single propeller and are, of course, greatly complicated in the case of tandem propellers, particularly if the R.P.M. ratio of the two propellers varies.

UTILIZING TEST RESULTS IN DESIGNING.

There are three principal methods of designing a new airplane.

1st. Comparison with an existing model.

2nd. Utilizing small model tests. In this case part of the parasite resistances must be calculated and added.

3rd. Synthesis of tests on parts.

None of these methods is sufficient when taken alone and it is advisable to combine them. The first method is undoubtedly the best, especially as regards questions of balance, stability, and maneuverability.

CONCLUSION.

It would appear that the very competent staff of our laboratories has at present more work than it can manage and that its efforts are scattered over too many varied experiments. It is customary for small models, supplied by constructors for testing, to be tested either at the Eiffel laboratory or at St. Cyr. Could not one of these laboratories, the Eiffel, say, be charged with all such tests, so that St. Cyr would be free to undertake more serious work? This would, of course, necessitate the previous standardization of the two tunnels so that the results would be in accord. When the tunnel at Issy-les-Moulineaux is completed (that is, when the work concerning the air stream and the methods of measurement is terminated), we shall have a third research center.

The defects in experimental data noted in this paper show very clearly what kind of research work has still to be done. It is quite certain that we must proceed from single parts to the complex whole and only deal with the latter, when satisfactory results have been obtained with the former.

As regards the test methods to be employed, we think that truck tests should not be neglected, though the truck, as now used, is by no means perfect. It is to be regretted that it has not been more developed, for it provides a method midway between wind tunnel tests and free flight tests. We regret, too, that the very interesting experiments by the Duc de Guiche, on surfaces carried on a special car, were interrupted by the war. In 1914, both the method and the manometric appliances used were almost perfect, and we were on the point of getting good results for the improvement of wing sections.

Speaking of manometric methods, we think a great mistake was made in not continuing them, as they gave analytical data much better than the synthetic data obtained by weight tests.

We know that in England, Professor Bairstow proposes to utilize this method again for studying airflow about a wing and deducing from it, if possible, a mathematical theory.

In the United States, the same method has been applied to airplanes in flight, chiefly as regards the tail planes. The results were extremely precise and instructive. Tests of this kind were begun in France in 1914 on a Blériot airplane, but were stopped by the war.

In particular, the manometric method permits studying the phenomenon of the breaking away of air filaments which has been noted on thick wings. This phenomenon occurs at different angles of attack, according to whether the test is carried out at increasing or decreasing angle of attack or at increasing or decreasing speed.

Lastly, we may note that the systematic study of various types of airplanes in full flight, by means of recording instruments, seems to have been completely given up, the only instruments now used being the recording airspeed indicator, the recording tachometer, and the barothermograph. It would be very instructive, however, to record the control displacements and their reactions on each type of airplane.

The use of accelerometers on new types of airplanes would furnish precise data regarding the accelerations imparted to the airplane during acrobatic stunts, and would make for a greater degree of accuracy under the very difficult conditions of static tests.