3 1176 00007 7488

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Technical Memorandum 156.

METHOD RENDERING IT POSSIBLE, IN TESTING AIRPLANE WING MODELS AT THE EIFFEL LABORATORY, TO OBTAIN COMPARABLE POLARS, WHETHER THE SUPPORTS ARE ATTACHED TO THE UPPER OR LOWER SIDE OF MODEL.

By G. Eiffel.

From "L'Aerophile," August 1-15, 1922.

FILE COPY
To be returned to
the files of the Langley
Memorial Aeronautical
Laboratory.

9,2

November, 1922.

METHOD RENDERING IT POSSIBLE, IN TESTING AIRPLANE WING MODELS AT THE EIFFEL LABORATORY, TO OBTAIN COMPARABLE POLARS, WHETHER THE SUPPORTS ARE ATTACHED TO THE UPPER OR LOWER SIDE OF MODEL.*

By G. Eiffel.

The many comparisons I have made of the results of my tests have always shown that the possible errors were of such a nature that the results obtained with the model were less favorable than those obtained on a full-sized airplane** and consequently do not incur the liability of mistakes of a dangerous nature.

I long thought these errors were due to our ignorance of the law of exact similitude enabling the transition from models to full-sized airplanes. Experiments performed in my laboratory early in 1921 demonstrated, however, that the method of attacking was almost entirely responsible for them. Thus, in attaching the models to the aerodynamic balance by means of two small rods secured to the top of the wing, less advantageous polars were obtained than when the rods were fastened to the bottom of the wing especially after Ky had attained a certain value.

On a complete airplane model, the errors for both methods of attacking were of the same nature as for the wing alone, but they were relatively much smaller and were usually negligible.

Mr. Robert has, moreover, described most of these experiments in his report to the "Premier Congrès de la Navigation Aérienne"

* From "L'Aérophile," August 1-15, 1922, pp. 227-230.

** See preface, page 20, of my book, "Resumé des principaux Travaux exécutés pendent la Guerre au Laboratoire d'Auteuil."

(First Congress of Aerial Navigation - see N.A.C.A. file 1105.5-2 the diagrams published in this report being based on experiments made in my laboratory.

As I have already mentioned, the perturbing effect of the rods, when attached to the top of a wing, was demonstrated in the early months of 1921. One of the first practical conclusions from these experiments is that it is important to avoid placing even very small obstacles on top of airplane wings, where the suction is strong, and that the top of the wings must be kept as smooth as possible.

At first thought, it would seem desirable to attach the models to the balances by means of wires, in order to diminish the effects of interaction. At Göttingen, however, where this method of attaching has long been employed, it has been observed that, in certain cases, wires also produce interaction phenomena. Such wires, moreover, offer resistances which are comparable and often much greater than the resistance offered by the models themselves. For this reason, their use entails repeated allowances for tare in each test of a new model and the very difficult experiments can only be performed by an experienced personnel.

In order to enable engineers and constructors to utilize the numerous experimental data contained in my works: "Nouvelles Recherches sur la Résistance de l'Air et l'Aviation" and "Résumé des principaux Travaux exécutés pendant la Guerre," Mr. Lapresle, director of my laboratory, undertook to find a method of transition from the coefficients Ky and Kx, for a wing model held by

rods attached on top, to the corresponding coefficients of the same model held by rods attached underneath.

This method is very easily applied and its principle may be stated thus: "The unfavorable effect of the attachment to the top of a wing model is equivalent to a reduction of the aspect ratio." For example, the wing models with an aspect ratio of $\lambda = 6$, which I employed, behaved as if they had an aspect ratio of only $\lambda = 4$, on account of the interaction between the rods and the top of the model.

For obtaining this law of transition, Mr. Lapresle made use of the theories of "induced drag" and "wing drag" Kx_i and Kx_p, introduced into aerodynamics by Professor Prandtl.

The induced drag is directly related to the manner of circulation of the air about the wing. It depends, therefore, to a greater or less degree, on all obstacles capable of appreciably modifying the air flow in the vicinity of the wing. In particula it seems probable that the induced drag is affected by attachment rods or wires, either on the upper or lower side of the wing.

The "wing drag" is produced largely by skin friction and by losses due to lift (pertes de charge) in the compression and re-expansion of the air flowing by the wing. On account of their nature, these particular drags can evidently be but little affect by the presence of obstacles around the wing. Under these conditions, it is reasonable to suppose that, for an air flow of given velocity, i.e. for a given Ky, the wing drag will remain the same, with any method of attachment, provided the attachments are

always of small dimensions in comparison with the dimensions of the model.

We may therefore proceed as follows in determining the law of transition from one method to the other. From the results obtained with the rods attached to the under side of the model (which, as shown by experience, cause no interaction), we may, according to the aspect ratio of the model, calculate the coefficient of induced drag by Prandtl's formula:

$$Kx_i = \frac{5.1}{\lambda} (Ky)^2$$

Knowing this coefficient of induced drag, we can derive from it, by subtracting it from the coefficient Kx_t of total drag, the coefficient Kx_p of wing drag in terms of Ky.

To the same wing model tested with the rods attached on top, we attribute the same law of variation of Kx_p in terms of Ky. Then by subtracting this coefficient of wing drag from the coefficient of total drag measured with the attachments on top, we determine the corresponding coefficients of induced drag. Prandtl's formula then enables us, knowing Kx_i in terms of Ky, to derive from it the proper aspect ratio to give the wing model tested with the attachments on top, so that it will actually give this coefficient of induced drag.

Calculation Example.- We are going to give, for the sake of illustration, the details of the calculation for the Odier wing No. 36 (see "Nouvelles Recherches sur la Resistance de l'Air e l'Aviation" by Eiffel), with an aspect ratio of

$$\lambda = \frac{900}{159} = 5.66 \text{ (see Pl. IV and Atlas, p.10).}$$

This wing (Fig. 1) has recently been tested with the supporting rods attached to the lower camber. The results of this test are given in Table 1 and graphically presented in Fig. 2.

Table 1.

Results of testing Odier wing 36 with supporting rods attached to lower side.

i	-6°	-3°	0°	3°	6°	9°	12°	15°
100 Ky	-0.865	0.860	2.25	3.70	4.94	5.90	6.60	7.28
100 Kx_t	0.424	0.192	0.134	0.172	0.279	0.427	0.652	4.060
100 Kx_i	0.007	0.007	0.046	0.123	0.220	0.315	0.391	0.476
100 Kx_p	0.417	0.185	0.088	0.049	0.059	0.112	0.261	0.584

We have included the induced drag coefficients given by Prandtl's formula:

$$Kx_i = \frac{5.10}{5.66} (Ky)^2 = 0.90(Ky)^2$$

and the wing drag coefficients:

$$Kx_p = Kx_t - Kx_i.$$

Fig. 3 shows the curve giving the variations of 100 Kx_p in terms of Ky.

On the other hand, we have taken from the publications of the Eiffel Laboratory ("Nouvelles Recherches sur la Resistance de l'Air et l'Aviation," Atlas, p.10), the following table giving the re-

sults of testing the same wing with rods attached on top.

Table 2.

Results of testing Odier wing 36 with supporting rods attached to upper camber.

i	-5°	0°	3°	6°	10°	15°
100 Ky	-0.573	2.10	3.43	4.65	5.70	6.94
100 Kx	0.375	0.158	0.240	0.342	0.580	1.060

On the curve in Fig. 3, we find the wing drag coefficients 100 Kx_p in terms of Ky and, by subtracting them from 100 Kx_t, we obtain the induced drag coefficients 100 Kx_i. We can thus complete the numerical table already given by the Eiffel Laboratory.

Table 3.

i	-5°	0°	3°	6°	10°	15°
100 Ky	-0.573	2.10	3.43	4.65	5.70	6.94
100 Kx_t	0.375	0.158	0.240	0.342	0.580	1.06
100 Kx_p	0.366	0.095	0.055	0.052	0.093	0.38
100 Kx_i	0.009	0.063	0.185	0.290	0.487	0.680

The aspect ratio required by a wing, in order that it may have these values of Kx_i in terms of Ky, is given by the formula for the induced drag:

$$Kx_i = \frac{5.10}{\lambda} (Ky)^2$$

whence

$$\lambda = 5.10 \frac{(Ky)^2}{Kx_i}$$

For the above experimental points, this formula gives:

Angle of attack	-5°	0°	3°	6°	10°	15°
Corresponding aspect ratio	3.6	3.5	3.25	3.8	3.4	3.6

The average is about 3.6 for an original λ of 5.66, or an average reduction of 2 units.

For the other wings we have studied, among those given in former publications of the laboratory, the mean value $\lambda - 2$ is practically correct and can be generally adopted. Such is the practical conclusion of this investigation.

In Fig. 4 we have given the polar of the Odier wing with an aspect ratio of 3.66, just as we derived it from actual tests with the attachments underneath.

The elements of this polar are easily deduced from the values given in Table 1. In order to obtain the total drags corresponding to the lifts indicated in this table, it is only necessary to add, to the given coefficients of wing drag, the coefficients of induced drag calculated by the formula:

$$Kx_i = \frac{5.10}{3.66} (Ky)^2 = 1.39 (Ky)^2$$

We thus come to

Table 4.

Elements of the polar of the Odier wing 36 for an aspect ratio 3.66 with supporting rods attached to lower side.

i	-5°	-3°	0°	3°	6°	9°	12°	15°
100 Ky	-0.865	0.860	2.25	3.70	4.94	5.90	6.60	7.28
100 Kx_p	0.417	0.185	0.088	0.049	0.059	0.112	0.261	0.584
100 Kx_i	0.010	0.010	0.071	0.190	0.340	0.482	0.606	0.738
100 Kx_t	0.427	0.195	0.159	0.239	0.399	0.594	0.867	1.322

In Fig. 4 we have indicated by crosses and connected by a dot-line the points actually obtained on the same wing with an aspect ratio of 5.66. It is evident that the coincidence is as satisfactory as could be desired. This agreement goes still further, since, if we trace the actual curves of the coefficients Ky in terms of the angles of attack compared with the aspect ratio, we obtain almost exactly the curve Ky, in terms of the angle of attack, given by my experiments.*

Remark:- The present polars take account of a correction of the influence of the limits of air currents, due to Professor Prandtl and which was not known at the time of my own experiments.

This correction, which renders it possible to experiment with larger models, resolves itself ultimately into a function of the induced drag. According to the method just indicated, if we consider the polars I have published as related to the aspect ratio $\lambda - 2$, the wing drags deduced from them will automatically also take account of this correction, which sometimes is of some impor-

* Two wings, the results of which I have published and which bear the numbers 32 (Lanier Laurence) and 38 (Coanda), form exceptions because these wings were tested with the attachments underneath. They must therefore retain the aspect ratio 6, as given in my works.

tance.

We have had the satisfaction of finding that our results, thus corrected, agree very closely with those published by the Göttingen Laboratory.

Translated by the National Advisory Committee for Aeronautics.