TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 145

DEFLECTION OF PROPELLER BLADES WHILE RUNNING

By R. Katzmayr

Translated from "Motorwagen," April 30, 1922

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October, 1922.

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DEFLECTION OF PROPELLER BLADES WHILE RUNNING.*

By R. Katzmayr.

The forces acting on the blades of a propeller proceed from the mass of the propeller and the resistance of the surrounding medium. The magnitude, direction and point of application of the resultant to the propeller blade is of prime importance for the strength calculation. The stress on the propeller blade is a combination of flexure and tension, producing a distortion of the blade. The amount of this distortion depends on the distribution of both mass and area of cross-section throughout the length of the blade. The amount and kind of distortion affect the efficiency of the propeller at different revolution speeds and it lies within the power of the designer to produce a distortion of the propeller blade in any desired direction by a suitable distribution of mass and area of cross-section. It is not to be ascribed ultimately to this fact that propellers from certain factories (e.g. Knoller-Jaray in Vienna) show uniform high efficiency at considerably differing speeds.

In the large propeller-testing laboratory erected at Fischamend during the war and since destroyed by the victors, the

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* Translated from "Motorwagen," April 30, 1922, pp. 223-225.

amount of distortion of propeller blades during flight was to have been accurately determined. The experiments with propeller models of one meter diameter, instituted by the writer, gave two useful results. The first was the amount of deflection in the tip of the blade (at which point it is usually the greatest) and the second was the distribution of the deflection throughout the propeller radius.

Since it was obviously impracticable to bring any kind of testing device near the revolving propeller, not so much on account of the element of danger as on account of the resulting considerable disturbance of the air flow, the deflection in both cases was photographically recorded and subsequently measured at leisure.

The first method was characterized by the use of a constantly shining incandescent lamp. This so-called "Zystoscope" lamp, of only 3.5 mm diameter and 3.8 grams weight, was firmly secured to the tip of the propeller blade (Fig. 1). The requisite electric current was supplied to the lamp by a wire of only 0.12 mm diameter, which was led from the hub through fine holes in the blade. On the propeller shaft there was a collector ring with two brass springs for conducting the current. At a suitable distance from the wing tip, a photograph camera was set up in such a manner that the sensitive plate was perpendicular to the plane of rotation of the propeller and the principal axis of the lens lay in the latter plane. With the revolution of the propeller a line of light was recorded on the plate. The fourth band from

the top in Fig. 2 was produced by turning the propeller slowly by hand. The lowest of the three parallel lines in said band is the zero line, corresponding to a deflection of 0. The wing tip was then deflected by hanging on one-kilogram and two-kilogram weights and the propeller was again turned by hand, when the photographic plate recorded the deflections produced at the tip of the propeller by these known weights. The amount of the deflections can be read on a millimeter scale which was photographed at the same time. The 7th band in Fig. 2 is a similar record, consisting, however, of only two lines, the zero line and the one for 2 kg load on tip of propeller. If the propeller is now run at various revolution speeds (e.g. at n = 590, 680, 770, 900, 1020, 1190 and 1480 r.p.m.), the amount of the corresponding deflection can be read directly from the photograph, since in all cases the zero line was first photographed. The latter is the lower line of each pair, the upper, in most cases thicker line being the record of the revolving propeller. A comparison of the deflection thus obtained with the deflections produced by the known weights gives the amount of equivalent "tip-load". The method is simple and accurate, but gives only the deflection of the tip of the blade and not the deflections of the blade throughout its whole length nor any distortions of the same. Other important data may however be obtained from the photograph. These data concern the fluttering of the blade. The crackling noise made by a revolving propeller is caused only in a very slight degree by the gas explosions in the engine (as may be easily veri-

fied from electrically-driven propellers), but far more by periodic vibrations of the propeller blades across the plane of rotation. This fluttering, which is, of course, closely connected with the revolution speed, is probably produced by the cavitation caused by the swiftly-moving propeller tips. This phenomenon is naturally more readily produced by internal combustion engines and is thus closely connected with the torsional vibrations of the propeller shaft. Entirely aside from the fact that the efficiency of a propeller is lowered by the fluttering, the glued joints are much stressed and liable to split. Such a fluttering is shown in Fig. 2 for $n = 680$ r.p.m. It is shown by the periodical approach and recession of the line of light for the revolving propeller with respect to the zero line. The variation of the wavy line gives the amplitude of the fluttering motion at right angles to the plane of rotation and also its frequency, by the position and number of wave crests per revolution.

The second method is characterized by the fact that not a continuous light, but one rythmically igniting in proportion to the revolution speed was used for showing the amount of deflection. In order to obtain photograms with the requisite sharpness for measuring, it was necessary to have an extremely short illuminating period. The light from an electric discharge seemed best suited for this purpose. The small percentage strength of the light, however, militated against the employment of a single electric discharge. The only solution of this difficulty was found in not using a single discharge for illuminating the

revolving propeller blade, but a large enough number of successive discharges so that the total amount of light emitted would give a clear picture of the blade. It was difficult to construct any device that would produce electrical discharges in synchrony with the revolutions of the propeller shaft, which seemed necessary, in order to be able to substitute, for a single discharge, any desired number of successive discharges. For this purpose, an ordinary magneto, such as used with internal combustion engines, proved exceptionally well adapted. This served also as the source of electricity. In the above instance there was a "Dixi" magneto available. First, the constancy of its ignition period was tested by driving it with an electric motor and sending its discharge through a Geissler tube, such as used in spectrum analysis. This tube was fastened to a disk on the same shaft as the magneto and consequently revolved in perfect synchrony with the latter. During the rotation, there was produced by the successive discharges a narrow illuminating line, which widened at n = 2000 r.p.m. only 3/4 to 1% in fan shape. This demonstrates that the variation in the ignition period was not over 1/360 of a complete revolution and was therefore very accurate. Moreover, by adjusting the ignition point on the magneto, the position of the illuminating line could be varied within the usual limits. The magneto was employed as follows: It was rigidly coupled to the shaft bearing the propeller. Its discharges were made through the same Geissler tube used in testing the constancy of the ignition period. The Geissler tube

was placed opposite a photograph camera in such manner that a portion of it was covered by the propeller blade revolving between the camera lens and the Geissler tube. Moreover, the Geissler tube could be rotated parallel to the plane of the photographic plate and to itself, whereby there was no longer a simple illuminating line, but a band, composed of several superposed lines of light, in which appeared the silhouette of the apparently still propeller blade, as shown in Fig. 3. From such a silhouette, not only the amount of deflection of the propeller blade at any desired distance from its axis of rotation can be determined, but also, by comparison of the apparent width of the blade with that of the stationary propeller, its distortion and consequently the variation in the aerodynamically effective angle of attack can be accurately measured. Alongside the silhouettes of the propeller for various revolution speeds and flight speeds, there was accordingly photographed the still propeller blade with the addition of a millimeter scale and without changing the position of the camera. By enlarging the photograms, a very high degree of accuracy was obtained. (Fig. 4 shows how the apparatus was arranged.) It may be further noted that the Geissler tube contained mercury vapor, which is rich in chemically active rays. For the surer ignition of the latter, there was a heating device, consisting of an electrically heated resistance box, which was suspended under the tube. (It may be readily recognized under the Geissler tube at the right.) It may be still further noted that, in the second method described, there must be no mechanical defect in the propeller to be tested. Both methods proved very satisfactory.

Translated by the National Advisory Committee for Aeronautics.

Fig. 1

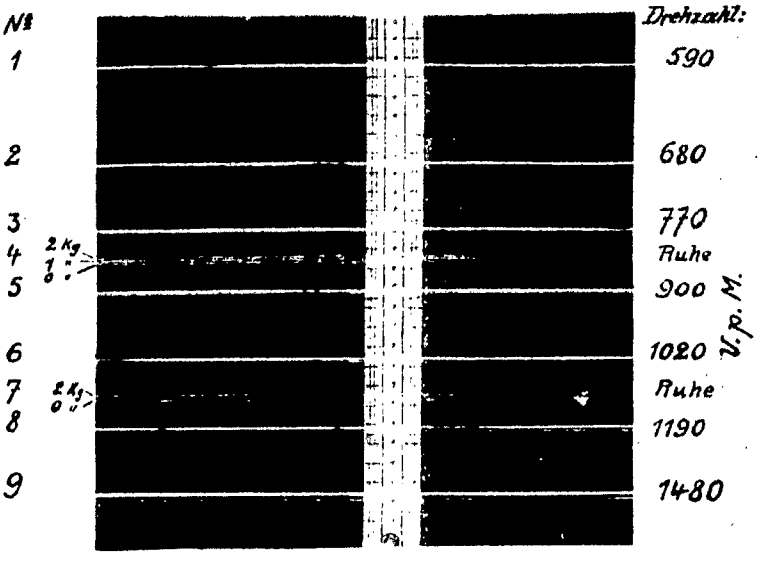

Fig. 2

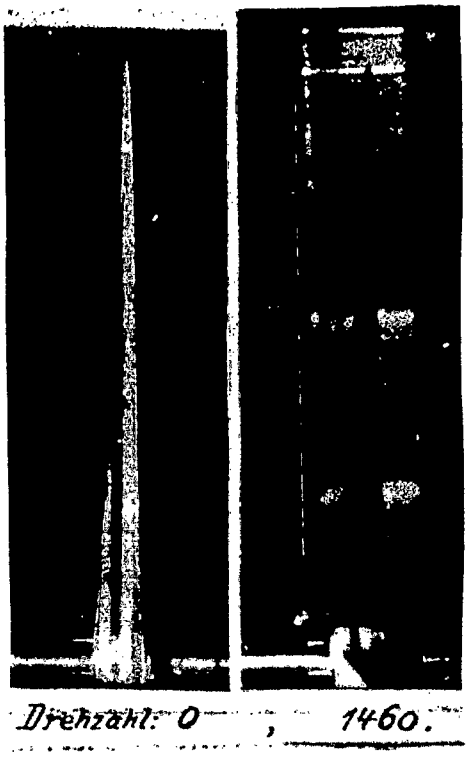

Fig. 3.

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