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The Time Constants of Biplane Wind Vanes

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Abstract

Biplane wind vanes with five interplane angles combined with two arm lengths are tested in wind tunnel concerning the time constant of their performed damped oscillation in the tunnel current. The observation is carried out in four steps of wind speed up to 20 m/s. The time constants are investigated with respect to the interplane angle and arm length of the vane combination.

1. Object of the experiment

In the well-known textbook of Prof. KLEINSCHMIDT a fantastic performance of wind vane of German Fuess make is described which is a box biplane arrangment [1]. It is really admirable although the details of the compared splayed vane are not mentioned there. The present experiment is attemped, before entering into the analysis of the amazing vane, to clarify some aerodynamics of biplane wind vanes in general.

2. Test set-up

A biplane wind vane composed of two flat plates of aluminium of thickness 1 mm with span 300 mm and chord length 100 mm each is arranged as illustrated in Fig. 1. The arm length from the central axis to the leading edges of the vane plates is varied in two ways, viz., 200 and 400 mm. The counterbalance is in each case so dimensioned that a complete balance of the oscillating system is effected.

The vane plates are hinged at their leading edges, respectively being fixed at their trailing edges by means of two cross bars so that the interplane angle can be changed without modifying the moment of inertia of the system except for a minor change due to the cross bar length. The interplane angle is changed while the leading edges are held constantly 20 mm apart, inserting cross bars of lengths 10, 20, 30, 40 and 50 mm. These lengths correspond to the interplane angles of $-5°44'$, $0,°+5°44'$, $+11°24'$ and $+17°16'$ respectively. Here the plus sign indicates the angle converging and the minus sign the one diverging to the windward direction.

The central axis incorporates a sliding resistance at its upper end in contact with a pointer of the vane boss and the mode of oscillation is registered on an electromagnetic oscillograph, when the wind vane is given an initial deviation from the flow direction of the tunnel current and released to perform a damped oscillation. The current speed is varied in four steps, viz., 5, 10, 15 and 20 m/s. Small variations, however, are now and then present in the values of the speed and corrections are given to the results as described in the next article.

3. Experimental results

The time constant of the oscillation is here defined as the time interval necessary for the curve connecting the successive crests of the amplitudes to diminish until $1/e$ of the initial value. A simple analysis gives the value of the time constant τ as

$$\tau=\frac{2I}{c},$$

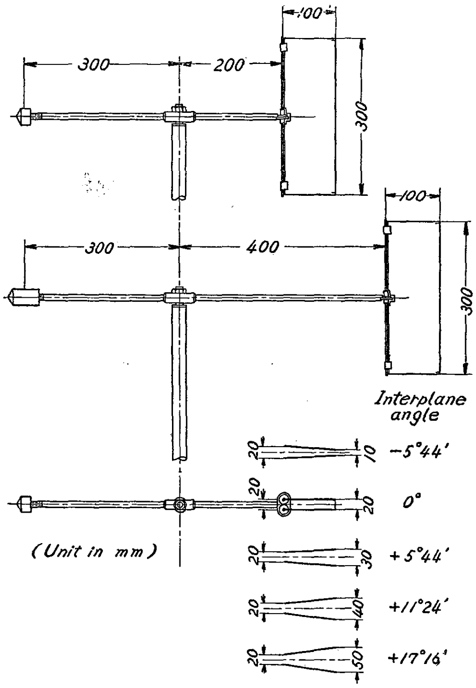

Fig. 1. Tested wind vanes.

where

$$c=\frac{1}{2}c_r\rho FVR^2,$$

with $c_r=$ the slope of normal air force coefficient of the vane biplane system with respect to its angle of attack, i.e., the angle between the resultant airflow direction and the axis of symmetry of the biplane, $\rho=$ air density, $F=$ the total vane area, $V=$ tunnel flow or wind speed, and $R=$ the arm length between the center of pressure* of the air force and the central axis. I stands for the moment of inertia of the oscillating system.

It can be seen that the time constant is inversely proportional to the wind speed if other factors are constant.

In Figs. 2 and 3 the values of the time constants obtained from the experiment are illustrated, multiplied by the wind speed respectively, for two cases of arm length of the vane leading edges.

It should be noted first that the values of τV do not coincide as the simple analysis indicates which assumes small amplitude of oscillation together with associated simplifications, but the assumption is fairly sound if the actual amplitudes of oscillation experimented are considered which are initially about 70°.

The most notable result for the vane with shorter arm length of 200 mm is the constancy of τV for different interplane angles as shown in Fig. 2. On the

* The center of pressure is slightly aft of the leading edge, and R is a little larger than the arm length shown in Fig. 1.

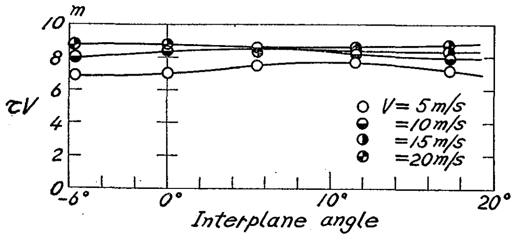

Fig. 2. Time constant τ multiplied by wind speed V, shorter arm. (M. R. I. wind tunnel).

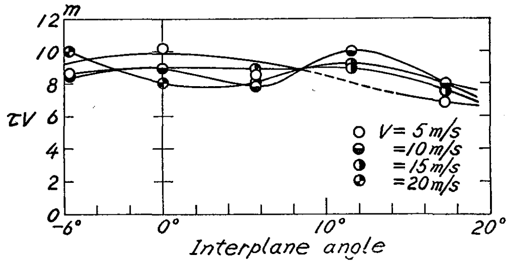

Fig. 3. Time constant τ multiplied by wind speed V, longer arm. (M. R. I. wind tunnel).

other hand τV differs for each interplane angle of the vane with longer arm length of 400 mm as shown in Fig 3. Further it is worthy of notice that τV is slightly larger for the longer arm length than for the shorter one, which result is, without doubt, due to a combined effect of the arm length and moment of inertia.

The most favourable interplane angle for 400 mm arm length lies in close vicinity of interplane angle 17° within the range here experimented.

4. Conclusions

1) For arm length of 200 mm the interplane angle has nothing to do with the time constant.

2) For arm length of 400 mm the most favourable interplane angle lies in the close vicinity of 17°, but larger angles are not yet experimented on.

3) Longer arm length gives unfavourable time constant in comparison with a shorter one.

Reference

[1] Kleinschmidt, E., 1935: Handbuch der meteorologischen Instrumente, Julius Springer, Berlin, p. 340.