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The Time Constant of a Streamer

by

M. Sanuki

Japan Meteorological Agency

S. Kimura and S. Toyama

Meteorological Research Institute

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Abstract

With a view to investigating the characteristics of a streamer as a wind-direction indicator, a model of cylindrical streamer is tested in the wind tunnel concerning the time constant of its performed damped oscillation in the tunnel current. For comparison a stiff cylindrical wind vane of precisely the same dimensions is also tested. The measurement is carried out in four steps of wind speed up to 20m/s. It is found that the time constant of the streamer is utterly constant independent of wind speed, which fact stands in contrast to the case of most wind vanes where the time constant is inversely proportional to the wind speed.

1. Aim of the present experiment

The present experiment is undertaken in order to investigate the characteristics of a streamer on one hand, and to obtain a wind-direction indicator with as large time constant as possible, suitable to mean wind direction measurement, on the other.

2. Test set-up

The model streamer is composed of a hollow cylinder of extra-fine silk cloth weighing only 3 grams, its forward frame of ring form with four spokes and a head counterweight shaft (Fig. 1). The assembly is rotatable on the vertical shaft.

This "collapsible" model is to be compared with a stiff one, illustrated in Fig. 1, too, and composed of aluminium-sheet cylinder of thickness 0.5 mm. The

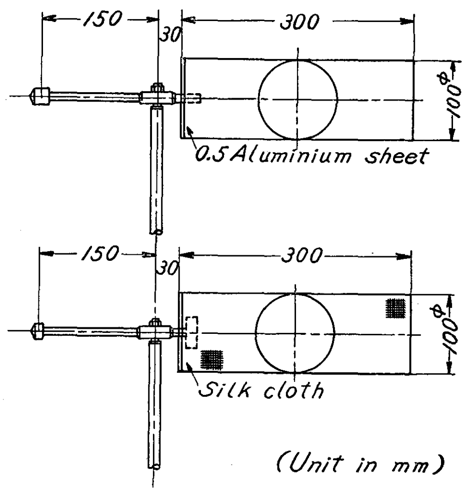

Fig. 1. Tested cylindrical wind vane (top) and streamer (bottom).

dimensions are precisely the same for both models except that the counterweights are different to balance against the increased weight of the stiff cylinder which amounts to 161 grams excluding the forward ring frame.

Each model is let to perform damped oscillation in the tunnel current from a certain initial amplitude. The mode of oscillation is registered on an electromagnetic oscillogragh by means of a sliding resistance wound around the upper end of the vertical shaft, and a contacter attached to the streamer or vane boss.

The tunnel current speed is varied in four steps, viz., 5, 10, 15 and 20m/s. The calculated moment of inertia is 0.00040 kg ms^2 for the streamer and 0.00127 kg ms^2 for the stiff cylindrical wind vane.

3. Experimental results

The time constant of the damped oscillation is here defined as the time interval necessary for the curve touching the successive amplitudes to diminish until $1/e$ of the initial value. A simple analysis gives the values of the logarithmic decrement Λ, the period T and the time constant τ respectively as

$$\Lambda = \frac{\pi c}{2\sqrt{Ic'}},$$

$$T = 2\pi\sqrt{\frac{I}{c'}},$$

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

where

$$c = \frac{1}{2} c_r \rho F V R^2,$$

$$c' = \frac{1}{2} c_r \rho F V^2 R,$$

with c_r = the slope of normal air force coefficient of the vane system with respect to its angle of attack, i.e., the angle between the resultant airflow direction and the vane cylinder axis, ρ = the air density, F = the longitudinal section area of the cylinder, V = the tunnel flow speed, R = the arm length between the vane rotation axis and the center of pressure of the air force. I stands for the moment of inertia of the oscillating system.

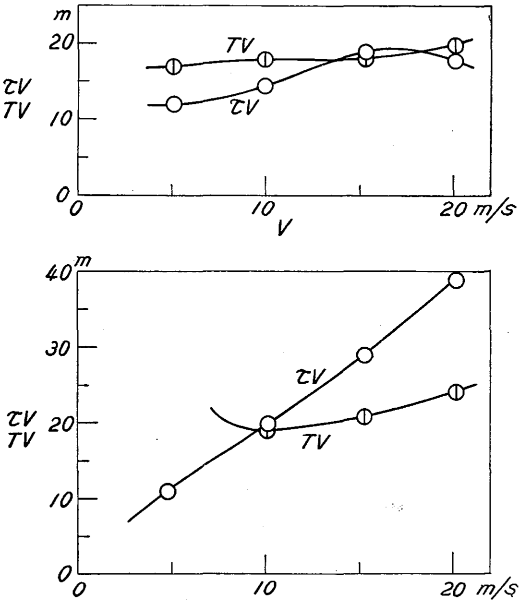

Fig. 2. Time constant τ and period T respectively multiplied by wind speed V for cylindrical wind vane (top) and streamer (bottom.)

It can be seen that the logarithmic constant is independent of the flow speed, and the period as well as the time constant inversely proportional to the flow speed, provided that other factors are constant. The last assumption will hold to a certain degree in case of the stiff vane, but in case of the collapsible streamer it may be highly questionable.

In Fig. 2 the experimental results of the period T and the time constant τ, both multiplied by the flow speed V, are illustrated for the vane and streamer. Both values are practically constant for the vane, although the time constant shows some deviation from the above formula compared with most samples of wind vane. On the contrary the streamer manifests a marked linear increase of τV with V, that is to say, the time constant is independent of the flow speed. As the period T is inversely proportional to the flow speed as can be seen in the plot, the experimental results mean either that the logarithmic decrement is variable with the flow speed, or that the above formulation is not valid any more. The plot of TV for the lowest flow speed of 5m/s is lacking as the oscillation is aperiodic in this case.

4. Conclusions

1) The time constant of a streamer is fairly large and independent of the flow speed. This is the most conspicuous feature and for this reason the conventional use of the streamer in strong winds may be justified.
2) In breezes, say, of wind speed of 5m/s, the streamer oscillates aperiodically.
3) The hollow cylindrical wind vanes, in general, have larger time constants than ordinary monoplane, biplane, or splayed wind vanes.

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