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Nonsteady Aerodynamics of Bluff Bodies, Laminar Boundary-Layer Separation, Wake Geometry

Theme

The paper presents experimental results on the aerodynamics of a set of two-dimensional elliptic cylinders with eccentricity of 0.8 and 0.6 during the organised wake condition. The dynamic calibration of the transducer used for measurement of fluctuating pressure is described in detail. The data on Strouhal number, unsteady pressures, and wake geometry are presented as a function of angle of attack during static condition of the models. The effect of Reynolds number on the fluctuating pressure is also examined.

Content

Two elliptic cylindrical models, 27-in. long, were designed to span the wind-tunnel cross section thus approximating the two-dimensional flow condition. The models were tested in a low-speed, low-turbulence, return type wind tunnel where the air speed can be varied from 4–150 fps with a turbulence level less than 0.1%. The measurement of the acoustic level pressure variations caused by shedding vortices was accomplished using the Barocel Modular Pressure Transducing system developed by Datametrics Inc. of Waltham, Massachusetts. The wake survey was carried out using a disc probe which was found to be relatively insensitive to pitch (±4°) and yaw (±20°).

The Strouhal frequency was measured in the Reynolds number range of 2×10^4–10^5 for three different angles of attack, and it was observed to vary linearly with win dspeed. The effect of angle of attack on the Strouhal number was also obtained in the same Reynolds number range. In general, the Strouhal number based on projected height showed comparatively less dependence on the angle of attack.

The unsteady pressure on the surface of the two elliptic models was recorded for $\alpha = 0$, 30°, 60° and 90°. Based on these measurements the following remarks can be made:

1) There are two points where the fluctuating pressure tends to vanish. They occupy positions which are approximately 180° apart and represent "stagnation points." One would expect this because of cancellation of pressures which are 180° out of phase. This effect is less complete at the rear of the cylinder probably caused by irregularities in the wake.

Table 1 Spacing of vortices in fully developed wake, Reynolds number = 70,000; L = longitudinal spacing, W = lateral spacing

	$e = 0.6$			$e = 0.8$			$e = 0^a$
α	L, in.	W, in.	W/L	L, in.	W, in.	W/L	W/L
0	16.00	5.0	0.31	10.00	4.3	0.42	0.32
30	19.25	5.2	0.27	16.50	5.1	0.31	
60	21.75	5.7	0.26	20.75	5.7	0.28	
90	22.75	5.8	0.26	22.25	5.9	0.26	

[a] See Ref. 1.

2) The fluctuating pressure increases as the mean pressure decreases and, in general, the variations can be represented by curves following a similar trend.

3) The mean pressure diminishes with increase in angle of attack. The same is true for the unsteady pressure. But, while the mean pressure coefficient approximately doubles in the range α = 0–90°, the corresponding increase in fluctuating pressure coefficient is as high as 10 to 20 times.

4) As expected, at zero angle of attack, the fluctuating pressure coefficient for the slender ellipse is considerably less than that for the thicker ellipse, but at 90° they are practically equal.

The fluctuating lift coefficients for both ellipses were calculated from the pressure data. For either ellipse the maximum fluctuating lift $[(1.0)_{e=0.6}, (0.72)_{e=0.8}]$ was found at 90° while the minimum value occurred at $\alpha = 0$. These compare with fluctuating lift coefficient of 0.6 for a circular cylinder as reported in literature.

Within the range of the Reynolds number investigated no significant change in wake geometry occurred. Average values for the spacing between the vortices are given in Table 1.

Reference

[1] Ferguson, N. and Parkinson, G. V., "Surface and Wake Flow Phenomena of the Vortex-Excited Oscillation of a Circular Cylinder," *Transactions of the American Society of Mechanical Engineers*, Ser. B, Vol. 89, 1967, pp. 831–838.