In spite of these shortcomings, it is believed that the use of Eq. (3) is preferable to the alternatives of either assuming $\bar{\delta} = 1$ or using Tracy's laminar results.[5]

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Some Observations in the Near Wake of Blunt Bodies

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Nomenclature

c' = velocity fluctuation
D = diameter of body
D_w = wake diameter (width)
f = shedding frequency
H = height of body
P_B = base pressure
P_s = stagnation pressure
R = space correlation
Re_D = Reynolds number (DU_∞/ν)
S = general Strouhal number (fD/U_∞)
S_w = universal wake Strouhal number (fD_w/U_w)
U_w = wake velocity $(U_\infty(1 - p_B/p_s)^{1/2})$
U_∞ = undisturbed ambient velocity
x,y,z = coordinates
Λ = integral scale

Introduction

INTEREST in the flow structure behind blunt, i.e., finite cylinders and cones placed perpendicular into a parallel airstream stems from practical cases like crosswind interference at rocket launching as well as the aerodynamics of structures and wake effects behind buildings. It is obvious that the great number of governing parameters and the fact that this is a transient kind of flow will limit the possibility of generalization of measurements in this kind of flow to some extent and thus its scientific value. For this reason little research has been done on this problem in contrast to the well investigated and documented far wake of an infinite cylinder. From practical considerations, however, it appeared worth while to obtain at least some general characteristics.

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Experimental Investigations

The measurements were performed in the open test section blower tunnel of the Hermann Föttinger-Institut at the Technische Universität Berlin and in the Wright Brothers Wind Tunnel of the Massachusetts Institute of Technology. Truncated circular cylinders with aspect ratios of 4 and 8 as well as cones served as models which were mounted on a flat plate fixed in the x-y plane in the test section with their axis at right angle to the shear free flow, (z direction). Most of the measurements were restricted to the region from 0-5 obstacle diameters downstream and Reynolds numbers less than 10^5 (subcritical range).

Flow Visualization

To study the flow pattern in a general way the flow was rendered visible by smoke. Surface flow patterns were obtained with a thin coating of paraffin lamp-black mixture. In case of the blunt cylinder they exhibited a remarkable straight separation line up to the top for all Reynolds numbers investigated.

Measurements of Wake Characteristics

A more detailed investigation was carried out in the wake of a cylinder with $H/D = 4$ at $Re_D = 4\ 10^4$ (subcritical; nonperiodic wake). Static pressure distributions on the model surface were measured at three different heights around the circumference. By use of a special hot wire probe consisting of five wires the mean flow velocity and its components were measured at various stations in the wake. The turbulence levels in the wake as obtained with a conventional hot wire reached values of up to 80% of the local mean velocity. Since in flows with such extreme conditions hot wire data are no longer correct, these results can only serve for general interpretations.

Two-point correlations of the c'-signal, R_x, R_y, and R_z, were measured and from these the integral scales evaluated. It was found that from $x/D = 2$ on the mean values of the macro scales over the cylinder height $\bar{\Lambda}/x = \text{const}$, being between 0.1 and 0.15 (Fig. 1). In the region very near the cylinder surface, the average turbulent "lump" is stretched in z direction. Further downstream it seems to have undergone a stretching by the mean shear which eventually leads to $\bar{\Lambda}_x > \bar{\Lambda}_y > \bar{\Lambda}_z$. Comparative correlation measurements behind the same cylinder fitted with an end plate at the same Reynolds number reveal that the macro scales in the wake of the infinite cylinder with shedding behavior are much larger than those of the finite cylinder with no regular separation. They are in good agreement with measurements reported by El Baroudi,[1] showing integral scales of the order of 10 D.

Spectral Measurements

To investigate the separation behavior of the flow at the cylinder some spectral measurements of the fluctuation with the probe located at $z/H = 0.5$, $x/D = 1.0$, $y/D = 0.5$ were conducted. For comparative reasons the measurements were made not only with the truncated cylinders but in addition

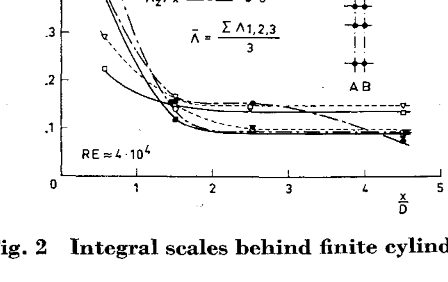

Fig. 2 Integral scales behind finite cylinder.

with the same cylinders fitted with end plates to simulate the case of infinite length. The cylinders were mounted sufficiently rigid to prevent oscillation. The results are presented in Fig. 2. In accordance with earlier findings the Strouhal number of the infinite cylinder is approximately 0.2, computed from the frequency peak protruding from the otherwise turbulent spectrum. In case of the finite cylinder with aspect ratio 4, a regular motion indicated by a distinct frequency in the spectral distribution with $S \approx 0.45$ was found at $Re_D \approx 2.4 \times 10^5$. Apparently the frequency peak tended to become weaker with decreasing Reynolds number and at $Re_D \approx 5 \times 10^4$ a distinct frequency could no longer be discerned. The spectra obtained with the cylinder of aspect ratio 8 showed a shedding frequency with $S = 0.2$ at subcritical Reynolds numbers with the indication to become stronger with Re_D increasing. The evaluation of Roshko's "universal wake Strouhal number," $S_w = fD_w/U_w$ showed for all measurements $S_w \approx 0.2$.

Naumann[2] found that due to the three dimensionality of the flow the separation line is no longer straight and thus the circulation of a separating vortex is no longer constant, which leads to a break up. This seems to be confirmed by some surface patterns presented by Gould, Raymer, and Ponsford.[3] The surface patterns which were observed during this work, however, exhibit a very straight separation line and at the same time there was no indication of vortex shedding. It appears therefore that some additional explanations may be necessary. For any blunt body part of the flow going over the top of the body is being dragged into the wake. The strength of this downwash obviously decreases with increasing Reynolds number and is restricted to a certain length of the cylinder from top downwards, i.e., its over-all influence decreases with increasing aspect ratio. One may consider the downwash flow as a kind of air curtain acting to some extent like a splitter plate. Depending on its over-all strength it dampens the feedback from both sides of the cylinder and thus the shedding mechanism. Two tests were made to check on this model. In the first case the cylinder with end plate was provided with a slit in the base open to atmosphere, so that by action of the low base pressure a weak jet was blown into the wake. This largely damped the shedding which was clearly observed when the slit was blocked. In the second test the downwash in the near region of the finite cylinder was prevented by a small plate behind the cylinder between half height and top. The presence of this plate accounted for the occurrence of regular shedding. The main observations may be summarized as follows: 1) the pressure distribution around a blunt cylinder, being similar to that of the infinite cylinder has the same Re_D – dependence; 2) the region of highly three-dimensional flow in the wake is restricted to the first 3–4 cylinder diameters; 3) turbulence levels in the near wake reach values of approximate 80% of the local mean velocity; 4) macro scales in the nonperiodic wake are almost an order of magnitude smaller than in the periodic, i.e., shedding case. Their mean values over the cylinder height increase linearly with downstream distance after the first 2 to 3 cylinder diameters; 5) the universal wake Strouhal number appears to be a constant for finite and infinite cylinders alike; and 6) vortex shedding from finite cylinders largely depends on Reynolds number and aspect ratio. Increasing aspect ratio as well as increasing Reynolds number lead to a flow behaviour similar to that of the infinite cylinder. In case of the finite cylinder the downwash is considered the damping mechanism for the shedding feedback.

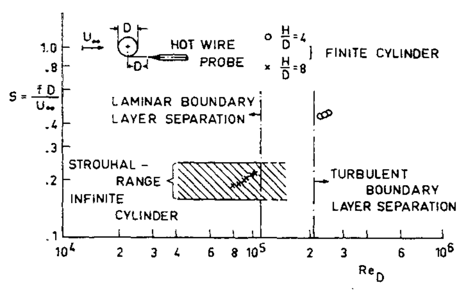

Fig. 1 Strouhal range vs Reynolds number for various cylinders.

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Solution of the Equations of Rotational Motion for a Class of Torque-Free Gyrostats

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Introduction

A GYROSTAT is a mechanical system composed of bodies whose relative motions cannot alter the mass geometry of the system; and, if the resultant moment of all external forces about the mass center of the system is equal to zero, the gyrostat is said to be torque free.

This paper deals with torque-free gyrostats G consisting of two bodies, A and B (Fig. 1). The inertia ellipsoid E_A of A for the mass center A^* of A may have three unequal principal diameters, whereas the inertia ellipsoid E_B of B for the mass center B^* of B is presumed to be an ellipsoid of revolution. Furthermore, it is presumed that B is connected to A in such a way that 1) B^* and the axis of revolution of E_B are fixed in A, but B can rotate relative to A about this axis and 2) the inertia ellipsoid E_G of the gyrostat G for the mass center G^* of G is an ellipsoid of revolution whose axis is parallel to that of E_B.

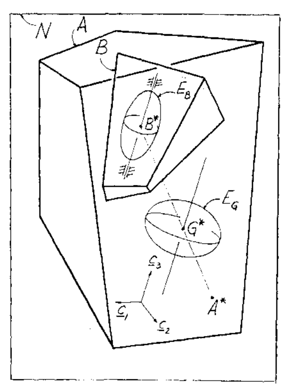

Fig. 1 Schematic representation of a gyrostat.

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