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technical briefs

On a Test of the Resonance Hypothesis

A. S. Mujumdar[1] and W. J. M. Douglas[1]

This note presents results of an experimental test of van der Hegge Zijnen's resonance hypothesis. Near wake turbulence spectra obtained over a range of stream turbulence intensities and integral scales revealed no preferential amplification of turbulent fluctuations at or near the Strouhal frequency thus invalidating predictions of the resonance hypothesis.

Nomenclature

C_D = drag coefficient
d = diameter of circular cylinder, side of square section
$E_1(\mathrm{St})$ = one-dimensional normalized energy spectrum, $\int_0^{1\mathrm{KHz}} E_1(\mathrm{St}) = 1.0$
I = intensity of turbulence ($= u/U$)
L = integral scale of turbulence
n = frequency of eddy shedding
Re = Reynolds number ($Ud/$)
St = Strouhal number (nd/U)
u^1 = rms fluctuating velocity in streamwise direction
U = mean flow velocity
kinematic viscosity

Introduction

Most of the recent work on heat or mass transfer from cylinders and spheres does not appear to support the resonance hypothesis of van der Hegge Zijnen [1].[2] (See Mujumdar [2], Boulos [3], Mizushina, Ueda and Umemiya [4] for cylinders, and Lavender and Pei [5], Newman, Sparrow and Eckert [6], Raithby and Eckert [7], Mujumdar and Douglas [8], Endoh, Tsuraga, Hiranu and Morihira [9] for spheres). However, Mujumdar and Douglas [10] have suggested that the idea of a resonant interaction between a predominant frequency in the free stream and that of a cylinder is physically plausible. They observed that when a circular cylinder is placed in a strongly periodic flow emanating from a turbine-type impeller the periodic component corresponding to the blade-passage frequency is stronger in the near wake than it is upstream of the cylinder. When there is no "dominant" frequency present in the free stream, however, it is not known whether preferential amplification of the Strouhal frequency fluctuations actually takes place. Thus the basic tenet of the resonance hypothesis has remained conjectural.

It was therefore decided to carry out a "direct" test of the resonance hypothesis by placing a normal hot-wire probe in the near wake of cylinders (d = 1/14, 1/2 and 1 in.) in cross-flow of turbulent air streams of varying intensity, I, ($0.05 < 1 < 0.12$) and integral scales, L, ($0.5 < L/d < 1.5$). The turbulence signal was recorded in the FM mode on an instrumentation tape recorder and then spectrum analyzed to study its frequency distribution.

Results and Discussion

The resonance hypothesis postulates that the velocity fluctuations corresponding to the energy-containing eddies in the free stream interact with the Strouhal fluctuations in the near wake causing the latter to amplify and enhance the heat and mass transfer rates in the wake region. Assuming isotropic turbulence and a Strouhal number of 0.20, the condition for maximum amplification for circular cylinders is L/d = 1.2. In order to test if this represents a true picture of the actual physics of the flow,

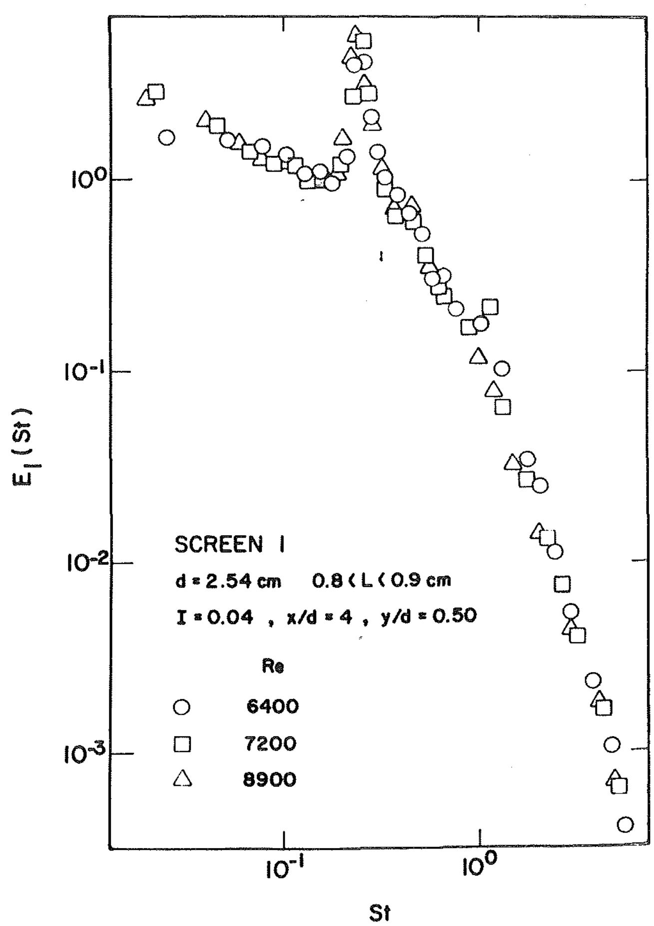

Fig. 1

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[2]Numbers in brackets designate References at end of Brief.

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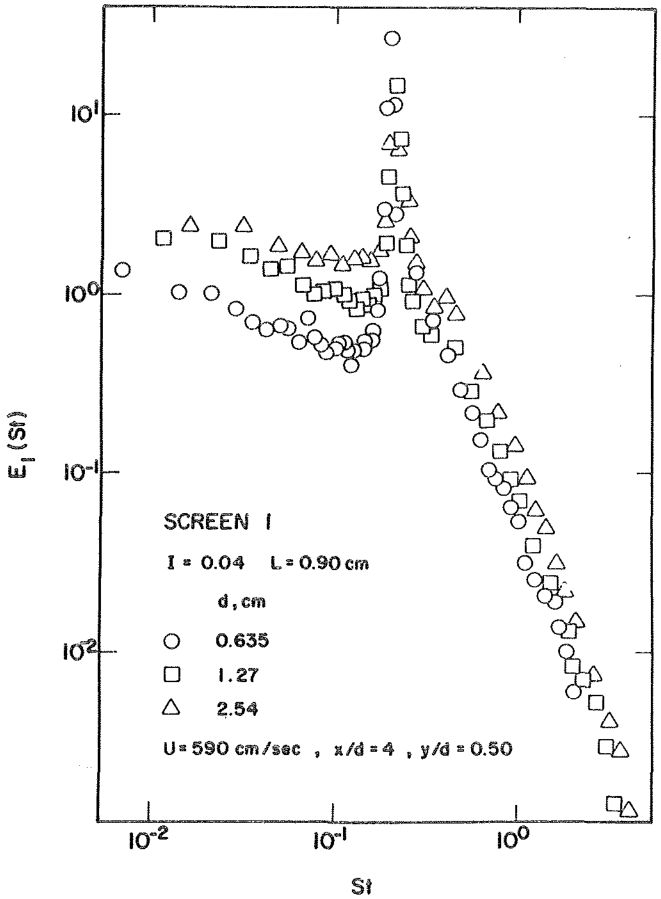

Fig. 2

a large number of turbulence energy spectra were obtained both in the free stream generated by six different screens of various configurations and in the near wake of smooth circular cylinders exposed to a wake range of turbulence intensities and scales. The cylinders spanned centrally the 11.5 in. × 11.5-in. cross section of a low-speed wind tunnel. Details of the turbulence generators used can be found in references [2, 8].

Figs. 1 and 2 show a few typical normalized spectra obtained in the near wake. Several hundred spectra were obtained using a wave analyzer with a resolution of 1 Hz from 1 Hz to 100 Hz and 10 Hz from 100 Hz to 1 KHz. As can be readily seen from these representative figures there was no preferential amplification of velocity fluctuations around the Strouhal frequency although the L/d values ranged from about 0.5 to 1.5. Interestingly, the normalized spectra for a given cylinder collapsed closely when the frequency was normalized in terms of the Strouhal number, nd/U. However, definite effect of the cylinder diameter was noted when the spectra were normalized in this manner. Since the blockage was quite small ($d/H < 0.10$) this is not ascribable to blockage effects. This suggests that Re and turbulence level are not adequate parameters to describe transport from bluff bodies exposed to turbulent flows; a diameter dependent parameter should perhaps be included in a general correlation.

In summary, these extensive measurements failed to discover any resonance-type interaction at or around the Strouhal frequency in the near wake turbulence thus casting doubt on the validity of the resonance hypothesis. The optimal L/d values obtained by van der Hegge Zijnen [1] and McLaren, et al. [11] should therefore be atrributed to other factors such as the spectral distribution in the free-stream, mechanical vibration, etc.

References

1 van der Hegge Zijnen, B. G., "Heat Transfer from Horizontal Cylinders to a Turbulent Air Stream," *Applied Science Research*, A7, 1957, p. 205.

2 Mujumdar, A. S., "Effect of Free-Stream Turbulence on Heat Transfer from Cylinders in Cross-Flow," PhD thesis, McGill Univ., Montreal, 1971.

3 Boulos, M. I., "Dynamics of Heat Transfer from Cylinders in a Turbulent Air Stream," PhD thesis, Univ. of Waterloo, Waterloo, Ont., 1972.

4 Mizushina, T., Ueda, H., and Umemiya, N., "Effect of Free-Stream Turbulence on Mass Transfer from Circular Cylinders in Cross-Flow," *International Journal of Heat Mass Transfer*, Vol. 15, 1972, pp. 769–780.

5 Lavender, W. J., and Pei, D. C. T., "The Effect of Fluid Turbulence on the Rate of Heat Transfer from Spheres," *International Journal of Heat Mass Transfer*, Vol. 10, 1967, p. 529.

6 Newman, L. B., Sparrow, E. M., and Eckert, E. R. G., "Free-Stream Turbulence Effects on Local Heat Transfer from a Sphere," TRANS. ASME, *Journal of Heat Transfer*, Vol. 94, Series C, 1972, pp. 7–16.

7 Raithby, G. D., and Eckert, E. R. G., "The Effect of Turbulence Parameters and Support Position on the Heat Transfer from Spheres," *International Journal of Heat Mass Transfer*, Vol. 11, 1968, pp. 1233–1252.

8 Mujumdar, A. S., and Douglas, W. J. M., "Eddy Shedding from Spheres in Turbulent Free Streams," *International Journal of Heat Mass Transfer*, Vol. 13, 1970, p. 1627.

9 Endoh, K., Tsuruga, H., Hirano, H., and Morihira, M., "Effect of Turbulence on Heat and Mass Transfer," *Heat Transfer—Japanese Research*, Vol. 1, 1972, pp. 113–115.

10 Mujumdar, A. S., and Douglas, W. J. M., "The Vortex Wakes of Stationary Cylinders Exposed to an Oscillating Turbulent Stream," *Journal of Basic Engineering*, TRANS. ASME, Vol. 92, 1970, p. 665.

11 McLaren, F. G., Sherratt, A. F. C., and Morton, A. S., "Effect of Free-Stream Turbulence on the Drag of Sharp-Edged Cylinders," *Nature*, Vol. 224, 1969, p. 908.

A Note on Several Theories of Turbulence in a Uniform Shear Flow

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Several theories for the development of turbulence in a uniform shear flow are compared with experiments. Greatest success is found with theories which model the Reynolds stress equations. Improvement of these theories however requires a better understanding of the turbulence interactions which transfers energy between fluctuating velocity components.

Introduction

IN this paper some of the recent theories for turbulence in a uniform shear flow, which produce quantitative predictions, are compared with the available experimental data, in more detail than has been done previously. It will be seen that one of the main difficulties lies in correctly describing the turbulence interactions which transfer energy between fluctuating velocity components. Reasonable success is obtained with the theories based on the Reynolds stress equations. Fuller details can be found in Mulhearn and Luxton [1].[2]

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