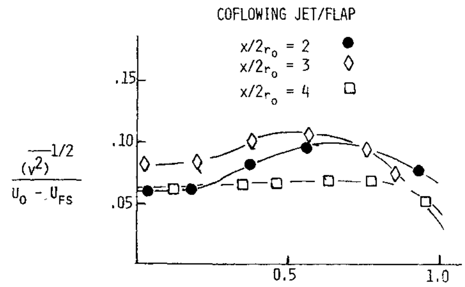

Fig. 4 Development of lateral turbulent intensity profiles for flow over flap, $z/2r_0 = 0.5, \lambda_j = 5.1$.

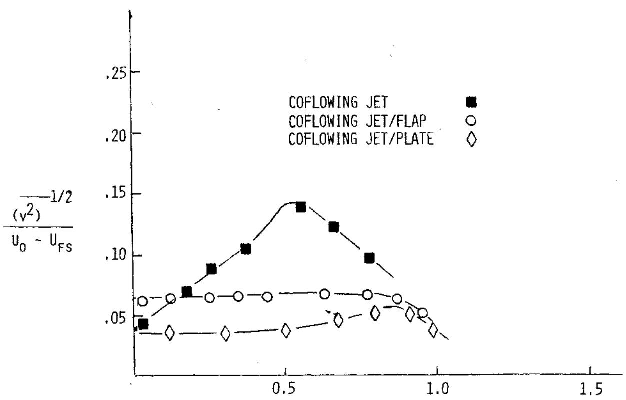

Fig. 5 Lateral turbulent intensity comparison $x/2r_0 = 4, z/2r_0 = 0.5$; $\lambda_j = 5.1$.

parison of the intensities for the different flow configurations at the same downstream location is also presented (Fig. 5).

Conclusion

The presence of the confining surfaces was found to be of importance in the resultant effects on both the mean and fluctuating parts of the turbulent velocity field of the jet.

The confining surfaces caused a more rapid increase in the turbulent intensities in the x-direction at the jet axis. Here, the value of λ_j was also found to be important. At the large value of λ_j, the turbulent intensities for the flow over the flap increased at a significantly less rapid pace than was the case for λ_j equal to 5.1. An indication that the flap and the plate serve to break up the potential core more rapidly was also noted and discussed.

Turbulent intensities in the lateral (y) direction for the three flow configurations were also measured. The turbulent intensity was found to be much greater in the shearing layer of the unconfined jet than in either of the other two configurations. Some evidence thus exists which indicates a damping of the turbulence in the y direction.

Acknowledgments

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References

[1]Catalano, G. D., Morton, J. B., and Humphris, R. R., "Experimental Investigation of an Axisymmetric Jet in a Coflowing Airstream," *AIAA Journal*, Vol. 14, Sept. 1976, pp. 1157-1158.

[2]Catalano, G. D., Morton, J. B., and Humphris, R. R., "An Experimental Investigation of a Three Dimensional Wall Jet," *AIAA Journal*, Vol. 15, Aug. 1977, pp. 1146-1151.

[3]Catalano, G. D., Morton, J. B., and Humphris, R. R., "Pressure and Velocity Measurements in a Three Dimensional Wall Jet," *AIAA Journal*, Vol. 17, April 1979, pp. 332-333.

[4]Catalano, G. D., Morton, J. B., and Humphris, R. R., "Some Two-Point Statistical Properties of a Three-Dimensional Wall Jet," *AIAA Journal*, Vol. 16, July 1978, pp. 693-698.

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Vortex Shedding from Square Plates Perpendicular to a Ground Plane

20001

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20009

Introduction

THE original motivation for this study developed out of an investigation of wind effects on central receiver solar collectors.[1] This particular configuration utilized large arrays of tracking mirrors (heliostats) which can be approximated as square plates near a ground plane. The work presented herein gives experimental results for the vortex shedding frequency behind square plates placed normal to a uniform flow over a ground plane as a function of Reynolds number and distance from the ground plane.

While a number of experimental as well as analytical studies have been performed concerning vortex shedding from different kinds of two-dimensional bluff bodies, a relatively few have been performed on three-dimensional bodies. Notable among those experiments performed on bluff bodies with aspect ratios equal to one are those for spheres,[2] circular disks,[3] inclined circular disks,[4] and inclined square plates.[4,5] However, no experimental studies have been reported to date which consider square plates in the presence of a ground plane.

Experimental Setup

These tests were conducted in the Texas Tech University low-speed wind tunnel, which has a 0.914 m × 1.219 m test section. For this particular experiment the facility was operated in an open-jet configuration to reduce blockage effects caused by insertion of the 10-cm square plate. The plate was placed above a horizontal ground plane with its bottom edge at various distances from the wall. The flow upstream of the plate was a uniform flow with a turbulence intensity of less than 0.005. The upstream ground plane boundary layer was thin, with its displacement thickness being less than 1% of the plate height.

Determination of the dominant vortex shedding frequency was accomplished by use of a DISA hot wire anemometer and a Honeywell SAI-48 correlator. A single hot wire was placed in the wake region of the plate. The output signal from the hot wire anemometer was autocorrelated to separate the dominant vortex shedding frequency from background turbulence present in the wake. In order to check this methodology, a test was conducted on a two-dimensional flat plate normal to the flow in which shedding frequencies were obtained for several Reynolds numbers near 1×10^4. These results compared well with data taken by Roshko[6] close to the same Reynolds number.

Vortex Shedding Frequencies

The Strouhal number for the square plate was obtained as a function of distance above the ground plane and as a function of Reynolds number as shown in Fig. 1. It should be noted that these results represent a special case in which the upstream boundary layer is thin with respect to the plate height.

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Index categories: Jets, Wakes, and Viscid-Inviscid Flow Interactions; Nonsteady Aerodynamics.

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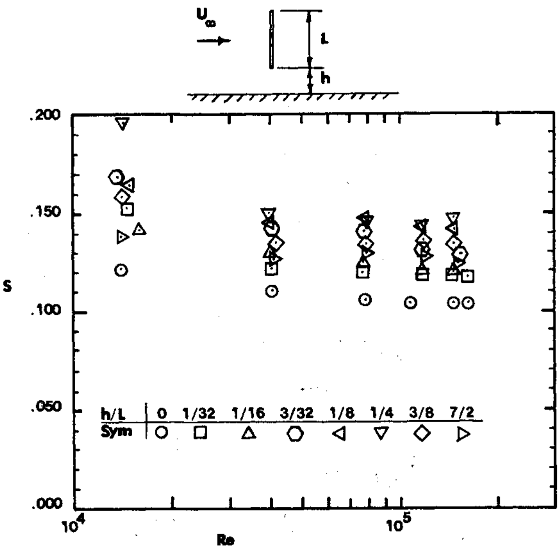

Fig. 1 Strouhal numbers for a square flat plate near a wall.

The Strouhal number is defined in this case as

$$S \equiv fL/U_\infty \qquad (1)$$

where f is the frequency of oscillation of the wake structure, U_∞ is the freestream velocity, and L is the plate breadth and height. These data show a tendency for the Strouhal number to decrease with Reynolds number, especially at the lower end of the Reynolds number range ($1.4 \times 10^4 - 1.5 \times 10^5$). There is also a tendency for the Strouhal number to increase with increasing distance away from the ground plane for $h/L < 0.25$. For $h/L > 0.25$ the Strouhal number decreases slightly. Data presented by Calvert[4] for a square plate in the absence of a ground plane agree extremely well with data obtained in this study for a large value of h. Both experiments yielded a Strouhal number of 0.126 at a Reynolds number of approximately 4×10^4.

Data Correlation

In an attempt to correlate these data a two-parameter formulation was selected. The Strouhal number S, which is a function of the plate Reynolds number Re and h/L as defined in Fig. 1, was assumed to be represented by the equation

$$S = g_h(h/L) S_\infty(Re) \qquad (2)$$

The function g_h was obtained first by noting the similarity of the S vs h/L curves. An equation of the form

$$g_h = 1 + ae^{-b\lambda}\sin[c(d\lambda - 1)] \qquad (3)$$

was fitted to the data where $\lambda = h/L$. It was found that the constant $a = 0.518$, $b = 4.6$, $c = 18$ deg, and $d = 20$.

The function S_∞ was obtained by noting the similarity of the S vs Re curves. Since $g_h = 1.0$ for large values of λ the S_∞ function represents the Strouhal number for square plates normal to a uniform flow in the absence of a ground plane. The function S_∞ was obtained by fitting the data to an equation of the form

$$S_\infty = a_1 + b_1/Re \qquad (4)$$

where it was found that $a_1 = 0.121$ and $b_1 = 407$.

These functions along with supportive data are shown in Figs. 2 and 3. In general the correlations are within $\pm 5\%$. At the lowest Reynolds number, however, the maximum deviation is approximately $\pm 10\%$. This deviation can largely be attributed to errors incurred in measuring the freestream velocity, which was only about 7 ft/s and difficult to measure any closer than $\pm 10\%$.

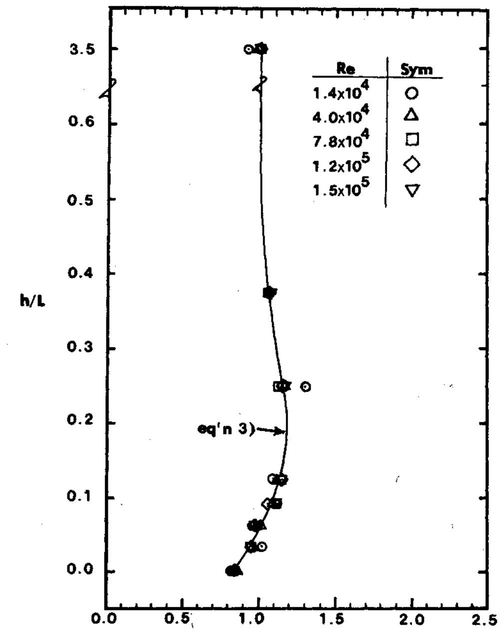

Fig. 2 g_h function vs h/L.

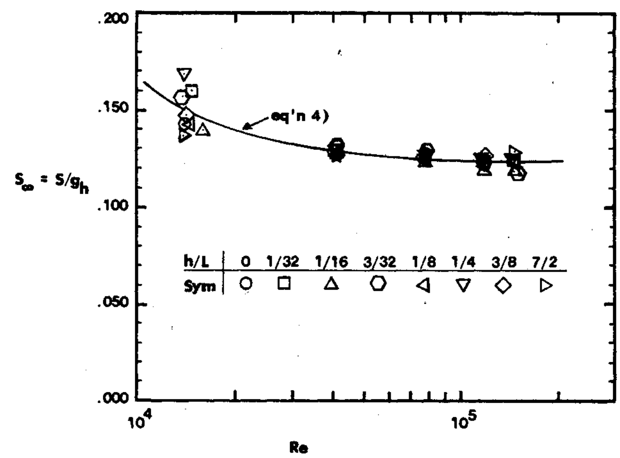

Fig. 3 S_∞ function vs Reynolds number.

Acknowledgments

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References

[1] Minor, J. E., Strickland, J. H., and Vann, W. P., "Wind Effects on Solar Tower Generators," Final Rept. on Task VII on D.O.E. Contract EG-77-C-01-3974, Texas Tech University, May 1979, pp. 2-33.

[2] Achenbach, Elmar, "Vortex Shedding from Spheres," *Journal of Fluid Mechanics*, Vol. 62, Pt. 2, 1974, pp. 209-221.

[3] Marshall, D. and Stanton, T. E., "On the Eddy System in the Wake of Flat Circular Plates in Three-Dimensional Flow," *Proceedings of the Royal Society of London*, A130, 1931, pp. 295-301.

[4] Calvert, J. R., "Experiments on the Flow Past an Inclined Disk," *Journal of Fluid Mechanics*, Vol. 29, Pt. 4, 1967, pp. 691-703.

[5] Eden, C. G., "Investigation by Visual and Photographic Methods of the Flow Past Plates and Models," A.C.A.R. & M58, 1912.

[6] Roshko, Anatol, "On the Drag and Shedding Frequency of Two-Dimensional Bluff Bodies," NACA TN 3169, 1954.