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Turbulent Flows Produced by Perforated Plate Generators in Wind Tunnels

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Abstract

A NEW application of perforated sheet metal plates has been shown to provide an efficient method of producing a large range of turbulent flows for experimental investigation. Fabrication of a standard uniformly perforated grid was done quickly, and different flow geometries were produced accurately without the use of special equipment. The standard grid and two geometric variations were used to produce a range of turbulent flows: i.e., isotropic, wake, and uniform shear flows comparable in quality to similar flows produced experimentally by other methods.

Contents

The system described here utilizes a perforated sheet metal plate to produce three different flows. Although this type of grid has been used to reduce the turbulence intensity in wind tunnels, in this new application a large variety of experimentally useful flow configurations can be quickly fabricated. Making easy variations of a basic grid geometry, an "isotropic" flowfield can be changed into a simulated "wake" flow or mean shear flowfields without resorting to the complication of introducing new structure inside the tunnel. These flows have the added benefit of an external turbulent flowfield that simplifies hot wire anemometry measurements by eliminating the intermittancy region. The perforated plate generator is an efficient solution to the usual constraints on flow manipulators such as permissible pressure drop, structural and spatial requirements, and cost of different manipulators in each different geometry.

Experimental data were obtained in a low-speed blowdown wind tunnel facility at the University of Illinois, Chicago. This equipment is described in detail by Gilbert.[1] Measurements were made using a constant temperature hot wire anemometer system.

The grids were formed by perforating standard 3.2-mm aluminum sheets with 50.8-mm diam circular holes arranged in a hexagonal array (Fig. 1). The mean hole diameters D were uniform to 0.025% and set on symmetric 55.9 mm centers M to 0.1%. This gave a computed solidity of $\sigma = 25\%$. Because of the manner of punching the holes, one edge of the hole was sharper than the others; however, no influence of the plate orientation could be detected.

The mean velocity profiles were uniform with a maximum deviation of $\pm 0.9\%$. This is slightly poorer than the results reported by Grant and Nisbet[2] using a bi-plane grid-generator, and borders upon being unacceptable by current standards. The longitudinal turbulent intensity was measured to be of the order of 5% of the mean velocity, uniform to $\pm 0.6\%$. The intensity ratio was slightly dependent on freestream Reynolds number, whereas the percent deviation was not.

Two additional measures of isotropy are the residual Reynolds stresses and the ratio of longitudinal to lateral turbulent intensities. The normalized Reynolds stress values of less than 10^{-5} may be compared to a value of 0.4 for wake flows. These stress values are two orders of magnitude less than Grant's results and therefore considered negligible. The intensity ratio was closer to unity than Grant's, being of the order of 10-20% as recommended by Comte-Bellot and Corsin.[3] Figure 1 shows the decay of longitudinal energy as a function of downstream distance. A $-5/4$ power curve shows good comparison with results reported by Comte-Bellot for this type of flow.

A simulated wake flow was achieved by inserting rings into the existing centerline row of holes in the perforated grid, thereby increasing the local resistance. These rings were fabricated by repunching 38-mm diam holes into the waste blanks from the first punching. The rings were lightly machined for a medium press fit into the perforated grid, with

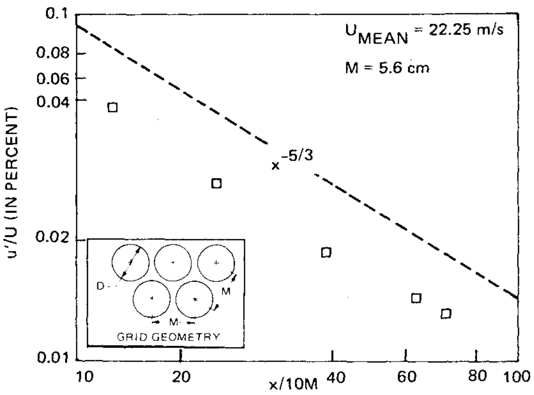

Fig. 1 Centerline decay of "isotropic" turbulence.

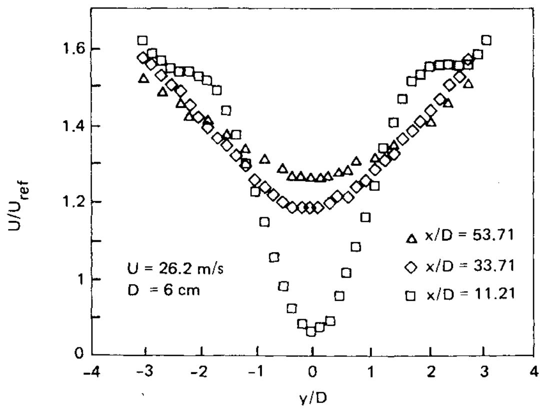

Fig. 2 Mean velocity profiles for the "wake" flow.

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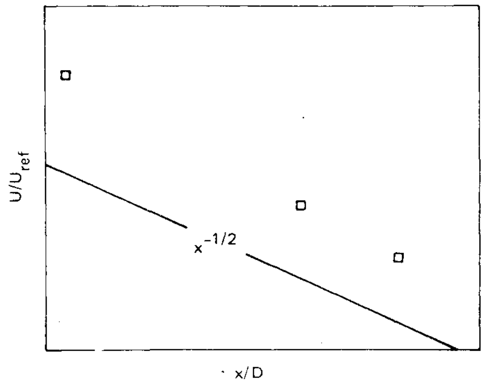

Fig. 3 Decay of centerline velocity deficit for "wake" flow.

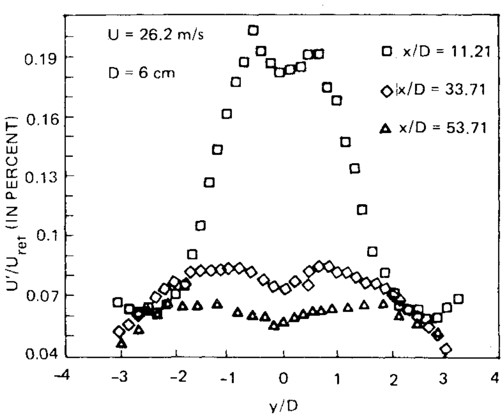

Fig. 4 Lateral distribution of longitudinal turbulent intensity in a simulated wake flow.

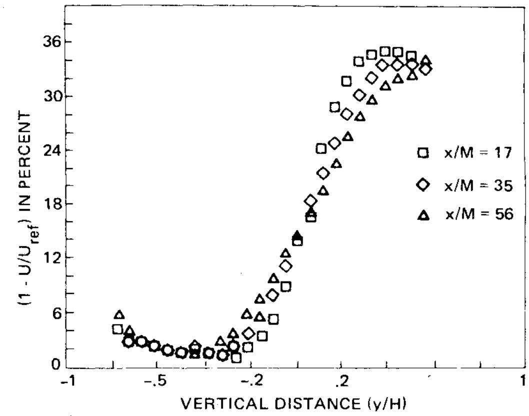

Fig. 5 Mean velocity profiles for the first parallel flow condition.

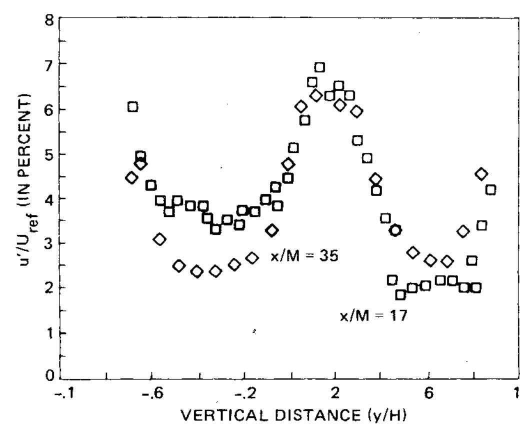

Fig. 6 Distribution of longitudinal turbulent intensity for Fig. 5.

a center spacing M of 61 mm. The resulting grid had an off centerline local solidity of 37% and a centerline local solidity of 58%. It should be noted that 58% is well into the range where jet instability effects become important. However, no signs of such instabilities were present, probably due to the confining effects of the stable adjacent flows.

The mean velocity profiles of the simulated wake flows are shown in Fig. 2. The general form of these profiles agree favorably with those of actual wake flows. Figure 3 shows that the decay of the centerline mean flow velocity deficit corresponds well to the $-\frac{1}{2}$ power law required by self-preservation in wake flows.

The longitudinal turbulent intensities also exhibit behavior expected for wake flows, shown in Fig. 4. When the turbulent intensity becomes a significant percent of the mean value, the accuracy of the determination is in doubt. This was possibly the situation at the first measuring location along the centerline.

Away from the center region, the turbulence level approached the characteristic value for grid turbulence of approximately 5%. The jetting effect in the mean velocity profile near the boundary was observed by other experimenters. Lateral intensity and Reynolds stress measured in this flow show good agreement with observed flow measurements.

A difference in mean velocities was created by inserting rings, similar to those described in the last section, into one-half of the uniform perforated grid. For a mesh spacing of 55.9 mm, inserts repunched with 44.5-mm-diam holes result in a grid with a local solidity of 43% vs 25% on the side without the inserts.

The mean velocity profiles, given in Fig. 5, show the two uniform flows with a shear layer between them. The mixing region between the flows did not spread appreciably, but established a uniform shear flow pattern which persisted, with little variation, until the end of the test section. The shear region also introduced a length scale associated with the width of the shear region. The dynamic behavior of shear flows is closely related to this length scale. The flow was very uniform and may be readily compared to mean shear profiles obtained by Rose,[4] or Champagne et al.[5] The turbulent characteristics were dominated by the shear region shown in Fig. 6. The expected shear generation of turbulence is shown by high turbulence activity in the center region.

This study has shown that the method of isotropic flow simulation using uniform perforated plates may be extended to other important flow geometries. Three different flow geometries produced from variations of a single standard grid configuration were examined. The observed turbulent flow characteristics were in good agreement with classical measurements.

Acknowledgment

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References

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