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ACOUSTICAL AND AERODYNAMIC CHARACTERISTICS OF END PLATE MATERIALS FOR TWO-DIMENSIONAL MODELS IN LOW NOISE WIND TUNNEL EXPERIMENTS

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1. INTRODUCTION

In experimental studies to investigate the generation mechanism of aerodynamic noise from various models in open-type wind tunnels, interference between the large-scale turbulence in the jet edge and the model either produces unwanted additional aerodynamic noise, or destroys the two-dimensionality of the flow around the model. Two types of end plates, acoustically reflecting plate made of plexiglass, and transparent plate composed of porous soft material backed with a punched steel plate for reinforcing the plate rigidity, are proposed and tested in order to avoid the flow-model interactions. First, the sound field of wide band noise radiated from a loudspeaker located at the test section of the wind tunnel is measured and compared with the free-field sound transmission, in order to examine the acoustical characteristics of the two plates. Second, flow field of a circular and a square cylinder models placed in the test section with and without end plate are compared in order to examine the aerodynamic effect of the end plate. Finally, the effect of the end plate is confirmed in aerodynamic noise measurement of the cylinder models, upon comparing the coherence between the radiated sound from the model and the velocity fluctuation in the model wake.

2. STRUCTURE OF THE WIND TUNNEL AND THE END PLATES

The wind tunnel used is of an open return type, with the flow ducting all lined with 100 mm glass wool, and splitter type silencers are placed at the inlet and the out let of a centrifugal fan. The nozzle exit is 200 mm wide and 150 mm high, and the maximum mean velocity at the exit is 52 m/s and the turbulence level is less than 0.5%. The test section is enclosed in an anechoic chamber of 4 m x 3.5 m x 2.5 m. The background noise is 25 dB with no flow and 65 dB at the flow velocity of 52 m/s. The over-all structure of the wind tunnel is similar to the one reported by Fujita, et al[1].

The acoustically transparent end plate is composed of 2 mm thick polyvinyl alcoholic porous material backed with a punched steel plate for reinforcing the plate rigidity. The plate is 600 mm wide and 900 mm long, which is large enough to cover the jet edge region. Two plates are placed at the top and the bottom of the test section, and a two-dimensional circular or square cylinder is placed between them. Two sides are open as shown in Fig. 1. The acoustically reflecting plate is made of plexiglass of 5 mm thick with the same dimensions as above.

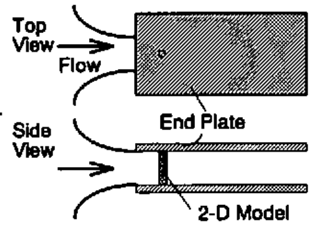


Fig. 1 End plate structure

3. ACOUSTICAL CHARACTERISTICS OF THE END PLATES

A loudspeaker was placed between the plates at one edge as shown in Fig. 2, and the attenuation of the wide band noise generated from the loudspeaker was measured along y-axis. The result is shown in Fig. 3, the case (A) is without end plates (open), the case (B) is with plexiglass plates and the case (C) is with the porous plates. The cases (A) and (C) are similar and have almost same attenuation characteristics as the free-field, which is shown by a solid line of -20 dB/decade. On the other hand, the case (B) has rather small attenuation between the end plates and shows sudden expansion of the sound field outside the plates.

It is confirmed that the porous plate does not disturb the sound field and is suitable for the end plate of the test section in the low noise wind tunnel.

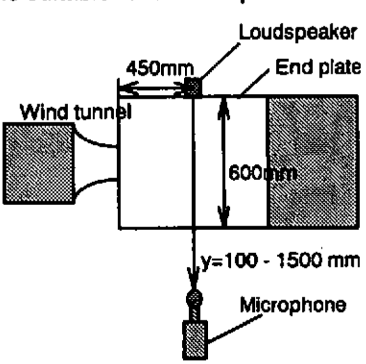


Fig. 2 Measurement of sound attenuation

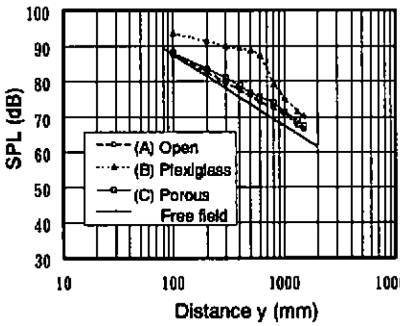


Fig. 3 Comparison of sound attenuation

4. MODEL WAKES AND THE RADIATED NOISE

Experimental Apparatus

Structure of the wake of the model was measured with hot-wire anemometer, and the coherence between the radiated noise and the velocity fluctuation in the wake was measured in order to verify the effect of the end plates, at the mean velocity of 25.8 m/s. Schematic diagram of the experimental setup is shown in Fig. 4.

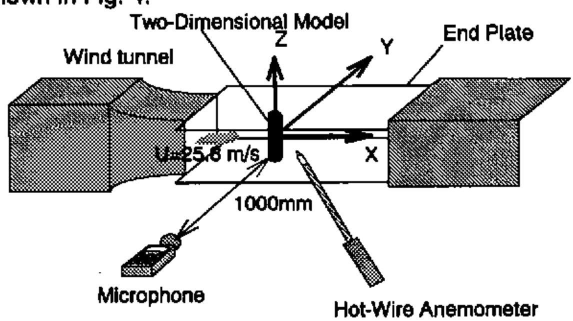
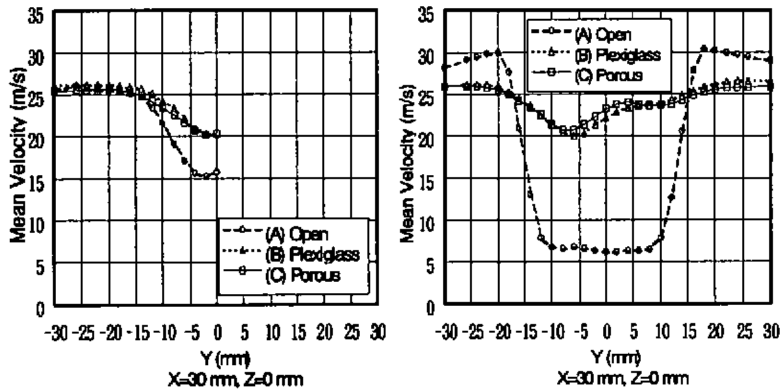


Fig. 4 Experimental setup of the measurement

Flow Field of the Model Wakes

Figure 5 shows the mean velocity profiles of the wakes of the circular and the square cylinders of 1 cm diameter measured using a hot-wire anemometer. In both cases, wakes are similar for the cases with either end plate, but the velocity profiles have much larger defect in open cases without the end plate. These results indicate that the end plates are necessary in order to maintain the two-dimensionality of the flows around the models.



(a) Circular cylinder (b) Square cylinder

Fig. 5 Mean velocity profiles in the model wake, U=25.8 m/s

Spectra of Radiated Noise

Figure 6 shows spectra of the radiated aerodynamic noise from the circular cylinder with thick lines, together with the background noise, or the wind tunnel noise without models, with thin lines. Peak frequencies in the spectra correspond to the shedding of the Karman vortices with the Strouhal number of 0.2. In Fig. 6, the peak level for the case (B) with the plexiglass plate is approximately 3 dB higher than that for the case (C) with the porous plate. This difference is in agreement with the difference between the cases (B) and (C) in the Fig. 3 at the distance of 1300 mm, location of the microphone for the radiated noise measurement. Peak level for the case (A) without end plate is much lower than the others.

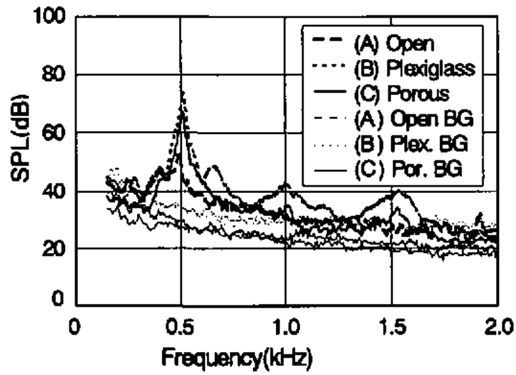


Fig .6 Comparison of the noise spectra

Coherence between Velocity Fluctuation and Radiated Noise

A hot-wire probe was traversed between Z=0 and 70 mm, at X=30 mm, Y=-10 mm, in order to measure the coherence between the velocity fluctuation in the cylinder wake and the radiated noise for three cases as shown in Fig. 7. The case (C) with the porous plate gives the highest coherence all along Z axis.

From this result, together with Figs. 3, 5 and 6, it is concluded that the porous material backed with the punched steel plate is suitable as the low noise wind tunnel end plate.

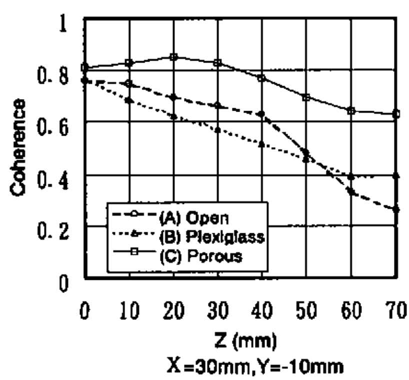


Fig. 7 Coherence between velocity fluctuation and radiated noise

References

[1] H. Fujita, et al, Proc. INTER-NOISE 93, pp. 1787-1790 (1993)