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STUDY ON THE REDUCTION OF KARMAN-VORTEX INDUCED SOUND USING QUIET FLOW WIND TUNNEL

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INTRODUCTION

If there is a circular cylinder in a uniform flow, Karman-vortex induced sound is generated in its wake. The Karman-vortex induced sound, generated in the heat exchanger, a device in a duct accompanying a flow, etc., eventually breaks the device by generating resonance if it coincides with the system's eigenvalue.

Reported herein is, firstly, the Karman-vortex induced sound noise reduction effect if the crossing angle and the distance between a cylinder, to be arranged in a uniform flow, and another cylinder with the same diameter, to be arranged downstream of it and crosswise to it, are varied just as in the researches conducted previously by one of the authors. Also, a similar test was conducted on prisms in addition to cylinders. Also reported is the relationship between the length and the generated sound studied by varying the length as well as the crossing angle of the cylinder (prism) downstream.

TEST APPARATUS AND METHOD

The nozzle and the bell mouth are set in an anechoic room. The nozzle, which measures 200 × 100 mm, has a contraction ratio of 1/16. The velocity of flow at the nozzle outlet has a uniform distribution while the distribution of turbulence is also a maximum of 0.5%. Of the crossing two cylinders (prisms), the one upstream is called the first cylinder (first prism) and the one downstream is called the second cylinder (second prism). D_1 and D_2 represent the diameters of the respective cylinders while H_1 and H_2 represent the lengths of one side of the respective prisms. The cylinders and prisms are made of brass and their surfaces have been finished smooth. Figure 1 shows the arrangement of the first and second cylinders.

The location of the microphone was set to be lateral to the tip of the nozzle and 500 mm distant from it as shown in Figure 1. The velocity of flow was 20 m/s throughout the test. In the test, measurement was conducted first by arranging the first cylinder (prism) only and the results were taken as the reference for calculating the noise reduction. Then the second cylinder (prism) was arranged behind the first cylinder and its angle and distance were varied. Furthermore, the length of the second cylinder (prism) only was decreased to examine the effect of the length. L_{D2} (L_{H2} for the prism) represents the length of the second cylinder in such a part. Measurement was conducted by varying the crossing angle θ at each length.

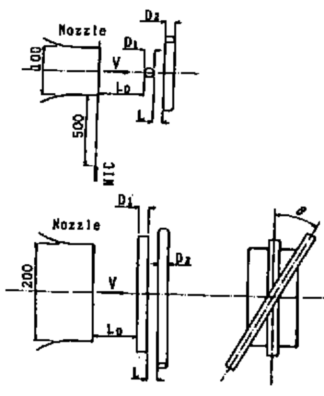

Fig. 1 Measuring arrangement

TEST RESULTS AND CONSIDERATION

First, only the first cylinder (single cylinder) with D_1 = 5, 8, 10, 12 (mm) to become the reference was measured. It is safe to say that its peak component is Karman-vortex induced sound since its Strouhal number turned out to be almost 0.2.

(1) Variation by Crossing of Two Cylinders with Same Diameter
(a) Variation in angle

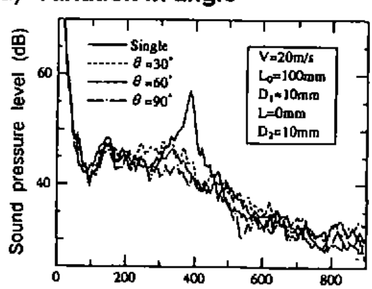

Fig. 2 Effect of crossing angle of two cylinders

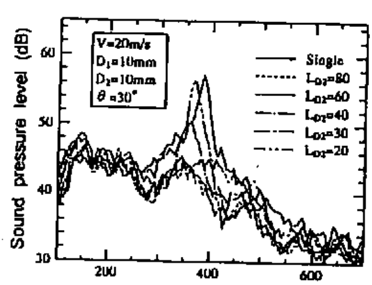

Fig. 3 Effect of the length of the second cylinder

Figure 2 shows the effect of the angle on the first cylinder's Karman-vortex induced sound as two cylinders with the diameter D_1=D_2=10 mm are crossed at the distance L=0mm. It turned out that the noise reduction effect increases as the angle increases so that, when θ = 90° , it is 14.6 dB. Therefore, it is safe to say that noise reduction by crossing is large.

(b) Variation in distance

Now, the effect when the second cylinder is installed behind the first cylinder and L is varied from 0 mm to 30 mm in steps of 5 mm was examined.
It turned out that the largest noise reduction effect is obtained when L = 0 mm, i.e. in the contacting condition. Also, a tendency of the noise reduction effect to decrease as the distance L increases, when it is a minimum of 20 mm in particular, was recognized.

(2) Variation in Length of Second Cylinder by Crossing of Two Cylinders

The effect was examined as the length of the second cylinder was varied as L_{D2} = 80, 60, 40, 30, 20 (mm) at the velocity of flow v = 20 m/s, the diameter of the two cylinders $D_1 = D_2$ = 10 mm, the distance L = 0 mm and the angle θ = 90°

According to Figure 3, noise reduction is large at about 17 dB almost without a variation throughout a range of the length of the second cylinder of L_{D2} = 80 ~ - 40 (mm). However, the figure also shows a tendency of the noise reduction effect to decrease as the length of the second cylinder decreases as L_{D2} = 30, 20 (mm).

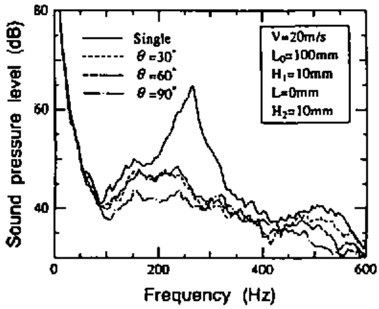

Fig. 4 Effect of crossing angle of two prisms

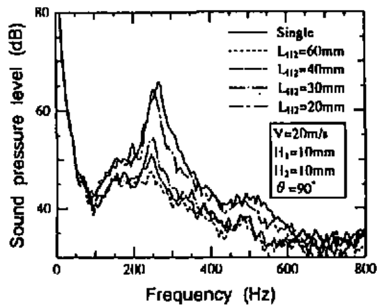

Fig. 5 Effect of the length of the second prism

(3) Effect of Variation in Prism Crossing Angle and Length of Second Prism

A test was conducted also on prisms likewise to the cylinders described above. Figure 4 shows the effect of variation in the angle when arranged at $H_1 = H_2$ = 10 mm and L = 0 mm. It is known according to the figure that noise is reduced by crossing in prisms too and that the effect is the most significant when θ = 90° , with the noise reduction being about 20 dB, which is larger than in cylinders.

Next, Figure 5 shows the effect when the length of the second prism was varied as L_{H2} = 60, 40, 30, 20 (mm) at θ = 90° , at which angle noise reduction is the largest. It is known, accordingly, that there is a tendency of the noise reduction effect to decrease as L_{H2} decreases as 60, 40, 30, 20 (mm). A noise reduction effect is hardly seen when L_{H2} = 20 mm in particular.

(4) Karman-Vortex Induced Sound Noise Reduction

Let us examine the Karman-vortex induced sound noise reduction effect by the first cylinder in view of the test results above.

(a) Variation in length of second cylinder by crossing of two cylinders

To compare the noise reduction in respective cases, noise reduction in variation in the length/diameter ratio L_{D2}/D_1 is adopted.

Figure 6 shows variation in the angle, at the diameter of the first cylinder D_1 = 10 mm, for the length of the second cylinder with the same diameter L_{D2} = 80, 60, 40, 30, 20 (mm). According to the figure, noise is reduced throughout a range of L_{D2}/D_1 = 2 ~ 8. There is a noise reduction effect of about 14 ~ 16 dB when $L_{D2}/D_1 > 4$ in particular. The noise reduction effect is small when $L_{D2}/D_1 < 4$ though depending also on the angle.

Those facts are assumed to be the result of the vortex itself weakening due to the phase in the axial direction of the Karman-vortex due to the first

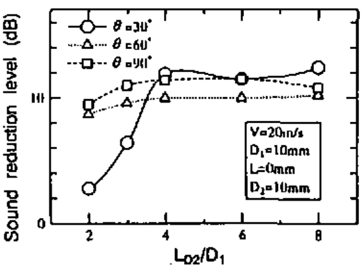

Fig. 6 Relationship between the noise reduction effect and L_{D2}/D_1

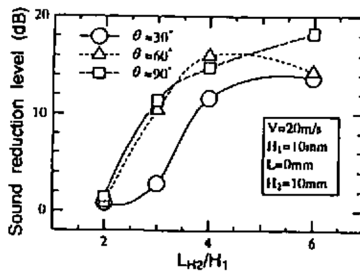

Fig. 7 Relationship between the noise reduction effect and L_{H2}/H_1

cylinders hifting. It is considered to be because, assuming such a region to weaken simultaneity to be the interference region, the length of the second cylinder comes to fail to satisfy the interference region. Consequently, it is recognized that, in the noise reduction effect by the second cylinder, the length L_{D2} being somewhat short does not affect the noise reduction effect so much, the practical application of which is expected.

(b) **Variation in length of second prism**

Figure 7 is a graph of the noise reduction when L_{H2} is varied at $H_1 = H_2 =$ 10 mm and $\theta = 90°$. When $L_{H2}/H_1 \geqq 4$, almost like results to cylinders were obtained with there being a noise reduction effect of about 12 ~ 18 dB. When $L_{H2}/H_1 < 4$, however, the noise reduction effect decreases at all the angles. There is hardly a noise reduction effect when $L_{H2}/H_1 = 2$.

CONCLUSION

In our research, it was clarified, using a quiet flow wind tunnel and arranging the second cylinder downstream of the first cylinder to generate Karman-vortex induced sound, that the peak component of the Karman-vortex induced sound decreases as their crossing angle and relative position are varied as well as the length of the second cylinder is decreased and so on. Some of the results of our test are shown below.

(1) Noise reduction is large at about 15 dB when the distance is L = 0 mm and the angle is $\theta = 90°$.

(2) It could be recognized that, in variation in the length of the second cylinder by crossing of two cylinders, there is a noise reduction effect even if the length/diameter ratio L_{D2}/D_1 may be somewhat small.

(3) It was clarified that, in variation in the length of the second cylinder with a different diameter, even if the second cylinder is made short, a sure noise reduction effect is expectable by increasing the diameter, with, when $D_2/D_1 > 1$, noise reduction of nearly 6 dB being obtained even at $L_{D2}/D_2 = 2$.

(4) In prisms, almost like results to cylinders were obtained. Noise reduction decreases suddenly at any angle, however, if the length of the second cylinder is set to be $L_{H2}/H_1 < 4$.