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Noise generated from Louver exposed to Flow and Countermeasure's Effect

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***Abstract*— This paper describes effects of configuration of the louver and the long hole on aerodynamic noise level. The aerodynamic noise is the most effective noise source of a high speed vehicle on the environmental noise and it is very important for our healthful life to reduce this kind of noise. The aerodynamic noise consists of wind noise generated from the pantagraph and the louvers. Here, the wind noise of louvers and perforated plates are measured and evaluated experimentally by using a low noise wind tunnel. As a result, the following conclusions were obtained. (1) Noise reduction of about 4 dB is achieved by using the louver of parallelogram frame with 45degree, (2) Noise reduction of about 1dB is achieved by doubling the number of fin, (3) To make the radius of the frame of the louver large is effective on the noise reduction, although the effect is small, (4) In perforated plate, the hole area to total area is getting small, the noise level becomes small.**

***Index Terms*— Aerodynamic Acoustics, Measurement, Louver ,Noise Reduction, Railway Vehicle, Low Noise Wind Tunnel**

I. INTRODUCTION

In noises of the railway vehicles, there are two general phases of noises from such as under and upside the vehicle. The former is the noises generated from vibrations of a rail and a wheel and a gear noise of a motor. They do not become problems due to an adoption of an elastic wheel [7] and an application of the acoustic barrier.

On the other hand, the latter are wind noise generated from the pantagraph and the objects of upper side of the vehicle with various configurations (Louver, clearance of vehicles, difference of level between the window and the body, moreover the configuration of the head of the vehicle). They become problems not to be able to cut the noise by the acoustic barrier [1].

At one time, the JR East (The Joetsu Shinkansen) developed a double-decker rail vehicle to be able to transport so many people. However it is raised questions about the operation because of the noise being 1dB larger than a single story rail vehicle.

The JR East pinned down the cause of large noise being the noise generated from the louver. And 0.5dB noise reduction was achieved by conducting various experiments [2].

This investigation focused the effect of the relation between the louver and the flow on the noise. But the effect of various parameters of louver on the noise has not been referred.

Then, in this study, it was tried to find the optimum configuration of the louver.

And the exhaust outlet of the head of the vehicle is obliged to assembled to the curved surface. The louver can't be used but the perforated plate. Then it is also tried to find the optimum perforated plate with long holes.

It is so important to keep the compartment comfortable and it is one of the differentiating techniques of rail vehicles.

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II. EXPERIMENTAL METHOD

A. Experimental Setup

Figure1 shows the photograph of the low noise wind tunnel used in this experiment . The contracted flow rate is 16 and the size of nozzle cross section is 200mm (Width)×200mm (Height). The back ground noise level at the position 1.3m apart from the middle of the nozzle is 61dB(A) when the flow velocity is 50m/s. The turbulent intensity is under 1% and the non-uniformity of the velocity distribution of the nozzle exit is under 1%.

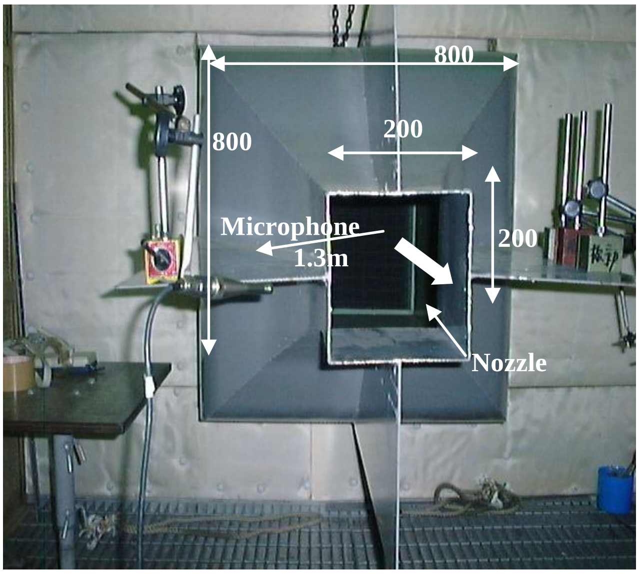


Fig.1 Low noise wind tunnel

B. Experimental Method

The deck board (800mm×600mm) is set in front of the nozzle as shown in Fig.2 and the test piece is put on the center of the deck board by the level difference not occurring. The five noise measuring positions are as follows.

M1: Just above
M2: Upstream
M3: Downstream
M4: Right side
M5: Left side

These positions are all 0.5m apart from the center of the test piece. The size of the test piece is 200mm×300mm.

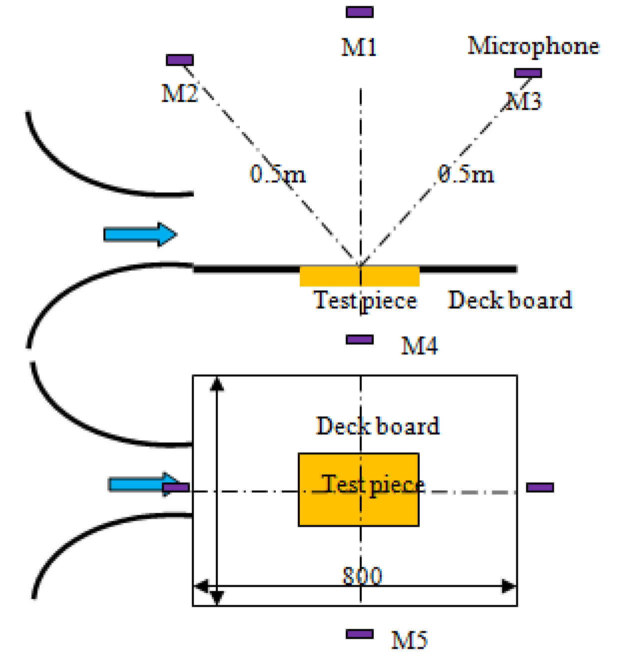


Fig2 Test apparatus and arrangement of test piece

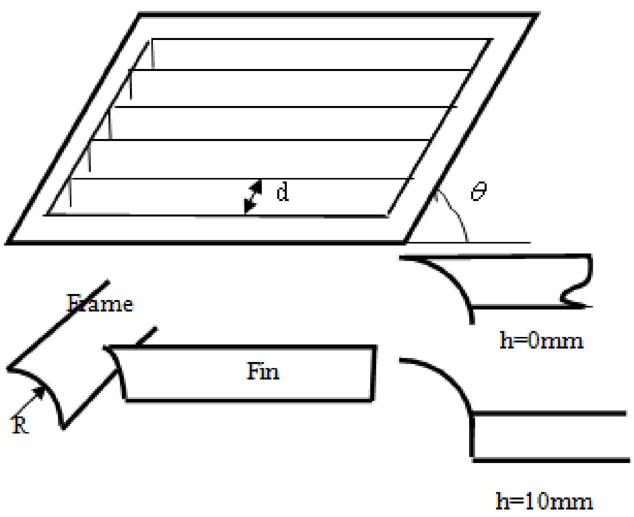
C. Measuring Method

The sound pressures obtained by five microphones are 1/3 octave analyzed (RION SA27). The frequency range is 16Hz ～ 10kHz. The experiment is conducted for three wind velocity such as 30, 40 and 50m/s. The wind velocity is measured by a simplified anemometer.

D. Test pieces

Louver with various configurations

Nine test pieces are shown in Table1. Fig.3 shows the test piece. The symbols in Table1 correspond those in Fig.3. The test piece A is a present state louver and this is a standard. Test pieces B and C are tested for the inclination angles θof the louver frame. The test piece D is tested for the depth *h* of the fin, Test pieces E and F are for the fin pitch *d*.



Fig,3 Test pieces of louver

Test pieces G and H are for an amount of *R* and the test piece I is for existing of the way of escape. The sound data are described by not only the overall value but also 1/3 octave band value.

Perforated plate with various aperture ratios

The perforated plate is shown in Fig.4. Test pieces a, b, c and x are those with long holes of aperture ratios of 32%, 37%, 42% and 0%. Namely X is a mere flat plate.

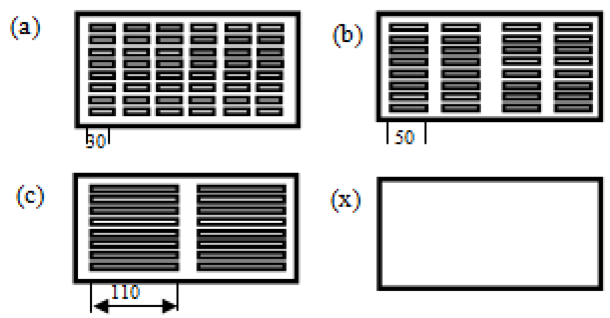


Fig.4 Test pieces of plate with hole

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Noise of louver

Noise levels at measuring points

Fig.5 shows the overall values of the noise level at each measuring point for three wind velocities. The noise level at downstream (M3) is the maximum and that at upstream (M2) is the minimum. The noise levels at just above (M1) and both sides (M4 and m5) are the same values. The velocity dependency is the seventh power of wind velocity (I is proportional to U^7 , U is the wind velocity).

Table.1 Test pieces of louver

Name	θ(deg)			d (mm)			R(mm)			Way of escape		H(mm)	
	90	60	45	15	30	50	0	10	20	WO	W	0	10
A	○				○			○		○		○	
B		○			○			○		○		○	
C			○		○			○		○		○	
D	○				○			○		○			○
E	○			○				○		○		○	
F	○					○		○		○		○	
G	○				○		○			○		○	
H	○				○				○	○		○	
I	○				○			○			○	○	
X	Plate used as reference												

W: With WO: Without

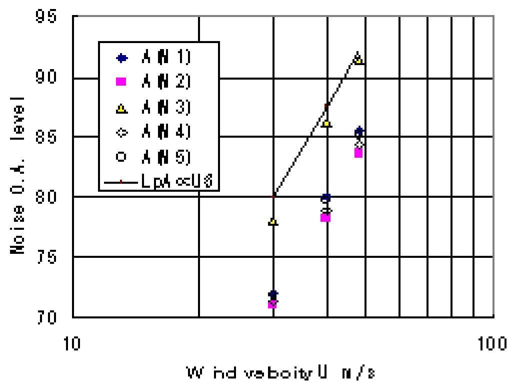


Fig.5 Noise level at each measuring point

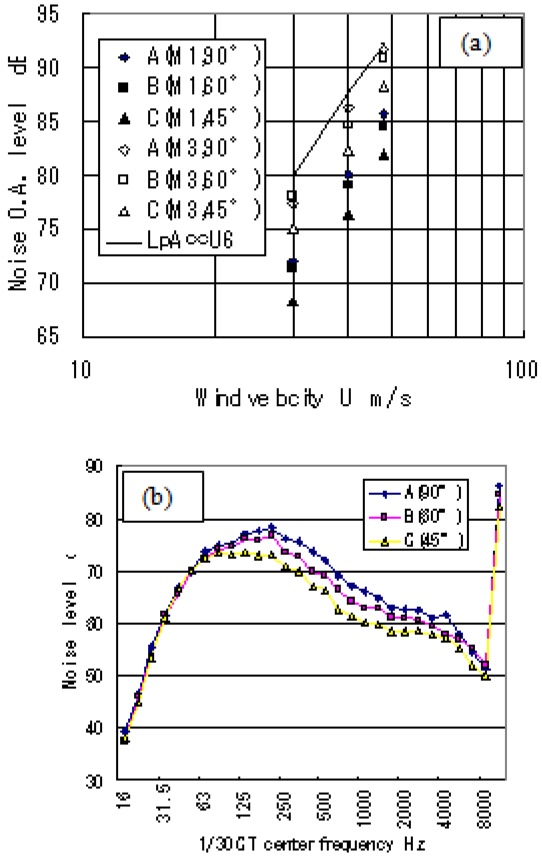


Fig.6 Noise level of parallel square

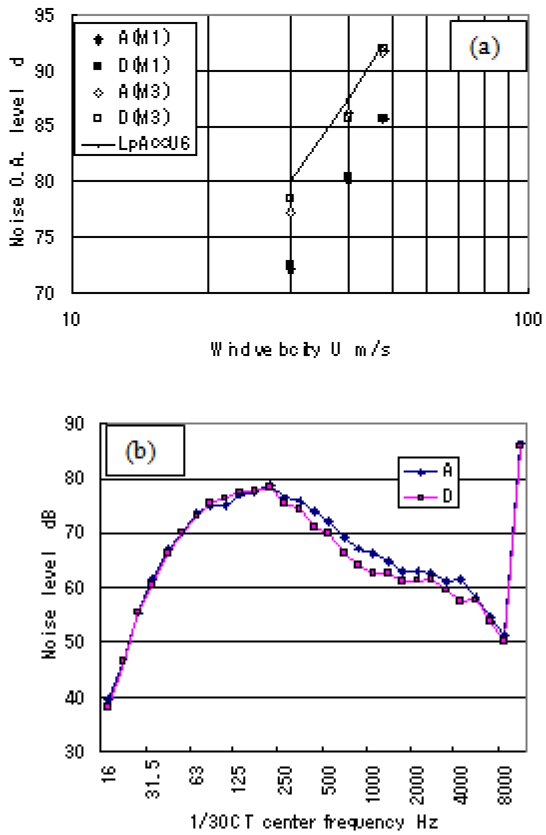


Fig.7 Effect of fin depth on noise level

The real line in this figure shows the sixth power of the wind velocity. This is the feature of the dipole noise source. These tendencies are all the same for all test pieces.

The noise level at downstream is 7dB larger than that at upstream. This value of about 7dB is all the same for all test pieces.

Noise levels at both sides and at just above are the same values and these values are 1～2dB larger than the value at upstream (M2). From these results, it can be considered that the noise source exists at the louver frame of downstream.

Maruta et al. confirmed that the noise source position is the frame of downstream by detecting the noise source about the shallow cavity experimentally [8]. Then the present result is valid.

Fig.6 (a) shows the overall noise level at measuring points of just above (M1) and at downstream (M3) for test pieces B (θ=60°) and C (θ=45°) in comparison with a standard A (θ=90°). The background noise level, which is made by using the flat plate, is confirmed to be 10dB smaller than the noises made by other test pieces. The noise levels of B and C are 1dB and 4dB smaller than that of A, respectively.

In previous study [9], the noise level of the circular cylinder against the inclination angle θ to the wind direction gives the result that the noise level at θ=40°becomes about 4～5dB smaller than that at θ=90°. From this fact, the present result is valid.

Fig.6 (b) shows the 1/3 octave band analysis result of noise levels for various test pieces at the wind velocity 40m/s. The noise reduction can be seen in the wide frequency range of 200～3000Hz. Especially the noise reduction is the largest at θ=45°.

Effect of fin depth

Fig.7 (a) shows the overall noise levels at measuring points of just above (M1) and downstream (M3) for the test piece D as shown in Table1. The test piece D is that of the fin setting 10mm downside in comparing with the test piece A. The difference of noise levels of both is little and it can be said that the fin depth does not give the effect to the noise level at all. However the effect of about 3dB can be seen around 1000Hz, It can be said that it is possible to reduce the noise by increasing the fin depth.

Effect of fin pitch

Fig.8 (a) shows the overall noise levels at measuring points of just above (M1) and downstream (M3) for test pieces E and F as shown in Table1. Test pieces E and F have the fin pitch of 15mm and 50mm comparing with the standard test piece A with the fin pitch of 30mm.

The noise level of E (fine pitch) is about 1dB smaller than that of A. From this fact, the fine pitch is better for noise reduction. It can be said that the noise reduction around 400Hz contributes to the overall noise reduction.

Effect of R in frame

Fig.9 (a) shows the overall noise level at measuring points of just above (M1) and downstream (M3) for *R* of the frame being 0mm (G), 10mm (A) and 20mm (H). From this result, the noise level of H is smaller than that of A. But the difference is little.

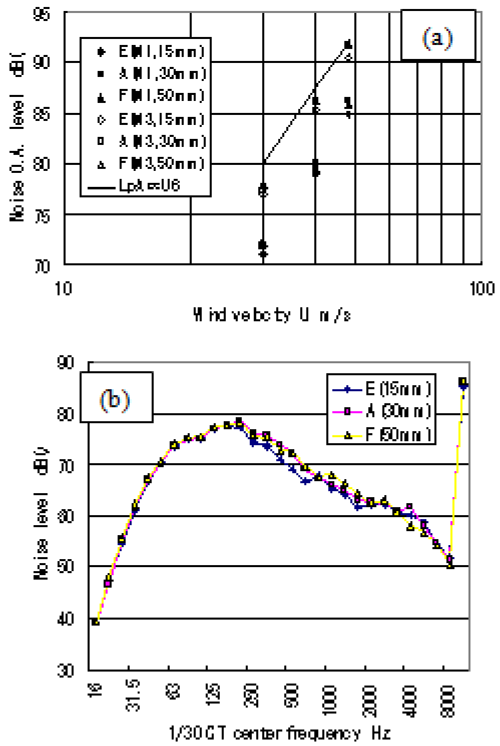


Fig.8 Effect of fin pitch on noise level

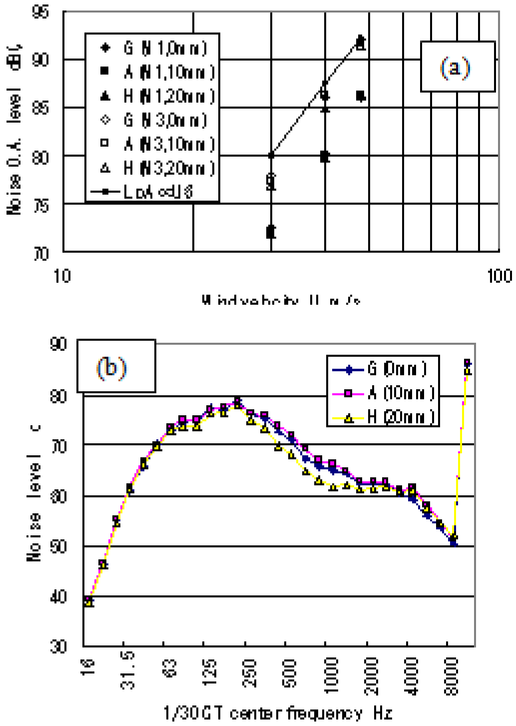


Fig.9 Effect of *R* of frame on noise level

Effect of existing of way of escape

Fig.10 (a) shows the comparison of the noise level between the test piece I (with way of escape) and the test piece A (standard). Both are about the same values. In Fig.10 (b), the 3dB noise reduction can be seen around 800Hz. This makes a contribution to the overall reduction of 1dB.

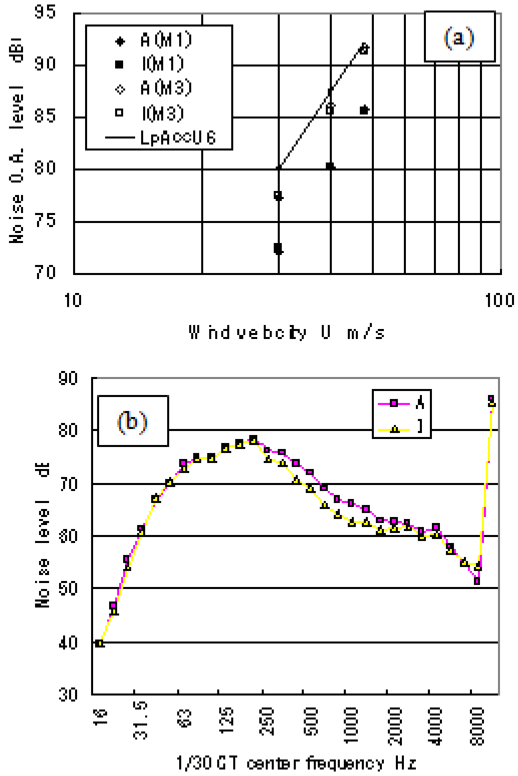


Fig.10 Effect of way of escape on noise level

B. Noise of perforated plate

Noise level of measuring points

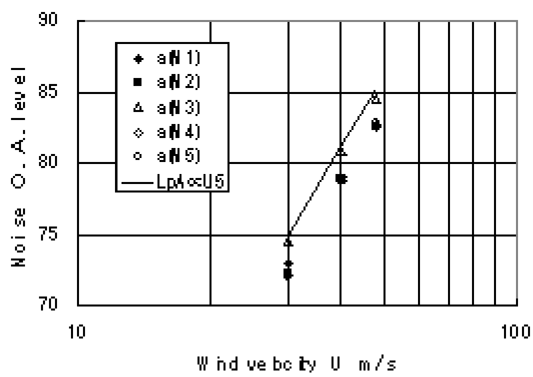


Fig.11 Noise level at each position of measurement

Fig.11 shows the overall values of noise levels at each measuring point for the test piece "a" against wind velocity. The noise level at downstream (M3) is 2～3dB larger than other measuring points and the noise levels at other measuring points are all the same. The velocity dependency of the noise level is fifth power of wind velocity. The real line in this figure shows the fifth power of the wind velocity. The tendency is the same as those of other test pieces.

Comparison of noise levels among various test pieces

Fig.12 (a) shows the results of overall noise levels measured at just above (M1) and downstream (M3). The noise level of the test piece X (flat plate), this is said to be the back ground noise, was 10dB smaller than those of other test pieces.

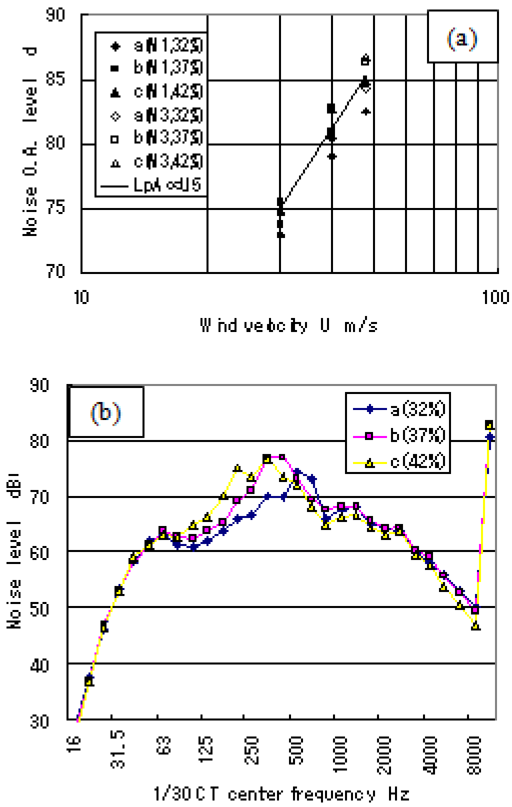


Fig.12 Comparison of noise levels among various test pieces

At wind velocity 48m/s, the noise levels are “a”<“b”<“c” The noise level of test piece “a” is 2dB smaller than that of “c”. The cause of “a” being smaller than “c” is that “a” has small aperture ratio and is close to the flat plate which noise is low. The same tendencies could be seen at other measuring points.

As can be seen in Fig.12, the peak frequencies of the 1/3 octave band noise decrease “a”, “b”, and “c” in order. Namely the peak frequency of test piece “c” is the minimum. These values are about 600Hz, 400Hz, and 200Hz.

The multiplication of these values and the length of the hole become constant (about 20Hz・m). The lengths of holes are 30mm, 50mm and 110mm respectively.

Namely the peak frequency can be obtained by $f_c = U_c / L$. This equation is the inverse of time which the vortex separated at the leading edge of hole is transported to the trailing edge by the conveying flow velocity (U_c=0.5U).

VI Conclusions

In order to examine the effect of the configuration of the louver and the perforated plate on the noise level, the noise level of test pieces with various configurations were measured and compared. The following findings could be obtained.

(1) The 4dB reduction can be achieved by the parallelogram frame with 45 degree comparing the standard louver.

(2) The tendency that the tight fin is better in the noise reduction could be seen and the doubling of the fine number makes 1dB reduction.

(3) The noise reduction effect of *R* is small but *R* is better to be large.

(4) The noise level of the perforated plate with small aperture ratio is smaller than that of large aperture ratio.

(5) The flow noise generated from the perforated plate with log holes becomes the largest at $f = U_c / L$. Where U_c is the conveying flow velocity and it is a half of the flow velocity.

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