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INCE: 10

AERODYNAMIC NOISE RADIATING FROM A WINDBREAK COVER ON A CAR ROOF

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1. INTRODUCTION

The abatement of aerodynamic noise radiating from a high-speed train is now a problem calling for urgent attention.

This paper presents the results of measuring the aerodynamic noise originating from several partial models of a windbreak cover, which is often set on a roof of a high-speed train in order to lower strong aerodynamic noise from current collection equipment, etc. in Japan.

The results contain frequency characteristics and directivity of the measured noise, from which basic and essential natures of the aerodynamic noise radiating from the windbreak cover itself may be revealed.

2. EXPERIMENTAL SETUP

Measuring experiments were performed with the equipment set by a small-size and low-noise wind tunnel and test pieces of a windbreak cover (Fig. 1). The test pieces were fitted onto a flat base plane above which an airflow from the nozzle(300 x 300 mm) passed along with the spouting velocities of 150, 200, 250, 300 km/h.

Test pieces can be classified into two types. One type can be called 'triangular projection' that has a right angle at all time and has an angle parameter of inclination(Fig. 2). The other type can be called 'net of fine mesh' that is forced to be stretched in an airflow instead of an inclined surface of the triangular projection. The ratio of an open area to a total area of the net surface was set approximately at 50%, because in such a case we found that a considerable flux of the airflow passed through the net, but the percentages of velocities of the decelerated flow seemed to be held below 70%. Such decelerating effect on the sound power can be suggested to be more than 9dB down in the case of aerodynamic sounds generated from some objects placed behind the net, being assumed to follow the 6th-power law.

3. MEASURING METHOD

Measuring points were selected at 4 points at least, so that an outline of radiation directivity of aerodynamic sounds from a test piece can be shown effectively(Fig. 3). A distance between the test piece and a measuring point was taken far enough to prevent much mix-up by non-compressive components of pressure fluctuation near an airflow.

Measured data of sound pressure were taken directly into a FFT analyzer and finally processed to frequency domain data such as 1/3 octave band levels, which can be stored and compared later easily with each other. The following values are ones omitted tacitly: an inclination angle of the front surface of the test piece, 45°, height of the test pieces, 30mm, and diameter of the net wires, 0.55mm.

4. EXPERIMENTAL RESULTS

Frequency Analysis

When we analyze measured aerodynamic sounds, we know that Strouhal number St is a very useful frequency parameter, which represents unsteady fluctuation in an airflow around the body.

$St \equiv fL/U$ (f: frequency, L: typical length, U: velocity of air flow)

On the other hand, the author found already that another frequency parameter should be also important specially when any projection or cavity is placed on a flat base plane[1][2]. Such a parameter is an acoustic parameter that is defined as kL where k is wavenumber and $k \equiv 2\pi f/c$, c is sound velocity. The author proposes to call it 'phase parameter' in this paper, because such a frequency parameter can be closely related to natures of interference by coherent sound waves. For example, lower frequency($kL \ll 1$) means a negligible phase difference, higher frequency($O(1) \leq kL$) means a considerable one.

Comparison of the Power Spectra

As shown in Fig. 4, radiation directivity of aerodynamic sounds from a triangular projection changes drastically in close relation to a change of frequency range. It can be understood easily that lower frequency components of the sounds radiated windward and leeward are remarkably strong.

An example of radiation directivity of measured sounds from a net of fine mesh is depicted in Fig. 5. It is noted that frequency components of the sound near 30kHz are strengthened and such a frequency seems higher but is quite lower in the sense that kL is considerably smaller than unity. The mechanism of sound generation from the net can be explained mainly by fluctuations of small-size eddies passing through the mesh and generating lift and drag forces toward the mesh wires.

Fig. 6 and Fig. 7 show dependence of SPL on an inclination angle of the front surface. It is seen that the dependence is reversed when compared with each other. Fig. 8 and Fig. 9 show dependence of SPL on flow velocity.

Thus, briefly speaking, frequency characteristics and dependence on flow velocity of aerodynamic sounds radiated from a windbreak cover seem to have double natures that are much different at a lower frequency. And the directivity of major components of the sound radiated from a net of fine mesh seem to be closely related to visibleness of the net surface when seen from the direction of each measuring point.

An example of the results of comparing aerodynamic sounds from different test pieces (triangular projection and net of fine mesh) is depicted in Fig. 10. We can get a hint to shift typical frequency by shift of typical length, from comparison in Fig. 10.

5. CONCLUSIONS

(1) It could be ascertained that a certain typical frequency component of aerodynamic sounds radiated from both triangular projection and net of fine mesh appeared clearly in relation to certain Strouhal number.
(2) In order to perform frequency analyses successfully, at least a couple of parameters should be used, which are Strouhal number and an acoustic parameter named 'phase parameter' in this paper.
(3) It turned out to be very likely that most power of aerodynamic sounds radiating from triangular projection could be converted to that of different sound frequencies which are high enough to be inaudible to anybody using the net of fine mesh.

References

[1] A. Sagawa, "Scattering characteristics of a quadrupole sound near a stepped surface", Proceedings of Inter-Noise 93, 1627-1630.

[2] A. Sagawa, E. Maebashi, J. Matsuo and Y. Suzuki, "Aerodynamic noises radiating from surface irregularities of high speed carbody", Proceedings of Inter-Noise 95, 285-288.

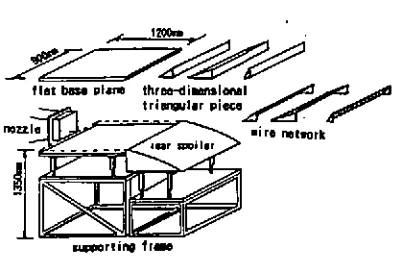

Fig. 1 Schematic diagram of experimental setup

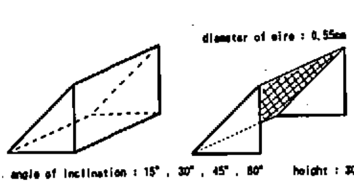

Fig. 2 Basic style of models

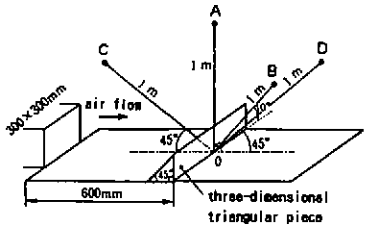

Fig. 3 Measuring points

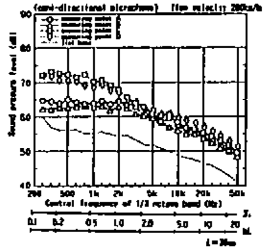

Fig. 4 Directivity of the power spectra of aerodynamic noise from three-dimensional triangular piece

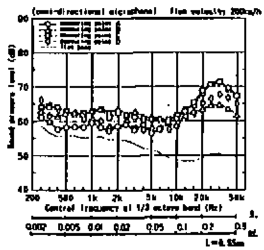

Fig. 5 Directivity of the power spectra of aerodynamic noise from wire network

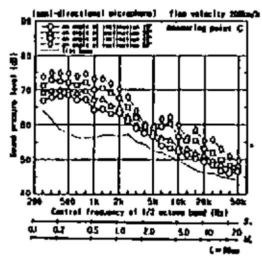

Fig. 6 Comparison of the power spectra of aerodynamic noise from three-dimensional triangular piece

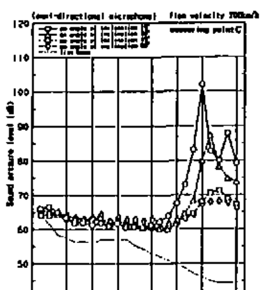

Fig. 7 Comparison of the power spectra of aerodynamic noise from wire network

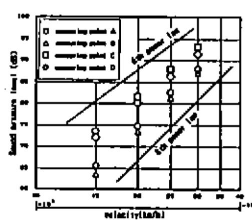

Fig. 8 Speed dependence of aerodynamic noise from three-dimensional triangular piece

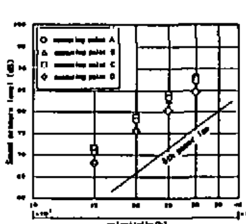

Fig. 9 Speed dependence of aerodynamic noise from wire network

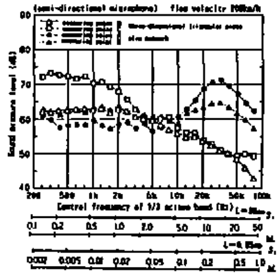

Fig. 10 Comparison of the power spectra of aerodynamic noise from two models