A Noise Reduction System Using Piezoelectric Materials

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1. Foreword

Acoustic noise penetrating the interior of rolling stock is a critical issue that may affect passenger comfort. To date, against a “transmitted noise” that is emitted from noise sources such as bogies and car bodies and that penetrates car body structures or interior walls, “passive countermeasures” such as sound insulation material or vibration-insulators have often been adopted. In many cases, such passive countermeasures may not be sufficient to reduce the unwanted noise in the low-frequency range and, specifically, noise below 500 Hz may remain without attenuation.

The Railway Technical Research Institute has thus been developing a noise reduction system that introduces a new method using piezoelectric materials that is applicable to the low-frequency range.

2. Outline of noise reduction system of an array type noise insulation panel

Figure 1 shows a cross section of the noise reduction system attached to a target wall surface (called the “target plate”). The noise reduction system comprises: a panel (called the “noise reduction panel”) on which small, flat plates (called the “noise insulation panel”) to which piezoelectric material is bonded, are arranged in a planar manner; and a control circuit.

The control circuit is an analog inductance circuit using an operational amplifier. Since the piezoelectric material generally includes capacitance, it forms a resonant circuit when connected to the inductance circuit. In this state, when the noise insulation panel vibrates due to incident noise, the piezoelectric material generates a voltage. The generated voltage is amplified in the vicinity of the resonance frequency to be applied to the piezoelectric material. This further amplified voltage has a phase opposite to that of the voltage generated by the incident noise, and consequently an antiphase force can be applied to the noise insulation panel, resulting in the effect of reducing the vibration of the plate. The target frequency can be set in a low-band range of several hundred Hz or below, and thus it is possible to freely adjust the inductance value by adjusting the resistance in the control circuit.

When the noise reduction panel is attached to the target plate, directly attaching the panel to the plate may not necessarily exhibit sufficient control of the vibration of the target plate, and hence a sealed layer of air is provided between the panel and the plate. The vibration of the noise insulation panel is restrained, and therefore the acoustic energy within the air layer also decreases. As a result, the acoustic energy incident on the target plate shrinks, thereby reducing the transmitted noise regardless of the vibration mode of the target plate. Figure 2 shows how this control mechanism works.

3. Result of noise reduction tests in railway vehicles

In a railway vehicle verification test, several noise reduction panels were applied to the ceiling of a Shinkansen vehicle. Since it had been proven beforehand that a dominant acoustic noise penetrating the ceiling exists at a frequency close to 200 Hz, prototype panels for 200 Hz, as shown in Fig. 3, were fabricated; these were installed behind the ceiling interior and tested under actual running conditions. As the result, as shown in Fig. 4, the noise in the cabin decreased by a maximum of 4 dB with its peak in the vicinity of 200 Hz with control, at a point 1,200 mm above the floor immediately below the panel.

4. Afterword

The noise reduction system using an array type noise insulation panel introduced in this paper is now being developed as a new method to combat acoustic noise. This development programme will now be applied to a variety of fields, and at the same time performance will be improved, including enhancement of the frequency range to be controlled.

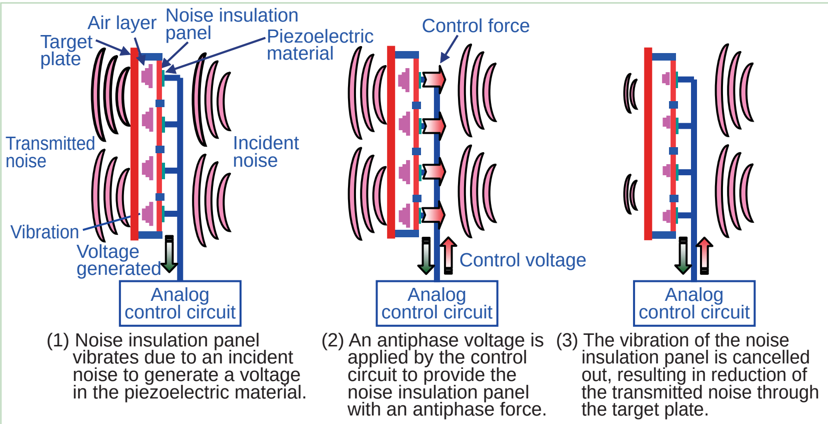


Fig. 2 Control mechanism

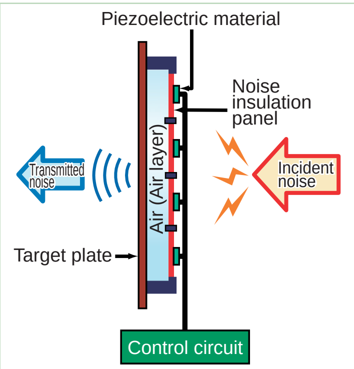


Fig. 1 Noise reduction system (a cross section)

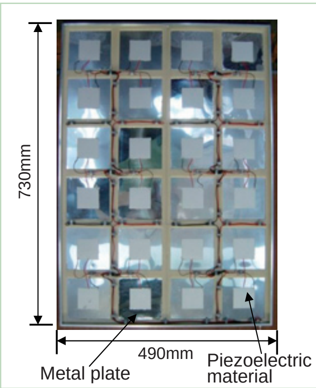
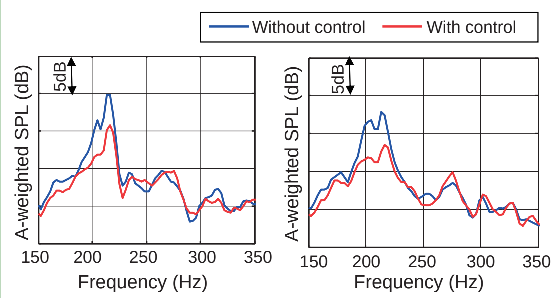


Fig. 3 Noise reduction panel



(a) Measurement point 1 (b) Measurement point 2

Fig. 4 Noise reduction effect in the Shinkansen vehicle