# Development of Active Noise Control system using Piezo Ceramic loudspeakers

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**Abstract**

We developed a new active noise control (ANC) system that uses ceramic loudspeakers. We also simulated the noise distributed over a railway vehicle by using detailed vibration data of the internal panel. This paper presents an outline of the above new ANC system, the basic principle and the deadening effect, and predicts the effect to deaden the internal noise of railway vehicles by the ANC system.

## 1 Introduction

In the development for speed-up of railway vehicles around the world, methods are being studied to keep the ride comfort and the internal noise at certain levels. In analyzing the internal noise in high-speed vehicles, two propagation paths are distinguished. One is the structure-borne sound transmitted from bogies to the structure through an anchor and internal panels to emit noise in the cabin. The other is transmission noise, or the external noise transmitted from the bogie and under-floor of the cabin, or the aerodynamic noise through the internal panels and windows. To reduce the internal noise in high-speed vehicles, it is essential to reduce the aerodynamic noise which increases in proportional to the sixth power of the velocity.

Therefore, we have developed an active noise control (ANC) system by using ceramic loudspeakers attached to the back of internal panel as a specific device which can reduce the transmission noise through the internal panels.

We also simulated the internal noise of a vehicle by using the noise emitted from the internal panels to the cabin as the input data, and we predicted the noise reduction effect of the ANC system.

## 2 Outline of ANC system

Figure 1 shows an outline and the basic circuit of the ANC system. Four piezo ceramic loudspeakers, a microphone and a control circuit are mounted on a frame to compose a construction of an independent control system. This module is attached to the back of internal panels and others for which noise shall be reduced.

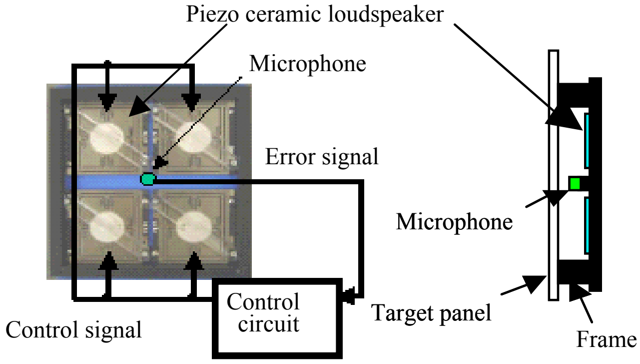


**Fig.1 ANC module**

After passing the piezoelectric loudspeakers, the noise penetrated from the external area of the vehicle becomes the noise in the module, which detected by a microphone and converted into an electric signal. The microphone signal is inputted into a control circuit, generates an opposite-phase control sound by a reverse circuit and emanates from the loudspeakers. This makes smaller both the noise which has penetrated into the object panels and the vibration of internal panels, to subsegneting reduce the noise emitted into the cabin.

The control circuit is designed as an analog feedback circuit in order to minimize the delay of signal propagation, size of the module and manufacturing cost. The hermetical construction with a frame, eliminates the interactive interference between adjacent modules to realize a independent control system with each module.

## 2.1 Control effect

We investigated the effect of the ANC system by using test equipment. The object was a 0.5mm-thick iron plate pasted with wallpaper. We attached four modules to its back. As a noise source, a loudspeaker under the test equipment emitted white noise. We measured a difference of the noise level at the point 500mm upper from the object plate with ANC control ON and OFF.

Figure 2 shows the effect of the ANC system to control noise. We confirmed that the noise in the module reduced about 5 dB maximum in the range from 200 to 400 Hz. Although the noise level increases in some areas under 200 Hz or around 500 Hz, we expect that it is possible to control only target frequencies and not those in the uncontrolled band.

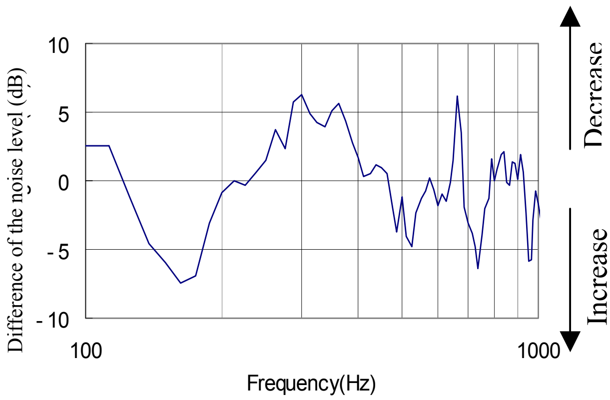


**Fig. 2 Sound deadening effect of the ANC for the noise transmitted a object panel**

## 2.2 Image of application

Although we have developed this ANC system to use for the internal panels in a cabin, it is a general-purpose system which is applicable to any place such as decks or driver cabins. As shown in fig. 3, it is possible to reduce the transmission noise by attaching the system to the object panels at the incident side of the cabin.

The modules are laid basically in necessary areas to function when power is supplied to drive IC devices in the control circuit.

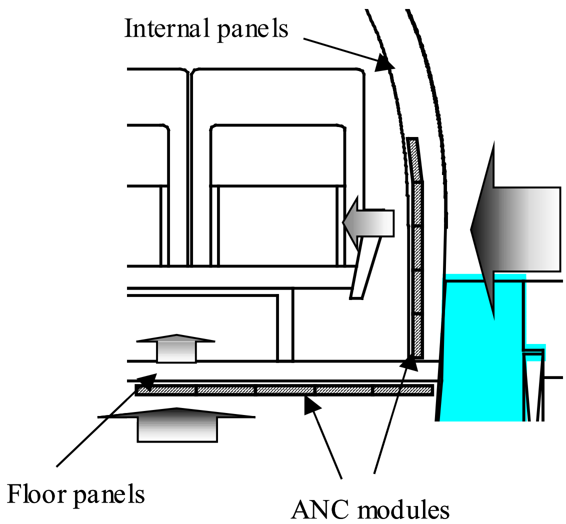


**Fig.3 Image of application of the ANC system to a vehicle**

## 2.3 Effect on running trains

To measure the effect of ANC system on running trains, we fitted 22 modules in the area under a window of internal panels in a cabin. Figure 4 shows the test result. In response to the reduction of the noise level in the modules at 200 to 400 Hz, the vibration level of the internal panels also reduced in the same frequency band. Although the internal noise consists of not only the noise transmitted from outside the cabin but also the structure-borne noise, we confirmed based on the test results that the ANC system can control noise without influenced by the vibration of internal panel which propagates from surrounding areas.

## 3 Analysis of internal noise

We simulated the noise distribution over a railway vehicle by using detailed vibrations data of internal panels in order to predict the effect of the internal noise levels reduction and ranges to reduce the noise transmitted from the internal panels in a vehicle.

Regarding the analysis of internal noise in high-speed vehicles, several methods have been proposed to use the transfer characteristics from every noise source to the estimate points after grasping the vibration and noise source level[1], or calculate the transmission noise of structure and internal panels by the SEA method[2]. In these methods, it is important to exactly understand the characteristics of noise source, propagation path of vibration and transmission characteristics. It has been a major approach to analyze the characteristics of the noise penetraiting into the cabin by experiments or analyses.

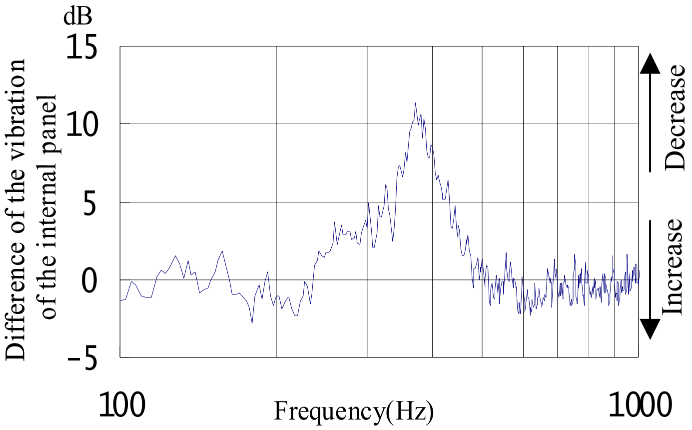


**Fig. 4 Effect of the vibration of internal panels on ANC control**

In view of the fact that the internal noise is the secondary emission noise from internal panels such as side panels, windows, floor and roof panels that make up the cabin, we performed a three-dimensional analysis of internal panels based on the vibration data in a small area and at representative points in the other areas.

### 3.1 Analysis model

In this simulation, we prepared a three-dimensional vehicle model shown in Fig. 5. We also modeled seats and rack in consideration of the spatial influence of the noise emitted into the cabin to make the three-dimensional analysis possible.

We used the data of internal panels collected in running as the boundary condition and inputted the acoustic absorbtion of the materials of internal panels and seats into the model. We calculated the frequency characteristics at certain seats and the noise distribution in the cabin at the plane 1,200mm upper from the floor where is approximately the same height as that of passenger ears.

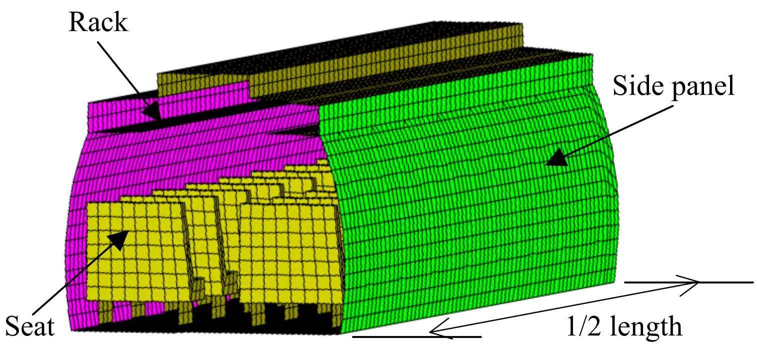


**Fig. 5 Analysis model**

## 3.2 Result of simulation

As an example, Fig. 6 shows the internal noise distribution at intervals of 100 Hz in the range 100 to 500 Hz which is based on the vibration data of internal panels on a train running in tunnel.

The distribution tends to be at higher levels near the side panels and lower levels along the walkway as a whole. It was thought that the transmission noise through the internal panels increased because the reflection noise from the tunnel wall was added in the tunnel. As the frequency became higher, the noise distribution pitch became smaller, and the whole noise level became nearly the same. We was able to understand the influence of noise distribution in the three-dimensional space in the cabin, including the appearance of a distribution in the longitudinal direction in the low frequency range. Especially in the range from 200 to 300 Hz, the noise level around the walkway is somewhat higher, and it tends to present a W-like figure in the cross-section direction.

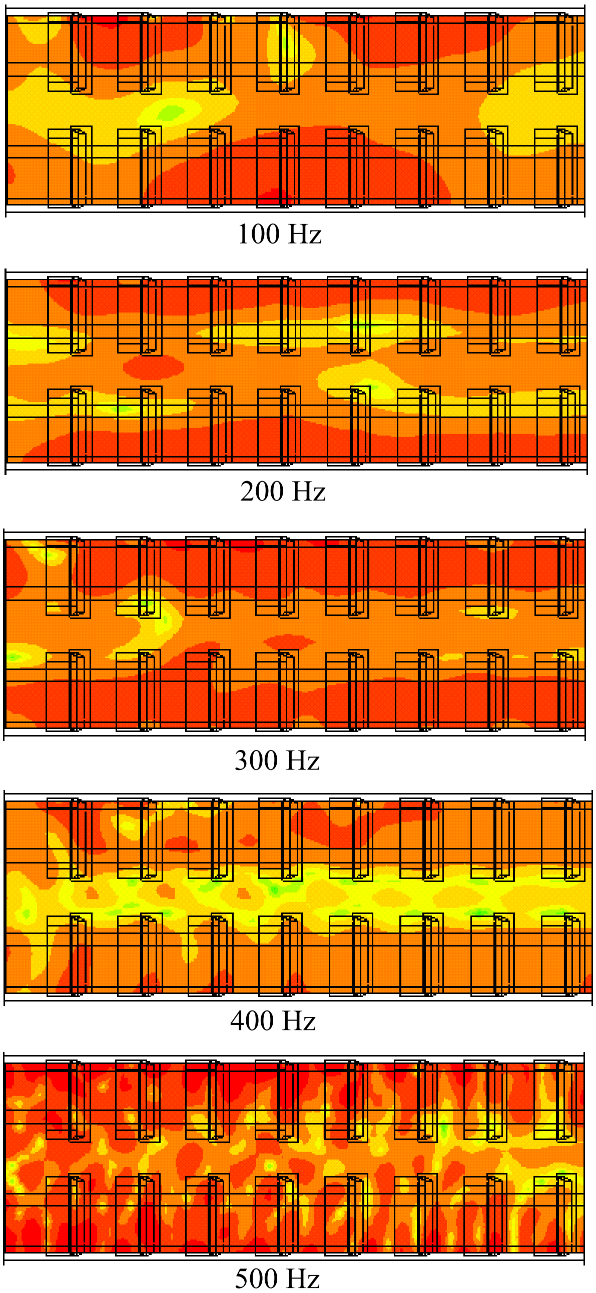


**Fig. 6 Internal noise distribution by simulation**

## 3.3 Comparison with the actual measurement result of internal noise

A comparison between the results of simulation and the actual measurement data of internal noise reveals its whole tendency, although fluctuations of frequency in frequency analysis are a little larger than those in actual measurement. The actual internal noise includes various elements such as the noise leaked through the gap between the internal panels or cabin doors in addition to the second emission noise from the internal panels. In frequency analysis, we recognized that almost the same tendency could be obtained by setting the acoustic rate.

The noise distribution in the cabin tends to be almost the same at that of the result of simulation, in that when the noise level near the internal panels is higher, it becomes higher along the walkway to present a W-like figure, and the distribution becomes flat at high frequencies.

## 3.4 Application of this simulation method

Because this simulation method assumes that noise is emitted only from internal panels into the cabin, it is applicable under the following conditions.

1. The cabin is a space closed by wall surfaces as internal panels.

2. There are no windows or gaps of internal panels to allow noise penetration.

3. An empty car without passengers.

In the actual internal noise, however, the penetration from the gaps of internal panels has great impact on noise characteristics in particuler.

Under these conditions, it is possible to aasses the current noise penetration routes and changes in the internal noise after the application of any coutermessure.

# 4 Prediction of the internal noise deadening effect by the ANC system

By inputting the area of application and the noise deadening effect level of the ANC module as the vibration data of each internal panel, we can simulate the noise deadening effect in the cabin in applying the ANC system to the internal noise analysis described in the chapter 3.

As a case of applying the ANC system whose effective frequency range is only 200 to 480 Hz for noise reduciton to the internal side panels and floor panels, Fig. 7 shows the changes in the frequency characteristics at 3rd seat from the end panels.

As a result, by reducing the noise emitted from internal side panels and floor panels maximum 6 dB, we were able to recognize that the noise level decreased maximum about 3 dB at the seat. Moreover, we knew that there were frequency ranges where the noise was hardly reduced or increased on the contrary around 320 Hz.

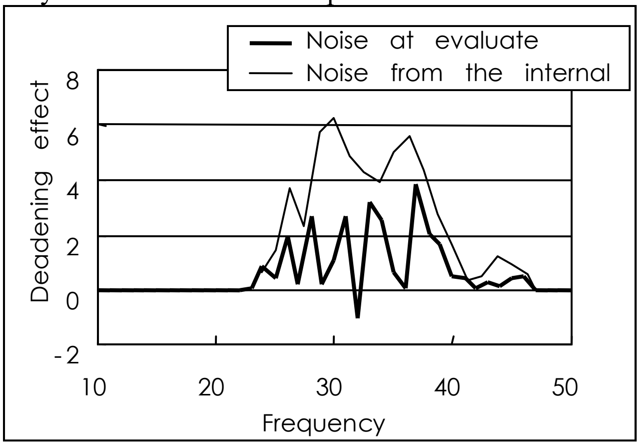


**Fig. 7 Prediction of noise deadening level at the 3rd sheet by ANC system**

This ANC system using piezo ceramic loudspeakers is applicable to the equipment case wall mounted under the vehicle floor. Therefore, it is possible to reduce the noise from the equipment as a wears to control the noise in the current problem of railway vehicles.

# 5 Conclusion

We developed the ANC system using piezo ceramic loudspeakers to effectively reduce the noise transmitted from the internal panels as internal noise.

Moreover, we have constructed an internal noise simulation tool by using the vibration data of internal panels, and predicted the changes in the internal noise by applying the ANC system.

In developing ANC system further, we intend to study the application of several materials, weight saving, electric power saving and other related issues. We have also to verify the effect of the noise transmitted from the internal panels in applying technique to actual vehicle.

In improving the control characteristics, we will assess how effectively we can reduce the internal noise through simulation, and work toward the commercialization of the system.

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