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ACTIVE ACOUSTIC POWER CONTROL OF ELEVATOR NOISE CAUSED BY VENTILATOR

A Enamito (1), Y Morikawa (1), T Hayashi (1), N Teshima (2) & Y Fujita (2)

(1) Energy and Mechanical Engineering Laboratories, Research & Development Center, TOSHIBA Corporation, 4-1 Ukishma-cho, Kawasaki-ku, Kanagawa 210, Japan, (2) Fuchu Works, TOSHIBA Corporation, 1 Toshiba-cho, Fuchu-shi, Tokyo 183, Japan

INTRODUCTION

The purpose of this study was to reduce the total acoustic power of a noise source by active noise control and thus to reduce the noise level in the entire area around the noise source. The authors first considered the optimum error microphone location for minimizing the total power of a noise source located in a free field, and noise reduction was realized.This technology was then applied to the noise radiated from the end of a ventilation duct into an elevator car. This noise source was not located in a free field. Thus, the new optimum error microphone location was investigated by simulation.This paper describes the power attenuation effects inside an elevator car examined experimentally using a random acoustic signal-rather than fan noise.

ADAPTIVE NOISE CONTROL SYSTEM

As shown in Figure 1, the active noise control system consists of one loudspeaker used as a noise source, two active speakers, one error microphone, and a controller. The power attenuation effects of noise radiated from the duct end into the car were examined using this adaptive control system.In practical use, the active speakers and error microphone should be outside the car. Thus, the active speakers are located on both sides of the duct end and the error microphone is located inside the ceiling (Figure 2).

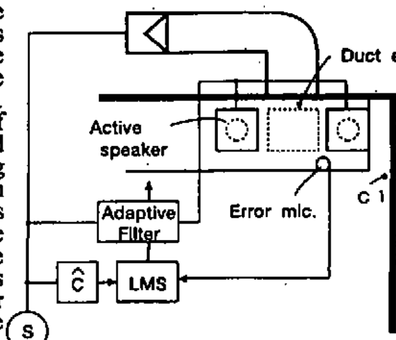


Fig.1 ANC system of elevator noise

OPTIMUM ERROR MICROPHONE LOCATION FOR MINIMIZING TOTAL POWER

Because the duct end is located opposite a side panel in a corner of the car, the acoustic noise wave propagates with reflection. In addition, the locations of the active speakers and the error microphone are restricted. Therefore, the suitable arrangement of the error microphone for minimizing total power inside a car differs from that in a free field. Thus, a new optimum location was considered.

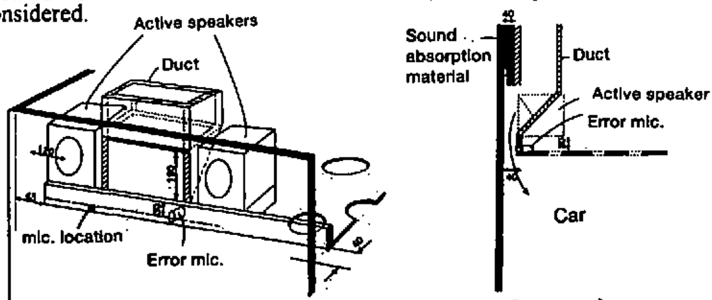


Fig.2 Arrangement of speakers and error mic.

In this study, the primary source and the secondary sources were modeled as monopoles. If the two secondary sources are operated under the conditions that the absolute value of the ratio of the secondary to primary source strengths is 1/2 and the phase of the secondary source is anti-phase, which minimizes the total power, the acoustic nodal points are set up around the sources. Thus, the error microphone should be positioned at one of these acoustic nodal points in order to achieve minimum power.1)

The acoustic nodal points around the duct end were investigated using this method. High-level standing waves were not excited inside the car, but first reflection waves from the wall were excited. Therefore, the acoustic nodal points around the duct end with the first reflection waves was investigated. The sound pressure level was estimated from the reflection waves from the two walls but not the ceiling because there were sound absorbing materials within the space between the side panel (wall) and the duct wall.

Figure 3 shows a contour map of sound pressure level in a plane 4 cm away from the side panel calculated with the image sound source. Low-frequency waves can be regarded as monopoles at the duct end. The primary source was located at the top of the duct end, and the secondary sources were located at the active speakers. The error microphone location range indicates the area on the ceiling where the microphone can be positioned. As shown in Figure 4, the minimum point of sound pressure level, that is, acoustic nodal point A, was excited inside the car. However, this location was unsuitable. Therefore, a suitable location within the error microphone location range was determined for reducing the sound pressure level. Two points (B,C) were excited.

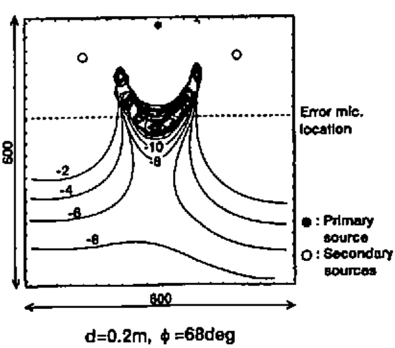


Fig.3 Contour of sound pressure level

In order to investigate the power attenuation effects in this case, the relationship between the error microphone location and the total acoustic power attenuation was calculated. Figure 5 shows the contour of power attenuation results with reflection waves. The power attenuation effects at the two points (B,C) were similar to the effect at nodal point A inside the car. In addition, the power attenuation effects at the above optimum location were similar to the effect without reflection waves. Thus, in the error microphone location, the optimum range for the error microphone is greater at the whole range. However, in the low-frequency range under 100 Hz, the effects at the two points (B,C) become similar to that at other locations. The authors therefore decided that point B was the optimum location.

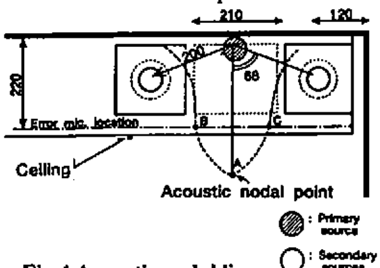


Fig.4 Acoustic nodal line

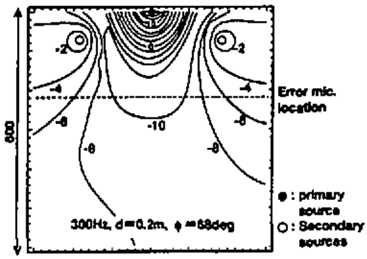


Fig.5 Relation between the error mic.location and acoustic power attenuation

EXPERIMENTS ON THE NOISE RADIATED FROM THE DUCT END INTO THE CAR

The power attenuation effects of noise radiated from the duct end into the car were examined experimentally using the Filtered-X LMS algorithm. In principle, the optimum error microphone location for minimizing total acoustic power was investigated by a simulation, assuming that the sound pressure level at the error microphone tends to zero. Therefore, first of all, it is necessary to reduce the error signal sufficiently. Because the reduction in error signal depends on the sound coherence in space, with respect to noise radiated from the elevator ventilation duct, it is important to consider the relationships between flow velocity, sound coherence in space, and the effect of noise reduction.

However, our first objective was to investigate the optimum location of the error microphone with the reflection waves. By using a random acoustic signal instead of fan noise, high coherence in the car was achieved. The sound pressure level measured at the error microphone was sufficiently decreased with control. The power attenuation effects are shown in Figure 7 and Figure 8(a) to (c) for various planes within the car, as shown in Figure 6.

Strictly speaking, the power output should be examined by measuring the power level with a sound intensity analyzer, but the authors measured the sound pressure levels at certain suitable points. A 5-10 dB reduction was obtained in the frequency range of 100-500 Hz in the entire area inside the car. This experimental result was confirmed by comparison with the simulation result.

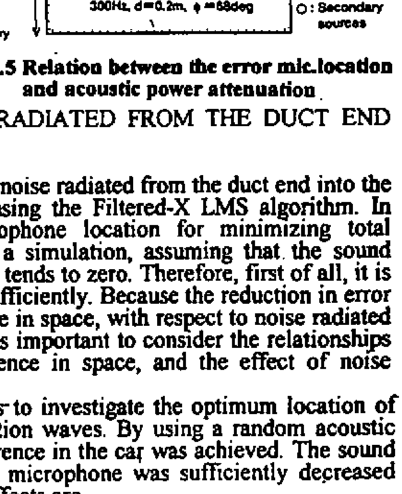
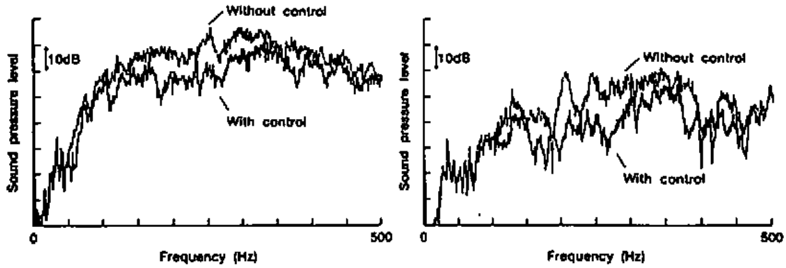
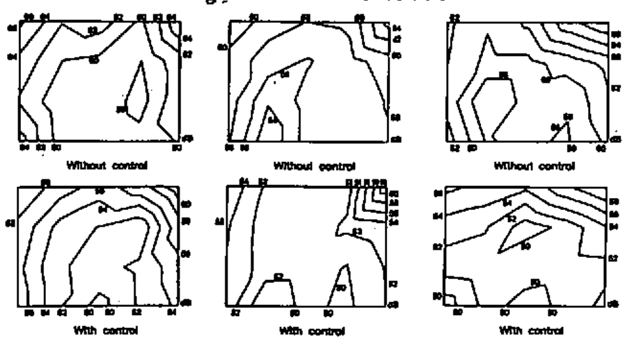


Fig.6 Measurement points inside car



point C1 point O

Fig.7 Effect of ANC inside car



(a)plane A **(b)plane B** **(c)plane C**

Fig.8 Contour of sound attenuation inside car

CONCLUSION

The purpose of this study was to reduce the total acoustic power of a noise source by active noise control. This technology was applied to the noise radiated from the end a ventilation duct end into an elevator car. The optimum error microphone location for minimizing total power of the noise source in the car with reflection was considered.The power attenuation effects were examined experimentally using a random acoustic signal. The experimental result was confirmed by comparison with the simulation result. The optimum design of an ANC system was confirmed by experiment. After this, the authors confirmed the power attenuation effects for fan noise from the ventilation duct by the optimum design.

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