Analysis on Technical Trends of Active Noise Cancellation for Reducing Road Traffic Noise

Won-Pyong Kang, Hak-Ryong Moon*, You-Jin Lim

1. INTRODUCTION

The problem of noise in industrial environments has grown with the increased use of industrial equipment such as engines, fans, transformers and ventilators. To reduce the noise problem, a method of passive noise reduction has been used such as a closeness, barrier, and silencer. This kind of passive noise equipment has the wide frequency band. But, the passive noise equipment is large, expensive, and inefficient in the low frequency band. Active Noise Cancelation (ANC) has been suggested for overcoming the limitations of passive noise reduction methods. Active noise reduction technology is to reduce the noise level and frequency by generating noise with the same station by converting the frequency phase of target noise by 180°. We analyze the technical trend of active noise cancelation in Korea and internationally. The result of the study indicates that active noise cancelation has been applied to various fields such as vehicles, airplanes, roads, audio equipment and so on. However, research of active noise cancelation for the road and transportation areas has been not much compared to other fields. It needs further research to apply active noise cancelation to the road in order to provide a comfortable lifestyle for civilians.

Keywords: Noise, Active Noise Cancelation (ANC), Intelligent Active Noise Control System, Technical Trend

1. INTRODUCTION

The problem of noise in industrial environments has grown with the increased use of industrial equipment such as engines, fans, transformers and ventilators. To reduce the noise problem, a method of passive noise reduction has been used such as a closeness, barrier, and silencer. This kind of passive noise equipment has the wide frequency band. But, the passive noise equipment is large, expensive, and inefficient in the low frequency band. Active Noise Cancelation (ANC) has been suggested for overcoming the limitations of passive noise reduction methods. Active noise reduction technology is to reduce the noise level and frequency by generating noise with the same station by converting the frequency phase of target noise by 180°, which was introduced by Leug(1936)[1]. Active noise cancelation technology has been applied to various areas of the vehicle, road, airplane, building and sound device. However, the research result of active noise cancellation for the road area is not much sufficient than that for other fields.

In this paper we analyze the research trends of active noise cancelation and suggest further research for the road area.

2. TECHNICAL TRENDS OF ANC IN KOREA

2.1 ANC for a Car Interior

The basic principle of the ANC in a car interior is as follows. This method is to measure interior noise using 2 microphones installed on the roof of a car. The ANC installed on the vehicle analyses the sound wave and sends the opposite wave through the speaker into the car interior. This action reduces noise by conflict of sound waves.

Hyundai motor developed Korea’s 1st ANC for a car interior. Currently, the Hyundai motor ANC is on a commercialization stage, which can reduce engine noise by10dB(A) to 20dB(A). Also, Hyundai motor is developing an active sound design that selects style of engine sound (Auto daily, 2013)[2].

2.2 ANC for an Acoustic Device

The purpose of active noise cancelation for headphones was developed to remove the outside noise and enable a user to listen to pure music. Currently, this technology is commercially available. However, with this active noise cancelation a user can not listen to the voice of person in front of himself/herself, which causes inconvenience. Moon et al.(2010)[3] suggested a method that leaves sound from the front and conducted a simulation for this method. Through this method it was possible to leave front noise and reduce the noise from other directions by 30dB (A). As shown in Fig 2, the Listen Beam is made at a 15° of left and right of the headphone through this method.

Fig 1: ANC system of Hyundai-Kia Motors (Auto daily, 2013)[2]
2.3 ANC for Public Transportation

Kim et al. (2012)[4] studied active noise cancelation of KTX (Korea Train eXpress). As shown in Fig 3, they made test-bed similar to KTX and compared simulation results of before and after modeling. Also, they simulated frequency band using pure-tones of 120Hz and 280Hz similar to the interior noise in KTX. The result of this study showed that noise was reduced in the frequency band of 120Hz and 280Hz.

2.4 ANC Barrier

Kwon et al.(2002)[5] studied a barrier of active noise cancelation using 6 microphones and 4 loudspeakers with a multi-channel Fx LMS algorithm. They used a TMS320CSS DSP (TI Corp.) for fast calculation. The frequency of the standard signal input by a frequency generator was 190Hz. They developed a basic model using active noise cancelation, and the result of this study showed an average of 20dB (A) noise reduction.

Cho et al. (2009)[6] also applied active noise cancelation to a barrier. The aim of this study was to reduce noise by 3 to 6 dB (A). As shown in Fig 4, they verified the performance of a developed barrier model through conducting a lab and outdoor test. The specifications of the hardware are as follows.
- 6713 CPU, Input and Output of 8 channels
- Wireless Data Communication Module for Input Signal of an Error Microphone
- Built in AK4556 Voice Codec, FPGA, DAC, ADC
- Dust and Moisture Proofing Case for Protecting Board

They used noise of multiple frequencies and Fx LMS algorithms for the lab and outdoor tests. The result of this study showed a reduction of 10dB(A) to 13dB(A).

3. INTERNATIONAL TRENDS OF ANC

3.1 ANC for a Car Interior

Toyota of Japan developed the first ANC for a car interior using 3 microphones. The target of this development was that crown hybrid engine which transferred noise to car interior for low speed driving. This development showed a noise reduction of 5dB (A) to 8dB (A) in the car.
3.2 ANC for Acoustic Device

Serizel et al. (2010)[9] applied active noise cancelation to hearing aids to reduce noise in open spaces. This study used Fx LMS algorithms and a multichannel Wiener Filter to control noise in hearing aids.

Famous foreign headphone companies already applied ANC to their products, and a lot of market of ANC headphones has formed.

Johansson and Claesson (2001)[12] aimed to reduce the interior noise of a propeller airplane. A propeller airplane generates low frequency noise with its propeller which is transferred to the airplane interior. This study applied a multiple reference narrowband feed forward. The controller was based on Fx LMS algorithms, and simultaneously applied to both propellers. They used 8 control sources and 11 control microphones. The result of this study showed a good performance for the convergence rate, tracking and robustness. The microphone located at the level of the passenger head showed a noise reduction of 10dB (A).

Pabst et al. (2008)[13] studied active noise cancelation of a light jet airplane. The frequency band of noise in a light jet airplane was a low frequency band of 50 to 200Hz, and the total sound pressure level was 85dB(A) to 95 dB(A). They applied modified Fx LMS algorithms and conducted the simulation of active noise cancelation in an airplane model as shown in Fig 9. Also, 8 microphones and 6 loud speakers were used in the simulation. The field noise was generated in the airplane interior. The result of this study showed a reduction of noise in the low frequency band.

3.4 ANC Barrier

In Japan, research of an ANC barrier was conducted earlier. An ANC barrier was installed and operated on the top of an existing barrier. As a result, noise between 160Hz and 630Hz band was reduced by
2dB(A) to 5dB(A) compared to the existing barrier. However noise reduction at 1 kHz by ANC barrier was similar to that by the existing barrier. Currently, Japan is preparing to commercialize an ANC barrier (Morgan, 2004[14]).

Fig 10: Japanese ANC Barrier (Morgan, 2004[14])

Also, Zou et al.(2010)[15] studied an active noise cancelation barrier. As shown in Fig 11, they used 8 single channel feed forwarded controllers on a wooden barrier (height of 1.5m) for simulation. The controller used Fx LMS algorithms, and the source noise was white noise below 1600Hz. The result of this study showed a noise reduction of 0.2dB (A) to 6.0dB(A) in 200Hz to 1250Hz band.

Fig 11: Simulation of ANC Barrier (Zou et al., 2010[15])

4. ANALYSIS RESULT

We analyzed technical trends of ANC as shown in Table 1. In the area of audio devices, a lot of products have been released internationally. But, research related to ANC in Korea has mainly remained to simulation. In the area of cars, the technical level of ANC was revitalized in the market internationally, and in Korea ANC is being prepared for the commercialization in luxury cars. In the area of public transportation, various research has been conducted internationally since the early 90s. For ANC barriers, Japan is already prepared for commercialization. In Korea, research and simulation about ANC is on the beginning stage. Existing Korean research was mostly conducted in lab and outdoor tests.

Table 1: Analysis Result of ANC Trend

<table>
<thead>
<tr>
<th>Classification</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car</td>
<td></td>
</tr>
<tr>
<td>Korea</td>
<td>-10dB(A) ~ 20 dB(A) reduction</td>
</tr>
<tr>
<td></td>
<td>-The first development in Korea</td>
</tr>
<tr>
<td></td>
<td>-Commercialization Preparation</td>
</tr>
<tr>
<td>International</td>
<td>-10dB(A) reduction(Honda)</td>
</tr>
<tr>
<td></td>
<td>-5dB(A)~8dB(A) reduction(Toyota)</td>
</tr>
<tr>
<td></td>
<td>-Market Vitalization</td>
</tr>
<tr>
<td>Acoustic Device</td>
<td></td>
</tr>
<tr>
<td>Korea</td>
<td>-30dB(A) reduction except from frontal noise(by simulation)</td>
</tr>
<tr>
<td>International</td>
<td>-Headphone market vitalization</td>
</tr>
<tr>
<td>Public Transportation</td>
<td></td>
</tr>
<tr>
<td>Korea</td>
<td>-KTX: Noise reduction in low frequency band</td>
</tr>
<tr>
<td></td>
<td>-Ship: Algorithm development</td>
</tr>
<tr>
<td>International</td>
<td>-Noise reduction in jet and propeller airplanes</td>
</tr>
<tr>
<td>Barrier</td>
<td></td>
</tr>
<tr>
<td>Korea</td>
<td>-Max. 13.8dB(A) reduction in lab</td>
</tr>
<tr>
<td>International</td>
<td>-Max. 6dB(A) reduction at field</td>
</tr>
<tr>
<td></td>
<td>-Commercialization Preparation</td>
</tr>
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</table>

The technical level of ANC is as described in Fig 12. The comparison standard of Korea and international trend is current state of trend. The level of ANC for cars in Korea was generally close to the international technology level. But in other areas ANC needs more research.
5. CONCLUSION
ANC has been variously applied to vehicle, airplane, road, audio device and so on. This research is to analyze the technology trend of ANC in Korea and internationally. The result of the study indicates that ANC has been focused on vehicles and audio equipment, and research of ANC for the road and transportation areas has been not much compared to other fields. It needs further research to apply active noise cancelation to barrier and public transportation areas in order to overcome the weakness of the existing soundproof equipment in Korea.

Therefore, this study indicates the necessity for ANC research for roads and transportation.

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REFERENCES


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