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Impact of Sound Insulation in a Combine Cabin

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Abstract

Purpose: Recently, environmental pollution and safety problems in agricultural production have become important issues. Initially, bio-production machines focused on high production efficiency rather than workers' safety and comfort, but this trend slowly has changed as time went on. **Methods:** This study was carried out to identify sound efficiently and reliably for noise reduction by using a combine cabin model. Ethylene propylene diene monomer (M-class) rubber (EPDM) was applied to improve noise reduction performance from parts connected directly to the front, rear, left side, and bottom side of the cabin. **Results:** As a result, an average noise reduction of 1.85 dB was achieved in the normal hearing range between 500 Hz to 2 kHz. **Conclusions:** Reducing the cabin noise levels can reduce a worker's fatigue, improve working environment, and contribute to future low-noise and high-quality cabin environment.

Keywords: Combine cabin, Ethylene propylene diene monomer (M-class) rubber (EPDM), Noise reduction, Normal hearing range

Introduction

Nowadays, it is important to consider consumers' expectations of the ride quality of bio-production machines. The focus has especially been on interior noise and vibration aspects (Lee and Kim, 1997). Initially, the focus of bio-production machines was on high production efficiency rather than on workers' comfort, but this trend has slowly changed. Consumers prefer more comfortable and quiet bio-production machines. Specifically, the driver's working environment is closely related to vibrations in the cabin as international regulation (ISO 2631-1, ISO 2631-5) applies to the driver (Joo et al., 2008). Cabin has been introduced in other bio-production machines alongside tractors and combines. After taking into account influences of work characteristics and measuring time, the noise level of a combine is measured to be higher than that of a tractor owing to more structural noise sources in the combine. The sources of noise and vibration are parts installed around the cabin, such as the engine, cutting part, and threshing part, and both noise and vibration can be reduced by using the cabin. Noise from a cabin can be clarified as airborne noise which is delivered through the structure-borne noise (Joo et al., 2009). A combine cabin model was used to reliably identify noise sources and pathways for noise reduction. Ethylene propylene diene monomer (M-Class) rubber (EPDM) was adopted as a noise insulation material to reduce noise in the cabin.

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Materials and Methods

To distinguish a combine's airborne noise from the main noise, the measuring positions were selected at the parts in direct contact with the cabin. Speakers were installed at the front, rear, left side, and bottom sides of the cabin to assess the noise around the cabin (Fig. 1). A cutting device was placed in front of the cabin; a conveying unit and threshing part were placed at the left side of the cabin; a grain tank was placed at the rear of the cabin; and an engine was located under the cabin.

A sound insulation performance test of the combine cabin was conducted at the front, rear, left side, and bottom side of the cabin. In the combine, the engine, cutting part, and threshing part worked at the same time, with the noise sources located around the cabin. The combine noise was affected by the transmission of the airborne noise generated from these noise sources. To identify the transmission pathways of noise in order to effectively diminish noise transmission and to evaluate how noise reduction was affected by using EPDM, an insulation performance test was carried out using a cabin with a speaker alone as the noise source. EP(D)M was divided into EPM and EPDM based on the combination of ethylene and propylene with a ternary copolymer. EPDM has excellent features compared with synthetic rubber such as a matching solid polymer structure for weathering and ozone resistance. Thus, auto parts, electrical wire insulation coating material, construction roofing sheet, tires and tubes, general industrial rubber parts, material, etc. are of diverse and extensive use in disposal. For this reason, noise reduction and insulation were considered widely, and this experiment was performed by evaluating these factors. A noise reduction performance test was conducted on the cabin to determine the transmission characteristics of the cabin's airborne noise. The noise reduction in the cabin structure was measured with the noise sources placed outside the cabin. Cabin noise reduction can be calculated using a conceptual equation (1).

$$NR = SPL_{outside} - SPL_{cabin} \quad (1)$$

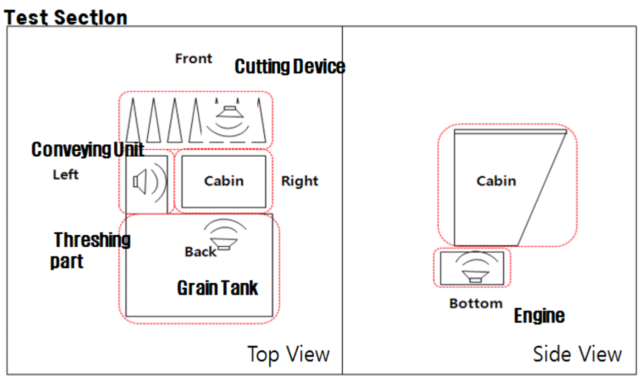


Figure 1. Measurements are performed at the major noise sources.

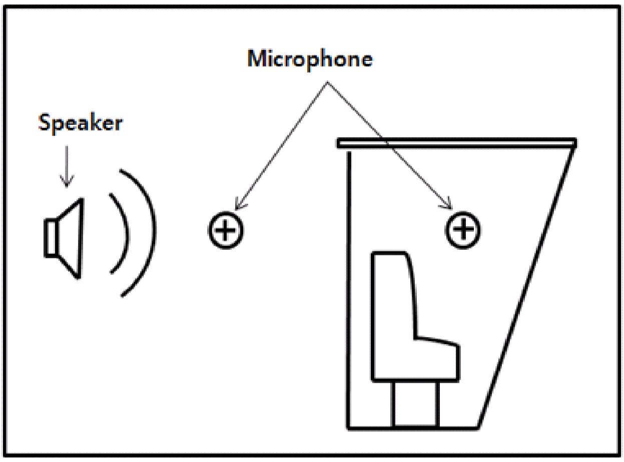


Figure 2. Overview of cabin in sound insulation test.

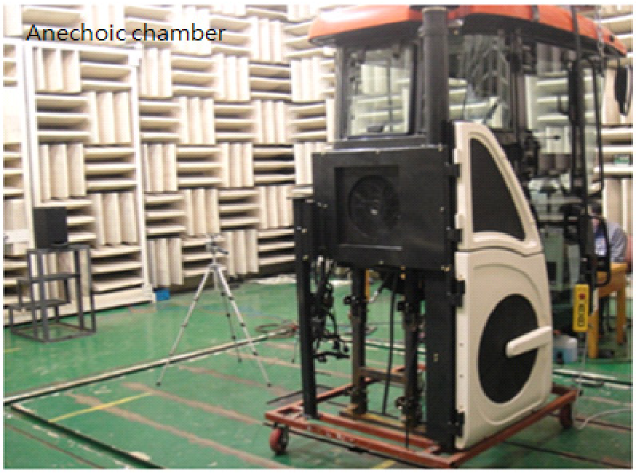


Figure 3. Cabin sound insulation test set.

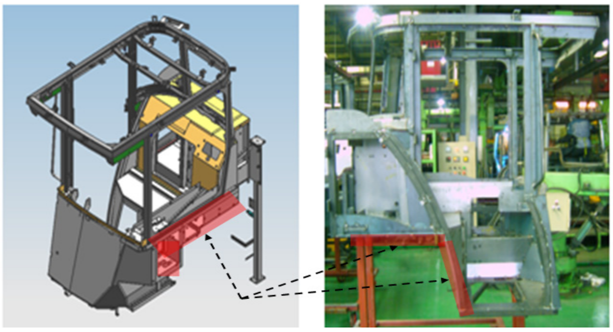


Figure 4. EPDM mounting position.

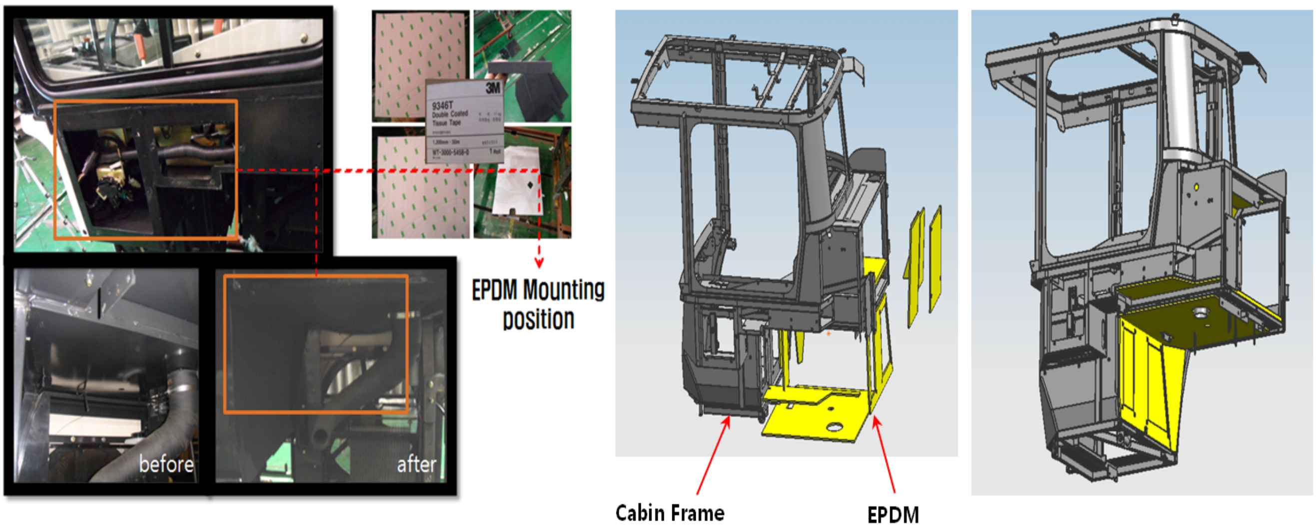


Figure 5. Before and after applying the EPDM.

Here, SPL stands for the sound pressure level and NR stands for noise reduction.

The test was performed in an anechoic chamber, to isolate the cabin for an accurate determination of the direction in which the noise is transmitted. The noise emitted from the speakers was pink random noise having a constant sound pressure level and octave band center frequency. Microphones were used to measure the noise pressure level emitted from the speaker and at the operator's ear position in the cabin. The amount of noise reduction was measured in each direction before and after applying EPDM insulation.

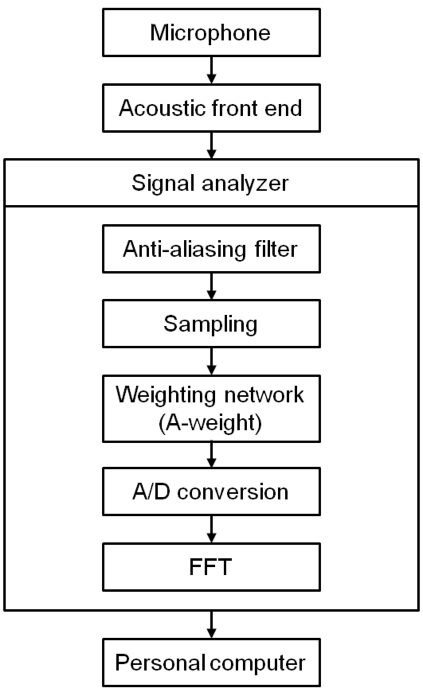


Figure 6. Flowchart for noise analysis.

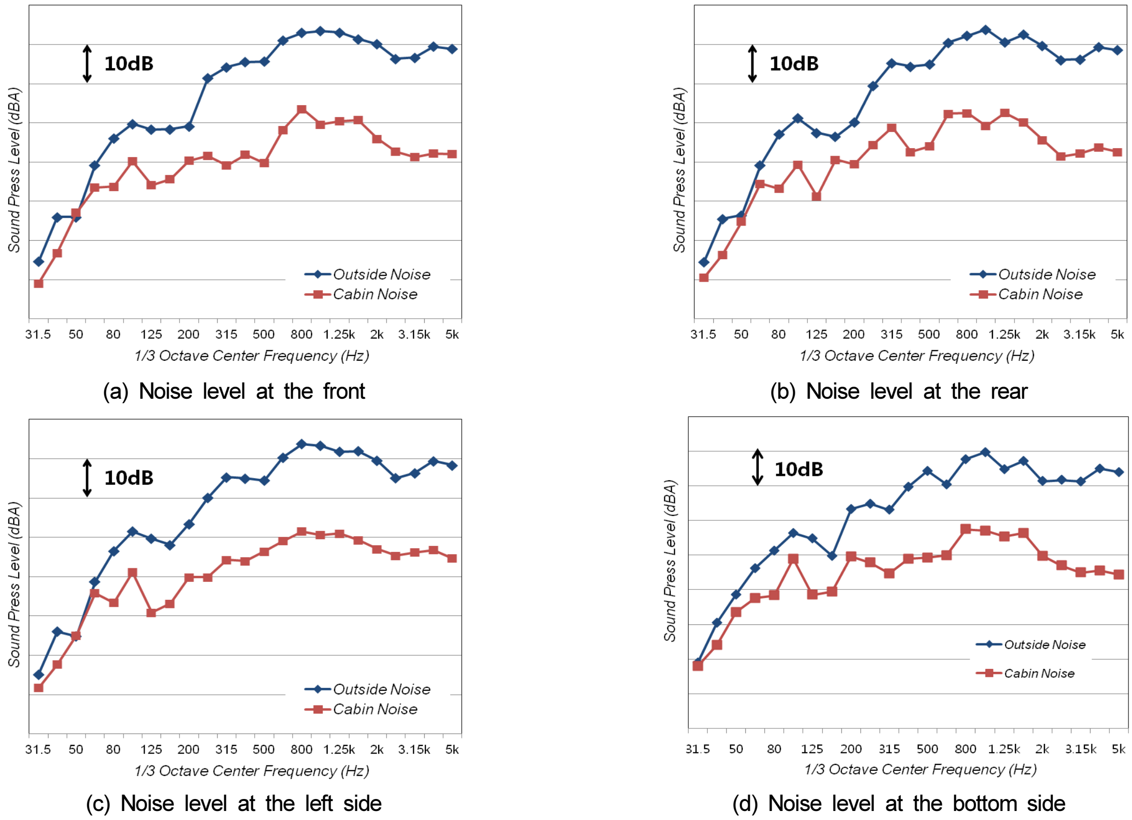
EPDM was applied to the parts affecting the cabin noise directly. The experiment was conducted at the left (lever and wire) and top areas of the cabin’s engine room. Figure 4 shows the EPDM’s mounting position for each specific part.

Figure 5 shows the cabin frame before and after applying EPDM. The EPDM was applied on the lever box and over the engine part. Noise signals of good quality were selected and analyzed according to the order shown in Figure 6. Fast Fourier transform (FFT) analysis of the measured data was performed using the functions of filtering, A/D conversion, and FFT in the range of 31.5 Hz to 5 kHz. A high-pass filter with a constant filter cutoff frequency was used. Sampling was done at an interval of t = 30.5 μs, and with f = 2 Hz width.

Results and Discussion

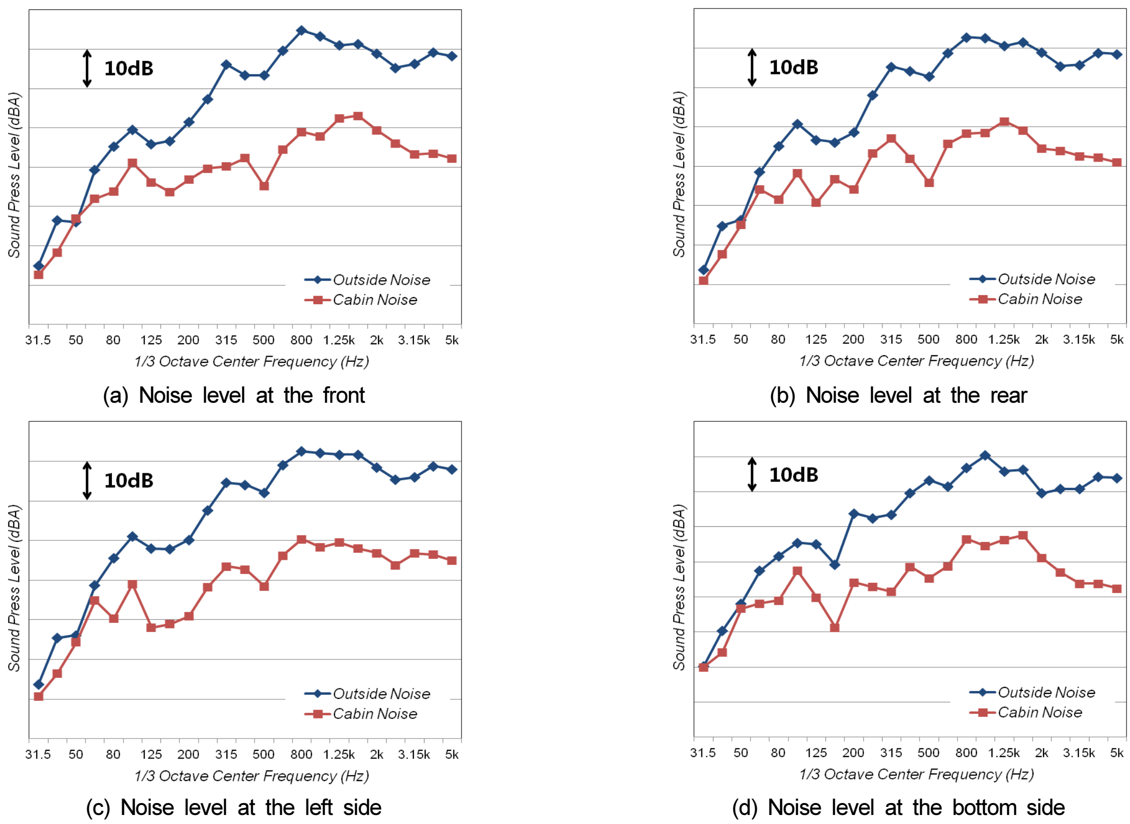
Measured data inside and outside the frequency of 1/3 octave band center frequency were compared according to their frequency by using sound pressure level (SPL). Figure 7 shows the noise level at the front, rear, left side, and bottom side before applying EPDM.

However, it is hard to find the frequency at which noise was reduced. Thus, frequencies were compared inside the cabin.



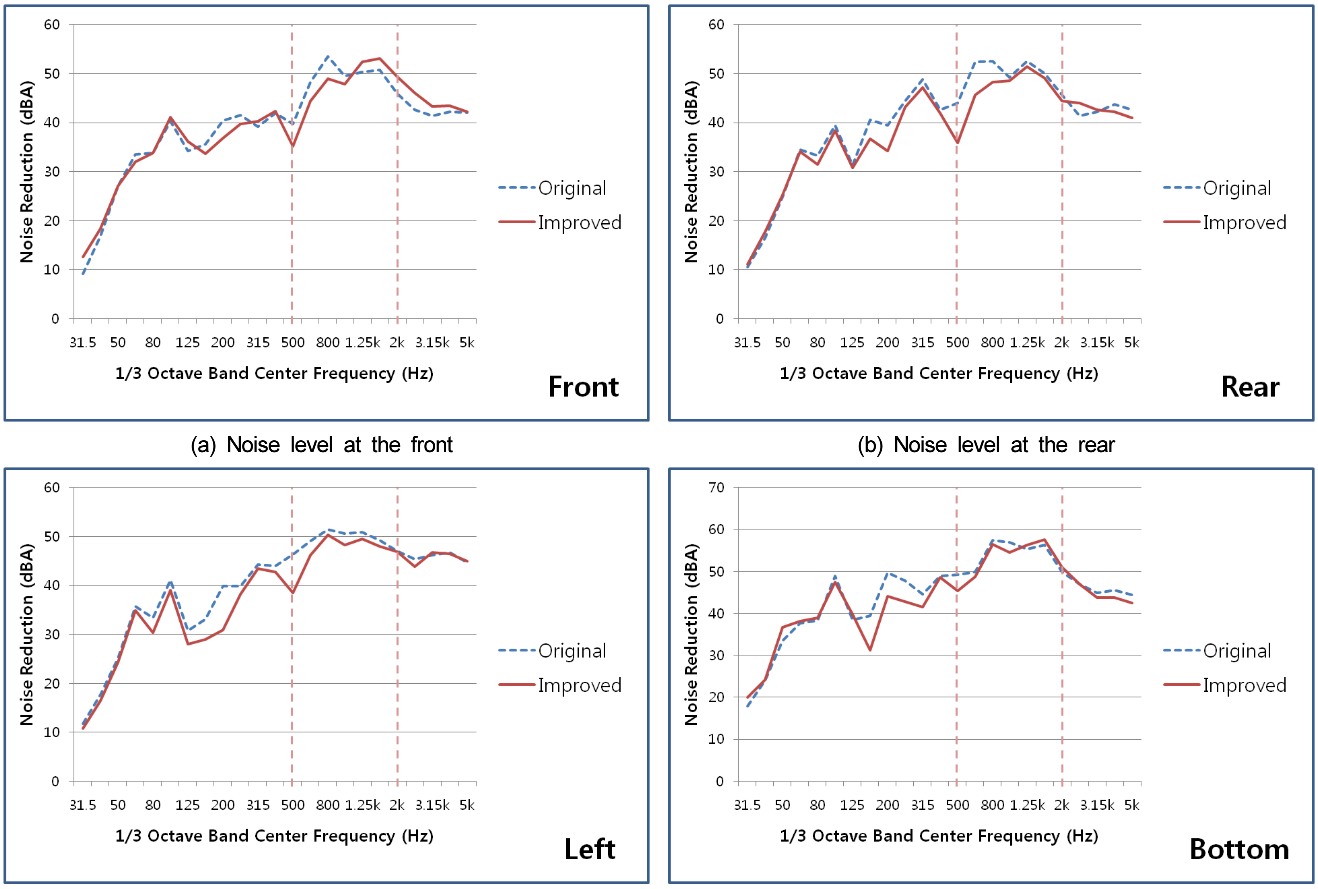
(a) Noise level at the front (b) Noise level at the rear (c) Noise level at the left side (d) Noise level at the bottom side

Figure 7. Noise level before applying EPDM.



(a) Noise level at the front (b) Noise level at the rear (c) Noise level at the left side (d) Noise level at the bottom side

Figure 8. Noise level after applying EPDM.



(a) Noise level at the front
(b) Noise level at the rear
(c) Noise level at the left side
(d) Noise level at the bottom side

Figure 9. Noise reduction in the cabin after applying EPDM.

Figure 9 shows noise reduction inside the cabin after applying EPDM. Noise reduction levels were compared for frequencies within the audible frequency range and the limitations of normal hearing between 500 Hz to 2 kHz. Clear and normal conversation was possible within this range. Resonance can rise with mechanical structural feature due to increase or decrease. Noise reduction was noticeable in the hearing range as given in Table 1.

Table 1 lists noise reduction in the normal hearing range at the four locations. The amount of noise reduction after applying EPDM is given. The results are expressed in dB. Overall, the average reduction was 1.85 dB. Figure 9 shows a decrease and an increase for each period. However, it tends to decrease in the normal hearing range. The average reduction of 1.85db is not substantial. We aim to further reduce the noise stress on the driver through modification of sound insulation by first determining the required thickness and then the position.

Table 1. Noise reduction in the normal hearing range

Position	Original (dB)	Improved (dB)	Noise Reduction (dB)
Front	48.3±4.1	47.3±5.6	1.0
Rear	49.4±3.2	46.2±4.7	3.2
Left	49.2±1.8	46.8±3.6	2.4
Bottom	53.6±3.4	52.8±4.2	0.8

Conclusion

The noise transmission pathways of a combine cabin were identified and a noise reduction in the range of 0-5 kHz was noticeable from acoustic tests. A noise reduction of 1.85 dB was achieved, thus improving hearing quality. The average noise reduction was 3.2 dB at the rear of the combine, where the grain tank and threshing units were located. Thus, reducing the cabin noise levels can reduce a worker's fatigue, improve working environment, and contribute to future low-noise and high-quality cabin environment.

Conflict of Interest

The authors have no conflicting financial or other interests.

Acknowledgement

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