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A Study on Sound Noise Control Method of Sound Fire Extinguisher with Wind

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Abstract:

Sound Fire Extinguisher can be an alternative to a changed fire fighting environment. However, Sound Fire Extinguisher, first released by US Defense Advanced Research Projects Agency (DARPA) and George Mason University students, can cause very large low frequency noise, which can be damaging to those who suppress conflagration. In this study, we tried to eliminate the low frequency noise of Sound Fire Extinguisher by applying directional characteristics improvement and Adaptive Noise Cancellation (ANC) technique. A proposed method for sound noise control has been verified through experiments to see how effectively it eliminates the low frequency noise of the Sound Fire Extinguisher. As a experiment result, considering the directivity characteristics of the loudspeaker, the side noise was reduced by 32 ~ 40dB by applying the the special acoustic lens and ANC method. These results show that the sound noise control effect of the special acoustic lens and ANC method applied to Sound Fire Extinguisher is very high. We hope that this study will contribute to the development of safe Sound Fire Extinguisher.

Keyword: *Fire Fighting Environment, Sound Fire Extinguisher, Sound Noise Control, Special Acoustic Lens, Adaptive Noise Cancellation (ANC)*

1. INTRODUCTION

The rapid development of civilization has changed the fire fighting environment. Especially, skyscraperization and large-sized buildings cause huge damage when conflagration occurs. The existing extinguish method, which relies solely on the chemical reaction of fire extinguish agents, has limitations in overcoming the changed fire fighting environment. To overcome the changed fire fighting environment, a new fire fighting technology is needed [1-3].

Sound Fire Extinguisher, which uses sound characteristics rather than fire extinguish agents, can be a new alternative in a changed fire fighting environment. Sound Fire Extinguisher was first released in 2012 and 2015 by US Defense Advanced Research Projects Agency (DARPA) and George Mason University students. The Sound Fire Extinguisher, released for the first time, suggested the possibility of using a sound component to control the flame. However, Sound Fire Extinguisher, released by DARPA and George Mason University students, caused a very large low frequency noise in order to provide sufficient sound energy due to the drawback that sound energy spreads in all directions [4-6].

A person using a fire extinguisher to suppress conflagration should be careful not to get burned, and the person who suppresses the conflagration must be protected. However, it is obvious that the existing Sound Fire Extinguisher, first released by DARPA and George Mason University students, will cause very large low frequency noise, which will damage the person who suppresses the conflagration. Therefore, to suppress conflagration with Sound Fire Extinguisher, it is more important to eliminate low frequency noise [7-9].

In this study, we aimed to control the side rear noise of Sound Fire Extinguisher by improving directional characteristics of sound. In addition, Adaptive Noise Cancellation (ANC) technique was applied to eliminate low frequency noise spreading laterally. Chapter 2 describes the basic theory of sound noise control, and Chapter 3 describes the ANC method. In Chapter 4, a proposed method for sound noise control of Sound Fire Extinguisher was considered. And we examined the effects through the experiments and the results of Chapter 5.

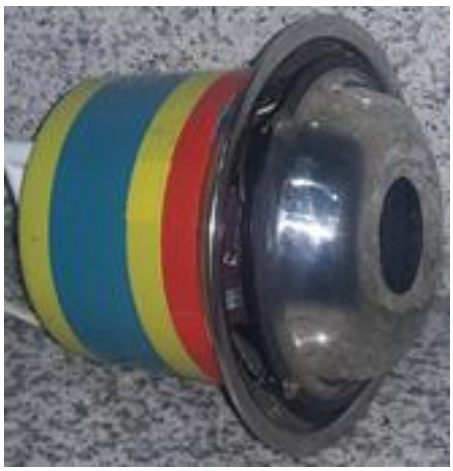

Fig 1. Sound Fire Extinguisher from SSERI [6]

2. A BASIC THEORY OF SOUND NOISE CONTROL

Multiple sounds are propagated without changing the transfer characteristic for each signal. However, at the point where the signals converge, interference occurs instantaneously between the signals. At this time, when signals having the same sound but reverse phase are synthesized, destructive interference appears in which the signal disappears. Equation (1) represents

a composite wave with destructive interference between signals [10].

$$Y(t) = A_1 \sin(\omega t - k) + A_2 \sin(\omega t + \pi - k)$$
$$= (A_1 - A_2) \sin(\omega t - k) \quad (1)$$

According to the 'Low frequency noise management guidelines' (2018) issued by the Ministry of Environment of the Republic of Korea, the noise below 100 Hz is defined as low frequency noise. The characteristic of low frequency noise is that it is mainly transferred to the body by vibration and pressure. Low frequency noise is propagated to far away because it has a large wavelength energy and is transferred through walls or windows. In our life, floor noises and construction noise are low frequency noise. Research on low frequency noise is somewhat lacking, but the severity of the disease is known through studies such as physical and mental damage, livestock stillbirth, or rupture of the internal organs [8][11-12].

We can not completely eliminate noise in our daily lives. However, it is possible to reduce the damage of noise by various methods. Passive noise control involves adjusting the noise source to reduce noise, to move away from noise, and to change the direction of noise. Examples of passive noise control include soundproof walls, ear muffs, and roadside trees, which are generally avoided from noise. Adaptive noise cancellation(ANC) is a very aggressive method to reduce noise by analyzing noise compared to passive noise control [12-14].

3. ADAPTIVE NOISE CANCELLATION (ANC)

ANC is a sound noise control technique introduced in the 1930s as a method of attenuating noise by playing the sound of reverse phase of noise together. In the air, the sound travels at 340M/s while the electric signal travels at 300,000Km/s, so that the noise can be attenuated by outputting the sound of the reverse phase that has already been analyzed for the time the noise is propagated. Figure 2 shows how noise can be attenuated by applying ANC [13-14].

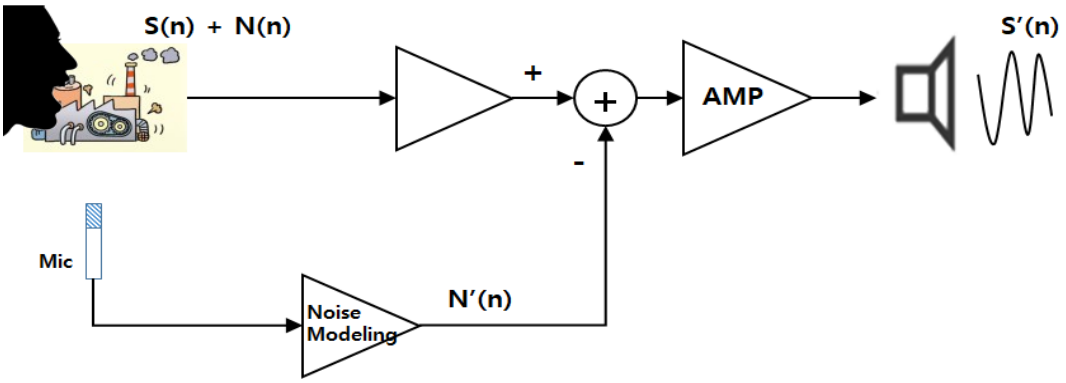

Fig 2. Noise control method using ANC[13]

For example, if the signal is S (n) and the noise is N (n), synthesize the generated sound 'S (n) + N (n)' and the reverse phase signals of noise modeling extracted N'(n), Noise is reduced and only S '(n) close to S (n) is output. In this case, the composite sound waves heard by the listener can be expressed as Equation (2).

$$Y(t) = S \sin(\omega_S t - k_S) + N \sin(\omega_N t - k_N) + N \sin(\omega_N t + \pi - k_N)$$
$$= S \sin(\omega_S t - k_S) + N \sin(\omega_N t - k_N) - N \sin(\omega_N t - k_N)$$
$$= S \sin(\omega_S t - k_S) \quad (2)$$

As shown in Equation (2), the noise disappears and only the voice signal of the speaker is transferred to the listener. However, it may be difficult to detect only noise, and a larger noise may occur when a non-reverse-phase sound is output.

4. A PROPOSED METHOD FOR SOUND NOISE CONTROL OF SOUND FIRE EXTINGUISHER

The Sori Sound Engineering Research Institute (SSERI) of Soongsil University applied the special acoustic lens to Sound Fire Extinguisher to focus sound energy on the flames. The special acoustic lens focuses sound energy on a point by changing the path of sound through reflection. Cone type

speakers are very low in directivity at low frequencies, transferring sound to the sides and back. However, applying the special acoustic lens suppresses the sound spreading to the side and rear. Figure 3 shows that the direction of the low-frequency sound spreading to the side and to the back changes the forward direction of the special acoustic lens [6][15].

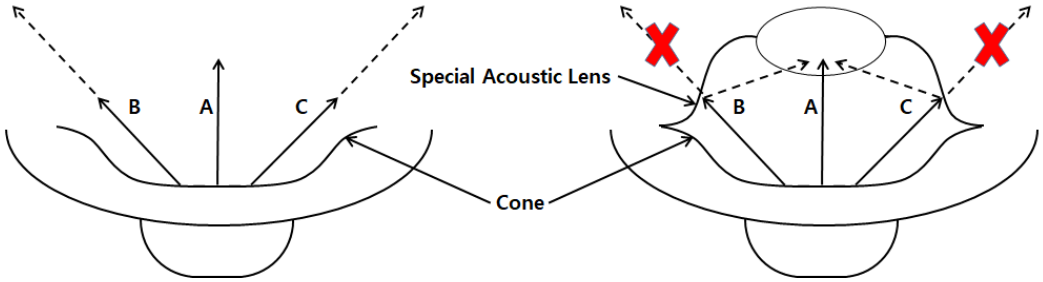

Fig 3. Directional change of noise

The ANC is advantageous for the control of low frequency noise and is effective when there is little change in noise characteristics. Sound Fire Extinguisher is very suitable for applying ANC technique because it generates low frequency noise below 100Hz and keeps the same noise component. In addition, it is difficult to predict the noise component in case of general noise, while the Sound Fire Extinguisher is the intentionally generated sound component, so it is only necessary to output the phase-adjusted sound without detecting the noise. Figure 4 shows the method of sound noise control of Sound Fire Extinguisher by applying ANC technique [13-14].

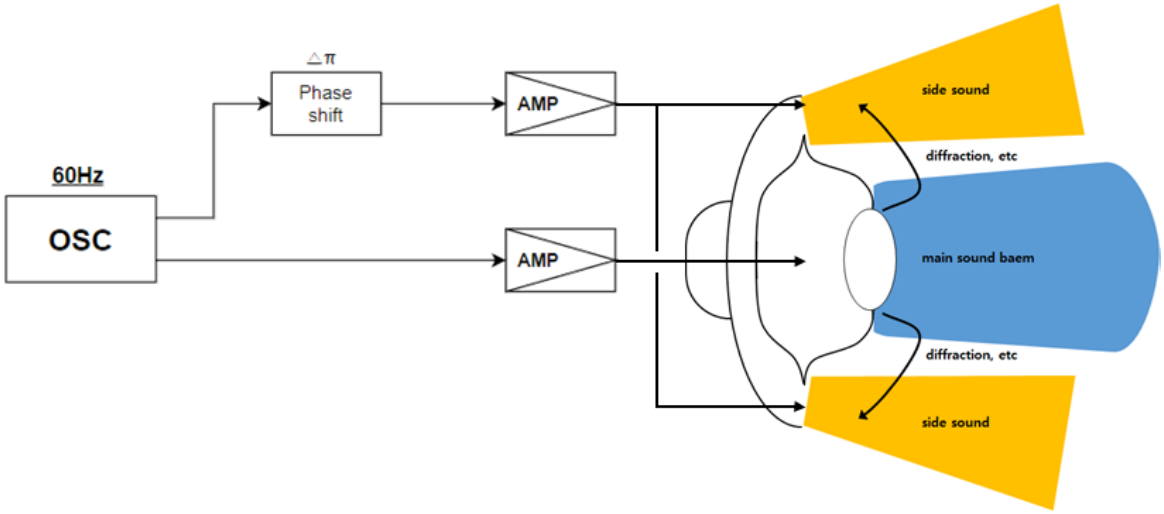

Fig 4. Sound Fire Extinguisher's sound noise control method

In Figure 4, a 60 Hz sound component is oscillated to suppress the flame, and the main sound beam amplified using the special acoustic lens is output. In addition, a side sound that phase shifts the same oscillation signal by π is output from the side of the Sound Fire Extinguisher. The amplified sound component, the main sound beam, is partially propagated to the side by diffraction, etc., and is synthesized with the side sound, which is a reverse phase signal, to produce destructive interference. Two sounds of different size and reverse phase generate a destructive composite wave. After the destructive is done, the signal amplitude of the composite wave is equal to the difference in magnitude between the two signals where the interference occurred [16-17].

5. EXPERIMENTS AND RESULTS

We tried to confirm how the noise direction change and ANC application applied to the Sound Fire Extinguisher reduce the low frequency noise propagated to the side of Sound Fire Extinguisher. In the experiment, we measured the effect of the proposed method for sound noise control on three types of loudspeakers. When the special acoustic lens was applied to the Sound Fire Extinguisher, the change of the directivity was confirmed by measuring the difference of sound size between the front and the side. In addition, we compared the loudness of the front side with the ANC technique. The sound component was applied to the 60Hz pure tone generated by the Sound Fire Extinguisher internal oscillation circuit and the output size remained the same. The size of the sound was measured using

Acoustilyzer AL1 from NTi Audio Co., and a C-WTD filter suitable for measuring low-frequency sound was applied. The cone speakers used in the experiments are low frequency speakers, and they have directional characteristics with a side sound of about 3dB less then front sound, when the 60Hz pure tone is output. The experimental method is shown in Figure 5.

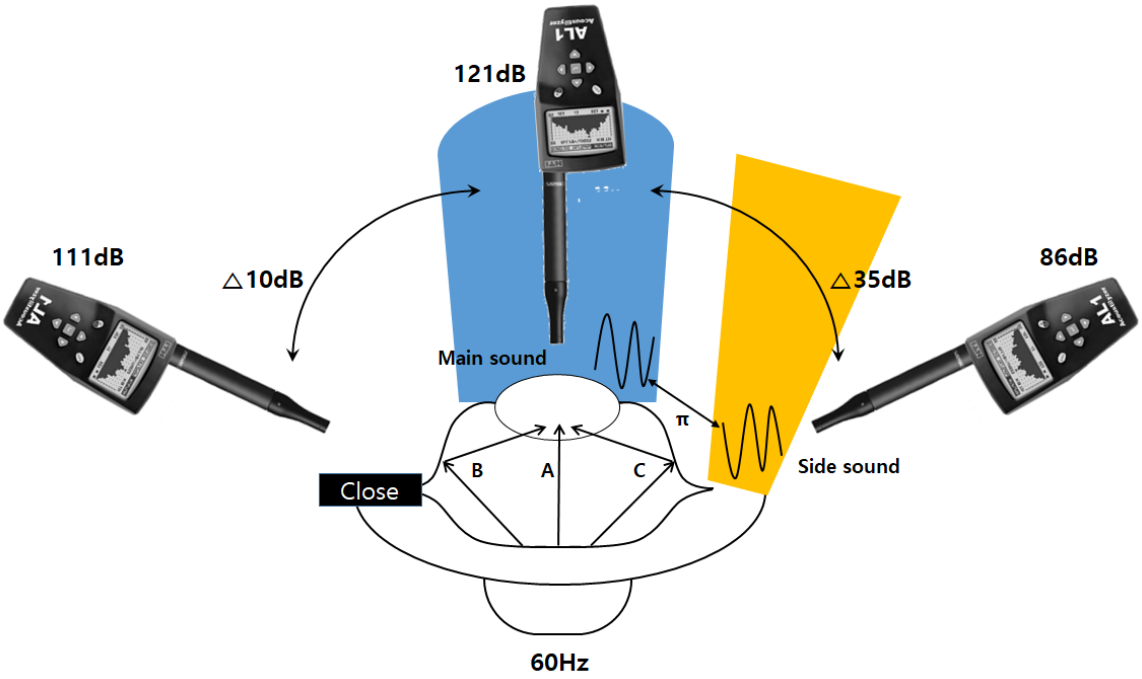

Fig 5. Sound Fire Extinguisher low frequency noise reduction measurements

As shown in Figure 5, the sound output from the front of the Sound Fire Extinguisher was amplified to 121dB, and the side without the ANC function was reduced by 10dB from the front. On the other hand, the side of the reverse phase sound output using the ANC technique was measured to be 86dB reduced by 35dB compared to the front side. As a result of this experiment, the low frequency sound amplified by 121dB is propagated to the side with the noise of 118dB size, but it is improved about 7dB by changing the direction of noise due to the special acoustic lens and improved by about 25dB by applying ANC technique. Table 1 shows how effectively the noise is controlled by applying the special acoustic lens and ANC technique to three different speakers.

Table 1. Sound noise control effect by speaker type by the Special Acoustic Lens & ANC Method

Speaker Type	Drive system	Resonance power	Side leakage power	Sound noise control effect
A (5.5 inch)	Quasi-sine wave	121 dB	86 dB	32 dB
B (6 inch)	Quasi-sine wave	122 dB	85 dB	34 dB
C (6.5 inch)	Sine wave	123 dB	80 dB	40 dB

6. CONCLUSION

In order to overcome the changed fire fighting environment, it is necessary to develop a new fire fighting technology. Sound Fire Extinguisher, which was first released by DARPA and George Mason University students, can be an alternative. However, existing Sound Fire Extinguishers generate very loud noise to provide adequate levels of sound energy to the flames. As a result, very large low frequency noise can be very damaging to conflagration suppressors. Sound Fire Extinguisher can provide a new principle in fire fighting technology and can increase fire fighting power along with existing extinguish method. However, if the Sound Fire Extinguisher causes damage to the human body, the role and meaning of the Sound Fire Extinguisher will be reduced.

In this study, we tried to find out how the acoustic lens and ANC technique applied to Sound Fire Extinguisher effectively control low frequency noise. As a result of the experiment in Chapter 5, it was confirmed that the special acoustic lens reduces the noise by 7dB through the change of the direction of the noise and reduces the noise by 25dB through the ANC

application. This results in a 32 dB reduction in noise through the Sound Fire Extinguisher's sound noise control, which means that the original low frequency noise is reduced to about 1/1600. In addition, it was confirmed that the special acoustic lens and ANC technique were applied to different types of loudspeakers, resulting in a 32 ~ 40dB noise reduction and a very high sound noise control effect. We hope that this study will be the basis for providing the safety of those who use the Sound Fire Extinguisher to suppress conflagration in the future.

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