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A Study on the Effect of Wind Around on Sound Fire Extinguisher

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Abstract:

Modern buildings are becoming more taller, and the interior is becoming more complicated. A new strategy for conflagration has become necessary due to changes in the fire fighting environment. Sound Fire Extinguisher is designed to be used in various fire fighting environments by escaping existing extinguishable method. A Sound Fire Extinguisher needs to consider wind around as it takes advantage of the sound characteristics. In this paper, we investigated the effect of wind around on the Sound Fire Extinguisher through experiments. Experimental results show that even if the wind is supplied vertically on the sound propagation pathways, the effect on the arrival position of the transmitted sound or the sound level reached is insignificant. However, when the wind was supplied, the sound level became somewhat irregular. From these results, we can confirm that the sound component of the Sound Fire Extinguisher must be supplied considering the irregularity of the sound level caused by the wind around.

Keyword: Fire Fighting Environment, Conflagration, Sound Fire Extinguisher, Sound Propagation Pathways, Wind Around, Sound Component

1. INTRODUCTION

Due to the development of human civilization, buildings are becoming taller and their inside becomes more complicated. The change of fire fighting environment necessitated a new strategy for conflagration. However, existing fire protection systems are not enough to overcome all the complicated fire fighting environments. In the case of conventional fire protection systems, most of them are spraying water or extinguishing agent directly to the flame. Sound Fire Extinguisher, designed to be used in various fire fighting environments, has been actively researched at the Sori Sound Engineering Research Institute (SSERI) of Soong-sil University. The existing extinguishment facility operates by detecting the occurrence of actual conflagration. If it is sprayed before conflagration occurs, it can damage the information communication facilities as well as various facilities. However, Sound Fire Extinguisher has features that can be applied to conflagration in various ways such as using sound component to flame to prevent conflagration by using before fire detection [1-6].

Sound Fire Extinguisher was first released by US Defense Advanced Research Projects Agency (DARPA) and George Mason University students. DARPA suggests that low-frequency sound can extinguish fire by resonating flame molecules, and George Mason University students have shown that fire is extinguished with commercially available speakers. Both of these cases, however, were not sufficiently applicable to actual extinguishment. In SSERI, special acoustic lens is used to concentrate sound energy on flame, so that it can be used in actual fire fighting field. However, as the Sound Fire Extinguisher uses the characteristics of the sound, in order for the Sound Fire Extinguisher to be used appropriately in the fire fighting field, the influence from the environment when the sound is propagated needs to be considered. [7-11].

Fig 1. Sound Fire Extinguisher

In this paper, we investigate the effect of Sound Fire Extinguisher on wind around. In Chapter 2, we describe the propagation pathways of the sound component considering the wind. Chapter 3 presents the results of experiments and conclusions in Chapter 4.

2. PROPAGATION PATHWAYS OF SOUND COMPONENT CONSIDERING WIND

2.1 Change of arrival position of sound component

The relationship between sound propagation velocity (c) and sound pressure (P) is expressed as Equation (1).

$$P = (\rho c)v \ \ [\text{Pa}] \quad (1)$$

ρ : Density of medium (Kg/m^3)
v : Velocity of the medium particles (m/s)

Through this relationship, the sound velocity in the air at the voluntary temperature (θ) is expressed as Equation (2).

$$c = c^0 + 0.61\theta \ \text{[m/s]} \quad (2)$$

c^0 : Sound velocity in the air at 0℃, 331.5 m/s

θ : Voluntary temperature [℃]

When the voluntary temperature is assumed to be ordinary temperature 25℃, the propagation velocity of the sound is generally 340 m/s. On the other hand, if the wind blows, the propagation pathways may change due to the phenomenon that the medium in which the sound is propagated moves. This phenomenon occurs because the propagation direction of the wavelength of sound is constant, but the medium that transmits the wavelength travels. Figure 2 shows the expected sound propagation pathways when vertical winds blow on the original sound propagation pathways [12].

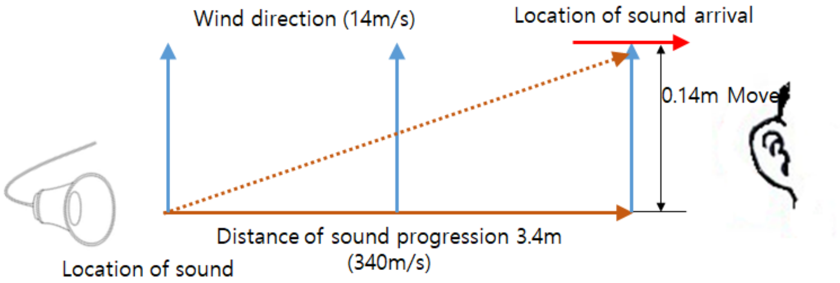

Fig 2. Predictions for sound propagation pathways, when the wind is blowing

Figure 2 shows that when a strong wind blows at 14m/s and a sound is transmitted at 3.4m, it reaches a different position by 0.14m in the wind direction than the original aimed position. However, compared with the distance to be propagated, the change of the position reached is very small. This is because the propagation velocity of the sound wave is more than 24 times faster than that of the medium travel velocity of 14 m/s due to the strong wind.

2.2 Refraction of sound by wind

When a wavelength propagates from one medium to another medium, the propagation direction is bent, which is a phenomenon caused by the difference in propagation speed of the wavelength in each medium. This is called refraction. It is Snell's law that shows the relation between the density of the medium and the propagation velocity and refraction of the wavelength for this refraction phenomenon. Sound is subject to wind speed because it must propagate in medium. If the propagation directions of sound and wind are the same, they propagate rapidly. If sound and wind propagation directions are opposite, they propagate slowly. Due to this wind speed, the refraction occurs at the boundary between the place where the sound moves fast and the place where the sound moves slowly. Figure 3 shows the predicted path where sound is refracted and propagated by wind speed. In this case, the relationship between the incident angle and the reflection angle at which sound is refracted can be expressed as Equation (3) [3,12].

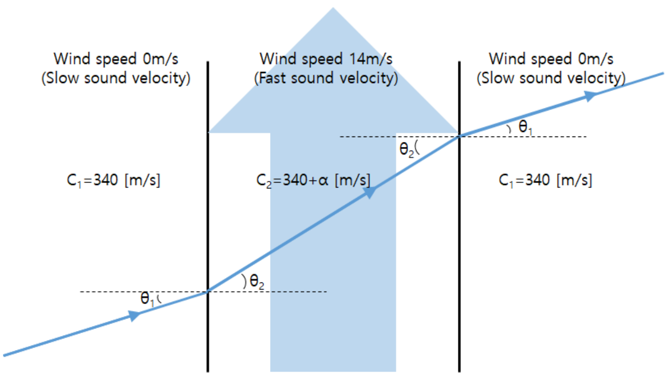

Fig 3. Refraction of sound by wind

$$\frac{c_1}{c_2} = \frac{\sin\theta_1}{\sin\theta_2} \quad (3)$$

c_1, c_2 : Propagation velocity of wavelength in medium 1, 2 [m/s]
θ_1, θ_1 : Incidence angle and refraction angle of wavelength in medium 1, 2

In Figure 3, the sound is propagated at a speed of 340m / s. When propagating the windy place, the propagation velocity of the sound is accelerated by the movement of the medium and the sound is refracted. On the other hand, if the place changes from a windy place to a windless place, it is refracted again and it becomes the same as the first direction.

3. EXPERIMENTS AND RESULTS

The sound level was measured at a distance of 90 cm from the sound component emitted by the Sound Fire Extinguisher, considering the use of the Sound Fire Extinguisher for conflagration suppression. We also artificially formed a wind at the midpoint of the sound transfer place to see how it is affected by the wind around. The method of forming the wind generated a wind at a distance of 65 cm using a blade, which is common in our surroundings. The wind speeds generated by the select buttons of the blade were 1m/s, 1.7m/s and 2.5m/s when measured on the propagation pathways of the Sound Fire Extinguisher sound component. The sound level was measured with AL1 Acoustilyzer from NTI AUDIO. When measuring the sound level, the measurement mode was set to "FLAT" to exclude the human hearing characteristic and compare the energy transfer characteristics with distance. The measured value was set to "SPL". The change in sound level was recorded using the Galaxy Note 4 on the smartphone and the AL1 Acoustilyzer was measured every 10 seconds on the recorded video. The experimental environment is shown in Figure 4.

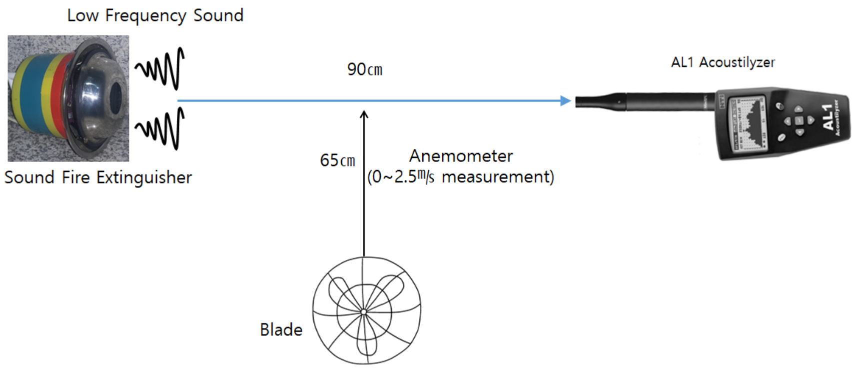

Fig 4. Experiment Environment

As shown in figure 4, the sound level changes were measured at wind speeds of 0m/s, 1m/s, 1.7m/s and 2.5m/s. The result of measuring the sound level change from the Sound Fire Extinguisher according to the wind speed is shown in figure 5.

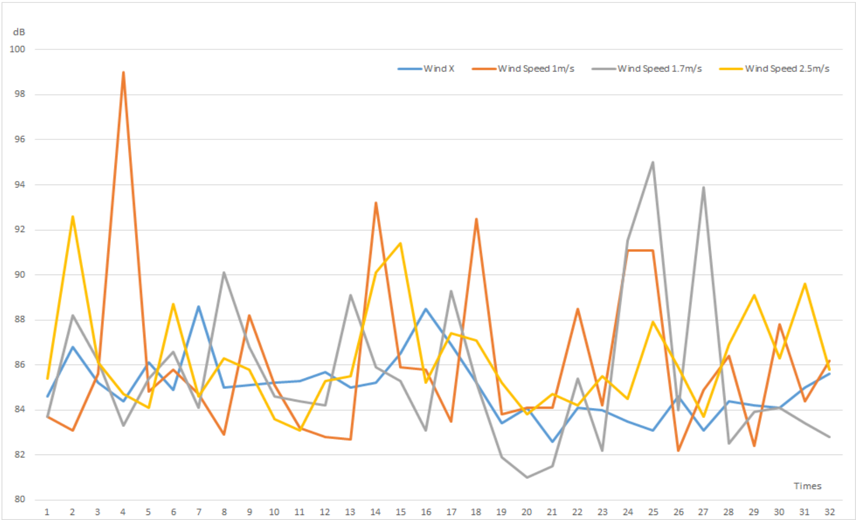

Fig 5. Variation of transmitted sound level due to wind effect

Figure 5 shows that the sound level delivered from the Sound Fire Extinguisher when there is no wind around is relatively uniform and less changeable, while the wind blows relatively higher sound level changes than without wind. Figure 6 shows the frequency of each sound lever for figure 5.

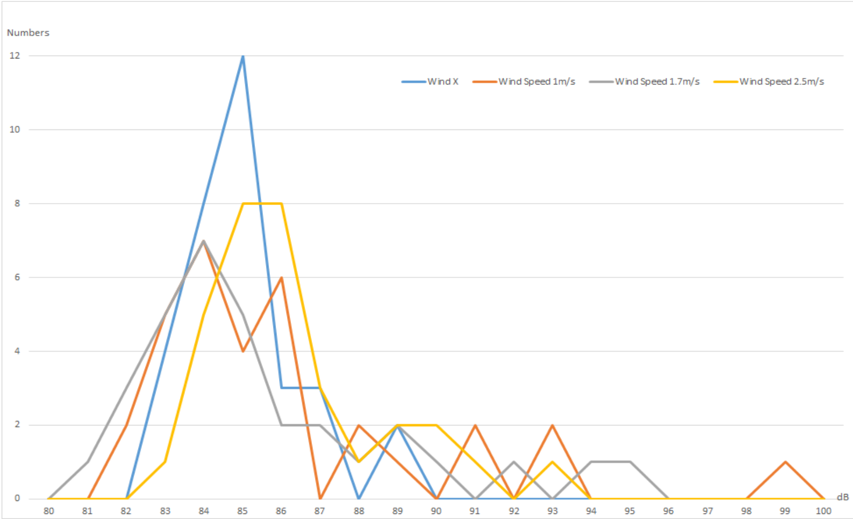

Fig 6. Frequency of transmitted sound level by wind effect

As shown in figure 5 and figure 6, when the wind is not blowing, the delivered sound level is mostly distributed in 83 ~ 89dB to provide a uniform sound. On the other hand, when the wind is blowing, the sound level is widely distributed compared to the case where the wind is not blowing. However, even though the wind was supplied vertically on the sound propagation pathways, the sound was reaching the measuring position smoothly. In addition, the wind speed was varied and supplied, but it was confirmed that it did not significantly affect the sound level reached. When the wind is supplied, the sound level is sometimes lower than when there is no wind. However, in some cases it was also found that the sound level was greater than in the absence of wind.

4. CONCLUSION

Fire fighting environment needs a fire protection system that can be used in various fire fighting environments. Sound Fire Extinguisher is a fire extinguisher that uses a low frequency sound component to break through the existing extinguishing facility. Sound Fire Extinguisher is expected to be used effectively in conflagration in several ways, such as preventing conflagration by using it before fire detection. However, the Sound Fire Extinguisher can be affected by the surrounding environment as much as it uses the characteristics of sound.

In this paper, we tried to confirm the influence of the windy environment on Sound Fire Extinguisher through experiments. As a result of the experiment in Chapter 3, when the sound component of the Sound Fire Extinguisher is transmitted at a distance of 90cm, there is no significant effect on the sound level delivered even when the wind is blowing. However, when the wind is not blowing, the delivered sound level is concentrated at 83 to 89dB, whereas when the wind is blown vertically to the propagation pathways, the transmitted sound level is spread widely at 81 to 99dB and is relatively uniform.

These results show that sound propagation pathways of the Sound Fire Extinguisher do not significantly affect the sound arrival position, nor do they significantly affect the delivered sound level, even if the wind is supplied vertically. This is because the velocity of air is relatively small compared to the propagation velocity of sound. However, the wind environment is somewhat irregular in the state and boundary of the medium, so that the delivered sound level becomes irregular. Eventually, even if the wind does not significantly affect the sound propagation pathways or sound level, we can confirm that the sound component of the Sound Fire Extinguisher must be adjusted to eradiate in consideration of the size of the irregularity, as the delivered sound level is irregular.

As the Sound Fire Extinguisher utilizes the characteristics of sound, it is expected that various environmental factors besides the influence of wind around will be studied and applied to conflagration field in more various ways.

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