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A Study on Cooling Effect of Sound Components

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Abstract:

Although fire is a necessity for mankind, it is also a subject of fear for humans under the name conflagration. As the building is becoming taller and larger, the precautionary measure as well as the preparation of aggressive conflagration is needed. Sound fire extinguisher is an extinguishment facility suitable for a complicated fire fighting environment. Also, it is expected that it will provide a function to prevent conflagration by the cooling effect of sound component of sound fire extinguisher. In this study, we tried to measure the cooling effect of the sound component of the sound fire extinguisher through the cooling measurement experiment. As a result of the experiment of charpter3, it was confirmed that the cooling time is reduced by 27% on average when the sound is provided, compared with the case where no sound is provided. In addition, it was confirmed that the time required for cooling is significantly reduced when sound is provided in most temperature range of 100 ° C or less. The sound effect of sound fire extinguisher 's sound component is expected to provide a function to prevent conflagration by operating before conflagration in a fire fighting environment where accessibility is difficult or conflagration signs are difficult to identify.

Keyword: Conflagration, Sound Fire Extinguisher, Sound Component, Cooling Effect, Conflagration Prevention

1. INTRODUCTION

The use of fire comes with the history of human civilization. Human beings are known to use fire from old stone age. Humans use fire in all areas of society, economy, culture, military, energy, as well as heating, cooking, and mining. As the development of civilization accelerated after the Industrial Revolution, people began to use fire for more large and more uses. In this way, fire is a necessary thing for mankind, but fire is a subject of great fear to man in the name of conflagration. Therefore, suppression or prevention of conflagration in humans is just as important as using fire. Until now, the method of suppression of conflagration has been to spray a large amount of water directly to the conflagration site, lowering the temperature to below the ignition point and flash point, and suppressing the combustion reaction of combustible materials to oxygen. Other methods include spraying a fire extinguishing agent in a fire extinguisher to shut off the supply of oxygen to suppress combustion. In addition, until now conflagration prevention methods have simply been to avoid fire from combustible materials or suppression with little effort at the beginning of conflagration [1-3].

However, as human civilization develops rapidly and societies become more complex, countermeasures against conflagration must also change. Newly built buildings are becoming higher and larger. Due to this trend, several elevators are installed in the building and the advanced information communication network is accommodated. These buildings are very difficult to spray water or fire extinguishing agent to the high level when conflagration occurs. And, it is very difficult to detect signs of conflagration in ducting facilities where elevators, wires, and communication lines are housed, and is also very vulnerable to the supply of water or fire extinguishing agents. In addition, information communication facilities and information communication networks installed in the buildings can cause enormous property damage when spraying water or fire extinguishing agents. For these reasons, the fire fighting environment has become very complex and more aggressive conflagration measures and preventive measures have become necessary.

Sori Sound Engineering Research Institute (SSERI) of Soongsil University is actively studying Sound Fire Extinguisher for various fire fighting environments. Sound Fire Extinguisher uses sound that is not water or fire extinguishing agent to fire extinguishment, so even if it spraying directly to the telecommunication equipments as well as electricity and communication line, there is no fear of damage. In particular, Sound Fire Extinguisher is expected to be able to prevent conflagration by supplying sound before conflagration because sound cooling effect is applied. The Sound Fire Extinguisher being studied is shown in Figure 1 [4-9].

Fig 1. Sound Fire Extinguisher

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In this paper, we tried to confirm whether the sound component of Sound Fire Extinguisher is effective for conflagration prevention and suppression of reignition after conflagration suppression through sound supplied cooling experiment. In Chapter 2, we discussed the motion characteristics of the medium and the transmission of heat during sound generation. Chapter 3 presents experiments and results, and Chapter 4 presents conclusions.

2. MOVEMENT OF MEDIUM AND THE TRANSMISSION OF HEAT IN SOUND GENERATION

2.1 Principles and progress of sound generation

If the sound is applied in a narrow sense, it can be said to be a longitudinal wave propagated in the air and heard by a person. A longitudinal wave is a wave whose direction of progress is parallel to the direction of vibration of the medium particles. Sounds are caused by vibrations, where particles of medium are gathered in the same space, and regions with high pressure and low pressure are gathered. And the wave propagates through the process of periodically changing regions where high pressure and low pressure exist in the space. The speed of sound propagated through this motion can be obtained by multiplying the frequency (f) by the wavelength (λ). The principles and progress of sound generation are shown in Figure 2 [10].

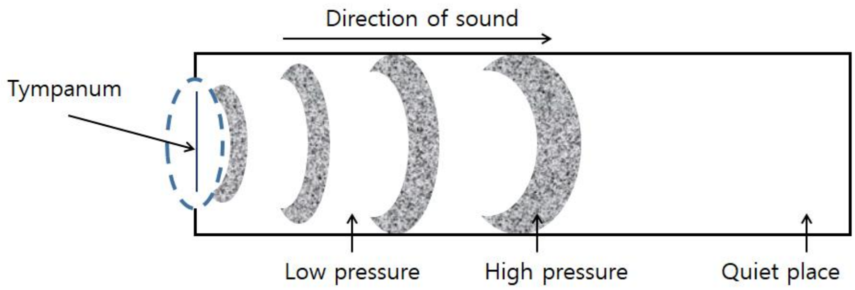

Fig 2. Principles and progress of sound generation [10]

In other words, when the sound is supplied, the mediumparticles in a certain space periodically move according to the frequency (f) of the sound and change the distribution of the particles.

2.2 Heat transfer

Heat transfer refers to the phenomenon of moving to a low place where heat energy is high, and generally refers to the heat transfer process by conduction, convection, and radiant between materials. Heat transfer is better when the temperature difference is large. The quantity of heat (Q) delivered by the heat transfer is expressed as Equation (1).

$$Q = a(t^0 - t) \tag{1}$$

a : Heat transfer coefficient (㎉/㎡·h·deg)
t^0: Temperature of one material
t : Temperature of the other material

Heat transfer between any material and air is caused by heat conduction between the material and air, and the heat transferred to the air is dissipated by conduction and convection between the air. In addition, when the motion of molecules is active, diffusion of air molecules containing heat energy is smoothly performed [10-11]. In the experiment of this paper, when supplying the sound to the coin heated by the candlelight, the uniformity of the air density is periodically changed through the propagation of sound, thereby facilitating heat transfer and diffusion. This principle can be said to cool the heat more quickly [11-12].

3. EXPERIMENTS AND RESULTS

Experiments were carried out to measure the change of metal coin cooled at 100 ℃ for more than 10 minutes. The cooling measurement experiment shows how quickly the sound is cooled compared to the natural cooling rate. Through these experiments, we tried to confirm the cooling effect of the sound component of Sound Fire Extinguisher. In the experiment, a low-frequency speaker (Britz AMP BR-5100T) was used so that a low-frequency sound component of 70 Hz was smoothly transmitted to the metal coin and its surroundings. In order to comparatively analyze the cooling phenomenon in the same environmental condition as possible, the change of the environment was minimized every time the experiment was performed. In addition, we measured the temperature change of both the case where the sound is not supplied and the case where the sound is supplied every time the experiment is performed. The 70Hz pure tone sound source produced by the Audition CC was played using Music APP of the tablet (ZTE Trek2 K88). The metal coin and ambient temperature changes were measured using the thermal imaging camera (FLIROne) and the smartphone Galaxy Note 4. The measurement results were recorded as images. The point where the temperature was measured was selected as the point where metal coin and its surroundings have the highest temperature. The experimental environment is shown in Figure 3.

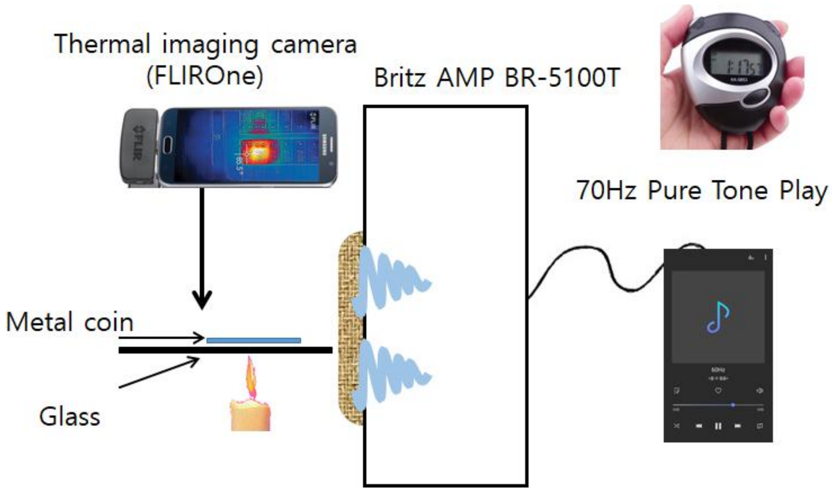

Fig 3. Experiment Environment

Heat transfer and diffusion can be greatly affected by the surrounding environment. In addition, thermal imaging camera may also cause errors depending on the location where the images are taken. All devices were fixed and measured to maintain the same experimental environment when supplying and not supplying sound in each experimental turns, and all of the experimental turns were completed within 30 minutes to keep the ambient temperature similar. However, the comparison with other experimental turns is insignificant because the experimental environment is somewhat different between the experimental turns and the location of the thermal imaging camera as well as the ambient temperature are slightly different. Experiment scene and thermal image recording screen is Figure 4.

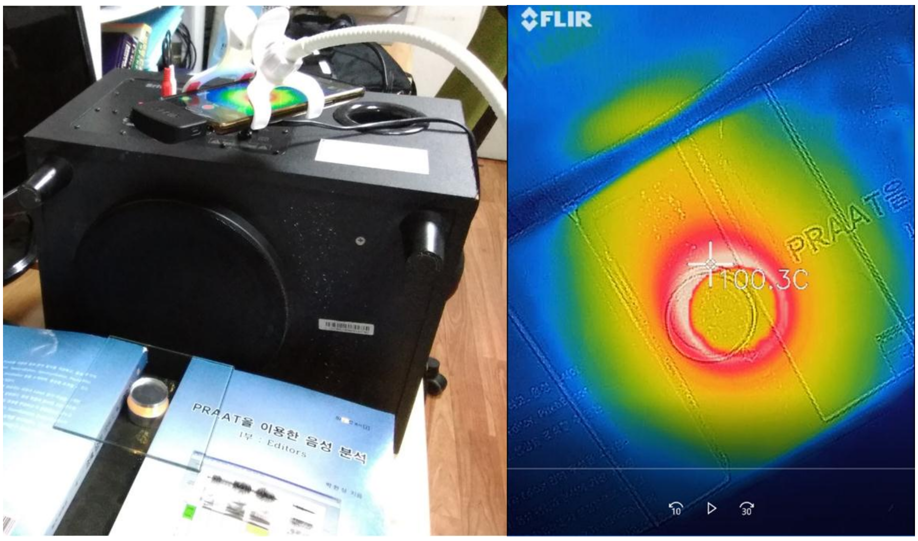

Fig 4. Experiment scene and thermal image recording screen

Figure 5 shows the result of measuring the temperature change when the sound was supplied and when the sound was not supplied. Figure 5 shows that when the sound was not supplied, the temperature dropped from 100℃ to 70℃ for 146 seconds while the sound was supplied for 96 seconds. In other words, it can be seen that the sound is cooled about 34% faster than the temperature is lowered by natural cooling.

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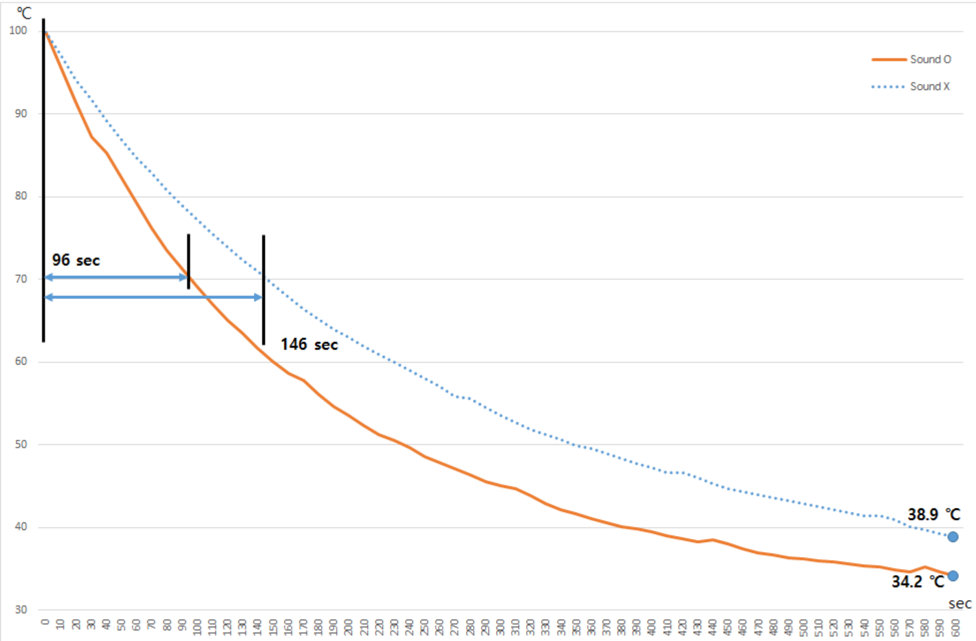

Fig 5. Temperature change measurement result

Figure 6 shows the thermal imaging camera taken 10 minutes after the start of measurement in Figure 5. Figure 6 shows that the temperature was 38.9℃ even after 10 minutes because the heat was concentrated around the coin when the sound was not supplied. On the other hand, when the sound was supplied, the temperature spread to the surrounding area and the temperature dropped to 34.2℃.

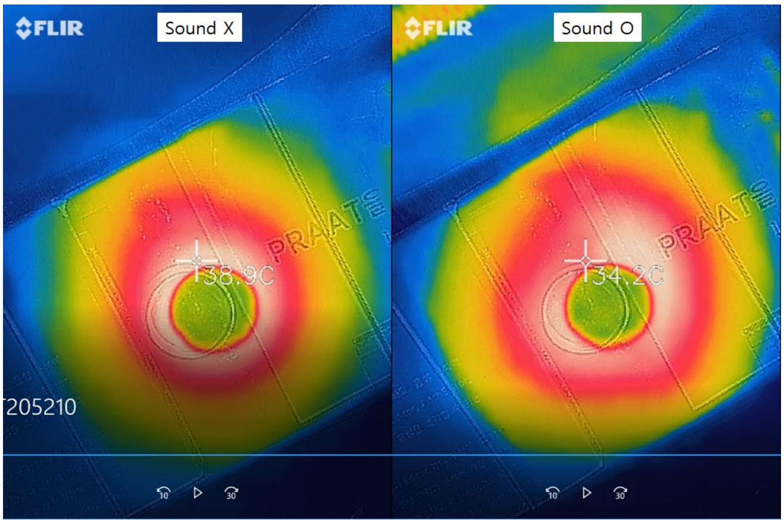

Fig 6. Thermal camera shooting screen (after 10 minutes)

Figure 4, Figure 5, and Figure 6 were performed eight times. Table 1 shows the results of measuring the temperature reduction time for all experimental turns. From the results in Table 1, it can be seen that in all experimental turns, the supply of sound is cooled more rapidly than when no sound is supplied. In particular, it can be seen that there is an effect of fast cooling over all the temperature ranges in which the temperature is reduced by 10℃. Throughout the experiment, it was confirmed that when the sound was supplied, the cooling rate was about 27% faster than when the sound was not supplied. When the 2nd and 7th, which had relatively little cooling effect, were excluded, the cooling rate was about 30% or more faster.

Table 1. Experimental results (measurement of the time required for temperature reduction)

Experimental turns		Time required for temperature reduction (sec)				
		100℃→90℃	90℃→80℃	80℃→70℃	70℃→60℃	60℃→50℃
1st	No sound supply	48	65	90	144	347
	Sound supply	29	40	56	99	236
	Cooling time reduction rate	40%	38%	38%	31%	32%
2nd	No sound supply	25	33	51	77	138
	Sound supply	22	29	43	61	117
	Cooling time reduction rate	12%	12%	16%	21%	15%
3rd	No sound supply	23	30	43	63	102
	Sound supply	17	22	31	44	75
	Cooling time reduction rate	26%	27%	28%	30%	26%
4th	No sound supply	37	47	59	80	121
	Sound supply	25	35	46	58	90
	Cooling time reduction rate	32%	26%	22%	28%	26%
5th	No sound supply	37	47	62	84	120
	Sound supply	23	34	39	55	85
	Cooling time reduction rate	38%	28%	37%	35%	29%
6th	No sound supply	40	50	63	90	141
	Sound supply	27	33	43	61	96
	Cooling time reduction rate	33%	34%	32%	32%	32%
7th	No sound supply	41	52	64	79	142
	Sound supply	38	42	53	68	106
	Cooling time reduction rate	7%	19%	17%	14%	25%
8th	No sound supply	45	57	68	92	145
	Sound supply	35	40	48	65	98
	Cooling time reduction rate	22%	30%	29%	29%	32%
Average cooling time reduction rate		26%	27%	27%	27%	27%

These experimental results show that low frequency sound components have an effect of reducing the temperature due to the influence of the combustion materials or the surroundings, and it is confirmed that it can help prevent conflagration by giving a cooling effect through the sound component of Sound Fire Extinguisher.

4. CONCLUSION

As human civilization develops rapidly and societies become more complicated, fire fighting environments are becoming more complex. Especially, since the building is becoming taller and larger, it is necessary to prepare more aggressive conflagration measures besides the existing extinguishment method. Sound Fire Extinguisher, which has been actively researched recently, is an extinguishment facility that is very suitable for complicated fire fighting environment. In particular, the cooling effect of the sound component of Sound Fire Extinguisher will provide a function to prevent conflagration of existing fire extinguishers by lowering the temperature before conflagration occurs.

In this study, we tried to confirm the cooling effect of the sound component of Sound Fire Extinguisher through the sound measurement cooling experiment. In the experiment using the 70Hz low frequency sound component, the time required for natural cooling when no sound was provided and the time required for cooling when the sound was provided were compared and analyzed. Experimental results show that when sound is provided, the cooling time is 27% faster than when no sound is provided. In particular, it has been confirmed that the cooling time is reduced to about 40% in several experiments. Experimental environment error may occur in the cooling experiment by non-contact thermal imaging camera. However, in all experimental turns, it can be seen that when the sound is supplied, the cooling time is significantly lower than when the sound is not supplied, which is a significant result of confirming the cooling effect due to the supply of low frequency sound components.

The sound effect of Sound Fire Extinguisher's sound component is expected to provide a function to prevent conflagration by operating before conflagration in a fire fighting environment where accessibility is difficult or confirmation of conflagration symptoms is difficult. Through a practical study of the cooling effect of the sound component, we hope that the Sound Fire Extinguisher can be used in the field of conflagration prevention.

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