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The Effect of Temperature in Underground Mining on the Dust Control using Ultrasonic Atomization
超音波霧化を用いた粉塵飛散抑制における地下採掘空間内温度の影響

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1. Introduction

Environmental control of the mine atmosphere is necessary for workers to work safely and comfortably. The factors to control are quality air (purifying air and removing contaminants), quantity air (regulating magnitude and direction of airflow) and temperature-humidity (controlling latent and sensible heat). To control the above factors, individual or joint processes are applied. The most important process is ventilation to maintain a suitable environment in the mine atmosphere. However, ventilation is not enough to completely control quality and temperature-humidity. Therefore, dust collectors and water spray systems are set to control dust dispersion (quality) and temperature-humidity. In particular, mineral dust control is an important factor which influences workers health in mining fields. The continuous exposure to fine dust, such as suspended particulate matter (<10 μm), increases the risk of disease. Especially in underground mining, it is necessary to control dust. In general, as humidity increases, the amount of suspended particulate matter decreases[1]. Thus, we focused on ultrasonic atomization of water to suppress dust[2]. The water particles generated by the ultrasonic atomization are very fine, and they can raise the humidity quickly without wetting the space. However, the water vapor capacity of the air (absolute humidity) is dependent on the temperature. Because saturated vapor pressure changes with the temperature. As temperature becomes lower, saturated vapor pressure becomes lower. The temperature of the shallow underground quarry we examined (Akita) is low (about 10°C) through a whole year. Therefore, it is difficult to control dust using the regulation of humidity in the underground quarry. We focused on the water particles generated by the ultrasonic atomization. These particles are able to stay for a long time at high value of relative air humidity and absorb dust and precipitate due to their heavier weight compared to air.

This study examined the effect of temperature in underground mining on the dust control using the water particles generated by ultrasonic atomization.

2. Experimental

An acrylic box (61 L) was used as the contained space to adjust relative air humidity. Relative air humidity was adjusted using dry air and water. The temperature in the box was maintained using an air conditioner. The ultrasonic atomization was performed with a submersible transducer (2.4 MHz; Honda electro. Co.) and 300 ml of ion-exchanged water (500 ml flask). The top of the beaker was covered with a plastic lid and the side of flask had an outlet port for the water particles generated by the ultrasound. The experimental apparatus is shown in **Fig.1**. The change of the relative air humidity by ultrasonic atomization in the box was recorded using a humidity sensor. The ultrasonic atomization was performed until the amount of atomization reached the calculated amount of water vapor. After the ultrasonic atomization, the weight of the flask was measured by an electronic scale to calculate the amount of the atomization.

Dust suppression experiments were performed using an ultrasonic atomization device, a dust sampler, a digital dust sampler (scattered light detection method), an acrylic box (61 L) as the experimental field, and green tuff particle (average diameter 6 μm) as dust. The relative air humidity in the box was regulated at 50%. The temperature in the box was adjusted to 10°C. Ultrasonic atomization was performed until the amount of atomization equaled that of water vapor, which raised relative air humidity incrementally 10-50%. Silica powder (1 g) was dropped from the top of the acrylic box to the floor of the box when these conditions were achieved. 10 min after the drop of silica, the measurement of the number of dust particles was started using a low volume air dust sampler for 10 min. The same experiment was conducted at 20°C and 30°C to compare to the result of the experiment at 10°C.

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3. Results and Discussion

Fig.2 shows the changes of the relative air humidity using the ultrasonic atomization at 10, 20 and 30°C respectively to reach the targeted relative air humidity of 80% from an initial level of 50%. Saturated vapor pressure changes with the temperature. Therefore, regardless of the same value of relative air humidity, water vapor amount (absolute humidity) in the acrylic box changed with the temperature. Thus, the additional amount of atomization was different at 10, 20 and 30°C even though the same target level of relative air humidity. After the addition of ultrasonic atomization into the box, the relative air humidity was raised at all conditions. As temperature became lower, the reached level of relative air humidity became lower. These results suggest that the water particles are difficult to transform into water vapor at low temperature. Therefore, water particles quantities in the box was able to be calculated by the additional amount of atomization and the changing amount of water vapor from the water particles.

Fig.3 shows results of dust control experiments without ultrasonic atomization at 10, 20 and 30°C. For all conditions, dust dispersion amount decreased with increase in relative air humidity. As temperature became lower, the dust dispersion amount became higher at same level of relative air humidity. Therefore, water vapor is effective for prevention of dust dispersion. However, the water vapor capacity of the air (absolute humidity) is dependent on the temperature. Next step in our experiment was dust control using ultrasonic atomization of water at 10, 20 and 30°C. **Fig.4** shows results of dust control experiments with ultrasonic atomization at 10°C. This results show that dust dispersion amounts decreased significantly compared to those without ultrasonic atomization at same relative air humidity. The water particles contributed to dust suppression. In particular the lower temperature condition which is difficult to transform from water particle to water vapor is effective to suppress the dust dispersion.

4. Conclusion

The effect of temperature on the dust control using the water particles generated by ultrasonic atomization was confirmed. Water vapor and water particles are effective to suppress the dust dispersion.

References

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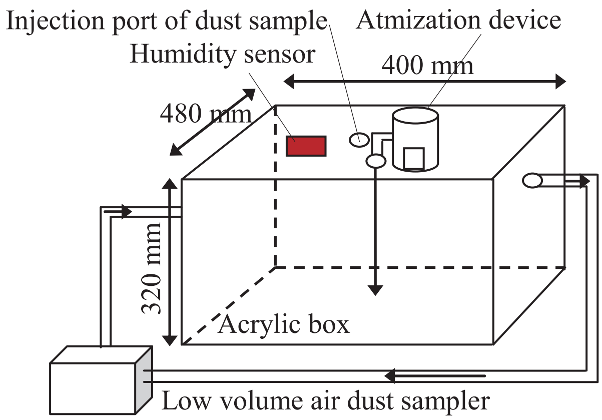

Fig.1 Schematic design of the experimental apparatus

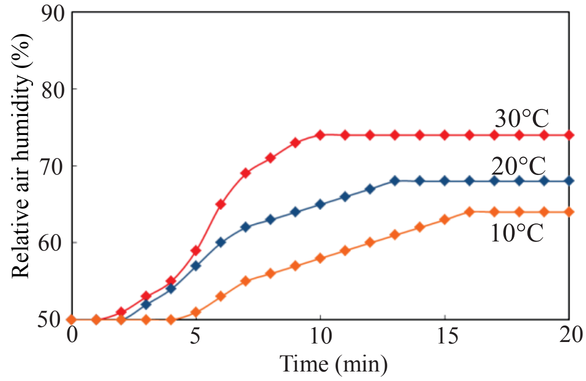

Fig.2 Changes of relative air humidity using ultrasonic atomization at 10, 20 and 30°C to reach the targeted relative air humidity of 80% from 50%.

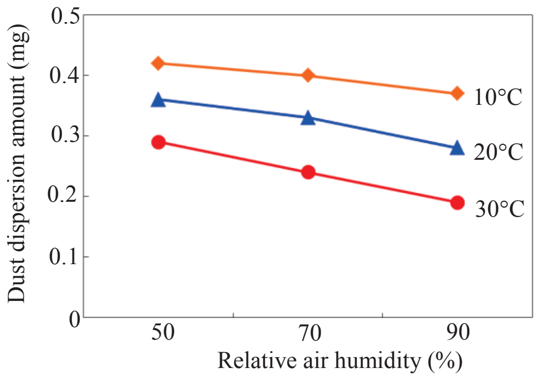

Fig.3 Dust dispersion amount at various relative air humidity.

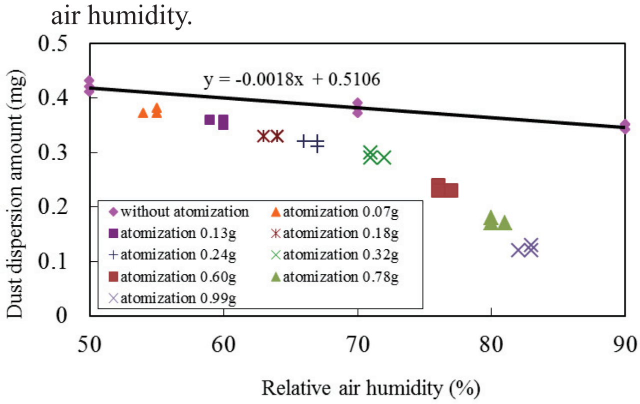

Fig.4 Relationships between the dust dispersion amount and the relative air humidity with and without water particles.