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Study on Mist Nozzle Spray Characteristics for Cooling Application

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Abstract: Evaporative cooling mist spray is a cost effective solution for many cooling applications. Selection of misting spray nozzle play a major role in order to provide the suitable spraying condition in regards to the application. One of the most widely use mist spray application is evaporative cooling of outdoor open area. This study was carried out to characterized the spray formation, size of droplet, velocity of the droplet and the angle of the spray formation from a commercial mist spray nozzle namely 1/8 SF-CE SM nozzle with 1 mm and 2 mm diameter hole. Water was supplied with different pressure of 1, 2 and 4 bar. High speed video camera and still digital camera using short burst of flash were used to produce the video and image for analysis. The results show that increase in water pressure affect the spray angle, increase droplet speed and decrease droplet size of the mist spray.

Keywords: spray, atomization, mist, water droplet, evaporative cooling

1. Introduction

Spray have many engineering applications, such as in combustion system, agriculture and industrial process, dust control, firefighting, spray drying, transport systems, nuclear reactor core cooling and many more. One of the more widely spread technique that utilized the usage of nozzle to formed spray is evaporative cooling, because it is an efficient technique for producing a comfortable environment.

Warming of urban area has increase because of the heat island crisis. One of the methods to mitigate this effect is by using spray water droplets. This method could decrease the temperature rising in urban area while using small amount of water and energy. For an example, if the water mist were sprayed in semi-outdoor area such as under a canopy, it could improve the environment on hot day conditions.

Through an experiment [1], they have verified the effectiveness of this method and confirmed a temperature reduction under a canopy about 3°C. Due to its simplicity, ease of operation and maintenance, and ease operation and maintenance, spray cooling is becoming more popular due to its simplicity, low capital price, and ease of operation and maintenance [2]. Spray nozzles are used to help distribute water into the inlet air flow in order to provide a large contact surface area between air–water and to enhance mixing by producing very fine droplets. This offers higher evaporation rate and greater air cooling [3].

This spray concept is to produce small droplet of water or mist to the surrounding, by applying pressure to the water and to burst it out through the nozzle. There are several types of nozzle can be used to produce the water mist spray including hollow cone, flat fan cone, full cone, spiral and others. The vast selections of nozzle and each with its

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own characteristics can make it difficult to select the select the best nozzle for the intended application. Thus, gaining information of the spray characteristics of nozzle is very important and help to maximize the effectiveness of a system [5,6].

In this study, water mist spray evaluation test rig had been developed for investigation of the nozzle condition and supplied water pressure effect to water mist spray characteristic. Video and still images of the spray will then be recorded and analyzed to obtain the spray angle, spray droplet velocity and the spray droplet size.

2. Experiment Setup

This experiment is conducted by using direct filming method for high speed camera (max video fps: 3000 fps) and short flash burst in dark room for DSLR (high resolution still image). In order to qualitatively and quantitatively analyze the spray characteristics, the proper post-processing of images is required. The entire images had been analyzing by using custom software.

The experiment and analysis procedure is somewhat similar to previous study [6]. The water was supplied at pressure of 1, 2 and 4 bar, air humidity of 76% and at room temperature. The test rig representation used for this experiment is shown in Fig. 1, and Fig. 2 shows the two types of nozzle that was used in this study.

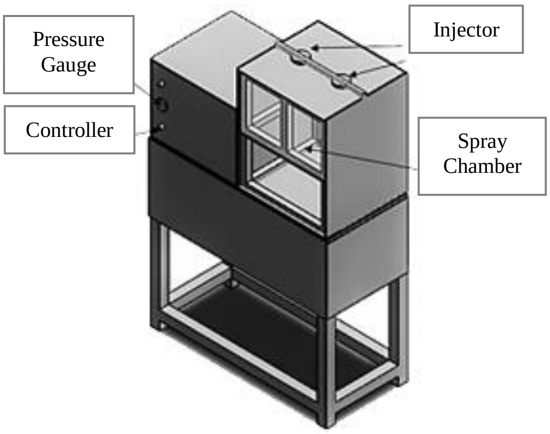


Fig. 1 - Test rig setup. Spray image then taken using DSLR and high-speed camera.

Fig. 2 - The two type of injector used (a) 1/8 SF-CE SM 1(1 mm hole diameter) and (b) 1/8 SF-CE SM 2(2 mm hole diameter)

3. Results and Discussion

3.1 Spray angle

Spray angle mainly determine the coverage area spray. It is defined by measuring the angle of the most outer section of the left and right boundary of the spray. The images of the spray formation were captured at water pressure of 1, 2 and 4 bar, air humidity of 76% and temperature of 27ºC by using High Speed Camera. Table 1 below shows the images of the spray formation for respected water pressure.

Table 1 and Table 2 shows the images acquired from the high speed camera. Spray angle is then measured and the averaged value for 3 reading is calculated. Fig. 3 show the result of spray angle with different water pressure and comparison is made between each nozzle spray angle. It can be seen that with the increase of water pressure from 1 bar to 2 bar, the spray angle increase for both nozzles. Interestingly, when the pressure was increased to 4 bar, the spray angle decrease slightly. This indicate that the probability of maximum spray angle for this nozzle is between 2 bar and 4 bar.

When compared between nozzle, spray angle for nozzle CM 1 which has the smaller hole diameter (1mm), produce smaller spray angle than nozzle CM 2 (2mm). The spray angle difference is higher when water pressure increased. This is believed due to the nozzle geometry and design.

Table 1 - Angle of spray formation1/8 SF-CE SM 1.

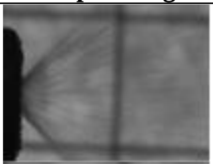
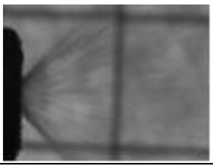
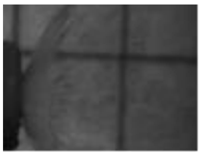
Pressure	Sample Image	Spray Angle θ
1 bar		108°
2 bar		112°
4 bar		107°

Table 2 - Angle of spray formation1/8 SF-CE SM 2.

Pressure	Sample Image	Spray Angle θ
1 bar		113°
2 bar		137°
4 bar		132°

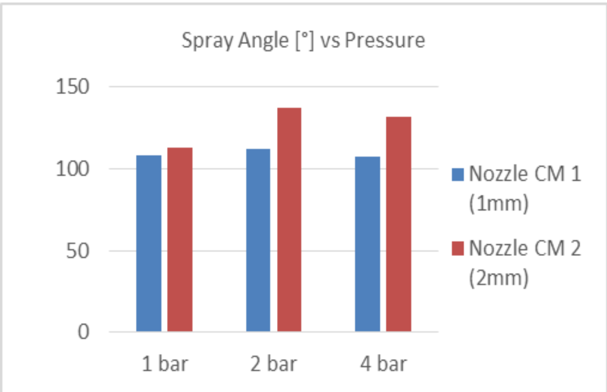


Fig. 3 - Changes in spray angle vs. water line pressure.

3.2 Droplet velocity

Using the images from high speed camera and conducting frame to frame analysis, displacement of individual droplet can be measured. The result then divided by the time interval between frame to obtain droplet velocity. Results shown in Fig. 4 shows the average droplet velocity for respective nozzle with different water pressure.

Results shown that when water pressure increased, the droplet velocity increase. This is true for both nozzles. At water pressure 4 bar, the average droplet velocity exceeds 10 m/s when compared to around 7 m/s at water pressure 1 bar. This is expected as with higher pressure, the water exited the nozzle with higher momentum thus the increase in velocity with water pressure. When compared between the two nozzle, there is a very slight difference in droplet velocity value, which is quite negligible.

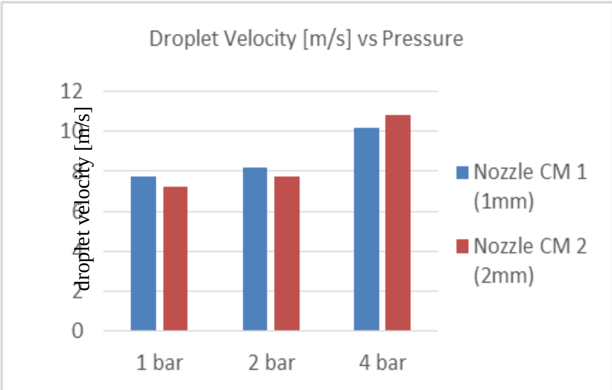


Fig. 4 - Changes in spray droplet velocity vs water line pressure.

3.3 Droplet size

Using the high resolution still image, droplet size was able to be measured. Droplet size is an important parameter that usually will be taken into high consideration when selecting nozzle for the intended application. Fig. 4 shows still image sample taken by DSLR. By using telephoto (high zoom) lens, a high resolution still images of the spray droplet were captured. The image was the undergo post processing similar to previous study [6] to determine which droplets in the image that fulfill the requirement for measurement. Fig. 5 show image sample captured in this study.

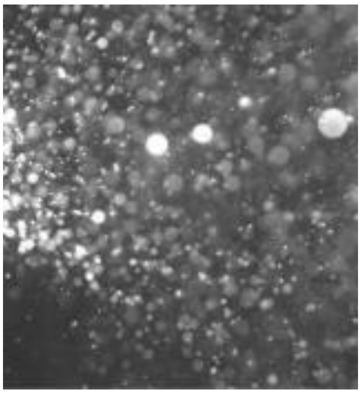


Fig. 5 - Sample of still image. (Nozzle CM 1, 1 bar water pressure).

Fig. 6 shows the changes in spray droplet size with water pressure. Overall there is clearly a decreasing trend in droplet size with the increase of water pressure. This is true for both the nozzle. Interestingly, there is a notable decrease in droplet size for nozzle CM 1 especial at the higher pressure when water pressure was increased, but the difference is very little with nozzle CM 2. This suggests that although generally droplet size decrease when pressure increased, the decreasing trend is different for each nozzle.

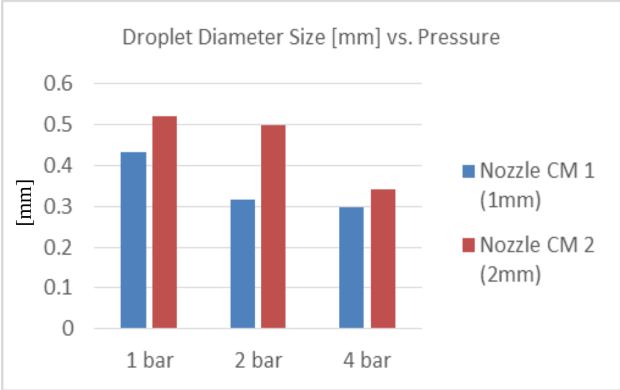


Fig. 6 - Changes in spray droplet size vs water line pressure.

4. Conclusion

The objectives of this study which are to study on qualitative and quantitative characteristic of mist spray nozzle of the commercially available 1/8 SF-CE SM 1 and 1/8 SF-CE SM 2. The study successfully manages to characterize the spray angle, spray droplet speed and droplet size for each respective nozzle. The study concludes that the spray angle increase until certain level of water pressure and show tendency to decrease as water pressure increased more than the optimum level. This is believed to be connected to the geometry of the nozzle as the nozzle is design to be use effectively at condition of 1 to 2 bar of water pressure.

Changes of droplet velocity and droplet size for respective nozzle were also observed. With increased water pressure, droplet velocity increase and droplet size decrease. This maybe favorable to achieve higher atomization of water which influence the cooling rate. As the nozzle used in this study are commercial available and readily used for mist spray cooling, the study shows that these nozzle spray characteristic is indeed favorable for the intended purpose. Each respective nozzle should produce the required mist for effective cooling, where the larger hole diameter nozzle should have higher discharge rate compared to the smaller nozzle, which help with larger area, while the smaller nozzle has the advantage of smaller droplet size which will help faster cooling, but limited to smaller area.

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References

[1] Yamaha, M., and Misaki, S. (2011) The evaluation of peak shaving by a thermal storage system using phase change materials in air distribution systems, *HVAC&R Research*, Volume 12, (2011), pp. 861-869.

[2] Alkhedhair, A., Guan, Z., Jahn, I., Gurgenci, H., and He, S. Water spray for pre-cooling of inlet air for natural draft dry cooling towers-experimental study. *International Journal of Thermal Sciences*, Volume 90, (2015), pp.70–78.

[3] Alkhedhair, A., Jahn, I., Gurgenci, H., Guan, Z., He, S., and Lu, Y. Numerical simulation of water spray in natural draft dry cooling towers with a new nozzle representation approach. *Applied Thermal Engineering*, Volume 98, (2016), pp. 924–935.

[4] Chaker, M., Meher-Homji, C. B., and Mee, T. Inlet fogging of gas turbine engines - Part II: Fog droplet sizing analysis, nozzle types, measurement, and testing. *Journal of Engineering for Gas Turbines and Power*, Volume 126, No. 3, (2004), pp. 571-580

[5] F.N., Du, D.X., and Law, C.K. A study on ethanol oxidation kinetics in laminar premixed flames, flow reactors and shock tubes. *Procceeding of Combustion Institute*, Volume 24, (1992), pp. 833-841.

[6] Sapit, A., Razali, M. A., Hushim. M. F., Ali, M. F. M, Khalid, A., and Manshoor, B. Study on spray characteristics and spray droplet dynamic behavior of diesel engine fueled by rapeseed oil. *ICPER 2014 - 4th International Conference on Production, Energy and Reliability*, Volume 13, No. 02005, (2014), pp.1-6.