DOI:10.18686/ahe.v7i35.12516

Effect of Surface Temperature Measurement Method on Heat Transfer Characteristics of Spray Cooling Surface

Long Huang, Yujiao Wang
Jiangsu Maritime Institute, Marine Electrical and Intelligent Engineering Institute, Nanjing 210016

Abstract: Spray cooling is an effective method for the cooling of electronic equipment. At present, the application of spray cooling technology in the heat dissipation of electronic devices has received more and more attention, especially in the heat dissipation of high-power electronic devices. Spray cooling technology atomizes the cooling working medium (water or air) into small droplets by spraying, forming and maintaining a very high temperature (usually 40 ° C ~70 ° C) under a certain pressure, so that the temperature of the working medium rises sharply to achieve heat dissipation [1]. At present, the research on the heat transfer characteristics of spray cooling surface mainly focuses on the analysis of its flow characteristics and heat transfer characteristics. Among them, surface temperature is an important parameter to characterize heat transfer performance, so it is very necessary and meaningful to study the influence of surface temperature on heat transfer characteristics of spray cooling [2]. Therefore, in this paper, two different measurement methods are used to study the changes of surface temperature and heat transfer system with spray pressure of combined surface under different power to obtain accurate and reliable surface temperature data.
Keywords: Surface temperature measurement method; Spray cooled surface; Heat transfer characteristic

Fund Project:
The Natural Science Foundation of the Jiangsu Higher Education Institutions of China(22KJD580001)
Jiangsu Maritime institute Innovation Technology Funding Project(kicx2020-2)

Introduction

Spray cooling is a heat dissipation method that uses liquid working medium to atomize droplets, and makes liquid film evaporate and vaporize to form boiling heat transfer by increasing contact area and contact time. The spray cooling system can be divided into two parts, that is, the working medium supply system and the cooling system. In the working medium supply system, the cooling medium is transported to the position of the spray gun through the pipeline, and water droplets are formed under the atomization of the spray gun, and the water droplets are evaporated and heat is taken away after contact with the working medium. In the cooling system, the spray flow is achieved by controlling the degree of atomization of the liquid in the nozzle. At present, the researches on spray cooling mainly focus on heat transfer characteristics, flow characteristics and phase transition characteristics, while the researches on surface heat transfer characteristics of spray cooling are relatively few [3]. According to the different properties of the liquid, the surface temperature can be divided into heat flux method (TDS), heat flux - convective heat transfer coefficient method (FTIR), convective heat transfer coefficient method (HFT), radiation heat transfer coefficient method (RGT) and other methods. Different measurement methods have their own characteristics [4].

1. Experimental equipment

The experimental device is shown in Figure 1. The experimental system is mainly composed of spray cooling device, temperature measuring device, data acquisition system and auxiliary heating system. Among them, the spray cooling device adopts pressure control of spray flow, the temperature measurement adopts thermocouple temperature measurement, the data acquisition system adopts digital signal acquisition card to collect temperature signals, and the auxiliary heating system provides heat source for the high-pressure steam generator [5]. Among them, the spray cooling system includes two spray tanks, each spray tank atomization chamber diameter of 12 mm, the working pressure of 10 MPa; The temperature measuring device includes a thermocouple sensor and a thermal resistance sensor. The experimental device is mainly used to study the heat transfer characteristics of spray cooling surface at different ambient temperatures (20°C~50°C), and its working pressure is 10 MPa. The auxiliary heating system is mainly to heat the two spray holes of the spray can to increase its temperature by adjusting the steam pressure of the steam generator. In order to compare the influence of different measurement methods on the heat transfer characteristics of spray cooled surface, two different measurement methods (pressure type and thermocouple temperature measurement) were used to measure the heat transfer characteristics of spray cooled surface under different flow rates and pressures at the same ambient temperature [6].

Figure 1. Spray cooling system

2. The surface temperature of the combined surface changes with the spray pressure under different power

Combined surface refers to the combination of different forms of surface to obtain a better cooling effect. The experimental results of these surfaces under different spray pressures are shown in Figure 2. It can be seen from Figure 2 that under different pressures, the surface temperature of the combined surface decreases with the increase of the spray pressure. This is because the contact area between droplets increases with the increase of pressure, and the heat absorption by evaporation becomes less. Under the condition of constant temperature, more heat can be used to maintain the surface temperature. Therefore, as the pressure increases, the combined surface has a better cooling effect at the same power. Under different pressures, the combined surface temperature decreases with the increase of spray flow. This is because when the spray pressure is small, the spray flow rate has little influence on the combined surface temperature [7]. When the spray flow rate increases gradually, the influence of spray pressure on the combined surface temperature increases gradually. Under different spray pressure, the combined surface has different heat transfer coefficient under the same power. This is because as the pressure increases, the contact area between the droplets increases.

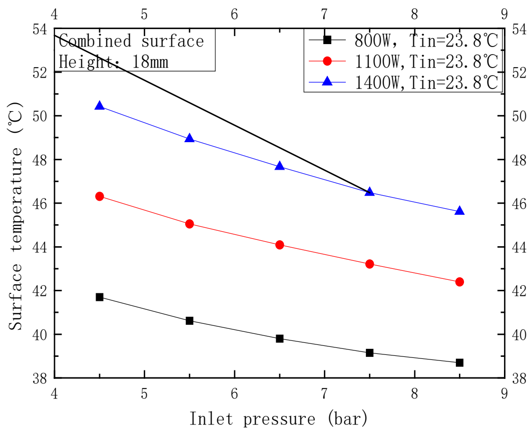

FIG. 2 Surface temperature curve of combined surface with spray pressure under different power

3. The heat transfer coefficient of the combined surface varies with the spray pressure under different power

The heat transfer coefficients of different surface types are measured separately under the same measurement pressure. Because the spray pressure will have different changes under different power, so under the same power, the change curve of the heat transfer coefficient of the spray cooling surface with different power can be calculated. It can be seen from Figure 3 that the effect of spray pressure on the heat transfer coefficient of the combined surface is the same as that of the single-phase flow surface. When the spray pressure is constant, the combined surface heat transfer coefficient first increases and then decreases with the increase of spray flow [8]. This is because as the spray pressure increases, the droplets formed

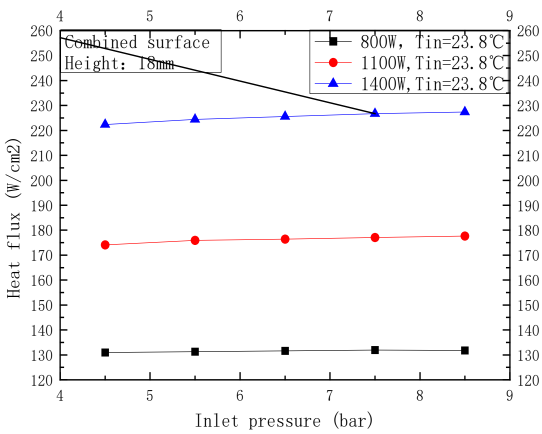

FIG. 3 The heat transfer coefficient of the combined surface varies with the spray pressure under different power

by liquid atomization become smaller. As the size of the droplets decreases, the liquid film thickness increases, and the contact area between the liquid film and the working medium becomes smaller, so that the average contact thermal resistance of the working medium per unit time increases. This is because as the spray pressure increases, the average thermal resistance of the combined surface gradually decreases. This is because heat absorption by liquid evaporation and heat absorption by liquid evaporation through capillary action will increase as the power increases. In the process of evaporation and absorption, more heat needs to be consumed to overcome the imbalance between the heat absorbed by evaporation and the heat released by evaporation [9]. As can be seen from the figure, when the spray pressure is constant, the combined surface heat transfer coefficient will increase with the increase of power. When the flow rate is constant, the combined surface heat transfer coefficient will decrease with the increase of power.

4. Results and analysis

In these two measurement methods, the surface temperature has a linear relationship with the spray flow rate, pressure and ambient temperature. For the same spray flow and pressure, the surface temperature obtained by direct measurement is lower than that obtained by indirect measurement. Under the same spray flow and pressure, the surface temperature obtained by direct measurement method is higher than that obtained by indirect measurement method. Under the same ambient temperature, the surface temperature obtained by direct measurement method is lower than that obtained by indirect measurement method. The linear equation can be obtained that the surface temperature obtained by the direct measurement method has a linear relationship with the spray flow and pressure, while the surface temperature obtained by the indirect measurement method has a nonlinear relationship with the spray flow and pressure. Therefore, in practical applications, in order to better understand the changes in flow field and heat transfer characteristics during spray cooling, appropriate measurement methods should be reasonably selected according to specific conditions. For example, under the condition of low heat flux, the surface temperature obtained by indirect measurement method can be used to measure the change of flow field and heat transfer characteristics during spray cooling. Under the condition of high heat flux, the surface temperature obtained by direct measurement can be used to reflect the changes of flow field and heat transfer characteristics.

References:

[1] Anniversaries Yong, Xu Muhao, Feng Hao et al. Study on transient heat transfer in closed spray cooling [J]. Acta Chemologica Sinica, 2019,71(03):1018-1025. (in Chinese)

[2] Liu Ni, Li Lirong, Huang Qianwei et al. Experimental study on effect of spray parameters on heat transfer characteristics of spray cooling [J]. Journal of Refrigeration,2016,37(05):93-99+111. (in Chinese)

[3] Huang Long, Wang Songming, Wang Yujie et al. Experimental study on critical heat transfer characteristics of spray cooling [J]. Refrigeration and Air Conditioning, 2019,20(03):54-59. (in Chinese)

[4] Yang Chunguang, Zhang Hao, Liu Jun. Experimental study on uniformity of spray cooling with open single nozzle [J]. High Power Laser and Particle Beams, 2019,32(07):23-28. (in Chinese)

[5] Liu Ni, Zhan Taijie, Hong Chunfang. Study on the Influence of Pressure Parameters on Heat Transfer Characteristics of spray cooling [J]. Electronic Components and Materials,2018,37(05):100-105. (in Chinese)

[6] Yang Tao, Zhou Fu-fu, Chen Bin, et al. Effect of Surface temperature Measurement Method on Heat transfer Characteristics of spray cooling surface [J]. Acta Chemica Sinica,2016,67(11):4558-4565. (in Chinese)

[7] Zhang Yuwei, Liu Ni, Wang Ke. Research progress of critical heat flux Model for spray cooling and its Influencing Factors [J]. Electronic Components and Materials,2016,35(08):1-5. (in Chinese)

[8] Zhou Fu-fu, Xu Teng-yu, Zhao Xi et al. Research on calculation method of transient heat flux of spray cooling surface [J]. Chinese Journal of Engineering Thermophysics,2016,37(11):2452-2456. (in Chinese)

[9] Zhang Yuwei, Liu Ni, Wang Ke. Research progress on heat transfer mechanism of spray cooling [J]. Electronic Components and Materials,2016,35(11):1-5. (in Chinese)

About the author:

Long Huang，male（1985.02—），the Han nationality，Native place:HEBEI Shijiazhuang，doctor，lecturer，Research direction: Spray cooling，Numerical calculation

Yujiao Wang，female（1988.12—），the Han nationality，Native place:jiangsu NANJING，Master，lecturer，Research direction: Spray cooling，Ship automation control