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# Simulation and Optimization of Heat Transfer Characteristics in Two-phase Region of Small Spray Cooling Unit

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

**Abstract:** In this paper, the working principle and structure of the spray cooling device are introduced, and the influence of spray height and flow rate on the heat transfer coefficient is discussed. The spray cooling device achieves the purpose of heat transfer and cooling by converting the liquid into small droplets and spraying on the surface to be cooled. The increase of spray height can enhance the heat transfer effect, improve the contact time between the droplet and the surface, and increase the heat transfer coefficient. The increase of spray flow can increase the contact area between the droplet and the heat source, increase the heat transfer surface area, and then increase the heat flux. Spray cooling devices have wide application prospects in the fields of electronic equipment cooling and industrial production.
**Keywords:** Spray cooling device; Heat transfer characteristics; Simulation; Optimization; Thermodynamic performance

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## 1. The working principle of spray cooling device

Spray cooling device is a device that uses spray technology for heat transfer and cooling. Its working principle is based on the nozzle to convert the liquid into small droplets, and spray onto the surface to be cooled, through the mass and heat transfer process between the droplet and the surface, the surface heat transfer to the droplet, and as the droplet evaporates and cools, the heat is released to the surrounding environment.

Specifically, the spray cooling device is usually composed of a nozzle, a liquid supply system, a cooling surface and a liquid discharge system. During the working process, the liquid is transported to the nozzle through the liquid supply system, and under the influence of high-speed gas or pressure, the liquid is dispersed into small droplets to form a spray. These droplets are sprayed onto the surface to be cooled by gravity and gas dynamics.

When the droplet touches the surface, since the surface temperature is higher than the droplet's saturated vapor temperature, the droplet begins to evaporate, absorbing heat from the surface. During the evaporation of the droplet, the liquid heat is transferred to the interior of the droplet through mass and heat transfer, which increases the temperature of

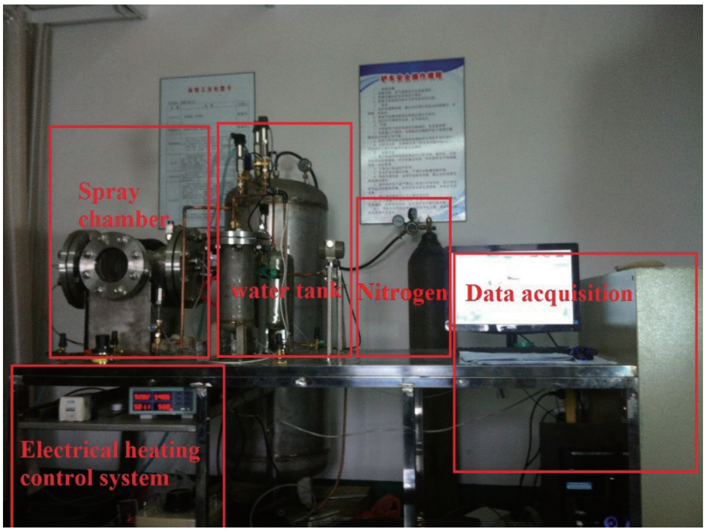


FIG. 1 Spray cooling device

the droplet. As the temperature rises, the droplets gradually evaporate into saturated steam and release the heat absorbed during evaporation. Eventually, the steam exchanges with the ambient heat, releasing the heat into the air and achieving a cooling effect on the surface.

# 2. Study on the influence of spray height and spray flow on heat transfer characteristic parameters

## 2.1 Influence of spray height on heat transfer coefficient

Spray height refers to the height of the spray drop in the spray cooling device after leaving the nozzle to reach the surface to be cooled. Spray height has a certain effect on heat transfer coefficient. The following are some relevant studies and observations:

1. Increasing the spray height can enhance the heat transfer effect: a larger spray height can increase the contact time between the spray droplet and the surface to be cooled during the descent process, thus increasing the chance of heat transfer. A longer contact time helps to promote the transfer and absorption of heat, so the heat transfer coefficient can be improved.

2. The relationship between the spray height and the droplet size: the spray height will affect the formed droplet size. In general, larger spray heights can produce larger droplet sizes, and larger droplet sizes generally have higher heat transfer coefficients. Therefore, within a certain range, increasing the spray height may lead to an increase in the droplet size, thereby increasing the heat transfer coefficient .

3. Influence of spray height on flow pattern: Spray height will also affect flow pattern, such as the transition from droplet flow to film flow. Membrane flow has a larger heat transfer surface area and a shorter heat transfer path, so it is more conducive to heat transfer, thereby improving the heat transfer coefficient.

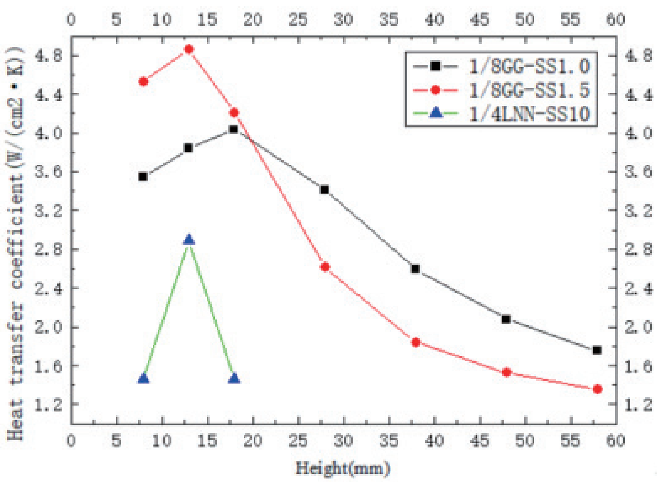
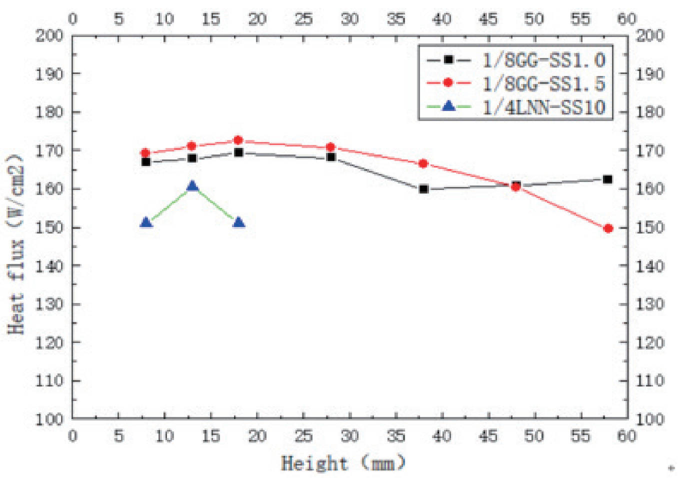



FIG. 2 Influence of spray height on heat transfer coefficient




Influence of spray height on heat flux

## 2.2 Influence of spray height on heat flux

Spray height refers to the height of the spray drop in the spray cooling device after leaving the nozzle to reach the surface to be cooled. Spray height has a certain effect on heat transfer coefficient. The following are some relevant studies and observations:

1. Increasing the spray height can enhance the heat transfer effect: a larger spray height can increase the contact time between the spray droplet and the surface to be cooled during the descent process, thus increasing the chance of heat transfer. A longer contact time helps to promote the transfer and absorption of heat, so the heat transfer coefficient can be improved.

2. The relationship between the spray height and the droplet size: the spray height will affect the formed droplet size. In general, larger spray heights can produce larger droplet sizes, and larger droplet sizes generally have higher heat transfer coefficients. Therefore, within a certain range, increasing the spray height may lead to an increase in droplet size, which in turn increases the heat transfer coefficient.

3. Influence of spray height on flow pattern: Spray height will also affect flow pattern, such as the transition from droplet flow to film flow. Membrane flow has a larger heat transfer surface area and a shorter heat transfer path, so it is more conducive to heat transfer, thereby improving the heat transfer coefficient.

## 2.3 Influence of spray flow rate change on heat transfer coefficient

The change of spray flow rate can affect the heat transfer coefficient. Here are some relevant observations and studies:

1. Increasing the spray flow rate can enhance the heat transfer effect: a larger spray flow rate will cause more spray droplets to contact the surface to be cooled, thus increasing the surface area and opportunity for heat transfer. The larger heat transfer surface area promotes the transfer and absorption of heat, so the heat transfer coefficient can be improved.

2. Relationship between spray flow and droplet size: Increasing spray flow may result in a smaller droplet size. Smaller droplet sizes usually have a larger specific surface area, which facilitates the transfer of heat. Therefore, increasing the spray flow rate may improve the heat transfer effect between the droplet and the surface to be cooled, thereby increasing the heat transfer coefficient.

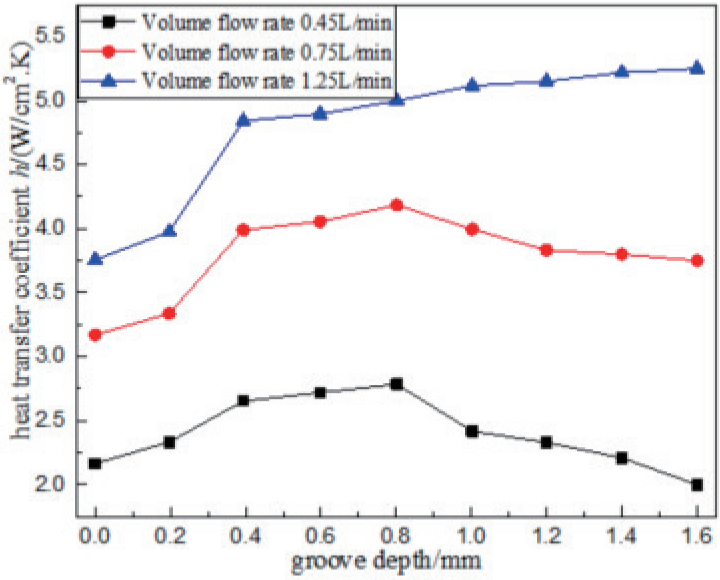


FIG. 3 Influence of spray flow rate change on heat transfer coefficient

## Peroration

In this paper, the working principle and structure of the spray cooling device are introduced, and the influence of spray height and flow rate on heat transfer coefficient is discussed. It is of great significance to study the working mechanism and parameter optimization of spray cooling device for improving heat dissipation efficiency and reducing heat source temperature. Spray cooling technology is widely used in the fields of electronic equipment cooling and industrial production. Through in-depth research and innovation, we can further improve the performance of spray cooling units, leading to more efficient and sustainable solutions for engineering and applications in the field of thermal management, promoting industrial development and energy conservation.

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## 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.