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Effect of Airflow on Heating and Evaporation of a Suspended Water Droplet

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Extended Abstract

With technology constantly improving, we are in a period of boom for high-power electronics and efficient energy conversion. These technologies, including electric vehicles, data centres, supercomputers, lasers, and airborne electronic equipment, are applied in various fields. There is a trend that as the integration of these technologies improves, the power of devices is also increasing. As a result, a large amount of heat is concentrated in relatively small spaces [1], which can cause the operating temperature of the device to rise and cause serious problems for the device's performance and the reliable and stable operation of the entire system. In this context, spray cooling systems have great potential because when sprayed, the liquid is broken up into many small liquid droplets. This allows for the large amount of heat to be dissipated efficiently, precise temperature control, low coolant flow requirements, low temperature differences, no boiling hysteresis, and reliable, stable operation over a long period [2,3]. To ensure the effective operation of a specific spraying technology, it is crucial to have a good understanding of the heat and mass transfer processes and phase change processes taking place in a single liquid droplet, as well as the factors affecting them.

This work aims to experimentally investigate the influence of the surrounding airflow regime on the heat and mass transfer processes of the suspended liquid droplet in its phase change cycle. Distilled water has been chosen for the experiments because it has a wide range of practical applications in various spray-based technologies. The experiments were conducted using an experimental set-up, the detailed operating principle of which is described in the papers [4,5]. The water droplet was suspended on a thermocouple bead using a mechanical pipette. Then, using a special introduction system consisting of two sliding glass tubes, it is placed at the centre of the experimental section. The experiments were carried out in various airflow transitional modes, by changing the Reynolds number of the supplied airflow Re_g from 1670 to 5050. During all experiments performed, the airflow was supplied to the experimental section with an ambient pressure of ≈101 kPa, a temperature of ≈20.5 °C, a relative humidity of ≈62 % and then heated to a constant temperature of 100°C using electric heaters. The main observed parameters of the experiments were the temperature and the size of the suspended water droplet. These parameters were recorded with the thermocouple, on which the droplet was suspended, every 0.1 s and a high-speed video camera at 25 frames/s, respectively. The reliability of the performed experimental investigation is guaranteed by comparing the measured equilibrium evaporation temperature of suspended water droplets with the temperature of a wet-bulb thermometer under the same airflow boundary conditions.

The performed experiments confirmed that the airflow regime has almost no effect on the equilibrium evaporation thermal state of the experimental water droplet. However, in transitional regimes, the influence of the airflow regime is significantly noticeable, since a higher airflow velocity determines a more intense external convective heating of the experimental water droplet. Based on the experimental diagrams of water droplet temperature and equivalent diameter variations, a mathematical model was created to compute the vapour mass flux g_v, which determines the intensity of phase change in the suspended water droplet. The calculation results show that at higher values of the Reynolds number for the air flow overflowing the droplet, the phase change of the suspended water droplet occurs more intensively, and the droplet evaporates more quickly.

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