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Influence of Air Parameters on a Liquid Droplet Thermal State in Phase Transformation Mode Cycle

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Extended Abstract

With a constant increase of heat flow density, the question of cooling problem arises. Striving to improve the heat exchange processes, many applied technologies in energy, industrial, transport and other sectors are based on the liquid injection process. Liquid is broken into small droplets and contact area between the liquid and gaseous phases is greatly increased. Traditional examples of spray system application include the combustion of liquid fuels in boilers, internal combustion or jet engines, water evaporation in air-conditioning systems, rapid cooling of gases and thermal process control. In these systems water is used traditionally as a working agent, however, efforts are now being made to use a variety of other liquids, such as ethanol and ethylene glycol, to improve the efficiency of the cooling process [1,2]. Although scientists have been studying liquid droplet processes for more than a century [3], the continuing need to modernise and make modern technologies based on liquid dispersions more efficient is driving the continued focus on so-called 'droplet' research.

The aim of this study is to experimentally investigate the influence of the bypassing air flow parameters and their effect on the thermal state of liquid droplets with different physical properties in the droplet's phase transformation mode cycle. Water is the most used liquid for experiments with droplets as they have a wide range of practical applications. Ethanol and ethylene glycol are chosen because recently there is a large focus on them for using in cooling spray systems. The experimental set-up and its working principal were detailed presented in the papers [4,5]. The droplet of the investigated liquid was suspended on a thermocouple bead and then placed in the test section of the experimental set-up where it was overflown with the air flow. The experiments were performed by changing the atmospheric air temperature in the range of 22-130°C and introducing additional humidity into the flow. The main parameters monitored during the experiments are temperature and size of a fluid droplet: the temperature dynamics of a droplet was observed with the thermocouple on which the droplet was suspended, and the change of the droplet size was recorded using a high-speed camera. The reliability of the experiments is ensured by comparing the measured data of the water droplet temperature in the air flow with the wet-bulb temperature at the same temperature and relative humidity.

The performed experiments confirmed that additional humidity and temperature of the atmospheric air flow are the main factors influencing the dynamics of the liquid droplet thermal state in its phase transformation mode cycle. The higher temperature of the supplied atmospheric air leads to faster warm up of the liquid droplet and the equilibrium evaporation temperature of the droplet becomes higher. Additional humidity content in the supplied air flow causes the liquid droplets to heat up more rapidly to the equilibrium evaporative state and the temperature that defines this thermal state is increased. However, from experimental data it is seen, that the increase in equilibrium evaporation temperature of the investigated liquid droplets due to additional humidity is different: for ethanol, characterised by volatile properties, the equilibrium evaporation temperature increases by about 10-15 °C; for water by about 7-12 °C and for ethylene glycol, with viscous properties, by only 3-5 °C in comparison to the same temperature of non-humidify atmospheric air flow. This shows that impact of humidity for heating liquid droplet thermal state depends on the physical properties of the materials: volatility and viscosity.

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