

Two-phase cooling characteristics of a multiple-intermittent spray

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Among the new techniques capable of removing high heat fluxes, spray cooling appears to be a notable method with its ability of removing heat relying on phase-change (nucleate boiling), additionally to the convective heat transfer linked with fluid motion, but optimum performance requires a precise control of the liquid mass rate supplied for cooling and subsequent removal of the vapor produced. Previous works showed that a multiple-intermittent spray has the potential to achieve this by proper matching the duration of each injection with the frequency of successive injections, but the formulation of an accurate method to control the temperature of the surface demands for an exact knowledge of how the fluid dynamic characteristics of the spray correlates with the heat transfer phenomena. The work reported here addresses these issues based on simultaneous phase-Doppler anemometer measurements of the spray characteristics at impact and instantaneous surface temperature in a simplified flow geometry consisting of a pulsed spray issuing perpendicularly to a flat heated aluminum disc. Analysis of the results shows that the heat transfer behaves differently before and after closing of the injector. During the first period, the interaction occurs with a dense cluster of droplets, which is not altered by the rising thermal plume and heat transfer is governed by the number flux of droplets arriving at the surface; during the second period, interaction occurs with a sparse cluster of droplets and heat transfer is dominated by the kinetic energy of droplets at impact. The effect of increasing the frequency of injection is brought upon by the increase amount of liquid impacting onto the surface. However, comparison with results previously reported and obtained with a different cooling liquid, show that the interaction between successive injections hinders the beneficial effects of using liquids with larger latent of vaporization. The results further evidence that a multiple intermittent spray provides a spray cooling system with a more accurate control over heat transfer which increases its potential as a fast response cooling system for dynamic power dissipation devices.

1. Setup and Diagnostic Techniques

The flow configuration is that of a spray striking perpendicular onto a flat disc with a 10 mm radius (r_{disc}), heated by an electric resistance. Three “Medtherm” eroding-K-type thermocouples were assembled in the disc and spaced by 4 mm (r_{tc}) with the first thermocouple located at the disc centre as depicted in fig. 1. Thermocouples signals are sampled at 50 kHz with a NI6024E National Instruments DAQ board plus a BNC2120, and the electrical signal is amplified with a gain of 300 before processing. Inaccuracies in temperature due to electronic noise increase as the surface temperature decreases and were found to be

smaller than $\pm 1\%$ at ambient temperature. The injector is a BOSCH pintle-type with 0.79 mm of pintle diameter inserted in a hole with 0.9 mm and the spray produced has a hollow-cone structure.

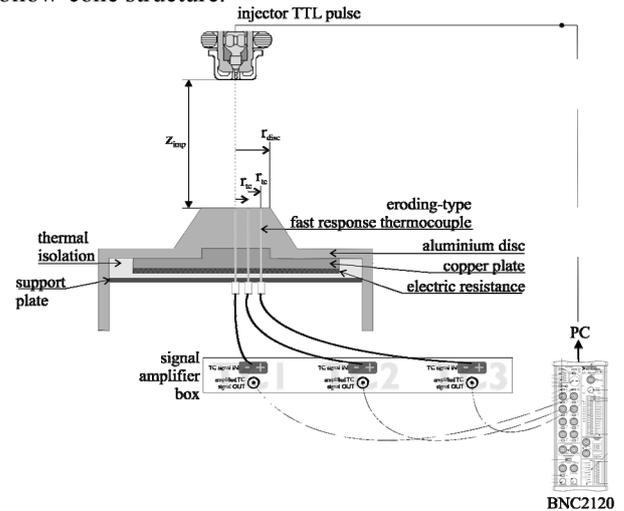


Fig. 1 Experimental setup

Local time-resolved measurements of droplet size, velocity are simultaneously measured with a two-component phase Doppler (PDA) DANTEC system consisting of a 55X transmitting optics, a 57x10 PDA receiving optics, oriented at 70° for a higher insensitivity to changes in the refractive index and a 58N10 Covariance processor.

2. Results

Fig. 2 shows the phase-average analysis performed on the simultaneous measurements of the two-phase cooling characteristics on the impact of a multiple-intermittent spray.

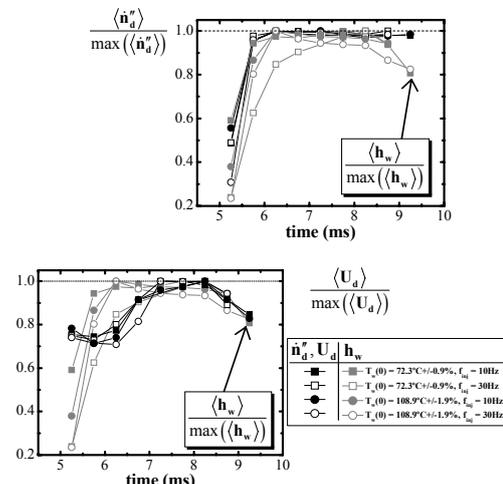


Fig. 2 Phase-average results for the spray characteristics and surface thermal transient behaviors.