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IMAGING MEASUREMENTS IN NANO-PARTICLE ENHANCE SPRAY COOLING

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ABSTRACT

Thermal control is a major constraint in spacecraft development as increased demand on electronics performance requires large heat dissipation from smaller surfaces which has led to increased challenges for thermal control. Spray cooling has a great amount of application in industrial processes as a heat removal method. It is thought to be the future in thermal management systems in space because of its capability for 'close' and accurate control of heat removal. Spray cooling is based on phase change heat transfer generating high heat transfer rates for low superheats. This last term is used to describe the difference in temperature between the heated surface and the cooling fluid. When the temperature of the surface to be cooled rises above the saturation temperature of the fluid splashed to the surface, a phase change occurs at the solid liquid interface during the boiling regime. However, the most interesting phase (regime) is the nucleating boiling where the critical heat flux, CHF, is reached. The CHF is then achieved due to the vapor generation is such as great that the liquid cannot still be in contact with the surface. Thus the heat is transferred through the vapor if there is not enough cold fluid. The thermal conductivity of vapor is lower and so the efficient of the cooling process. This turns out in a decrease on heat flux.

Nowadays it is being taken more into account nanofluids as a technique capable of enhancing heat transfer. Nanofluids, a mix of nano-size particles in a base fluid, have been found to have a very high thermal conductivity as compared to the base fluid. In You et al., 2003; Kim et al., 2004a; Moreno et al., 2005 water was used with various Al_2O_3 particle concentration in a flat plate nucleate pool boiling system. They came across with no change in the heat transfer coefficient but a dramatic enhancement in CHF. They also found that high concentrations can degrade nucleate boiling. The aim of this project is study the effects of spray cooling with suspended nano-particles as an enhanced method for heat transfer removal.

The working fluid was water with different concentrations of alumina-oxide particles added. The alumina oxide particles were supplied by Nanophase Technologies (Nano Tek® Alumina Oxide AL-01000-003-025) which had a mean diameter of 60 nm. Three different concentrations were used and the following: .5 g/L, 1 g/L, 2 g/L. Since clumping of particles can affect the heat transfer properties of the droplets, the solution was placed on inside an ultrasonic bath and left there for at least 24 hrs and immediately used in the experiments. Two nozzles were used in this experiment to study a wide range of sauter diameter of droplets. The experiment was carried out using three experimental techniques which looked into different characteristics of spray cooling.

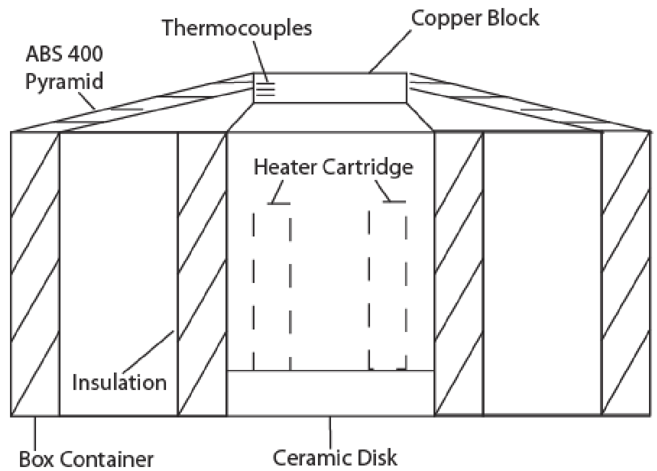

Figure 1. Copper Block Heater Setup

In the first mode, the fluid was sprayed onto a copper block heater surface while it was imaged with a high speed camera and synchronized with a high speed Nd-YAG laser. 9 thermocouples were positioned inside the copper block heater, as seen on Figure 1, to measure critical heat flux, while a camera was used to record different impact properties and the influence of nano-particles. Some of these properties were pool buildup size, spread, and duration of pool. For the second

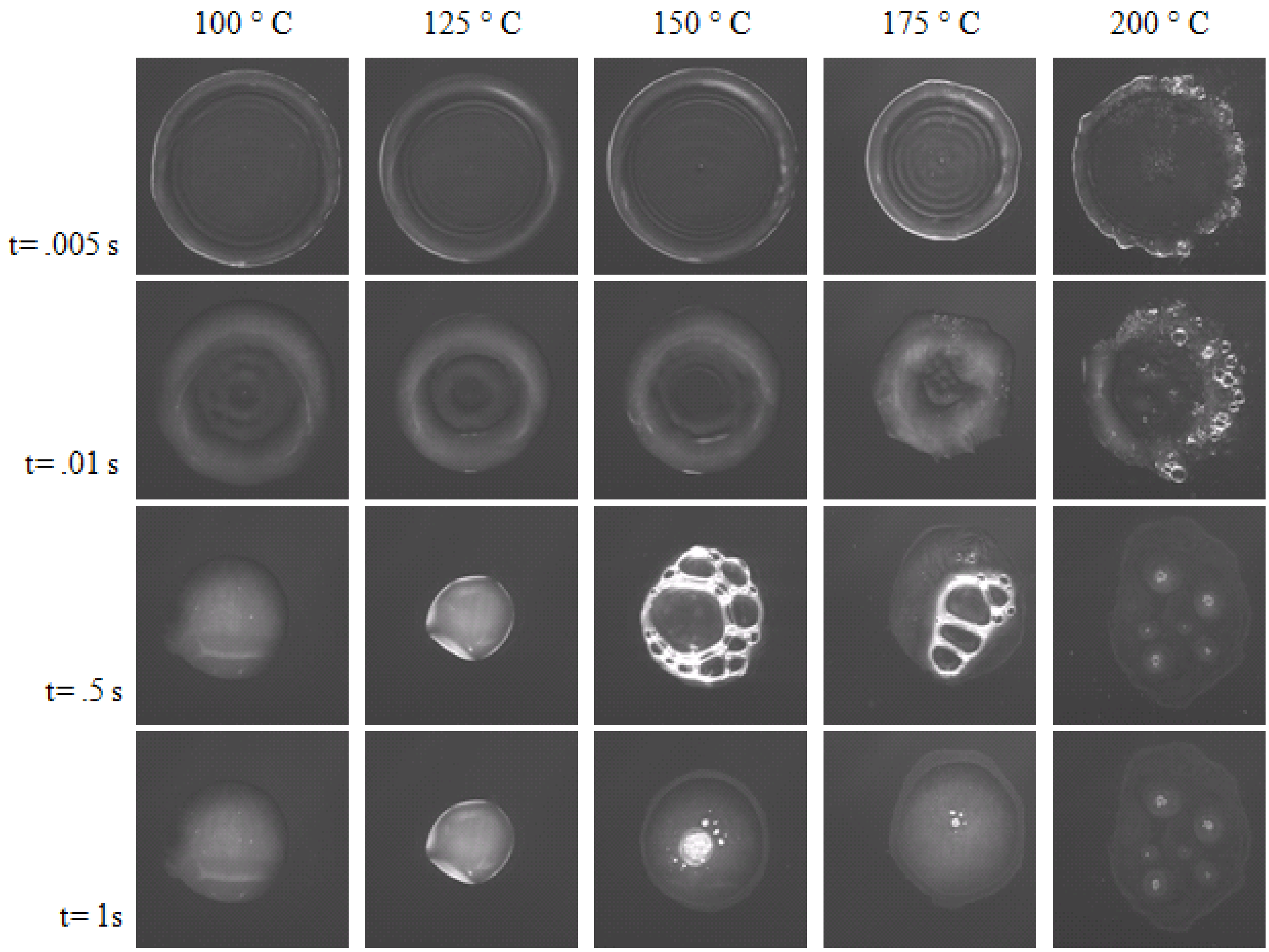

Figure 2. Effects of Temperature on a 1g/L Alumina Oxide drop from height of 30 *cm.*

imaging technique, the spray on the heated surface was also considered to be an impinging jet, so to visualize the flow of this jet and how the heated surface affected it, PIV (Particle Image Velocimetry) was used in the study. A third imaging technique was used to study the droplet behavior when in contact with a heated surface. A transparent glass heater made of aluminum silicate glass and coated with an ITO (indium tin oxide) film was used as the heater. The size of the drops had an average diameter of 2.38 mm. When compared to the copper block study, this method allows images to be taken from directly below the clear glass heater. Furthermore, these images allow for a clear edge detection of drops as they spread on the surface and what characteristics they develop when the droplets have different concentrations of nanoparticles, as seen on Figure 2. The experiment used a pulsed laser to provide the background illumination. This project is a continuing research project.

ACKNOWLEDGMENTS

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