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Microgravity Experiments from Sub-Orbital to Orbital Platforms (3)

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FLAT PLATE PULSATING HEAT PIPE WITH SELF-REWETTING FLUID IN PARABOLIC FLIGHT CONDITIONS

Abstract

Self-Rewetting fluids mean binary or multi-component dilute aqueous solutions of long-chain alcohols with unusual surface tension behavior. For these mixtures the presence of small proportions of alcohols in water changes dramatically the wetting and surface tension properties. Contrary to ordinary liquids, the surface tension becomes an increasing function with temperature that, in addition to the variation induced by the preferential evaporation of the more volatile components, provides a reverse Marangoni effect along the liquid-vapor interface driven towards the hot region. One of the most interesting applications of this effect is a spontaneous liquid inflow towards hot spots or dry patches of evaporation-based heat transfer devices. Pulsating Heat Pipes (PHP) are passive heat transfer devices where the working fluid is distributed along a meandering capillary tube in the form of liquid slugs and vapor plugs. The heat exchange is triggered by thermally driven self-sustained oscillations of the working fluid. The presence of the characteristic slug and plug flow pattern instead of a stratified or annular flow mainly depends on the Bond number. Since the role of surface tension driven flows became dominant with the decrease of the Bond number, i.e. reducing gravity, the effect of self-rewetting fluids in a PHP becomes very important for a microgravity experiment.

This article reports the results of tests on board a 'zero-g' plane, during the 65th ESA Parabolic Flight Campaign. A Flat Plate PHP filled with ordinary liquid (water) and self-rewetting mixture is investigated under variable gravity conditions. The experimental setup includes a transparent side enabling the visualization of the oscillating flow pattern during the experiments. The thermal performances in terms of temperatures, start-up levels and flow regimes have been characterized for the two working fluids for different power input, in the 0-200W range. The most important results show that, even for low power input, the PHP filled with pure water is not able to work under low-g conditions, because the evaporator

immediately exhibits dry-out conditions. During the low-g period, the evaporator became completely dry and the oscillations stopped, preventing heat transfer between the hot and cold side and resulting in increased temperatures. On the other hand, the PHP filled with self-rewetting fluid still operated during the microgravity phase. Under some conditions the liquid re-wet several times the evaporator zone triggering the oscillatory cycle. The results are discussed and the phenomenon is explained on the basis of the different surface properties at the slug-vapor interfaces.