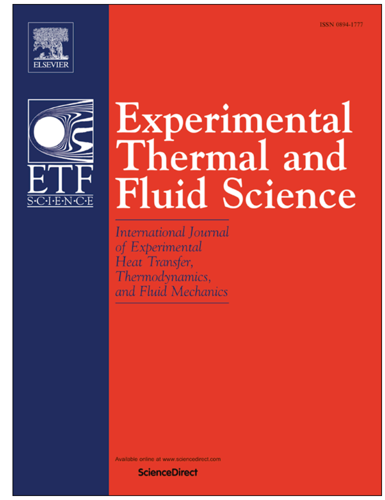

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INFRARED ANALYSIS OF THE TWO PHASE FLOW IN A SINGLE CLOSED LOOP PULSATING HEAT PIPE

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Research Highlights

- Adiabatic section made of sapphire tubes, transparent both to visible and IR spectrum.
- Thermal-hydraulic characterization at different heat input levels.
- Direct Fluid temperature measurement with IR camera.
- Temperature gradients along a liquid slug could be measured with 1,5 K accuracy.
- Liquid film wetting and de-wetting phenomena qualitatively detected by the IR.

Abstract. A Single Loop Pulsating Heat Pipe (SLPHP) filled at 60% vol. with pure ethanol, having an inner diameter of 2mm, is designed with two sapphire tubes mounted between the evaporator and the condenser. Being the sapphire almost transparent in the infrared spectrum, such inserts allow simultaneous high-speed visualizations and infrared analysis of the fluid regimes. Two highly accurate pressure transducers measure the pressure at the two ends of one of the sapphire inserts. Three heating elements are controlled independently, in such a way to vary the heating distribution at the evaporator. It is found that particular heating distributions promote the slug/plug flow motion in a preferential direction, allowing to establish a self-sustained circulatory motion. It is demonstrated that a direct infrared visualization of the two-phase flow passing through the sapphire inserts is a valuable technique to measure the liquid slug bulk temperature after a proper calibration of the camera, with uncertainty of 1.5˚C (99.7% confidence level). Additionally, the fluid infrared visualization allows to appreciate the liquid film dynamics (wetting and dewetting phenomena) during the device operation, and to map the temperature gradients of liquid slugs thanks to the high-sensivity of the infrared measurements (0.05 K).

Keywords: Pulsating Heat Pipe, Infrared Analysis, Liquid film dynamics.

1. INTRODUCTION

As modern computer chips and power electronics become more powerful and compact, the need of more efficient cooling systems increases. In this scenario, Pulsating Heat Pipes (PHPs) are relatively new, wickless two-phase passive heat transfer devices that aim at solving thermal management problems mostly related to electronic cooling (Akachi, 1990, 1993). Despite the advantages of this emergent technology, such as its compactness, the possibility to dissipate high heat fluxes and the ability to work also in microgravity conditions, the PHPs governing phenomena are quite unique and not completely understood (Zhang and Faghri, 2008). Since the Single Loop PHP (SLPHP) can be considered the basic constituent of a multi-turn Pulsating Heat Pipe, its full thermo-fluidic characterization is fundamental for the complete description of the PHP working principles. At present, several studies already contribute to the understanding of SLPHP behavior (Khandekar and Groll, 2004, Khandekar et al. 2009, Spinato et al. 2015, Spinato et al. 2016), but further work is needed to have a clearer view on the thermo-fluid dynamics of the two-phase flow. Detecting quantitatively the liquid slug temperature with a non-intrusive technique is a mandatory step for a better comprehension of the PHP heat transfer phenomena. Additional efforts are also imperative to find new techniques able to describe the liquid film evolution during the device operation for the flow patterns usually observed within PHPs, i.e. the slug/plug flow and the semi-annular flow. In fact, being the Taylor flow the common flow pattern observed in PHPs, where vapor bubbles are surrounded by a liquid film deposited on the inner section of the tube wall, the analysis of the liquid film dynamics during the PHP operation is necessary in the understanding of the device fluid-dynamics and in the developement of further numerical models (Nikolayev, 2011). Also the most recent numerical modelling