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Water-copper nanofluid application in an open loop pulsating heat pipe

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ABSTRACT

Several investigations have pointed the operational behavior of passive thermal control devices such as loop heat pipes (LHPs) and pulsating heat pipes (PHPs) in the past, which have cleared many points related to their design. However, an interesting aspect related to passive thermal control devices that operate by means of capillary forces to pump the working fluid have gained attention during the last years, is in regard to the use of nanofluids on such devices. Nanofluids are known as regular fluids with addition of solid nanoparticles with sizes (diameter) below 40 nm, which are used to enhance the working fluid's thermal performance by enhancing its thermal conductivity. Previous works have demonstrated that the liquid's thermal conductivity can be enhanced by 20% if nanoparticles are added on a concentration of 5% by mass. PHPs operate by the dynamics of slug/plug formation, removing heat from a high temperature source and dissipating in a low temperature sink, and are highly influenced by the bubble critical diameter related to a specific working fluid. Thus, an experimental open loop PHP (OLPHP) was tested with water-copper nanofluid, with an addition of 5% by mass of copper nanoparticles. Improvements on the overall device's operation have been observed when using the nanofluid with lower temperatures, as well as a direct influence on the thermal conductances throughout the PHP.

1. Introduction

Nanofluid application is a recent area of investigation with promising results for thermal control systems. Nanofluids are those fluids in which microscopic or nanoparticles are held in suspension. The effect is to improve the thermal conductivity of the fluid. By adding 5% of the working fluid's mass with nanoparticles, the liquid thermal conductivity can be increased by up to 20% [1]. Some researches have already presented important contributions using nanofluids usually composed of water and copper nanoparticles with sizes around 25 nm [1,2], which all represent the recent advances on this new and innovating technology. The investigations performed so far have pointed to the potential in using nanofluids in several thermal control applications with great improvement on the heat transfer coefficient, especially when liquid single-phase thermal control has been used. It is important to mention that investigations performed so far utilizes regular pumping devices to transport the nanofluid throughout the loop. However, very little is known about nanofluids application in devices such as heat pipes and loop heat pipes (LHPs) that require the generation of capillary forces to drive the working fluid [3]. In this last case, the capillary evaporator presents a porous wick structure with fine pores and the interaction with the nanofluid needs to be better investigated.

Few works have been presented related to nanofluids application in LHPs so far, but show the potential of this line of research in the future. Mishkinis et al. [4] presented the analysis of an LHP operating with gold nanoparticles, which did not show any major improvement. Riehl [3] also presented an investigation on nanofluids applied to LHPs, which showed that since nanoparticles are carried with the working fluid, more flow restrictions are imposed to the device, also resulting on a higher pressure drop across the wick structure.

As pulsating heat pipes (PHPs) operate by means of slug/plug dynamics [5], the presence of solid nanoparticles can act as nucleation sites necessary for nucleation boiling as well as improving the thermal conductivity of the fluid [6]. Focusing on this important application, this paper is intended to present experimental tests of a PHP configured as an open loop, using water as the working fluid and its related nanofluid with copper nanoparticles. A comparison between the operation of this PHP is presented and discussed, showing the benefits upon using nanofluids in this application.

2. Water-copper nanofluid

The nanofluid is composed of a pure substance, like water, with solid nanoparticles usually mixed with mass fractions from 1 to 5%. The nanoparticles are materials with size below 100 nm in diameter

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