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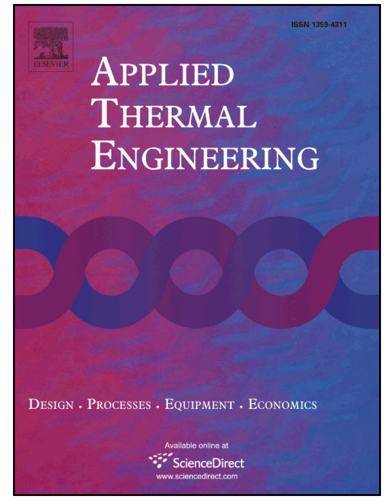

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Thermal Analysis and Entropy Generation of Pulsating Heat Pipes Using Nanofluids

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ABSTRACT
Demanding of high-performance cooling systems is one of the most challenging and virtual issues in the industry and Pulsating heat pipes (PHPs) are effective solutions for this concern. Nanofluids also have attracted attentions, due to its superior heat transfer properties in recent years. In the present study, the flow, heat transfer and entropy generation based on the second law of thermodynamics have been investigated and compared with the flow of Al_2O_3, CuO, Ag nanofluid and pure water through PHPs. The results show that, silver nanofluid provides the highest entropy generation. Also, the effects of different particle volume concentrations on the heat and flow characteristics of Al_2O_3 nanofluid have been studied. It is indicated that the optimal volume concentration of nanoparticles is about 0.5-1% to minimize the entropy generation and appropriate thermal operation.

Keywords: Pulsating heat pipe, Nanofluids, Heat transfer, Entropy generation

1. Introduction

High-tech industries provide systems with expanded features and lead to overheat flux, so it must be taken away by effective cooling equipments. Pulsating heat pipes (PHPs) are one of the most applicable devices with high heat transfer rate. Although in recent years many researchers have done experimental and numerical studies of flow and heat transfer of PHPs, the oscillation behavior of these devices has not identically figured out. Cheng and Ma developed the mathematical model of pulsating motion of PHPs [1]. They showed that in a multi-degree vibration of the system, the vapor plugs act like a linear spring. They concluded that the circulation occurring in the closed loop PHPs is generally due to the temperature difference of cooling and heating section. Jiansheng *et al.* showed that the non-uniform heating pattern accelerates the start-up of PHPs and increases the thermal resistance of the PHPs [2]. It recommended that the non-uniform heating pattern used for start–up and uniform heating pattern used when the device becomes steady. Aboutalebi *et al.* experimentally examined the effect of rotating speed on the operation of the PHPs [3]. The results show the higher thermal performance and reduction of thermal resistance in the rotating closed loop PHPs (RCLPHP). In 50% filling ratio, the circulation phenomenon occurs in all of the rotating speeds.
The poor thermal conductivity of conventional working fluids puts a limit on heat transfer. One way to enhance the thermal conductivity is suspending nanoparticles into the classic fluids such as water, oil and ethylene glycol, subsequently, the thermophysical properties of the fluid changes. It was introduced for the first time by Choi (1995) [4]. Many investigations are about the measurement of these properties. Most of these studies have been focused on modeling thermal conductivity of nanofluids [5, 6] and also there are several numerical and experimental investigations about convective heat transfer of nanofluids [7-15].
In order to simulate the heat and fluid flow, usually Eulerian-Eulerian single-phase (homogenous) and two-phase models are used [12-15]. In homogenous model, it is assumed that the particles and matrixes are in thermal equilibrium and the relative velocity between two phases is zero and the effective properties are used in the governing equations. According to the experimental studies, adding nanoparticles to the base fluids in an ultrasonic bath for 1.5 hour, the homogenous solution of nanofluids without particle sedimentation is observed [16]. Despite of single-phase model, the two-phase model is totally different. The interaction between solid-fluid phases, have been taken into account of the governing equations.
There are several investigations about the heat pipes utilizing nanofluids. Shafahi *et al.* studied thermal performance of a cylindrical and flat-shaped heat pipes analytically [17, 18]. She reported that by reducing of particle diameter, the thermal resistance decreases.