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Particle size effect on heat transfer performance in an oscillating heat pipe

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ABSTRACT

The effect of Al_2O_3 particles on the heat transfer performance of an oscillating heat pipe (OHP) was investigated experimentally. Water was used as the base fluid for the OHP. Four size particles with average diameters of 50 nm, 80 nm, 2.2 μm, and 20 μm were studied, respectively. Experimental results show that the Al_2O_3 particles added in the OHP significantly affect the heat transfer performance and it depends on the particle size. When the OHP was charged with water and 80 nm Al_2O_3 particles, the OHP can achieve the best heat transfer performance among four particles investigated herein. In addition, it is found that all particles added in the OHP can improve the startup performance of the OHP even with 20 μm Al_2O_3 particles.

1. Introduction

Utilizing the thermally-excited oscillating motion and phase-change heat transfer, the oscillating heat pipe (OHP) transports heat from the evaporator to condenser. Comparing with the conventional heat pipe, the OHP has a number of unique features: (1) An OHP is an "active" cooling device that converts heat from the heat generating area into the kinetic energy of liquid plugs and vapor bubbles to initiate and sustain the oscillating motion. (2) The liquid flow does not interfere with the vapor flow because both phases flow in the same direction. (3) The thermally-driven oscillating flow inside the capillary tube effectively produces some free surfaces that significantly enhance evaporating and condensing heat transfer. (4) The oscillating motion in the capillary tube significantly enhances the forced convection in addition to the phase-change heat transfer. And (5) as the input power increases, the heat transport capability of an OHP dramatically increases. Because of these features, extensive investigations of OHPs [1–12] have been investigated since the first OHP developed by Akachi in 1990 [1]. These investigations have resulted in a better understanding of fluid flow and heat transfer mechanisms occurring in OHPs.

Most recently, it was found that when nanoparticles [13,14] or microparticles [15] were added into the base fluid in an OHP, the heat transport capability can be increased. The thermally-excited oscillating motion in the OHP can make the particles suspend in the base fluid. Although the nanoparticles added on the base fluid cannot largely increase the thermal conductivity [14], the oscillating motion of particles in the fluids might have additional contribution to the heat transfer enhancement in addition to the thermal conductivity. In 2006, Ma et al. [13,14] charged the nanofluids (HPLC grade water and 1.0 vol.% diamond nanoparticles of 5–50 nm) into an OHP and found that the nanofluids significantly enhance the heat transport capability of the OHP. The investigated OHP charged with diamond nanofluids can reach a thermal resistance of 0.03 °C/W at a power input of 336 W. In 2008, Lin et al. [16] charged the sliver nanofluids with a diameter of 20 nm into an OHP and proved that the nanofluids can improve the heat transport capability of OHPs. With a filling ratio of 60%, the OHP can achieve a thermal resistance of 0.092 °C/W for their OHP. In 2010, Qu et al. [17] conducted an investigation of the effect of spherical 56 nm Al_2O_3 particles on the heat transport capability in an OHP, and found that the Al_2O_3 particles can enhance heat transfer and an optimal mass fraction exists. Although these investigations have demonstrated that the particles can enhance heat transfer in an OHP, it is not known whether there exists an optimum particle size for a given type of particles.

In the current investigation, the particle size effect on the heat transfer performance of an OHP was investigated experimentally. Water was used as the base fluid. Four size particles with diameters of 50 nm, 80 nm, 2.2 μm, and 20 μm were studied in order to determine whether the optimum particle size exists for the maximum heat transport capability of the OHP.

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