Influence of nanoparticle concentrations on flow boiling heat transfer coefficients of Al_2O_3/R141b in micro heat exchanger by direct metal laser sintering

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Influence of nanoparticle concentrations on flow boiling heat transfer coefficients of Al_2O_3/R141b in micro heat exchanger by direct metal laser sintering

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Abstract: Al_2O_3/R141b+Span-80 nanorefrigerant for 0.05 to 0.4 wt% is prepared by ultrasonic vibration to investigate the influence of nanoparticle concentrations on flow boiling heat transfer of Al_2O_3/R141b+Span-80 in micro heat exchanger by direct metal laser sintering. Experimental results show that nanoparticle concentrations have significantly impact on heat transfer coefficients by homogeneity test of variances according to mathematical statistics. The heat transfer performance of Al_2O_3/R141b+Span-80 nanorefrigerant is enhanced after adding nanoparticles in the pure refrigerant R141b. The heat transfer coefficients of 0.05, 0.1, 0.2, 0.3 and 0.4 wt% Al_2O_3/R141b+Span-80 nanorefrigerant respectively increase by 55.0%, 72.0%, 53.0%, 42.3% and 39.9% compared with the pure refrigerant R141b. The particle fluxes from viscosity gradient, non-uniform shear rate and Brownian motion cause particles to migrate in fluid especially in the process of flow boiling. This migration motion enhances heat transfer between nanoparticles and fluid. Therefore, the heat transfer performance of nanofluid is enhanced. It is important to note that the heat transfer coefficients nonlinearly increase with nanoparticle concentrations increasing. The heat transfer coefficients reach its maximum value at the mass concentration of 0.1% and then it decreases slightly. There exists an optimal mass concentration corresponding to the best heat transfer enhancement. The reason for the above phenomenon is attributed to nanoparticles deposition on the minichannel wall by Scanning Electron Microscopy observation. The channel surface wettability increases during the flow boiling experiment in the mass concentration range from 0.2 to 0.4 wt%. The channel surface with wettability increasing need more energy to produce a bubble. Therefore, the heat transfer coefficients decrease with nanoparticle concentrations in the range from 0.2 to 0.4 wt%. In addition, a new correlation has been proposed by fitting the experimental data considering the influence of mass concentrations on the heat transfer performance. The new correlation can effectively predict the heat transfer coefficient.

Key words: Nanoparticle; Concentration; Minichannel; Sintering; Flow boiling; Heat transfer coefficient

1. Introduction

In recent decades, electronic equipment trends for integration with the development of science and technology. More heat is produced in the unit area and the conventional cooling technology has been unable to dissipate large amounts of heat from small surface areas. As a consequence, cooling systems with liquid have been increasingly developed [1].

Since Choi firstly proposed nanofluid which was defined as suspensions of nanoparticles into base fluid [2], nanofluid has attracted many researchers around the world as a significant alternative to enhance the heat transfer performance [3-9]. Due to large specific surface areas of nanoparticles, nanofluid possess superior the heat transfer properties such as high thermal conductivity and long-term stability.

References [10-14] show that thermal conductivity and heat transfer performance could be enhanced by suspending nanoparticles in a base fluid. These studies mainly concentrated on the influence of thermophysical properties and nanoparticle concentrations of nanofluid on the heat transfer. For example, Peng et al. [15] studied the influence of particle parameters and surfactant on aggregation behavior of nanoparticles in refrigerant and found that the primary size and surfactant of particle had an influence on the steady-state hydrodynamic diameter. It indicated that the particle parameter of suspended nanoparticles in nanofluid had significantly impact on heat transfer. Omer's study found that the thermal conductivity and specific heat capacity of nanofluid increased with the augmentation of fluid temperatures [16]. Consequently, thermophysical properties have an impact on the heat transfer performance.

There are a few literatures studied the influence of nanoparticle concentrations on heat transfer characteristics [17-20]. Mahbubul et al. studied the