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Investigations on the pool boiling heat transfer and critical heat flux of ZnO-ethylene glycol nanofluids

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ABSTRACT

Surfactant free and fairly stable ZnO-ethylene glycol (EG) nanofluids are prepared using prolonged sonication (>60 h). Extended period of sonication results in superior fragmentation and dispersion of ZnO nanoparticles, as is evident from the DLS data. Thermal conductivity of the prepared nanofluid displays a maximum enhancement of 40% for 3.75% volume fractions of ZnO loading in EG at 30 °C. The nucleate pool boiling heat transfer characteristics of ZnO-EG nanofluids with various loading of ZnO nanoparticles are measured at atmospheric pressure employing a cylindrical polished copper heater surface. The boiling heat transfer coefficient enhances with ZnO concentration and attains a maximum of 22% compared to that of base fluid for ZnO volume fraction of 1.6%. However, further loading of ZnO nanoparticles in EG decreases the heat transfer coefficient. Critical heat flux measurements are performed with a thin Constantan wire. CHF value appreciably increases with increasing ZnO loading and displays a maximum enhancement of ~117% for nanofluid containing 2.6% volume fractions of ZnO.

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1. Introduction

Boiling is an effective method of heat removal used in a variety of phase change heat exchanger like boilers, evaporators, etc. Boiling phenomena of fluids are important for systems which are characterized by ultra high heat flux in a compact volume. This has prompted the researchers to try various methods for enhancing the rate of boiling heat transfer, especially in the nucleate boiling regime. Nanofluids containing homogeneously dispersed solid nanoparticles in a liquid show significant enhancement in thermal conductivity [1-3] and thereby possess potential for improved heat transfer during convection [4,5]. These initial findings encouraged the researchers to investigate the scope and application of nanofluids for boiling heat transfer. The nucleate boiling depends on several factors, such as, heater wall superheat, heater surface materials and morphology, presence of dissolved gases, fluid thermo-physical properties, presence of nucleation sites and the rate of bubble growth etc. Critical heat flux (CHF) in pool boiling is defined as the peak heat flux under which a boiling surface can sustain nucleate boiling. On attaining the CHF, transition from nucleate boiling regime to film boiling regime occurs, which is undesirable and causes temperature of the heated surface to reach the melting point. Therefore, an enhanced CHF is advantageous not only for increasing the safety margin of the thermal system, but also to design compact and efficient cooling systems required for electronic devices, nuclear and chemical reactors, air conditioning, etc.

A survey of the published literatures indicates a fair consensus that aqueous nanofluids improve CHF compared to water [6]; however, there exist conflicting reports on the boiling heat transfer coefficient (HTC) of nanofluids. Taylor et al. [7] provided a comprehensive review of nanofluid pool boiling. The recent review by Barber et al. [8] on boiling heat transfer of nanofluids incorporate a concise and fair account of the advantages and limitations of nanofluids in respect of their boiling performance and application. The pool boiling behavior for low concentration nanofluids (<1 g/L) has been studied by Kwark et al. [9] over a flat heater under atmospheric pressure. They [9] observed an optimal concentration of particle loading beyond which the boiling HTC decreased but the CHF remained constant. The mechanism of formation of nanoparticle coating on heater surfaces during nanofluid boiling was suggested [9] as due to microlayer evaporation.

Many researchers [10-14] demonstrated a decrease in HTC, while others [7,15–19] observed a fairly large increase. Examples of no effect on HTC of nanofluids are also reported [20-22]. Nearly 60% enhancement in HTC for Al₂O₃-water nanofluids on a heated copper block was reported by Shi et al. [16], while Bang et al. [10]





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