

Flow Loop Experiments Using Polyalphaolefin Nanofluids

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Experiments were performed using a flow-loop apparatus to explore the performance of nanofluids in cooling applications. The experiments were performed using exfoliated graphite nanoparticle fibers suspended in polyalphaolefin at mass concentrations of 0.6 and 0.3%. The experimental setup consisted of a test section containing a plain offset fin cooler apparatus (gap or nongap fin), which was connected to a flow loop consisting of a gear pump, a shell and tube heat exchanger (that was cooled or heated by a constant temperature bath chiller/heater), and a reservoir. Experiments were conducted using nanofluid and polyalphaolefin for two different fin strip layouts. Heat transfer data were obtained by parametrically varying the operating conditions (heat flux and flow rates). The heat transfer data for nanofluids were compared with the heat transfer data for neat polyalphaolefin fluid under similar conditions. The change in surface morphology of the fins was investigated using scanning electron microscopy. The nanofluid properties were measured using rheometry for the viscosity, differential scanning calorimetry for the specific heat, and laser flash apparatus for the thermal diffusivity. It was observed that the viscosity was ~ 10 times higher for nanofluids compared with polyalphaolefin and increased with temperature (in contrast, the viscosity of polyalphaolefin decreased with temperature). The specific heat of nanofluids was found to be 50% higher for nanofluids compared with polyalphaolefin and increased with temperature. The thermal diffusivity was found to be 4 times higher for nanofluids compared with polyalphaolefin and increased with temperature. It was found that, in general, the convective heat transfer was enhanced by $\sim 10\%$ using nanofluids compared with using polyalphaolefin. Scanning electron microscopy measurements show that the nanofluids deposit nanoparticles on the surface, which act as enhanced heat transfer surfaces (nanofins).

Nomenclature

A	=	area
A_c	=	area of cross section
A_h	=	heating area
C_p	=	specific heat capacity
D	=	hydraulic diameter
h	=	heat transfer coefficient
k	=	thermal conductivity
k_{fin}	=	thermal conductivity of fin material
L	=	length of pipe or tube
l	=	liquid property
l_1	=	length of fin
m	=	mean value
Nu	=	Nusselt number
n	=	number of fins
nf	=	properties of nanofluid
n_f, n_{st}	=	number of fins in each row and column
P	=	perimeter
Pe	=	Peclet number
Pr	=	Prandtl number
Q, q	=	total heat transfer rate, heat flux

Re	=	Reynolds number
s	=	fin parameter, surface property
T	=	temperature
U	=	mass averaged velocity
α	=	thermal diffusivity
κ	=	thermal conductivity
μ	=	viscosity
ρ	=	density
ϕ	=	volume fraction
Ω	=	forced convective heat transfer parameter

I. Introduction

NANOFUIDS are colloidal solvents containing dispersed nanometer (~ 10 – 100 nm) sized particles [1]. Nanofluids have been discovered to enhance the conductivity of solvents at low concentrations ($< 4\%$) as the size of the particles is decreased [2]. Large variations in thermal conductivity have been reported in the literature for various nanofluid compositions, that is, solvent type, pH of aqueous solvents, stabilizers (e.g., surfactants), material of the nanoparticles, concentration of the nanoparticles, size, and aspect ratio of the nanoparticles [3]. The enhancements in the thermal conductivity of the nanofluids were found to be higher than predicted by the classical theories [4,5]. These theories were proposed for heterogeneous colloidal mixtures of micron-scale particles in solvents. Several mechanisms have been proposed to account for the aberrant (or anomalous) behavior of the thermal conductivity of nanofluids [2,3].

A review of the recent literature and of the recently proposed theories suggests that localized Brownian convection is potentially the dominant mechanism responsible for the observed increase in thermal conductivity [6]. A comprehensive examination of the literature for aqueous nanofluids also shows a potential trend for maxima in the thermal conductivity of 10–50 nm diameter spherical nanoparticles [6,7]. This maxima is primarily governed by the competing effects of two transport resistances: 1) convective–conductive resistance arising from Brownian convection [6], and

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