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New thermophysical properties of water based TiO_2 nanofluid—The hysteresis phenomenon revisited ☆

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ABSTRACT

Homogeneous stable suspensions acquired by dispersing dry Al_2O_3 and TiO_2 nanoparticles in controlled pH solution and distilled water, respectively, were prepared and investigated in this study. First of all, the mean nanoparticle diameters were studied by dynamic light scattering (DLS) technique, and the nanofluid stability was analyzed by zeta potential measurements. The nano-crystalline structures were characterized by scanning electron microscope and transmission electron microscope. The rheological behavior was determined for both nanofluids at nanoparticle volume concentrations up to 0.3%. The effect of temperature for the heating and cooling phases was analyzed from 25 °C to 80 °C. Furthermore, the influence of temperature, pressure drop, pumping power, zeta potential, size and densities were analyzed for fresh prepared samples as well as for samples used in a flat plate solar collector over a period of 30 days. The thermal conductivity enhancement of the two nanofluids demonstrated a nonlinear relationship with respect to temperature and volume fraction, with increases in the volume fraction and temperature. All resulted in an increase in the measured enhancement. Existence of a critical temperature was observed beyond which the particle suspension properties altered drastically, which in turn triggered a hysteresis phenomenon. The hysteresis phenomenon on viscosity measurement, which is believed to be the first observed for Al_2O_3/water and TiO_2/water-based nanofluids, has raised serious concerns about the use of nanofluids for heat transfer enhancement. The pressure drop and pumping power of the nanofluid flows are found to be very close to those of the base liquid for low volume concentration. It may be concluded that nanofluids can be utilized as a working medium with a negligible effect of enhanced viscosity and/or density. Our findings provide a view on the thermo physical properties of nanofluids that is compared with that in the literature, and new findings (such as viscosity, hysteresis phenomenon and pumping power) have been presented, which are not available in literature as yet.

1. Introduction

Conventional fluids, such as water, engine oil, and ethylene glycol, are usually used as heat transfer fluids. Their poor heat transfer rate is understood as an obstacle for enhancing efficiency of heat exchangers. A novel type of heat transfer fluids called "nanofluids" is recognized for enhancement of heat exchanges for better performance. Nanofluids are two phase fluids where solid nanoparticles are immersed in base fluids. The main reason for this is to enhance the heat transfer characteristics of conventional fluids by improving their thermal conductivity. In the previous decade, nanofluids have achieved considerable devotion due to their enhanced thermal conductivities. In this regard, Eastman et al. [1] reported that the thermal conductivity of the conventional fluid upsurges by 40%, when 0.3% of copper nanoparticles were suspended in ethylene glycol. Pak and Cho [2] carried out an experimental work for the determination of forced convection heat transfer coefficients with 13 nm Al_2O_3 and 27 nm TiO_2 sub micron particles dispersed in water. For a fixed Reynolds number, the convective heat transfer coefficient was improved by 75% for an Al_2O_3 particle concentration of 2.78%. Heat transfer coefficients were also observed to increase with concentration. Such outcomes have driven both the industrial and scientific community to examine the heat transfer and rheological properties of nanofluids.

Abbreviations: FESEM, field emission scanning electron microscopy; SEM, scanning electron microscopy; TEM, transmission electron microscopy.

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