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Experimental investigation of the thermophysical properties of AL_2O_3-nanofluid and its effect on a flat plate solar collector ☆

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ABSTRACT

Experimental investigations have been carried out for obtaining the thermophysical properties of 60:40 (by mass) ethylene glycol/water mixture and water based alumina nanofluids. The effect of density and viscosity on the pumping power for flat plate solar collector has been investigated as well. Nanofluids of 0.05–0.1%v/v concentrations were prepared and characterized. Water based alumina nanofluids were found more preferable against sedimentation and aggregation than ethylene glycol/water mixture based nanofluids. The measured thermal conductivities of both types of the nanofluids increased almost linearly with concentration and are consistent in their overall trend with previous works done at lower concentrations by different researchers. In contrast to thermal conductivity, viscosity measurements showed that the viscosity of the Al_2O_3–water nanofluids exponentially decreases with increasing temperature. Furthermore, the measured viscosities of the Al_2O_3–water nanofluids showed a non-linear relation with concentration even in the low volume concentration except 0.05%v/v at below 40 °C. On the other hand, Al_2O_3–EG/water mixture exhibited Newtonian behavior. 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 EG/water-based nanofluids, has raised serious concerns regarding the use of nanofluids for heat transfer enhancement purposes. Results suggest that nanofluids can be used as a working medium with a negligible effect of enhanced viscosity and/or density. Results also show that the pressure drop and pumping power of the nanofluid flows are very close to that of the base liquid for low volume concentration.

1. Introduction

Conventional fluids, such as water, engine oil, and ethylene glycol are normally used as heat transfer fluids. Their poor heat transfer rate is now realized as an obstacle for improving efficiency of heat exchangers. New type of heat transfer fluids called “nanofluids” is now developed for the sake of improvement of heat exchangers' performance. Nanofluids are two phase fluids where solid nanoparticles are suspended into base fluids. The key idea to improve the heat transfer characteristics of conventional fluids is by enhancing their thermal conductivity. In the last decade, nanofluids have attained substantial attention due to their thermal conductivity properties. According to Eastman et al. [1], the thermal conductivity of the conventional fluid increases by 40%, when 0.3% of copper nanoparticles are suspended in ethylene glycol. For a fixed Reynolds number, the convective heat transfer coefficient increased by 75% for an Al_2O_3 particle concentration for 2.78% was reported by Pak and Cho [2]. Such results have motivated both the industrial and science community to investigate the heat transfer and rheological properties of nanofluids.

Notable attention has been given to solar energy in the recent years. The use of fossil fuels will be limited due to their shortage in reserve as well as for environmental considerations. As a result, the situation is motivating researchers to find other possible sources of energy. Heat transfer enhancement in solar thermal collectors is one of the key issues of energy saving and compact design. Solar thermal energy is widely used for various applications, such as electricity generation, chemical processing, and thermal heating, due to its renewable and nonpolluting nature [3]. Reports on using nanofluids as heat transfer fluids in solar collectors are few in number up to date [4–8,56].

Al_2O_3-based nanofluids are essential because of their availability and unique thermal properties. Al_2O_3 nanofluids which are prepared by two-step method using ultrasonic vibrator result unstable. Different approaches have been chosen by a number of researchers for preparing stable nanofluids by using various surfactants, optimizing the pH, temperature for various nanofluids, and by surface modification of the particles. Reports on Al_2O_3-based nanofluids prepared by high pressure homogenizer are very few [9,10].

With the addition of nanoparticles an increment in the thermal conductivity is observed from all the experimental results. Also, comparison

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