Investigations on Thermal Conductivity, Heat Transfer Coefficient and Viscosity of Graphite Nanoparticle Dispersed Nanofluid

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The thermal conductivity ($k$), heat transfer coefficient (HTC) and viscosity of the ethylene glycol/water dispersed with graphite nanoparticles was studied under heating and cooling conditions for temperatures ranging from 0 °C to 75 °C using tubular heat exchanger system built in house. Flow rate was varied from 5 l/h to 25 l/h giving Reynolds number ($Re$) ranging from 50 to 750. The HTC increased with the increase of $Re$ as well as temperature. The thermal conductivity of the nanofluid was determined at constant low $Re$ (200) for all concentrations and temperatures used in the experiment. The concentration dependence of thermal conductivity was found to be much different than that predicted by models suggested in literature. The viscosity was measured for different concentrations of nanoparticles (0 to 0.8%) as well as temperatures 275 K to 340 K. The temperature dependence of viscosity was found to follow Arrhenius type equation $\eta = \eta_0 \exp(E/k_BT)$ with very little change in the activation energy from that of the base fluid. On the other hand the pre-exponential constant increased six folds with the increase in nanoparticle concentration. An empirical relation derived from Brownian motion was found between the product of viscosity and thermal conductivity ($\Omega = k \cdot \eta$) with respect to concentration of the nanoparticles which was found to be true for whole range of temperature and compositions studied.

KEYWORDS: Nanofluid, Graphite Nanofiber, Heat Transfer Coefficient, Thermal Conductivity, Viscosity.

1. INTRODUCTION

The efficient heat exchangers are needed for industries, power plants, refrigeration systems, air conditioning systems, radiators, etc. Good heat transfer properties of coolant are needed for high efficiency of heat exchangers. The conventional coolants have several drawbacks such as low thermal conductivity, low heat carrying capacity and improper flow. Nanofluids which are based on the addition of suitable nano particles made of metals, metal oxides or carbon based materials such carbon nanotube, into the base fluid have been extensively studied in recent years.1–5

Even a small amount (<1% volume fraction) of Cu particles or carbon nanotubes dispersed in ethylene glycol or oil is reported to increase the inherently poor thermal conductivity of the liquid by 40% and 150%, respectively.6,7

There are several review articles published8–12 on the theory and experiments on nanofluids. These indicate the great potentials for applications of nanofluids in many fields which have been demonstrated by several authors.

Despite all these efforts, there are hardly any studies on practical applications such as automotive engine coolant, thermic fluid or refrigerants. It should be pointed out that many of the earlier studies are related to copper oxide, aluminium oxide, silica, iron oxide etc. which do not possess as high thermal conductivity as metals or graphite. In fact, graphite has very high thermal conductivity comparable to that of metals. Considering these aspects, we have chosen in the present studies, commercial automotive coolant (based on ethylene glycol + water mixture) as the base fluid and graphite nanoparticle as the additive. From practical application point of view, it is essential to study the heat transfer characteristics both above as well as below room temperature which has been carried out in these studies.

Another important factor in nanofluid is the viscosity which depends on temperature. This parameter becomes important especially at low temperatures and needs to be addressed especially for automotive coolants. Not many studies are reported for the temperature dependence of viscosity of nanofluids especially at low temperature. Nguyen et al.13 have reported temperature and particle size dependence of viscosity in water based nanofluids. Prasher et al.14 found that the viscosity of nanofluids is extremely

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