Heat Transfer Properties of Nanodiamond-Engine Oil Nanofluid in Laminar Flow

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Abstract

In the present paper, the effects of adding nanodiamond to the engine oil on heat transfer enhancement are investigated. A smooth tube was used as the test section and was heated by an electrical coil heater to produce a constant heat flux. Thermal conductivity and heat capacity of nanofluids were measured for various volume concentrations and temperatures. In addition, convection heat transfer coefficient of nanofluid was obtained for different nanoparticle concentrations as well as various Reynolds numbers. Experimental results clearly indicate the heat transfer augmentation due to the presence of nanoparticles in the base fluid.

Keywords: Nanofluid, Thermal conductivity, Heat transfer, Laminar flow

Introduction

Traditional heat transfer fluids such as water, ethylene glycol and oil have inherently low thermal conductivity relative to metals and even metal oxides. Therefore, fluids with suspended solid particles are expected to have better heat transfer properties compared to conventional heat transfer fluids. Modern technology makes it possible to produce ultra fine metallic or nonmetallic particles of nanometer dimensions, which makes a revolution in heat transfer enhancement methods.

The term of nanofluid was firstly used by Choi [1]. Nanofluids found to possess long time stability and large efficient thermal conductivity [2]. For example Lee [3] reported that suspension of 4% volume fraction of CuO 35 nm particles in ethylene glycol shows 20% increase in thermal conductivity.

There are relatively few studies involved in describing fluid flow and convective heat transfer performance of the nanofluids. Li and Xuan [4] studied convective heat transfer of 35 nm Cu/ water nanofluid and showed that the suspended nanoparticles remarkably enhance heat transfer process with smaller volume fraction of Cu nanoparticles.

In the present research, experimental investigations have been carried out to study the effect of using nanofluid in heat transfer augmentation.

Experimental facility and procedure

Figure 1 shows the schematic diagram of experimental set-up. The flow loop consists of test section, cooler, receiver, gear pump, flow measuring apparatus, various thermocouples and flow controlling system. In order to control the fluid flow rate a reflux line with a valve was used. The test section was a copper tube of 1.02 m long and 6mm inner diameter. The nanofluid flowing inside the tube was heated by an electrical heating coil wrapped around it. The test section (tube and heater) was completely insulated with glass wool pads. Two K-type thermocouples were used to measure the bulk temperatures of nanofluid flow at inlet and outlet of test section. Also, six K-type thermocouples were mounted on the external surface of the test tube to measure wall temperature..

In order to measure the total pressure drop of flow across the test section, a high precision differential pressure transmitter (PMD-75) was employed.

Flow measuring section consisted of 300 cm^3 glass vessel with a valve in bottom. Flow rate was measured directly from time required to fill the glass vessel.

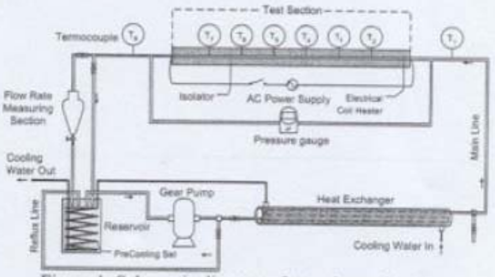

Figure 1: Schematic diagram of experimental set-up.

In this study, nanodiamond-engine oil nanofluid was used as the working fluid. The heat fluxes exerted were 5, 14 and 26 kW/m^2 with Reynolds numbers varying from 2 to 100.

Furthermore, the thermal conductivity of nanofluids was measured using KD2 apparatus which is based on the Hot Wire method. The thermal conductivity of nanofluids with different weight fractions was measured in different temperatures changing from 28 °C to 50 °C.

Results and Discussion

In present study nanofluids with different concentrations of diamond nanoparticles including 0.2%, 0.5%, 1.0%, and 2.0% volume fractions in 20W50 engine oil were used. The nanofluid was prepared and dispersed using mechanical (ultrasonic vibrator) and chemical (adding dispersant) treatments. A SEM image of the nanoparticles can be seen from Figure 2.

The variation of thermal conductivity coefficient with weight fraction is shown in figure 4. These thermal conductivities are measured in the room temperature of 29°C. As it can be noted, thermal conductivity increases with increasing volume fraction. For these data, the correlation can be obtained

$$k_{ef} = 0.126 + 0.074\varphi - 0.056\varphi^2 + 0.015\varphi^3$$

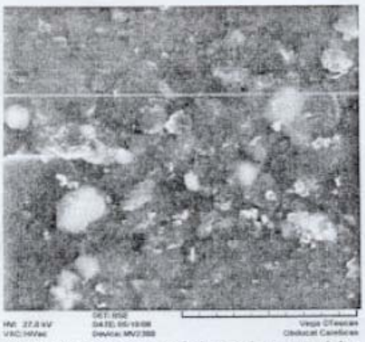

Figure 2: SEM image of diamond nanoparticles

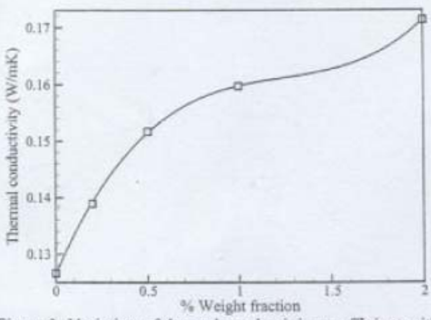

Figure 3: Variation of thermal conductivity coefficient with volume fraction in room temperature

Moreover, utilizing nanofluid led to a great increment in heat transfer. This increment is more for greater Reynolds numbers. Nusselt number and heat transfer coefficient, which are the parameters of heat transfer, are studied. Figure 4 shows variation of mean heat transfer coefficient as a function of weight fraction in two Peclet numbers (Pe=10000 and Pe=15000) and heat fluxes (q''=5 and 26 kW/m^2). The effect of nanoparticles in enhancing heat transfer can be easily seen in this figure. In addition, one can note the effect of heat flux changes on the heat transfer coefficient.

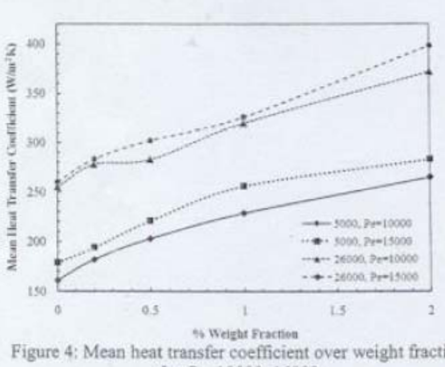

Figure 4: Mean heat transfer coefficient over weight fraction for Pe=10000, 15000

Conclusion

In this article, the effects of adding diamond nanopowders (Nanodiamond) to engine oil were considered. As primary parameters, thermal conductivity and heat capacity of the produced nanofluids were measured. After that, forced convection heat transfer of nanofluid flow through a horizontal smooth tube was investigated. Following conclusions are made on the basis of aforementioned sections:

1) Adding nanodiamond to engine oil significantly increased thermal conductivity of the base fluid (about 35% at most), it also increased heat capacity of the base fluid (about 20% at most).

2) Higher Reynolds (Peclet) numbers and higher heat fluxes lead to higher heat transfer coefficients.

3) Utilization of nanofluid as the coolant in the tube enhanced heat transfer around 60%. This enhancement was more in lower heat fluxes.

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