Heat Transfer And Pressure Drop of Nanofluids Containing Aluminium Oxide with Transformer Oil in Horizontal Pipe

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Abstract **– Nanoparticles are class of materials that demonstrate unique physical and chemical properties compared to those of the same material at the bulk scale. One method of enhancing the thermal conductivity, and hence the heat transfer coefficient, of a fluid is to add nanoparticles to the fluid creating a so called nanofluid. The tested nanofluids are prepared by dispersing Al_2O_3 into Transformer oil at different concentrations such as 0.1%, 0.2% and 0.5%. Than the properties like thermal conductivity, viscosity and density are measured to find out the thermo physical properties like specific heat, heat transfer coefficient and pressure drop with the help of certain equipments. Experimental results shows that thermal conductivity of nanofluids is higher than the that of base fluid and it is also increased with the increasing temperature by 2.1% (for 0.1% particle concentration), 2.6% (for 0.2% particle concentration, 4.5% (for 0.5% particle concentration). The results also show that viscosity and density of nanofluids are decreased with increasing temperature but with particles concentration the viscosity decreases but density increases. It is also observed that the Reynolds number with respect to Nusselts number also increases for the increasing particle concentration. It is found that with increase in flow rate of nanofluid heat transfer coefficient (h) is also increasing which will also result in increase in thermal conductivity of nanofluid. The heat transfer coefficient of nanofluid is also higher than base fluid at flow rates 30, 40 and 50 LPH.**

Keywords: Al_2O_3; heat transfer coefficient; thermal conductivity; particle concentration.

I. INTRODUCTION

With the recent advances in nanotechnology, the particles of the order of nanometers can be produced with great ease. As a result, the idea of suspending these nanoparticles in a base liquid for improving thermal conductivity had been proposed by Romano, Das [3, 4]. Such suspension of nanoparticles in a base fluid is called a nanofluid. Due to their small size, nanoparticles fluidize easily inside the base fluid, and as a effect, clogging up of channels and erosion in channel walls are no longer of a problem. It is even possible to use nanofluids in micro channels Buzea [7]. When it comes to the stability of the suspended particles, it was shown that sedimentation of particles can be prevented by utilizing proper dispersants.

The situation changed with the appearance of nanofluids. The concept of nanofluid was proposed by Singh et al. [1] as a fluid containing dispersed nanometer sized solid particles compared with the traditional fluids or suspensions containing coarse particles, nanofluids are having superior thermal properties. The small dimension and relatively large specific surface area of nanoparticles not only increase the stability of the suspensions, but also improve the heat transfer capabilities importantly.

Nanofluids (Nanoparticle fluid suspensions) is the term coined by Choi to describe this new class of nanotechnology based heat transfer fluids that demonstrate thermal properties superior to those of their host fluids or conventional particle fluid suspensions Granqvist [2]. These nanoparticles can possess properties that are substantially different from their parent materials. Similarly, nanofluids may have properties that are considerably different from their base fluids, like much higher thermal conductivity, among others Romano [3]. The goal of nanofluids is to achieve the highest possible thermal properties at the smallest possible concentrations (preferably < 1% by volume) by uniform dispersion and stable suspensions of nanoparticles in host fluids. Three methods of generating these nanofluids are available: creating them from chemical precipitation , purchasing the nanoparticles in powder form and mixing them with the base fluid, and direct purchase of prepared nanofluids.

II. EXPERIMENTAL DISCUSSION

2.1 Material and nanofluid preparation.

Transformer oil and aluminum oxide (Al_2O_3) were used to prepare nanofluids. The aluminum oxide were provided by Intelligent Materials Pvt Ltd Panchkula and were used same as received. Nanofluids were prepared by two step method i.e by dispersing nanoparticles in base fluid i.e transformer oil. Volume concentration's were made 0.1% , 0.2% and 0.5% by dispersing in 0.1945 gm, 0.389 gm and 0.9725gm of nanoparticles in 50 ml of transformer oil with surfactant oleic acid 2ml used so that nanoparticles are completely dispersed. Sonication was used to make nanoparticles more stable in transformer oil and it is done for 1 hour 30 min each so that to attain more stability before measuring thermal conductivity and viscosity of nanofluids.

2.2 Measurement of thermal conductivity and viscosity of Al_2O_3 nanofluids.

To find out heat transfer coefficient the effective thermal conductivity and viscosity is required. KD2 pro thermal meter is required to measure thermal conductivity which is hot transient wire based method. The KD2 Pro is a fully portable field and lab thermal properties analyzer. It uses the transient live heat source method to measure, volumetric specific heat capacity and diffusivity. It has been designed for ease of use a maximum funtionality. This devise is much more than a simple readout for time and temperature. This fully mathematical solution delivers thermal conductivity/resistivity to within ±10 %. The viscosity is measured by the Cone and Plate type Brookfield programmable viscometer (model: LVDV-III-Pro). The measurements were done at different concentrations like 0.1%, 0.2% and 0.5% of nanofluids connected to a temperature controlled bath which can vary the fluid temperature between -10 0C and 100 0C. The schematic of the viscosity measurement set-up is shown in the figure 3.7. The spindle used in the setup is CPE-42. This viscometer has a viscosity measurement range between 0.3 and 6000 cP. Total volume of nanofluid required in the flat cup for measurement is 1 ml. All the measurements are performed under steady state conditions. The speed can be varied from 0.01 to 250 rpm. The shear rate can be varied from 0 to 760 (1/s). The "gap" between the cone and the plate must be verified/ adjusted before measurements are made. This is done by moving the plate (built into the sample cup) up towards the cone until the pin in the centre of the cone touches the surface of the plate, and then by separating (lowering) the plate 0.0005 inch (0.013mm). The Brookfield DV-III Ultra Programmable Rheometer measures fluid parameters of Shear Stress and Viscosity at given Shear Rates. Viscosity is a measure of a fluid's resistance to flow. The principle of operation of the DV-III Ultra is to drive a spindle (which is immersed in the test fluid) through a calibrated spring.

2.3 Experimental setup for measuring the convective heat transfer coefficient.

The experimental setup used for measuring heat transfer coefficient is similar to the one used by Wen and Ding [5], and is shown schematically in Fig.1. It is consists of flow loop, heating unit, cooling unit and measuring and controlling unit. The flow loop consists of pump, flow meter, test section and collection tank. A straight copper tube of length 1.5 m, inner diameter 0.0127 m and outer diameter 0.0095 was used as test section. There are 8 PRT's heated thermocouples in the test section each thermocouple is placed at calculated distance to obtain surface temperature of wall. And two PRT's thermocouples are placed as inlet and outlet to measure the bulk mean temperatures of nanofluid. The cooling unit used in this setup is known as shell and tube heat exchanger it is the most common type of heat exchanger used in thermal industries. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it.

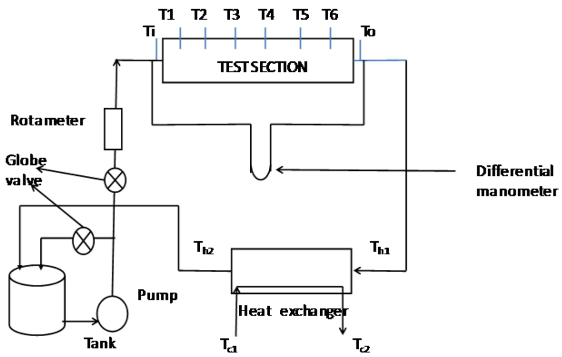


Fig. 1 Schematic diagram of setup

The convective heat transfer coefficient (h) is defined as:

$$H(x) = q / (T_w(x) - T_f(x)) \quad (1)$$

where x represents axial distance from entrance of the test section, q is heat flux, T_w is measured wall temperature, T_f is the fluid temperature decided by the following energy balance:

$$T_f(x) = T_{in} + qSx / (\rho c_p uA) \quad (2)$$

Where c_p is the heat capacity, ρ is fluid density, A and S are respectively the cross sectional area and perimeter of the test section, and u is average fluid velocity.

The convective heat transfer coefficient (h) Eq. (1) is expressed in the form of nusselt number *defined as:*

$$Nu(x) = h(x)D / k \quad (3)$$

Where D is tube diameter, and k is fluid thermal conductivity. The Nu number is related to Reynolds number defined as $Re = \rho uD / \mu$ and the prandlt number $Pr = v/\alpha$, where v is fluid kinematic viscosity, α is the fluid thermal diffusivity, and μ is the dynamic viscosity.

III. RESULT AND DISCUSSION

3.1 Thermal conductivity of nanofluid.

Fig. 2 shows the effective thermal conductivity of nanofluid with three concentrations at different temperatures from 20º to 80º. The concentrations 0.1%, 0.2% and 0.5% with respect of transformer oil and 2 ml of oleic acid gives best stability. It can be seen that effective thermal conductivity increased with increase in temperature as well as increased with increase in concentration of particles. Thermal conductivity of nanofluid is more than base fluid (transformer oil). From this we concluded that temperature and concentrations are major parameter's with the help of which we find thermal conductivity of nanifluid. Experimental results shows that the thermal conductivity of nanofluid is higher than base fluids and is also increased with increasing temperature by 2.1% (for 0.1% concentration), 2.5% (for 0.2% concentration) and 4.5% (for 0.5% concentration). It should be noted that the base fluid used by choi et al. [6] is oil, which has much lower thermal conductivity than water.

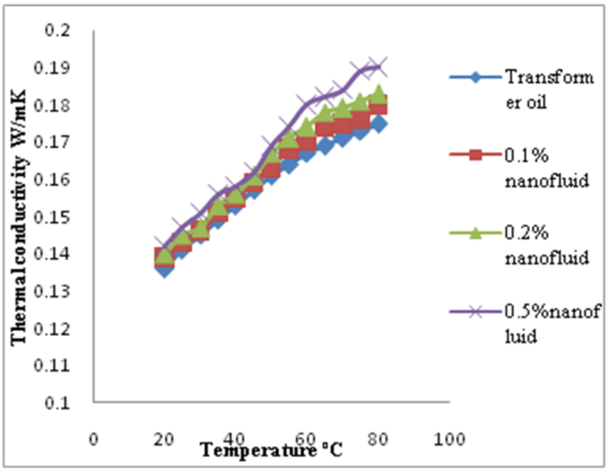


Fig.2 Thermal conductivities versus temperature

3.2 Viscosity of nanofluid.

The viscosity of nanofluid is measured by the Cone and Plate type Brookfield programmable viscometer (model: LVDV-III-Pro) connected to a temperature controlled bath which can vary the fluid temperature between -10 0C and 100 0C. The schematic of the viscosity measurement set-up is shown in the figure 3.7. The spindle used in the setup is CPE-42. This viscometer has a viscosity measurement range between 0.3 and 6000 cP. Total volume of nanofluid required in the flat cup for measurement is 1 ml. All the measurements are performed under steady state conditions. The speed can be varied from 0.01 to 250 rpm. The shear rate can be varied from 0 to 760 (1/s). The "gap" between the cone and the plate must be verified/ adjusted before measurements are made. This is done by moving the plate (built into the sample cup) up towards the cone until the pin in the center of the cone touches the surface of the plate, and then by separating (lowering) the plate 0.0005 inch (0.013mm). The Brookfield DV-III Ultra Programmable Rheometer measures fluid parameters of Shear Stress and Viscosity at given Shear Rates. Viscosity is a measure of a fluid's resistance to flow. The principle of operation of the DV-III Ultra is to drive a spindle (which is immersed in the test fluid) through a calibrated spring. The fig. 3 shows the variation in viscosity of different concentrations of nanofluid with respect to base fluid.

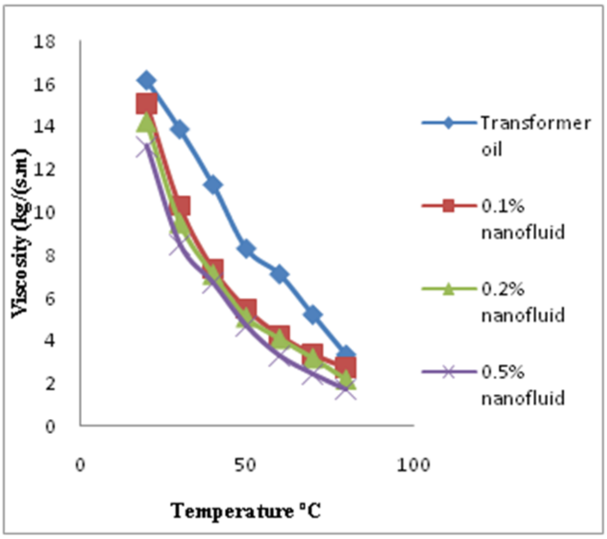
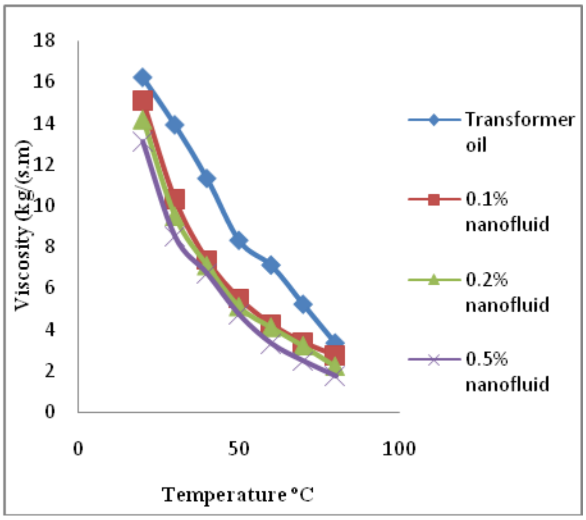


Fig. 3 Temperature versus viscosity of Nanofluid

From above graph it is concluded that as the temperature increases the viscosity of nanofluid and base fluid decreases. And as per the comparison of nanofluid and base fluid the viscosity of nanofluid is less than base fluid this shows that the nanofluids are less viscous than base fluids because of the nano particles (Al_2O_3) used in base fluids.

3.3 Density of nanofluid

The density of nanofluid is measured with the help of apparatus known as pycnometer. It is small bottle with capacity of 6.55 ml. At different temperature ranging from 32ºC to 80ºC density of three concentrations including base fluid is measured. It was found that 0.5% particle concentration has higher density than 0.1%, 0.2% and base fluid.



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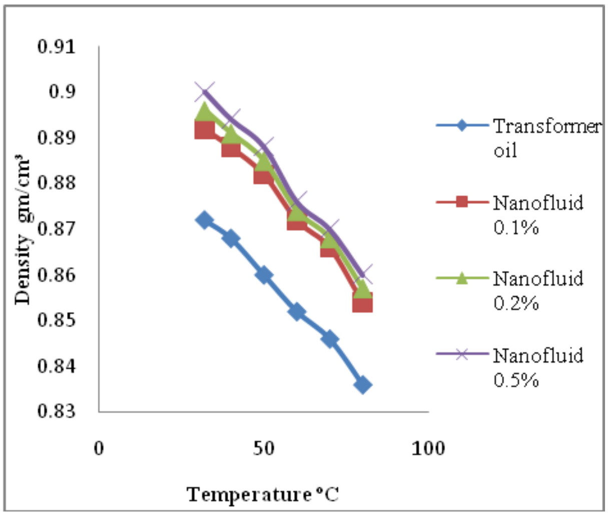


Fig.4 Temperature versus density of nanofluids

Convective heat transfer coefficient

3.3.1 Convective heat transfer coefficient of transformer oil

Before doing experiments with nanofluid the reliability and accuracy of experimental setup were tested using transformer oil as working fluid. The results are shown in fig.5 and are compared with the values of well known shah equations for laminar flows

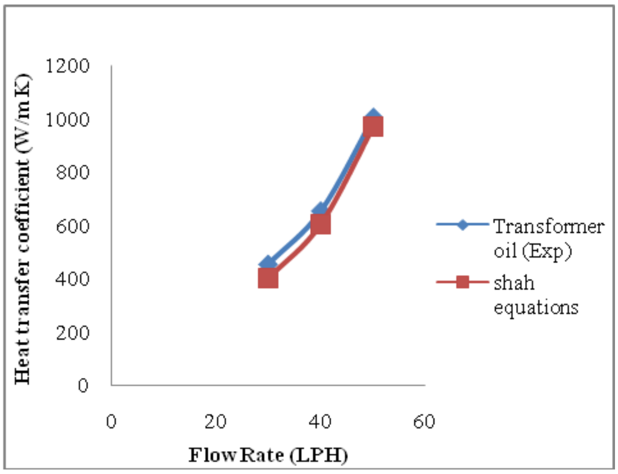


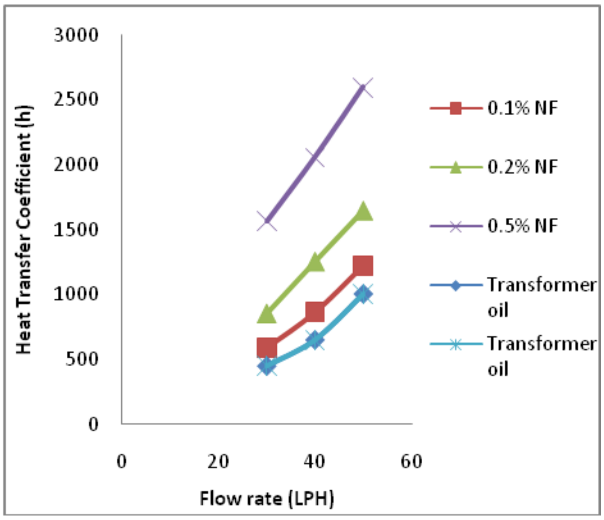
Fig 5 Heat transfer coefficient versus flow rate

Above graph shows the small change in heat transfer rate. Now in the further discussion results of nanofluids are going to be compared with base fluid.

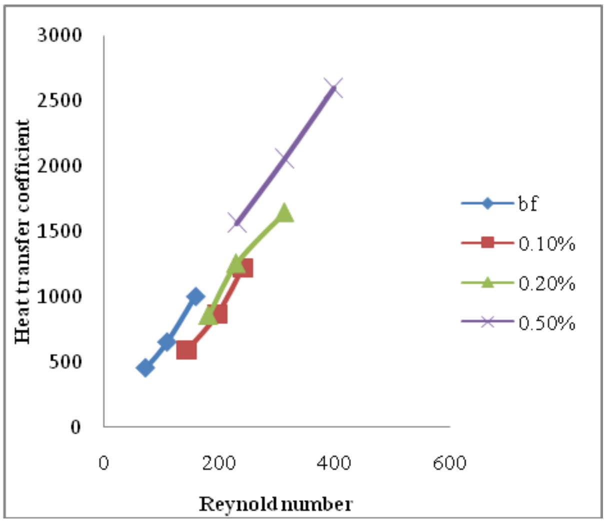
3.3.2 Convective heat transfer coefficient of nanofluid.

After establishing the accuracy of experimental setup, systematic experiments were performed at different flow conditions (Reynolds numbers), aluminium oxide nanofluid concentrations, and constant voltage. The results are further discussed in sub-sections. Reynolds number and nusselt number are calculated with the viscosity and heat transfer coefficient.

3.3.2.1 Effect of Al_2O_3 concentration on the convective heat transfer coefficient



(a)



(b)

Fig. 6 Comparison of heat transfer coefficient with different parameters (a) Heat transfer coefficient versus flow rates of nanofluid (b) heat transfer coefficient versus Reynolds number.

Fig 6(a) shows the effect of Al_2O_3 concentrations at different flow on convective heat transfer coefficient. As a result it is observed that as the flow is increased the heat transfer coefficient of nanofluid is higher than base fluid (Transformer oil). But if it is compared between nanofluid concentrations than 0.5 % concentration has more heat transfer coefficient than 0.1 % and 0.2 % concentrations.

The percentage increment is shown as below:-

1) For flow rate 30 LPH it can be see that nanofluid incremented 30.73% (for 0.1% conc.), 89.33% (for 0.2% conc.), 246% (for 0.5% conc.)
2) For flow rate 40 LPH the increment is 32.4% (for 0.1% conc.), 92.2%% (for 0.2% conc.), 215.63% (for 0.5% conc.)
3) For flow rate 50 LPH from the data the increment shown is 21.47% (for 0.1% concentration), 63.65% (for 0.2% conc.), 158.34% (for 0.5% concentration).

3.3.2.2. Effect of Reynolds number (flow conditions) on the convective heat transfer coefficient.

From the fig. 6(a) it is indicated that the heat transfer coefficient increases with increasing Reynolds number. At different concentrations there is massive increase in Reynolds number as compared with base fluid. The maximum Reynolds number achieved in 0.5% concentration is Re = 400 and the minimum Reynolds number achieved in base fluid is Re = 72. It is observed that the effect of heat transfer coefficient is maximum at Re = 400 at 0.5 % concentration but in case of transformer oil it is minimum at Re = 72.

4 Effect of pressure drop with flow rates

In this study, nanofluids with concentrations 0.1, 0.2 and 0.5 vol. % suspended particles are used to study the pressure drop test under laminar flow conditions. From the experimental data it is observed that the pressure drop of nanofluids is lower than pressure drop of transformer oil**.** When the flow rate is increased the pressure drop of nanofluid is also decreased. It can be observed from the fig.7 below.

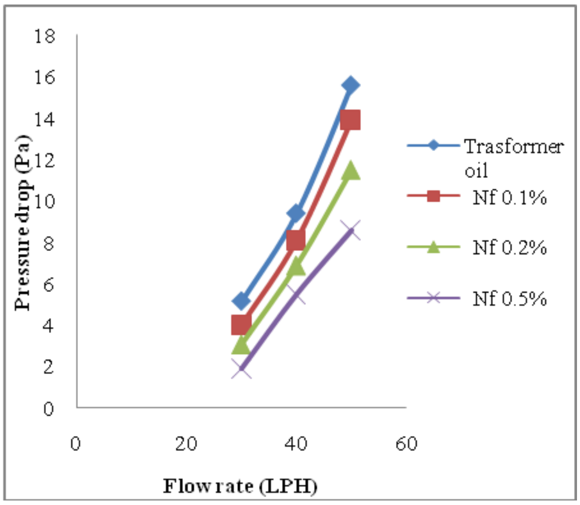


Fig 7 Pressure drop versus flow rates

IV. CONCLUSION

The theoretical and analytic results above are concluded in this chapter on the basis of performing experiments of thermo physical properties like Thermal conductivity , density , viscosity ,specific heat , Heat transfer coefficient and pressure drop and we will also discuss about the achievements which we accomplished from above experiments.

1) The obtained nanofluids by dispersion of nano-sized particles in the base fluid and then these colloidal solution was completely suspended with each other and then sonicated in ultra sonicator to give more stability.

2) The viscosity of heat transfer fluid was measured by the Cone and Plate type Brookfield programmable viscometer (model: LVDV-III-Pro) connected to a temperature controlled bath which can vary the fluid temperature between -10 ºC and 100 ºC. from the experiment we observed that nanofluids have lower viscosity and higher thermal conductivity at higher temperature. Viscosity and density both decrease with the increasing temperature but at different concentrations viscosity decreases and density increases.

3) The thermal conductivity of nanofluids and base fluid was measured with the instrument KD2 pro at different ranges of temperature. The experimental results gives the drastic change in enhancement of nanofluid as compare to base fluid with increase in the temperature. With the change is particle concentration the thermal conductivity of nanofluid is increased.

4) Oleic acid is used as very good surfactant element for nanoparticles to be dispersed completely in base fluid Transformer oil. In 3000 ml of nanofluid 4% of oleic acid is used for the stabilized dispersion of nanoparticles in basefluid.

5) It is also measured that the nusselts number with respect to flow rate and we found that with increase in flow rate the nusselts number of nanoparticle is increased with the change in concentration and it is also more than base fluid.

6) Reynolds number of nanofluid increases because the viscosity of nanofluid is less than base fluid and correspondingly with the increase in concentration reynolds number enhances.

7) The data for pressure drop shows that nanofluids have lower pressure drop as compared to base fluid with the change in flow rates. And also if the concentration of nanofluids is higher than the pressure drop will be lower.

8) The friction factor calculation of nanofluid and base fluid shows us that the friction factor of base fluid is higher as compared with three concentrations of nanofluid. But with the increase in flow rate gives us increment in friction factor of nanofluids.

9) From all the parameters and thermal properties of base fluid and nanofluid that the heat transfer coefficient (h) is incremented tremendously with high percentage. Higher the concentration of nanoparticles in nanofluids higher is the heat transfer coefficient (h) of nanofluids.

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