Study of Properties of Nanofluids and its Effect

Nikhil S. Nagulkar[1], Dr. S. M. Lawankar[2]

[1]*P.G. Student, Dept. of Mechanical Engineering Govt. Engineering College, Amravati, Maharashtra, India*
[2]*Assistant Professor, Dept. of Mechanical Engineering Govt. Engineering College, Amravati, Maharashtra, India*

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Abstract -*Enhancement of heat transfer coefficient to be an important research areas in various field of engineering. Heat transfer coefficient can be increases by using nanofluids in heat exchanger like Radiator. In this paper more focused on the heat transfer enhancement of Car radiator by using Nanofluid. Many researchers have done a lot of research on nanofluid technology and its applications in the heat transfer devices. This paper reviews the previously published literatures in this area. Nanofluid is the new generation fluid, it improves properties such as density, thermal conductivity, viscosity, specific heat of basic fluid in which nanoparticles added. The Prandtl number, Reynolds number and Nusselt number are functions of thermophysical properties of nanofluids and these numbers strongly influence the convective heat transfer coefficient. The thermophysical properties vary with temperature and volumetric concentration of nanofluids. Such as Density, specific heat, thermal conductivity and viscosity. Effect on prandlt number, Reynolds Number, heat transfer coefficient of different particle volumetric concentrations solutions are discussed in this paper.*

Key Words*:* *nanofluid, thermal conductivity viscosity, convective heat transfer, heat exchanger, radiator*

1. INTRODUCTION

Conventional coolants have been widely employed to dissipate heat in majority of the engineering applications. Typical coolants include matter in all three states namely solid, liquid and gas based on the requirements of application and possible mode of heat transfer. However, with the latest technological advancements, an emerging class of new coolants namely nano-coolants (coolants with dispersed nano-particles) find their applications in a variety of engineering application and they are expected to replace conventional coolants in the near future. A typical Nano fluid is prepared by dispersing certain types of selected nano-particles in a suitable base fluid (water, ethylene glycol and coolant) with different volume concentrations; the specific advantage of Nano fluids includes enhanced thermal properties when compared to the base fluid. Mixing of additives in coolants has been in use from decades to enhance the heat transfer and reduce the pressure drop along the flow. There has been more attention toward to increase convective heat transfer rate of nanofluid particle having size less than 100nm.

Xuan et al. [1] measured the thermal conductivity of Cu/water nanofluids with hot wire method. They studied the effect of various parameters such as particle volume fraction, size and properties of nanoparticles on the thermal conductivity and revealed that thermal conductivity was highly dependent on these parameters. They concluded that for 2.5 % to 7.5 % nanoparticle volume fraction, the thermal conductivity was increased by factor of 1.24 to 1.78.

Kakaç et al. [2] reviewed that heat transfer capabilities of ordinary fluids such as water, oils and ethylene glycol can be increased significantly by addition of nanoparticles. They marked the importance of heat transfer fundamentals for a diverse advancement in the field of nanotechnology. Theoretical and experimental understanding of microscopic particle mechanism is vital.

Vajjha et al. [3] studied the effect of Al2O3 and CuO based nanofluids on the performance of an automobile radiator. Base fluid used was the mixture of water and ethylene glycol. Radiator under consideration was employed with flat tubes. Experiments were carried out in the laminar flow region. They concluded that the average heat transfer coefficient was increased considerably with particle volume concentrations. They showed that for 10 % Al2O3 nanofluid, the average heat transfer coefficient was improved by 94 %, while for 6 % CuO nanofluid, it was increased by 89 %. Also, for a fixed inlet velocity, average skin friction coefficient was increased by increasing the particle volume concentration. But, for the same amount of heat transfer, pumping power requirement with respect to base fluid was reduced by 82 % and 77 % for Al2O3 and CuO nanofluid, respectively.

Peyghambarzadeh et al. [4] studied the effect of Al2O3/water nanofluid on the cooling performance of an automobile radiator. Five different concentrations varying from 0.1 to 1 % (vol.) of Al2O3/water nanofluids were taken. Flow rate of fluid inside the tubes were changed from 2 to 5 litre per minute. Experiments were carried out in fully developed turbulent region. Inlet temperature of fluid through the tubes was varied from 37 °C to 49 °C. They concluded that the heat transfer performance of the heat exchanger was improved by increasing the flow rate of fluid flowing through the tubes. With respect to pure water, heat transfer was enhanced by 45 % by adding Al2O3 nanoparticles. By increasing the Reynolds number of working fluid, effective thermal conductivity was increased by 3%.

Naraki et al. [5] deliberated the effect of CuO /water nanofluids on the overall heat transfer coefficient of a car engine cooling system. Experiments were carried out in laminar flow regime. Two methods were employed to obtain the more stabilized nanofluids i.e. adjustment of pH value and addition of suitable surfactant. They concluded that highly stable and negligibly agglomerated nanofluids were prepared with pH value of 10.1 and with addition of SDS (Sodium Dodecyl sulfonate) as surfactant. Nanoparticle volume concentration was varied from 0.15 to 0.4 % (wt.). Nanofluid inlet temperature was taken 50 °C to 80 °C. They observed that, the overall heat transfer coefficient was improved by 6 % and 8% for 0.15 and 0.4 %(wt.) Particle volume concentration respectively. Reynolds number of air circulating over the tubes contributed to the overall heat transfer coefficient by 42 %. The overall heat transfer coefficient was also effect by nanofluid volumetric flow rate, inlet nanofluid temperature and particle volume concentration with contribution of 23 %, 22 % and 13 %, respectively.

Leong et al. [6] investigated the performance of an automotive car radiator by using Cu/EG nanofluids as coolant. Results were compared by taking Reynolds number of air and coolant as 6000 and 5000, respectively. They found that heat transfer rate was increased by 3.8 % by adding 2 % of Cu nanoparticles. Thermal performance of heat exchanger was found highly dependent on air and coolant Reynolds number. An increment of 42.7 % and 45.2 % was observed when air's Reynolds number was increased from 4000 to 6000 for ethylene glycol and Cu/EG nanofluid, respectively. While, thermal performance was increased by only 0.9 % and 0.4 % when coolant Reynolds number was increased from 5000 to 7000 for ethylene glycol and Cu/EG nanofluid, respectively. They observed that frontal area of heat exchanger was reduced by 18.7 % by adding 2% of Cu nanoparticles into the base fluid. Pumping power for nanofluid was found 12.13 % higher than that with pure ethylene glycol, while keeping volumetric flow rate of nanofluid constant to 0.2 m3/s.

Ali et al. [7] studied the effect of particle volume concentration and particle material on the thermal conductivity and thermal diffusivity of nanofluids. Nanofluids were prepared using Al and Al2O3 nanoparticles, while three different base fluid namely, distilled water, ethylene glycol and ethanol were used to prepare nanofluids. Thermal conductivity and thermal diffusivity of various nanofluids were measured by using hot wire laser beam displacement method. Results showed that thermal properties vary linearly with particle volume concentration. They also revealed that metallic nanofluids always provide greater enhancement in thermal properties as compared to non-metallic nanofluids. They experimentally concluded that for a particle volume concentration of 0.42 % thermal conductivity of Al/water, Al/EG and Al/ethanol nanofluids were higher than that of base fluid by 18.63 %, 20.5 % and 24.27%, respectively. While at same concentration for Al2O3/water, Al2O3/EG and Al2O3/ethanol, it was increased by 9.56 %, 12.1 % and 15.1 %, respectively.

Nieh et al. [8] employed Al2O3/water and TiO2/water nanofluids in air cooled radiator to improve the performance. Thermo-physical properties of nanofluids were measured at different nanoparticle volume concentration and then pressure drop and heat dissipation rate were measured at different Reynolds number. Efficiency factor and heat dissipation rate was greater for nanofluids as compared to that with ethylene glycol/water solution. They concluded that the TiO2/water nanofluids showed the greater enhancement than Al2O3/water nanofluids. Heat dissipation rate was enhanced by 25.6% , 6.1% improvement for pressure drop was seen , pumping power was increased by 2.5 % and efficiency factor has 27.2% enhancement as compared to ethylene glycol/water mixture.

Das et al. [9] studied the effect of temperature on thermal conductivity enhancement of nanofluids. By using water as base fluid, two different nanofluid were prepared of Alumina and copper oxide nanoparticles. Thermal conductivity and thermal diffusivity of nanofluids were measured by using temperature oscillation method. They observed that thermal conductivity of nanofluids was enhanced by two to four times when its temperature increased from 21°C to 51°C. This observation makes the use of nanofluids feasible in the cooling application where heat transfer fluids reaches a very high temperature. It was observed that nanofluids containing smaller CuO particles demonstrate extra enhancement of conductivity with temperature.

Eastman et al. [10] revealed the effect of Cu/ethylene glycol nanofluids on the thermal conductivity. They concluded that Cu/ethylene glycol nanofluids provide higher thermal conductivity as compared to pure ethylene glycol or other oxides/ethylene glycol nanofluids. It was shown that thermal conductivity of nanofluids containing 3 % concentrations of Cu nanoparticles of particle size 10 nm was higher by 40 % as compared to base fluid. They concluded that metallic Nanofluids exhibits higher thermal conductivity enhancement as compared to non-metallic nanofluids.

Table -1.1: summary of studies on the experimental model for heat transfer enhancement.

Sr no	Nanoparticles	Base fluid	Vol. fraction of particles	Heat transfer enhancement	Reference
1	Al_2O_3	Water	1%	45%	Peyghambarzadeh et al. [4]
2	Al_2O_3	Water	1%	45%	Heris et al. [12]
3	Cu	Ethylene Glycol	0.30%	40%	Eastman et al. [10]
4	CuO	Water	0.40%	8%	Naraki et al. [5]
5	Cu	Ethylene Glycol	2%	3.8%	Leong et al. [6]
6	Al_2O_3	Water	3.7%	50-60%	Yu et al. [8]
7	Al_2O_3	Water	6.8%	40%	Nguyen et al. [13]
8	Cu	water	0.8%	55%	S. Zeinali Heris [17]
9	TiO_2	Water and EG	0.5%	37%	Devireddy Sandhya et al. [16]

2 correlations for thermo physical properties

Heat transfer coefficient of Nanfluids depend on thermal conductivity, heat capacity, density, viscosity of base fluid and nanoparticles, some important thermo physical properties with their correlation are discussed below.

Density

The nanofluid Density is calculated by using of the Pak and Choi [10] correlations, which are defined as follows:

$$\rho_{nf} = (1-\varphi)\rho_f + \varphi\rho_p \tag{8}$$

Specific heat

The specific heat is calculated from Xuan and Roetzel [1] as following:

$$(\rho cp)_{nf} = (1-\varphi)(\rho cp)_f + \varphi(\rho cp)_p \tag{9}$$

Thermal conductivity

An alternative formula for calculating the thermal conductivity was introduced by Yu and Choi [10], which is expressed in the following form

$$K_{nf} = K_f \frac{K_p + 2K_f - 2\varphi(K_f - K_p)}{K_p + 2K_f + 2\varphi(K_f - K_p)} \tag{10}$$

Viscosity

The viscosity of the nanofluid as per the well-known Einstein equation for calculating viscosity, is defined as follows

$$\mu_{nf} = (1 + 2.5\varphi)\mu_f$$

3. Effect of Temperature and Concentration on Thermal Conductivity, Specific Heat, Viscosity

3.1 Effect of Temperature and concentration on Density

Density of Al_2O_3 and ZrO_2water/EG based nanofluids measured at 70^0C and 80^0C. With increase in concentration of nanoparticles from 0.1 vol. % to 0.3 vol. % density goes on increasing. Density of nanofluids decreases with the increase in temperature. density of nanofluids is higher than base fluid.

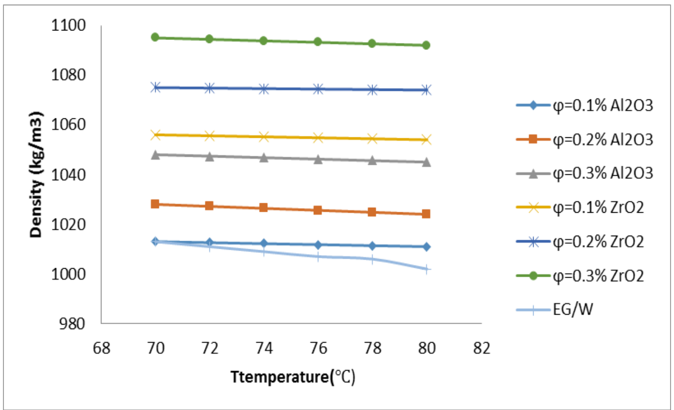

Fig:1 different particle volumetric concentrations as a function of temperature and density.

3.2 Effect of Temperature and concentration on Thermal Conductivity:

Thermal conductivity of nanofluids is measured by KD2 PRO with KS1 sensor needle. at 70^0C and 80^0Cfor 0.1%,0.2%,0.3% volume concentration .From fig. 2, it can be conclude that thermal conductivity of nanofluids increases with increase in temperature. As well as with increase in concentrations of particles. Thermal conductivity of nanofluids is higher than base fluid

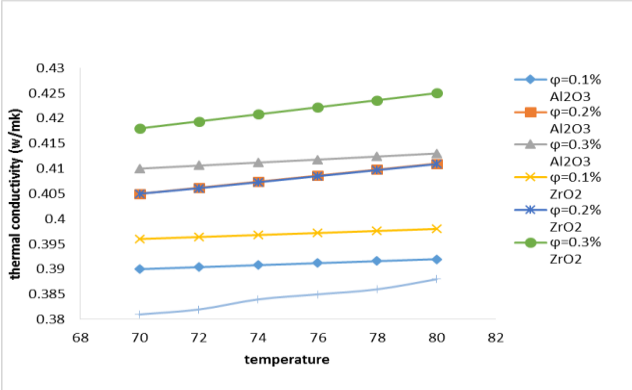

Fig: 2 different particle volumetric concentrations as a function of temperature and thermal conductivity.

3.3 Effect of Temperature and concentration on viscosity

Solution are prepared for different volumetric concentration 0.1%,0.2%,0.3% and measured viscosity at different temperature it can say that as there is increases in concentration of nanoparticles three is increase in viscosity and as temperature increases viscosity goes on decreasing. There is increase in density of mixture and consequently more force will be required to overcome the inertial forces, as a result viscosity increases but there was significant decrement of viscosity with temperature. Viscosity of nanofluids is higher than base fluids

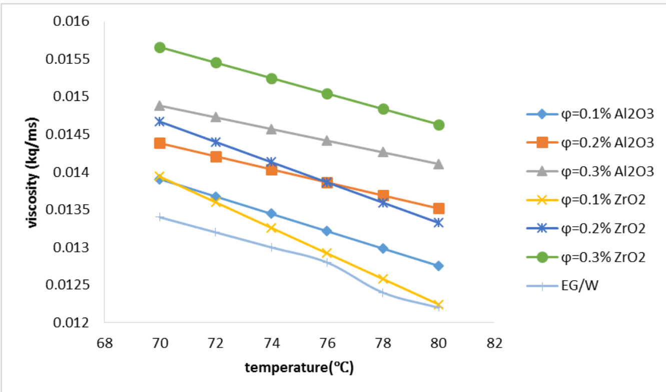

Fig: 3 different particle volumetric concentrations as a function of temperature and thermal conductivity

3.4 Effect of Temperature and concentration on Specific Heat:

Variation of specific heat of Al_2O_3 and ZrO_2 Nanofluids with nanofluid temperature for all the Al_2O_3 and ZrO_2 particle volume concentrations are shown in Fig. 4. The specific heat of Al_2O_3 and ZrO_2 nanofluids decreases with increase in the volume concentration of nanofluids. Specific heat of nanofluids also increases with increase in the nanofluid temperature and the same can be observed. Specific heat of nanofluids is less than base fluids.

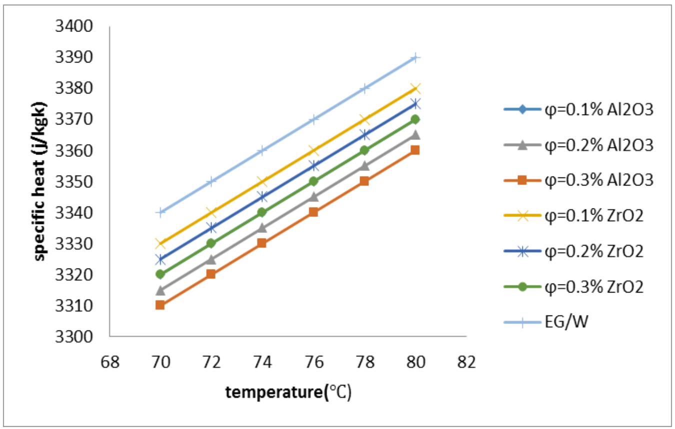

Fig: 4 different particle volumetric concentrations as a function of temperature and thermal conductivity

4. Effect of Properties Variation

4.1 Effect on the Prandtl Number:

The concentration and temperature are intertwined to influence the Prandtl number of a nanofluid. Therefore, the Prandtl number of nanofluids can be enhanced either by increasing the concentration or by operating at a lower temperature. The dominant thermophysical property here is viscosity, which is higher at lower temperature and higher at higher particle concentration.

4.2 Effect on the Reynolds Number:

There is a gradual decrease in the Reynolds number with an increase in particle volumetric concentration at all temperatures. Increase in particle concentration increases the density and the viscosity of the nanofluids. However, the proportion of increase in viscosity value is much higher than the increase in the density value. Therefore, the end result is that there is a decrease in the Reynolds number due to an increase in the concentration. This leads us to conclude that a low particle concentration of nanofluid would be preferable to keep the Reynolds number higher and achieve a higher heat transfer coefficient.

4.3 Effect on the Convective Heat Transfer Coefficient:

The experimental data of Vajjha et al. [3] the convective heat transfer coefficient was calculated for 1% volumetric concentration of nanofluids. The heat transfer coefficient a function of temperature. As recommended, using a low concentration of 1% volumetric concentration, the heat transfer coefficient is found to be higher than that of the base fluid However, if the concentration is increased, the decrease in the Reynolds number becomes more dominant than the increase in the Prandtl number and the advantage of nanofluids over the base fluid is diminished. It is noticed that the Leong et al. [6] Al2O3 nanofluids of 1% concentration enhance the heat transfer coefficient.

5. Conclusions

The heat transfer enhancement takes place using suspensions of nanometer-sized solid particle materials in base fluids. Thus, this paper presents an overview on the recent investigations in the thermo physical characteristics of nanofluids and their role in heat transfer improvement in heat exchangers like Radiators. Most of the experimental and numerical studies showed that nanofluids exhibit an improved heat transfer coefficient compared to its base fluid and it increases significantly with increasing concentration of nanoparticles. The enhancement of the heat transfer capability of nanofluids makes their use in heat exchangers, leading to better system performance and leads advantage in energy efficiency. On the other side, nanofluids stability and its production cost are major factors that hinder the commercialization of nanofluids. Despite we have future scope to enhance heat transfer in heat exchangers like Radiator by using different Nano powder at different concentration.

Nomenclature

ρ_{nf}	Density of nanofluid, kg/m^3
ρ_{bf}	Density of base fluid, kg/m^3
ρ_p	Density of nano particle, kg/m^3
μ_{nf}	Viscosity of nanofluid, kg/m s
μ_{bf}	Viscosity of base fluid, kg/m s
μ_p	Viscosity of nano particle, kg/m s
$\emptyset$	Volumetric concentration
h	Heat transfer coefficient, W/m^{2}K
k_{nf}	Thermal conductivity of nanofluid, W/mK
k_{bf}	Thermal conductivity of base fluid, W/mK
k_p	Thermal conductivity of nano particle, W/mK
Nu	Nusselt number
Pr	Prandlt number
Re	Reynolds number

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