Heat Transfer Enhancement by the Usage of Low Concentration MgO-Water Nanofluid

Sanjay V. Kadam, Suhas S. Mohite, Vishal S Kumbhar

Abstract*: *The current tentative work proposes the convective heat transfer enhancement by means of using low concentrations MgO-Water nanofluid flowing via tube. Nanofluid is the rising heat transfer fluids which consists solid nano-sized particles suspended in base fluid. Total three volume concentrations (0.005%, 0.01%, and 0.05%) and four unique sizes of nano particle (7 nm, 40nm, 60 nm, 100nm) are used to prepare nanofluid with distilled water. There are different correlations available to find nano fluid properties but they are not applicable as these are dependent on number of parameter like base fluid properties, particle size, shape and concentration of nano particle in a base fluid. Therefore actual measurements of different properties are carried out. Experimental investigation is executed for different Reynolds no, particle concentration and different size of nano particle. It is experimental that average heat transfer augmentation of 44.73% is obtained for 0.05% volume concentration (40 nm size) as compared to distilled water. It is found that there is augmentation of heat transfer with amplifying in particle concentration and reducing in size of nano particles. The typical improvement in Nusselt number for particle sizes of 7 nm, 40 nm, 60 and 100nm are found to be 37.76%, 36.53%, 35.15% and 32.26% respectively as compared to distilled water. It is found that as volume concentration increases and size of nanoparticle decreases there is augmentation of heat transfer.

Index Terms: *Base Fluid, Nanoparticle, Heat Transfer,*

I. INTRODUCTION

In latest years, contemporary technology has been manufacturing particles of metal right down to the nanometre scale, which has formed brand new class fluids, known as nanofluid. It has been shown that nanofluid has higher “stability” as compared to the ones fluids containing micro sized particles. Many exciting residences of nanofluid were pronounced in past a long time which opens their potential applications in heat transfer intensification. The poor heat transfer characteristic of conventional fluids is a number one obstacle in making compact heat transfer device. A new idea is to suspend nano sized solid particles in the fluid. Particles within the order of millimeter and micrometer size creates several issues which includes abrasive movement of the particles which ends up in erosion of pipelines and therefore increase in pressure drop in practical appliance. Besides, these solutions often are badly affected by instability, rheological issues and have a tendency to settle rapidly. However, using nano-sized particles help in minimizes a number of these negative aspects. The reduction in particle size from micro to nano increases surface to volume ratios 1000 times enhancing heat transfer and also overcomes other problems associated with large particle size, viz., abrasion erosion, pressure drop, settling. Successful employment of nanofluid helps the modern-day miniaturization of heat transfer systems.

Since long time substantial amount of studies is going in the vicinity of heat transfer augmentation. Considerable studies are performed to develop techniques of heat transfer enhancement the usage of passive and active techniques. Also in recent year’s number of research are accomplished in enhancement of heat transfer by way of changing the convectional heat transfer fluids with the aid of nanofluid.

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II. RELATED WORK

Choi [1]. is the first researcher to put forward the concept of nanofluid through his theoretical study by proving that thermal conductivity of conventional fluids is increased by mixing the small quantity of metallic particles. S. Lee [2]. investigated that addition of small amount of nanoparticles complements the thermal conductivity. Sadik Kakac [3]. gave concise assessment of the articles on the convection with nanofluid. Brief evaluations at the current studies on forced convection heat transfer through nanofluid are summarized by Lazarus Godsin [4]. Khalil Khanafer [5]. presented critical synthesis of thermo-physical properties nanofluids in their work. They showed that for low concentrations of nanofluids classical equations can be used evaluate the thermal conductivity and viscosity. Yimin Xauan [6]. proposed the correlations by single phase and multiphase approach. Dongsheng Wen [7]. discussed numerous feasible causes for the improvement in heat transfer through the usage of γ-Al_2O_3 nanofluid. Comparison of heat transfer enhancement delivered out by using specific concentrations of CuO and Al_2O_3 is experimentally reported by S. Zenali Heris [8].
shows heat is augmnted with raise in particle concentrations of Al_2O_3. S.M Fotukian [9]. in his experimental investigation concluded that there is about 25% increase in heat transfer Ravikanth S. Vajjha [10]. via his experimental work derived relationship for heat transfer and friction factor. There is 10% augment in heat transfer by adding Al_2O_3 nanoparticles. A.A. Abbasian Arani [11]. examined the effect of different diameter (10 nm, 20 nm, 30nm and 50nm) TiO_2 nanoparticles They suggested that the nanoparticles with 20 nm diameter provided maximum heat augmentation. Similar

investigation is carried out by K. B. Anoop [12]. for Al_2O_3 nanoparticles with sized of 45 nm and 150 nm. Particle with 45 nm showed better heat transfer rate. S.M Fotukian [13]. Showed that growing the quantity fraction of nanoparticles did now not display plenty effect on augmentation of heat. S.M. Peyghambarzadeh [14]. examined the effect of CuO and Fe_2O_3 nanoparticles with three concentrations of 0.15%, 0.4%, and 0.65% in car radiator. Three different inlet temperatures (50°C, 65°C, and 80°C) are considered for the study. Effect of Al_2O_3 nanoparticles on heat enrichment is investigated by Chavan and Pise [15]. they found 36% improvement in heat transfer M. A. Boda, M. Ramachandran et. al. [16]. this assessment highlights on nanofluid concept for augmentation of convective heat transfer, application and instruction method. Addition of nano particle complements the thermal conductivity of nanofluid as a result convective heat transfer.

It is observed from literature review that there is merely any experimental search available on heat transfer enhancement using Magnesium Oxide (MgO) nanoparticles. Hence the purpose of present experimental work is to examine the forced convection heat transfer by using different concentrations of MgO nanoparticles with different average size of nano particles suspended in distilled water.

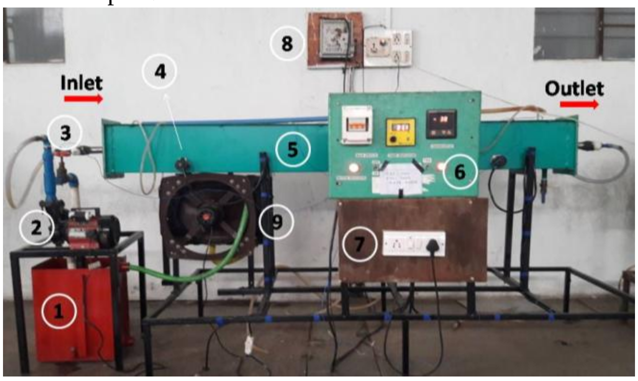
NOMENCLATURE

Cp	Specific heat, J/kg K
D	Tube diameter, m
h	Heat transfer coefficient, W/m^2 K
k	Thermal conductivity, W/m K
L	Length of tube, m
$\dot{m}$	Mass flow rate, kg/s
Nu	Nusselt number
Pr	Prandtl number
q	Heat transfer rate, Watt
Re	Reynolds number
T	Temperature, K
ΔT	Temperature difference, K
V	Velocity, m/s
Greek Symbols	
ρ	Density, Kg/m^3
μ	Dynamic viscosity, Pa.s
Φ	Particle volume concentration, %
Subscripts	
b	Bulk
bf	Base fluid
nf	Nanofluid
A_s	Cross section area
np	Nanoparticle

III. EXPERIMENTATION AND NANO FLUID PREPARATION

A. *Experimental setup*

The photo of experimental setup used for gift work is proven in Figure 1. The test setup consists of an aluminum tube with 28 mm internal diameter and 1.68 m length. To supply the stable heat flux to test tube, electric heater wounded on the tube and then insulated from surrounding. The fluid is pumped from reservoir, passed to test tube and then to heat exchanger and finally into reservoir. The flow rates are measured and controlled manually by the time required to fill the 1 litre of vessel. Inlet, Outlet and tube surface temperatures are measured by calibrated K-type thermocouples.



1- Nanofluid Tank, 2- Electric Motor, 3-Flow control valve, 4- Electric Heater, 5- Heater to provide constant heat flux, 6- Control Panel, 7-Switch Board, 8- Main supply switch

Fig.1 Photograph of experimental setup

B. *Estimation of nanofluid volume concentration*

It is essential to know the exact amount of nanoparticles that is required to perform experimental trials. Mixture law formula is used to find out the quantity of nanoparticles required to prepare the nanofluid. For this purpose sensitive weight balance is used. Initially samples of 200 ml with different concentrations are to be made to find out the properties of nanofluid. Weight nanoparticles for preparing the 1 liter of MgO nanofluid of different volume concentrations using water as a base fluid are estimated using following mixture law formula

$$\%\ \text{volume concentration} = \frac{\left(\frac{W_{MgO}}{\rho_{MgO}}\right)}{\left(\frac{W_{MgO}}{\rho_{MgO}}\right)+\left(\frac{W_{base\ fluid}}{\rho_{base\ fluid}}\right)} \quad (1)$$

Table 4.1 shows the amount of MgO nanoparticles required for 1 liter of nanoparticles using water as base fluid.

Table 1 Volume concentrations of MgO nanoparticles with corresponding weight

Volume by Volume concentration (%)	Weight of MgO nanoparticles in grams (for 1 liter)
0.005	0.1791
0.01	0.3582
0.05	1.791
0.1	3.583

C. *Nanofluid Preparation*

MgO nanoparticles of average particle size is 7 nm, 40 nm 60 nm 100 nm are used to prepare the nanofluid. Three different volume concentrations namely 0.005%, 0.01%, 0.05% are used in this work.

Two step techniques are used to prepare the nanofluid of various concentrations. Two step strategies involve, direct blending of the nano particle and suspending it within the base fluid.

When nanoparticles are mixed in the fluid agglomeration occurs. To suspend the particles uniformly in the base fluid nanofluid of different concentrations are kept in ultrasonic sonicator. Sonication allows the breaking of the bonds present in nanoparticles so that they are suspended in base fluid properly. All the nanofluid samples are kept in sonicator for 6 hours to prepare stable nanofluid. After 6 hours of Sonication the samples are uniformly dispersed in base fluid. There is no any addition of surfactant to nanofluid to maintain its stability because it may affect.

D. *Properties of nanofluid*

There are number of models are offered to compute the thermo-physical properties of nanofluid but actual measurement of thermo-physical properties is essential so as to get actual properties of nano fluids.

1. Density

Density of nanofluid is measured manually by taking 10 ml of nanofluid sample and measuring its weight on digital weighing equipment. Density is same for all available average size nano particles, so density of all samples is equal for all size of nanofluid at same concentration however will increase with boom in addition.

Table 2 Density of nanofluid for various diameters at different concentration

Concentration of nano particle (ϕ %)	ρ (7nm, 40nm, 60nm and 100nm) (kg/m^3)	ρ_{nf} (kg/m^3)
0.005	3560	998.1281
0.01	3560	998.2562
0.05	3560	999.281
0.1	3560	1000.562

1. Specific Heat

Specific heat of nanofluid is calculated by using following relation given by Xuan and Roetzel.

$$C_{pnf} = \frac{\phi \rho_p C_p + (1-\phi)\rho_{bf} C_{bf}}{\rho_{nf}} \quad (2)$$

The value of specific heat for other diameter nanoparticle is also same because density of all diameter of nanoparticle is same.

Table 3 specific heat of nanofluid for different concentration

Volume concentration (%)	Specific heat (J/KgK)
Distilled water	4182
0.005	4164.666
0.01	4164.094
0.05	4159.52
0.1	4153.816

2. Viscosity

The viscosity of nanofluid is measured using rheometer. It is determined that as quantity concentration of particle increases the viscosity increases at the same time as as size of nano particle will increase viscosity decreases. From figure 2 it is seen that maximum viscosity is observed for nanofluid of 7 nm size nanoparticles and minimum for nanofluid of 100 nm nanoparticles for all concentration.

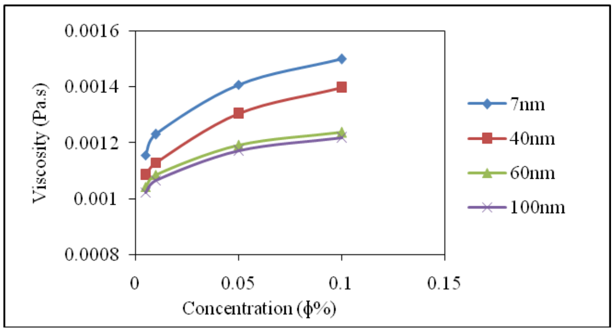


Fig. 2 Viscosity of nanofluid of various nanoparticle sizes at different concentration.

3. Thermal Conductivity.

Thermal conductivity is measured by using Guarded Hot plate apparatus. From figure 3 it clear that maximum value of thermal conductivity is for nanofluid of smallest diameter i.e. 7nm and minimum value is observed for nanofluid of 100 nm diameter. This is because for small size nanoparticle surface area to volume ratio is higher as compared to big size nano particle.

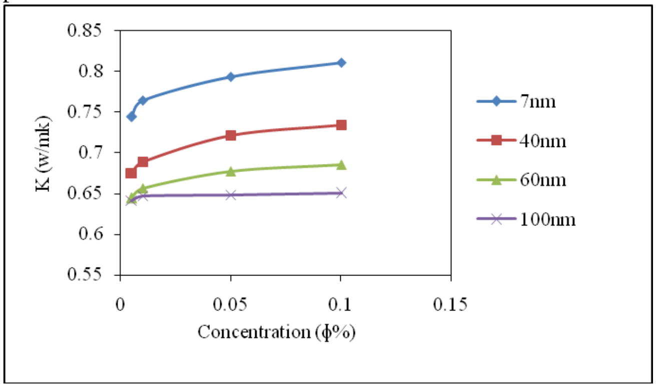


Fig. 3 Thermal conductivity of nanofluid of various nanoparticle sizes at distinctive concentration

IV. RESULT AND DISCUSSION

A. *Data Reduction*

Heat transfer rate is given as,

$$q = \dot{m} C_p \Delta T \quad (3)$$

Heat transfer coefficient is obtained as:

$$h = \frac{q}{A_s(T_{surface} - T_{bulk})} \quad (4)$$

The Reynolds number is expressed as follows:

$$Re = \frac{\rho v D}{\mu} \quad (5)$$

Nusselt number and friction factor is given by:

$$Nu = \frac{hD}{k} \quad (6)$$

B. *Validation of Test Setup*

To ensure the exactness of the experimental setup the trials are to begin with carried out the usage of distilled water and results of Nusselt number in comparison with Dittus-Boelter and Gnielinski co-relation.

$Nu = 0.023 Re^{0.8} Pr^{0.4}$ (Dittus-Boelter Correlation)

$Nu = 0.012 (Re^{0.87} - 280) * Pr^{0.4}$ (Gnielinski Correlation)

$f = 0.0791 (Re^{1/4})$ (Blasius Formula)

Figure 4 and 5 indicates the assessment among experimental results with present correlations. Results show that there is good promise among experimental values and consequences acquired from correlation. The typical variation between experimental data and data obtained from correlation is found to be 9% and 7% for Nusselt number and friction factor by Dittus Boelter and Blasius formula respectively.

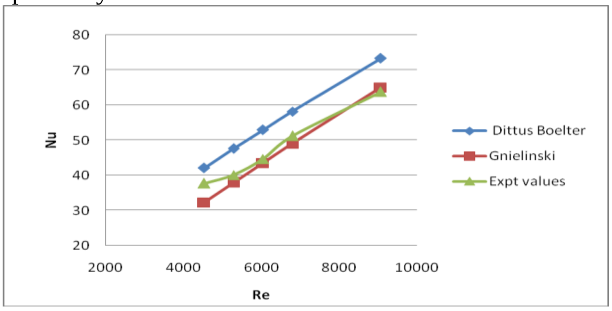


Fig.4 Comparison among experimental Nusselt number variety and Nusselt number received from correlation at diverse Reynolds range.

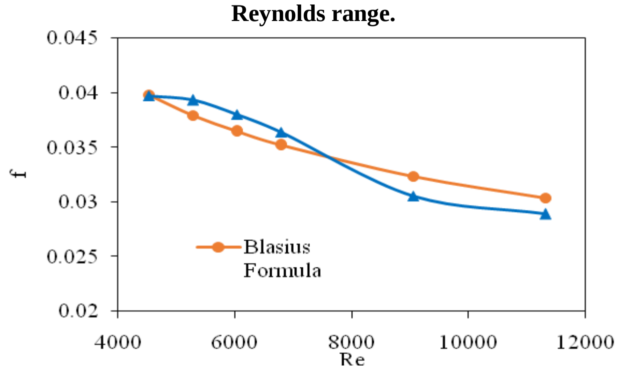


Fig.5 Comparison among experimental friction factor and friction factor received from correlation at diverse Reynolds number

C. *Effect of nano particle Volume Concentration.*

MgO/Water nanofluid with diverse volume concentrations of 0.005%, 0.01%, and 0.05% are used. Figure 6 suggests the variant of Nusselt range towards Reynolds range for distinct concentrations of nanofluid.

Augmentation in Nusselt quantity is due change in properties of fluid additionally different parameters along with Brownian movement of particles, disturbances in boundary layers because of the collisions of nanoparticles at the wall surfaces play important role in heat transfer enhancement. Therefore it is concluded that addition of small amount of nanoparticles raise the overall performance extensively. It is determined that average heat transfer enhancement of 44.73% is obtained for 0.05% volume concentration (40 nm size) as compared to distilled water.

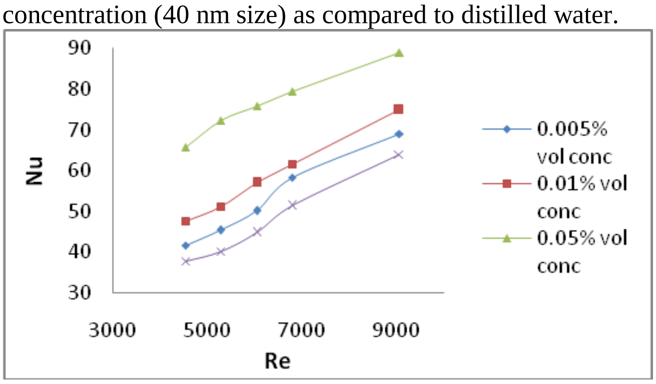


Fig. 6 Nu variation against for exclusive concentrations of 40 nm average size of nanoparticle

D. *Effect of particle % volume concentration on pressure drop*

The pressure drop measured by using digital manometer. From figure 7 it is determined that the pressure drop is elevated approximately 27% for nanofluid with 0.1% quantity concentration which as a result pumping energy is accelerated.

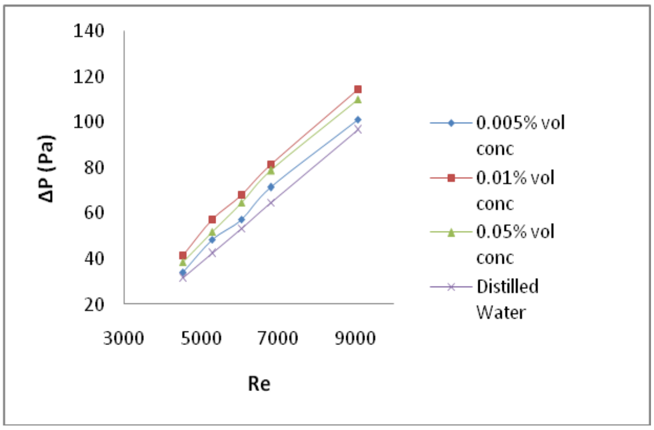


Fig. 7 Pressure drop deviation aligned with Reynolds range for distinctive concentrations of nanofluid

E. *Effect of size of nano particle on Nu and pressure drop*

To notice the consequence of average size of particle of MgO, the particle volume concentration 0.05 % is kept constant and the size of nano particle varies as 7 nm, 40 nm, 60 nm and 100 nm. The different trials are conducted by changing Reynolds no. As particle common size amplifies the Nusselt number decreases as proven in figure 8. This is because as the scale of nano particle increases the surface to volume ratio of particle decreases. The average enhancement in Nusselt number for particle sizes of 7 nm, 40 nm, 60 and 100 nm are found to be 37.76%, 36.53%, 35.15% and 32.26% respectively as compared to distilled water.

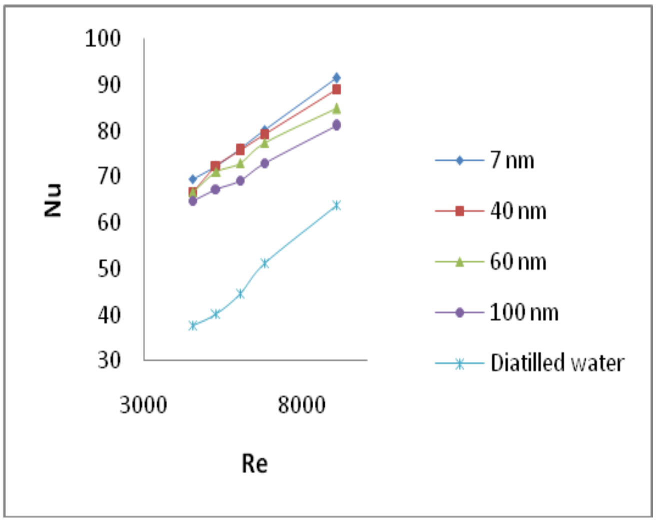


Fig.8 Nusselt number variation towards Reynolds number for distinct particle sizes of 0.05% concentration nanofluid.

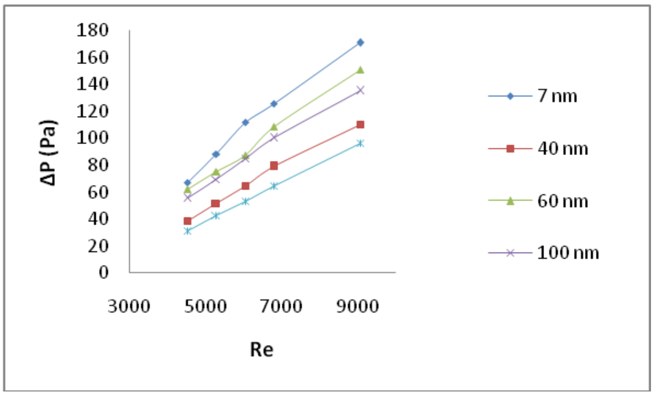


Fig.9 Pressure drop variant towards Reynolds number for specific particle sizes of 0.05 %. Concentration of nano fluid.

It is obvious that from fig. 9 as nano particle size decreases the pressure drop improved because viscosity is increased.

V. CONCLUSION

High particle volume concentration and size of nano particle adversely affect and creates problems like settling. Therefore in present experimental work the convective heat transfer study is achieved by using low attention MgO/Water nanofluid flowing through circular tube subjected to steady heat flux condition. Measurement of viscosity and thermal conductivity is carried out. The result suggests that there is growth in viscosity of nanofluid with growth concentration of nanoparticles and decrease with increase particle size. Thermal conductivity is visible to be boom with particle volume concentration and reduces with growth in size of nano particle. The experimental result the usage of MgO/Water nanofluid absolutely indicates that the heat transfer coefficient of nanofluid complements with growth in Reynolds wide variety. It is located that there is augmentation of heat transfer with growth in particle concentration and reduces in size of nano particle.

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Publication

1. Sanjay Kadam, Pratik Pishte, S. S. Mohite, "Numerical Investigation on Thermo-Hydraulic Performance of Tube with Wire Coil Inserts"5thInternational Conference on Computational Methods for Thermal Problems Indian Institute of Science, Bangalore, India, July 9-11,2018
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