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Experimental Study of Heat Transfer Enhancement in Shell and Tube Heat Exchanger Using Nano Fluid

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ABSTRACT
A different types of heat exchanger are used in every industry and power plant. In that shell and tube heat exchanger are used mostly for different applications. Normally to generate heat transfer rate, we used base fluid in heat exchanger but Nano fluid also used as a heat transfer fluid used in shell and tube heat exchanger and that perform very well of shell and tube heat exchanger. Normally, nano particle have a different size, shape and volume concentration affect the performance of the work. In this paper, different volume concentrations of SiO_2 - water and ZnO - water nanofluid is compared with basefluid and studied. where inlet and outlet temperature, friction factor, heat transfer rate and pressure drop are studied. In shell and tube heat exchanger, effect of different parameter on heat transfer enhancement using nanofluid have also reviewed. A heat transfer rate enhancement during the experiment also note. Generally, we used 0.1%, 0.2% and 0.3% volume concentration of SiO_2-water and ZnO-water nanofluid. Result shown that the cold nanofluid flow in the tube side and heat transfer rate is also increased and pressure drop is also high as compared to basefluid.
Key Words: *Shell and tube heat exchanger; SiO_2-water nanofluid; ZnO- water nanofluid; volume concentration; heat transfer rate and pressure drop.*

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I. INTRODUCTION

From this research paper, study of the heat transfer rate enhancement process in shell and tube heat exchanger using nanofluid. Heat transfer rate increased that means low energy used and saving the energy. Energy conservation is beneficial for our country and all the world. For using this method, we saving the energy and utilized this energy from other work. Shell and tube heat exchanger used because it is construction very simpler and low cost. In shell and tube heat exchanger many techniques are available to increase heat transfer rate like number of baffles, fins, increased circular tube diameter etc. And other side changing some modification and technique in thermal properties of working fluid are also a way to improve the heat transfer rate. and nanofluid is different from the other fluid.In nanotechnology, suspended nanoparticles with mixing of fluid which also known as nanofluid. Also an improve heat transfer rate used to basefluid like oil, water, lubricant is suspended with nanoparticles in the fluid as an nanofluid. [1] Gabriela and Angel huminic investigated the application of nanofluid in different types of heat exchanger.

Properties of nanofluid and volume concentration also affect the heat transfer improvement technique. [2] Usman and Hafiz conducted the advance technique in heat transfer application of nanofluid. In convection process rapidly improvement of heat transfer. [3] Elias, Saidur and Sohel investigated the shell and tube heat exchanger, nanoparticle shape also effects the heat transfer rate and performance. Which are the cylindrical shape suspended nanoparticle are most considered in this study. [4] Sebastien, Andre, Olivier and Jean investigated the nanoparticle shape effect on performance and heat transfer rate of SiO_2 – water and ZnO – water and compared both nanofluid using different shape and ZnO evonik shape factor are useful most in experiment. [5] Yanjun, Jose and Luis Lugo has carried out the study of heat transfer and pressure drop using ZnO/ethylene glycol water nanofluid in transition flow and volume concertation is 0 to 5wt% and result show that the 13.62% for the 5wt% volume concentration is beneficial for heat transfer rate.[6] L. Godson has carried out the convective heat transfer coefficient and effectiveness of silver/water nanofluid are increases and volume concentration also is also increased. [7] Nishant Kumar investigated the volume concentration of nanoparticle increases then improvement in thermal conductivity and heat transfer rate with high mixing of particles. [8] Z. Said has carried out the CuO/water nanofluid heat transfer rate higher as compared to basefluid and life cycle analysis of total energy, CO_2 emissions and cost over the life using ECO audit software.

[9] Amol Niwalkar carried out the study of heat transfer rate using different volume concentration. Result show that heat transfer coefficient of SiO_2/water nanofluid increases and particle mass flow rate and volume concentration is also increased. [10] Shahrul and Saidur investigated the three types of nanofluid. Where two nanofluid prepare without any surfactant and one nanofluid prepared by surfactant. So result show that surfactant using nanofluid heat transfer coefficient is higher.

II. METHOD AND MATERIAL

2.1 Preparation of nanofluid

A nanofluid preparation is an important stage and it is made by carefully. So experimental study carried out with SiO_2 and ZnO nanoparticle purchased from tech for nano industries and volume concentration of this nanofluid is 0.01%, 0.02% and 0.03%. The law of mixture formula used to preparation of nanofluid by amount of nanoparticles.SiO_2 and ZnO nanoparticles required by using this formula and volume concentration is calculated by using this equation as:

$$\% \text{ Volume Concentration} = \frac{m_n/\rho_n}{m_n/\rho_n + m_f/\rho_f} \quad (1)$$

A basefluid and suspension of nanoparticle was prepared by SiO_2 and ZnO nanoparticle with water as a basefluid. SiO_2 and ZnO nanoparticle with 50 nm average diameter dispersed in water as a basefluid with different volume concentrations. A poly vinyl pyrrolidone k-30 surfactant used after then nanoparticle added in the fluid and stirred.Magnetic stirrer instrument used for stirring.

Figure 1: Prepared ZnO – W nanofluidFigure 2: Prepared SiO_2 – W nanofluid

2.2 Experimental setup

The experimental setup carried out to investigate the heat transfer improvement process. In this experiment, two different section are used by nanofluid and water flow section. It is consisting of shell and tube heat exchanger,nanofluid tank, water tank, two different pumps used to create liquid movement, Rotameter used to measure and control flow rate.

Table 1: Specification of shell and tube heat exchanger

Specification	Shell	Tube
Material	S.S 316	Mild Steel
Inner Diameter	66.9	4
Outer Diameter	73	6
Length	200	200
Number of Tubes	-	32

In this experiment, cold nanofluid flow into the tube side and hot water flow into the shell side. Pressure gauge and digital thermometer also used.

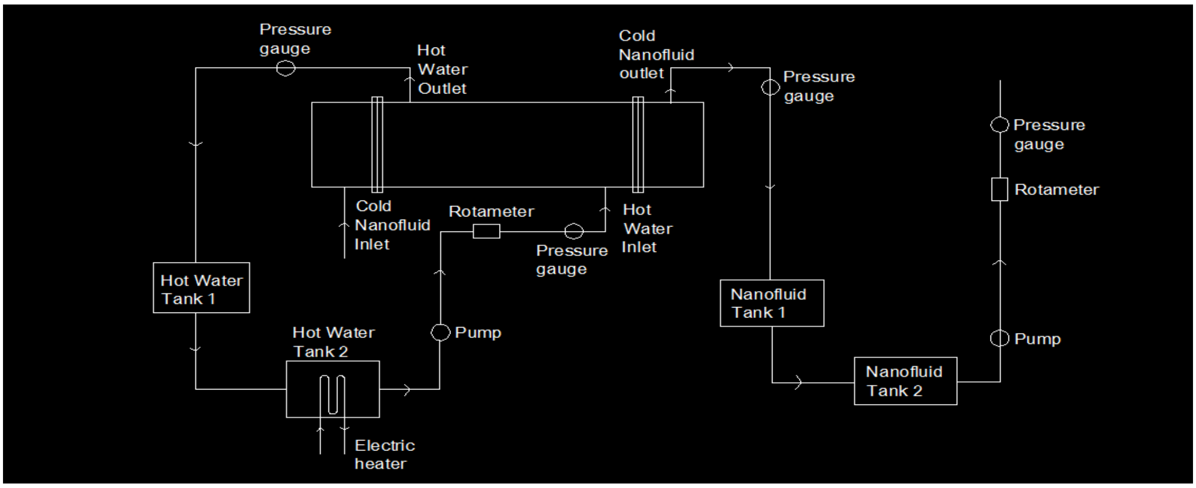


Figure 3: Experimental setup – Model Diagram

Figure 4 Experimental setup

III. DATA REDUCTION AND METHOD

The nanofluid data it is depending on the nanoparticle, nanofluid properties, data calculation method etc. So data of this topic is consider by this study as shown as:

3.1 Nanoparticle

In this experimental work, we studied to the nanoparticle and its properties. Generally, SiO_2 and ZnO nanoparticle used for this experiment to find out heat transfer rate. Nanoparticle properties depends on the physical properties, chemical properties and thermal properties.

Table 2: Properties of nanoparticle

Chemical symbol	SiO_2	ZnO
Chemical name	Silicon Dioxide	Zinc oxide
Density	2.4 g/cm^3	5600 kg/cm^3
Molar mass	59.96 g/mol	81.40 g/mol
Specific heat	680 J/kg.K	410 J/kg.K
Melting point	1600˚C	1975˚C

3.2 Nanofluid properties

The nanofluid properties is most useful to study of the convective heat transfer coefficient. The properties of nanofluid is density, thermal conductivity, specific heat and viscosity and these properties are most useful to find out heat transfer coefficient, overall heat transfer coefficient. The following equation are used to find out nanofluid properties:

To consider the find out density of nanofluid by using Pak and cho equation.Following equation is:

$\rho_{nf} = Ø\rho_p + (1-Ø)\ \rho_{bf}$(2)

To find out the thermal conductivity of nanofluiod by using Maxwell equation. Following equation is:

$K_{nf} = \underline{k_{np} + 2k_{bf} + 2Ø(k_{np} - k_{bf})}$

$K_{bf}k_{np} + 2k_{bf} - Ø\ (k_{np} - k_{bf})$(3)

To calculate the specific heat of nanofluid by using Xuan and Roetzel equation. Following equation is:

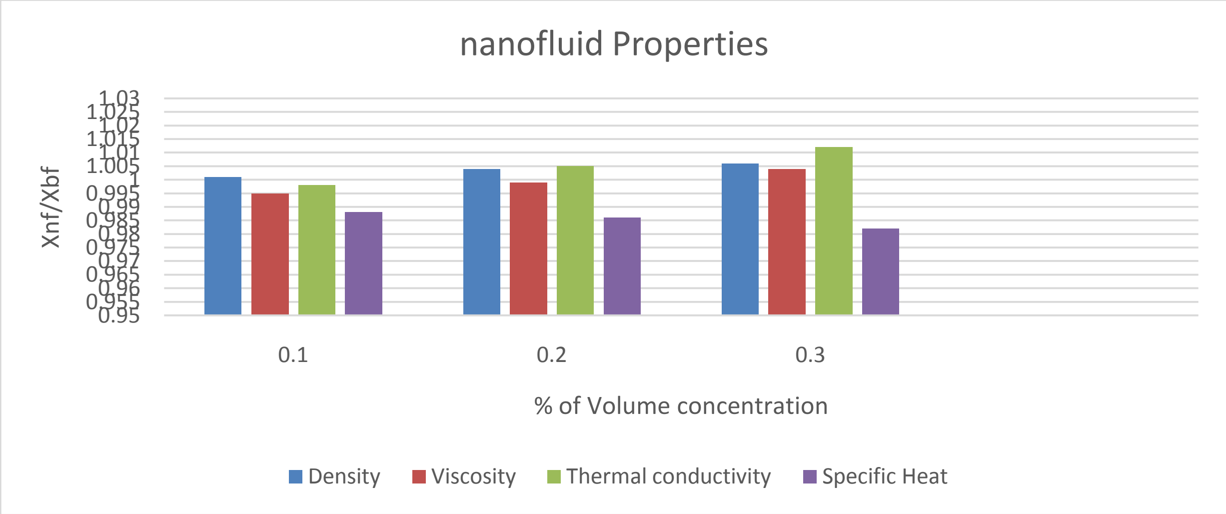
$Cp_{,nf} = \underline{[(1-Ø)\rho_{bf}Cp_{,bf} + Ø\rho_p Cp_{,p}]}$

Pnf (4)

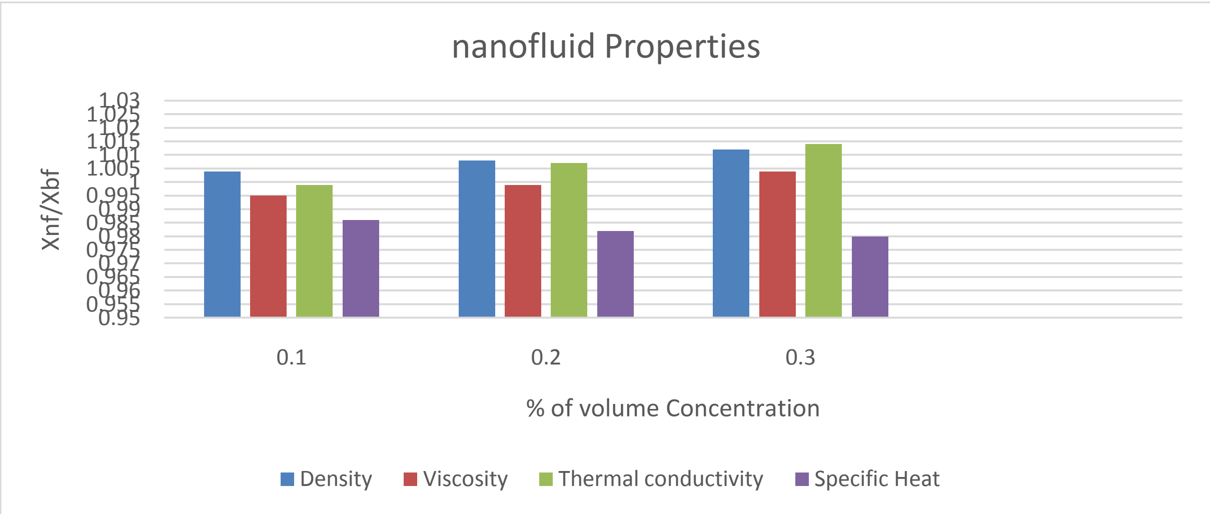
To calculate the viscosity of nanofluid by using Einstein equation. Following equation is:

$\mu_{nf} = \mu_{bf}\ (1 + 2.5Ø)$(5)

When you see the different types of properties against nanoparticle volume concentration are showing in the figure and also seen the variation of density, viscosity, specific heat and thermal conductivity of nanofluids.



(a) SiO2 – W Nanofluid



(b) ZnO – W Nanofluid

Figure 5: Properties Enhancement with % of Volume Concentration

3.3 Data calculation method

The experimental data such as inlet and outlet temperature, pressure, mass flow rate, convective heat transfer and overall heat transfer in shell and tube heat exchanger were collected. The mathematical formulation to calculate dimensionless number, convective heat transfer coefficient and overall heat transfer coefficient. The heat transfer rate for calculating some equation:

Calculate of heat transfer rate on shell side using this equation:

$Q_h = m_h Cp_h (T_{hi} – T_{ho})$(6)

Calculate of heat transfer rate on tube side using this equation:

$Q_c – m_c Cp_c (T_{co} – T_{ci})$ (7)

Calculate of convective heat transfer coefficient can be determined by:

$Q = h A \Delta T_{LMTD}$(8)

Calculate of convective heat transfer coefficient can be determined by:

$Q = U A \Delta T_{LMTD}$ (9)

Logarithmic mean temperature difference is calculated by:

$$\Delta TLMTD = \frac{(T_{hi}-T_{co}) – (T_{ho}-T_{ci})}{\ln \frac{(T_{hi}-T_{co})}{(T_{ho}-T_{ci})}} \quad (10)$$

When the calculate from dimensionless number such as:

Nusselt number of nanofluid, calculated by:

$$Nu = \frac{hl}{k} \quad (11)$$

Prandtl number of nanofluid, calculated by:

$$Pr = \frac{\mu Cp}{k} \quad (12)$$

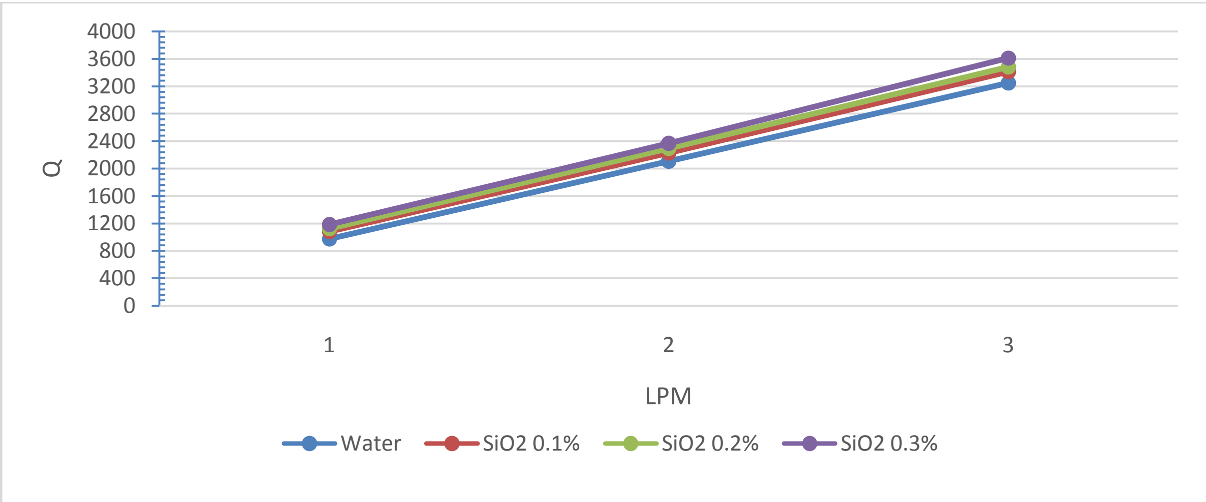
Reynold number of nanofluid, calculated by:

$$Re = \frac{pvl}{\mu} \quad (13)$$

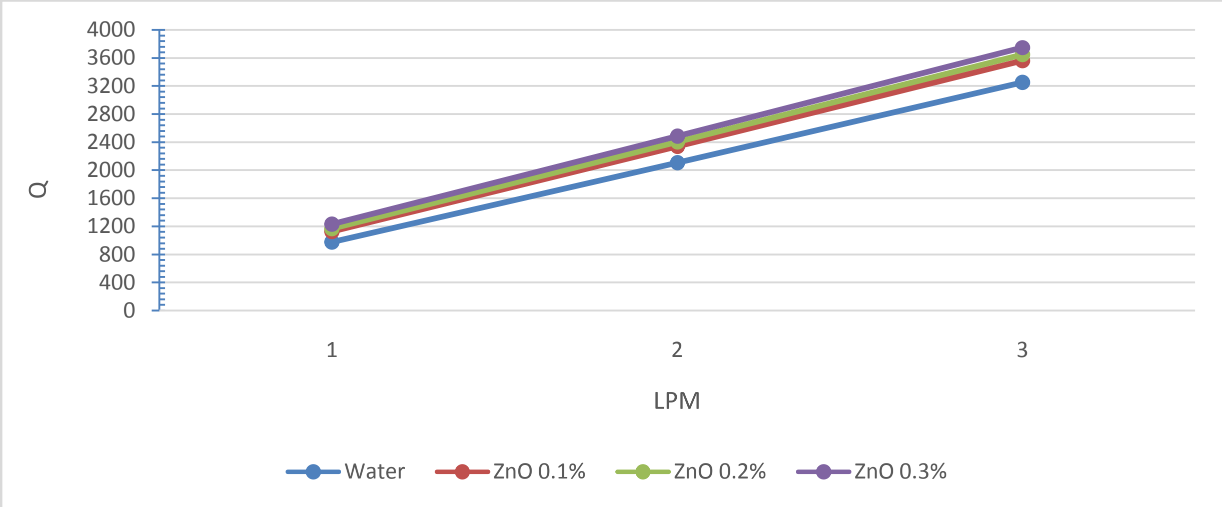
The evaluate data for using these formulations to accuracy of measurement for nanofluid into shell side and tube side.

IV. RESULT AND DISCUSSION

In these figure 6 show that the different effect of volume flow rate and % of volume concentration of SiO_2 and ZnO nanofluid on heat transfer rate. It is show that nanofluid volume concentration increase then heat transfer rate also increased and it is also show that volume flow rate increase then heat transfer rate also increased.



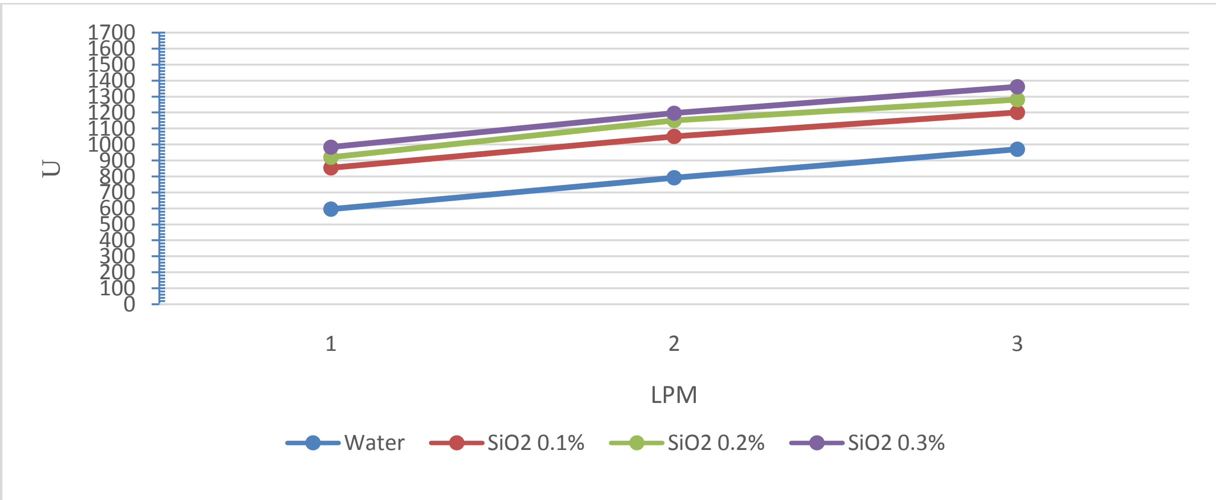
(a) SiO_2 – W nanofluid



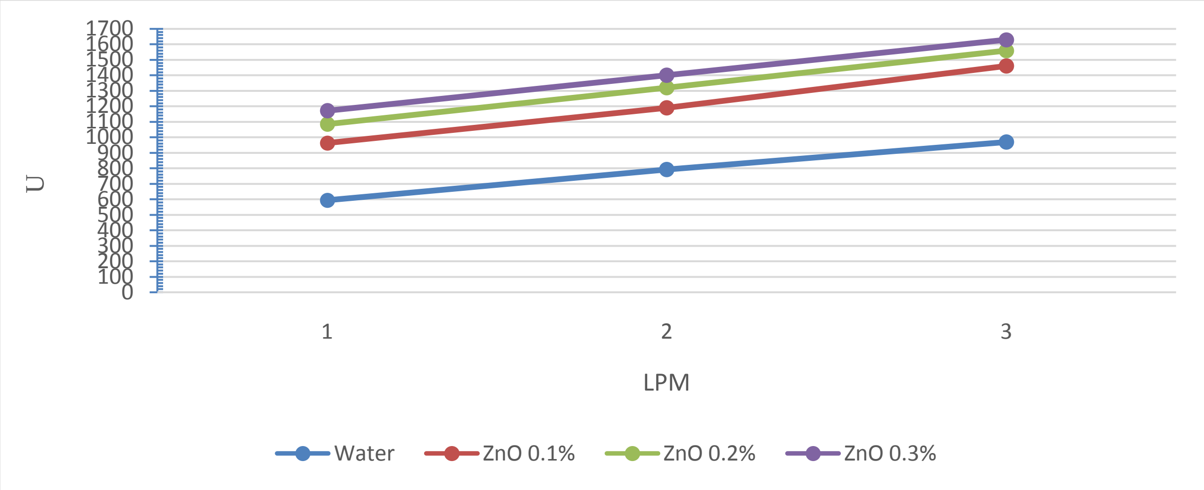
(b) ZnO – W nanofluid

Figure 6: Comparison of actual heat transfer for various volume flow rate

In this figure 7 show that the different effect of volume flow rate and % of volume concentration on overall heat transfer coefficient. It is show that volume flow rate increase then overall heat transfer coefficient also increased. It is also show that nanofluid volume concentration increase then overall heat transfer coefficient also increased.



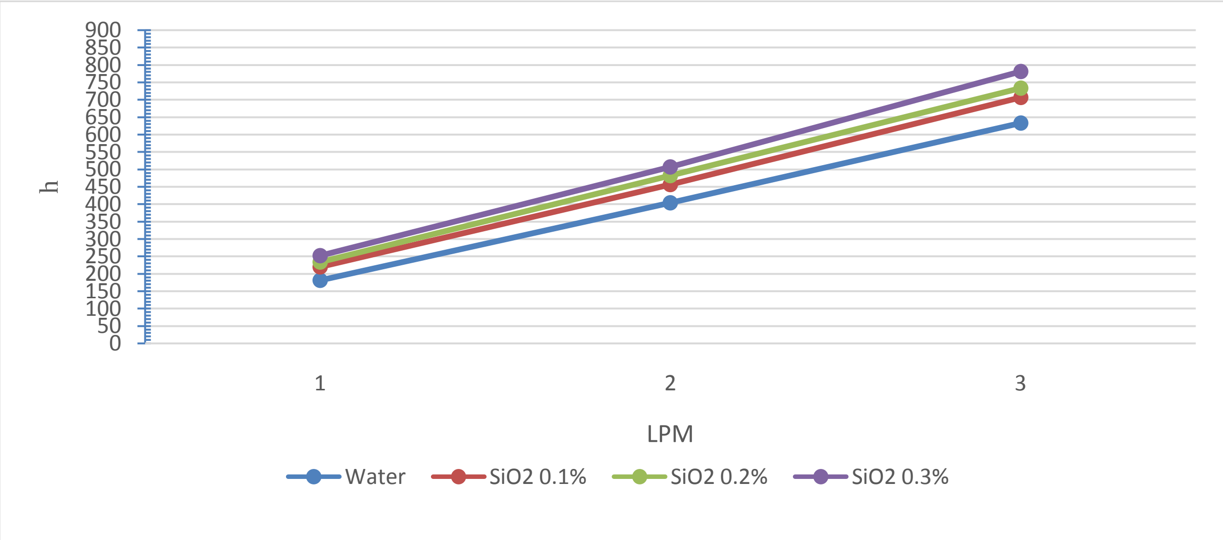
(a) SiO_2 – W nanofluid



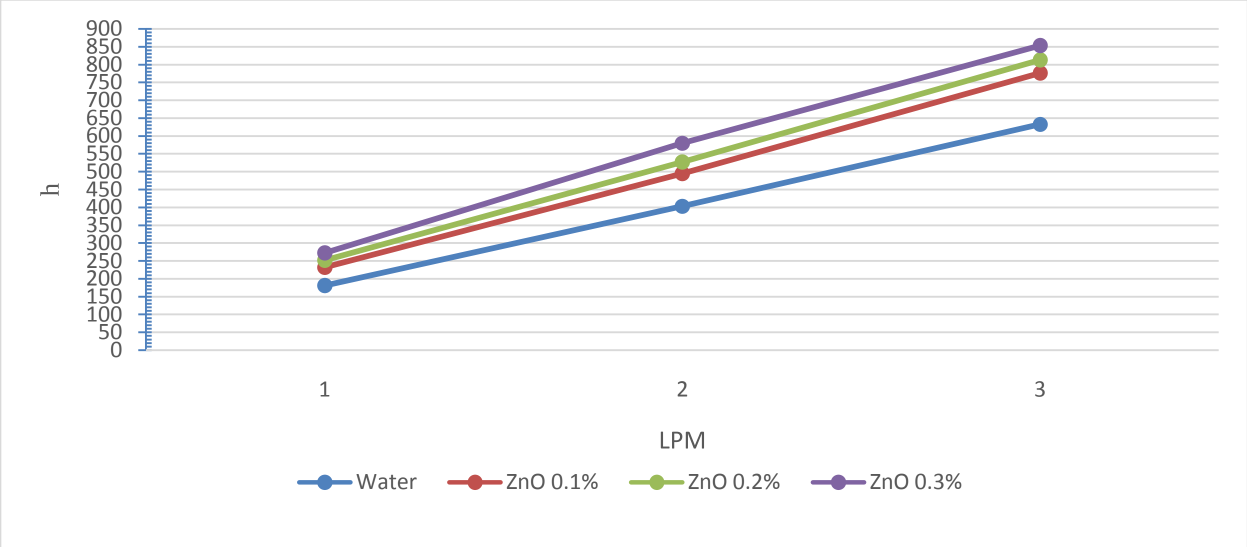
(b) ZnO – W nanofluid

Figure 7: Comparison of Overall heat transfer coefficient for various volume flow rate

In this figure 8 show that the different effect of volume flow rate and % of volume concentration on convective heat transfer coefficient. It is show that volume flow rate increase then convective heat transfer coefficient also increased. It is also show that nanofluid volume concentration increase then convective heat transfer coefficient also increased.



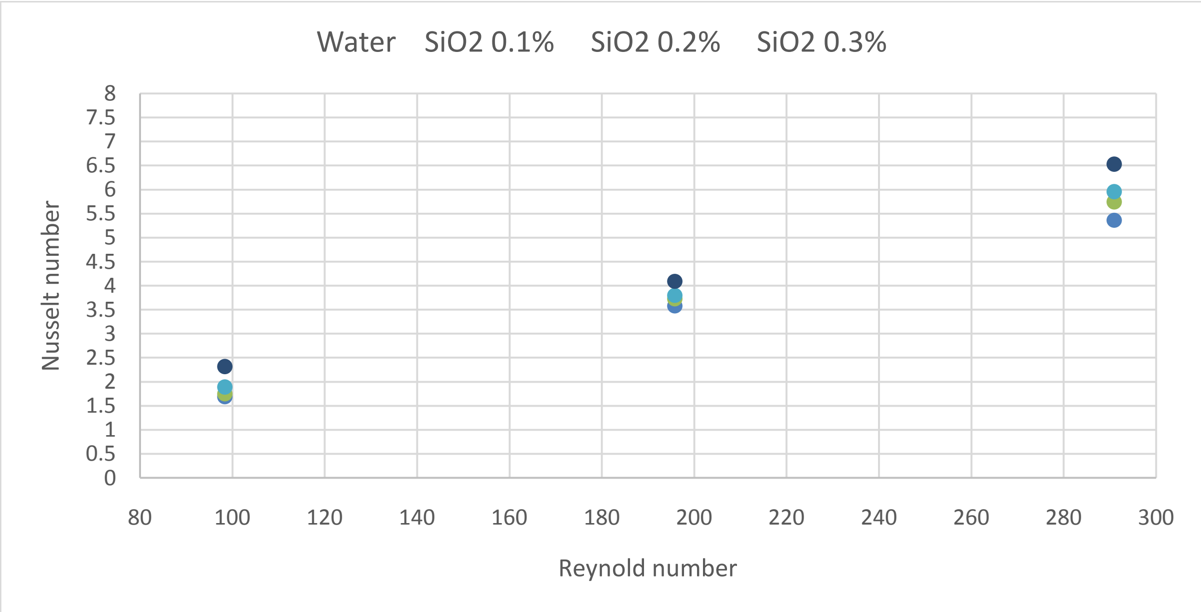
(a) SiO_2 – W nanofluid



(b) ZnO – W nanofluid

Figure 8 Comparison of convective heat transfer coefficient for various volume flow rate

In this figure 9 show that Reynold number to Nusselt number graph. In these graph seen the Nusselt number of cold fluid increase with increased Reynold number. Also Nusselt number and Reynold number increases then nanofluid volume concentration also increased.



(a) SiO_2 – W nanofluid

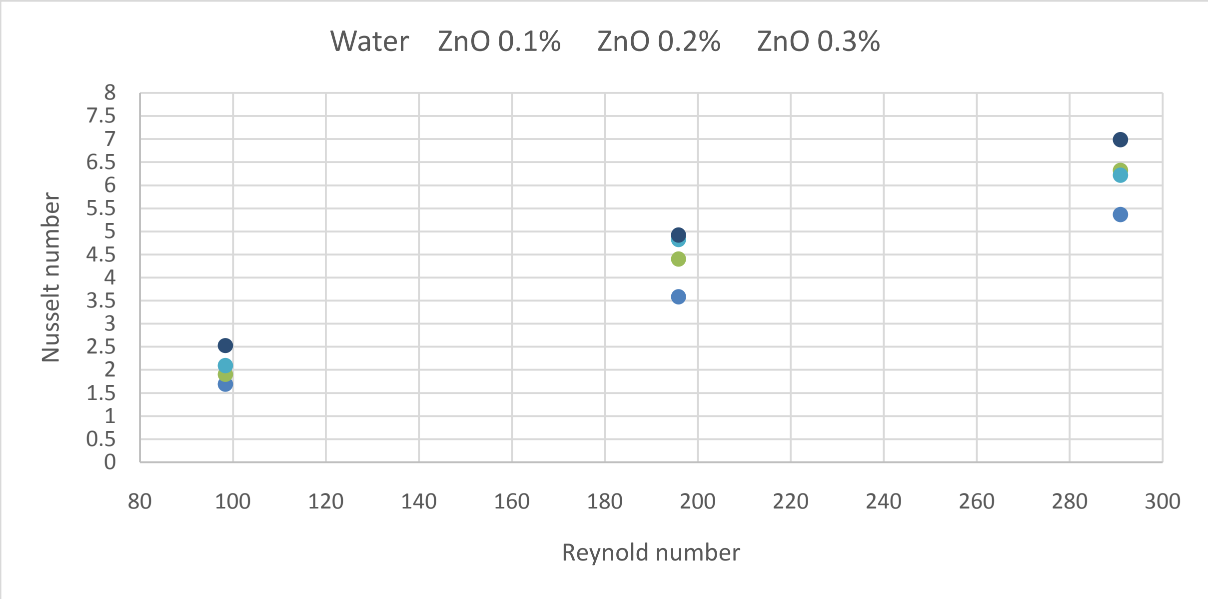
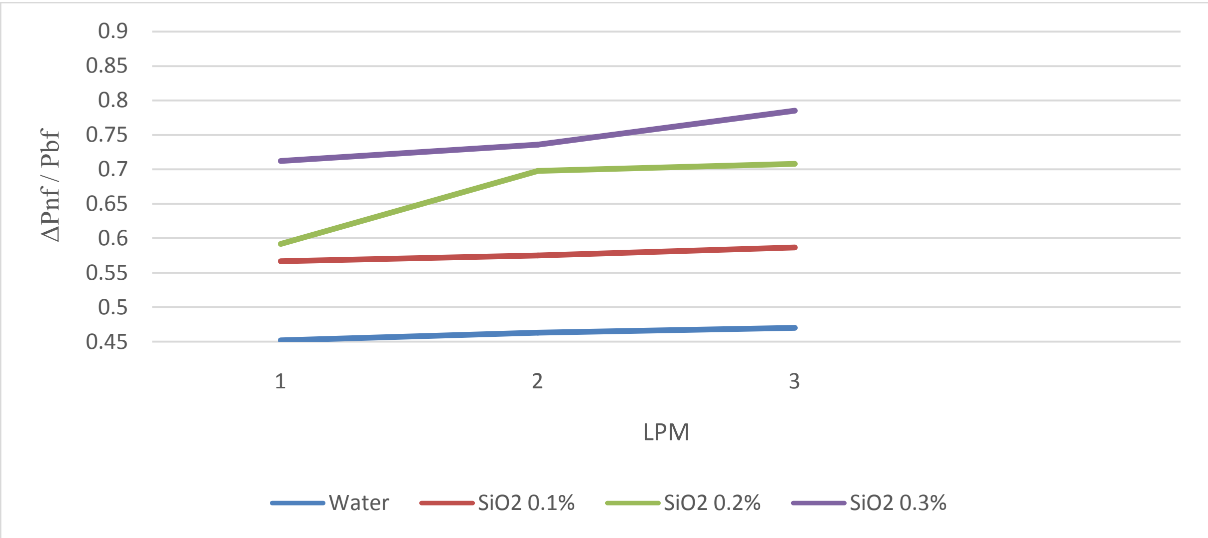
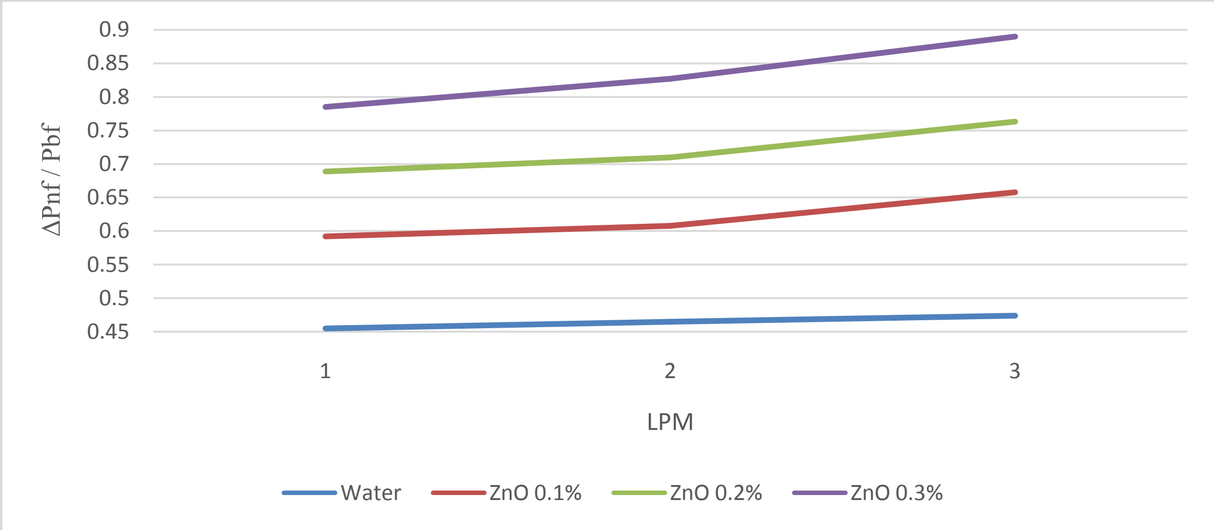


Figure 9 Comparison of Nusselt number with Reynold number

In this figure 10 show that pressure drop ratio for working fluid (nanofluid) to base fluid against volume flow rate. These graph show that nanofluid pressure drop is high as compared to basefluid. It is also show that volume flow rate increase then pressure drop is increased.



(a) SiO_2 – W nanofluid



(b) ZnO – W nanofluid

Figure 10 Comparison of ratio of pressure drop with various volume flow rate

V. CONCLUSION

In this study work,Experiment of heat transfer enhancement in shell and tube heat exchanger using two different nanofluid are studied. SiO_2 – W and ZnO – W nanofluid at different mass flow rate and different volume concentrations 0.1%, 0.2% and 0.3%. So following conclusions were this experimental study:

- The heat transfer rate increase with volume flow rate also increased and heat transfer rate enhanced with increasing volume concentration of SiO_2 – W and ZnO – W nanofluid. Study show that the nanofluid heat transfer rate high as compared to basefluid. Heat transfer rate enhanced by 25.4% and 20.3% respectively with ZnO – W and SiO_2 – W nanofluid for volume concentration of 0.3% of nanofluid. ZnO – W nanofluid more suitable for heat transfer rate.
- In this study, SiO_2 – W and ZnO – W nanofluid thermal conductivity studied with various volume concentration. Volume concentration increase then increment in thermal conductivity because suspended nanoparticles increase turbulence then energy exchange increased.
- The experimental study shows that, Reynold number increase then parameter of heat transfers also increased. Nusselt number and overall heat transfer coefficient enhanced with the Reynold number.
- Experimental study shows that, pressure drop for nanofluid is more as compared to basefluid water. Turbulent flow pressure drop is higher than laminar flow as basefluid water. Around 10% and 6% more pressure drop respectively with ZnO – W and SiO_2 – W nanofluid as working fluid as compared to water basefluid.
- The study shows that, heat transfer rate and pressure drop for nanofluid is more as compared to basefluid water.

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Nomenclature

Ø	volume concentration
mn	amount of nanoparticle
ρn	density of nanoparticle
ρf	density of basefluid
mf	mass flow rate of basefluid
ρnf	density of nanofluid
ρbf	density of basefliud
knp	thermal conductivity of nanoparticle
kbf	thermal conductivity of basefluid
Cpnf	specific heat of nanofluids
Cpbf	specific heat of basefluids
µbf	viscosity of basefluids
µnf	viscosity of nanofluids
qh	heat flow rate
Cph	specific heat of hot fluid
mh	mass flow rate of hot fluid
Cpc	specific heat of cold fluid
mc	mass flow rate of nanofluid
Tci,Tco	inlet and outlet temperature of cold fluid
Thi,Tho	inlet and outlet temperature of hot fluid
Q	Heat transfer rate
U	Overall heat transfer coefficient
ΔT_{LMTD}	Logarithmic mean temperature difference
A	Heat transfer surface area
Pr	Prandtl number
Re	Reynold number
Nu	Nusselt number

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