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An Experimental Investigation of Heat Absorption and Rejection Rate of TiO_2-Water Nanofluid

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***Abstract*: Nanofluids are colloidal suspension of nanosized solid particles in a liquid. Generally nanoparticles are made of metals, oxides, carbides, while base liquids may be water, ethylene glycol or oil. Having suspended tiny particles in the base liquid improves the thermal conductivity and thus the increase in heat transfer performance is expected.**

A test study has been completed to examine the heat transfer performance of water and TiO_2 nanoparticles. This current experiment demonstrates the increases in convective heat transfer in nanofluid. The nanofluid developed by adding TiO_2 nano sized particles of 10-20 nm in base liquid. Demineralized water is used as base liquid. Nanofluid with different volume fraction of TiO_2 nano sized matter between 0.025-0.5 percent used in this current work. The test setup consists of a test section that includes copper pipe of 1000mm length, inner diameter 10mm and a heater. To minimize the heat loss in test section, insulation layer is covered. Thermocouples are utilized in test section to measure the temperatures. The effect of solid volume fraction, nanofluid flow rate and the inlet temperature on heat transfer performance of the nanofluid is examined in this current work. The results show an increment in heat transfer with raising volume fraction of TiO_2 nanoparticles and increase in temperature.

***Keywords*: Heat transfer, Nanofluid, Particles, TiO2.**

I. INTRODUCTION

The number of research works is carrying on developing heat exchanger with higher performance to achieve savings of energy. Achieving optimization of the heat exchanger is becoming an important role as heat exchanger is a major component in the systems such as Thermal power station, advanced electronics equipment cooling system, Automobile engines cooling system, manufacturing cooling system etc. Increasing the performance of heat exchanger is nothing but increasing the heat transfer rate in turns increasing the heat transfer coefficient. Generally there are two possible methods to obtain enhancing heat transfer rate, they are

1. Optimizing the design of heat exchanger

2. Optimizing the operating parameter

Here in the method of optimizing the design of heat exchanger enhancement has been achieved by developing the designs like heat exchanger with extended surface, Micro channel and Mini channel heat exchangers and twisted tape heat exchangers.

In the method of optimizing the operating parameter we can see the two sub methods they are a) Active method b) Passive method, Generally using active methods are Electro hydrodynamics heat transfer, Ultra sound waves heat transfer and Synthetic jet heat transfer and Generally using passive methods are Surface coating, Nanoscale coating, Nanofluids, Hydrodynamic Cavitations, Turbulence promoters and mixing promoters.

In all above mentioned heat transfer rate enhancing methods the following three are the effective ones

- Utilizing Nanofluids
- Inserting fluid Tabulators
- Roughing Heat Exchanger surface

Here in this work to achieve the enhancement in heat transfer rate. We replaced the conventional heat exchanger fluids (Ethylene glycol, Water and Engine oil) by nanofluid. A research work says, the closed loop cooling system use in all power stations of USA. This closed loop cooling system empowered with a nanofluid has a potential to conserve 10-30 trillion BTU of energy.

II. PREPERATION OF NANO FLUIDS

The synthesis of nanofluid is the main key step in experimental study of nanofluid. To synthesis nanofluid all most all solid nano particles of higher thermal conductivity can be used. The normally using solid materials like metallic and non-metallic solids. Metallic solid includes Copper, Aluminum, Silver, Gold, Iron and non-Metallic solid involves Silicon, Alumina, Silicon Carbide, Carbon nano tubes, Copper Oxide, Titanium Oxide.

Generally two main techniques are used two synthesis nanofluid they are;

- Single step method
- Two step method

Single Step Method:

In this step at the same time as makes and disperses the nano sized matters directly into a base liquid. In this method nanoparticles are prepared by a physical vapour deposition (PVD) method or by liquid chemical method. Here directly condensing of nano phase powders from the vapour phase directly into a flowing a low vapour pressure fluid occurs. By using this method the problem of agglomeration can be reduced to a significant extent. By using this method minimization of agglomeration of nano particles and stability of nanofluid can be achieved. This method is best suitable for metallic nanofluids. The limitations of application of this method are it cannot be scale up to large scale applications and it only suitable for small scale applications with that other limitation is that this method is limited to low pressure base fluids.

Two Step Method:

This method is the most widely used method for preparing nanofluid. In this method nano particle generation and nanofluid preparation is done in two separate steps. In this method nano particle is first produced as dry powders by using chemical or physical methods. The prepared nano sized matter will be dispersed into a base fluid (Water). In the second processing step with the help of concentrated magnetic force agitation. It is easier than single step method as nano particles can be buy in the market and then disperse them in the base fluids. But the major disadvantage of this method is, here the dispersed nano particle has tendency to aggregation and clustering. This partial dispersion leads to lower heat transfer enhancement compared to single step method and hence large quantity of nano particles volume fraction (more than 20%) is required. This method is more suitable for oxide particle and carbon nanotubes.

B. Specifications of TiO_2 nano particles and Base fluid:

Table1: Specifications of TiO_2 nano particles

Properties	**Titanium Dioxide**
Chemical Formula	TiO_2
Color	White
Morphology	Spherical
True Density	4010 kg/m^3
Bulk Density	150-250 kg/m^3
Sp.Surface Area	200-220 m^2/g
Phase	Anatase
Average partcle Size	10-20 nm
Specific Heat	690 J/kg K

Table2.Specifications of Base fluid (water)

Properties	Water
Density	1000 kg/m^3
Thermal conductivity	0.6078 W/m-K
Dynamic viscosity	0.00088385Pa-sec
Specific Heat	4178 J/kg K

III. EXPERIMENTAL SETUP

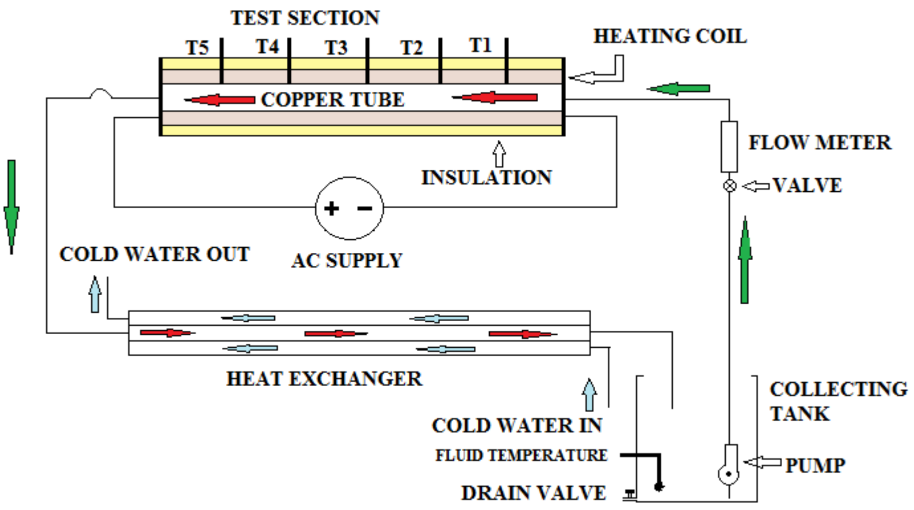

Fig.1.Schematic view of experimental setup

The above Fig.1 shows the experimental setup for "An experimental investigation of heat absorption and rejection rate of TiO_2 – water nanofluid". The setup mainly consists of the following components namely heating element, heat exchanger, reservoir and pump. Here in the heating element it consist a pipe, which is made up of copper and wounded by the nichrome wire. The ends of the nichrome wire are connected to the AC power supply. As the power is made supply to the nichrome wire, it generates the heat due to the resistance of current flow. The nichrome wire absorbs the generated heat and gets heated. With the test section experimental set up consists of concentric tube heat exchanger to analyze the heat rejection rate of nanofluid. Here in the heat exchanger the outer pipe is made up of a galvanized iron (GI) and inner pipe made up of copper. Here the nanofluid made to flow in the inner copper tube and water to flow in the outer tube. The heat exchanger is equipped with valve it is ability to make to flow parallel and counter. At the bottom of set up a reservoir is placed to store the nanofluid which has to be supplied to the test section and heat exchanger and the reservoir is made up of mild steel, which is coated with FCR coating to avoid corrosion. The pump is used to supply working fluid or nanofluid from reservoir to test section and heat exchanger.

The experimental setup with the above principle components also consist of measuring components such as flow meter having a maximum capacity 30 cc/sec to measure flow rate of working fluid supplied to the test section using the pump. It is fixed in between the reservoir output and entry section of the heating element. To measure the temperature of working fluid at different states of system the thermocouple are fixed at the different points along the flow of working fluid.

Data Analysis:

The below mentioned formulae are used to calculate the heat absorption , mass flow rate, density, specific heat and heat transfer coefficient of TiO_2 nanofluid at Test section.

- **Heat Absorption:** $Q = m * C_p * \Delta T$
- **Mass Flow Rate:** $m = \rho$ *Flow Rate
- **Density:** $\rho nf = (1-\phi)\ \rho bf + \rho p$
- **Specific Heat:** $(\rho Cp)nf = (1-\phi)\ (\rho Cp)bf + (\rho Cp)p$
- **Heat Transfer Coefficient:** **h** $= Q/A*\Delta T$

The below mentioned formulae are used to calculate the mass flow rate, heat transfer rate, average heat transfer rate, surface area, logarithmic heat temperature difference and overall transfer coefficient of TiO_2 nanofluid at Heat Exchanger.

- **Mass Flow Rate:** For Hot Fluid $m_h = \rho \times \text{Flow Rate}$

  For Cold Fluid $m_c = \rho \times \text{Flow Rate}$
- **Heat Transfer Rate:** For Hot Fluid $Q_h = m_h \times C_{ph} \times (T_{hi}-T_{ho})$,

For Cold Fluid $Q_c = m_c \times C_{pc} \times (T_{ci}-T_{co})$

- **Average Heat Transfer Rate:** $Q = (Q_c+Q_h)/2$
- **Surface Area:** $A_{os} = \pi \times d_o \times L$
- **Logarithmic Mean Temperature Difference (LMTD):** $\text{LMTD} = \frac{(T_{hi}-T_{co})-(T_{ho}-T_{ci})}{\ln\frac{(T_{hi}-T_{co})}{(T_{ho}-T_{ci})}}$
- **Overall Heat Transfer Coefficient:** $U = \frac{Q_{avg}}{A_{os} \times \text{LMTD}}$

IV. RESULT AND DISCUSSION

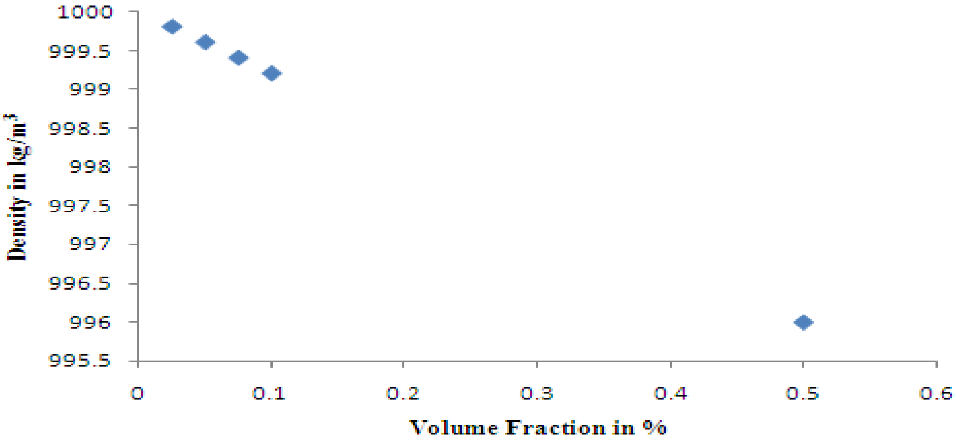

Fig2.Density of TiO_2 – Water Nanofluid for Different Volume

Fig.2 shows the variation of density of Titanium dioxide (TiO2) – Water nanofluid with respect to the volume fraction of Titanium dioxide (TiO2) nanoparticles. As the bulk density of nanoparticles is less than the density of base fluid, the nanofluid which is prepared by dispersing nanoparticles in base fluid. In the fig.2 it is observed that density of nanofluid reduces by raising the volume fraction nanoparticles in the fluid because the bulk density of nanoparticles in the fluid is less than the base fluid, so density of Titanium dioxide (TiO2) – Water nanofluid decreases by raising the volume fraction of Titanium dioxide (TiO2) nanoparticles in the base fluid.

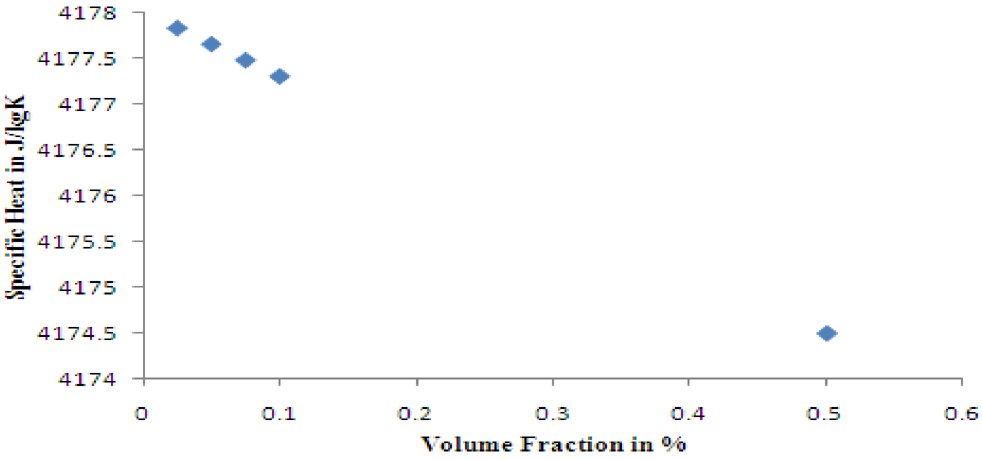

Fig3.Specific Heat of TiO_2- Water Nanofluid for Different Volume Fraction

Fig.3 shows the variation of specific heat of Titanium dioxide (TiO2) –Water nanofluid with respect to the volume fraction of Titanium dioxide (TiO2) nanoparticles. In the fig.3 it is observed that the specific heat of nanofluid decreases by raising the volume fraction of nanoparticles. As the specific heat of TiO2 nanoparticles is less than the specific heat of base fluid, so specific heat of TiO2 – Water nanofluid which is prepared by dispersing nanoparticle in base fluid reduces by raising the volume fraction of TiO2 nanoparticles in the base fluid.

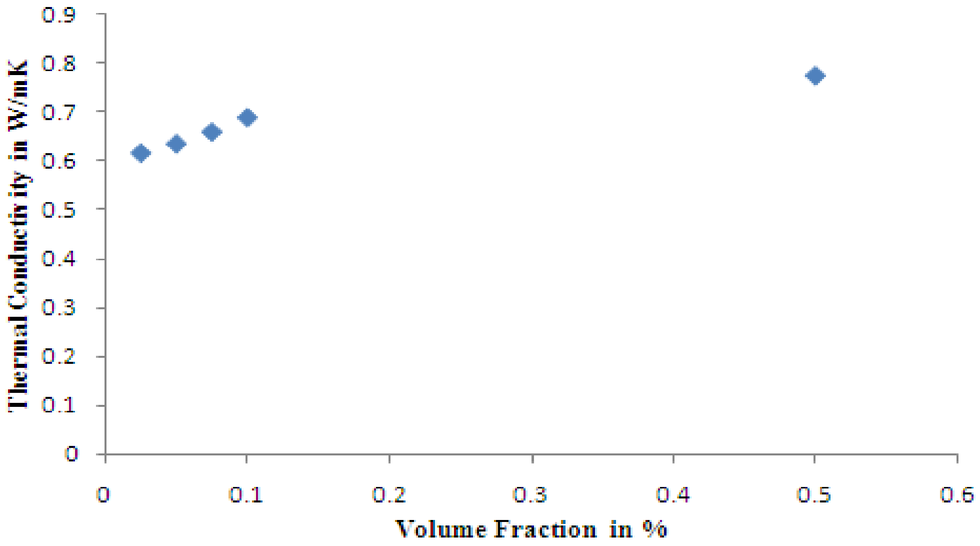

Fig4.Thermal Conductivity of TiO_2-Water Nanofluid for Different Volume Fraction

Fig.4 shows the variation thermal conductivity of TiO2 – Water nanofluid withrespect to the volume fraction of TiO2 nanoparticles. In the fig.4it is observed that the thermal conductivity of nanofluid enhances by increasing the volume fraction of nanoparticles. Because the thermal conductivity of TiO2 nanoparticles is higher than the thermal conductivity of base liquid, so thermal conductivity of TiO2 – Water nanofluid which is prepared by dispersing nanoparticle in base liquid enhance by increasing the volume fraction of TiO2 nanoparticles in the base fluid.

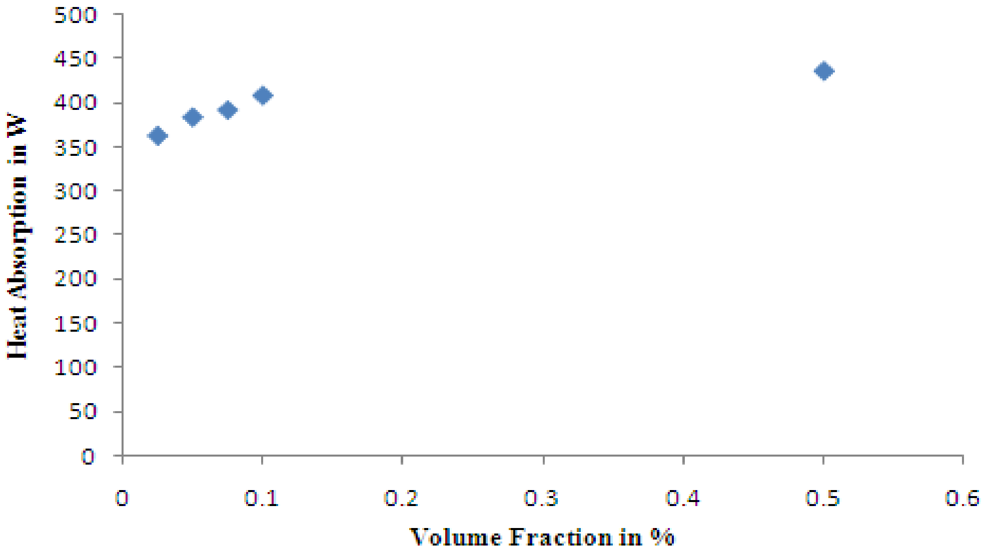

Fig5.Heat Absorption of TiO_2 – Water Nanofluid for Different Volume Fraction

Fig.5 shows the variation heat absorption of TiO2– Water nanofluid with respect to the volume fraction of TiO2 nanoparticles. In the fig.5 it is observed that heat absorption of nanofluid increases by raising the volume fraction of nanoparticles. Since the thermal conductivity and film Coefficient of TiO2 nanofluid is increases by increasing the volume fraction results in increases of heat absorption of nanofluid which is prepared by dispersing nanoparticle in base liquid by raising the volume fraction of TiO2 nanoparticles.

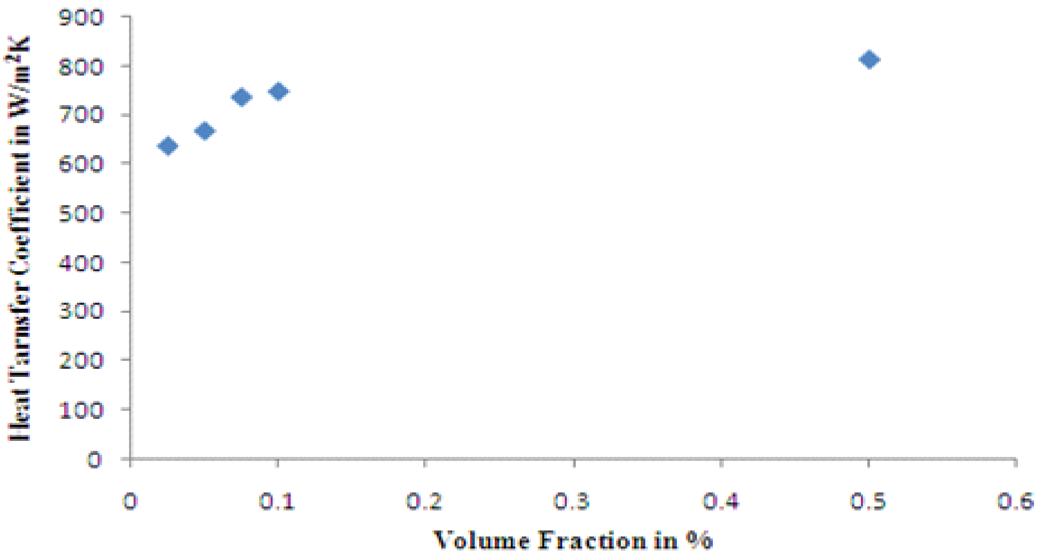

Fig6.Heat Transfer Coefficient of TiO_2-Water Nanofluid for Different Volume Fraction

Fig6 shows the variation of heat transfer coefficient of TiO2-Water nanofluid with respect to the vaolume fraction of TiO2 nanoparticles. In the fig it is observed that heat transfer coefficient of nanofluid increases by increasing the volume fraction of nanoparticles. Since the specific surface area of the dispersed TiO2 nanoparticles increases the available heat transfer area for the fluid and higher thermal conductivity of TiO2 nanoparticles makes the heat transfer coefficient of the nanofluid which is prepared by dispersing nanoparticles in base fluid increases by increasing the volume fraction of TiO2 nanoparticles

V. CONCLUSION

In this work by observing the experimental results for Thermo physical properties of nano fluids and experimental results for test section and heat exchanger the following conclusions can be made.

- The homogeneous and stable nanofluid can be obtained by making mechanical stirring.

- Bulk density of nano particle is lesser than that of base fluid therefore there is decrease in density of the nanofluid by raising the volume fraction.

- Viscosity of nanofluid increases by raising the volume fraction, because viscosity of nanofluid sis depends only on the volume fraction of nano sized matters.

- Specific heat of nano particle is lesser than that of base fluid, which results volume fraction increases in the fluid specific heat of nanofluid decreases.

- Thermal conductivity of nanoparticles is higher than the base fluid hence as volume fraction increases in the range of 0.025–0.5% the fluid thermal conductivity of nanofluid increases minimum of 8 % to maximum of 30 % compare to the base fluid.

- In test section heat transfer coefficient of nanofluid increases by raising the volume fraction of nanoparticles. Because the specific surface area of the dispersed TiO_2 nanoparticles increases the available heat transfer area for the fluid. And a higher thermal conductivity of TiO_2 nanoparticle makes the heat transfer coefficient of the nanofluid increases. By raising the volume fraction of TiO_2 nanoparticles. In the range of 0.025 – 0.5% the fluid heat transfer coefficient of nanofluid increases minimum of 6% to maximum of 34% compare to the base fluid.

- Overall heat transfer coefficient of nanofluid increases by raising the volume fraction of nanoparticles. Because the specific surface area of the dispersed TiO_2 nanoparticles increases the available heat transfer area for the fluid. And higher thermal conductivity of TiO_2 nanoparticles make the overall heat transfer coefficient of the nanofluid and cold fluid increases by raising the volume fraction of TiO_2 nanoparticles. In the range of 0.025 – 0.5% the fluid heat transfer coefficient of nanofluid increases minimum of 9% to maximum of 57% compare to the base fluid.

REFERENCES

[1] Fei Duan, 2012. Thermal Property Measurement of Al2O3-Water Nanofluids. Smart Nanoparticles Technology, 335-356

[2] Ra Zvan Silviu Luciu1, Theodor Mateescu, Victoria Cotorobai and Thierry Mare, 2009. Nusselt Number And Convection Heat Transfer Coefficient For A Coaxial Heat Exchanger Using Al2O3–Water Ph=5 Nanofluid, Sectia, 71-80

[3] S.Lee, J A Eastman, et, al., 1999. Measuring Thermal Conductivity of Fluid Containing a Oxide Nanoparticles. ASME Vol. 121, 280-289.

[4] Vincenzox Bianco, Oronzio Manca Sergio Nardini, Kambiz Vafai, 2015. Heat Transfer Enhancement with Nanofluids, CRC Press Taylor & Francis Group, Boca Raton

[5] Xinwei Wang and Xianfan Xu, Stephen U. S. Choi, 1999. Thermal Conductivity of Nanoparticle–Fluid Mixture, Journal Of Thermophysics and Heat Transfer Vol. 13, No.4

[6] Kaufuix V. Wong and Omar De Leon, 2009. Applications of Nanofluids: Current and Future, Hindawi Publishing Corporation Advances in Mechanical Engineering Volume 2010, Article ID 519659, 11pages doi:10.1155/2010/519659

[7] Andreea Kufner, 2013. Design Parameters to Obtain Al2O3 Nanofluid to Enhance Heat Transfer. International Journal of Research in Engineering and Technology eISSN: 2319-1163 Volume: 02

[8] Jaafar Albadr, Satinder Tayal, Mushtaq Alasadi, 2013. Heat transfer through heat exchanger using Al2O3 nanofluid at different concentrations. Published by Elsevier Ltd.