Thermal performance analysis of closed two-phase thermosyphon charged with using varying percentage of ethanol and AL2O3 nanofluids.

[1]Bhimrao C. Markand, [2]H. G. Patil

[1]Student, [2]Professor
D N Patel College Of Engineering Shahada
Department of Mech. Engineering
Sharda nagar Nandurbar

Abstract **-Thermal performance of thermosyphon is most significant piece in the field of thermal engineering. Thermosyphon are a massive prospect towards cooling of high heat dissipating electronics. The implementation of a two phase closed thermosyphon for checking the thermal performance is being presented in this project. The thermosyphon work on the principle of evaporation and condensation and thus enhances large amount of heat. The working fluid used is ethanol and the second trial was done by addition of suspended particles of 10 nm aluminum powder in solution of ethanol 10 % by volume. The four factors were studied; the effect of heat load, the effect of working fluid types, the effects of flow rates of cooling water and the inclination with vertical. It is observed that heat transfer increases as heat load increases, heat transfer increases by using Al2O3 Nanofluid than ethanol. As flow rates of cooling water decreases the heat transfer increases. The maximum heat transfer takes place at vertical orientation (i.e.90^0) and also as the inclination decreases the heat transfer also decreases.**

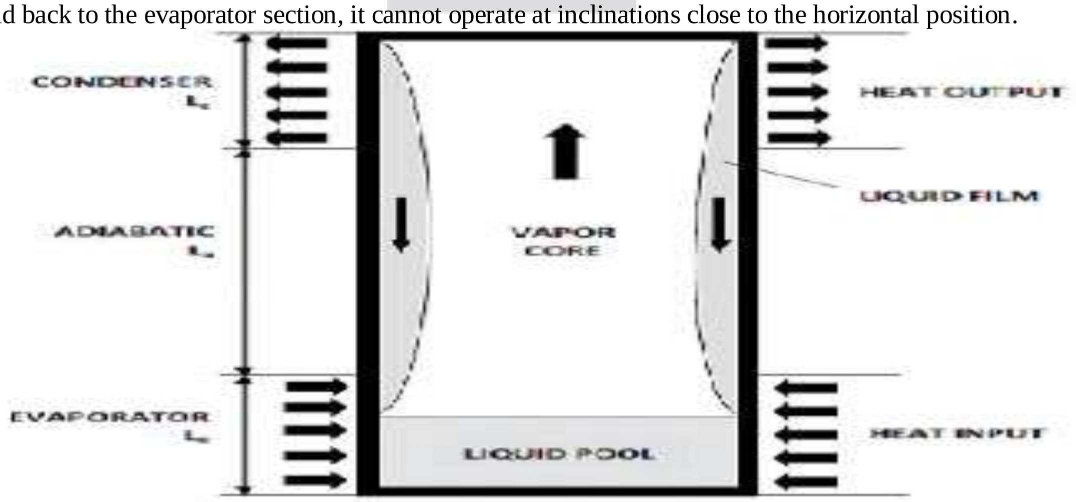
Keywords**: Al2O3Nano fluid, Two phase Closed Thermo-syphon, Heat pipe**

I. INTRODUCTION

Heat transfer and energy supply play a major role in various industries including transportation, air conditioning, power generation, nuclear plants, electronic devices etc. The modification of the surfaces of heat exchangers as well as use of high performance working fluids were among many techniques implemented for enhancing the overall performance of the heat exchangers. Heat pipe is a device that employs an evaporation mode of heat transfer in the evaporator section and the condensation mode in the condenser section to convey heat. The liquid flow from the condenser to the evaporator section could be produced by the gravitational force, capillary force, or other external forces that directly acting on the fluid (i.e. electrostatic force). On the other hand, the vapour flow from the evaporator to the condenser section is caused by the vapour pressure difference between these two sections.

Thermosyphon Geometry and Working Principle

A cross section of a closed two-phase thermosyphon is illustrated in Fig. 1; the thermosyphon consists of an evacuated sealed tube that contains a small amount of liquid. The heat applied at the evaporator section is conducted across the pipe wall causing the liquid in the thermosyphon to boil in the liquid pool region and evaporate and/or boil in the film region. In this way the working fluid absorbs the applied heat load converting it to latent heat .The vapour in the evaporator zone is at a higher pressure than in the condenser section causing the vapour to flow upward. In the cooler condenser region the vapour condenses and thus releasing the latent heat that was absorbed in the evaporator section. The heat then conducts across thin liquid film and exits the thermosyphon through the tube wall and into the external environment. Within the tube, the flow circuit is completed by the liquid being forced by gravity back to the evaporator section in the form of a thin liquid film. As the thermosyphon relies on gravity to pump the liquid back to the evaporator section, it cannot operate at inclinations close to the horizontal position.



II. REVIEW OF WORK CARRIED OUT

Many investigations were carried out in order to analyze and to enhance the thermal performance of Thermosyphon. These are as follows.

K.S. Ong and Md. Haider-E-Alahi

[1] Investigated performance of an R134a filled thermosyphon. They carried out the experiments to study the effects of temperature difference between bath and condenser section, fill ratio and coolant mass flow rate. The thermosyphon was of a copper material with inside and outside diameter of 25.5mm and 28.2mm respectively. The overall length of thermosyphon was 780mm (300mm-evaporator length, 300mm-condenser length). They obtained the results that the heat flux transferred increased with increasing coolant mass flow rate, fill ratio and temperature difference between bath and condenser section.

S.H. Noie, S. ZeinaliHeris, M. Kahani and S.M. Nowee

[2]Presents Nan fluids of aqueous Al2O3 nanoparticle suspensions were prepared in various volume concentration of1–3% and used in a TPCT as working media. Experimental results showed that for different input powers, the efficiency of the TPCT increases up to 14.7% when Al2O3/water Nanofluid was used instead of pure water. Fluids with nanoparticles (particles smaller than 100 nm) suspended in them are called Nano fluids that they have a great potential in heat transfer enhancement.

Sameer Khandekar, Yogesh M. Joshi and Balkrishna Mehta

[3] Investigated the thermal performance of closed two-phase thermosyphon using water and various water based nanofluids (of Al2O3, CuO and laponite clay) as a working fluid. They observed that all these nanofluids show inferior performance than pure water.

Preecha Khantikomoland WasanSrimuang

[4] Presents an experimental investigation of the heat transfer characteristics of a CEOFHP. The effects of four factors were examined: types of working fluids, heat loads, and flow rates of cooling water and total lengths. R123, ethanol and water with filling ratio of 50%of the total internal volume were used for working fluids. Three total lengths of the CEOFHP: 150, 300 and 450 mm were performed in same evaporator length. The heat load was varies in the range of 5-15 kW/m2. The results showed that the maximum heat flux of 14.5 kW/m2 occurred at the following conditions: R123 as working fluid with the total length of 150 mm and heat load of 15 kW/m2. The increasing levels of heat flux are water, ethanol and R123 respectively. The heat flux increases with heat loads. The flow rate of cooling water had a significant effect on heat flux. The heat flux decreases with the

Gabriela Huminic and Angel Huminic

[5]investigate the heat transfer characteristics of two-phase closed thermosyphon (TPCT) with iron oxide-Nano fluids are presented. The TPCT is fabricated from the copper tube with the outer diameter and length of 15mm, 2000 mm, respectively. The TPCT with the de-ionic water and Nan fluids (water and nanoparticles) are tested. Effects of TPCT inclination angle, operating temperature and nanoparticles concentration levels on the heat transfer characteristics of TPCT are considered. The nanoparticles have a significant effect on the enhancement of heat transfer characteristics of TPCT.

Data reduction

In this study TPCT was insulated completely. The absence of any heat loss from evaporator, adiabatic and condenser sections of the TPCT to the surroundings. Therefore amount of heat input at the evaporator section is equal to the amount of heat rejected at the condenser section. The heat input that transferred to the evaporator section was calculated from the following relation

$$Q\,(in) = \frac{V^2}{R} \qquad (1)$$

The heat flux that transferred to the evaporator section was calculated from the following relation

$$q\,(in) = \frac{V^2}{R \times A_{se}} \qquad (2)$$

Where V is the voltage supplied to evaporator section, R is resistance of coil, A_{se} is the surface area of evaporator section.

The heat out removed from the condenser section was obtained by using the equation as follows

$$Q\,(out) = \dot{m} \times C_p \times (T_{out} - T_{in}) \qquad (3)$$

The heat flux removed from the condenser section was obtained by using the equation as follows

$$q\,(out) = \frac{\dot{m} \times C_p \times (T_{out} - T_{in})}{A_{sc}} \qquad (4)$$

Where $\dot{m}$ is the mass flow rate of cooling water, C_p is constant pressure specific heat of water, Tin is the water temperature of the inlet cooling jacket and Tout is the water temperature of the outlet cooling jacket, A_{sc} is the surface area of condenser section.

The efficiency of TPCT can be expressed as a ratio of the output heat by condensation to the inlet heat by evaporation

$$\eta = \frac{Q_{out}}{Q_{in}} \qquad (5)$$

III. EXPERIMENTAL SET UP

Aluminum oxide (Al2O3) nanoparticles with physical characteristic presented in Table 1 were used in this study.

Table 1 Physical Characteristic of Al2O3 nanoparticles used in this experiment

Particle	Average Diameter (nm)	Superficial Density(Kg/m3)	Actual Density(Kg/m3)	Cp (J/Kg K)	K (W/m K)
Al2O3	10	160-400	3700	880	4

The schematic diagram of experimental set up is illustrated in Fig. 2 The test rig consist of TPCT made of copper tube with internal diameter 25.4 mm, 1mm thickness and 500 mm in length. The evaporator, adiabatic and condenser sections had125mm, 125mm and 250 mm length respectively .Band heater used for heating the evaporator section, ammeter used to measure voltage and resistance. Digital temperature indicator was used to measure temperature along the thermosyphon tube; coolant tank was used to supply the cold water to evaporator section. Beaker was used to measure mass flow rate of outlet of coolant by using stop watch.

Condenser section is surrounded by concentric cylinder through which coolant flows. The coolant flow is varied by a controlled valve. For initial evacuation of tube arrangement is made to attach vacuumed pump at the top and also pressure gauge is attached to measure the pressure inside the tube. Evacuation is necessary to eliminate the effect of non condensable gases.

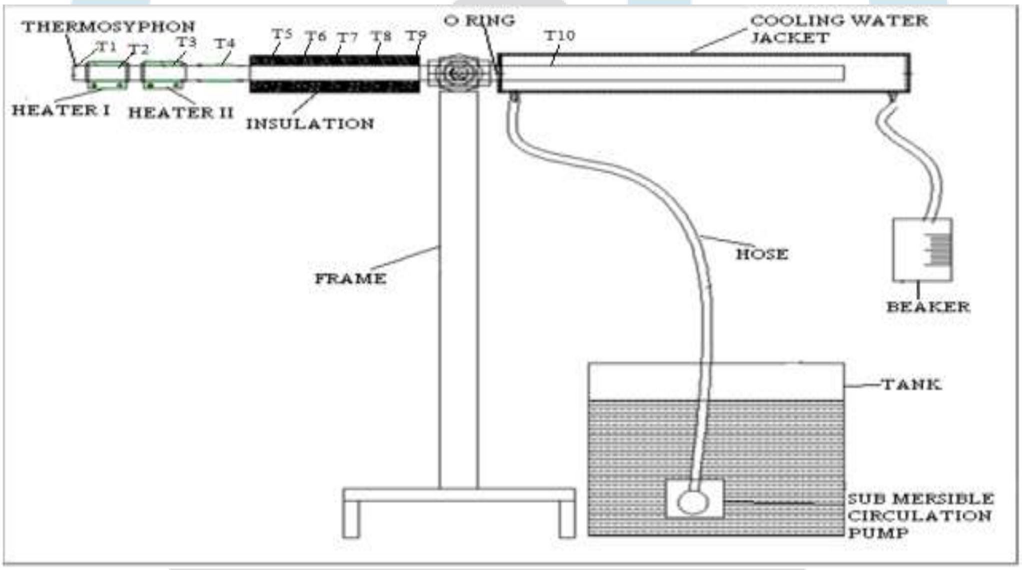


Fig. 2 Schematic diagram of experimental set up of two phase closed thermosyphon

Experimental procedures began after charging the working fluid in the TPCT and supplied the cooling water to the condenser section. The electrical heater was turned on and time was allowed for the operating temperature to reach a steady state. Then the Temperatures (T1-T10 points) were recorded.

IV. RESULT AND DISCUSSION

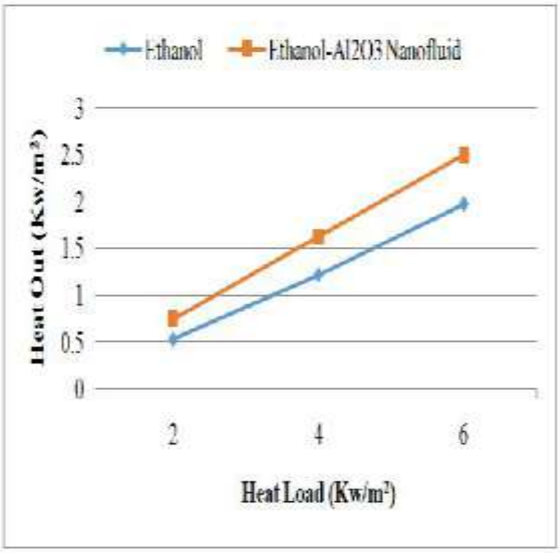
The effect of heat loads

The TPCT with total length of 500 mm was used for formative the effect of heat loads on thermal performance.

The tests were conducted at different heat loads and working fluids. Fig.3 shows the connection between heat loads that was supplied to evaporator section and heat flux of TPCT

The results shows that the heat loads have significant persuade on the heat flux. As heat load increases the heat flux also increases, if the heat load changed from 2, 4 to 6 Kw/m2, the heat flux increased from 0.75, 1.6 to 2.5 Kw/m2 respectively in case of ethanol-Al2O3 Nan fluid. Thus it can be concluded that the heat flux increases linearly with the heat load.

Fig 4 shows the relationship between input power and efficiency for different working fluids. The result shows that as input power increases the efficiency also increases. The maximum efficiency was observed 86.44% at 60 w in case ofethanol-Al2O3 Nanofluid. It can be concluded that the efficiency increases linearly with the heat load.



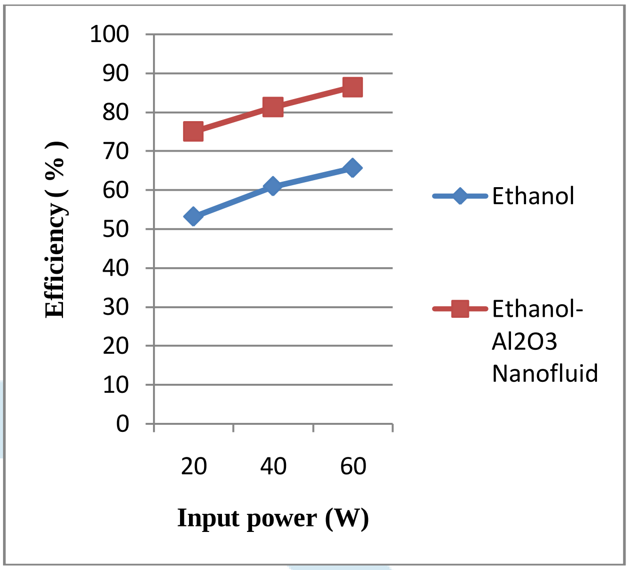


Fig.3 effect of heat load on heat out for different working fluids

Fig. 4 The effect of input power on efficiency for different working fluids

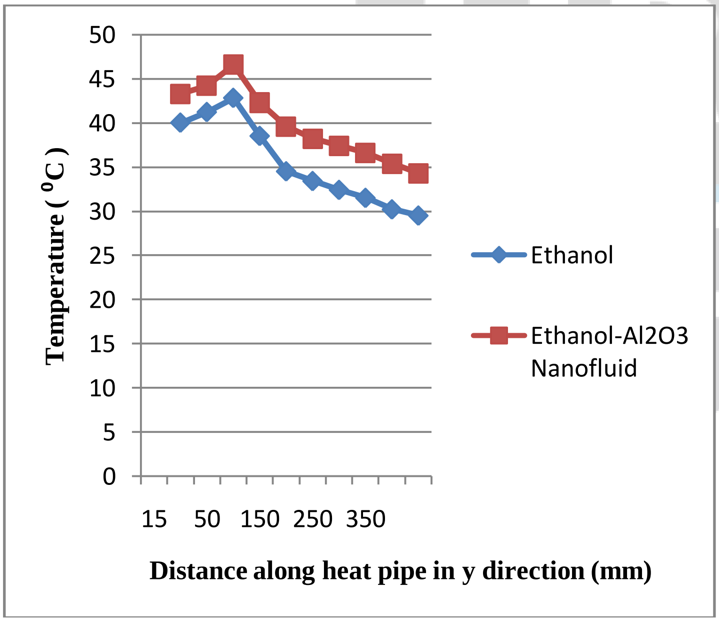
The effect of working fluids types

Fig 5 shows temperature allocation along the surface of the TPCT with different working fluids.

The experimental results shows that the temperature of each working fluid increases in evaporator section at one point it reaches maximum and after this point, the temperatures decreased toward the adiabatic section and reached its minimum value at the bottom part of condenser section. If the working fluid was changed from ethanol to ethanol-Al2O3Nano fluid, it was found that the temperature at surface increased. The maximum temperatures obtained by ethanol and ethanol- Al2O3 Nanofluid were 42.80C and 46.60Crespectively. From above it can be concluded that the heat transfer increases as working fluid changes from ethanol to ethanol- Al2O3 Nanofluid.

The effect of flow rates of cooling water

For checking the consequence of flow rates of cooling water test was conducted with constant parameter, total length of 500 mm, heat load of 2 Kw/m2 and working fluid of ethanol. Temperature distribution along the surface of TPCT with different mass flow rate of cooling water were plotted in Fig.6 For occurrence, at the heat loads of 2kw/m2, if the mass flow rate changes from 0.0014925 kg/s, 0.002439 kg/s to 0.005 kg/s, the maximum temperature decreases from 42.8 0C,38.10C to34.20C respectively. Thus it can be concluded that as mass flow rate of cooling water decreases the heat transfer increases.



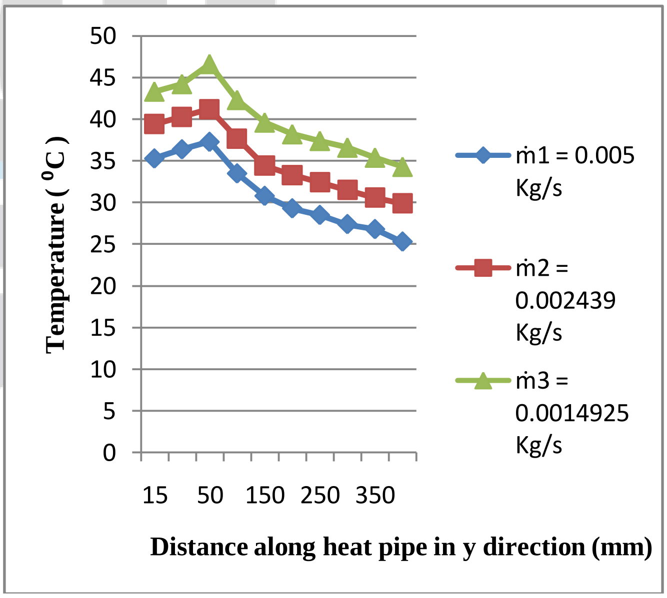


Fig.5 Temperature distribution along the surface of the TPCT with different working fluids for Total length = 500 mm, heat load = 2 Kw/m2 and mass flow rate =0.0014925 Kg/s

Fig.6 Temperature distribution along the surface of the TPCT with different working fluids for Total length = 500 mm, heat load = 2 Kw/m2.

The Effect of inclination with vertical

For checking the effect of inclination with vertical tests were conducted with constant parameter of total length of 500 mm ,heat load of 2 Kw/m2, mass flow rate of 0.0014925 Kg/s and working fluid of ethanol. The temperature distribution along the surface of TPCT with different angles were plotted in Fig.7At instant of heat load of 2 Kw/m2 if the angle changes from900, 800, 700 and 600 to 500 the maximum temperatures decreases from 42.8, 41.3, 39.2 and 36.7 to 33.4. Thus it can be concluded that the maximum heat transfer occurred at vertical orientation and as angle decreases the heat transfer also decreases.

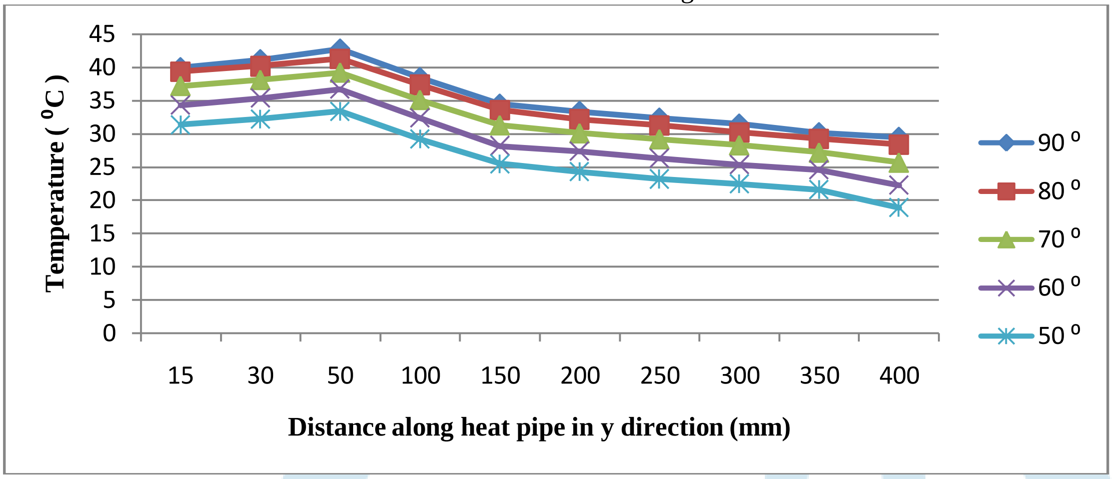


Fig.7 **Temperature distribution along the surface of the TPCT with different working fluids for Total length = 500 mm, heat load = 2 Kw/m2 and mass flow rate = 0.0014925 Kg/s**

V. CONCLUSIONS

1. The Properties of Ethanol are studied at various proportions of Mixtures and find out maximum heat input for various mixtures by heat transfer limitations correlations The use of ethanol-Al2O3 Nan fluid as the working fluid gives improved transfer of heat flux and efficiency as compare to ethanol.
2. The heat input had effect on the heat flux of the TPCT. The heat flux increased linearly with the heat load
3. The mass flow rate of cooling water also affect the thermal performance of the TPCT. The heat transfer increases as mass flow rate of cooling water decreases.
4. Inclination thermosyphon tube had significant effect on the thermal performance of the TPCT. As angle of inclination increases from horizontal efficiency of thermosyphon increases The maximum heat transfer occurred at vertical orientation and as angle decreases the heat transfer

VI. ACKNOWLEDGEMENT

This paper consists of detailed experimental investigation of Thermosyphon charged with nanofluid under various working conditions considering factors like tilt angle, Mass flow rate of coolant. Detailed characteristic curves are explained in the paper so that one can select the Thermosyphon heat pipe according to their application.

REFERENCES

1. Balkrishna Mehta and Sameer Khandekar, Two phase closed thermosyphon with nanofluids, 14th international heat pipe conference, Florianopolis, Brazil, April 22-27, 2007.
2 Huminic, G., Huminic, A., Heat transfer characteristics of a two-phase closed thermosyphon using nanofluids, Int. J. Exp.Therm. Fluids Sci, 35 (2011), pp. 550–557
3. M. R. Sarmasti Emami, S. H. Noie and M. Khoshnoodi, "Effect of aspect ratio and filling ratio on thermal performance of an inclined two-phase closed thermosyphon". Iranian Journal of Science & Technology, 2008, pp. 39-51.
4 H. Jouhara1, O. Martinet and A.J. Robinson, Experimental study of small diameter thermosyphon charged with FC-84,FC-77,FC-3283 5th European thermal science conference ,Netherland,2008
5. PreechaKhantikomoland WasanSrimuang, An experimental investigation of heat transfer Characteristics of a closed end oscillating heat pipe, 10thIHPS Taipei, Taiwan Nov.2011
6. S.H. Noie, S.Z. Heris, M. Kahani and S.M. Nowee, Heat transfer enhancement using Al2O3/water, nanofluid in a two-phase closed thermosyphon, International Journal of Heat and Fluid Flow 30 (2009) 700–709.
7. W. Srimuang, S. Rittidechand and B. Bubphachot, Heat transfer characteristics of a vertical flat thermosyphon, Journal of Mechanical Science & Tech. 23 (2009) 2548-
8. Singh, A. K., Thermal conductivity of nanofluid, Defence science journal, 2008, 58(5), pp. 600 – 607.