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RESEARCH ARTICLE

CFD Analysis and Experimental Investigation on Thermal Performance of Closed loop Pulsating Heat pipe using different Nanofluids

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Abstract

This paper presents Enhancement of the Thermal performance of a heat pipe charged with Nanofluids. The SiO_2 /DI Water and Al_2O_3/DI Water served as the working nanofluids with concentrations by different mass 10g/lit, 20g/lit, 30g/lit in heat pipe. The heat pipe is fabricated by a straight copper tube with an outer diameter 3mm, thicknes 1mm and length of 1785mm. This paper presents a discussion on the effect of various performing parameters by varying different heat inputs as well as nanofluids concentration as SiO_2/DI Water and Al_2O_3/DI Water. CFD results analysis to comparison for Experimental results show that at a heating power of 10w, 14w, 18w, 22w the Thermal resistance, Thermal heat transfer Co-efficient, Thermal Thermal conductivity and Efficiency for CLPHP SiO_2/DI Water and Al_2O_3/DI Water heat pipe are 69.37%, 75.99% and 11.98% DI water respectively, which are better than that of pipes using DI water as the working nanofluids.

Introduction

The heat pipes were developed especially for space applications during by the NASA and one main problem in space applications was to transport the temperature from the inside to the outside, because the heat conduction in a vacuum is very limited hence there is a necessity to develop a fast and effective way to transport heat, without having the effect of gravity force. Nowadays heat pipes are several applications, heat from various engineering systems including electronic components, cell phones, computers Ext. A limiting factor for the heat transfer capability of a heat pipe is related to the working Nanofluids transport properties. In order to overcome this limiting factor for the heat transfer capability of a heat pipe is related to the working nanofluids transport properties.

The present scenario high flux levels demands exploration of new heat transfer augmentation mechanisms besides the conventional techniques Nanofluids are recent emerging as alternative to conventional heat transfer nanofluids. A heat pipe is an excellent heat conductor, one end of a heat pipe is the condensation section.when the evaporation section is heated, the liquid in the heat pipe evaporates rapidly. This vapour releases its heat at the condensation section, which has a small vapour pressure difference, and condenses back into liquid. The condensed liquid in the condensation section then flows back to the evaporation section along the inner wall of the heat pipe and undergoes endothermic evaporation in the evaporation section. The heat transfer of a closed loop pulsating heat pipe and uses working nanofluids that changers phases in a continuous endothermic and exothermic cycle, giving the heat pipe excellent heat transfer performance.

Nanofluids is a stable solid-liquid suspension created by mixing of nanoparticles with the traditional working Nanofluids the nanoparticles in the heat pipe nanofluids include metal particles Diamond and oxide particles. Different nanoparticles Such as gold, Silver, Diamond, Alumina, Titanium, Copper Oxide, Nickel Oxide and iron oxide have been utilized in heat pipe as a working nanofluids .A common range of concentration for different nanoparticles, namely SiO_2, Al_2O_3, CuO, and TiO_2 in Water is considered as the operational nanofluids within the heat pipe under various heat inputs.

Experiments Apparatus and procedure.

Fig 1: Experimental setup.

Fig 2: Experimental Setup Different Orientation.

The heat pipe in this study was made of straight copper tubing with on outer diameter of 3mm, 1mm thickness and length of 1785 mm. It mainly divided three different sections such as evaporator section, adiabatic section and condenser section Lengths of 630mm, 680mm and 475mm respectively. The Experimental setup mainly consists of a Resistance Heater. The temperatures on the heat pipe were measured using a Digital temperature indicator with eight thermocouples (k-Type) at different points. The accuracy of temperature measurements was 0.50℃ The Digital temperature indicator is used to record the thermocouple readings at different positions of the heat pipe. Thermocouples of k-type (8 numbers) are used to measure the temperature at the different sections of the heat pipe. In total eight thermocouples were attached on the heat pipe wall. The cooling jacket, which consists of inlet and outlet ports for cooling water at the inlet and outlet are measured j-type thermocouples.

The copper tubes in the condenser section are connected to the glass tubes simply by fitting a small silicon tube (OD 4mm /ID 3 mm). This approach is not suitable for the copper and glass connection in the evaporator zone due to the high temperatures. In this case a copper joint is located at each end of U-turns by mean of a steel ring, then the glass tubes are inserted in the copper fitting and coupled to the copper tubes. Mica heater plates (200mm x 50mm x 3mm) have been built and circular cross section channels have been embedding the copper U-turns. Proper thermal contact between the U-turns and copper plates is obtained a high conductive paste.

The closed loop pulsating heat pipe was charged with nanofluids at different fluids mass concentrations as 10g/L, 20g/L and 30g/L respectively. An AC power supply is the source of power for the cylindrical resistance heater, used for heating of the evaporator section. The heating power in the evaporation section was kept at 10W, 14W, 18Wand 22Wby variable transformer with variable power supply of resistance heater at an accuracy of 0.5W. The flow rate of cooling water is measured when the heat pipe attains steady state conditions. It is adjusted to get the temperature difference of 3-6°C. The test of heat pipe performance was with varying parameters such as fluid concentrations and heat in power(W) and different orientations heat pipes in 15°, 30° 45°, 60°,75° 90° to evaluate the thermal performance. SiO_2 and Al_2O_3 were used as working nanofluids different mass concentration with a filling ratio of 50% by total volume. The CLPHP was set into the test ring. The temperature of the heater and cold baths was set at the required value cold Nanofluids were supplied to the jackets of the condenser section. When the evaporator temperature was increased until it reached under test conditions. The time was required to achieve steady state was about 30min after that a steady state was reached.

Results and Discussions

Effect of the heat transfer rate on overall thermal resistance of heat pipe:

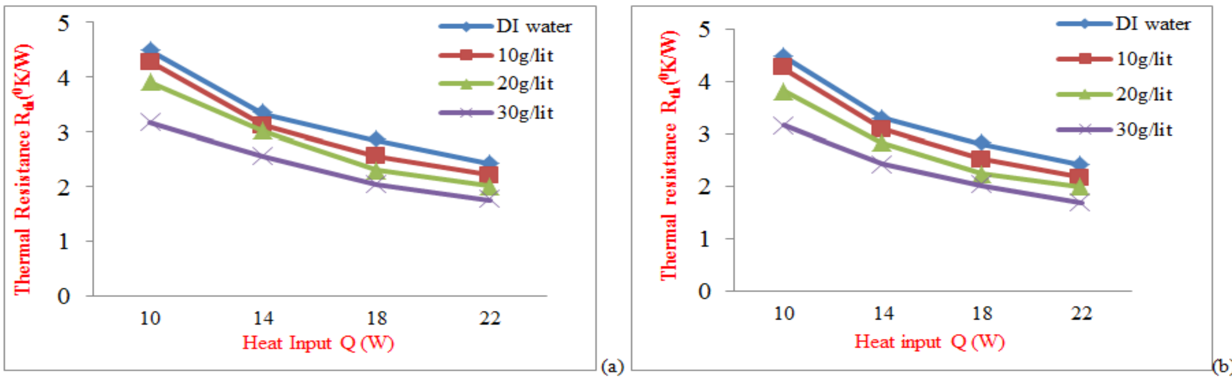


Fig 3: Thermal Resistance v/s Heat Input (a) SiO_2 and (b) Al_2O_3 Nano fluids.

Fig.3 shows the changes in the overall thermal resistance of the heat pipe for various heating power as well as different nanofluids concentration values of SiO_2/DI water and Al_2O_3/DI water nanofluids heat pipe. The overall thermal resistance of heat pipe decreases as mass concentration of nanofluids. the experimental results shows that the minimum value of overall thermal resistance is obtained 1.76^{o}k/w, at 22w with 30g/lit, SiO_2 nanofluid which is 55.27% less than pure water . Thermal resistance of heat pipe more decreases as mass concentration of Al_2O_3 nanofluids. Experimental results show that the minimum value of overall thermal resistance is obtained 1.68 ^{o}k/w, at 22w with 30g/lit Al_2O_3 nanofluids which are 65.2% less than pure water. Comparison b/w SiO_2 and Al_2O_3 nanofluids less Thermal résistance Al_2O_3 Nano fluids.

Effect of the Heat Transfer coefficient of heat pipe:

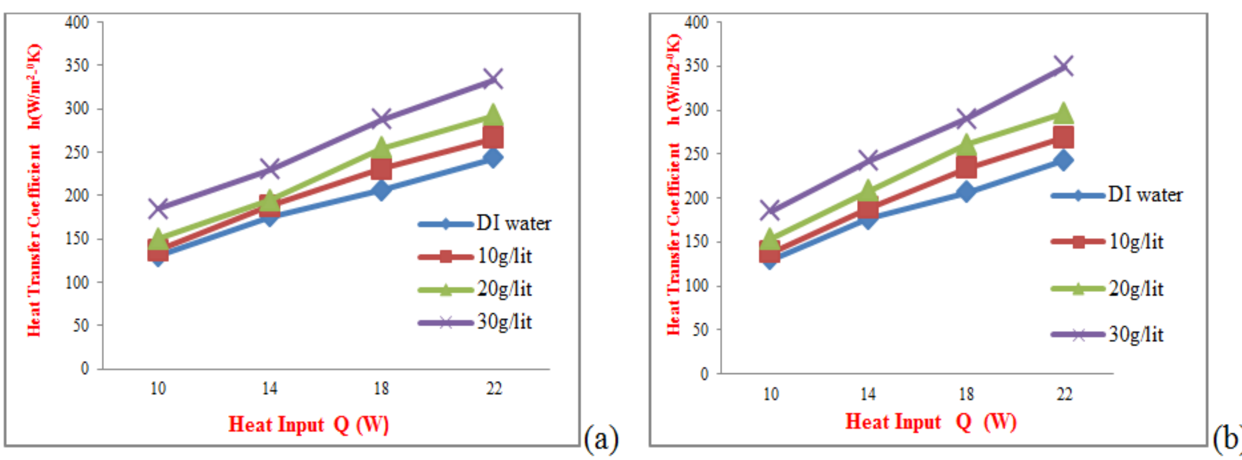


Fig4: Thermal Heat Transfer Coefficient v/s Heat Input for (a) SiO_2 and (b) Al_2O_3 Nanofluids.

Fig.4 shows the Heat Transfer co-efficient increases as concentration of nanofluids increases. The experimental results shows that the maximum value of heat transfer rate is obtained 22w with 30g/lit SiO_2 nanofluids values 333.33 W/m² °K more than that 27.27%more than that of pure water and the maximum value of heat transfer rate is obtained 22w with 30g/lit Al_2O_3 nanofluid values 349.11 W/m² °K more than that 30.46% more than pure water .Comparison b/w Al_2O_3 and SiO_2 nanofluid more than 3.19 %.

Effect of the heat transfer rate on overall thermal conductivity of heat pipe:

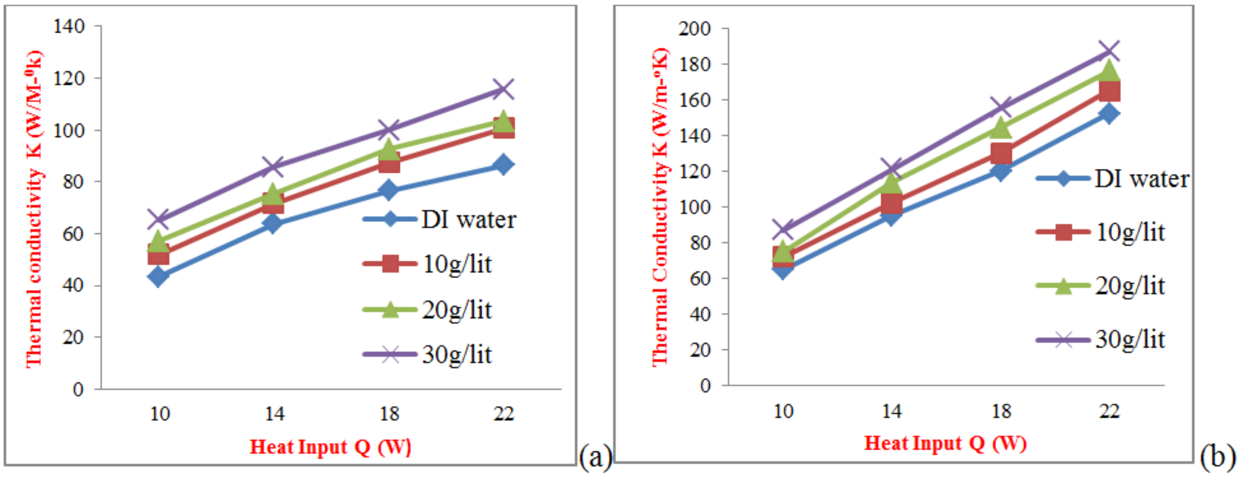


Fig 6: Thermal Conductivity v/s Heat Input for (a) SiO_2 and (b) Al_2O_3 Nanofluids.

Fig.5 shows the changes in the overall thermal conductivity of the heat pipe for various heating power ,as well as different nanofluids concentration values of SiO_2/DI water and Al_2O_3/DI Water nanofluids heat pipe. that the overall thermal conductivity of heat pipe increases as concentration of nanofluids increases as different mass concentration of nanofluids increases. The Experimental results shows that the maximum value of thermal conductivity 115.6 W/m °K is obtained at 22W with 30g/lit SiO_2 nanofluid which 25.22% more than pure water and maximum value of thermal conductivity 186.96 W/m °K is obtained at 22W with 30g/lit Al_2O_3 nanofluid which 53.77% more than pure water. Comparison of SiO_2 and Al_2O_3 nanofluids thermal conductivity more than SiO_2 28.55%.

Effect of the heat transfer rate on the overall thermal Efficiency of heat pipe:

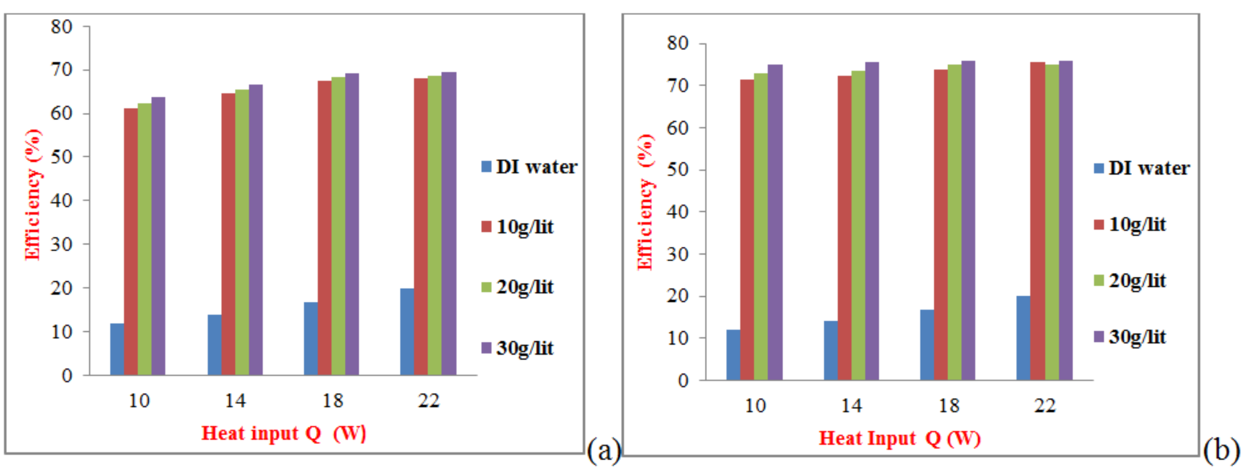


Fig 6: Efficiency v/s Heat Input for (a) SiO_2 and (b) Al_2O_3 Nanofluids.

Fig, 6 The efficiency of heat pipe can be expressed as a ratio of the output heat by condensation to the inlet heat by evaporation, the changes in the thermal efficiency of the heat pipe for various heating power, as well as different nanofluids concentration values of SiO_2/DI water and Al_2O_3/DI water nanofluids heat pipe. shows the efficiency of heat pipe increases as different mass concentration of nanofluids increases the Experimental results shows that the maximum value of efficiency is obtained 69.37% at 22w with 30g/lit SiO_2 nanofluid which is 49.4% more than Distil water and the experimental results Shows that the maximum value of efficiency is obtained 75.99 % at 22w with 30g/lit Al_2O_3 nanofluid which is 43.98% more than distil water.

CFD Results

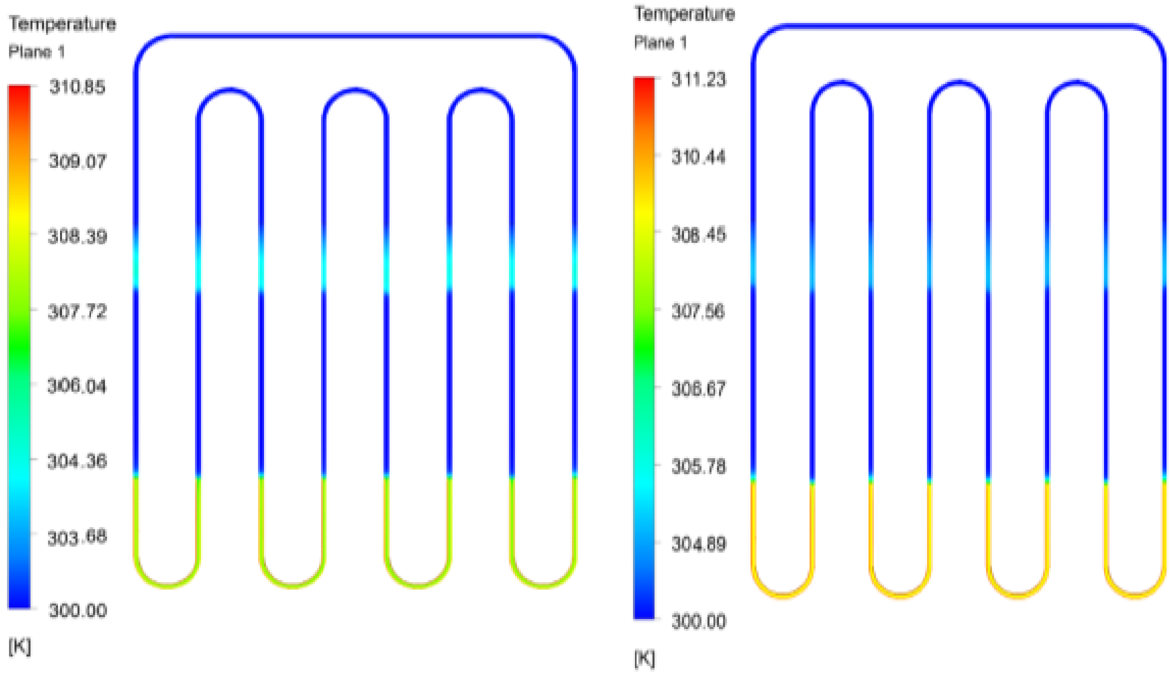


Fig 7: Temperature contours 5 and 10 min

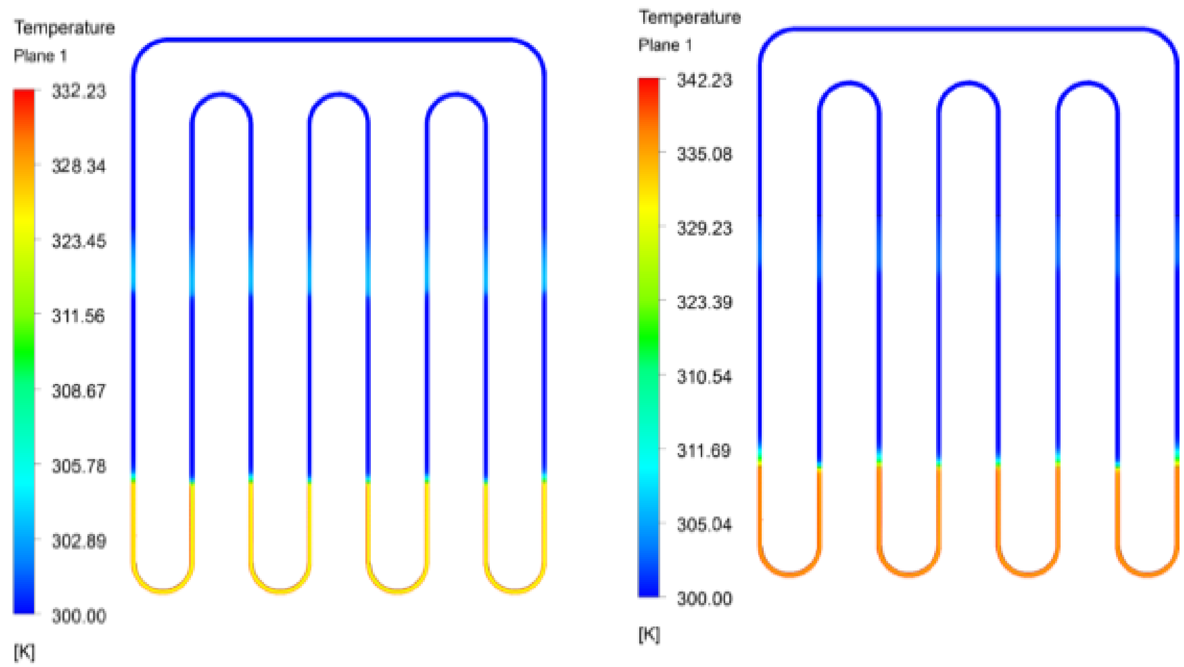


Fig 8: Temperature contours 15 and 20 min

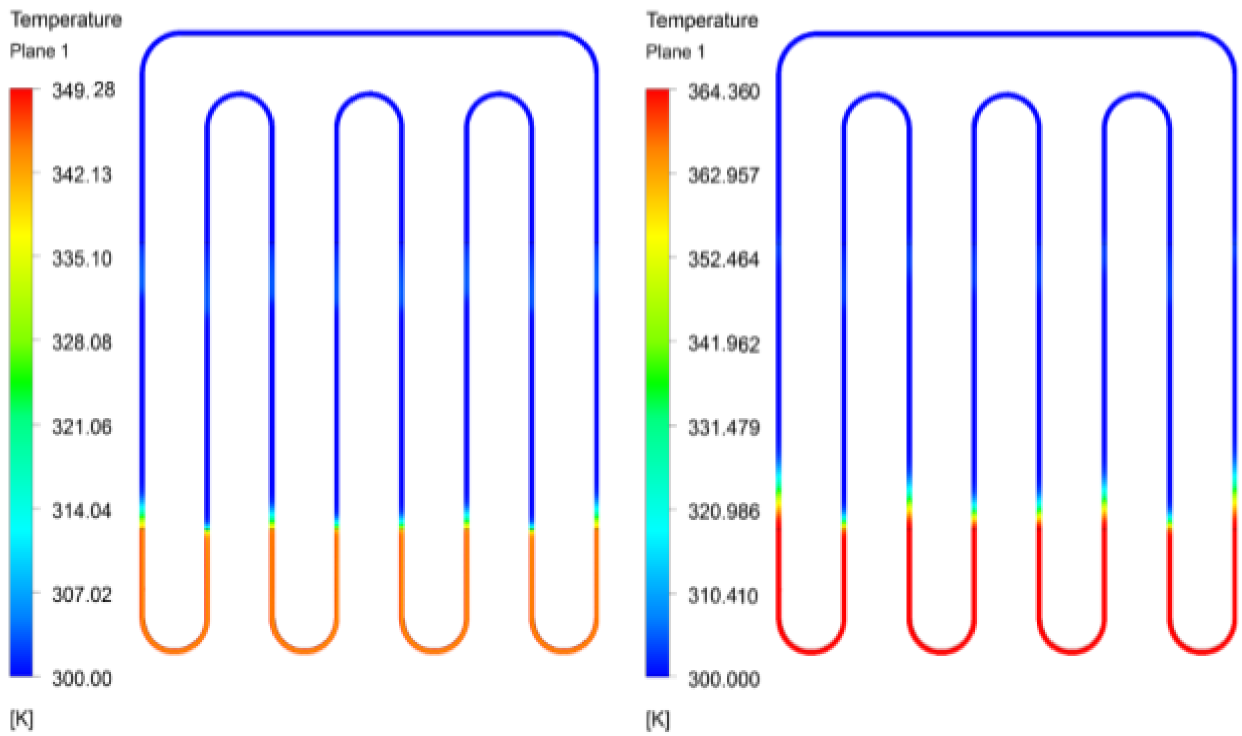
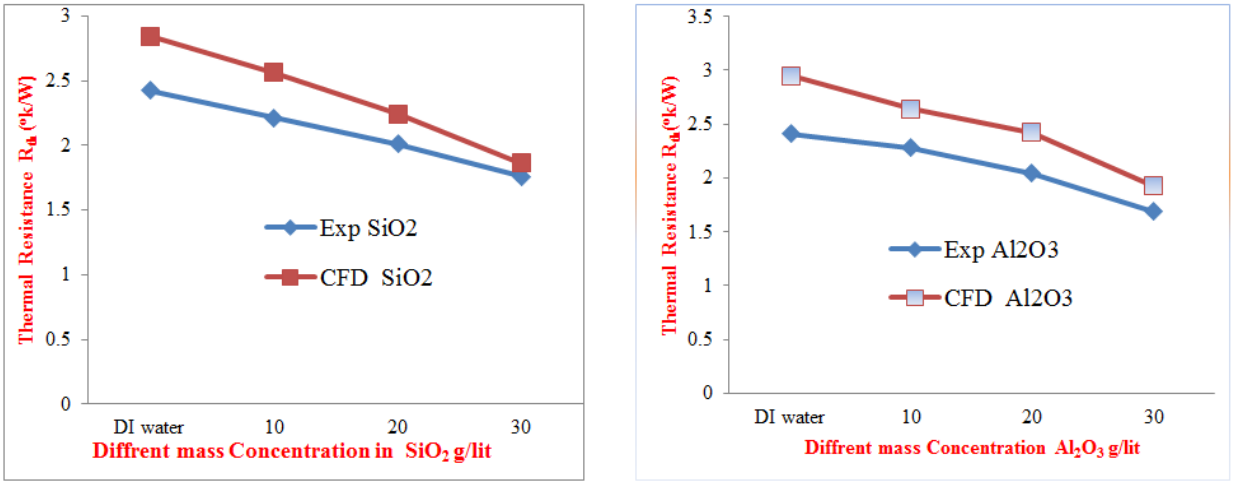


Fig 9: Temperature contours 25 and 30 min



(a) (b)

Fig.10 Exp Results and CFD Results comparison of Thermal Resistance for SiO_2 and Al_2O_3 Nanofluids.

Fig.10 shows that the Thermal resistance of heat pipe decreases as mass concentration of Nanofluids. CFD analysis to compare the experimental results. The experimental results shows that the minimum value of overall thermal resistance is obtained 1.76°k/w, at 22w with 30g/lit, SiO_2 Nanofluid which is compare CFD results 2.35 °k/w. Thermal resistance of heat pipe more decreases as mass concentration of Al_2O_3 nanofluid. Experimental results show that the minimum value of overall thermal resistance is obtained 1.68°k/w, at 22w with 30g/lit,Al_2O_3 nanofluid which is compare CFD Results 1.82 °k/w. Comparison b/w SiO_2 and Al_2O_3 nanofluids less thermal résistance Al_2O_3 Nano fluids in CFD Analysis And Experimental Result.

Conclusions

Based on the CFD Analysis of the experimental investigations presented in this Paper, the conclusions are follows

1.The thermal Performance of SiO_2 and Al_2O_3 Nanofluids is influenced by alteration in fluids interface due to presence of nanoparticles.

2.The thermal resistance of heat pipes decreases with the increase of concentration of nanofluids. The minimum value of overall thermal resistance is obtained.

3.The Heat transfer rate increases of the heat pipes with SiO_2 and Al_2O_3 nanoparticles as the increases mass concentration of nanofluids. The maximum value of heat transfer rate is obtained 333.83w and 349.11w at 22 w with 30g/lit nanofluids which is 27.27% and 30.45more than that of pure water.

4.The thermal Efficiency of the heat pipe increases with increasing nanoparticle mass concentration in the base fluids. The maximum value of thermal efficiency is obtained 22w with 30g/lit nanofluids which is 69.37% and 75.99%.and 57.39% and 64.01% more than that of pure water.

5. Competition b/w SiO_2 Nano fluid and Al_2O_3 Nano fluid thermal efficiency more than Al_2O_3Nanofluids 6.62%.

Nomenclature: **Greek symbols** **Acronyms**

R_{th}: Thermal Resistance (°k/W). ɳ =Thermal Efficiency of heat pipe (%) CFD: Computational Fluid Dynamics
h: heat transfer coefficient (W/m^{2}K).ɷ= nanofluids concentration (g/lit). CLPHP: Closed Loop Pulsating Heat Pipe.
K: Thermal Conductivity (w/m K). ρ=Density of water (kg/m3) HP: Heat Pipe, DI: Distil

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