EFFECT OF NANOFLUID ON GROOVED HEAT PIPE THERMAL PERFORMANCE

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Abstract : Nanofluid is effectively employed as the working medium in the grooved Heat pipe of 600 mm length. The nanofluids preferred in this study is 50 nm diameter of copper oxide. An experimental work is carried out to investigate the effect of thermal performance with varying concentrations like 25 mg/lit, 50 mg/lit, 100 mg/lit, 150 mg/lit and 170 mg/lit and with varying filling ratio 25%, 50%, 75%, 100% & 125% at varying inclination angle and heat inputs. The experimental results showed that100% concentration level and 75% filling ratio 45 °produces better output in efficiency and thermal resistance in the copper oxide nanofluid.

Keywords: Grooved heat pipe, Nano fluids, Thermal efficiency, Thermal resistance

1. Introduction

A Heat pipe consists of three sections namely Evaporator region, Adiabatic region and Condenser region. By an external source heat is applied to the evaporator section, conducted by means of wick structure and pipe wall .The working fluid vapourises in the evaporator region. As a result vapour pressure produced which drives the vapour moves from adiabatic region to condenser region. The vapour condenses in the condense section and latent heat of vapourisation gets released in the condenser region. Due to the presence of capillary effect , drives the fluid back to the evaporator from the condenser. The heat pipe is a device can transport the heat continuously from evaporator to the condenser region. This process will repeats there is enough amount of capillary pressure to drive the condensed fluid back to the evaporator region.

Yu- Tang Chen (2010) conducted experiment on flat heat pipe to find out thermal performance by varying the concentrations. Silver nanofluid of particles size 35 nm used and water as the base working fluid. It was observed that the heat pipe with silver nano fliud shows lower thermal resistance value than the DI Water. Woo-Sung HAN *et al*. (2011) investigated the grooved heat pipe charged with different concentrations of hybrid nanofluids with Ag-H_2O and Al_2O_3 –H_2O.It was suggested that hybrid nano fluids produced greater overall thermal resistance with increasing concentration of nano particles than the pure water.

C.Y.Tsai *et al* (2004) used gold nanofluid as working medium for conventional circular heat pipe. Experiments were conducted and measured the thermal resistance of nano fluids and DI water. It has been observed that for a same volume of charge, there is a significant decrease in thermal resistance of heat pipe with nanofluid as compared with DI water. Zhen-Hua Liu *et al* (2015) conducted experimental study to investigate the thermal performance of an inclined miniature grooved heat pipe using water-based CuO nano fliud. In this study the inclination angle has a strong effect on the heat transfer performance of heat pipes using both water and the nano fluid. with the increase of inclination angle both the heat transfer characteristics of the evaporator and condenser section increase gradually and achieve the maximum at the inclination angle of 75°.In heat pipe using water ,the maximum heat fluxes of the inclined heat pipes vary very little compared with that of the horizontal heat pipe.In heat pipe using nano fluids ,the maximum heat flux for inclined heat pipe can increase doubly and the inclination angle itself has only weak effects on the maximum heat flux.

The use of nanofluids in heat pipes has more and more attention because of the heat pipes are operated with the phase change of working fluid to transport the heat energy from one end to another end. The selection of working fluid is very important one to enhance the thermal performance of heat pipes. The enhanced heat transfer effects of nanofluids in the single phase and the phase changing heat transfer, researchers have used various nanofluids in heat pipes to enhance their thermal performance, Peng *et al*(2004).The performance characteristics of a cylindrical miniature grooved heat pipe using aqueous CuO nanofluid as the working fluid at steady and unsteady cooling conditions were studied and experiment results show that the nanofluid can apparently improve the thermal performance of the heat pipe for steady operation, Wang *et al* (2010).

In the present work, the performance of the grooved heat pipe has been analyzed using copper oxide nanofluid as the working fluids. The effect of nanoparticles concentration and filling ratio of the working fluid have been analyzed and reported.

II. Experimental Setup and Procedure

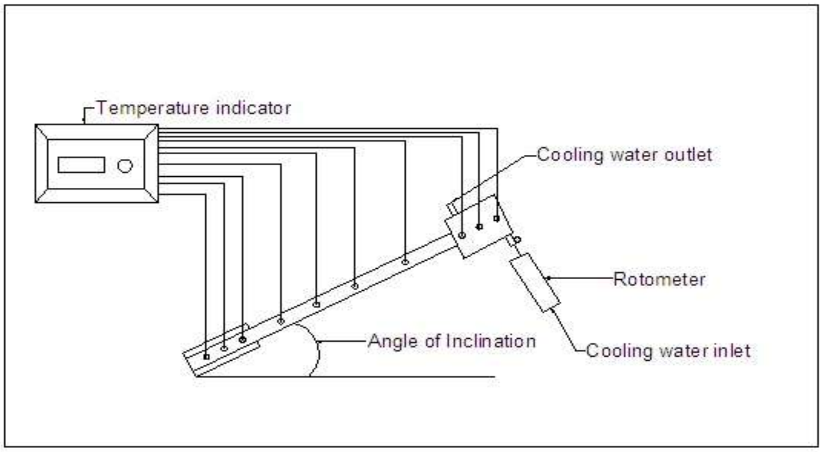

Fig. 1. Experimental setup

The experimental setup of the heat pipe as shown in figure 1. The adiabatic section of the heat pipe is covered with insulation material (glass wool). The power input (heat) is applied to the evaporator region of the heat pipe by using electric heater and measured using electric transducer (wattmeter). Three thermocouples are placed along the length of the pipe to measure the temperature of the evaporator and condenser section and four thermocouples are placed to measure the temperature of the adiabatic section. In addition to the above, two more thermometers are placed along the path of the coolant to measure the temperature of the coolant (water) inlet and outlet. The uncertainty in temperature measurements was ± 0.1 °C. The nano particles used in the experiment were copper oxide particles with a size of 50 nm. The base working fluid was DI water. The mixture was created using an ultrasonic homogenizer. Nanofluid concentration of ,25 mg/lit, 50 mg/lit, 100 mg/lit, 150 mg/lit and 170 mg/ lit was used in this study.

In this experiment, input heat flux is given to the evaporation region by using variac and can be measured by wattmeter. The power supply was turned on and the power incremented at this point in the tests, it took approximately 50 to 80 minutes to reach steady-state. Once the steady-state condition had been reached, the temperature distribution along the heat pipe was measured and recorded, along with the other experimental parameters. The power was incremented from 30 W to 70 W with incremental value of 10 W. The process was repeated for varying tilt angles (0°,15°,30°,45°,60°,75° & 90°) and with varying filling ratios (25%, 50%, 75%, 100% & 125%) and varying concentration levels (25 mg/lit, 50 mg/lit, 100 mg/lit, 150 mg/lit and 170 mg/ lit).

III. Result and Discussion

3.1 Effect of nanoparticle concentration in nanofluid

The copper oxide nanofluids with different concentrations (25 mg/lit, 50 mg/lit, 100 mg/lit, 150 mg/lit and 170 mg/ lit) are used as working fluid in grooved heat pipe. Figs 2-6 show the variation of thermal efficiency of the grooved heat pipe with various heat inputs and inclination angles. The thermal efficiency of the grooved heat pipe increases with increase in angle of inclination up to 60^{o} and decreases for further angle of inclination. When the nanoparticles concentration level increases, the thermal efficiency of heat pipes increased due to higher thermal conductivity and heat transfer capacity of the working fluid. If the concentration level of nanaoparticle in working fluid increase further, the efficiency of heat pipe decreased as poor evaporation takes place in evaporator section.

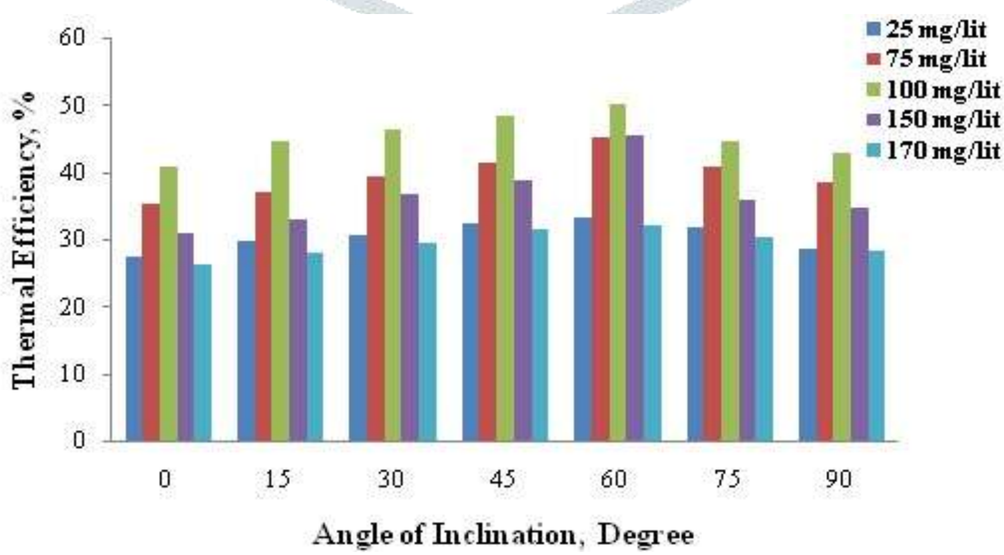

Fig 2. Variations of grooved heat pipe efficiency for various inclinations at 30 W heat input

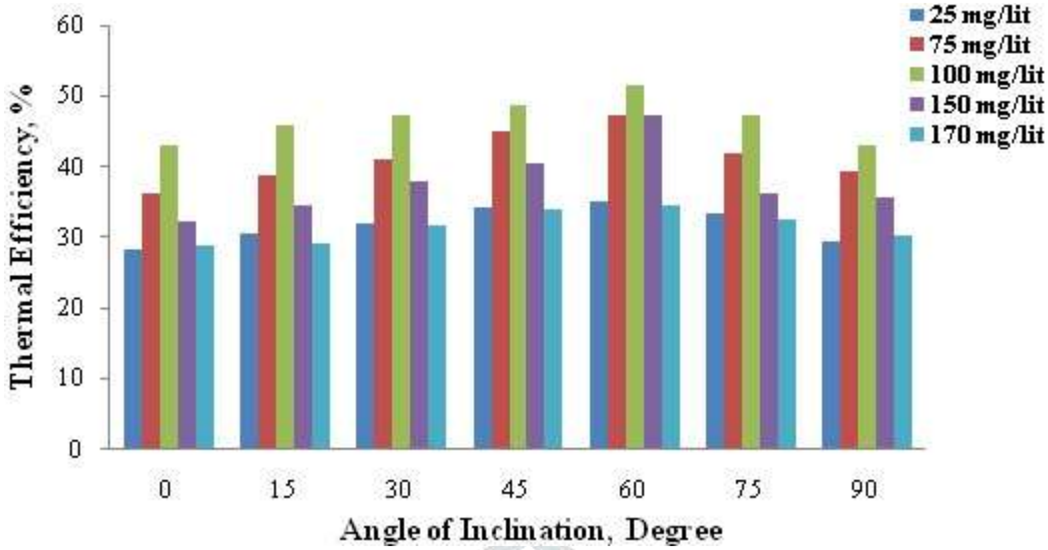

Fig 3.Variations of grooved heat pipe efficiency for various inclinations at 40 W heat input

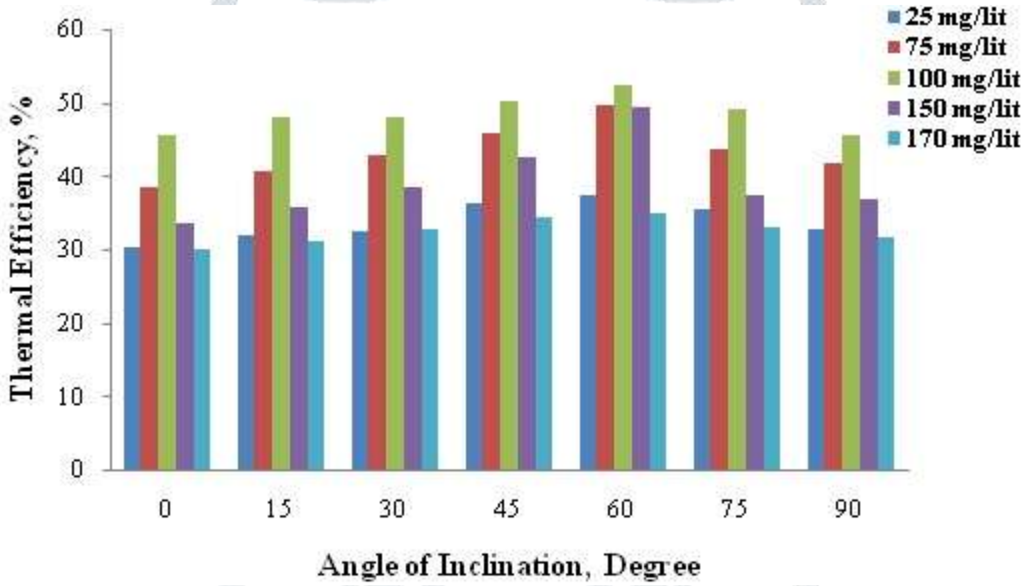

Fig 4. Variations of grooved heat pipe efficiency for various inclinations at 50 W heat input

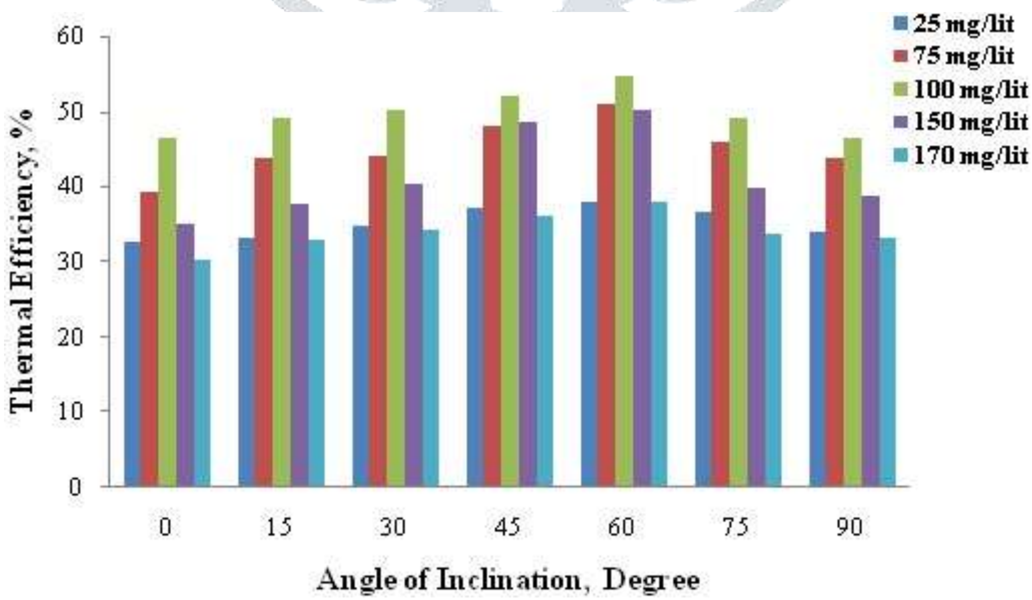

Fig 5. Variations of grooved heat pipe efficiency for various inclinations at 60 W heat input

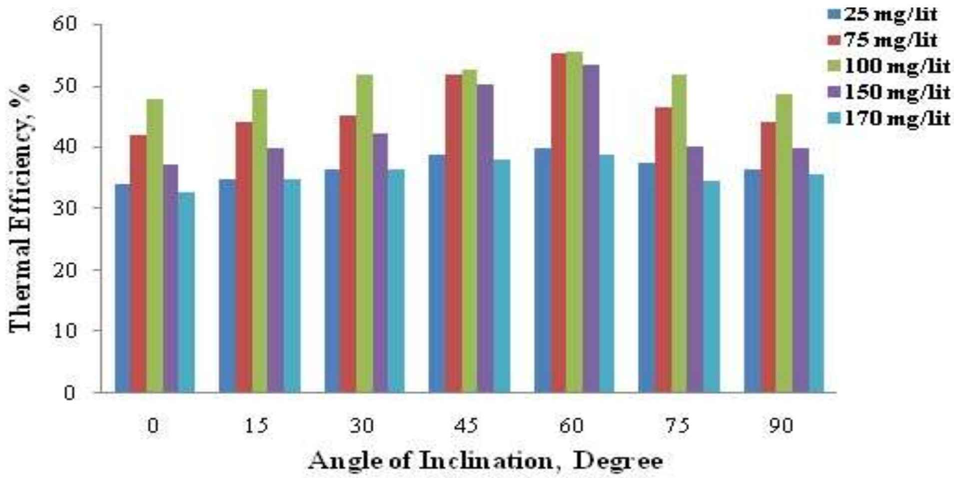

Fig.6 Variations of grooved heat pipe efficiency for various inclinations at 70 W heat input

Effect of fill ratio on the heat pipe efficiency

Figures 7 - 11 show the variations of thermal efficiency of grooved heat pipe for various fill ratio and heat input. Based on the result the thermal efficiency of the grooved heat pipe increases when the fill ratio increases and reaches higher value when the fill ratio is 75 % and lower in efficiency for further increase of fill ratio.When the fill ratio is low, the vapourization rate of the working fluid in the evaporator section is faster for the given input and the condensation occurs at the lower rate. At lower fill ratio the thermal efficiency of the grooved heat pipe is lower due to accumulation of vapour at the condenser section. When the fill ratio is high, the evaporator section temperature is low and the evaporation occurs at a lower rate. At the higher fill ratio the thermal efficiency of the grooved heat pipe decreases due to little vapour is flow in to the condenser section.

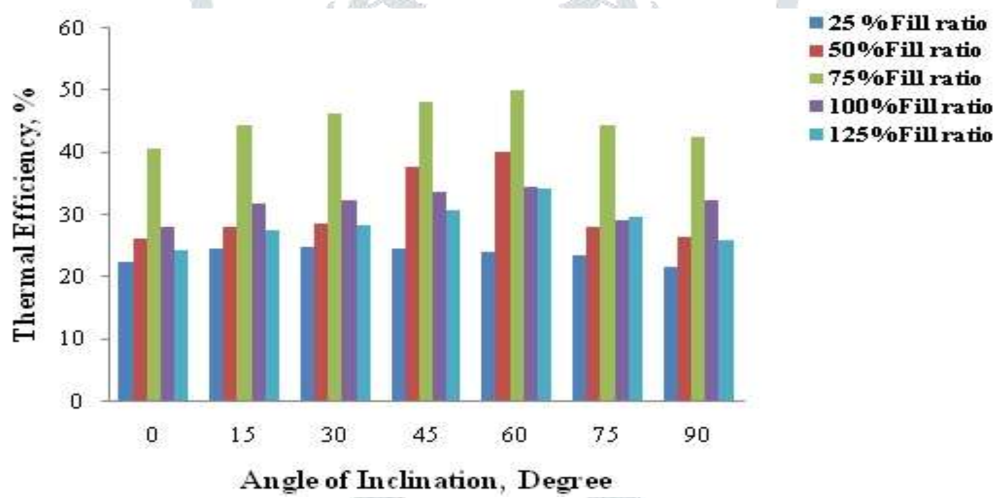

Fig.7 Variations of grooved heat pipe efficiency for various inclinations at 30 W heat input

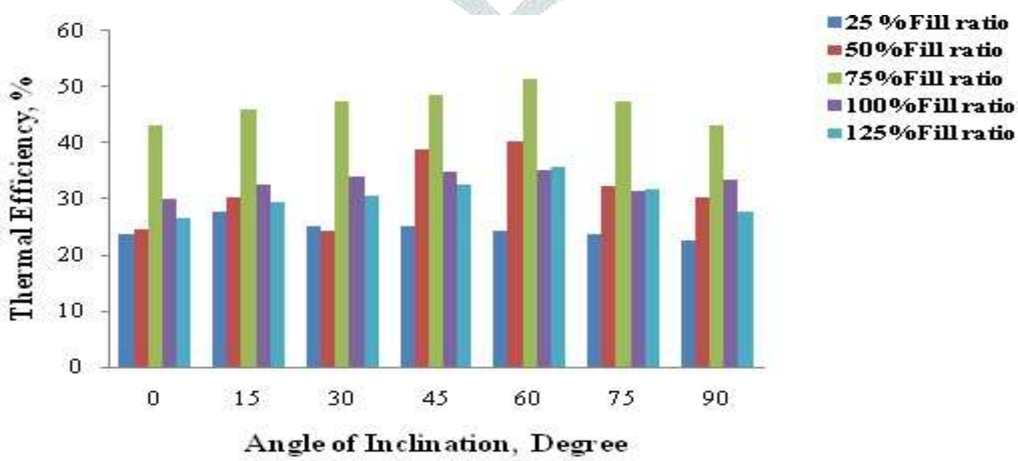

Fig.8 Variations of grooved heat pipe efficiency for various inclinations at 40 W heat input

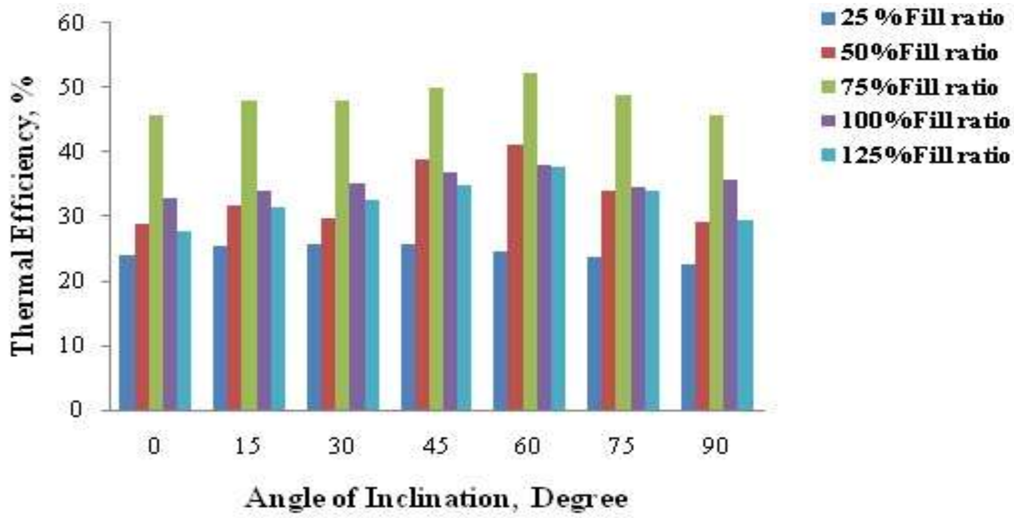

Fig.9 Variations of grooved heat pipe efficiency for various inclinations at 50 W heat input

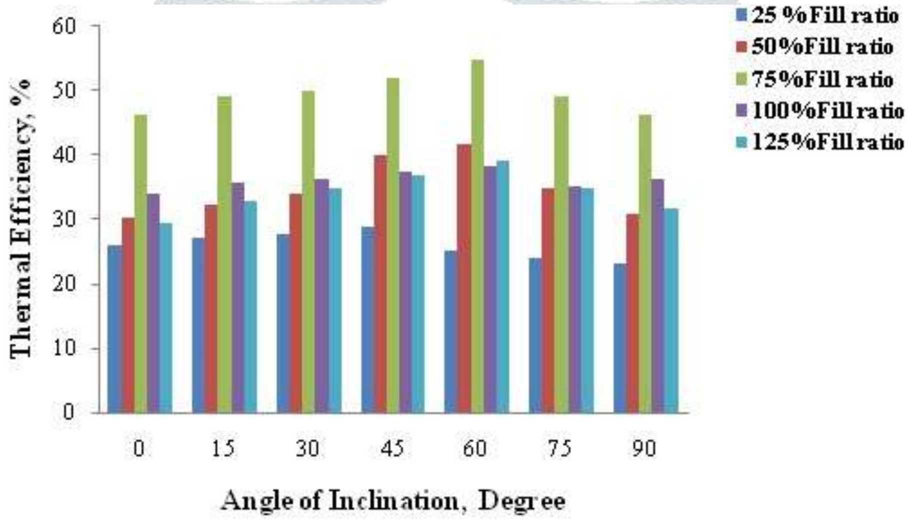

Fig.11 Variations of grooved heat pipe efficiency for various inclinations at 60 W heat input

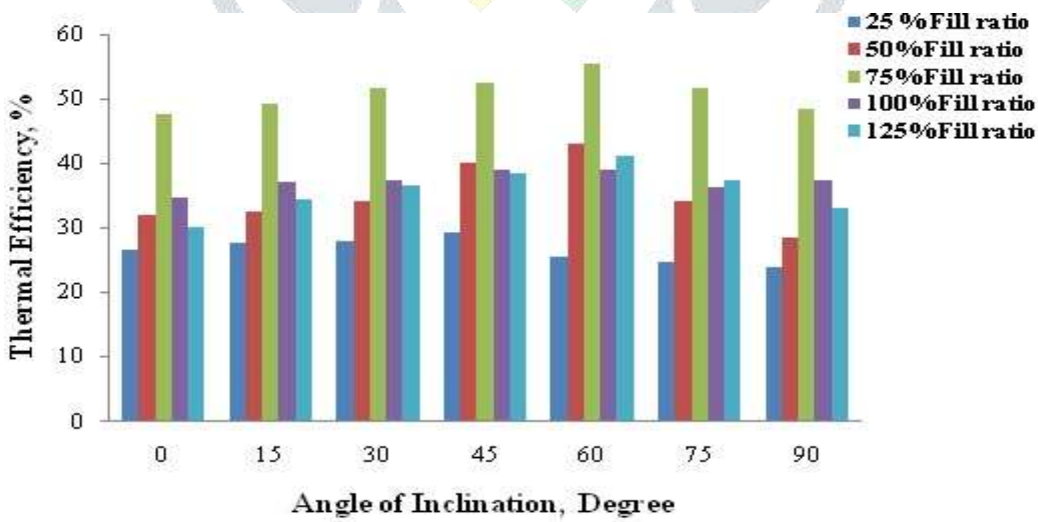

Fig.12 Variations of grooved heat pipe efficiency for various inclinations at 70 W heat input

IV. Conclusion

1. From the graphical analysis, the thermal efficiency of grooved heat pipe is higher for 100 mg/lit concentration than other four concentrations. For higher concentrations of nanofluids, the thermal efficiency decreases and thermal resistance increases due to deposition of nanoparticles inside the heat pipe container.

2. When the filling ratio of the working fluid in the evaporator section is 75 %, the thermal efficiency of the grooved heat pipe is maximum for all heat inputs and inclination of the heat pipe.. The grooved heat pipe reaches maximum efficiency when the inclination angle is 60° and 70 W heat input.

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