Thermal Performance of Grooved Heat Pipe Using Nano Fluids

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Abstract: Heat pipe is an effective heat transfer device which transports huge amount of heat between the two temperature limits with minimum temperature gradient. The main problem with heat pipe working fluids is poor heat transfer characteristics of working fluids. The suspended nano sized particles in the base fluids investigated in recent years by various researchers across the world for finding new opportunities. The suspended nano sized particles enhance the heat transfer characteristic and transport properties than the base fluids like water or ethylene glycol. In this analysis the nanofluids are used as the working fluids in the heat pipes. The nanofluids used in this work are Copper oxide, Iron oxide and Titanium dioxide with a particle size of 50 nm. The concentration of nano particles in the base fluid is 100 mg/l. The base fluid is De-Ionized water. The experiments are conducted for various heat inputs (30, 40, 50, 60 & 70 W) and inclination of the grooved heat pipe (0°, 15°, 30°, 45°, 60°, 75°, & 90°). The experimental results are compared with the base fluid.

Key words: Grooved heat pipe, Inclination angle, Thermal efficiency, Thermal resistance, Nano Fluid

INTRODUCTION

Heat pipes are passive heat transfer devices which transfer the heat from one point to another. It transfers heat by evaporation and condensation of working fluid which is partially filled in the heat pipe. The heat pipe consists of three sections namely evaporator region, adiabatic region and condenser region [1]. By an external source heat is applied to the evaporator section, conducted by means of wick structure and pipe wall. The working fluid vapourizes 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 vaporization gets released in the condenser region. Due to the presence of capillary effect, drives the fluid back to the evaporator from the condenser region. 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.

As an increasing value of heat dissipation in electronic circuits, the heat flux is critically high due to the presence of advanced nano –size circuit technology, the size of die on the processor has been reduced or remained same size. In the year of 2000 the heat flux was about 10-15 W/cm² and had reached 100 W/cm² in 2010 [2].

The techniques like bulk micro machining and eutectic bonding technology used to fabricate the radial grooved Micro Heat Pipes (MHP). It has been tested with various load conditions like wafer with filled MHPs array and plain wafer. The evaporator temperature were measured and compared for both the conditions. It was observed that for 27 W the plain wafer produced the evaporator temperature was 27 % greater than filled one. Therefore filled MHPs arras showed the best performance [3]. Cecile Goffaux et al., (2012) investigated the optimization of grooved heat pipe by Genetic Algorithm. In this he explained about the suitability about discrete variables and management of discontinuous variables. He applied genetic algorithm for maximum heat transport capacity and minimal external envelope diameter [4].
Horng –Jou Wang et al., (2005) studied experimentally and theoretically the capillarity of rectangular cross section micro grooves. In the experimental work micro grooves were constructed first by photolithography method and a layer of copper placed on the surface to increase the properties. The effects of maximum pumping capillary pressure, pressure drop due to friction and gravitational forces were calculated [5].

The conventional working fluids like water, ethylene glycol which has low poor thermal and heat transfer characteristics. To overcome these problems the nanofluids are recommended. Nanofluids are the suspending ultrafine metallic or nonmetallic particles which have nanometer sized dimensions in traditional fluids like water, engine oil, ethylene glycol [6]. The nanofluids have amazingly higher thermal conductivities and greater heat transfer characteristic than those of conventional pure fluids [7, 8].

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 fluid shows lower thermal resistance value than the DI Water [9]. Woo-Sung HAN et al., (2011) investigated the grooved heat pipe charged with different concentrations of hybrid nanofluids with Ag-H\textsubscript{2}O and Al\textsubscript{2}O\textsubscript{3}-H\textsubscript{2}O. It was suggested that hybrid nano fluids produced greater overall thermal resistance with increasing concentration of nano particles than the pure water [10].

Shung-Wen Kang et al (2006) studied the thermal performance of grooved heat pipe with 35 nm diameter silver nano-particles. They conducted the experiments for nanofluid and DI water and compared the results. He observed that for same charge volume, the temperature distribution of the heat pipe is measured that the thermal resistance of nano-fluid filled heat pipe decreased 10–80% compared to DI-water with input power of 30–60 W[11]. Lazarus et al., (2013) conducted the experiments on heat pipe using silver nanoparticles in the DI water as the working fluid. They reported that the reduction in thermal resistance of 76.2% is observed with a concentration of nanoparticles of 0.009% by volume and the enhancement of evaporation heat transfer coefficient by 52.7% [12].

Ghanbarpour and Khodabandeh [13] studied the entropy generation in cylindrical miniature grooved heat pipes which is filled with distilled water and water based titanium dioxide and aluminium oxide nanofluids of different concentration as working fluids. They compared the results with experimental results. The aluminium nanofluid has lower entropy generation the heat pipes with titanium dioxide nanofluids. Guo-Shan Wang et al. [14] examined the performance of cylindrical miniature grooved heat pipe using aqueous copper oxide nanofluid as the working fluid. They experimentally reported that that the nanofluid as the working fluid can apparently improve the thermal performance of the heat pipe for steady operation than the water. The total heat resistance reduced by 40% and the maximum heat removal capacity improved by 40% than the water filled heat pipe.

Zhen-Hua Liu et al. [15] have examined the thermal performance of inclined miniature grooved heat pipe using water base CuO nanofluid as working fluid. They concluded that the angle of inclination of the grooved heat pipe has the strong effect of its performances.

Ki-Ho Park et al., (2005) investigated the operating characteristics of the copper heat pipe using nanofluids. The silver nano particle was used as the working fluid. At 90° inclination angle, the nanofluids have much higher thermal transfer performance than the conventional fluids. Experimental results showed that the heat pipe with 10,000 ppm Ag nanofluids had the high heat transfer performance. The thermal resistance of the heat pipe with nanofluids was 0.36 K/W [16]. 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 [17].

In the present work, the performance of the grooved heat pipe has been analyzed using DI water, copper oxide, iron oxide and titanium dioxide nanofluid as the working fluids. The experiments on the grooved heat pipes are conducted for various heat inputs and various angle of inclinations. The results are compared with DI water filled heat pipe based on the thermal efficiency and resistance.

**Experimental Setup & Procedure:** The nano particles used in this study is 50 nm in sizes. The concentration of the nano particle in the base fluid is 100 mg/l. De-ionized water used as the base working fluid. The nanofluids are prepared by dispersing nano particles in the base fluid. Then that fluid is allowed for sonication for 12 hours to avoid agglomeration of particles. The sonication period depends upon of the material, size and concentration of nanoparticle in the base fluid. The experimental setup of the heat pipe is shown in Figure 1.
Fig. 1: Experimental setup

In these experiments, the grooved heat pipes have the outer diameter, inner diameter and length of the heat pipe are 9.5 mm, 8.75 mm and 600 mm respectively. The evaporator length and condenser length of the heat pipe is 150 mm and 150 mm respectively. The width of the groove used in the circular heat pipe is 136 µm. The temperatures of the heat pipe are measured on the various location of the heat pipe by T-type Thermocouple. Three thermocouples were attached at the evaporator section, four thermocouples were attached at the adiabatic section and three thermocouples were attached at the condenser section and additional two thermocouples were attached to determine the water inlet & outlet temperature.

The heat energy supplied to the evaporator through the variac and wattmeter is used to measure the heat input. The power supply was switched on and the power is entered in to the test section, the temperature distributions on the surface of the heat pipe are noted until it reaches the steady state. The heat pipe reaches the steady state approximately by 50 to 70 minutes. Once the steady-state condition had been reached, the cooling water allowed cooling the heat pipe for next experimental purpose. The experiments are conducted for various heat inputs (30, 40, 50, 60 and 70) and inclinations (0°, 15°, 30°, 45°, 60°, 75° & 90°).

Experimental Results

Effect of Tilt Angle on Thermal Efficiency: The heat pipe thermal efficiency is defined as the ratio of the heat released from the condenser to the heat supplied at the evaporator region. The thermal efficiency is calculated for all heat inputs and tilting angles of the grooved heat pipe. The Fig. 2-7 shows the variations of thermal efficiency of the grooved heat pipes for various heat inputs and inclinations for all nanofluids and they are compared with the base fluid (DI water). The thermal efficiency of the grooved heat pipe increases with increasing the heat input at the evaporator region. At the time of higher heat input, more amount of heat is absorbed by the working fluid and it vaporized. The vaporized fluid moves freely and it converted to the liquid by the liberation of latent heat in the condenser region.

The thermal efficiency of the grooved heat pipe increases with increasing values of the tilting angle. It is due to the fact that the gravitational force has a significant effect on the heat pipe section along with the capillary action of grooved structure. From the all figures it was inferred that the efficiency of grooved heat pipe with working fluid titanium dioxide gives greater than the other nano fluids for all values of tilt angle. The tilt angle of 45° gives best result and that value is 74.76 %. After 45° inclination, the efficiency of the heat pipe seems to decrease in view of the fact that the formation of the liquid film is at higher rate inside the condenser due to the deposition of coolant in the bottom side of the condenser resulting in the increased value of the thermal resistance.
Fig. 2: Variations of heat pipe efficiency with nano fluids for 30 W heat input

Fig. 3: Variations of heat pipe efficiency with nano fluids for 40 W heat input

Fig. 4: Variations of heat pipe efficiency with nano fluids for 50 W heat input

Fig. 5: Variations of heat pipe efficiency with nano fluids for 60 W heat input
Fig. 6: Variations of heat pipe efficiency with nano fluids for 70 W heat input

Fig. 7: Effect of 0° Tilt angle on Thermal Resistance

Fig. 8: Effect of 15° Tilt angle on Thermal Resistance

Fig. 9: Effect of 30° Tilt angle on Thermal Resistance

Fig. 10: Effect of 45° Tilt angle on Thermal Resistance
The thermal resistance of the grooved heat pipe filled with titanium dioxide has the lower thermal resistance than the other fluids. Since the titanium dioxide nanofluid has the higher thermal and heat transfer characteristics than the others. The value of thermal resistance filled with titanium dioxide is 0.271 °C/W.

**CONCLUSION**

The present study investigated the thermal performance of a grooved heat pipe using nanofluids and DI water with different heat inputs and tilt angles. From the experimental results the following conclusions were made:

- From the experimental results, with Titanium dioxide nano fluid as the working fluid produces better efficiency and lower thermal resistance than other nano fluids at all tilt angles and heat inputs.
- It was concluded that 45 ° tilt angle shows better performance in titanium dioxide, copper oxide iron oxide nano fluids and in DI Water.
- Thermal efficiency of the grooved heat pipe filled with Titanium oxide nano fluid is 74.76 %, Iron oxide is 65.22%, Copper oxide is 52.49 % and DI Water is 23.06 % at 45 ° tilt angle.
- Thermal resistance of the grooved heat pipe with Titanium oxide nano fluid is 0.271 °C/W , Iron oxide is 0.314 °C/W , Copper oxide is 0.368 °C/W and DI Water is 0.654°C/W at 45 ° tilt angle.

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