Enhancement of Thermal Performance in Miniature Grooved Heat Pipe using Aluminum Oxide Nano Fluid in Aqueous Solution of Ethyl Propyl Alcohol

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Abstract:- **This study demonstrates the enhancement of the thermal performance of Miniature grooved heat pipe using aluminum oxide (Al_2O_2) nano fluid with DI Water and Ethyl propyl alcohol with nano fluid. Nano fluids are stable suspensions of nano fibers and particles in fluids. Latest investigations show better thermal behavior such as improved thermal conductivity and convection coefficients in comparison to pure fluid or fluid with larger size particles. Grooved heat pipe was fabricated from a straight copper grooved tube with the outer diameter and length of 6,240 mm respectively. Results of 18 experiments were performed using the working fluids (DI + nano(Al_2O_2) + ethyl propyl alcohol with Al_2O_2 nano particle in DI water), three orientations (0°, 45° and 90°) and three heat input rates are reported. 40 nm Al_2O_2 nano particles with a concentration of 60mg/lit were used. Orientation range of 45° to 55° in particular was optimum for nano fluid. Orientation angle 45° were found optimal for Nano + ethyl propyl alcohol. The effect of orientation on the thermal performance was found significant.**

Keywords— Aluminum oxide nano particle, ethyl propyl alcohol, grooved heat pipe, orientation angle, Thermal performance

I. INTRODUCTION

With the development of technology, the requirements of heat transfer enhancement have become more sophisticated for a variety of devices. Some traditional methods for heat transfer enhancement such as increase the heat transfer surface area of cooling devices and the flow velocity have reached their limits. In recent years, many researchers have attempted to suspend millimeter or micrometer sized particle in the traditional fluid to form suspension fluid. The major problem with these particles is poor stability of suspension, clogging and eroding mini channels and micro channels. It was choi [1] who first suggested dispersing metallic or non-metallic nano particles in conventional heat transfer fluid, which is termed as nano fluid. The superiority of nano fluid is the high thermal conductivities without sedimentation, erosion, clogging of small channels etc. Based on the series of high heat transfer performance, the heat transfer properties of nano fluid in heat pipe have been investigated by many researchers. Heat pipe is
one such novel device, which can operate over a wide range of temperatures with a high heat removal capability. Due to its compactness and its ability for larger heat transfer, heat pipes are predominantly used in Spacecrafts, Energy recuperation, Power generation units, Electronic equipment cooling(viz. laptop), Air-conditioning, Engine cooling other areas where compactness of the heat exchanger is required[2-4].

The idea of utilizing nanoparticles within the working fluid of a grooved heat pipe has become a subject of interest in recent years. The nano particles within the fluid change its thermal conductivity [5].It has been shown experimentally that for a given concentration level, the thermal conductivity of nano fluids increases with a decrease in particle diameter [6-7].

A typical grooved heat pipe consists of an evacuated – closed tube filled with a definite amount of working fluid and hermetically sealed. Grooved heat pipe has evaporator, adiabatic (or) transport and condenser sections. When the grooved heat pipe is heated at evaporator end the working fluid evaporates undergoing liquid – vapor phase change, moves through the hollow core to the other end (condenser section). In the transport / adiabatic section, vapor travels at near sonic speed. In gravity – assisted grooved heat pipe pool boiling takes place in evaporator section and in condenser section film wise condensation occurs. Nanofluids are stabilized suspensions of nanoparticles typically <100nm. Nano fluid as working fluid in heat pipes is a novel idea that can be found only in the literature of the last decade. Kang et al. investigated the effects of silver nano fluid on circular heat pipe with 200 mm length and 6 mm diameter. They observed 10–80% decrease in thermal resistance of the heat pipe compared to DI-water. They also investigated the effect of nano fluid concentration on heat pipe thermal performance. The results which they obtained demonstrated that thermal resistance of heat pipe decreased by increasing the concentration of nano fluid. Some experimental investigations have shown that nano fluid have much higher thermal conductivities than their pure base fluid. [8-9], increases convection rate [10-11] and also improve the critical heat flux. [10-12] .

II. EXPERIMENTAL WORK

A. Experimental Setup

The grooved heat pipe employed for the experimental investigation consists of three classical sections over a length of 240 mm grooved copper tube with internal and external diameters of 5 mm and 6 mm respectively (Figure 1).

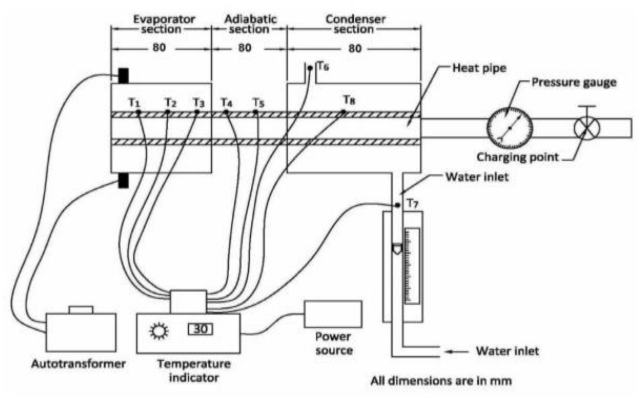


Fig. 1: Experimental setup

The lengths of the evaporator (L_e), adiabatic (L_a) and condenser (L_c) sections were 80mm, 80mm and 80mm respectively. Distilled water and nano fluid, aqueous solution of ethyl propyl alcohol and Al_2O_2 nano particle with a concentration of 60 mg/lit were used as the working fluids. The working fluid fill ratio FR, (ratio of volume of liquid filled in to grooved heat pipe volume) of 40 percent and an aspect ratio AR, (length of evaporator to the internal diameter) of 16 were used. The powers incremented for various orientations (0°, 45°, and 90°from horizontal) were 10W, 20W and 30W. Eight K-type thermocouples were used to measure the wall temperature of grooved heat pipe, three attached to the evaporator section; two to the adiabatic section and other three to the condenser section. All the thermocouples were connected to the temperature indicator.500W (maximum) coil type heater was used as a heat source in the evaporator section. The power was varied with the help of auto transformer and the heat input rate was measured using wattmeter. Cooling water to the condenser section was manually controlled and maintained at 120ml/min as indicated by a rotometer.

B. Test procedure

Key factors influencing the thermal performance of a grooved heat pipe are filling ratio, aspect ratio, inclination angle, operational temperature and pressure and the working fluid. In the present study tests were conducted to investigate the influence of Al_2O_2 nano particle in DI water and ethyl propyl alcohol + Al_2O_2 nano particle mixture and grooved heat pipe orientation at three different heat input rates.

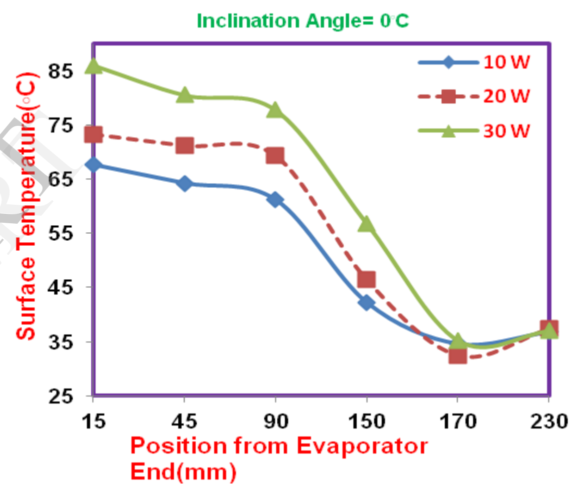
The power supply was turned on and the powers incremented were 10W, 20W and 30W. Approximately 20-30 min was required to attain steady state in each of the 18 experiments (3 orientations x 2 working fluids x 3 heat input rates).After the attainment of steady state condition, the temperature distribution along the grooved heat pipe was measured using the temperature indicator connected to 8 thermocouples.

III. RESULTS AND DISCUSSION

A. Effects of temperature distribution on grooved heat pipe

Fig.2 a,b,c shows position from evaporator end against surface
temperature along the grooved heat pipe. When heat input increases, the surface temperature of DI + nano and aqueous solution ethyl propyl alcohol with nano used in the grooved heat pipe increases. The surface temperature of grooved heat pipe with aqueous solution of ethyl propyl alcohol +nano is higher than the DI+nano. The temperature was maximum for 30 W grooved heat pipe charged with aqueous solution of ethyl propyl alcoholl.

a)



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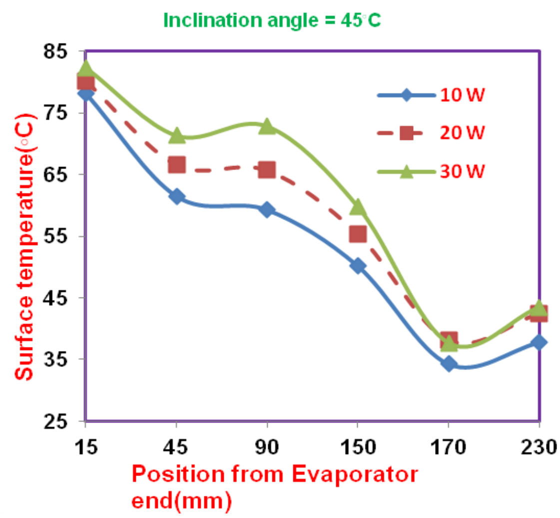

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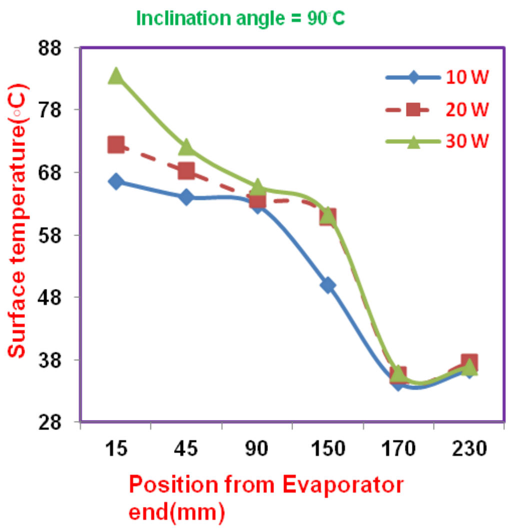
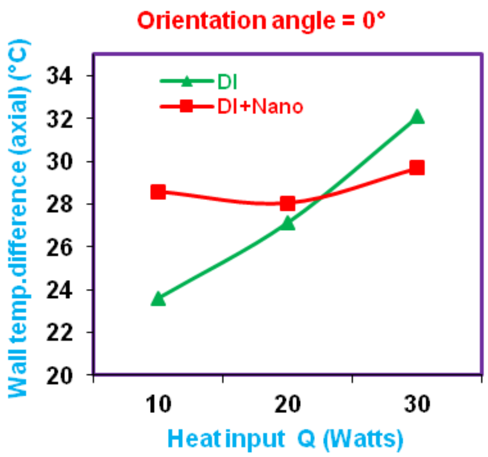


Fig.2 Grooved heat pipe surface temperature against position from evaporator end (mm)

B. Effect of heat input rate grooved heat pipe on wall temperature difference

Plots of wall temperature difference (axial) against heat input rate for the three grooved heat pipe orientations are shown in Figure 3 a, b, c. Considerable lowering of wall temperature difference is observed due to nano particles for both the fluids. The lowest differences are observed with 45° orientation for all the heat input rates 10W, 20W, 30W.

a)



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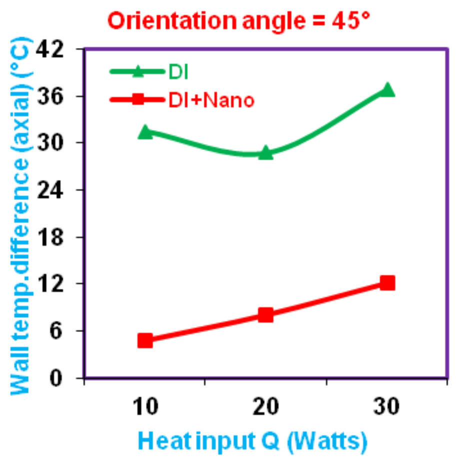


c)

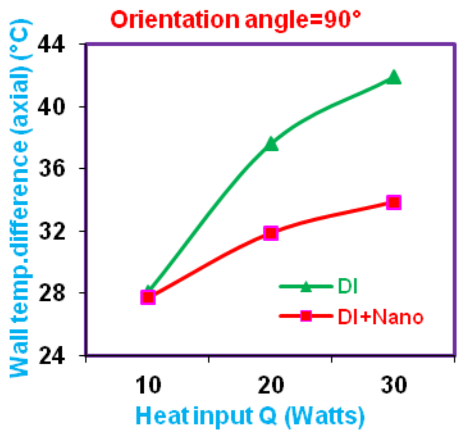


Fig.3 Grooved heat pipe Wall temperature difference (axial) against heat input rate

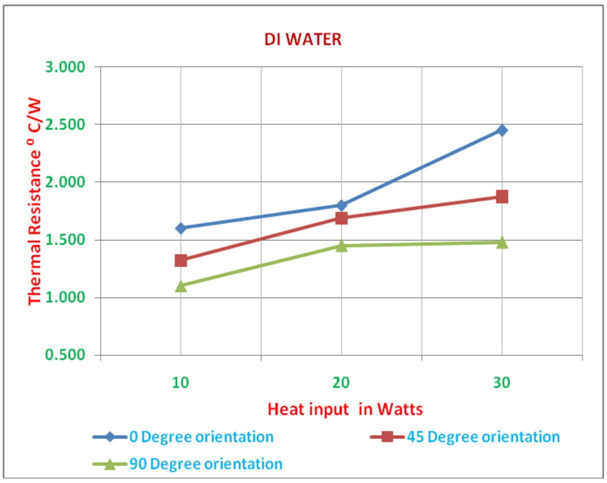
C. Effects of grooved heat pipe on thermal resistance

Grooved heat pipe thermal resistance with Al_2O_3 + DI water nano fluid at the horizontal (0°) and vertical (90°) orientations are almost equally higher compared to other orientations. Thermal resistance at these orientations was not improved by the presence of nano particles. With the employment of nano particles, thermal resistance decreases with increase in orientation angle up to 50° and increases there after up to 90° (Figure 4). Hence the optimum range of orientation is 45° to 60° from horizontal and specific optimal value for least thermal resistance is 50°.

In heat pipes vapour pressure is the driving force at the evaporator end and gravity or capillary causes the condensate return. Gravity speeds up the condensate return.At lower grooved heat pipe orientations close to the horizontal, the vapour with a tendency to move up condenses ineffectively in the adiabatic section wall ahead of condenser. Gravity assistance for condensate return is inadequate. Thus the flow and heat transport are affected reducing the thermal resistance.

At higher grooved heat pipe orientation angles close to the vertical, the condensate return is sudden and rapid disturbing the rate of evaporation and the counter current vapour flow. This again affects the heat transfer and flow in the grooved heat pipe reducing the thermal resistance. When oriented between 45° and 60° the evaporation, vapour flow, condensation and condensate return are favorable for enhanced thermal performance.

a)



b)

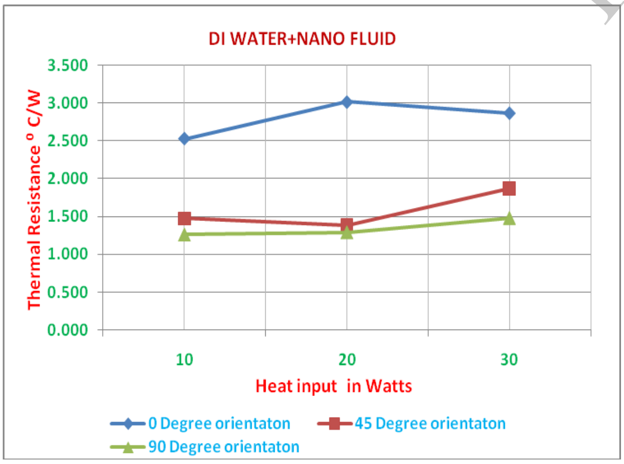


Fig.4 Effect of grooved heat pipe orientation on thermal resistance

IV CONCLUSIONS

- Thermal resistance values corresponding to the DI water+ Al_2O_2 (nano) particle mixture is undesirably are higher from the Al_2O_2 (nano) particle mixture values when grooved heat pipe is oriented 0°,45 °and 90 °
- Al_2O_2 (nano) particle mixture helps improve the thermal performance of grooved heat pipe.
- The role of grooved heat pipe orientation is significant in enhancing the thermal performance employing Al_2O_2 (nano) particle mixture. This is pronounced for all the heat input rate.
- Considerable reduction in thermal resistance values is observed for Al_2O_2 (nano) particle mixture when the grooved heat pipe orientation is 45° , maximum reduction being 79.41 percent at 10 W heat input rate. Hence 45° orientation is optimal.

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