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Heat Transfer Enhancement Of Miniature Thermosyphon Using Copper Nano Fluid (Cuo) In Aqueous Solution Of N-Butanol

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Abstract

Nano fluid is a suspension of ultrafine particles in a conventional base fluid that tremendously enhances the heat transfer characteristics. Latest investigations show better thermal behaviour such as improved thermal conductivity and convection coefficients in comparison to pure fluid or fluid with larger size particles. Miniature thermosyphon was fabricated from a straight copper tube with the outer diameter and length of 6,180mm respectively. Results of 18 experiments were performed using the working fluids (DI water+ nano(Cuo) + n-butanol and Cuo nano particle in DI water), three orientations (0°, 45° and 90°) and three heat input rates are reported. 40 nm Cuo nano particles with a concentration of 100mg/lit were used. Orientation range of 45° and 50° in particular are optimum for nano fluid, 45° was found optimal for DI water + nano + n-butanol. The effect of orientation on the thermal performance of miniature thermosyphon was found significant.

Key words: *Cuo nano particle, n-butanol, thermosyphon orientations, thermosyphon thermal performance*

1. Introduction

Heat exchanger is the device used to transfer heat. The compactness of the heat exchanger determines the excellence of the design. Heat pipe is one such novel device, which can operate over a wide range of temperatures with a high heat removal capability [1]. Due to its compactness and its ability for larger heat transfer, heat pipes are predominantly used in Spacecraft's, Energy recuperation, Power generation, 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 thermosyphon 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 miniature thermosyphon consists of an evacuated – closed tube filled with a definite amount of working fluid and hermetically sealed. Miniature thermosyphon has evaporator, adiabatic (or) transport and condenser sections. When the miniature thermosyphon is heated at evaporator end the working fluid evaporates undergoing liquid – vapour phase change, moves through the hollow core to the other end (condenser section). In the transport / adiabatic section, vapour travels at near sonic speed. In gravity – assisted thermosyphon pool boiling takes place in evaporator section and in condenser section film wise condensation occurs. Nanofluids are stabilized suspensions of nanoparticles typically <100nm. Nanoparticles enhance the thermal conductivity [8-9], increases convection rate [10-11] and also improve the critical heat flux.[10-12] .

2. Experimental setup

The miniature thermosyphon employed for the experimental investigation consists of three classical sections over a length of 180 mm copper tube with internal and external diameters of 5 mm and 6 mm respectively (Figure 1). The lengths of the evaporator (L_e), adiabatic (L_a) and condenser (L_c) sections were 60mm, 60mm and 60mm respectively. Distilled water, aqueous solution of n-butanol ($5x10^{-3}$ moles/litre) and Cuo nano particle with a concentration of 100 mg/lit were used as the working fluids.

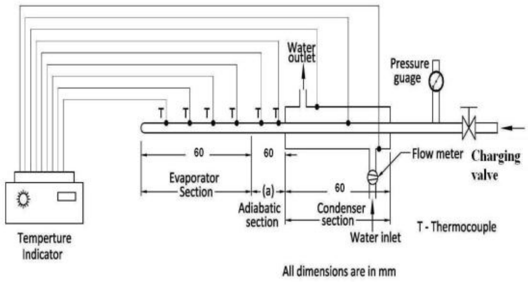

Fig. 1: Experimental setup

The working fluid fill ratio FR, (ratio of volume of liquid filled in to thermosyphon volume) of 40 percent and an aspect ratio AR, (length of evaporator to the internal diameter) of 12 were used. The powers incremented for various orientations (0°, 45°, and 90°from horizontal) were 10W, 20W and 30W. Nine K-type thermocouples were used to measure the wall temperature of miniature thermosyphon, three attached to the evaporator section; three to the adiabatic section and the 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 80ml/min as indicated by a rotometer.

3. Test Procedure

Key factors influencing the thermal performance of a miniature thermosyphon 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 Cuo nano particle and n-butanol+Cuo nano particle mixture and thermosyphon 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 miniature thermosyphon was measured using the temperature indicator connected to 9 thermocouples.

4. Results and Discussions

4.1 Effects of Temperature distribution on miniature thermosyphon

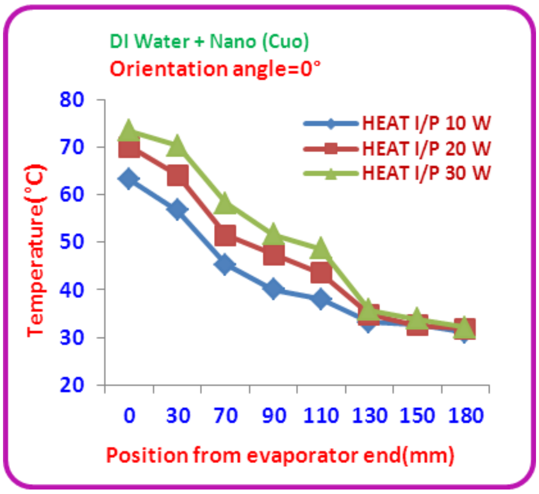

Fig. 2: Temperature against position from evaporator end with orientation angle 0°

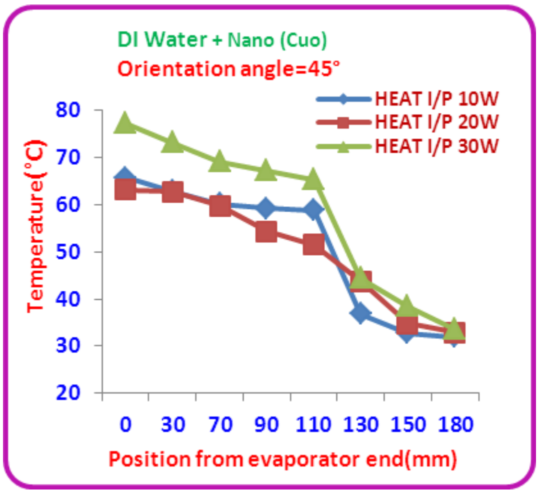

Fig. 3: Temperature against position from evaporator end with orientation angle 45°

Fig.2 to 7 shows position from evaporator end against surface temperature along the thermosyphon. When heat input increases, the surface temperature of DI + nano and aqueous solution n-butanol with nano used in the thermosyphon increases. The surface temperature of thermosyphon with aqueous solution of n-butanol+nano was higher than the DI+nano. The temperature was maximum for 30 W thermosyphon charged with aqueous solution of n-butanol.

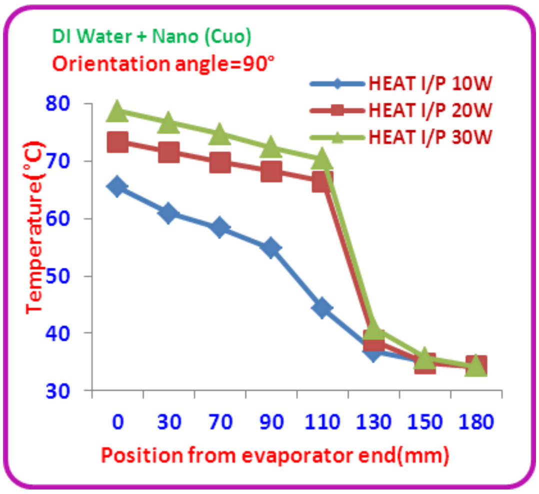

Fig. 4: Temperature against position from evaporator end with orientation angle 90°

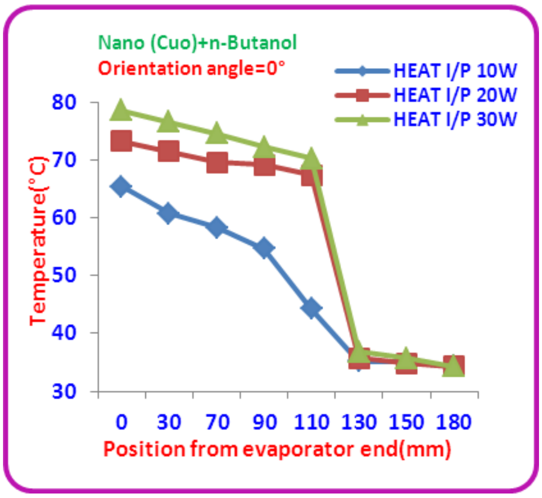

Fig. 5: Temperature against position from evaporator end with orientation angle 0°

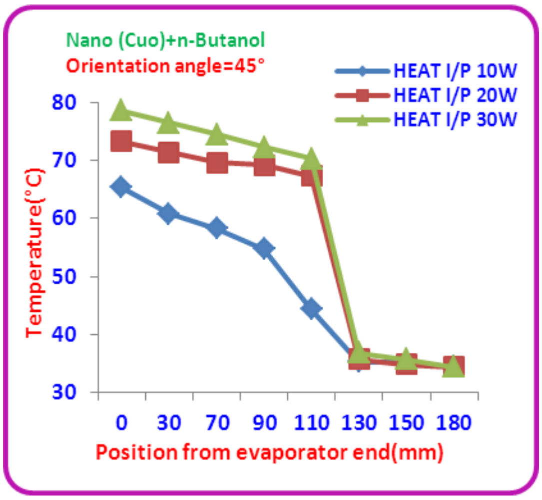

Fig. 6: Temperature against position from evaporator end with orientation angle 45°

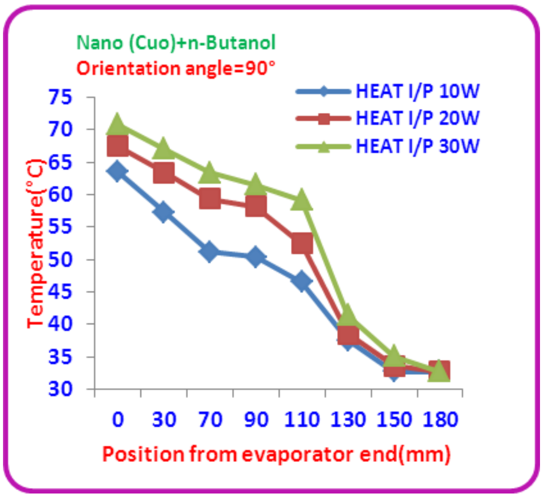

Fig. 7: Temperature against position from evaporator end with orientation angle 90°

4.2 Effects of heat input rate on miniature thermosyphon wall temperature difference

Plots of wall temperature difference (axial) against heat input rate for the three thermosyphon orientations were shown in Fig.8to10. Considerable lowering wall temperature difference was observed due to nano particles for both the fluids. The lowest differences were observed with 45° orientation for all the heat input rates 10W, 20W, 30W.

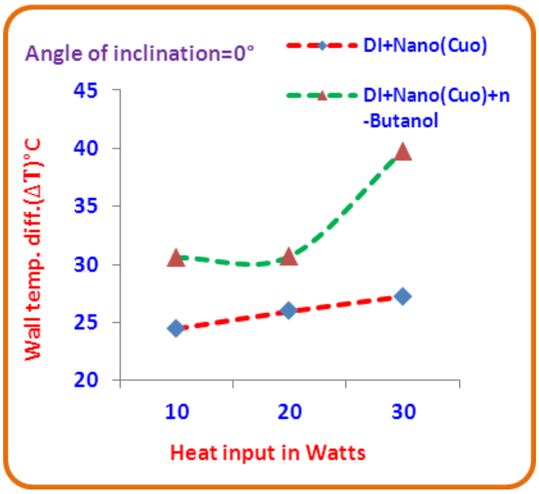

Fig. 8: Wall temperature difference against heat input with angle of inclination 0°

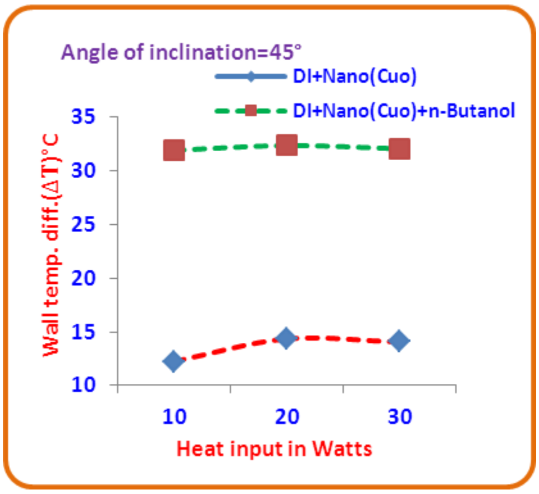

Fig. 9: Wall temperature difference against heat input with angle of inclination 45°

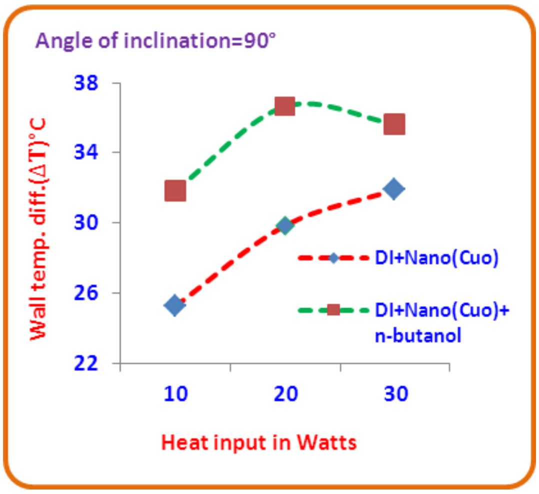

Fig. 10: Wall temperature difference against heat input with angle of inclination 90°

4.3 Effects of Nano particles and orientation on miniature thermosyphon thermal resistance:

Thermosyphon thermal resistance with Cuo + DI water nano fluid at the horizontal (0°) and vertical (90°) orientations were 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° (Fig. 11 to 13). Hence the optimum range of orientation is 45° to 60° from horizontal and specific optimal value for least thermal resistance is 50°.

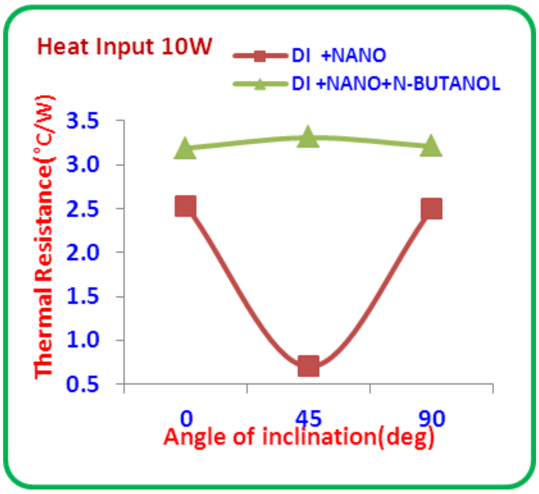

Fig. 11: Thermal resistance against angle of inclination 0° with 10 W heat input

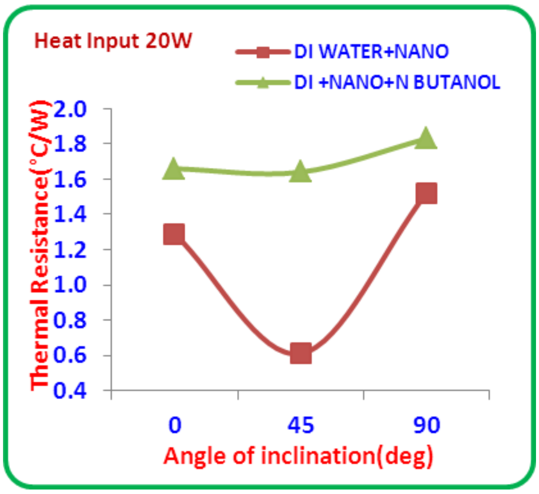

Fig. 12: Thermal resistance against angle of inclination 45° with 20 W heat input

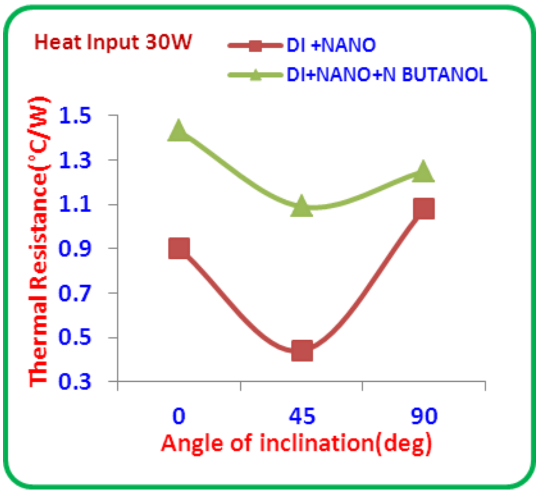

Fig. 13: Thermal resistance against angle of inclination 90° with 30 W heat input

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 thermosyphon 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 thermosyphon 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 thermosyphon reducing the thermal resistance. When oriented between 45° and 60° the evaporation, vapour flow, condensation and condensate return were favorable for enhanced thermal performance.

5. Conclusion

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

6. Acknowledgement

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