Experimental investigation of copper oxide (CuO) nanofluid on cylindrical heat pipe thermal performance

Girishkumar G S [1], Sri. C.N. Nataraj [2]

[1]*P G student, Department of Studies in Mechanical Engineering, University of B.D.T College of Engineering, Davangere, Karnataka, India*

[2]Associate Professor, Department of Studies in Mechanical Engineering, University of B.D.T College of Engineering, Davangere, Karnataka, India

---***---

Abstract- An experimental investigation was performed on the thermal performance of a cylindrical heat pipe with inner diameter and length of 22 mm and 450 mm respectively. The heat pipe charged with base distilled water and CuO nanoparticles of 10 nm and 40 nm in diameter. The effects of power inputs, heat pipe tilt angle and copper oxide nanoparticles size on the thermal resistance of the heat pipe were investigated. The nanoparticles have a significant effect on the enhancement of thermal performance of heat pipe. Experimental results emphasized that the copper oxide nanofluids significantly improved the thermal performance of the heat pipe with a volume concentration of 1% for maximal heat transfer enhancement. Compared with distilled water the thermal resistance was decreased by 0.086 m^0C/W (33.23%) for 40 nm and 0.118 m^0C/W (43.76%) for 10 nm than that with the based working fluid at 40^0 for 40% filling ratio.

Key Words: Cylindrical Heat pipe, CuO nanofluid, Effect of nanoparticle size and Tilt angle, Thermal performance enhancement

1. INTRODUCTION

Technological advances in microelectronic devices with decreasing sizes and increasing heat loads demand for more effective cooling technology. Due to higher density of chips design of electronic components with more compact makes heat transfer more difficult. Therefore, heat pipe has been used in a wide variety of applications in the electronic components with high speed and high level of heat generation. There are many researches presented the heat transfer characteristics of the heat pipe. Among them, nanofluids, which are engineered by dispersing metallic/non-metallic nanosized particles in base fluids like water, oil, ethylene glycol etc. have received much attention for the past decade due to their enhanced heat transfer capability. Nanofluids possess remarkably higher thermal conductivity and greater heat transfer properties compared with conventional pure fluids. Nanofluids are found to exhibit a noticeable changes in their thermophysical rheology properties such as specific heat, thermalJ conductivity, density and viscosity due to the nanoparticle types and concentrations. Several researchers have experimentally attempted to use nanofluids as a working medium in heat pipe using nanoparticles such as silver, CuO, diamond, titanium, nickel oxide as well as gold. Other studies applied nanofluids in heat pipes have focused on factors that affects its use such as heat pipe size and type, its operating conditions, material of the nanoparticles as well as the base fluid types. The alumina (Al2O3), silver (Ag) and copper oxide (CuO) are among the common and cheaper nanoparticles experimentally utilized and this is well reported by a number of researchers. Paisarn Naphon et al. [1] experimentally investigated that thermal efficiency of titanium nanofluid is 10.60% higher than that with the base working fluid. Yu-Hsing Lin et al. [2] studied the effect of silver nanofluid on pulsating heat pipe for various fillilg ratios. Yurong He et al. [3] Heat transfer and flow behaviour of aqueous suspensions of TiO2 nanoparticles (nanofluids) flowing upward through a vertical pipe. Shung-Wen Kang et al. [4] experimentally investigated that thermal performance of heat pipe for different silver nanoparticle size of 10 nm and 35 nm and also concentrations ranged from 1 mg/l to 100 mg/l. Mohamed I. Hassan et al. [5] investigated The effect of water-based nanofluids using different aluminum oxide nanoparticle concentrations, 1-3 vol%, on heat pipe performance after several use was investigated. Jubin V Jose et al. [6] review aim to compile the effect of nanofluid in heat pipes. Performance of different nanoparticles and different base-fluids are investigated. Maryam Shafahi et al. [7] studied the thermal performance of a cylindrical heat pipe utilizing nanofluids. Three of the most common nanoparticles, namely Al_2O_3, CuO and TiO_2 are considered as the working fluid and found that smaller particles have a more pronounced effect on the temperature gradient along the heat pipe. Kamble D.P. et al. [8] studied the thermal performance of the heat pipe under different operating conditions for hybrid nanofluids (Al_2O_3 + CuO) with water base as working fluids. Thermal performance of heat pipe increases with increasing (Al_2O_3 + CuO) water based nanofluid compared to that of pure water. Shung-Wen Kang et al. [9] The experiment was performed to measure the temperature distribution and compare the heat pipe temperature difference using silver nanofluid (10 nm and 35 nm)and DI-water. The tested nano-particle concentrations ranged from 1, 10 and 100 mg/l. Demonstrated that the temperature difference decreased 0.56–0.65 _C compared to DI-water at an input power of 30–50 W. In addition, the nanofluid as working medium in heat pipe can up to 70Wand is higher than pure water about 20 W. Jian Qu et al. [10] investigation was performed on the thermal performance of an oscillating heat pipe (OHP) charged with base water and spherical Al_2O_3 particles of 56 nm in diameter. The effects of filling ratios, mass fractions of alumina particles and power inputs on the total thermal resistance of the OHP were investigated. Experimental results showed that the alumina nanofluids significantly improved the thermal performance of the OHP, with an optimal mass fraction of 0.9 wt.% for maximal heat transfer enhancement. Compared with pure water, the maximal thermal resistance was decreased by 0.14 °C/W (or 32.5%) when the power input was 58.8Wat 70% filling ratio and 0.9% mass fraction.

As mentioned above, the papers presented the study on the heat transfer and flow characteristics of the heat pipe with nanofluids have been reported. Only some have worked on thermal resistance of the heat pipe with nanofluids. The objective of this paper is to study the thermal performance enhancement of the heat pipe with nanofluids. Effect of heat pipe tilt angle and nanoparticle size on the thermal performance on heat pipe are considered. The obtained results of the nanofluid are compared with the base fluid.

2. DESCRIPTION OF THE EXPERIMENT

2.1 Preparation and properties of nanofluid

The nanoparticles used in these experiments were copper oxide particles of 10 nm and 40 nm in size. The base working fluid was distilled water. Copper oxide (CuO) nanofluid was prepared using a two step method. CuO nanoparticles were prepared first. Then, they were produced using a catalytic chemical vapor deposition method (purchased from Nano wings Private Limited, Telangana). The copper oxide nanoparticles were then added to pure water. Citrate surfactant is used in the CuO nanofluid suspension. The mixture was prepared using an ultrasonic homogenizer. Nano-fluid volume concentration of 1% is used in this study.

And have the following properties of Cuo nanoparticles:

1. Specific heat = 520 J/kg K
2. Melting point = 1326^{0}C
3. Density = 6.31 g/cm^3

An experimental system is setup to measure the thermal resistance of cylindrical heat pipe. The inner diameter and length of the heat pipe used in these experiments were 22 mm and 450 mm, respectively. The heat pipe contained stainless steel as wick material of dimension 45 mm wide and 288 mm length.

Fig.2.11: CuO nanofluid (40 nm and 10 nm)

2.2 Experimental setup

Fig. 2.21: Experimental setup of heat pipe

2.3 Procedure

- Heating controlled by an electric heated wire wound in the evaporator wall. The wire is connected to a variator.
- No heating or cooling occurs in the adiabatic section.
- For cooling, a water jacket with tap water surrounds the condenser.
- The water flow is measured with a Measuring jar and stop watch.
- Temperatures are measured at several positions at the outer wall and at the coolant inlet with K-type thermocouples.
- The thermocouples are read with a digital thermocouple thermometer.

3. RESULTS AND DISCUSSION

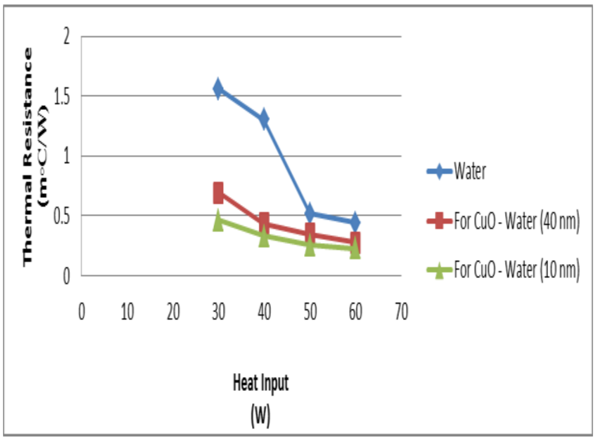

Chart -1: Variation of heat pipe thermal resistance with heat inputs for 0^0.

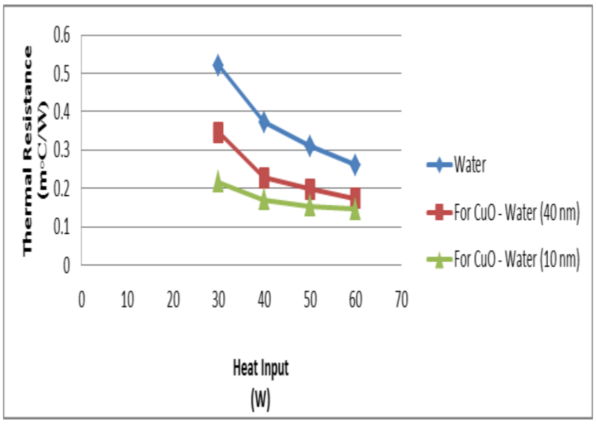

Chart -2: Variation of heat pipe thermal resistance with heat inputs for 40^o.

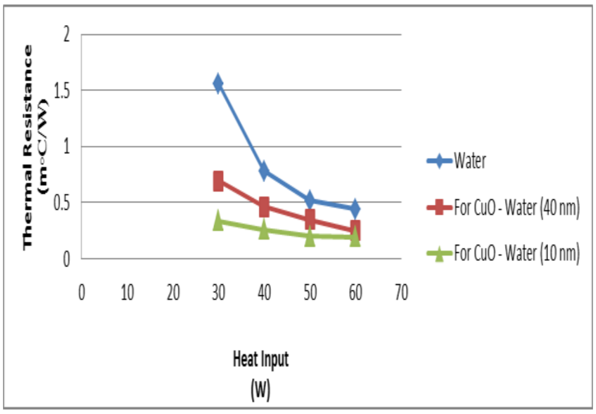

Chart -3: Variation of heat pipe thermal resistance with heat inputs for 80^0.

Charts 1, 2 and 3 shows the variation of heat pipe thermal resistance with different heat inputs for heat pipe tilt angle of 0^0, 40^0 and 80^0 at 40% of charge amount of distilled water and CuO nanofluid (10 nm and 40 nm). CuO nanoparticle size and heat pipe tilt angle affects more on thermal resistance of the heat pipe. It can be seen that the thermal resistance tends to decrease as the CuO nanoparticle size decreases for the volume concentration of 1%. In this study the thermal resistance of the heat pipe is very low when the heat input was 50-60 W for CuO (10 nm) nanofluid than that of CuO (40 nm) and base workind fluid at 40^o.

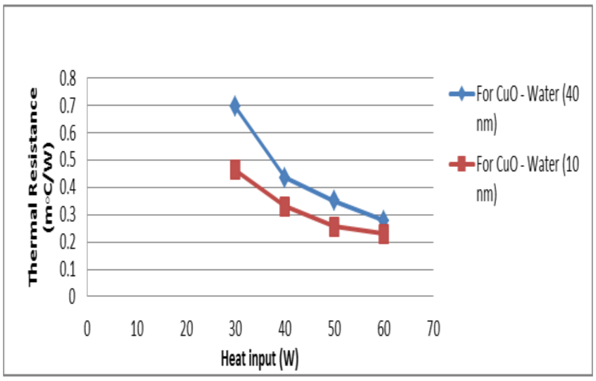

Chart-4: Variation of heat pipe thermal resistance for different heat inputs with CuO (10 nm and 40 nm)at 0^{o}.

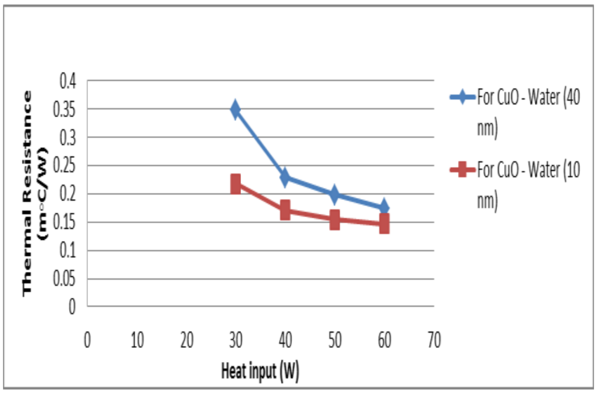

Chart -5: Variation of heat pipe thermal resistance for different heat inputs with CuO (10 nm and 40 nm) at 40^{o}.

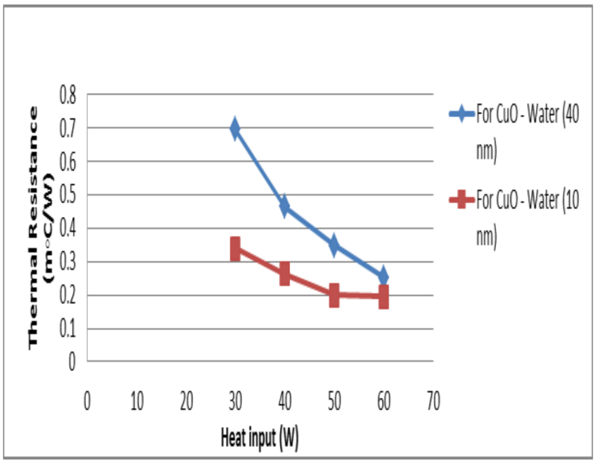

Chart -6: Variation of heat pipe thermal resistance for different heat inputs with CuO (10 nm and 40 nm) at 80^{o}.

Charts 4, 5 and 6 reveals that effect of nanoparticle size. Thermal resistance decreases as the nanoparticle size decreases but as the concentration increases thermal resistance also increases. It is observed that the themal resistance of the heat pipe for 10 nm is low as compared to 40 nm at 40^{o}. For the optimum condition at 40^{0} tilt angle and 40% charge amount for CuO (10 nm) nanofluid that results in maximum decrease in thermal resistance is achieved.

4. CONCLUSION

Heat pipe technology has used a wide variety of applications in the various heat transfer devices more specially in the electronic components. However, the heat transfer capacity is limited by the working fluid properties. The heat transfer enhancement can be accomplished by changing fluid properties and flow feature with nanoparticles suspension. New experimental investigation on the decreasing of thermal resistance of the heat pipe with CuO nanofluid is presented. Effects of nanoparticle size and heat pipe tilt angle on the heat pipe thermal resistance are taken into account. For the heat pipe with nanoparticle volume concentration of 1% at 40^{0} the thermal resistance is decreased by 0.086 m^{0}C/W (33.23%) for 40 nm and 0.118 m^{0}C/W (43.76%) for 10 nm than that with the based working fluid.

ACKNOWLEDGEMENT

Firstly, thank to my project guide **Sri. C.N. NATARAJ,** Associate Professor and all the **staff members** of Department of Studies in Mechanical Engineering, **University of B.D.T College of Engineering, Davangere, Karnataka** for their guidance, encouragement and suggestions at every step.

I would like to express our gratitude to **Sri.C.D. HAMPALI,** Senior Associate Professor and all the staff members of **REVA UNIVERSITY, BANGALURU** for facilitating in all the way.

REFERENCE

[1] Paisarn Naphon, Pichai Assadamongkol, Teerapong Borirak, "Experimental investigation of titanium nanofluid on the heat pipe thermal efficiency", International Communications in Heat and Mass Transfer 35 (2008) 1316-1319.

[2] Yu-Hsing Lin, Shung-Wen Kang, Hui-Lun Chen, "effect of silver nanofluid on pulsating heat pipe thermal performance", Applied Thermal Engineering 28 (2008) 1312-1317.

[3] Yurong He Yi Jin, Haisheng Chen c, Yulong Ding, Daqiang Cang, Huilin Lu, "Heat transfer and flow behaviour of aqueous suspensions of TiO2 nanoparticles flowing upward through a vertical heat pipe", International Journal of Heat and Mass Transfer 50 (2007) 2272–2281.

[4] Shung-Wen Kang, Wei-Chiang Wei, Sheng-Hong Tsai, Shih-Yu Yang, "Experimental investigation of silver nano-fluid on heat pipe thermal performance", Applied Thermal Engineering 26 (2006) 2377–2382.

[5] Mohamed I. Hassan , Ismail A. Alzarooni, Youssef Shatilla, "The effect of water-based nanofluid incorporating Al2O3
nanoparticles on heat pipe performance", Energy Procedia 75 (2015) 3201 – 3206.

[6] [6] Jubin V Jose, A Ramesh, Ebin Joshy, "A Review of Performance of Heat Pipe with Nanofluids", International Journal of Research and Innovations in Science and Technology Volume 1 : Issue 1 : 2014.

[7] Maryam Shafahi, Vincenzo Bianco, Kambiz Vafai, Oronzio Manca, "An investigation of the thermal performance of cylindrical heat pipes
using nanofluids", International Journal of Heat and Mass Transfer 53 (2010) 376–383.

[8] [8] Kamble D.P. Gadhave P.S., M.A.Anwar, "Enhancement of Thermal Performance of Heat Pipe Using Hybrid Nanofluid", International Journal of Engineering Trends and Technology (IJETT) – Volume17 Number 9–Nov2014.

[9] Shung-Wen Kang, Wei-Chiang Wei, Sheng-Hong Tsai, Shih-Yu Yang, "Experimental investigation of silver nano-fluid on heat pipe thermal performance", Applied Thermal Engineering 26 (2006) 2377–2382.

[10] Jian Qu, Hui-ying Wu, Ping Cheng, "Thermal performance of an oscillating heat pipe with Al2O3–water nanofluids", International Communications in Heat and Mass Transfer 37 (2010) 111–115.

BIOGRAPHIES

GIRISHKUMAR G S
M Tech. (Thermal Power Engineering).
U.B.D.T College of Engineering, Davangere.
V.T.U, Belagavi, Karnataka, India.

Sri. C.N. NATARAJ
Associate Professor,
Department of Studies in Mechanical Engineering,
U.B.D.T College of Engineering, Davangere.
V.T.U, Belagavi, Karnataka, India.