Study of Thermal performance of Heat Pipe using Hybrid Nanofluid: A Review

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Abstract

Effective heat transfer by heat pipe using nanofluid plays an important role in thermal management. Nanofluids are highly preferred for various thermal application because of its stability and high ability to transfer heat. Heat transfer enhancement of nanofluid depend on different parameters like thermal conductivity, volume concentration of particles, particle shape, mass flow rate in a heat pipe. Thermal conductivity may be affected by using composite nanoparticles for a constant volume concentration and mass flow rate. Composite (hybrid)nanoparticle is a mixture of two or more different material of nanosize .Hybrid particles are used to prepared hybrid nanofluid. The idea of preparing hybrid nanofluid is to achieve heat transfer enhancement in heat pipe with increased thermal conductivity. In this review paper the aim is to study the hybrid nanofluid and its effects on heat pipe thermal performance.

Keywords: Thermal Conductivity, Hybrid Nanofluid, Volume Concentration, Heat Transfer, Heat pipe.

1. Introduction

Nowadays heat pipe is used for effective heat transfer. It is used to transfer heat to a relatively long distance and widely used in various applications like Aerospace, Medicine, Agriculture, Transportation, and Automotive Industry. Various factors which enhance heat transfer rate of heat pipe are working fluid, inclination angle, power input, pumping losses etc. The thermal conductivity of heat pipe can be improve by change in working fluid such as nanofluid if there is no change in structure of heat pipe. The choice of working fluid affect the resistance of a heat pipe.

The nanofluids is used to obtain the highest possible thermal properties with the use of the smallest possible volume fraction of the nano-particles. When these are dispersed in a uniform and stable manner into a base fluid show a drastic increase in heat transfer enhancement. Demand of efficient method of heat transfer is required due to increase in the overheating problems in the components. For this purpose nanofluid is the effective solution using heat pipe. Use of nanofluid with heat pipe increases the life of equipment, increases cooling rate, energy saving. Further the idea is introduce for the use of hybrid nanofluid to achieve higher heat transfer rate in the heat pipe.

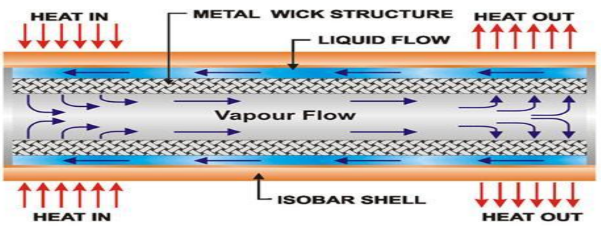

Fig 1. Schematic of Circular Heat Pipe

Fig 1.Is the schematic of heat pipe in which there are three sections evaporator section, adiabaticsection, condensersection. Heat pipe works on the principle of latent heat of vaporization. Heat is gained by evaporation section (hot side) which convert the working into vapours and these vapours migrates along the cavity to the condenser. Adabatic section is insulated which leads to low transfer of heat to the environment at this section. Thus in the condenser section (cold section) vapour condenses back to the fluid and absorbed by the wick inside the heat pipe. Wick again transfer the fluid from condenser to evaporator section through capillary action. In this way cycle is completed.

M.G.Mousa et al (2011), experiment was performed to study the overall effect of heat pipe using nanofluid. The 100 nm diameter of Al_20_3 were used and compared this experimental results of nanofluidwith Deionized water. Results shows that thermal resistance depend on concentration of heat pipe it decreases with increase in concentration. Shang et al (2008), investigated the heat transfer rateusing Cu-H_2O nanofluid in a closed loop OHP with different filling ratios. The result found that heat removal rate is enhanced by 83% using Cu-H_2O nanofluid. Also found that directly suspending nanoparticles in the DI water without use of stabilizing agent had more heat transfer enhancement than the case when it was added to DI water.R. Manimaran (2010), performs the experiment with the aim to understand the behaviour of nanofluid in heat pipe. It was observed that the inclination angle of heat pipe effects the parameters like heat transfer coefficient of both the sections, wall temperature, total heat flux and thermal resistance.

2. Factors Affecting Parameters of Heat Pipe and Nanofluid:

The parameters which mainly affects nanofluids are base fluid, particle volume concentration, particle size, particle shape, particle material, temperature, additive, and acidity. Particle material like Alumina, CuO, SiC, TiC, TiO_2, Au, Fe, Cu and Ag contains different ability to conduct heat, stability and chemical inertness. Spherical particles are mostly used in nanofluids. It has better ability to transfer heat. However, rod-shaped, tube-shaped and disk-shaped nanoparticles are also used. Volume concentration of nanofluid mostly influence the thermal conductivity. With increase in the concentration of nanoparticles in the base fluid thermal resistance decreases. Hybrid nanofluid which gives better heat transfer rate is a composite of nanoparticles and thermal conductivity depend on the composite material.

Other parameters which affect heat pipe are material of heat pipe, type of heat pipe, Filling ratio, wick structure, wickmaterial. Fraction of heat pipe which is initially filled with the liquid is known as filled ratio. Operation limit is there for filled ratio. At 0 % filled ratio, pure conduction takes place with undesirable thermal resistance and heat pipe structure contains only bare tubes and no working fluid. At 100% filled ratio i.e fully filled heat pipe works as a single phase thermosyphone.When there was less amount of charge, more space is available for accommodation of vapor which make the pressure relatively lower. Which helped nanofluid for vaporization and increase heat transfer.

The wick structure are available like grooved, wire mesh, powder metal, fiber which allows transfer of liquid via capillary action. Among them grooved heat pipe has the lowest capillary action. Thermal conductivity also depend on the type of material used for heat pipe. Copper heat pipes are generally used because they are easy available and cheaper.

3. Study of Heat pipe using Hybrid nanofluid in different conditions:

Woo-Sung HAN and Seok-Ho RHI(2011),investigated experimentally according to the volume concentration(0.005 %,0.05%,0.1% and hybrid combination) of particles, heat input(50-300 W), orientation(5°,45°,90°) of heat pipe the Grooved heat pipe with Ag,Al_2O_3 nanofluid and Ag+Al_2O_3 hybrid nanofluid. The stainless steel tubes was used to made grooved heat pipe with a diameter of 12mm and wall thickness of 1mm.The special wire resistance heater was designed which have internal resistance of 3.3 Ω.

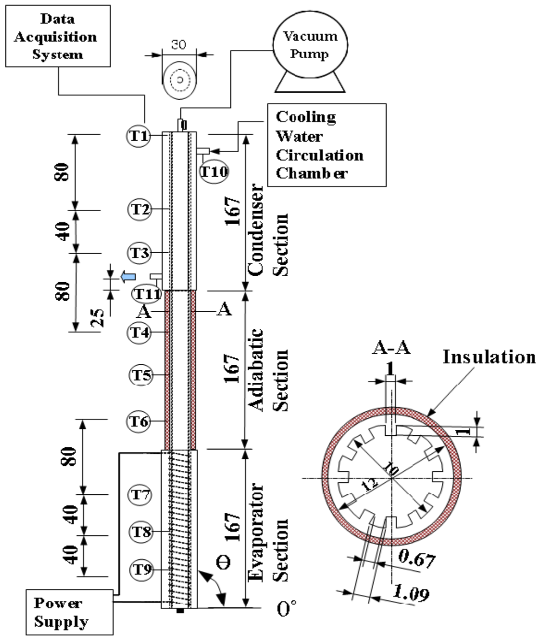

Fig 2. Schematic of Experimental setup

From the experiment it was concluded that in Grooved heat pipe performance at lower angle is better than vertical position. Nanofluid and hybridnanofluid shows lower conductivity as compared withwater. With increase in concentration thermal resistance was high and also hybrid nanofluid get worse in terms of thermal resistance and T*.

Ashish Chaudhari & S.Y.Bhosale (2016), experimentally studied the thermal behavior of circular heat pipe using CuO+BN/H_2O hybrid nanofluid. Aim of this study was to see the effect of various concentration ofCuO+BN/H_2O hybrid nanofluid, inclination angle, heat input on thermal resistance. Fig 3 indicate the experimental setup with heat pipe of length 600 mm, wall thickness of 0.5 mm ,25.4 mm outer diameter, adiabatic section 300 mm, evaporator and condenser section were 150 mm long each respectively. For cooling of condenser section cooling water was circulated at constant temperature. Evaporator section was heated using electrical heater.Fig 3.shows the experimental setup of this study

Fig 3 .Experimental Setup

The total thermal resistance of a heat pipe can be evaluated from equation:

$$R_{th} = (T_e - T_c)/Q$$

Where Tc &Teare the average temperatures of condenser andevaporatorand can be found out by:

$$T_e = 1/n \sum_{(i=0)}^{n} T_i$$

$$T_c = 1/n \sum_{(i=0)}^{n} T_i$$

It was found that optimum result are observed at an angle of 45° (100W) for volume fraction of 2% of hybrid nanofluid.

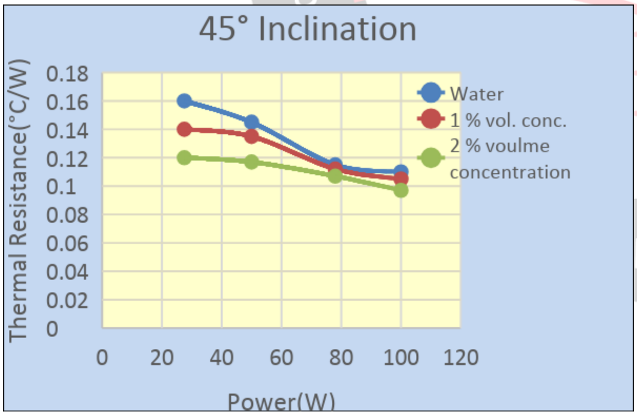

Fig 4. Thermal resistance vs. power input for 45° inclination of heat pipe for different concentration w.r.t water

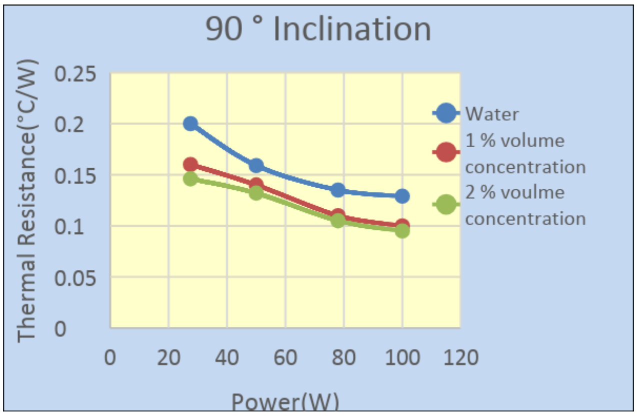

Fig 5. Thermal resistance vs. power input for 90° inclination of heat pipe for different concentration w.r.t water

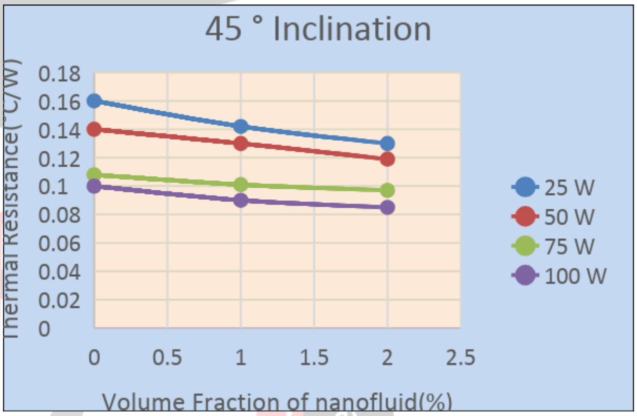

Fig 6. Thermal resistance vs. volume concentration for 45° inclination for different power input.

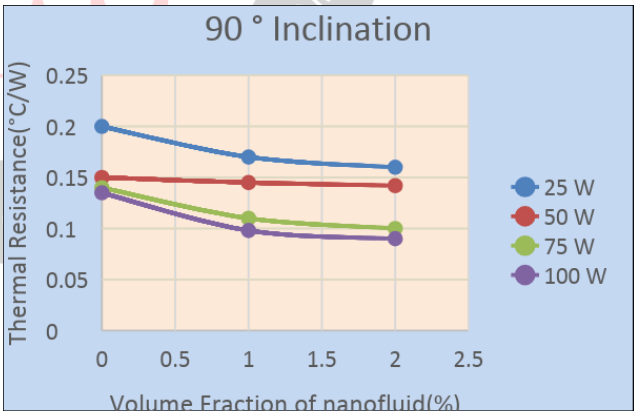

Fig 7. Thermal resistance vs. volume concentration for 90° inclination for different power input.

From the experiment it was found that (Fig. 4 & Fig 5) for 2 % of volume concentration of hybrid nanofluid thermal resistance reduces by an amount 32%.(Fig 6 & Fig 7)For 2 % volume concentration and variation of inclination angle from 0° to 90° thermal resistance reduces by an amount of 33.62%.

Kamthe Swapnil, PawarDhananjay ,Zurunge Gaurav, Ranade Anand and Kamble D.P.(2016)studied theheat transfer rate of circular heat pipe which contains Al_2O_3-BN/Water hybrid Nanofluid. Three heat pipe were used with a length of 600mm,one with water as working fluid and other two with 1% & 2 % volume concentration of hybrid nanofluid. Experiment was done at different heat input (25 W,50W,75W,100W) & inclination angle of (0°,15°,30°,45°,60°,75°,90°).

From the experimentation it was concluded that for 2 % volume concentration of Al_2O_3+BN hybrid nanofluid thermal resistance reduces by 39.92% than distilled water as working fluid. For 2 % volume concentration variation of inclination angle by 30° to 90° reduces thermal resistance by 39.00 %, varying heat input from 25 W to 100W and inclination angle of 0° thermal resistanceis reduces by 49.62 %.

4. Conclusion

From the above analysis on the review of effect of performance of hybrid nanofluid in heat pipe is studied. From which following conclusion can be drawn are:

1) Thermal resistance depend on the volume concentration, heat input and inclination angle of hybrid nanofluid.
2) Thermal conductivity increases with increase in concentration of hybrid nanofluid, and increase with increase in heat input and inclination angle.
3) Heat pipe using hybrid nanofluid gives better results as compared to water as working fluid.
4) Al_2O_3+BN/H_2O and CuO+BN/H_2O both gives better results as compared to water as a working fluid and on increasing the volume concentration, inclination angle there performance increases as thermal resistance decrease.
5) If comparison is made between Al_2O_3+BN/H_2O and CuO+BN/H_2O,Al_2O_3+BN/H_2Oreduced thermal resistance more thanCuO+BN/H_2O and shows better performance.

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