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A REVIEW ON EFFECT OF NANOFLUID ON THE PERFORMANCE HEAT PIPE

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ABSTRACT

With the Cutting edge time of downsizing of equipment's, heat pipe have pulled in genuine thought in the field of heat exchanger. Nanofluids in like manner have pulled in a wonderful thought starting late on account of its prevalent heat exchangerproperties.This overview expect to maximise the effect of nanofluid in heat pipe. Execution of different nanoparticles and water base-fluids are analyzed. Most of the papers investigated here reported a change in execution ofheat pipe. Vicinity of a perfect union of nanoparticles in base fluid was moreover reported. Paper in like manner displays a perspective on possible examination application

I. INTRODUCTION

Nanotechnology is a field of emerging technology. From 1990's, the researchers started study on applying nanoparticles to enhance heat transfer. In 1995 Choi [1] proposed the concept of nanofluid. Nanofluids are stable colloidal suspension of nano-meter sized particles in the base fluid. In the modern days, nanofluids have attracted the attention of research groups due to their enhanced heat transport properties. Heat pipe is a special type of heat exchanger that can transfer large amount of heat by phase change of working fluid and capillary action. It can transfer thermal energy about 1000 times than copper, the best known conductor. It is widely used in electron ic cooling systems, solar heaters etc. The application of nanofluid in heat pipe was first investigated in 2003 H T Chient et al[2].The study was conducted on the improvement on thermal performance of disk shaped miniature heat pipe with nanofluid. Various mechanisms of heat transfer enhancement by nanofluids were proposed such as interface effect, Brownian motion, thermophorisis, formation of porous layers etc.

II. LITERATURE REVIEW

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Various mechanisms of heat transfer enhancement by nanofluids were proposed such as interface effect, Brownian motion, thermophorisis, formation of porous layers etc.Study of heat pipes with nanofluids in 2007, Y.H Lin et al [3] investigated the performance of heat pipe with silver- water nanofluid. Experiment was done with different concentrations, filling ratio and heating power. Higher value of filling ratio makes bubble formation difficult. Also lower value of filling ratio lead to easy dry out. P Naphon et al [4] in 2008 performed experiment with water, alcohol and nanofluid (alcohol+ nanoparticle) (TiO2)21nm). Effect of tilt angle on performance was studied and it was found that efficiency increases with increase in tilt angle due to the flow of li quid 600(De-water) and 450 (alcohol) was the best tilt angle with maximum heat transfer. With higher tilt angle thick liquid layer form over evaporator, which eventually increase thermal resistance.Effect of filling ratio was also studied. It was found that for higher filling ratio, there is only reduced space for vapour in condenser. Therefore evaporation of fluid decreases and optimum was found to be 66%.Z H Liu et al [5] conducted study with nanoparticle Cu, CuO and SiO with DI water as base fluid. Cu and CuO enhanced the performance while SiO deteriorates the performance. Heat transfer coefficient at condenser and evaporator was found to increase. Heat transfer was found to increase with particle size. Reasons put forward by the author for getting the enhancedPerformance were: 1) increase in thermal conductivity of base fluid 2) decrease of solid-liquid contact angle between nanofluid and heater surface 3) predominant Brownian motion 4) formation of coating layer on heater surface. Coating layer of Cu and CuO is compactly porous structure compactly aggregated nanoparticles while coating of SiO2 is slurry lick layer without porous structure and is not stable and washes away when cleaned.M. Shafahi et al. [6] studied thermal performance of rectangular and disc shaped heat pipe with nanofluid. Author reports a substantial increase in thermal performance of flat shaped heat pipe. Heat load capacity of flat shaped heat pipe increases with particle loading.Sameer K et al. [7] in 2010 conducted a review on methodologies to predict hydrodynamic properties of uni-directional two-phase Taylor bubble flow.M G Mousa [8] conducted experiment with pure water and Al2O3- water based nanofluid in heat pipe. Surface temperature was found to decrease with increase in nanoparticle concentration. Thermal resistance reduces with increase in filling ratio and reach minimum at 0.4 filling ratio. Porous layer formation was reported to be the predominant reason for improvement in performance as it increases the wettability. Author reported optimum concentration of 0.6 to 0.8 volume fraction of nanoparticle. In 2012, Y H Hung et al. [9] investigated performance of heat pipe with Al2O3-water nanofluid (0.5, 1, 3 wt %). Chitosan 0.2% was used as dispersant in this experiment. The optimum filling ratio was at 20-40% range. Tilt angle for maximum performance was 40-700. For lower concentration, higher thermal performance was obtained at lower filling ratio. For higher concentration, higher thermal performance was obtained at high filling ratio. At higher concentration of nanoparticle author reported a drop in thermal efficiency due to drop in convective heat transfer. Author also reports that at evaporator with vaporization nanoparticle remain at the evaporator surface which leads to 1) rapid increase in nanofluid concentration at evaporator lead to premature dry out.N Putra et al. [10] investigated performance with 5 different nanofluids. Thermal conductivity was found to increase with particle concentration. Temperature difference between the ends decreases with particle concentration. Hence evaporator temperature gets reduced. Author reports the formation of coating layer on wire mesh which 1) improved capillary structure 2) improved surface wettability 3) reduces contact angle 4) increases the surface roughness. Mesh heat pipe with best performance was Al2O3 water nanofluid with 5% volume concentration.

III.TECHNOLOGY

The heat transfer performance of a heat pipe (see chapter 5) is related to the thermophysical restrictions of the working fluid. Thermophysical restrictions on the other hand depend mainly on the thermal conductivity of the working fluid. Thermal conductivity illustrates the ability of a substance to conduct heat. The higher the thermal conductivity of the fluid the more effective is the heat transfer capability of heat pipe (Iborra Rubio, 2012).
In order to enhance the thermal conductivity, highly conductive solid nanoparticles can be added to a base fluid (Shafahi et al., 2010a) e.g. water, ethylene glycol or pump oil (Behi and Mirmohammadi, 2012). The result is a nanofluid i.e. a colloidal suspension of solid particles with the size lower 100 nanometers (Behi and Mirmohammadi, 2012). Table 1 illustrates the variance in thermal conductivity from base fluids (non-metallic liquids) to nanofluid solid particles (metallic solids) which are usually over hundreds times more conductive (Iborra Rubio, 2012).

3.1 Heat pipe description

Heat pipes are effective heat transfer devices with a phase transformation of an intermediate heat medium in a closed cycle (evacuated tube). The two phases: evaporation and condensation are used to transfer the heat supplied e.g. from a processor. Heat pipes are used due to their ability to achieve high thermal conductance in steady state operations (Bozorgan and Bozorgan, 2013). As seen in Figure 3 heat pipes are composed of three sections: evaporator (hot part), condenser (cold part) and an adiabatic section, where vapor and liquid circulates between evaporator and the condenser (2, Heat pipe, 2010).

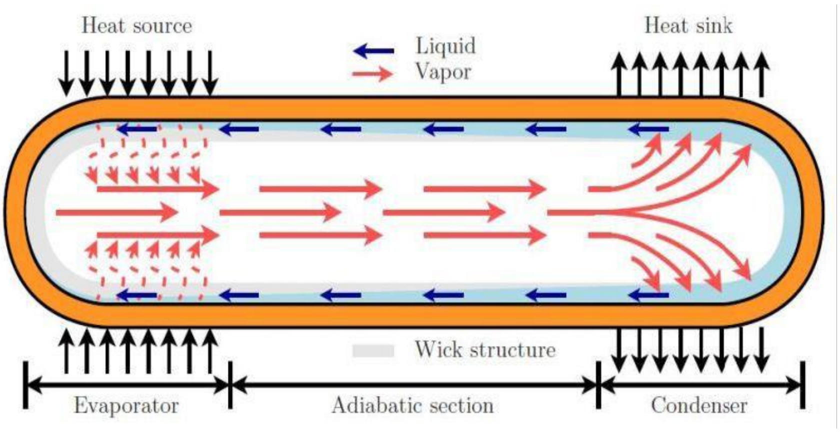

Figure 1: Technical description of a heat pipe (2, Heat pipe, 2010)

The general heat pipe transfers heat efficiently between two solid interfaces using capillary forces generated by a wick and a fluid as seen in Figure 3. The heat is transported at high rate (with two phase heat transfer) with temperature drop and does not require any external pumping power. Thus, heat pipes have two distinct advantages. First, it does not require an external source to circulate the working fluid. Second, the two phase heat transfer occurs with one-two order of magnitude higher heat transfer coefficient than that of a single phase heat transfer (Reay and Kew, 2007a, b). Figure 3 illustrates the heat pipe as a closed tube where the inner surface is lined with a wick or a porous material that is filled with liquid near its saturation temperature. The liquid in the wick and the open vapor corridor is separated by a vapor-liquid interface, which is found in the inner surface of the wick. Heat pipe characteristics are dependent upon size, shape, material construction, working fluid and heat transfer rate. The operational characteristic of a heat pipe is defined by heat boundaries, effective thermal conductivity andtemperature difference. Heat pipes have been used in controlling the temperature of vehicles and space units (Chi, 1976). Furthermore they are used in innovation intensive hard ware applications as for instance laptops and game consoles (1, Heat pipe, 2010).

1.2 The incremental effect of nano fluids in heat pipes

Nanofluids are used in heat pipes in order enhance the thermal efficiency of the heat pipe and they are evaluated by their effect on the thermal efficiency. The thermal efficiency represents the ratio of heat rejected at the condenser section and the heat input at evaporator section (Senthilkumar et al., 2011). The considered parameters of thermal efficiency are the following (Naphon et al., 2008):

1. Charge amount of working fluid
2.Tilt angle of heat pipe
3. Volumetric concentration of nanoparticles
4. Thermal resistance
5.Temperature Gradient

1.3 Different nanofluids but same concentration

By studying the temperature difference between evaporator and condenser an evaluation of on the thermal efficiency of the heat pipe can be made. It also enables studies on the incremental heat dissipation enhancement of the heat pipe without increasing the wall temperature of the heat pipe (Shafahi et al., 2010a). The working fluids studied in Figure 5 are: pure water, silver *(Ag)*, silicon carbide *(SiC)* and aluminum oxide *($Al2O3$)* based working fluids with 10 % volumetric concentration.

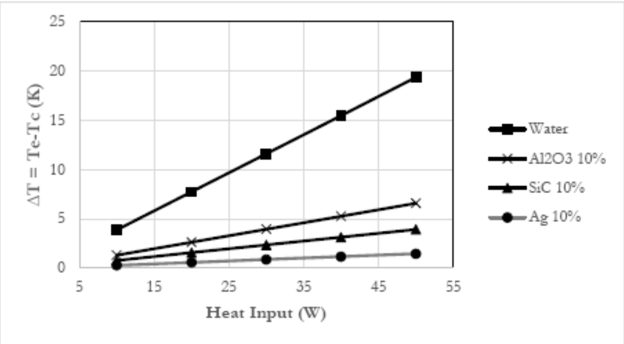

Figure 2: Temperature difference between evaporator and condenser depending on nanofluid and heat input. Results are based on simulation from attached data in appendixes.

1.4 Different concentrations but same nanofluid

Figure 6 shows how the temperature difference is influenced by nanoparticle concentration of silicon carbide *(SiC)* compared to water, under varied heat input powers. It can be observed that the temperature difference is a linear function of heat input and by increasing the nanofluid concentration, the temperature difference is decreased significantly. Also by increasing the heat load, an increase in each working fluid is observed, where water as a working fluid has the largest inclination and therefore cannot operate under a larger heat load in comparison to silicon carbide with various concentration as can be seen in Figure 6.

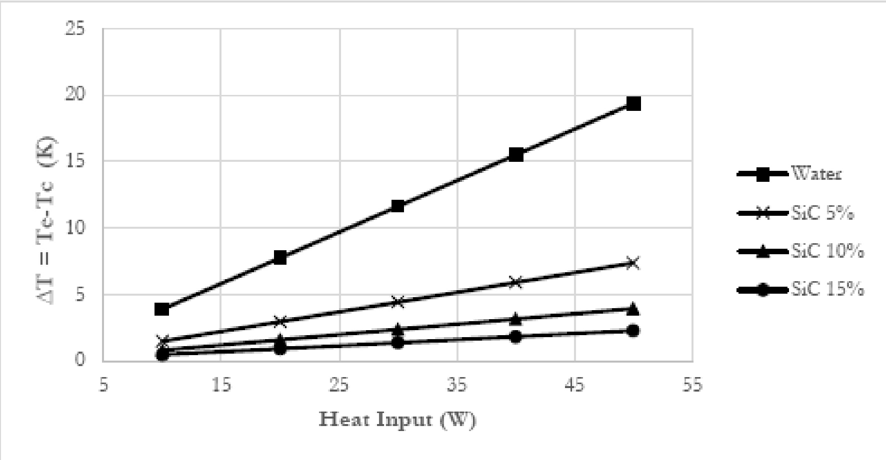

Figure 3 Temperature difference between evaporator and condenser depending on concentration and heat input. Results are based on simulation from attached data in appendixes.

IV. CHALLENGES FOR NANO FLUID BASED HEAT PIPE

Recent and existing studies have mainly showed positive effects of applying nanofluids in heat pipes by enhancing the heat transfer characteristics of heat pipes. As revealed by the results of the model in this study and other studies, the thermal conductivity in heat pipes increases with nanofluids applied as working fluids. Experiments and research have discovered a sediment layer on the wick after being heated. This affects, as mentioned earlier, the thermal performances of heat pipes both positively and negatively (Liu and Li, 2012). Current studies are focused on how the thermal performance will be affected if the sediment layer becomes thicker and if the sediment layer will maintain a certain thickness during the entire operation since this has a significant impact on the practical engineering application of nanofluids in heat pipes (Liu and Li, 2012). Another field of study for improving the thermal performance of a heat pipe is the operating temperature. Liu et al. have shown the significance of operating temperature on heat transfer enhancement of nanofluids in several kinds of heat pipes. Recent experiment on closed two-phase thermosyphons, which are gravity driven heat pipes (KTH, Heat Pipes), carried out by Liu et al. showed that a better heat transfer enhancement was not obtained with a higher operating temperature, but at a lower operating temperature .

Current research are focused on the application of nanofluids in heat pipes trying to find the optimal types of nanofluids, nanoparticle size and shape, and nanoparticle concentration in order to maximize the thermal performance (Keblinski et al., 2005). Other research are carried to find the impact of various operating parameters, such as thermal resistance, viscosity, operating temperature, the heat flux and thermal conductivity (Nine et al.,2014).Another difficulty encountered in the nanofluids synthesis is the tendency of nanoparticles to agglomerate into larger particles which limits the benefits of the high surface between the nanoparticles (Saidur et al., 2011). To cope with this issue, particle dispersion additives are most of the time added to the base fluid when the nanoparticles are dispersed. However, this practice has a tendency to change the surface properties of the particles, and the nanofluids may contain a significant amount of impurities that affects the thermal performance of a nanofluids (Lee and Mudawar, 2007).

V. METHODOLOGY

The methodology applied in this report is derived from the definition of a paradigm. Science is a collection of facts, theories and methodologies. Homogenous rules in methodologies are vital in order to classify a science as legitimate (Kuhn, 1996). Consequential to this logic the following operations framework is applied in this report, where the operations 1 and 3 as well as 2 and 3 are conducted concurrently:

1. **Definition:** literature study in order to gain fundamental knowledge of nanofluids and their effect on thermal performance of heat pipes
2. **Implementation**: Modeling with experimental data from KTH Lab research by Ghanbarpour and analytical data from the web
3. **Reporting:** analysis, comparison and evaluation of findings in literature and results from the model

VI. Future research suggestions and sustainability

A more intensified research and effort is required in the field of nanofluids in where a variety of issues, such as synthesis, thermophysical properties, characterization, filling ratio and concentration level of nanoparticles needs to be examined. A multidisciplinary approach comprising researches in different field is required. An important focus in the development of nanofluids could be determining the key energy transport mechanism in nanofluids. As most heat transfer depends on the thermal conductivity of nanofluids as the key function for improved thermal performance, future research should focus on the main parameters that affect the thermal conductivity of nanofluids. This is based on studies concerning the effect of particle shape and size etc. on the thermal conductivity of nanofluids. Concerning sustainability, a challenging direction for future applied research in the field of heat pipes and nanofluids is to pursue green designs by choosing nontoxic or biodegradable nanoparticles (Gupta et al., 2012). This leads to the conclusion that the direction to commercialize nanofluids is to aim to low cost, high volume production of stable and sustainable nanofluids.

VII. CONCLUSION

After investigation of different properties of nano liquids which expands heat move rete in heat exchanger, it is watched that the capacity of heat upgrade of nanofluid in heat exchange supplies. Nanofluids are fundamentally utilized for their improved properties as coolant in heat exchange hardware, for example, heat exchangers,

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electronic cooling system(such as level plate) and radiators. Heat exchange over direct surfaces has been broke down by numerous analysts. Be that as it may, they are additionally helpful for their controlled recognizable properties. Water based nanofluid has been found to improve more productivity. Nanofluids in sun oriented authority is another application where nanofluids are utilized for their tunable optical properties.A higher particle conductivity of nanoparticles increases the thermal conductivity of the nanofluid, which in turn increases the effective thermal conductivity of the heat pipe, ultimately decreasing the thermal resistance in the heat pipe and enhancing the thermal performance.A higher concentration of nanoparticles increase the thermal conductivity of the nanofluid, which in turn increases the effective thermal conductivity of the heat pipe, ultimately decreasing the thermal resistance in the heat pipe and enhancing the thermal performance.The difficulties with the production process, e.g. high production cost, of nanofluids stall the commercialization of nanofluids in heat pipes More effort must be put on research in the .field of nanofluids concerning synthesis, thermophysical properties, filling ratio and concentration level of nanoparticles.

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