# STUDY ON EFFECT OF NANOFLUIDSON HEAT TRANSFER CHARACTERSTIC OF HEAT PIPE

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**Abstract— With the increase in requirement of advanced technical equipment , of which there basic initial work is carried out on the applications, which used heat pipes for heat transfer. Heat pipes are one specific type of heat exchangers, having very wide application in electronics and other fields, because of its compactess, high efficiency, less number of components and no need for external circulation of working fluid. This heat pipes previously carrying conventional fluid as working medium inside them. But in recent years nanofluids in heat pipes have attracted a notable attention due to its superior heat transfer properties. . Addition of nano size solid particles having high thermal conductivity to the working fluid of low conductivity, will enhance the overall heat transfer coefficient of the system and in turn the efficiency. The effect of filling ratio, volume fraction of nano particles on thermal performance in various kind of heat pipes with different base fluids under various operating conditions has been discussed . This paper discusses relativity of total heat resistance between the heat pipe with nano fluid and with existing fluids. Also the basic work of heat pipe nanofluid and the effect of nanofluid concentration on heat pipe are discussed. The studied results have shown a remarkable influence on decrease in thermal resistance of the heat pipe wall.**

**Keywords— heat pipe, nanofluids , nano particles, heat transfer.**

## I. Introduction

Heat pipe is special type of heat exchanger that can exchange large amount of heat by phase change of working fluid and capillary action. It can transfer thermal energy about 1000times than copper, the best known conductor. In electronic component and also in computer , medical and many other components where these heat pipes are commonly used to avoid the damage of core on overheating, and allow it to work on In these device the heat transfer take place between two fluids separated by solid wall by the way of conduction and convection modes which are directly linked to the thermal properties of two fluid and the solid wall. Researchers had found that addition of highly conductive particles to these working fluids result in enhancement of thermal conductivity of the working fluid and thus the improvement in the efficiency of the heat exchanger- heat pipe. Microchips used in electronic component are produced with gradual decrease in its size for compacting in its required application. For such manufacturing of these microchips, need of proper heat disscipation system is increasing day by day. Thus the nanofluids are found to be more effective for better heat transfer. This was because in small spaced chips nanofluid can be more possibly adjust for formation of the heat pipe for these chip shaped devices.The primary factors influencing the enhancement of heat transfer properties are

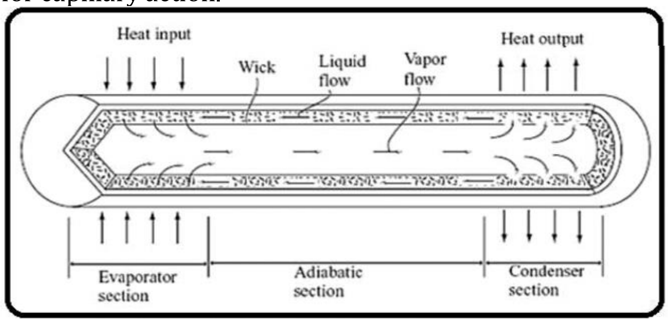
- Material, size, shape, concentration, stability, dispersion, settling velocity of the particles.
- Thermal properties like ρ, Cp, μ, k, h etc. Of the resultant fluid.

Some examples of applied nanoparticles are pure metals (Au, Ag, Cu, and Fe), metal oxides (CuO, SiO2, Al2O3, TiO2, ZnO, and Fe3O4), Carbides (SiC, TiC), Nitrides (AlN, SiN) and different types of carbon (diamond, graphite, single/multi wall carbon nanotubes). Traditional liquids, such as water,

The main purpose of using nano fluids is to attain highest possible thermal properties at the smallest possible concentration(< 1% by volume) by uniform dispersion and stable suspension of nano particles (10 to 80 nm) in base fluids.

## II. HEAT PIPE MECHANISM

The whole heat pipe work on the principle of latent heat transfer of vapourization. Thus, when the heat gained by the working fluid is equal to latent heat of evaporation the working fluid gets converted to vapour and passes towards the condenser section of the heat pipe. Thus at the condenser region the vapour gets condensed and returns back to the evaporator through the wick by action of capillary. The mechanism is something like there is vapour flow at the center of the heat pipe while at the outer side and adjacent to the inner wall of the heat pipe there is wick structure which is responsible for the condensate return for capillary action.




## III. NANO FLUIDS.

The concept of nanofluids was first used by Choi, in his research he used suspended nano sized particles into a based fluid and named them to be nanofluids. The size of nanoparticles varies from 1-100 nm. When these are dispersed in a uniform and stable manner into a base fluid show a drastic increase in heat transfer enhancement. When solid nano particles of high thermal conductivity are added to the base fluid of poor conductivity the resultant properties of the nanofluid have to be established either theoretically or experimentally, so that overall performance of the heat exchanger can be evaluated.

Here in this paper the nanofluids related to heat transfer augmentation are discussed. The increases in effective thermal conductivity are important in improving the heat transfer behavior of fluids. A number of other variables also play key roles. For example, the heat transfer coefficient for forced convection in tubes depends on many physical quantities related to the fluid or the geometry of the system through which the fluid is flowing. These quantities include intrinsic properties of the fluid such as its thermal conductivity, specific heat, density, and viscosity, along with extrinsic system parameters such as tube diameter and length and average fluid velocity. Therefore, it is essential to measure the heat transfer performance of nanofluids directly under flow conditions. Researchers have shown that nanofluids have not only better heat conductivity but also greater convective heat transfer capability than that of base fluids. The following section provides the wide usage and effective utilization of nanofluids in heat exchangers as heat transfer fluids.

Here are some of the advantages of nanofluids as shown below:

- Pharmaceutical and biology purpose nanofluids.
- Nanofluids for heat transfer applications.
- Nanofluids for chemical industries.
- For pollution reduction, Process/extraction, Surfactant and coating nanofluids.
- Nanofluids for tribology.

## IV. LITERATURE REVIEW:

Heris et al. [1]presented the experimental results of the convective heat transfer of CuO/water and Al2O3/water nanofluid inside a circular tube with constant wall temperature. It was emphasized that, the increase in the convective heat transfer /water.

Xuan and Li [6,7] studied the single-phase flow and heat transfer performance of nanofluids under turbulent flow in tubes. Their experimental results showed that the convective heat transfer coefficient and the Nusselt number of nanofluids increase with the Reynolds number and the volume fraction of nanoparticles under turbulent flow.

Moraveji et al. [4] investigated the effect of nanofluid on convective heat transfer on the developing region of a tube with constant heat flux using computational fluid dynamics. They reported that the convective heat transfer coefficient was enhanced with increasing the nanoparticle concentration and Reynolds number. Further, the heat transfer coefficient decreased with increasing the axial location and particle diameter.

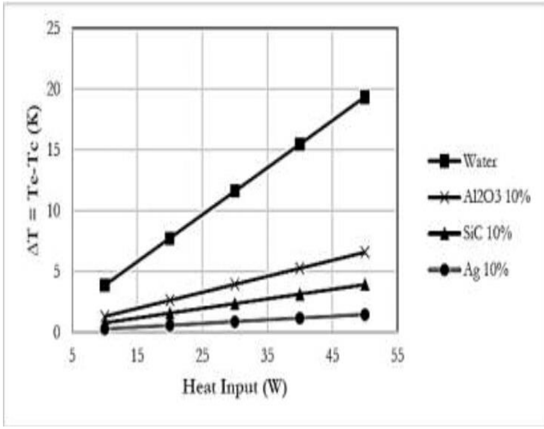
Wang et al. [5] studied the thermal performance of heat transport of the four-turn pulsating heat pipe by comparing various working fluids with pure water. The experimental analyses were based on two operating orientations (vertical and horizontal) of a copper tube with an external diameter of 2.5 mm. FS-39E microcapsule and Al2O3 nano-fluidwere used for the test. The results of the investigation proved that the functional working fluids increase the heat-transport ability of the heat pipe when compared with pure water with the FS-39E microcapsule being the best working fluid in the horizontal orientation.

Huminic and Huminic [3] used iron oxide nanoparticles that were obtained by the laser pyrolysis technique. Results show that the addition of 5.3% (by volume) of iron oxide nanoparticle in water presented an improved thermal performance compared with the operation with deionized water.

Noei et al. [2] investigated the enhancement of heat recovery in a heat pipe with aqueous Al2O3 nanofluid and concluded that for different input powers, the efficiency of a two phase close thermosyphon increases up to 14.7% when the Al2O3/water nanofluid was used instead of pure water.

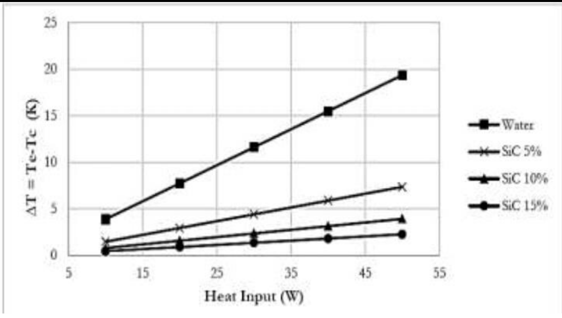
1) DIFFERENT NANOFLUIDS BUT SAME CONCENTRATION.

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. The working fluids studied in Figure 1 are: pure water, silver (Ag), silicon carbide (SiC) and aluminum oxide ($Al2O3$) based working fluids with 10 % volumetric concentration.



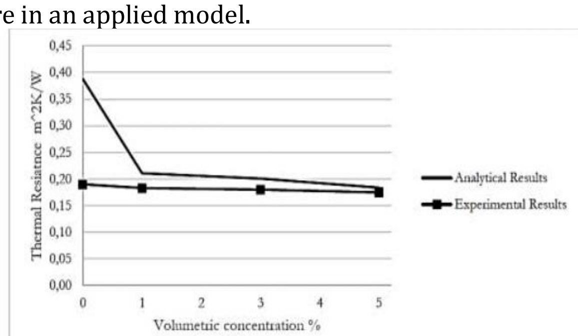

2) DIFFERENT CONCENTRATION BUT SAME FLUID.

Figure 2 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 2



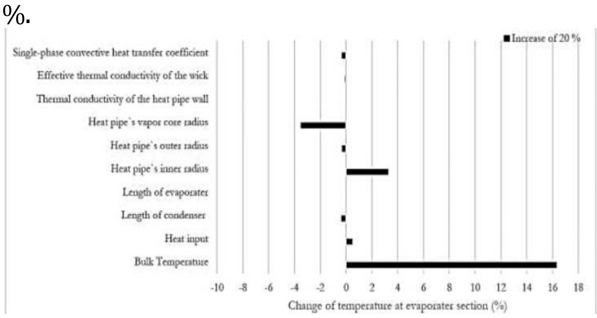

3) ANALYTICAL VS.EXPERIMENTAL RESULT: EFFECT OF WATER BASED ALUMINIUM OXIDENANOFLUID ON THERMAL RESISTANCE.

Figure 3 shows the variations in experimental as well as the analytical results -those which are drawn from an applied model. The heat pipe is constructed taking into account the objective of getting low thermal resistance to increase the efficiency of heat pipe. The results are drawn for the following figure for various concentrations. It can be seen that the two results vary because of uncertainties associated in practical approach, which are actually not there in an applied model.

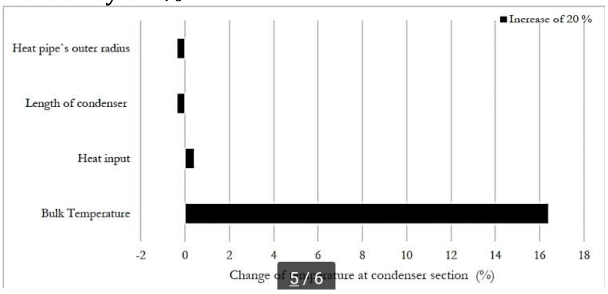



4) TEMPERATURE AT EVAPORATOR SECTION.
From figure 4 it can be seen that when the depending parameter value in the model is increase by an amount of 20%, then there is a drastic change at the end of the evaporator section. The depending parameters considered starting from bulk temperature to single phase heat transfer coefficient. The parameters taken under observation are:
   - Bulk temperature
   - Heat pipes inner radius

Heat pipes vapour core radius when the depending parameter value in the model is increase by 20%. It is seen that there is 16.3 % rise in evaporator temperature section. The temperature ranges from 288K to 345.5 K. with this increase a positive impact on bulk temperature and heat pipes inner radius with a large magnitude can be seen. The vapour core radius has a negative effect when there is decrease in evaporator temperature section by 3.5%.




5) TEMPERATURE AT CONDENSER SECTION.
Fig. 5 shows that when value of depending parameters in model is increased then there is an incremental effect on condenser section's temperature. As can be seen in Figure 5, there are four parameters starting from bulk temperature to heat pipe's outer radius all these parameters affect the temperature of condenser section. The temperature at condenser end increases with 16.4% with increase in bulk temperature by 20%.on the other hand, when there is rise in temperature by 20% then there is reduction in heat pipes outer radius and length of condenser by 3.4%.




ENHANCEMENT OF THERMAL CONDUCTIVITY.

A significant increase in the viscosity and heat transfer coefficient are the unique features of nanofluids.it is a known fact that metal at room temperature are in solid phase and have higher thermal conducting properties than those of fluids. For example thermal conductivity of a copper metal sheet is 700 times that of water and about 3000 times higher than engine oil. Thus fluids containing suspended metal particles are expected to have increased thermal conductivity relative to pure fluids .

- Dispersion of the suspended particles Dispersion is a system in which particles are dispersed in a continuous phase of a different composition. Surface-active substances (surfactants) can increase the kinetic stability of emulsions greatly so that, once formed, the emulsion does not change significantly over years of storage. Some of the surfactants are thiols [8], oleic acid , laurate salts, etc. Pak and Cho [9], Xuan and Li [7] and others claimed that the abnormal increase in thermal conductivity is due to uniform dispersion of the nanoparticles.
- Intensification of turbulence Even though thermal conductivity (k) is a function of primary variables such as thermodynamic pressure and temperature, in a turbulent flow the effective thermal conductivity (kth) due to the effects of turbulent eddies is many times higher than the actual value of k th. Similarly in nanofluids, such intensification is believed to be possible due to the addition of nanoparticles. Xuan and Li[7]. However, Buongiorno [10] has claimed that due to the particle size, the effects of both dispersion and turbulence are negligible and not sufficient to explain the enhancement of thermal conductivity in nanofluids.
- Brownian motion -It is a seemingly random movement of particles suspended in a liquid or gas and the motion is due to collisions with base fluid

molecules, which makes the particles undergo random-walk motion. Thus, the Brownian motion intensifies with an increase in temperature as per the kinetic theory of particles. Keblinski et al. [11] and Koo and Kleinstreuer [12] have suggested that the potential mechanism for enhancement of thermal conductivity isthe transfer of energy due to the collision of higher temperature particles with lower ones. The effectiveness of the Brownian motion decreases with an increase in the bulk viscosity.

- Thermophoresis -Thermophoresis or the Sore´t effect is a phenomenon observed when a mixture of two or more types of motile particles (particles able to move) is subjected to the force of a temperature gradient. The phenomenon is most significant in a natural convection process, where the flow is driven by buoyancy and temperature. The particles travel in the direction of decreasing temperature and the process of heat transfer increases with a decrease in the bulk density.
- Diffusiophoresis - Diffusiophoresis (also called as Osmo-phoresis) occurs when there is a migration of particles from a lower concentration zone to a higher concentration one. However, this is not a favourable condition since the nanofluids may lose their nonagglomeration characteristics. Thus, the resulting fluid will result in a discrete spread in the particle density. Buongiorno [10] has stressed that the Brownian motion, Thermophoresis and Diffusiophoresis are significant in the absence of turbulent eddies.

## V. METHODOLOGY

The capillary action is caused inside the evaporator section due to higher pressure at the concave meniscus than the vapour in condenser section [13]. The higher pressure in balanced by flow of vapour into the condenser section where liquid and vapour are at nearly equal pressure. The different pressures acting against the capillary pressure are frictional pressure drops between the vapour and liquid route, pressure drop in liquid due to its weight and the forces acting on it like centrifugal forces and the pressure drop due to transition in phase. The pressure drop related to the transition in phase is only significant only at very high evaporation or condensation rates. This represents the energy jump required for kinetic energy change from liquid –vapour phase. However the phase transition pressure drop is mostly negligible and will not be considered further in the following research.

Thus the capillary pressure is responsible to drive the vapour from evaporator section to the condenser section. It is the limitation of fluid flow for a given capillary pressure difference generated, when this pressure is exactly equal to the pressure required for the flow of fluid. The corresponding heat input is called the critical heat input. Any value higher than critical heat input will cause the region in the condenser section to dry up due to lack of pressure that forces the vapour to flow into condenser section. The length of the dry out region is called the dry out length. So at critical heat input there is zero dry out length and for any higher value of critical heat input the dry out length increases.

## VI. Model

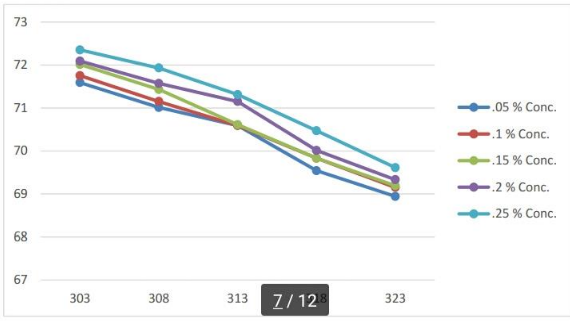
In our research we found the maximum theoretical heat transfer possible in a heat pipe within the capillary limit. The properties of the nanoparticles and nanofluids that effect the thermal properties of working fluid in heat pipe are surface tension of the nanoparticle used, density of the nanofluid mixture and the vapour density and viscosity of nanofluids and vapour. Using these values we calculate the different pressure drops that take place in the heat pipe. After these values we calculate the total pressure difference between the capillary effect which helps drive the vapour back to the condenser section and pressure that pushes liquid from evaporator to condenser section.

Using iterative method we have obtained the necessary values that are needed such as viscosity and density of nanofluids. For iteration the initial values were obtained using the following equations

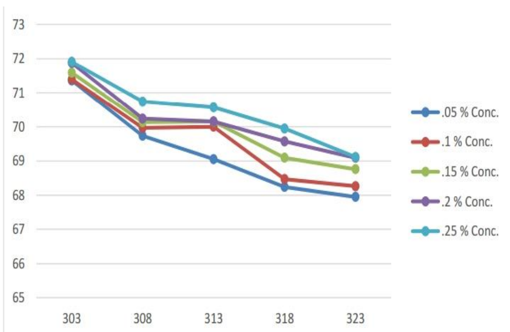
$$P_{nf} = P_{bf} ( 1 - \mu ) + P_{nf} * \mu$$

$$Y_{nf} = ( 1 + 7.3 * \mu * 123 * \mu * \mu ) Y_{bf}$$

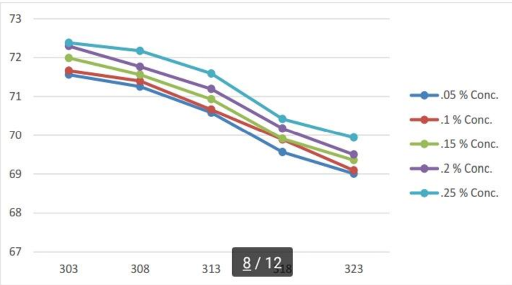
Where the subscripts “np” refers to nanoparticle, while the subscript „bf‟ is an indication of the base fluid. The relation for the viscosity relation was developed by Maiga[14] by using experimental data of water based nanofluids provided by Wang.Through iterative and graphical methods the following surface tension equation for different nanoparticles was formulated and used in our calculation. The graphs [15] used for the calculation are mentioned below:



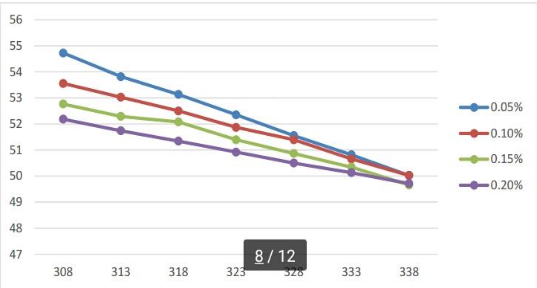

Graph 1. $Al_2O_3$ Nanoparticle diffused in working fluid over a temperature range of 30- 50 C at different particle concentration.




Graph 2.$SiO_2$ Nanoparticle diffused in working fluid over a temperature range of 30- 50 C at different particle concentration.



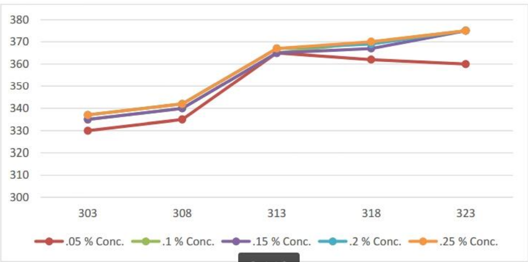

Graph3..$TiO_2$ Nanoparticle diffused in working fluid over a temperature range of 30- 50 C at different particle concentration.




Graph4.. ZnO Nanoparticle diffused in working fluid over a temperature range of 30- 50 C at different particle concentration.

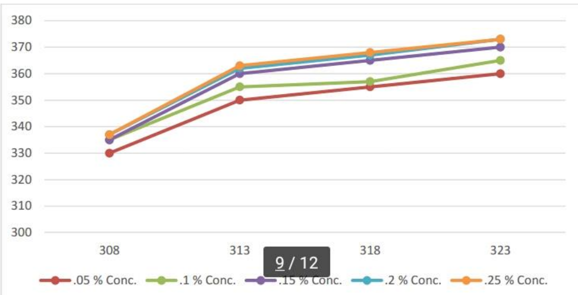
## VII. RESULTS AND DISCUSSION

After extracting the necessary nanofluid properties from our research we were able to calculate the heat transfer possible in a heat pipe within the capillary limit. The heat flow though a heat pipe with suspended nanoparticles in the working fluid is presented below:

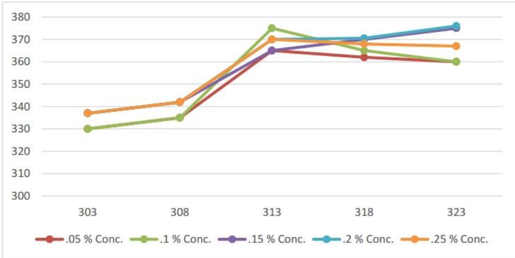



**Graph 5** Heat dissipation in a heat pipe with $Al_2 O_3$ Nanoparticle diffused in working fluid over a

Graph 5. Heat dissipation in a heat pipe with $Al_2O_3$ Nanoparticle diffused in working fluid over a temperature range of 303 – 323 K.




Graph 6. Heat dissipation in a heat pipe with $SiO_2$ Nanoparticle diffused in working fluid over a temperature range of 308 – 323 K.




**Graph 7** Heat dissipation in a heat pipe with $Ti\,O_2$ Nanoparticle diffused in working fluid over a temperature range of 303 – 323 K.

Graph 7. Heat dissipation in a heat pipe with TiO2 Nanoparticle diffused in working fluid over a temperature range of 308 – 323 K.

## VIII. CONCLUSIONS

In our research we conclude that introduction of nanoparticles in the working fluid of heat pipe has a positive effect on its thermal efficiency. This is in support of our literature survey [31-36] that we did before conducting this research. Through our research and calculation we were able to derive the following facts:

- With the introduction of nanoparticles in the heat pipe the thermal efficiency of the heat pipe increased by a factor of 1.05 – 1.2.
- The introduction of nanoparticles in the heat pipe also resulted in a lower thermal resistance of the fluid, due to which more heat transfer was possible.
- With the increase of concentration of nanoparticles in the heat pipe the thermal efficiency increased.
- $Al_2O_3$ Nanoparticle showed to have the best effect on thermal efficiency in a heat pipe. It showed a increase in heat flow by a factor of 1.16 at 323 K at .25 % particle concentration .

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