# Study of Effect of Nanofluid on Performance of Heat Pipe

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## ABSTRACT

***Over last ten to twenty years, a lot of work is carried out on applications which used heat pipes for heat transfer. These heat pipes were carrying conventional fluids as working medium inside them. But in recent years, experiments have been carried out to use suspended nano sized particles into conventional base fluids to enhance the thermal conductivity of heat pipes. It has been found that the nanofluids are responsible for effective heat transfer. In this paper the basic work of heat pipe nanofluids and the effects of nanofluid concentration on performance of 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,nanoparticles,nanofluid, thermal resistance.***

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## 1. Introduction

The micro and miniature components such as microchip or IC's of the cabinets of personal computers or other corresponding constituents that are necessary building blocks of an operating systems are getting smaller and smaller day by day. On the other hand the effective heat transfer requirements for the same are increasing, and getting heat removed from these components is the bottleneck problem so as to avoid the overheating of these components there is an increased demand of efficient ways of heat transfer. Thus the nanofluids are found to be very effective for transfer of heat while used in heat pipes. From industrial point of view, there is an increasing need in energy savings, increased life span of equipment, increase in thermal rating, time reduction in processes, the enhancement in cooling and/or heating is very important aspect.

While comparing with copper the heat transfer coefficient of a heat pipe is of much higher magnitude. Heat pipes are very effective media of heat transfer as they carry heat over longer distances without any loss of heat through them.But when it is the case of miniature component's heat dissipation, micro heat pipes are most possibly preferred. While in case of the working fluid to be used for the heat pipe, preferably nanofluids, the particle size as well as morphology, volume concentration of those nanoparticles in the base fluid plays an important role in increasing the effective heat transfer rate from the heat pipe.

### 1.1 Heat Pipe Mechanism

The whole heat pipe mechanism works on the principle of latent heat of vaporization. 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.

### 1.2Nanofluids

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

- More heat transfer between consecutive particles because of the high surface area.
- Particles have brownian motion, thus the dispersion stability is high.
- Pumping power is reduced as compared with the pure liquids to achieve augmentation of heat
- Particle clogging is much reduced as that of the micro particles which tend to form slurries.
- Can be used for a numerous applications by varying the particle concentrations, filling ratios, etc.

1.2.1 Applications of nanofluids:

- 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.

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.

## 2. Literature Review:

Heris et al. [8] 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 coefficient due to the presence of nanoparticles was much higher than the prediction of single-phase heat transfer correlation using nanofluid effective properties. However, the Al2O3/water nanofluid showed higher enhancement when compared to CuO/water.

Xuan and Li [9,10] 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.

Xue [11] proved the interface effect between the material particles and base fluid in nanofluid and the theoretical resolutions on effective thermal conductivity of nanotube, nanofluid and Al2O3 with pure water which was in good agreement with experimental results.

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. [13] 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 [1] 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. [12] 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.

However, due to the small particle size, the nanoparticle effect on the viscosity of the dispersions might be remarkable, especially for nanotube or other high or low aspect ratio nanoparticle dispersions. Some of the properties of nanoparticles & base fluids are listed in Table 3.1 useful for assessing the nanofluid properties.

| **Property** | **Water** | **Ethylene Glycol** | **Cu** | **$Al_2O_3$** | **BN** | **$TiO_2$** |
|---|---|---|---|---|---|---|
| **C(J/kgK)** | 4179 | 2415 | 385 | 765 | 535.6 | 686.2 |
| **ρ(kg/$m^3$)** | 997.1 | 1111 | 8933 | 3970 | 6500 | 4250 |
| **k(W/mK)** | 0.605 | 0.252 | 400 | 40 | 20 | 8.95338 |
| **α ($m^2$/s)** | 1.47 | 93 | 1163 | 1317 | 57.45 | 30.7 |

**Table-1:Nanofluids-Thermo physical Properties.**

## 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. 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.

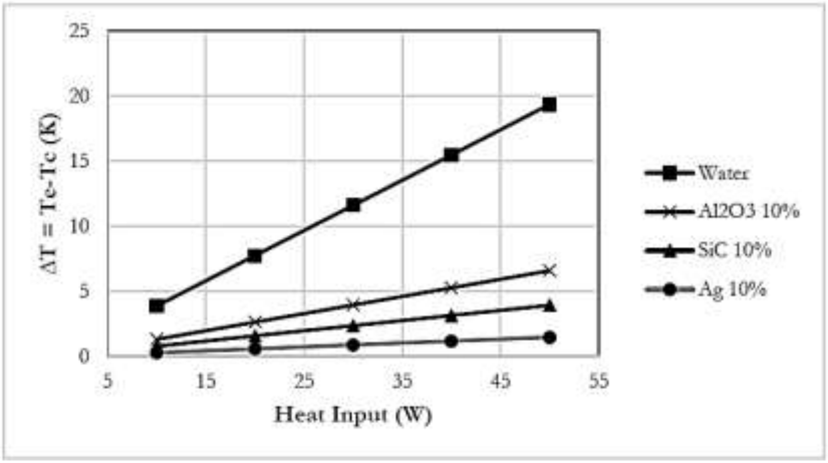

**Fig-1: temperature difference vs. heat input**

## 4. Different Concentrations But Same Nanofluid

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

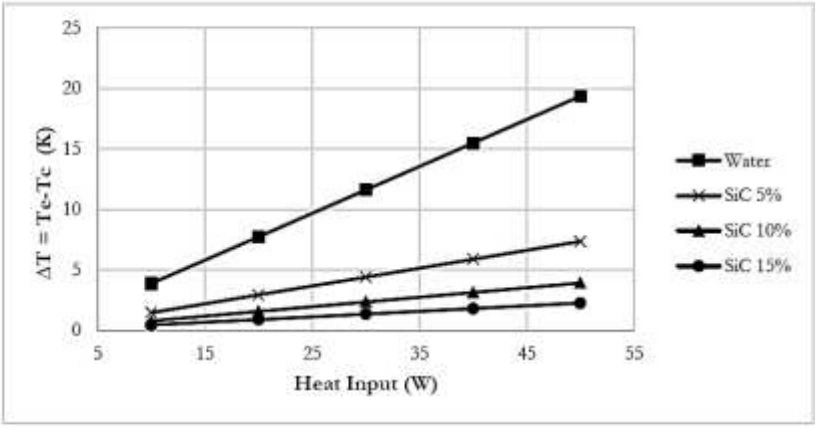

**Fig-2:temperature difference vs. heat input as per varying concentration**

When the heat input of 50W is applied i.e the maximum in this case, it can be seen that there is a large variation of results for different concentrations of *SiC*nanofluids when compared with pure water. When concentrations of 5%, 10%, and 15% of *SiC*nanofluids are applied then there is decrease in temperature difference in evaporator and condenser temperature with 62%, 80% and 88% respectively. Thus it can be stated that there is increase in overall thermal conductivity when the concentration of nanoparticles is increased in base fluid, thereby decreasing thermal resistance of heat pipe wall and difference in temperature between evaporator and condenser section.

## 5. Analytical Vs. Experimental Results: Effect of Water-Based Aluminium Oxide Nanofluid 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.

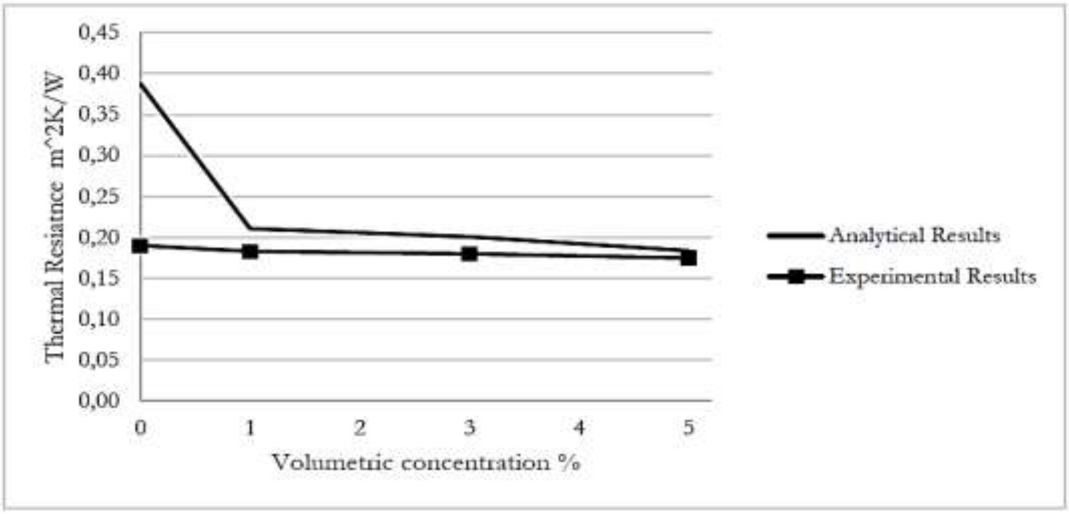

**Fig-3: thermal resistance vs. various concentrations for $Al_2O_3$ nanofluid.**

## 6. Analysis of Thermal Resistance With Increasing Concentration

When the volume concentration of the particles is increased there is a continuous decrease in the thermal resistance of heat pipe. Here in this research we will totally focus on analytical results from fig 3:

It is seen that there is reduction in thermal resistance with 46%, 48%, and 53%, when volume concentration of 1%, 3%, and 5% aluminium oxide nanofluid ($Al2O3$) is applied. The responsible parameters for this increase in thermal conductivity are the higher thermal conductivity of nanofluids and the wick in which there is a saturated liquid. As well as the decrease in temperature difference between evaporator and condenser section.

On the other hand, when experimental results are considered for the same concentrations of nanofluids, there is decrease in thermal resistance by 4%, 5%, 8% respectively, as there are uncertainties in practical experiments.

## 7. 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%.

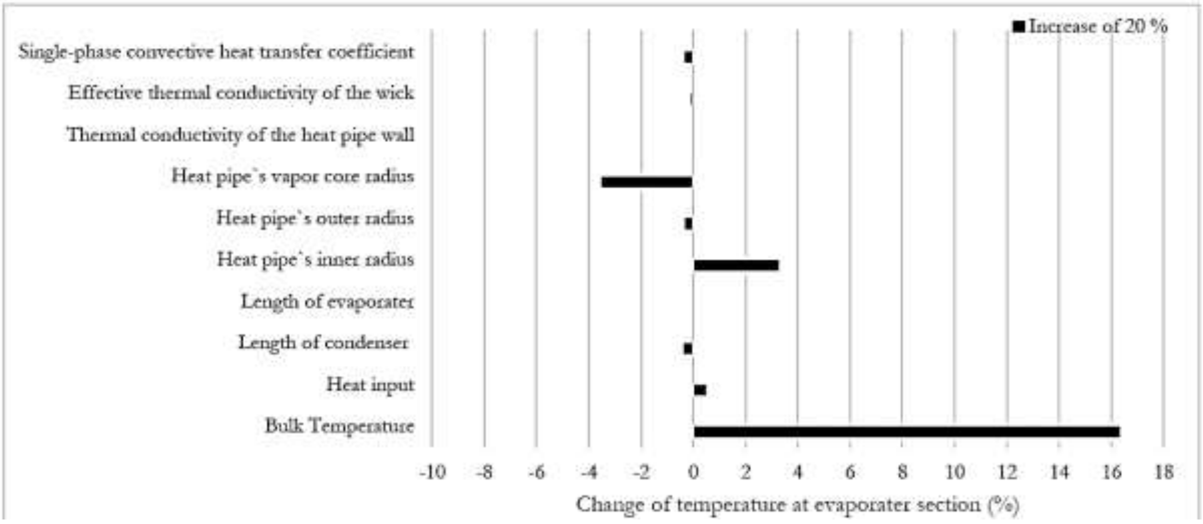

**Fig-4: Parameters affecting temperature at evaporator section**

## 8. Temperature at Condenser Section

Fig. 5 *s*hows thatwhen 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%.

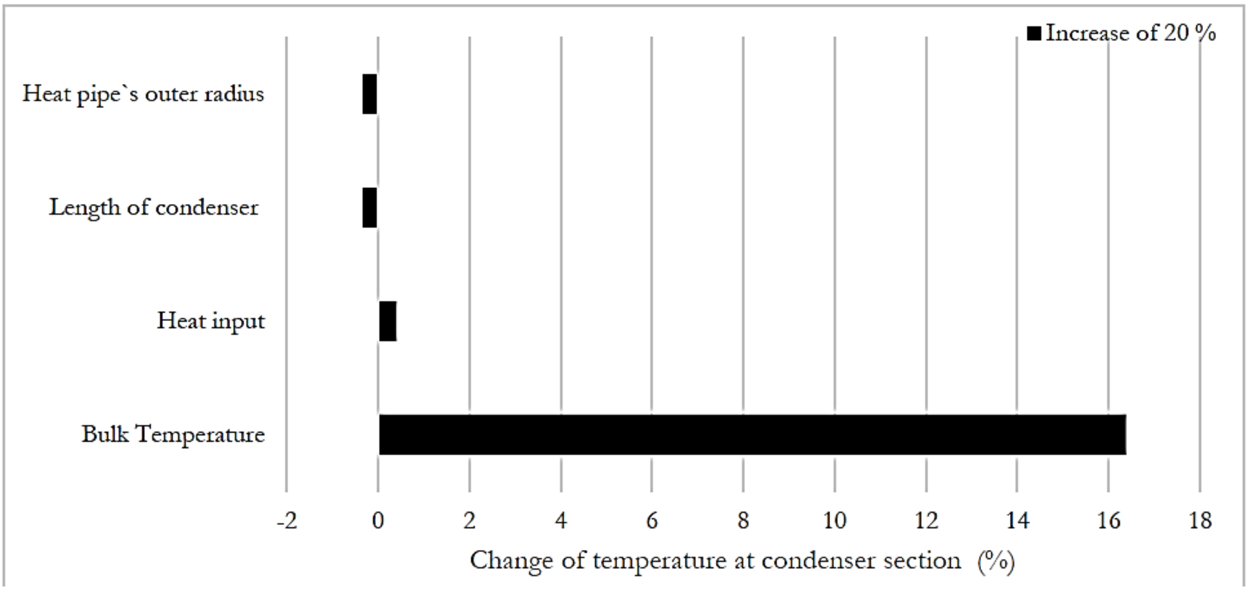

**Fig-5: Parameters affecting temperature at condenser section.**

## 9. CONCLUSION

This paper describes that when nanofluids are used as working fluids, there is significant variation and changes in overall heat pipe characteristics.On refereeing to the available literature it can be seen that for various types of heat pipes there are numerous applications of nanofluids. For different types of heat pipes including mesh wick heat pipe, two phase closed thermosyphon, micro grooved heat pipe, oscillating heat pipe, etc. when nanofluids are added to these heat pipes, there is a remarkable change in overall heat removal capacity and reduction in overall thermal resistance.But still there are many challenges and troubles are associated with the use of nanofluids at practical application level. Studies have shown a positive impact when heat pipes are used with nanofluids working fluid.Thus it can be stated that on adding nanofluids to heat pipe there is an increase in their thermal conductivity.The present research of nanofluids in heat pipes is still at its initial stage and needs further development.

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