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# A REVIEW ON HEAT PIPE BY USING DIFFERENT NANO FLUIDS

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## ABSTRACT

*The use of nanofluids in a heat pipe is a very efficient way of enhancing the thermal performance through a heat pipe. This paper is a review on the use of various nanofluids consisting of many novel properties, which helps in increasing the heat transfer through a system. Both the principles of thermal conductivity and phase transition are used in a heat transfer device called the heat pipe.SiC,silver,cu-water,alumina are some of the nanofluids used as a working fluid in the heat pipe. Size of the particle plays an important role in the heat pipe, the smaller the size of the particle the more pronounced effect it has on the temperature gradient along the heat pipe. The nano particle concentration increases with a decrease in the thermal resistance of the heat pipe. By the evaporation and condensation of the working fluid or coolant the thermal energy is transferred from one point to another, through a heat pipe by a process called evaporative cooling.The heat pipe basically consist of the container,the working fluid and the wick or capillary structures. Isolation of the working fluid from the outside environment is done with the help of container or casing .The capillary or the wick is mainly made up of steel,aluminium,nickel,copper having different pore size.screen mesh,sintered powder and grooved tube are the most common types of wicks which are used. Heat pipes are also known as superconductors because there is hardly any loss between the transfers of heat from one point to another. The use of nanofluids enriches the thermal performance in a heat pipe more than water.*

***Keywords: Capillary, Condensation, Nanofluids, Phase Transfer, Thermal Conductivity***

## I. INTRODUCTION

Most of the solids where not compatible with the heat transfer properties of the traditional fluids, so traditional fluids such as water, engine oil, ethylene glycol were engineered by ultra-fine metallic or non metallic nanometer dimension particles .From this a new class of fluids was developed called as nanofluids. This was achieved by the Argonne national laboratory situated near Lemont,IL outside Chicago. Fluids consisting of nanosized particles are called nanofluids (nanoparticles). Metals, oxides, carbides or carbon nanotubes are the materials used in the implementation of nanoparticles in a nanofluid.The device which transfers heat between two solid interfaces based on the principles of thermal conductivity and phase transition, it is called as a heat pipe. Heat pipe is a two dimensional device which can be used for the transformation of heat from one point to

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another with very less temperature variations and in the improvement of thermal performance of the system with the use of various nanofluids. The nanofluids in a heat pipe are basically used for the intensification of heat transfer through a heat pipe. When a thermally conductive solid surface comes in contact with a liquid at the hot interface of a heat pipe it turns into vapour by the absorption of heat from that surface. As soon as the vapour reaches the cold interface of the heat pipe it again condenses into a liquid by realising the latent heat. Due to either capillary action, centrifugal force or gravity the liquid again returns to the hot interface and the cycle continues. Heat pipes are highly effective thermal conductors due to very high heat transfer coefficient for boiling and condensation. Due to there passive cooling capability heat pipes are used in different heat transfer applications. Heat pipe are used in many applications such as spacecraft, computer systems, solar thermal, permafrost cooling, cooking, ventilation heat recovery, nuclear power conversion, wankel rotary combustion engines. There are different types of heat pipes such as the pulsating heat pipe, the sintered heat pipe, cylindrical heat pipe, rotating heat pipe, screen mesh heat pipes and flat heat pipes which can be used for the heat flux transformation and isothermalization of surfaces. The enhancement of thermal energy through a heat pipe changes with various nanofluids .Compared to base fluids such as oil and water, nanofluids are found to possess thermophysical properties such as thermal conductivity, thermal diffusivity, viscosity and thermal heat transfer coefficient. Proper or accurate concentration of nanoparticles within the nanofluid helps in producing the maximum heat transfer through the heat pipe. Effective increase in the thermal conductivity of a heat pipe is observed by employing phase change machanisms, evaporation /condensation of working fluid. The working fluid property, heat pipe wick structures, heat pipe material, the dimensions of the heat pipe plays an important role in enhancing the performance of the heat pipe. There should be a proper concentration of nanoparticles in the selected nanofluid, so that the thermal conductivity of the system increases and the thermal resistance decreases. In comparision to the ordinary fluid system the nanofluid system has more stability.

**1.1 Simple Demonstration of a Heat Pipe**

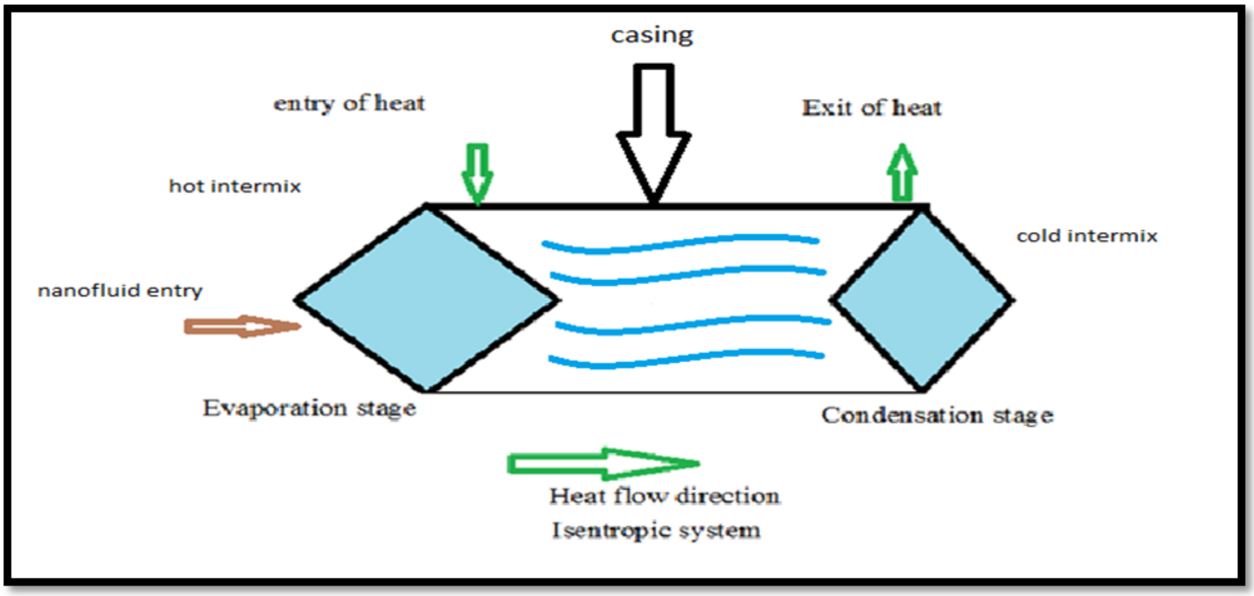


**Fig: Demonstration of a Heat Pipe**

### 1.2 Following are Some of the Nanofluids to be Used in the Heat Pipe.

1) Water

2) Silicon carbide (SiC)

3) Silver

4) Alumina

**Table:1.1 DIFFERENT HEAT MEDIUMS**

| Medium | Boiling point at atm $^0$C | Melting point at atm $^0$C | Useful range |
|---|---|---|---|
| Acetone | 57 | 57 | 0-120 |
| Methanol | 64 | -98 | 10-130 |
| Nitrogen | -196 | -210 | -203-160 |
| Helium | -261 | -271 | -271-269 |
| Silver | 2212 | 960 | 1800-2300 |
| Lithium | 1340 | 179 | 1000-1800 |
| Mercury | 361 | -39 | 250-650 |
| Toluene | 110 | -95 | 50-200 |
| Ethanol | 78 | -112 | 0-130 |
| Water | 100 | 0 | 30-200 |
| FutecPP2 | 76 | -50 | 10-160 |
| Ammonia | -33 | -78 | -60-100 |
| Sodium | 892 | 98 | 98-892 |

### 1.3 Water as Working Fluid

Water is a traditional fluid and has high latent heat. Due to which it has better heat transporting capacity as a working fluid. In comparison to R134a, it requires 14 times less mass transfer essential or the transfer of the same heat between the ends of the pipe. One of the most important features of water to be used as a working fluid, that it does not harm the environment. Due to the use of water fewer footprints are produced in manufacturing of heat pipes. It helps in reducing the temperature gradient due to which we achieve high efficiency.

### 1.4 Properties are as follows

- It has high thermal conductivity.
- It has high latent heat.
- The global warming potential and the ozone depletion potential is minimal in case of water.

### 1.5 Silicon Carbide as a Working Fluid.

By using silicon carbide as a nanofluid in a heat pipe the heat transfer coefficient increases as compared to that of water. In comparison to the usage of distilled water, the thermal resistance reduces significantly with silicon carbide. It also helps in increasing heat removal capacity from the heat pipe. Formation of porous coating layer on the wick surface at the evaporator section helps in producing good capillary structures and icreasing the wettability and heat transfer area of the system. In case of silicon carbide the nanoparticles concentration plays an important in intensification of the thermal performance of the system.

### 1.6 Silver as a Working Fluid

Under various heat loads, with silver nano particles immersed as a working fluid, the heat pipe wall temperature is comparatively less as that of pure water. In case of silver nanofluids the thermal resistance of grooved heat pipes depends on the size of the nano particle. Nanofluid potential as a substitute for conventional pure water results in higher thermal performance of the nanofluid. This makes the nanofluid as more efficient cooling fluid with respect to devices with high energy density. Silver nanofluid heat pipe thermal performance is more then that of a conventional heat pipe.

### 1.7 Alumina as a Working Fluid

In case of alumina as a working fluid in a heat pipe shows that high concentration of nanoparticle will not be able to improve the thermal performance as the high concentration of nanoparticle leads to high water adsorption which results in the formation of a coating layer through the gathering of nanoparticles on the surface of the evaporator section.

The fill ratio, angle of inclination, and parameters such as heat input plays an important role in increasing the thermal performance in an heat pipe.

### 1.8 Properties of Different Nano Fluids

#### 1.8.1 Water

- Density -999.97kg/m$^3$
- Boiling point-100$^0$C
- Melting point -0$^0$C
- Triple point temperature – 0.01$^0$C
- Molar mass-18.01528 g/mol

#### 1.8.2 Silicon Carbide

- Density -3.21 g/cm$^3$
- Molar mass-40.10 g/mol
- Thermal conductivity-120W/m.K
- Specific heat-750 j/kg.K
- Melting point-3000K

#### 1.8.3 Silver

- Heat of fusion-11.28 Kj/mol
- Heat of vapourisation-254 Kj/mol

- Density -10.49 gm/$cm^3$
- Thermal conductivity(range)- 4k to 300k
- Thermal expansion-18.9µm/(m-k)at 298K
- Thermal conductivity-429 W/(m-k)at 300K
- Melting point -1234.93K

**1.8.4 Alumina**

- Thermal conductivity- min:12 max :38.5 W/m.K
- Density: min:3-max:3.98 mg/$m^3$
- Melting point-2345K
- Boiling point-3250K
- Molar mass-101.96 g/mol

## II. REVIEW OF SOME RESEARCHER

**2.1) M.GHANBARPOUR et al [1]** Studied the influence of SiC as a working nanofluid in a heat pipe. It states that heat pipe is basically used to transfer heat from one point to another with minimum temperature drop. Due to their passive cooling capability heat pipe are widely used in many heat transfer applications. Heat pipe is a common device in many thermal applications such as heat exchangers, aerospace, solar system and electronic cooling. The Heat transfer performance of the system may be enhanced by having efficient thermo physical properties of the heat pipe. Water and water based SiC nanofluids with nano particle mass concentration of 0.35%, 0.7% and 1% as working fluids are fabricated and tested with four cylindrical copper heat pipes containing two layers of screen mesh. Investigation is done on the SiC nanofluid properties and characteristics about its improvement in thermal performance by using screen mesh heat pipes at different concentration and inclination angles. SiC nanofluid containing 0.35wt%, 0.7wt% and 1 wt% of SiC nanoparticles shows a reduction in the thermal resistance of the heat pipe by 11%, 21% and 30%.An inclination angle of 60 in all concentrations shows the lowest thermal resistance and it also reveals that the inclination angle plays a very crutial part in enhancing the thermal performance of the heat pipe. When SiC nanofluid has nanoparticle mass concentration of 1wt%, the maximum heat removal capacity of the heat pipe increases by 29%. A series of nanofluid with 1wt%,0.7wt5 and 0.35wt% nanoparticle loading were fabricated by using SiC nanoparticles with alpha type crystal structure purchased from the superior graphite(USA).For this purpose α-SiC nanoparticles were immersed in distilled water as the base liquid to gain 1wt% of α- SiC nanofluid. This known as the two-step method preparation. The pH of the nanofluid was adjusted and mixed by ultrasonic mixing. In the pH region from 2 to 10 the zeta potential analysis was done and the stability and the optimum pH of nanofluid were identified. The SiC nanofluid properties are measured and calculated at different weight concentration.

**2.1.1 Material specification**

- Power supplier
- Heat pipe
- Hot plate
- Cold plate

- Variable angle holder
- Constant temperature bath.
- Thermocouples
- Mass flow meter

**2.1.2 Experimentation Setup**

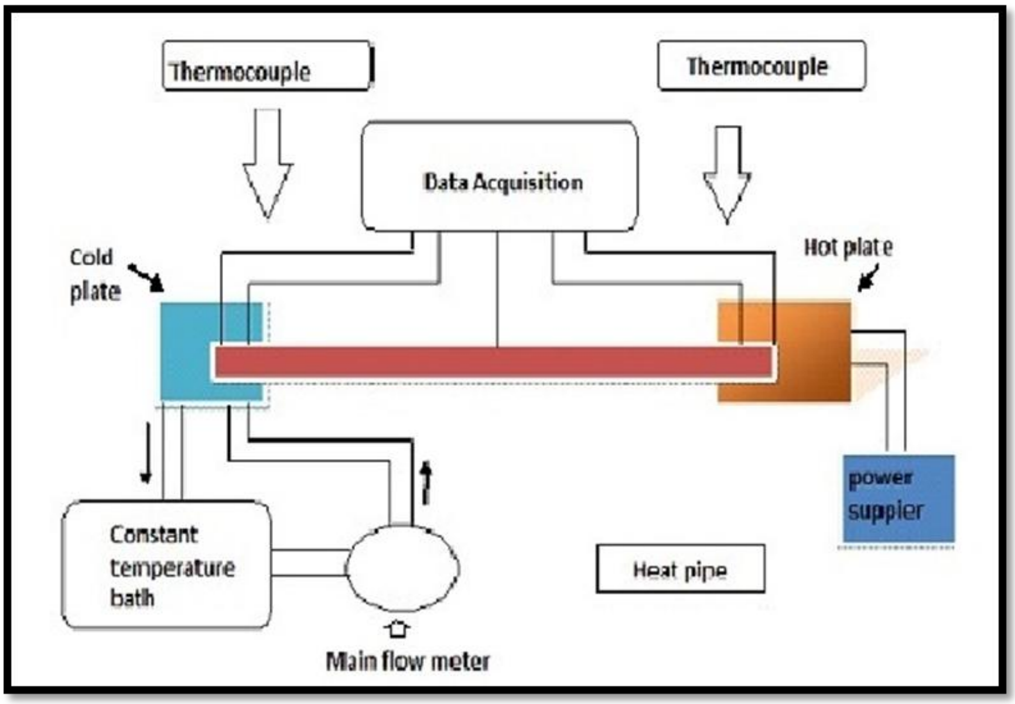


**Fig: Experimentation Setup**

A heat pipe made of copper tube having length 25cm, diameter of 6.35mm and the wall thickness of 0.71mm is used.

**2.1.3 Dimension of different sections**

- Evaporator section-50mm
- Adiabatic section-150mm
- Condenser section-50mm

Copper heating blocks are attached to the evaporator of the heat pipe and heat fluxes are provided to it by an electrical catridge.Cooling at condenser of the heat pipe is provided by water at a constant flow rate and temperature of 288k and 51kg/h repectively.Five K type thermocouples are used to measure the temperature of the heat pipe surface, out of which two thermocouples are implemented at the evaporator section, one at the adiabatic section and the rest at the condenser section.

**2.1.4 Result and Discussion**

The temperature difference between evaporator and condenser wall surface was reduced by using Sic as a working nanofluid.The overall thermal resistance of the heat pipe decreases by 35% compared to horizontal heat pipe and water by using 1%wt of SiC nanofluid at an inclination angle of 60degree.

**2.2 Shung-wen-kang et al[2]** The paper enlightens the use of silver as a nanofluid in the heat pipe.Electronic cooling application such as note-book computers uses the heat pipe on a large scale.Atleast one heat pipe is present in every note-book computer in todays world.These parts are low in cost and are highly reliable to carry less then 25W of power.Cooling applications requiring heat pipe which are high in power are limited only to custom applications such as minimum thermal resistance and restricted areas.Due to limited number of manufacturers the cost of larger heat pipes is more.More heat transfer is achieved with the progress in nanotechnology and thermal engineering.It shows as that nanofluids have efficient thermal conductivity and enhance heat transfer properties then traditional nanofluids. The research shows that as the volume fraction of ultra- fine particles increase the thermal conductivity of nanofluids. Pure ethylene glycol or ethylene glycol having the same volume fraction of dispersed oxide nano-particles has more thermal conductivity then a nanofluid consisting of copper nano-particles dispersed in ethylene glycol. The demonstration is done by using silver nano-particles immersed in water and by which the thermal performance of the heat pipe is increased.

**2.2.1 Experimentation**

Silver nano-particles of 35nm were used in this experiment. Pure water is the base working fluid. Using the catalytic chemical vapour deposition the Ag nano-particles were prepared. In this Ag nano-fluid suspension no surfactant was used. In this experiment nanofluid of 1mg/l, 10mg/l, 50mg/l and 100mg/l were used. By forced convection method heat was removed from the condenser section.The operating temperature was varied over a range of 40-45 degree Celsius with a temperature tolerance of $\pm 1^{\circ}C$ .A dc power supplier by which the electrical resistance was powered was utilized by the power supply and the measurement system. The contact thermal resistance between the heater and the heat pipe surface was reduced by applying thermal grease on one side of the evaporator section.

**2.2.2 Material Specifications**

- Diameter of pipe-6mm
- Length of the pipe-200mm
- (CT605D) power supply.

**2.2.3 Result**

The factors such as nano-particle concentration and nano-particle size play an important role on the thermal performance of the heat pipe.

**2.3Yi-Hsuan-Hung et al [3]** In this experiment alumina is used as a nanofluid.By using a cationic chitosan dispersant the alumina nanofluid is produced by direct synthesis method. By using three different concentration of 0.5, 1.0 and 3.0wt% of alumina as a working fluid the experiment was carried out in the heat pipe.

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| Table: Detailed data of alumina nanofluid. | |
|---|---|
| Parameters | Specification |
| Specific surface area | ≥100 |
| Purity | ≥99.8 |
| Thermal conductivity | 27-38W/mK |
| Size of the particle | 10-30(nm) |
| Density | 3880kg/m$^3$ |
| Color and appearance | White powder |

Lengths of the pipes-0.3m,0.45m and 0.6m, Diameter of the pipes-9.52mm, Thickness-0.89mmThe size of the primary size particle used in the heat pipe is 20nm.The programmable power supply,datalogger heat pipe,insulation material,computer,flow meter,variable angle holder,isothermal unit,heater ,flow meter,valve are the different devices used in the experimental setup of the heat pipe.different angles of the heat pipe were used to enhance the efficiency of the heat pipe. Tilt angle, CVR, length of the heat pipe, heating power, weight fraction of the nano-particles are the different parameters in intensifying the thermal performance of the heat pipe.

**2.3.1 Result**

The thermal performance changes under different parameters.0.5wt% and 1wt% shows the best thermal performance in this demonstration. The thermal conductivity increases with higher concentration of nanofluid.

**2.4 Maryam Shafahi et al [4]** In this research nanofluids are used to enhance the thermal performance in a cylindrical heat pipe in a two dimensional system. The thermo physical properties are used to improve the heat transfer capability of the heat pipe .Density and viscosity are the two important parameters by which the nano-particle concentration is changed and the thermal properties of the fluids are changed. Due to heat applied at the evaporator section, the pressure increases in the working fluid. The maximum heat transfer, thermal resistance and the temperature profile are the various parameters which were investigated in the demonstration of nanofluid by using a cylindrical heat pipe. Optimum concentration helps in the attaining the maximum heat transfer. Condensation takes place in the condenser and the latent heat is released in the condenser and the condensate flows back to the evaporator. This action takes place due to the capillary action and the thermal resistance is reduced and the thermal efficiency is increased in the heat pipe.

**2.4.1 Result and Discussion**

Increasing the nanofluid concentration decreases the maximum liquid velocity within the working fluid. The maximum heat load capacity also depends on the nanoparticle concentration.

**2.5 Hamdy Hassan et al[5]**This researcher explain that the heat pipe depends on various mechanisms on which the transfer of heat from on point to another or the transfer of condensate to the evaporator section. Osmotic membrane, employing centrifugal force, a capillary structure and the gravity force are the different parameters on which the transfer of condensate to the evaporator end depends. Gray invented the rotating heat pipe and the and uses the concept of centrifugal acceleration to transfer the liquid from condenser to evaporator. The heat transfer rates increases with decrease fluid loading and increases with the increase in the rotational speed within the heat pipe. Three solid particles such as Cu,CuO and $Al_2O_3$ are the nanoparticles used in carrying out this experiment in the heat pipe.

**2.5.1 Assumption Made in Considering the Nanofluid.**

Nanofluid is incompressible, laminar and Newtonian.

The heat transfer decreases by increasing the mass of working fluid for a given temperature difference between the wall and the saturated vapour.

**2.5.2 Result**

Suspension property of the nano-particles is good in water. Using solid nano- with water increases the thermal conductivity and ultimately increases the fluid density and viscosity within the heat pipe.

## III. CONCLUSION

The heat pipe consists of three sections such as condenser, adiabatic section and evaporator. The thermal conductivity increases within the heat pipe by varying the nano-particle concentration and by using different nanofluids instead of traditional fluids such as water or oil.

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