Effect of Inclination Angle on Heat Pipe Thermal Performance using Nano Fluids: A Review

Naveen Kumar Soni1 Prof. R. C. Gupta2
1Research Scholar 2Associate Professor
1,2Department of Mechanical Engineering
Jabalpur Engineering College, Jabalpur (MP)

Abstract—The inclination of heat pipe plays an important role on its thermal performances. The thermal performance of heat pipe is directly dependent on its wick structure, as the wick structure of heat pipe is directly related to its capillary limit. The participation of nano particles in nano fluid within heat pipe is also plays important role to enhance the thermal performances of heat pipe. The review paper is mainly discusses the different position of heat pipe with different wick structure using nano particles in base fluid and find optimum orientation to enhance the thermal performances of heat pipe using nano fluid.

Key words: Heat Pipe, Thermal Performances, Inclination Angle, Nanofluid, Fluid Concentration

I. INTRODUCTION

Heat pipe is a device of heat transfer large quantities of heat with minimum temperature gradient without any additional power between the two temperatures limits [18]. The heat pipe was first invented by Richard S. Gauer Motor Engineer. Heat pipe were developed especially for space applications during the early by the NASA. One main problem in space applications was to transport the temperature from the inside to the outside, because the heat conduction in a vacuum is very limited; Hence there was a necessity to develop a fast and effective way to transport heat. The idea behind is to create a flow field which transport heat energy from one spot to another by means of convection, because convective heat transfer is much faster than heat transfer due to conduction.

As the improved construction of the general heat pipe, flat heat pipe become a hotspot technology of heat pipe research and development [10] and widely applied in many fields, such as space craft thermal control, high heat flux electronic equipment cooling, medical and health under taking, and household appliances. Heat transfer fluids such as water, mineral oil and ethylene glycol play a vital role in many industrial processes, heating or cooling processes and microelectronics. The heat transfer properties of these common fluids are poor when compared most of the solids and it becomes a primary obstacle to the high compactness and effectiveness of heat exchangers.

The essential initiative is to seek the solid particles having thermal conductivities several hundred times higher than those of conventional fluids. Many types of particles such as metallic, non-metallic and polymeric, can be added into fluids to form slurries. However, the usual slurries with suspended particles in the order of millimeters or even micrometers may cause severe problems.

In heat pipe the abrasive action of the particles causes the clogging of flow channels, erosion of pipelines and their momentum transfer into an increase in pressure drop in practical applications. Furthermore, they often suffer from instability and rheological problems. In particular, the particles tend to settle rapidly hence even through the slurries give better thermal properties they are unable to act as coolants in practical applications. There is an urgent need for new and innovative coolants with improved performance. The novel concept of nano fluid heat transfer fluids containing suspensions of nanoparticles has been proposed as a means of meeting these challenges [1].

For the time being nanofluids plays an important role in heat pipes to increase the heat transfer compared to conventional fluids. Thermal conductivity is an important parameter in enhancing the heat transfer performance of a heat transfer fluid. Researchers have also tried to increase the thermal conductivity of base fluids by suspending nanometer sized solid particles in fluids since the thermal conductivity of solid is typically higher than that of liquids, as seen table (a). The concept of “nanofluid” has firstly proposed by Choi and Eastman [1].

The term nano fluids is used to indicate a newly introduced special class of heat transfer fluids that contain nano particles less than 100nm of metallic or non-metallic substances uniformly and stably suspended in a conventional heat transfer liquid. Nano fluids can be considered to be the next generation heat transfer fluids because they offer exciting new possibilities to enhance heat transfer performance compared to pure liquids. The thermo physical and transport properties of the conventional fluids are improved by adding the nanoparticles in base fluids. The effective thermal conductivity of nano fluids increases with increase in temperature [3]. In convective heat transfer in nano fluids, the heat transfer coefficient depends not only on the thermal conductivity but also on other properties such as the specific heat, density and dynamic viscosity of a nano fluid. At low volume fraction, the density and specific heat of nano fluids looks to be very similar to those characterizing the base fluid.

The wick structure of heat pipe also plays the important role to enhance the thermal performance of heat pipe. That is why every researcher concentrates on the design of wick structure. The most commonly used wick structures for heat pipes are simple and homogeneous, such
Effect of Inclination Angle on Heat Pipe Thermal Performance using Nano Fluids: A Review

There are many different wick structures that are used in heat pipes. These structures can be made of different materials and configurations to optimize performance. Some common examples include:

- Grooved: This type of wick has grooves or channels that are etched into the surface. The grooves increase the surface area and provide channels for the working fluid to flow through.
- Screen: A screen wick is made of a mesh or perforated metal that allows the working fluid to pass through while still holding the capillary forces. This type of wick is often used in environments with high temperature gradients.
- Sintered metal powders: Sintered metal powders are used to create porous structures that can hold the working fluid. These wicks can be made from different metals and have a high thermal conductivity.
- Fiber: Fiber wicks are made from materials like cotton or kapok, which are known for their high thermal conductivity and capability to handle large temperature differences.

The choice of wick structure depends on the specific application and the requirements of the heat pipe. A heat pipe performance ultimately depends on the proper wick structure for heat pipes based on their real application. If a heat pipe works in conditions with unfavorable gravitational force and a few bends, the grooved wick heat pipe is a good choice because of its superior thermal performance. If a heat pipe has complex geometry and works at a small or negative tilting angle, sintered powder metal is the optimum wick structure. For cooling electronic components in telecommunications devices and computers products, the sintered powder metal wick is the best choice because such application require a compact heat sink size with many turns and bends. The high capillary pumping pressure achieved by using a sintered powder metal wick due to its small pore size, allows a heat pipe to operate in any orientation. Other wick structures do not work as well in non-vertical orientations because they cannot lift the returning working fluid along the length of the heat pipe against gravity.

A heat pipe performance ultimately depends on the application (i.e. how and where the heat pipe is used). The heat pipe flattening and or bending, ambient temperature as well as the orientation of the heat pipe will influence its performance [2]. The thermal efficiency of heat pipe increases with increasing value of orientation up to range for different fluid and wick use in the heat pipe. It is due to the fact that, the temperature of the working medium increases and hence more amount of heat can be removed in the condenser section. It is not only due to the capillary action of wick but the gravitational force also has a considerable cause on the flow of working fluid between the evaporator section and the condenser section. Conversely, when the angle of inclination of heat pipe exceeds from range, the heat pipe thermal efficiency starts to decrease from its value. It is due to higher rate formation of liquid film inside the condenser resulting in the increased value of the thermal resistance [16].

### III. LITERATURE REVIEW

The following literature reviews describe important research regarding the different orientations, different nanofluids and different wick structures used in heat pipes:

Stephen U, S. Choi and Jeffrey A. Eastman (1995)- In this paper it propose that an innovative new class of heat transfer fluids can be engineered by suspending metallic nanoparticles in conventional heat transfer fluids . The resulting “nanofluids” are excepted to exhibit high thermal conductivities compared to those of currently used heat transfer fluids, and they represent the best hope for enhancement of heat transfer.

The results of a theoretical study of the thermal conductivity of nanofluid with copper nanophase material are presented the potential benefits of the fluids are estimated and it is shown that one of the benefits of nanofluids will be dramatic reduction in heat exchanger pumping power.

For example to improve the heat transfer by a factor of 2, the pumping power with conventional fluids should be increased by a factor of 10. However if a nanoparticle based fluid with a thermal conductivity of 3 times that of a conventional fluid were used in the same heat transfer equipment, the nanoparticle based fluid would double the rate of heat transfer without an increase in pumping power. The invention of nanofluids presents new challenges and opportunities for thermal scientist and engineers [1].

Salem A Said, Bilal A. Akash (1999) - Two types of heat pipes were studied experimentally using water as a working fluid. One with a wick and another with no wick. The wick was made of cotton, which is normally used in oil lamps. The heat pipe was positioned at different angles of 300, 600 and 900 with the horizontal. Results show that the
performance of the heat pipe that contained a wick was
more significant in terms of overall heat transfer coefficient
than that with no wick, for the temperature range studied. It
resulted in about 55%, 25% and 70% increase for 300, 600
and 900 tilt angles respectively [15].
Yimin Xuan, Qiang Li (1999) - This paper presents
a procedure for preparing a nanofluid which is a suspension
consisting of nanophase powders and a base liquid. By
means of the procedure, some sample nanofluids are
prepared. The theoretical study of the thermal conductivity
of nanofluids is introduced. The hot wire apparatus is used
to nanofluids with suspended copper nanophase powders.
He found that by mixing of nanophase powders
and base fluid. The nanofluids show great potential in
enhancing the heat transfer process. One reason is that the
suspended ultrafine particles remarkably increase the
thermal conductivity of the nanofluid. The volume fraction,
shape, dimensions and properties of the nanoparticles affect
the thermal conductivity of nanofluids. The hot wire method
has been used to measure the thermal conductivity of
nanofluids. The measurement results illustrate that the
thermal conductivity of nanofluids remarkably increases
with the volume fraction of ultrafine particles for the water-
cu nanoparticles suspension. For example the ratio of the
thermal conductivity of the nanofluid to that of the base
liquid varies from 1.24 to 1.78 If the volume fraction of the
ultra fine particles increases from 2.5% to 7.5% [19].
Piyanun charoensawan, Sameer khandekar,
Manfred Grolleta (2003)- Closed loop pulsating heat pipes
are complex heat pipe transfer devices having a strong
thermo hydrodynamic coupling governing the thermal
performance. In this paper a wide range of pulsating heat
pipes is experimentally studied thereby providing vital
information on the parameter dependency of their thermal
performance. The influence characterization has been done
for the variation of internal diameter, number of turns,
working fluid and inclination angle of the device.
CLPHPs made of copper tubes of internal diameter
2.0 and 1.0mm, heated by constant temperature water bath
and cooled by constant temperature water ethylene glycol
mixture (50% each by volume). The number of turns in the
evaporator is varied from 5 to 23. The working fluids
employed are water ethanol and R.-123.
He found various results-

a) Gravity certainly affects the heat throughout.
Although the internal diameter of the tubes tested
in the present study as governed by the critical
bond number is well within the specified limit,
bubble shapes are affected by the buoyancy forces.
b) Different fluids are beneficial under different
operating conditions. An optimum trade off of
various thermo physical properties has to be
achieved depending on the imposed thermo
mechanical boundary conditions [12].
Ck Loh, Enisa harris et al. (2005) - The
performance of a heat pipe under specific orientations is
directly related to its wick structure. Wick structures with
low capillary limit work best under gravity assisted
conditions, where the evaporator is located below the
condenser. There are numerous published studies that
explore heat pipe performance limits, however none of them
explicity looked into the effect of orientation on heat pipe
performance with different wick structures. The objective of
this paper is to conduct a comparative study on heat pipe
performance with different wick structures subjected to
different orientations of the evaporator is on top of the
condenser. And for 6mm OD, the groove heat pipe has
better thermal performances that mesh in the +900 to 00
ranges [2].
Fig. 1: Thermal Performance Of 6mm OD, 200mm Length
Heat Pipes With Different Wick Structures At Different

Fig. 2: Thermal Performance Of 5mm OD, 200mm Length
Heat Pipes With Different Wick Structures At Different
Shung- Wang kang, Wei- chiang Wei et al (2006) -
This paper discusses the thermal enhancement of heat pipe
performance using silver nano- fluid as the working fluid. In
the present case DI water diluted with 10nm and 35nm
silver particles, inside a 211µm wide x 217µm deep grooved
Circular heat pipe was experimentally tested.
He found that-

a) With greater silver nano particles dispersed in
workingfluid the increase in heat pipe wall temperature
was smaller than that for a pure water filled heat pipe
under various heat loads.
b) Comparing two nano particle sizes with the thermal
resistance value using DI- water the maximum
reduction was 50% (10nm) and 80% (35nm),
respectively. Therefore the thermal resistance of
grooved heat pipe appears to be dependent on the size of the nano particles [17].

Zhenghui, Yuan-you, Ran bao (2010) - An experiment study was performed to investigate the thermal performance of an inclined miniature grooved heat pipe using water based CuO nano fluid as the working fluid. This study focussed mainly on the effects of the inclination angle and the operating pressure on the heat transfer of the heat pipe using the nano fluid with the mass concentration of CuO nano particles of 1.0 wt%. The experiment was performed at three steady sub-atmospheric pressures. The present investigation indicates that the thermal performance of an inclined miniature grooved heat pipe can be strengthened by using CuO nano fluid. He found the results the inclination angle affects the heat transfer characteristics of the heat pipe using water. With the increase of inclination angle, both the HTC of the evaporator and the condenser section increase gradually and achieve the maximum at the inclination angle of 75°. The evaporation HTC and the condensation HTC of inclined heat pipes increases by about 60-80% and by about 2-8 times respectively comparing with those of the horizontal heat pipe however, the maximum heat fluxes of the inclined heat pipe and also the operating pressure has an obvious effect on both the enhancement ratios of the maximum heat flux and the HTC for the heat pipe using nano fluid. The two enhancement ratios increase as the increase of the pressure [20].

Senthikumar R, Vaidyanathan S, Sivaraman B (2011) - An experiment was carried out study the thermal enhancement of the heat pipe using copper nanoparticles are uniformly suspended with the de-ionized water using ultrasonic homogenizer to prepare the copper nano fluid. The average particle the copper nano fluid. The average particle size of the copper is 40nm and the concentration of copper nanoparticles in the nano fluid is 100mg/lit, the study discusses about the effect if heat pipe inclination, type of working fluid and heat input on the thermal efficiency and thermal resistance. From the experiment study it is found that the thermal efficiency of copper nano fluid is higher than the base fluids like DI water. The obtained experiment results depict that the nano fluids have a great potential for heat transfer which makes them suitable for use many applications than the conventional cooling mediums [16].

Suchana akter jaha, Mohammad ali et al. (2013) - This research is to study the effect of inclination angle and working fluid on the heat transfer characteristics and performance of CLPHP. The performance characterization has been done using two different working fluids of water ethanol with inclination angle of 0°, 30°, 45°, 60°, 75° & 90°. He found that the best performance is obtained at 75° orientations. In all circumstances water provided to better performing than ethanol in the experiment [18].

G. kumaresh, Somchais wongwises et al (2014) - The heat transfer performance characteristics of sintered wick and mesh wick heat pipes are experimentally studied and compared using CuO/DI water nano fluids at various heat input and inclination angles. It is found that the heat transport capacity of sintered wick heat pipe is 14.3% more compared with mesh wick heat pipe under the same operating conditions. Similarly, a higher reduction in the surface temperature of 27.08% is observed for the sintered wick heat pipe with 1.0wt% of CuO/DI water heat pipes. Based on the observed results, it is concluded that the thermal performance of sintered wick heat pipe is better than that of the mesh wick heat pipe [6].

M. Nazarimanshe, T. Yousefi, M. Ashjae (2015) - One of the effective parameters in the heat transfer is the angle which affects the direction and the amount of capillary and gravity. These two forces considerably influence the evaporation and condensation cycle of working fluid. Changing the angle from +90° which the two forces act in
the same direction and it causes to expedite and improve the return of the fluid up to -900 which the forces act in opposite directions, has a great act in opposite directions, has a great effects on the cycle of heat transfer. Finally, the results of the experiment are indicative of the fact that the best concentration is 50ppm and with the maximum entrance power of 40W, the cool source temperature standing at 400°C at an angle of 300, the maximum decline pertaining to thermal resistance in proportion to the base fluid reaches 40% in comparison with other conditions [9].

Conclusion- This review describes the research results of heat transfer characteristics of various wick structures of heat pipes using nano fluid and DI water as working fluid at different orientation.

1) The limited number of available references has shown that orientations of heat pipes with different wick structure using nano fluid have enhance the heat transfer rate and range of orientations is 300-750.
2) The nano fluid have increase the heat transfer rate compare to normal DI water.
3) The thermal efficiency of heat pipe increases with increasing nanoparticles concentration in base fluid.
4) In closed loop pulsating heat pipes at different heat input give rise to different flow patterns inside the tubes.
5) Thermal efficiency of heat pipe is improved by 24.9% for 1.0 wt% CuO nano fluid compared with the DI water at the optimum tilt angle is 450.
6) Heat source orientation and gravity have less effect on sintered powder metal heat pipes due to the fact that the sintered powder metal wick has the strongest capillary action.

REFERENCES