Investigation on Heat Pipes using Different Concentrations of Nanofluid

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Abstract

With the modern era of miniaturization of equipments, heat pipes have attracted major attention in the field of heat transfer. Nanofluids as the working fluid in heat pipes also have attracted a notable attention in recent days due to its superior heat transfer properties. The use of nanofluids in a heat pipe is a very efficient way of enhancing the thermal performance. This project aims to compile the effect of nanofluid on the performance of heat pipes. Effect of different composition of nanoparticles on the performance of heat pipes is studied.

The project work covers design and development of a test rig for checking the performance of heat pipe. Pure water and Al_2O_3-water based nanofluid are used as working fluids. The effect of different composition by percentage of mass on heat transfer will be studied. The results so obtained would compared and optimum value of composition would be found out.

Keywords: Heat pipe, nano-fluid, concentration, and thermal conductivity.

1. Introduction

The application of heat pipe primarily in notebook computers has increased manifolds over the past decade. Heat pipes are used in almost every notebook computers now a days.As the technology of use of nanoparticles in thermal engineeringis advancing, many efforts have been made to augmentation of heat transfer. The conventional techniques used in enhancement of heat transfer cannot meet the challenge of increasing demand of heat extraction in processes. Since the conventional fluids used in convection heat transfer or in boiling heat transfer properties compared to most solid. Therefore, the concept of altogether a new family of heat transfer fluids called"Nanofluids," is being used. These are engineered by suspending ultrafine metallic or nonmetallic particles of nanometricdimensions in traditional fluids such as water, engine oil, ethyleneglycol(Choi, 1995).From the experimental results done so far, it has been found that the nanofluids have very high thermal conductivities and better heat transfer properties than those of conventional pure fluids. The experimental results also illustrate that the thermal conductivity of nanofluids increases considerably with the volume fraction of ultra-fine particles.

A heat pipe is a heat transfer device that combines the principles of both thermal conductivity and phase transition to effectively transfer heat between two solid interfaces. Due to very high heat transfer coefficients for boiling and condensation, heat pipes very high equivalent thermal conductivity.

It has been found that most of the solids are not conversant with the heat transfer characteristics of the conventional fluids, so fluids such as glycol,engine oil,and water were suspended with very fine metallic or non-metallic nanometricparticles. This has led to development of altogether different family of fluids was called as nanofluids. Fluids which consistof nano-sized particles are called nanofluids (nanoparticles). Metals, oxides, carbides or carbon nanotubes are the materials used for impregnation of Nanoparticles in a nanofluid.

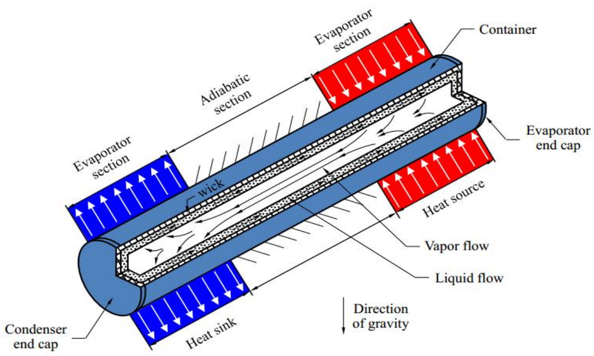

Fig. 1 Schematic of a conventional heat pipe.

2. Technical knowhow of Heat pipe with nanoflids

From 1990's, the researchers started study on applying nanoparticles to enhance heat transfer. In 1995 Choi proposed the concept of nanofluid. Nowadays, nanofluids have attracted the attention of research groups due to their enhanced heat transport properties.

Amir Faghri et al. in his paper, has described in details, about the heat pipes. The details include the history of heat pipes and also the working principle of heat pipe. He has also explained about the types of heat pipesand their performance characteristics. Limitations of heat pipe applications as also the heat pipe startup and shutdown has been described in detail. Analysis and simulation of heat pipe and various applications of heat pipes. Numerical modeling, analysis, and experimental simulation of heat transfer through heat pipes has considerably progressed due to better understanding of different processes occurring inside the heat pipes.

Jubin V Jose, A.Ramesh, EbinJoshy et al. in their review aim to compile the effect of nanofluid in heat pipes. Performance of different nanoparticles and different base-fluids are investigated. By the review on the various researches done on the performance of heat pipe with nanofluid, authors reported enhancement in performance. Most of the papers reviewed here reported an enhancement in performance of heat pipes.

Shaibaaz, M. S.Surve, Suprabhat A.Mohod, Manoj Dhawade et al.in their 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. 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. The heat pipe consists of three sections namely the condenser, adiabatic section and evaporator.

The journal papers stated above cover and overall picture of types of heat pipes. It includes fundamental principles of heat pipeoperations, heat transfer phenomenon and its limitations, and simulation of heat pipe. They also provide a means for modelling and simulation of different types of heat transfer modes at different environmental parameters. Nano particles suspended in base fluids makes it a nanofluid. Nanofluidsare playing a vital role in heat transfer applications where other heat transfer methods fail.

Considering the review on the various researches done about the performance characteristics of heat pipe with nanofluid, most of the authors reported enhancement in performance. This shows the applicability ofnanofluid as working fluid. From the journals reviewed here, it was found that there was an optimum particle loading concentration above which it affects the performance. Operating range increase, hence dry out occur at high heat flux and thermal resistance found to decrease while for certain nanoparticles, performance deteriorates. Hence the structure of porous layer formed at evaporator surface is an important parameter. There are still challenges in the study of phase change of nano-fluids. It is one of the areas which are still to be explored. Concentration of nanoparticles in base fluid has considerable effect in heat transfer rates.

3. Experimental setup

The experimental setup was designed and fabricated with the following specifications.

Heat Pipe specifications

Type of heat pipe: Mesh wick Heat Pipe
Metal used for Heat pipe wall: Copper
Metal used for wick structure: Phosphorous Bronze
Mesh number for wick: 180 mesh/inch (0.0051 mm)
Pipe length: 180 mm
Length of evaporator: 60 mm
Length of adiabatic section: 60 mm
Length of condenser: 60 mm

Test-Rig details

Rack Dimensions: 1085×600×1350 (h)
h= height of the Rack.
Control panel dimensions: 400×300×450 (h)
ON/OFF switch: rotary switch- 6A
Heater switch: toggle switch-6A
Connection details: Ammeters in series, voltmeter in parallel
Ammeter: 0 to 5A
Voltmeter: 500 V
Temperature indicator 1: indicates the temperature for first three heat pipes.
Temperature indicator 2: indicates the temperature for last two heat pipes.
Heater: Band heater of the capacity of 100W.

Table 1: Experimental observations

Input power		**Te (⁰C)**	**Tc (⁰C)**	**Te-Tc (⁰C)**	**Rth (⁰C /W)**	**Time**
25 W	00%	59.8	59.8	57.3	44.7	1 hour 30 Min
	0.1%	60.7	60.3	54.8	43.3	
	0.3%	61.8	64.5	60.9	46	
	0.6%	63.6	64.2	59.6	49.9	
	1%	64	64.3	61.7	50.6	
50 W	00%	86.9	87.4	82.2	61.4	60 Min
	0.1%	88.3	88	75.6	61.9	
	0.3%	90.1	91	84.5	63.4	
	0.6%	91.7	93.5	84.4	65.2	
	1%	93.3	87.8	82.5	68.3	

75 W	00%	110.9	112	102.8	71.4	60 Min
	0.1%	112.3	112.5	93.3	70.4	
	0.3%	112.1	119.3	106.4	73	
	0.6%	119.7	120.8	104.9	75.1	
	1%	122	107.4	102	78.6	
100 W	00%	120	119	107.1	80.1	60 Min
	0.1%	121.6	128.3	99.1	80.8	
	0.3%	124.4	134	113.2	82.8	
	0.6%	128.7	130.7	111.7	83.3	
	1%	131.3	112.8	107.5	88.1	

Fig. 2: Test rig

Thermocouples

Total 24, out of which 4 are pencil type RTD's and rest are bare RTD's

-First 12 thermocouples are mounted from heater to condenser as shown

-Next 8 thermocouples are from condenser to evaporator.

-Rest of the two sensors are kept open for further changes.

Type J, K, T are base metal thermocouples.

The K type thermocouple is the most common type of thermocouple because itsnot very costly, its accurate, its reliable and it has wide temperature range.

Nanofluid details

Nanofluid used: Aluminum Oxide (Al_2O_3)

Base Fluid: Water

Particle Size: 100 nm. (From TEM micrograph)

Concentrations: 0%, 0.1%, 0.3%, 0.6%, 1.0%

4. Experimentation

Heat pipe unit is designed and manufactured in order to carry out comparative study of performance analysis of heat pipes that consist nanofluid as their working charge with the heat pipe which carries water as working fluid.

The nanoparticle used is Al_2O_3 particles of 100 nm in sizes. In the current set up, nanofluids of the concentrations of 0%, 0.1%, 0.3%, 0.6%, and 1.0% are used for heat pipes respectively. From left to right the heat pipe has distilled water as working fluid, and rest are with nanofluids as mentioned above. In the experiment, the outer diameter and length of the heat pipe are 12.7 mm and 180mm, respectively.

The overall thermal resistance of circular heat pipe is calculated by equation-

$$R_{th} = \frac{Te - Tc}{Q} \quad \text{.......} (1)$$

5. Results and discussion

Following results are obtained from the experimentation.

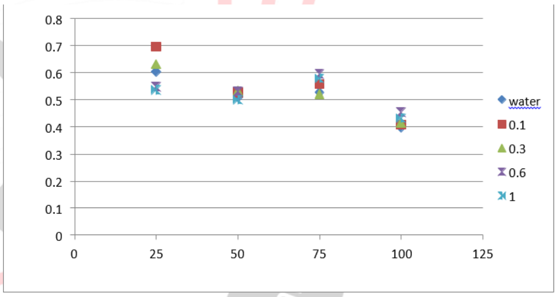

Fig 3. Graph of resistance vs concentration

Conclusions

This analysis discusses the thermal enhancement of circular heat pipe performance using Alumina /Water nanofluid as working fluid.For that purpose the effect of different concentration of nanofluid, heat input on thermal resistance of circular heat pipe is studied. From the experimentation the following conclusions are drawn

1. Thermal resistance of circular heat pipe decreases with increase in volume concentration of nanofluid and increase in heat inputcompared with distilled water as working fluid.
2. With increase in the volume concentration of nanofluid the thermal resistance of circular heat pipe for 0.1% to about 1% volume concentration of nanofluid as working fluid reduces by an amount of 23% compared with distilled water as working fluid.

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