EXPERIMENTAL ANALYSIS OF HEAT PIPE USING FOR AMMONIA, ACETONE & ETHANOL AS WORKING FLUIDS

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Abstract— Heat pipe is a convective heat transfer device which can transfer heat with minimum temperature difference by evaporation and condensation. In heat pipe heat is absorbed by the working fluid by evaporation at one end and the absorbed heat is rejected at other end by condensation. The evaporation and condensation are takes place by natural means i.e. by density difference and no need of supply any additional power to the system. The present work we are evaluating the performance of heat pipe by experimentation with different working fluids and with different heat pipe materials. We are using copper and aluminum as heat pipe materials and ammonia, acetone, and ethanol as working fluids. And this two heat pipe materials are with wick and without wick, the wick is used in respective materials made of screen mesh. By this experimental investigation we are trying to find out the best suitable combination of heat pipe material and working fluid.

Keywords—heat pipes,working fluids, heat transfer characteristics.

1. INTRODUCTION

The heat pipe is a device that is used to increase the heat transfer rate. It is a very simple and an efficient device which can be considered as a super thermal conductor that transmits heat by the evaporation and condensation of a working fluid. In practice the thermal conductance of a heat pipe is several times more than the best available metal conductor. The present work is aimed at explaining the operating principles of the heat pipe along with its design and thermal analysis. This is followed by preliminary heat pipe design considerations fluid, wick, container selection and the fluid flowing through the heat pipe.

The term heat pipe as the name implies is a device for transferring heat from a source to sink by means of evaporation and condensation of a fluid in a sealed system. The transfer of thermal energy by conduction using solid materials is essentially limited by the thermal conductivity of the material structure. The best obtained thermal conductors are metallic and tend to be high cost materials. Because the thermal energy is being transported by evaporation-condensation process rather than by conduction, the heat pipe can transfer heat much more effectively than a solid conductor of the same cross-section. In practice, the thermal conductance of heat pipe may be well several hundred times than that best available metal conductor.

The heat pipe is a very simple and very efficient heat transfer device. Basically, it can be considered a super-thermal conductor that transmits heat by the evaporation and condensation of a working fluid [1]. Heat pipe has no moving parts, requires no external energy is reversible in operation and completely silent. It is rugged like any piece of tube or pipe and can withstand a lot of heat is transfer.

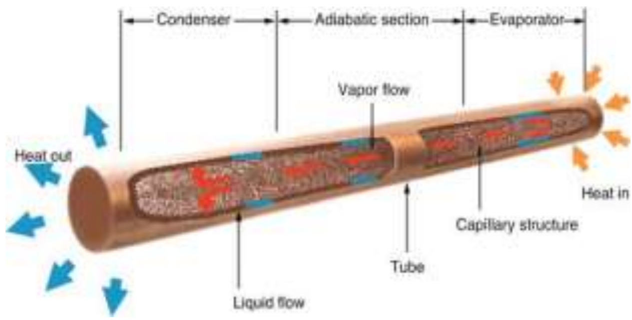


Fig. 1 Schematic view if Heat Pipe

2. PIPE MATERIALS AND WORKING FLUIDS

1). MATERIALS:

A).Copper:

Copper is a chemical element with symbol Cu and atomic number 29. It is a soft, malleable, and ductile metal with very high thermal and electrical conductivity. A freshly exposed surface of pure copper has a reddish-orange colour. Copper is used as a conductor of heat and electricity, as a building material, and as a constituent of various metal alloys, such as sterling silver used in jewellery, cupronickel used to make marine hardware and coins, and constantan used in strain gauges and thermocouples for temperature measurement.

B).Aluminium:

Aluminium is a chemical element with symbol Al and atomic number 13. It is a silvery-white, soft, nonmagnetic, ductile metal in the boron group. By mass, aluminium makes up about 8% of the Earth's crust; it is the third most abundant element after oxygen and silicon and the most abundant metal in the crust, though it is less common in the mantle below. The chief ore of aluminium is bauxite. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 270 different minerals.

Aluminium is remarkable for its low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium and its alloys are vital to the aerospace industry and important in transportation and building industries, such as building facades and window frames. The oxides and sulphates are the most useful compounds of aluminium.

Table-1. Properties of Materials [1]:

Material	Melting Point ℃	Boiling Point ℃	Thermal Conductivity W/ (M.K)	Density G/Cm3
Copper	1084.62	2562	401	8.96
Aluminium	660.32	2470	237	2.70

They are used in two types of heat pipes based on the wick (capillary) structure:

- With Wick and Without Wick

With Wick material: The main purposes of wick are to generate the capillary pressure, and to distribute the liquid around the evaporator section of heat pipe. The commonly used wick structure is a wrapped screen wick [1]. It is a porous structure made of materials like steel, aluminum, nickel or copper in various ranges of pore sizes.

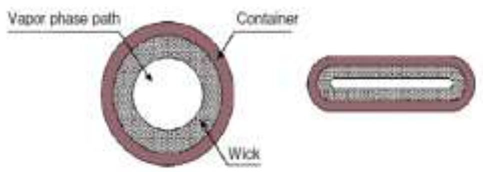


Fig. 2 Wick material in the heat pipe

Without Wick material: This Heat pipe is a wickless pipe. Terrestrial applications can usually take advantage of gravitation to move condensate without a wick. When the condensate is returned by gravitation, the system becomes thermosyphon

2). WORKING FLUIDS:

A). Ammonia:

Ammonia is a compound of nitrogen and hydrogen with the formula NH3.ammonia is a colourless gas with a characteristic pungent smell. It is a common nitrogenous waste, particularly among aquatic organisms, and it contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to food and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceutical products or is used in many commercial cleaning products. It is lighter than air, its density being 0.589 times that of air. It is easily liquefied due to the strong hydrogen bonding between molecules; the liquid boils at −33.3 °C (−27.94 °F) and freezes at −77.7 °C (−107.86 °F) to white crystals. Ammonia may be conveniently deodorized by reacting it with either sodium bicarbonate or acetic acid. Both of these reactions form an odorless ammonium salt.

B). Acetone:

Acetone is the organic compound with the formula (CH3)2CO. It is a colorless, volatile, flammable liquid, and is the simplest and smallest ketone [2][3].Acetone is miscible with water and serves as an important solvent in its own right, typically for cleaning purposes in laboratories. About 6.7 million tons were produced worldwide in 2010, mainly for use as a solvent and production of methyl methacrylate and bisphenol A. It is a common building block in organic chemistry. Familiar household uses of acetone are as the active ingredient in nail polish remover and as paint thinner.

C). Ethanol:

Ethanol, also called alcohol, ethyl alcohol, and drinking alcohol, is a chemical compound, a simple alcohol with the chemical formula C2H5OH. Its formula can be written also as CH3−CH2−OH or C2H5−OH (an ethyl group linked to a hydroxyl group) and is often abbreviated as EtOH. Ethanol is a volatile, flammable, colourless liquid with a slight characteristic odor. It is a psychoactive substance and is the principal type of alcohol found in alcoholic drinks.

Ethanol is naturally produced by the fermentation of sugars by yeasts or via petrochemical processes and is most commonly consumed as a popular recreational drug [2][3]. It also has medical applications as an antiseptic and disinfectant. The compound is widely used as a chemical solvent, either for scientific chemical testing or in synthesis of other organic compounds, and is a vital substance utilized across many different kinds of manufacturing industries. Ethanol is also used as a clean-burning fuel source.

Table-2. Properties of Fluids:

Fluid	Melting point ºC	Boiling point at atmospheric temperature ºC	Useful range ºC
Ammonia	-77	-33	-60 to 100
Acetone	-95	57	0 to 120
Ethanol	-112	78	0 to 130

Some things to consider when you choose the working fluids are [1],

- Compatibility with wick and wall materials.
- High thermal conductivity.
- Low liquid and vapor viscosities.
- High surface tension.
- Good thermal stability.
- Wettability of wick and wall materials.
- High latent heat.
- Vapor pressures not too high or low over the operating temperature range.

3. EXPERIMENTAL SETUP

The heat pipe testing has been designed and constructed to developed of the water to water i.e., source tank temperature (Heat In) reading [2] [3] of heat pipe to sink tank temperature (Heat Out) reading of heat pipe also a evaporation process (Te) to condensation process (Tc) as shown in fig. 2; the temperature indicator is used in this investigation to measure the maximum temperature for the given required time.

Table-3. Parameters of Heat Pipe:

Specifications	dimensions
Length of pipe	300 mm(1 feet)
Diameter of pipe	12.7 mm(1/2 inch)
Digital Temperature indicator	Range of -50^{0}c to 300^{0}c
Capacity of heater	2000 watts, 230 Amps
Materials of heat pipe	Copper and Aluminium
Wick material	Screen mesh of respective materials.
Working fluids	Ammonia, acetone and Ethanol.

Fig. 3 Fabricated Actual Experimental Setup

Fig. 4 Arrangement of heat pipes with copper and aluminium pipes

A heat pipe heat exchanger is a simple device which is made use of to transfer heat from one location to another, using evaporation – condensation cycle [4]. The heat pipes are referred to as the "super conductors" of the due to their fast transfer of capability with low heat loss.

The working of heat pipe is heat input region of the heat pipes is called evaporator, the cooling region is called condenser. In between the evaporator and condenser regions, there may be an adiabatic region.

4. WORKING OF HEAT PIPE PROCESS

A typical heat pipe consists of a closed hollow tube, which is made from a thermo conductive metal such as copper and aluminum. The pipe contains a relatively small quantity of "working fluid" (such as ammonia, acetone and ethanol) with the remainder of the pipe being filled with vapor phase of the working fluid. On the internal side of the tube's side-walls a wick structure exerts a capillary force on the liquid phase of the working fluid. This is typically a sintered metal powder (sintering is a method for making objects from powder, by heating the material until its particles adhere to each other) and the respective materials of screen mesh or a series of grooves etched in the tube's inner surface[4]. The basic idea of the wick is to flow up the coolant. Heat pipes contain no moving parts and require no maintenance and are completely noiseless.

In theory, it is possible that gasses may diffuse through the pipe's walls over time, thus reducing this effectiveness [5]. The advantage of heat pipes is their great efficiency in transferring heat. They are actually a better heat conductor than an mass of solid copper. The heat pipe is similar in construction of the thermo syphon but in this case, a wick constructed from a few layers of wire gauge, is fixed to the inside surface and capillary forces return condensate to the evaporator [6]. In the heat pipe evaporator position is not restricted and it may be used in any orientation of heat pipe process.

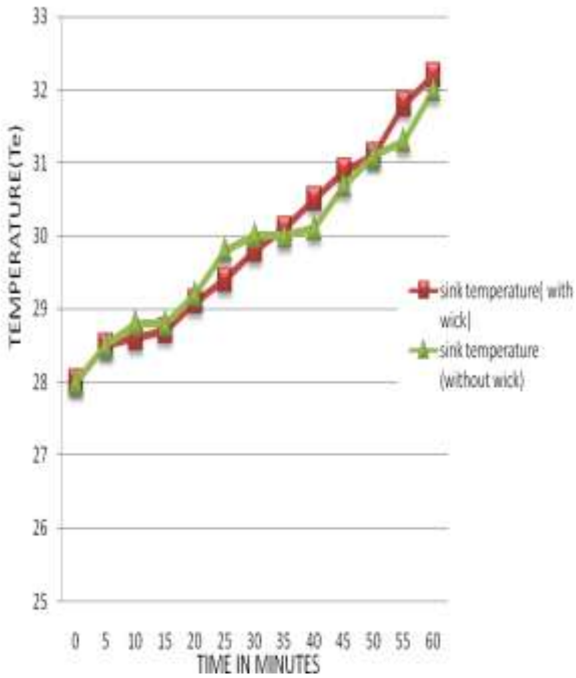
Fig. 5 Arrangement of heat pipes with source tank includes heater and sink tank to measure the temperature readings

Fig. 6 And the heat pipes difference of temperatures with wick (35^0c) and without wick (32^0c) materials

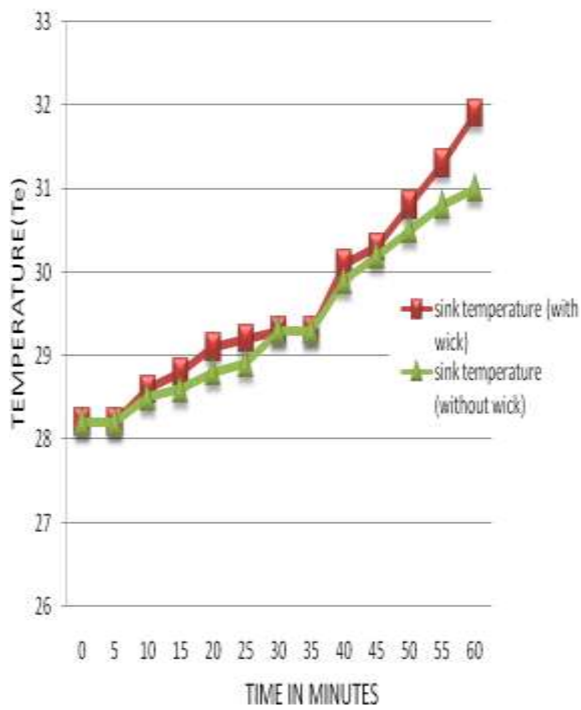
Figures 3 to 6 show the photographic representation of readings. Fig. 5 shows the Source tank and Sink tanks; there are two sink tanks and each contains individual with wick and without wick heat pipe[4]. Ammonia, acetone and ethanol are there as a refrigerant available from left to right sink tanks which are shown in fig 5. Fig 6 presents the water's temperature near to heater and at the top layer of water in source tank respective.

5. RESULTS

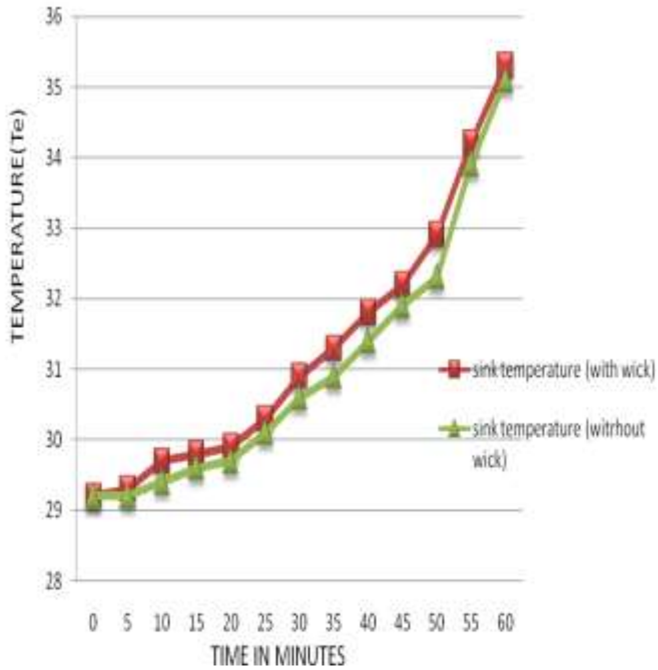
(I) Copper with Ammonia(with & with out wick)

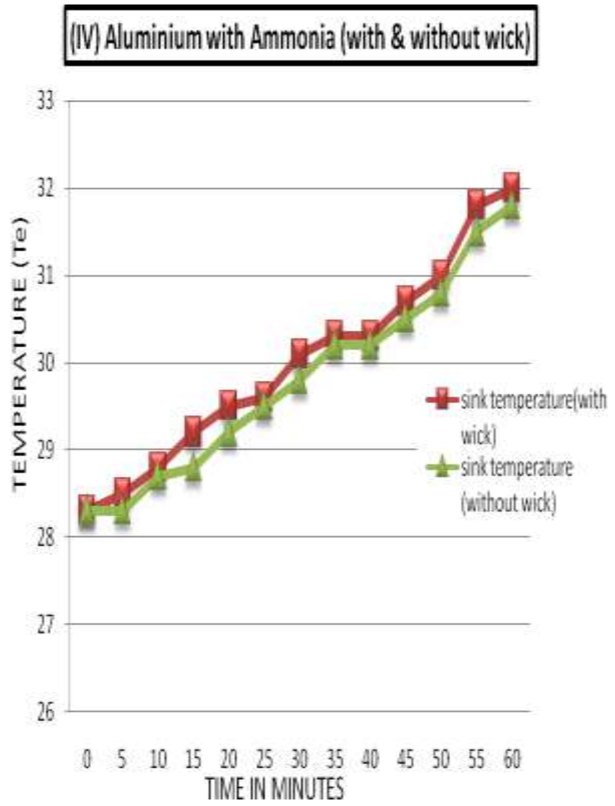


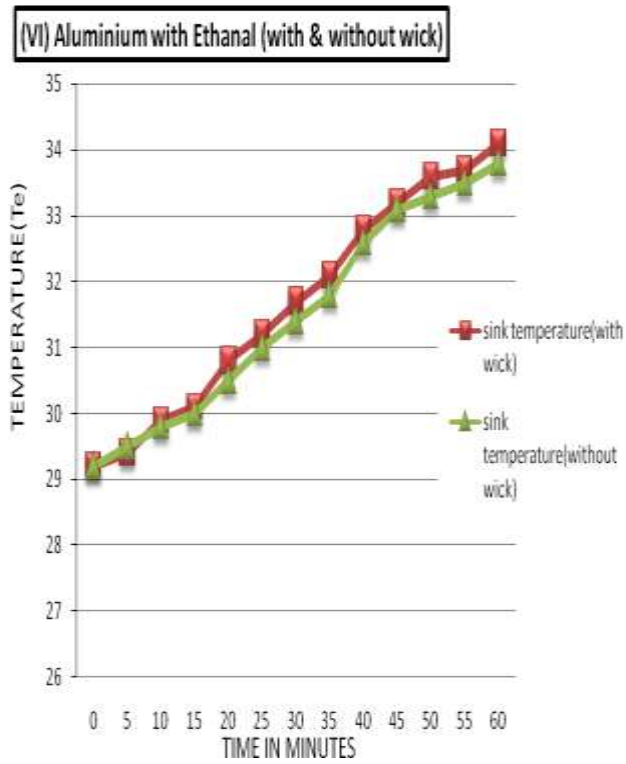
(II) Copper with Acetone (with & without wick)

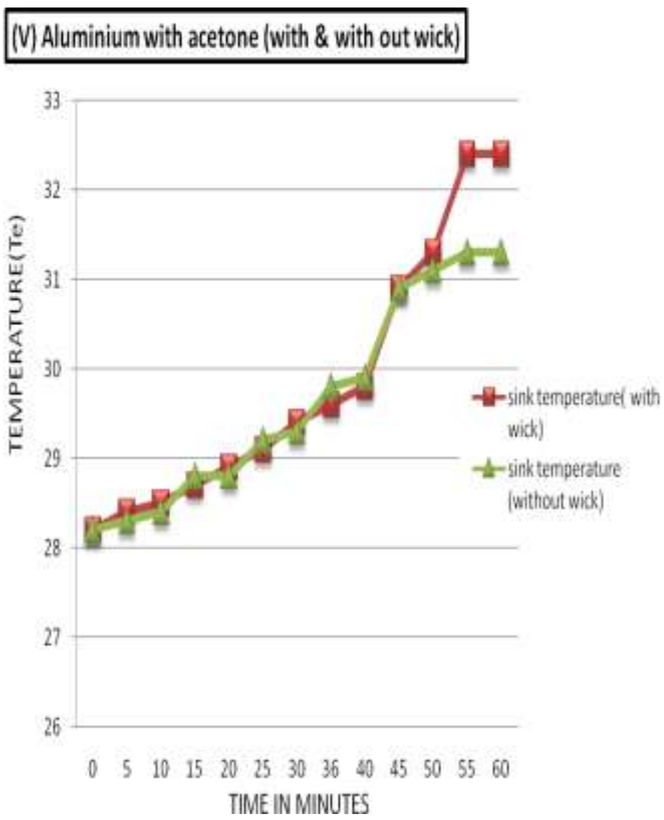


(III) Copper with Ethanol (with & without wick)









6. CONCLUSION

The experiment investigating of thermal performance of heat pipe is done by this varying of coolant flow rates, working fluids and materials.

- For maximum heat transfer copper and ethanol are the best materials and fluid combination for heat pipe, because copper is having high thermal conductivity and ethanol is having a wide range of temperature applications.
- Comparison should be done on heat pipe with & without wick material interns of heat transfer in evaporation (Source) and condensation (sink) process. It is also a with wick is more heat transfer in all processes.
- Experiments should be done copper and aluminium with different working fluids such as ethanol, ammonia and acetone which are having wide range of temperature applications.
- For minimum thermal performance of heat pipe copper and ethanol are the best material and fluid combination of heat pipe as temperature gradient decreases with time, and the experimental analysis of heat pipes are done and finally the temperature distribution and evaporation to condensation processes are obtained.

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