Loop Heat Pipe

Githin V Sam  
Department of Mechanical Engineering  
Saintgits College of Engineering, Kottayam, India

Jesvin Sam  
Department of Mechanical Engineering  
Saintgits College of Engineering, Kottayam, India

Jethin Babu  
Department of Mechanical Engineering  
Saintgits College of Engineering, Kottayam, India

Jithin Victor  
Department of Mechanical Engineering  
Saintgits College of Engineering, Kottayam, India

Abstract

Loop heat pipes (LHPs) are two phase heat transfer devices that use evaporation and condensation of a working fluid to transfer the heat and use the capillary force developed in fine porous wick to circulate the fluid. They possess all the main advantages of conventional heat pipes, but owing to the original design and special properties of the capillary structure are capable of transferring heat efficiency for distances up to several meters at any orientation in the gravity field, or to several tens of meters in a horizontal position. They do not require any electrical energy for heat transport because of the absence of any mechanical moving parts. The main objective of this project is to fabricate a 2m long loop heat pipe for efficient transfer of heat. The main parts include a wick, a heater block, an accumulator, 2m long copper wire and a condenser. An external fan was introduced to speed up the natural condensation process. The wick was made with copper with 0.3 mm micro drilled pores. The working fluid used is ethanol. After fabricating the model, the pipe was completely filled with ethanol and temperature readings were noted using a temperature sensor at two different positions. A good agreement was reached between the two values.

Keywords: Loop heat pipes, efficient transfer of heat

I. INTRODUCTION

Loop heat pipes (LHPs) are two-phase heat transfer devices. It uses the evaporation and condensation of a working fluid to transfer the heat from one point to other. Capillary forces are developed in the fine porous wicks which helps to circulate the fluid. It does not require electrical power because they have no moving mechanical parts. The pressure loss at the wick in the Loop Heat Pipes can be kept lower than in the conventional HPs. The wick is made of copper instead of PTFE (polytetrafluoroethylene) and has pores of size 0.3mm. Loop Heat Pipes are similar to heat pipes but have the advantage of being able to provide reliable operation over long distance. They can transport a large heat load over a long distance with a small temperature difference. Different designs of Loop Heat Pipes ranging from powerful, large size LHPs to miniature LHPs (micro loop heat pipe) have also been developed and successfully employed in a wide sphere of applications both ground based as well as space applications. Compared with conventional Heat Pipes (HPs), which also use capillary forces to circulate the working fluid, the LHPs can transport heat over longer distances.

In the conventional Heat pipes, vapor flows through the center of the pipe from an evaporation area to a condensation area, while liquid flows through the wick, which is located in the inner surface of the entire pipe, from the condensation area back to the evaporation area. Therefore, if the distance needed for heat transport becomes longer, the length of the wick and the entire pipe also become longer. In contrast, in the LHPs, the wick is located only in the evaporator. Therefore, if the distance needed for the heat transport becomes longer, the length of the wick does not change. Because of this difference, the pressure loss at the wick in the LHPs can be kept lower than in the conventional HPs. The wicks in the LHPs develop high capillary pressures that are used to operate against gravity and can also be used to increase the horizontal distance for heat transport. The heat losses from vapor and liquid lines to ambient air and due to the pressure losses in the single-and two-phase fluids in the vapor and liquid lines. Figure 1 shows the layout of loop heat pipe.

Fig. 1: Layout of Loop Heat Pipe
Unlike conventional heat pipes, the wick structure used in the LHPs should not have excessively high effective thermal conductivity to avoid heat leaks to the liquid present in the compensation chamber. It should be noted that there is a need for compromise between back conduction problem and the desire for good thermal conductivity of wick to promote efficient heat exchange in the evaporating zone.

II. COMPONENTS

A. Copper Tube:

Copper tube is most often used for supply of hot and cold tap water, and as refrigerant line in HVAC systems. There are two basic types of copper tubing, soft copper and rigid copper. Copper tubing is joined using LPG welding. Copper offers a high level of corrosion resistance, but is becoming very costly. The vapor line consist of copper tube of 0.7in diameter and the liquid line consist of copper tube having 0.5in diameter.

B. Fan:

A mechanical fan is a machine used to create flow within a fluid, typically a gas such as air. The fan consists of a rotating arrangement of vanes or blades which act on the fluid. The rotating assembly of blades and hub is known as an impeller, a rotor, or a runner. Usually, it is contained within some form of housing or case. This may direct the airflow or increase safety by preventing objects from contacting the fan blades. Most fans are powered by electric motors, but other sources of power may be used, including hydraulic motors and internal combustion engines. Fans produce flows with high volume and low pressure (although higher than ambient pressure), as opposed to compressors which produce high pressures at a comparatively low volume. A fan blade will often rotate when exposed to a fluid stream, and devices that take advantage of this, such as anemometers and wind turbines, often have designs similar to that of a fan.

C. Condenser:

In systems involving heat transfer, a condenser is a device or unit used to condense a substance from its gaseous to its liquid state, typically by cooling it. In so doing, the latent heat is given up by the substance, and will transfer to the condenser coolant. Condensers are typically heat exchangers which have various designs and come in many sizes ranging from rather small (hand-held) to very large industrial-scale units used in plant processes. For example, a refrigerator uses a condenser to get rid of heat extracted from the interior of the unit to the outside air. Condensers are used in air conditioning, industrial chemical processes such as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers. Natural convection air cooled condenser of dimension 9”x9” fin type is used. The fins are made of Aluminium.
D. Accumulator:
An accumulator is an apparatus by means of which energy can be stored. A GI moulded accumulator is used to store the working fluid which is ethanol.

E. Heater:
Heaters are appliances whose purpose is to generate heat. Such a system contains a boiler, furnace, or heat pump to heat water, steam, or air. The heat can be transferred by convection, conduction, or radiation. Heaters exist for various types of fuel, including solid fuels, liquids, and gases. Another type of heat source is electricity, typically heating ribbons made of high resistance wire. This principle is also used for baseboard heaters and portable heaters. In loop heat pipes, GI ceramic injection moulded heater is used to heat the ethanol.

![Fig. 4: Heater](image1)

F. Wick:

![Fig. 5: Wick](image2)

0.5in diameter copper tube with 0.3mm holes drilled onto the tube acts as the wick. The capillary forces developed in these pores give the required pressure difference to cause the ethanol flow.

G. Ethanol:
Commonly referred to as the drinking alcohol or spirit. It is the principal type of alcohol found in alcoholic beverages. This is the working fluid used. It has a boiling point of 78.1 degree Celsius.

III. METHODOLOGY

Prior to fabrication, model was first designed in CATIA and analysed in ANSYS FLUENT (figure 6) to find out the thermal efficiency. After obtaining the appropriate design, the required materials were purchased and fabrication initiated.
The wick was initially fabricated by micro drilling 0.3mm holes into the copper tube. The wick is shown in figure 5. One end of the pipe was closed by Gas welding. The wick of diameter 0.6inch was inserted into copper tube of diameter 0.7 inch and Gas welded.

The open end of the wick was welded to the accumulator. The accumulator is made of Galvanized iron. The other end of the wick was welded to 2m copper tube which formed the vapor line. The open end of the wick was welded to the accumulator. The accumulator is made of Galvanized iron. The other end of the wick was welded to 2m copper tube which formed the vapor line. At the end of the vapor line, 9*9 inch condenser with aluminum fins was kept.

This causes phase change of the vapor ethanol to liquid. From the condenser to the accumulator, a copper tube of 0.5 inch diameter acts as the liquid line. An injection molded heater was attached to the accumulator. The entire model was build up on cast iron frame. After assembling the entire model, leak test was conducted by using R-22 and soap solution. After conducting leak test, it was filled with ethanol as shown in figure 8 and sealed. After filling with ethanol, the entire pipe sections were insulated using thermo wool and thermo foam in order to prevent heat from escaping from the tube. The finished model is shown below.
IV. RESULTS AND DISCUSSIONS

A. Temperature Measurement on Two Metre Long Loop Heat Pipe:
After the fabrication process was completed, the process of measuring the temperature at various locations throughout the LHP was carried out. Temperature was measured with the help of two temperature measuring sensors. The first sensor was placed at the starting of vapor line in order to measure the heater temperature. The second sensor was placed at the end of the vapor line.

It was found that both the temperature readings were approximately close which implies that the capillary structure of the wick material enabled the hot vapor to travel through a distance of 2m through an ordinary copper tube. Two temperature readings are shown in the figure. The heater temperature was 62°C and the temperature at the end of the vapor line was 60°C.

B. Pressure Losses over Long – Distance LHPs:
Figure 11 shows the calculated distributions of the pressure losses for the LHP. The figure shows that the wick, vapor line, and the liquid line had the largest pressure losses at all the heat loads. The pressure loss across the liquid line was much larger than those across the wick or the vapor line. To simplify the layout of the LHP, the outside diameters of the liquid line was made smaller as compared to vapor line. This emphasizes that when LHPs are designed for a long distance heat transport, it is important to take into account the pressure loss across the liquid line.
V. CONCLUSIONS

A two metre long Loop Heat Pipe was designed in CATIA and different parts were analysed using ANSYS FLUENT. After analysis we found out that higher efficiency was observed with the new wick design. Unlike the conventional heat pipe which has the wick present throughout the pipe, here the wick is present only at the beginning of the heat pipe. After making the appropriate alterations in the design, the model was fabricated with ethanol as the working fluid.

The capillary forces developed in the fine porous wick helps to circulate the working fluid, thereby eliminating the need for electrical energy as there are no mechanical moving parts. Temperature was measured using two temperature sensors and it was found to be approximately equal at any point in the vapor line. A good agreement was reached between the two values. High efficiency was obtained above 60°C.

REFERENCES