Experimental Application of Heat Pipes in Hydraulic Oil Cooler

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Abstract - **The concept of heat pipe can be effectively used in in hydraulic system. The heat pipe heat exchanger has less maintenance cost, space and running cost. The heat pipe equipped hydraulic oil cooler uses heat pipe module comprises of a base metal block with oil channels machined on the top face of aluminum block on which top plate is fitted. The heat pipe used to transfer the heat from the hot oil to the surrounding air through fins is press fitted in the cavity of this metal block. The heat pipe evaporator section is in direct contact with hot oil whereas the condenser section of the heat pipe is fitted in the circular cavity in the spiral radial fin structure. The spiral fins act as heat enhancement method as they offer maximum surface area. The oil cooler can be mounted externally to the oil tank system thereby ensuring contamination free operation as the oil tank is sealed. In this study the purpose is to increase heat transfer rate of oil which prevents the overheating of oil and improves components life. Cooling of oil also helps in saving pumping power of system.**

Keywords- Heat pipe, Condensation, Evaporation, Pump.

I. INTRODUCTION

Heat pipe is a passive heat transfer device, offer simple and reliable operation, with high effective thermal conductivity, no moving parts, ability to transport heat over long distances and quiet vibration-free operation. A heat pipe has light weight, low cost and the flexibility of many different size and shape options. In heat pipe heat is transferred from hot junction to cold side by vaporizing and condensation of working fluid. The evaporator side is in contact with hot side, the working fluid vaporizes by absorbing the heat. This heat is released in surrounding through condenser side. If the condenser side is provided with fins then the heat transfer rate is increased. The fluid returns back to evaporator section by capillary action of wicked structure. This heat pipe concept can be used in hydraulic oil cooler in which hot oil is cooled effectively. In hydraulic system temperature of oil increases during its operation. The temperature of this oil should be lowered before it is return to tank. The increased heat transfer rate of oil using heat pipe lowers the temperature of return oil. When the temperature of oil is low, its viscosity increases and higher viscosity helps in saving the pumping power required for oil. This increases the system efficiency.

II. LITERATURE REVIEW

Heat pipe is an efficient tool for maximum heat transfer. Ansys-based FEM models have been developed by Q. Wang, Y. Cao, R. Wang[1] for heat pipe cooled piston crown and correlating the numerical results with the experimental measurements. The effective thermal conductance of the annular heat pipe was found to be about 3980 W/m-°C, about 240 times that of the crown material. The research has done in this area using heat pipe in hydraulic motor pump for heat dissipation. The heat pipe radiator model is designed by YonglingFula, Meng Zhang, HaitaoQilb, Gaocheng An [2]. The results in terms of Temperature are simulating by using ANSYS software. The result shows that the heat generated is difficult to transfer only through natural cooling. The average oil temperature is found to be 150.08 ^{0}C .When the heat pipe radiator model is used the average oil temperature is found as 73.844 ^{0}C.It shows that the heat pipe radiator can ensures the hydraulic motor pump work in an appropriate range. It can greatly reduce the temperature of the oil in hydraulic motor pump which makes the oil in the hydraulic motor pump at a low level. At the same time it also helps reducing the temperature gradient. C. R. Kamthane, P. M. Khanwalkar [3] has developed hydraulic oil cooler equipped with the heat pipe cores that have a shroud with fans and other brackets and braces to secure the components into the reservoir. The article showed that the modules of heat pipe were tested to investigate the characteristics of heat pipe. Since the model is developed for oil cooling, tests were carried out over a temperature difference of 45℃ to 80℃ of inlet and outlet of oil. Heat dissipated by single module is found near about 200 watt, and with natural convection it will be 120 watt. Prof. Chavan Dattatraya Prof. L S Utpat, and Prof. Dr. G S Tasgaonkar has [4] done case study of oil cooler model. The study shows that as the oil flow rate rises, the total heat rejected increases. The tests were carried on oil cooler keeping the flow rate constant for increasing inlet oil temperature. This unit is more efficient at lower temperatures. We can improve the cooling efficiency by using number of heat pipes or by changing material of heat pipe. If the heat pipes with fins are used over forced convection the heat transfer rate can be further improved.

III. DESIGN METHODOLOGY

For designing hydraulic cooler the heat generated in hydraulic system is calculated as:

A. Input Data:

Specific heat of oil = 1.8 kJ/kg ^{0}C

Oil flow rate = 0.0220 Kg/s

Oil pressure in system = 20 bars

Heat Generated in system = p (Pa) × Q (m3/s))/1000

$= (2\times10^6 \times 2.2\times10^{-5}) \times/1000$

= 0.044 kW

So the increase temperature of oil,

$$= \frac{\text{Heat generation in (KW)}}{\text{Oil specific heat (kJ/kg}^0\text{C)* oil flow rate (Kg/s)}}$$

$$= \frac{0.044\ \text{(KW)}}{1.8\ (\text{kJ/kg}^0\text{C}) \times 0.0220\ (\text{Kg/s})}$$

$= 2^0$C

So the outlet temperature of oil = 52^{0}C

Based on the above calculations the heat load is identified and heat pipe of following specification is selected.

Diameter = 32 mm

Length = 12 mm long

Evaporator length = 6 mm

Condenser length = 6 mm

Type: Short cylindrical heat pipe

Material: Copper

Working fluid: Water

Wick structure: Sintered copper

B. Heat pipe Geometry:

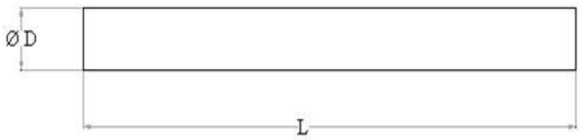

Fig.1 Heat Pipe Geometry

The above calculated heat load shows that heat pipe rejecting minimum 15 watts heat should be selected.so above standard size 4 heat pipes are used according to total heat load.

C. Single Heat pipe module:

The heat pipe module contains of a base aluminum block in which oil channels machined on the top face of the block as shown in figure and then sealed with a top plate. The heat pipe used to transfer the heat from the hot oil to the fins is press fitted in the cavity of the aluminum block. The radial blower is mounted centrally between the four heat pipe modules. This blower takes cold air in the system axial and discharges it in radial direction.

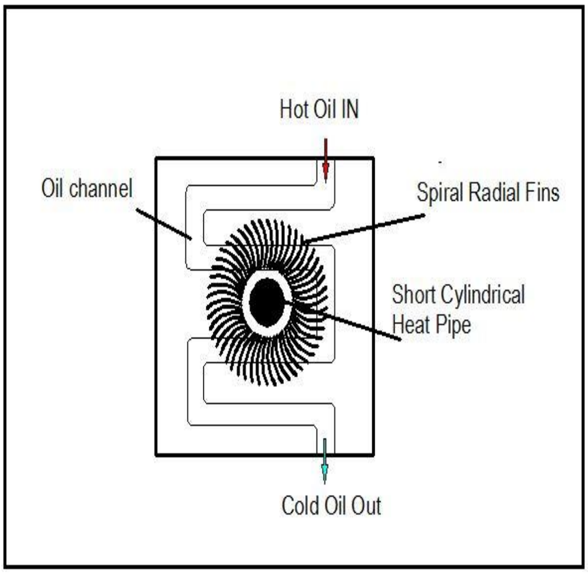

Fig.2 Heat Pipe Module

IV. PROPOSED EXPERIMENTAL SET UP

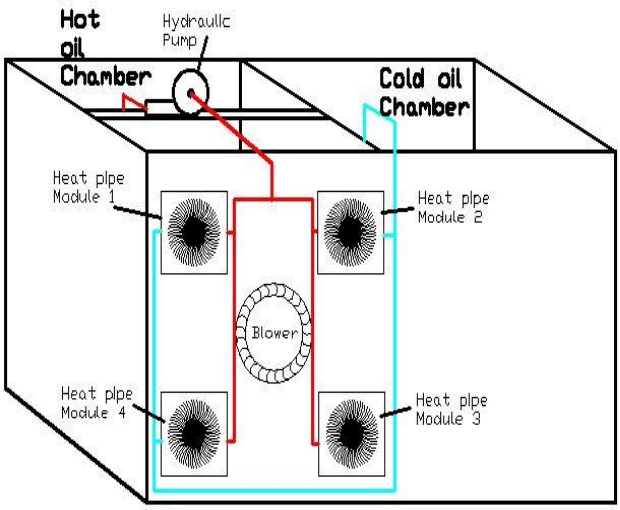

Fig.3 Experimental set up

This set up consist of tank split in two parts one has hot oil in it while other has cold oil. Hot oil from hot chamber is pumped into heat pipe module assembly as shown. The heat pipe dissipates heat from oil effectively through spiral radial fins. The radial blower is also used to have forced convection resulting increase in heat transfer rate. The cold oil is then drawn out and collected in cold oil chamber.

V. RESULTS & DISCUSSION

With the help of above literature survey and proposed set up, graphs for the trends of results for performance of heat pipe are as follows.

The graph for mass flow rate of oil and overall heat transfer coefficient found as.

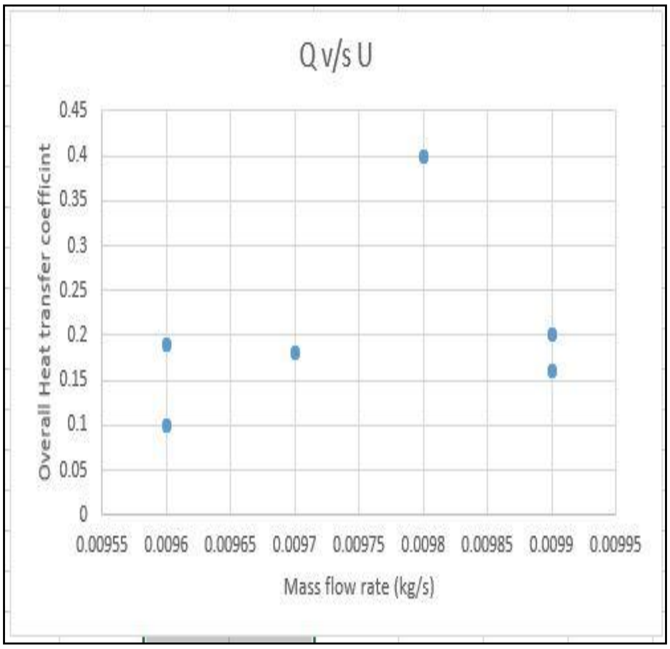

Fig.4 Overall Heat transfer coefficient and mass flow rate

Trends of results for mass flow rate of oil with heat transfer rate

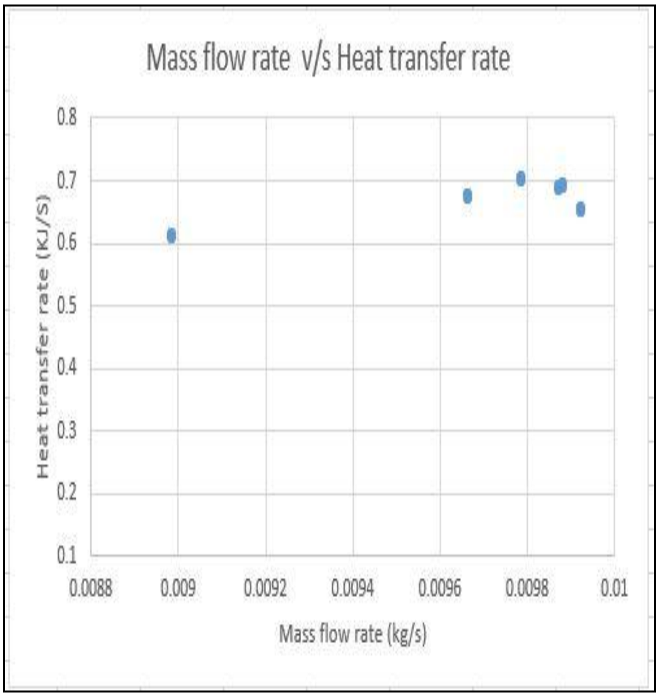

Fig.5 Mass flow rate and Heat transfer rate

Trends of results for temperature difference of oil between inlet and outlet with heat transfer rate.

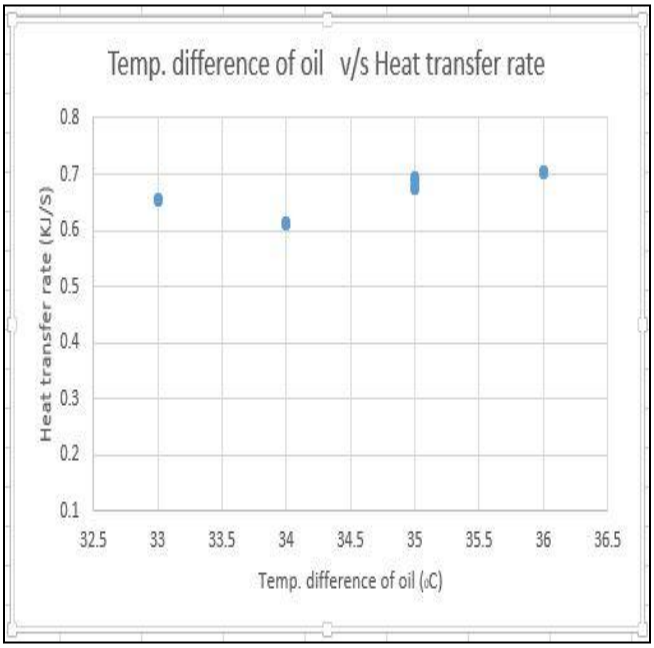

Fig.6 Heat transfer rate and Temperature difference of oil.

VI. CONCLUSIONS

1. The heat transfer rate of oil is increased reaches up to 0.70 kJ/S for nearly constant mass flow rate of oil as shown in graphs. The blower helps to transfer heat effectively.
2. The overall heat transfer rate also increased during given flow rate of oil.
3. The temperature difference between oil inlet and outlet is decreases which means oil outlet temperature is decreasing for the given flow rate of oil.

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