

Design and analysis of hydraulic oil cooler by application of heat pipe



^{#1}Ashish A. Wankhede, ^{#2}Kishor P. Kolhe

¹wankhedeashish0@gmail.com

²skishor75@gmail.com

^{#1}Department of Mechanical Engineering, JSPM's Imperial College of Engineering and Research, Wagholi, Pune, India.

SavitribaiPhule Pune University

^{#2}Department of Mechanical Engineering, JSPM's Imperial College of Engineering and Research, Wagholi, Pune, India.

SavitribaiPhule Pune University

ABSTRACT

a Heat pipe is an essentially passive heat transfer device having high thermal conductivity. In hydraulic power pack use of traditional shell and tube heat exchanger would require lot of space, more power and maintenance cost. So heat pipe device is easily implemented for cooling of hydraulic oil. The heat pipe equipped hydraulic oil cooler uses a heat pipe module comprises of aluminium base block with oil channels machined on it. From hot oil chamber hot oil is passed through each modules of heat pipe. The hot oil passed through evaporator end transferring heat to condenser end. Heat transfer takes place by alternate evaporation and condensation of working fluid inside it. The condenser section of heat pipe is fitted with radial finned structure exposed to air to improve heat transfer rate. Ambient air is drawn over the fins using blower so that the fluid condensed and returns to heat source to repeat the process. In this hydraulic oil cooler heat is removed from hot oil to surrounding air using heat pipes and fins. The objective of the present experimental set up is to enhance the heat transfer of hydraulic oil using heat pipe. The study shows the heat pipe developments for cooling of oil for various applications like power pack, chemical industries etc.

Keywords— a Condensation, Evaporation, Fins, Heat pipes.

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I. INTRODUCTION

A heat pipe is a heat transfer device with an extremely high effective thermal conductivity. The heat pipe has its simple configuration is like a cylindrical vessel with the internal walls lined with a capillary structure or wick that is saturated with a working fluid. When the heat is input at the evaporator section, fluid vaporizes, this creates a pressure gradient in the pipe. This pressure gradient forces the vapour to flow along the pipe to a cooler section where it condenses giving up its latent heat of vaporization. The working fluid is then returned to the evaporator by the capillary forces developed in the wick structure. All heat pipes have an evaporator and condenser section where the working fluid evaporates and condenses, respectively. Heat

pipes can be designed to operate over a wide range of temperatures from cryogenic applications utilizing titanium alloy/nitrogen heat pipes, to high temperature applications using tungsten/silver heat pipes. Applications of heat pipe for cooling purpose is widely available. Heat pipe provided with cooling fins to enlarge its contact surface with surrounding medium. A heat pipe with cooling fin is generally termed as a heat pipe cooler.

II. LITERATURE SURVEY

There are a lot of studies on heat pipe and working fluid inside heat pipe Heat pipe is a passive cooling device with high thermal conductivity. Heat pipe is most reliable, efficient in heat transfer, low cost, and high performance

cooling elements [1].Applying the heat pipe methodology for cooling normally integrates with cooling fin to enlarge its contact surface with cooling medium. A heat pipe integrated with cooling fin is generally named as a heat pipe cooler.

Nowadays, cooling efficiency cannot reach a specified value, which is the main question of a heat pipe cooler. Most of studies on the heat pipe cooler ignored the considerations of the changed heat transfer property inside the heat pipe and investigated only the Integration structure of heat pipe cooler [2-5].Experimental studies on design and fabrication of coaxial dual-pipe heat pipe in connection with cooling water and cooling fin for enhancing the heat transfer property is carried out. The heat pipe is influenced by the outside cooling apparatuses is also considered.The coaxial dual-pipe heat pipe cooler has developed the adiabatic section and increased the effective cooling length of the heat pipe, which will further increase cooling power of the heat pipe cooler [6].Heat pipe is an efficient heat transfer device for maximum heat transfer. Ansys-based FEM models have been developed by Q. Wang,Y. Cao, and R. Wangfor heat pipe cooled piston crown. This numerical results are compared 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 [7]. The concept of heat pipe has also used in hydraulic motor pump for improving heat dissipation. The heat pipe radiator model is developed by YonglingFula, Meng Zhang, HaitaoQilb, Gaocheng An [8]. The obtained results Temperature distribution 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°C [8].When the heat pipe radiator model is used, the average oil temperature is found as 73.844 °C.It shows that the heat pipe radiator used in the hydraulic motor pump can work in an appropriate range. It can greatly reduce the temperature of the oil in hydraulic motor pump. This makes the oil in the hydraulic motor pump at a low level and also helps inreducing the temperature gradient.C. R. Kamthane, P. M. Khanwalkar has developed hydraulic oil cooler using the heat pipe cores that have a shroud with fins and other brackets and braces to secure the components into the reservoir. The study 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°C to 80°C of inlet and outlet of oil. Heat dissipated by single module is found near about200 watt, and with natural convection it will be 120 watt [9].

III.PROBLEM DEFINATION

Generally hydraulic fluid temperatures above 180°F (82°C) damage most seal compounds and accelerate degradation of the oil. The operation of any hydraulic system at temperatures above 180°F should be avoided, fluid temperature is too high when viscosity falls below the optimum value for the hydraulic system's components. This can occur well below 180°F, depending on the fluid's viscosity grade.To maintained stable fluid temperature of hydraulic system its capacity to dissipate heat must exceed its heat load preventing the system from overheating. There

are two ways to solve overheating problems in hydraulic systems either decrease heat load or increase heat dissipation of oil. Hydraulic systems dissipate heat of oil through the reservoir. Therefore, check the reservoir fluid level and if level is low, fill to the correct level. Also avoid any obstructions to air flow around the reservoir, such as a build-up of dirt. The ability of the heat exchanger to dissipate heat is dependent on the flow-rate and temperature of both the hydraulic fluid and the cooling air or water circulating through the exchanger. So there is need of such heat exchanger which can dissipate maximum heat compared to conventional system. Dissipating maximum heat cools oil which improves its viscosity. As the viscosity is more the pumping power require for oil will also be less this is an advantage of efficient oil cooler.

IV.DESIGN METHODOLOGY

A. Input Data:

Oil Grade = SAE 20 W 40

Specific heat of oil = 1.6987 kJ/kg °C

Oil flow rate = 0.028 Kg/s

Rated Oil pressure for system = 20 bars

Mass in kg/sec = (flow rate in Kg/s) X (density in Kg/liter)
= 0.0047 X 0.896 kg/liter
= 0.00421 Kg/s

Heat Generated in system = $p \text{ (Pa)} \times Q \text{ (m}^3\text{/s)}/1000$
= $(2 \times 10^6 \times 2.8 \times 10^{-5}) \times 1000$
= 0.056 kW

So based on the above calculations heat generated in the system is calculated. This amount of heat must be delivered into atmosphere. For this heat load suitable heat pipe is selected from standard chart.

B. Selection of Heat pipe:

TABLE I
MAXIMUM WATTS AT DIFFERENT
TEMPERATURES

DIAMETER	40°C	60°C
32 mm	15 WATT	18 WATT

C. Hydraulic Pump

Hydraulic Pump = Enerpac - Electric - 0.5HP

Electrically powered, 110/115V

Oil flow at full pressure = 20 (in³/min)

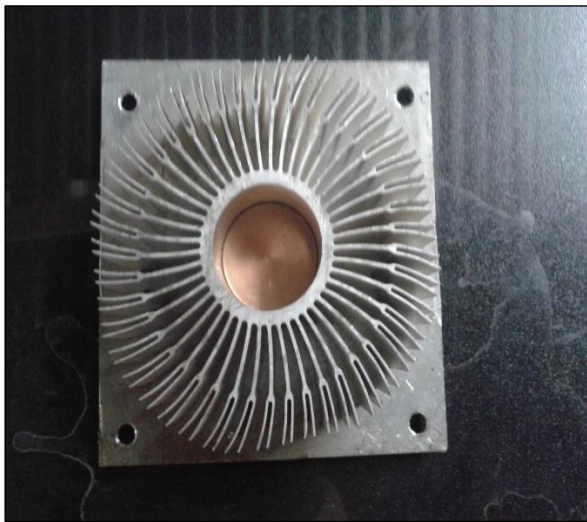


Fig. 1 Standard Heat Pipe

Above figure show the heat pipe selected for given heat load. 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

The above heat pipe can transfer heat up to 18 watts effectively. So three heat pipes are capable of for a given heat load are used in experimental set up.

D.Oil Tank



Fig. 2 Oil tank divided in two chambers

- Material used: Mild Steel
- Height = 150 mm
- Length = 350 mm
- Width = 170 mm

E. Heat pipe Module

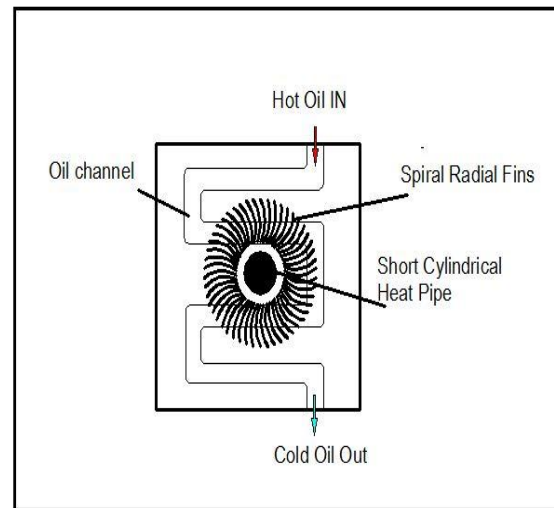
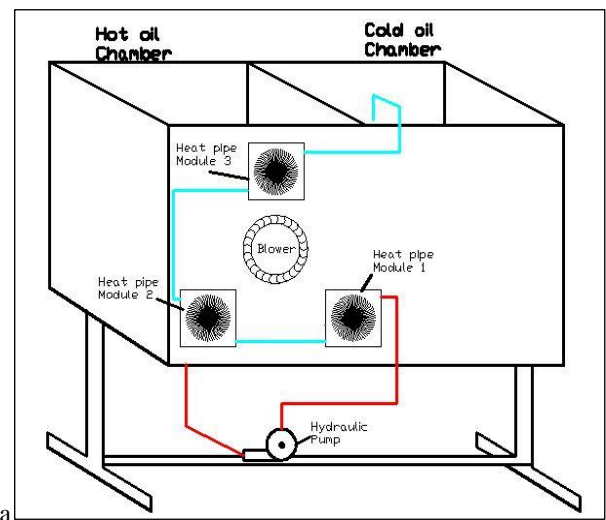


Fig.3 Heat Pipe Module

The heat pipe module contains block made up of aluminum in which oil channels and sealed with a top plate as shown in figure. The heat pipes are press fitted in the cavity of the aluminum block. Spiral fins are attached to the condenser section of heat pipe to enhance the heat transfer as shown

V.EXPERIMENTAL SETUP



The above set up consist of tank made up of mild steel divided into two chambers, hot and cold oil chambers as shown. Hydraulic pump of 0.5 HP is circulating oil through three modules of heat pipe. The oil is heated using heater coil. The oil is in contact evaporator section of pipe and heat from hot oil is transferred through working fluid of heat pipe. Hot oil flows from module 1 to module 3 as shown in above figure. The cold oil is collected in cold chamber. The radial blower is fitted centrally which forces air over the fins. Because of forced convection heat transfer rate increases. The cold oil is collected in a beaker and time is noted to measure oil flow rate. Once the cold oil temperature is known the heat transferred through the oil is calculated using relations,

$$Q = m \times C_p \times (T_h - T_c)$$

Where,

Q = heat is transferred from the system (KJ/s)

M = mass flow rate (kg/sec)

C_p = Specific heat of oil in kJ/kg °C.

$(T_h - T_c)$ = Temperature of hot oil at inlet and cold oil at outlet of heat pipe module

VI.RESULT & DISCUSSION

The model of heat pipe module with spiral fins is developed in ANSYS version R 14.5. The thermal analysis of spiral fins is carried out and obtained results are as follows:

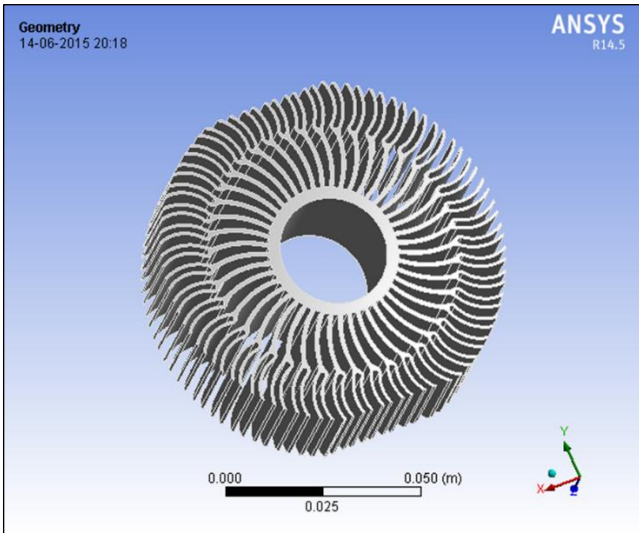


Fig.5 Spiral fin model

Detailed Mass Properties

Analysis calculated using accuracy of 0.990000000

Information Units kg - mm

Density = 0.000002660

Volume = 45749.346346060

Area = 106970.325514622

Mass = 0.121693261

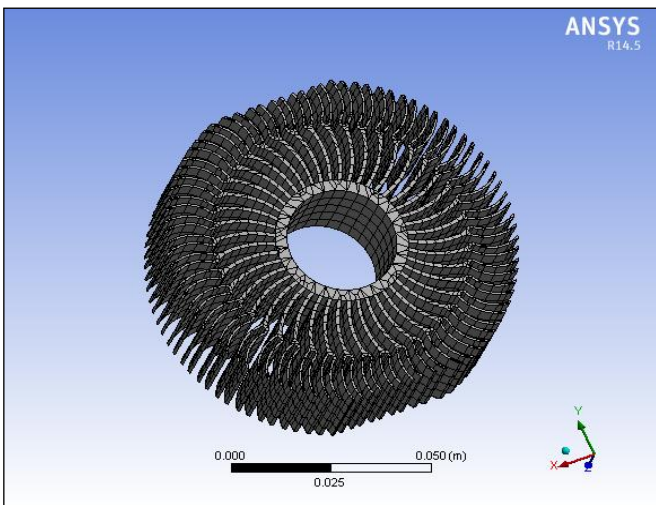


Fig.6 Meshed model of Spiral fins

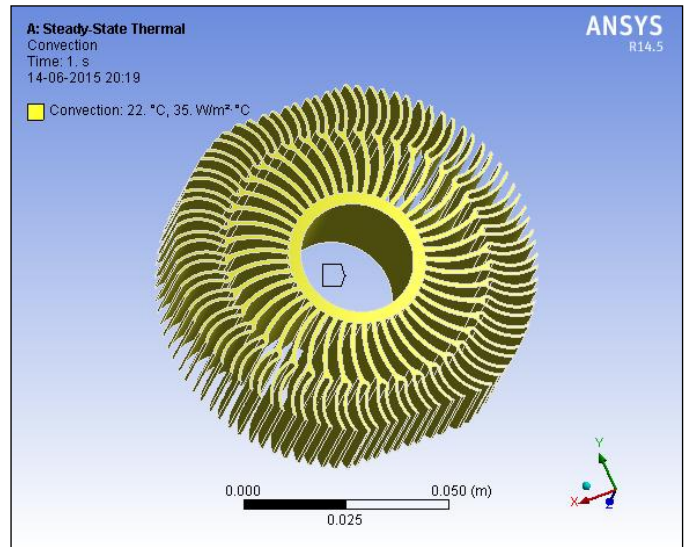


Fig.7 Thermal distribution of heat flux

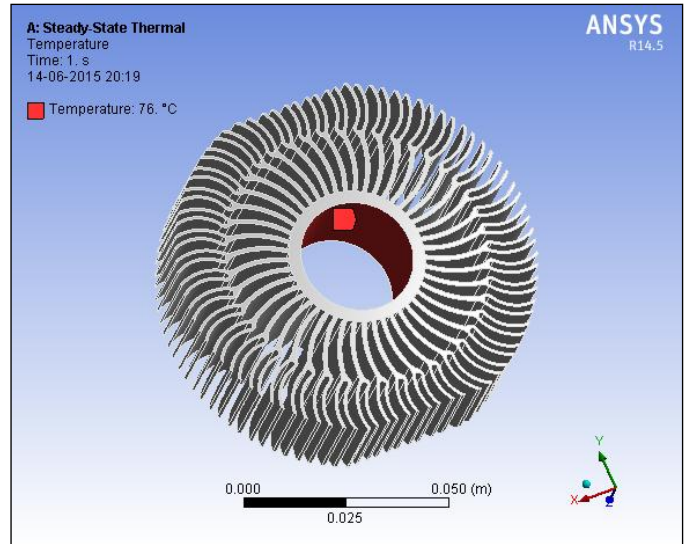


Fig. 8 Temperature Distribution

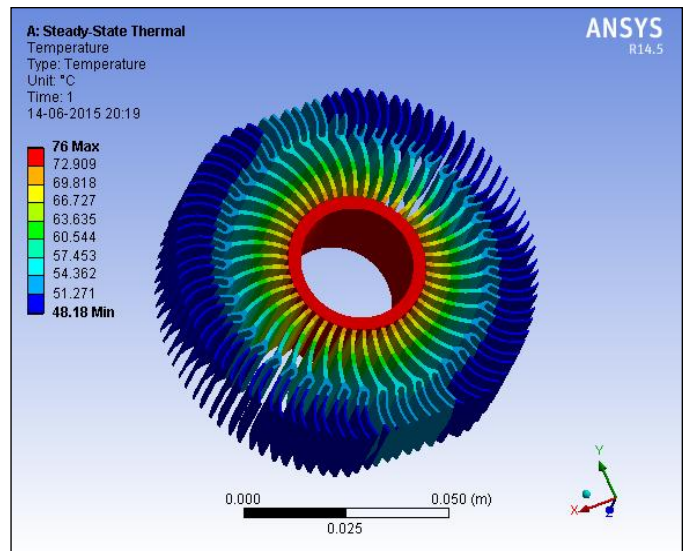


Fig 9. Temperature behaviour of spiral fins

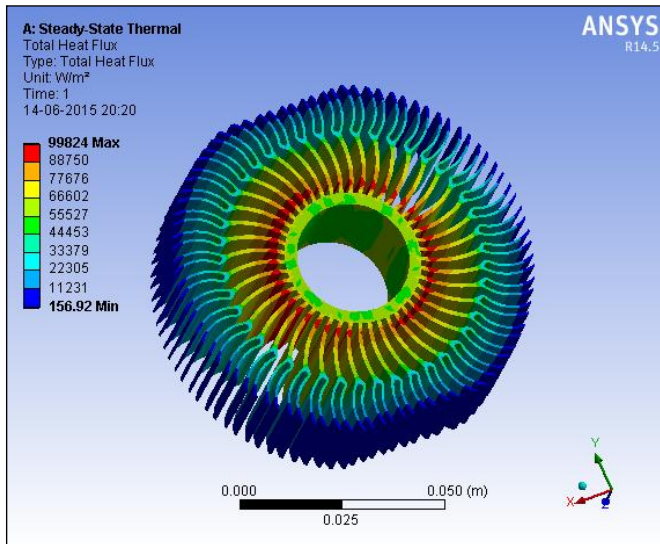


Fig.10 Rate of Heat Energy Transfer through Fins

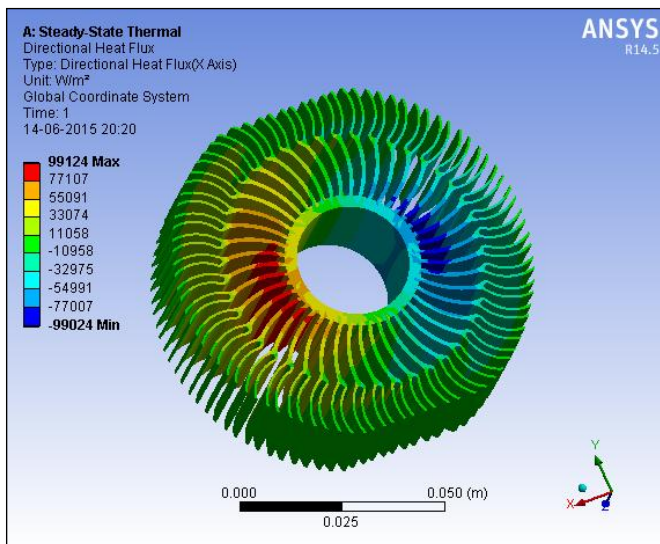


Fig.11 Rate of Heat flux Transfer through Fins

The maximum heat transferred through the spiral fins is 156.20 W/m^2 which covers the maximum fins surface. Theoretically the heat generated is 56 watts which is less hence design is safe.

VII. CONCLUSION

Theoretically heat generated by above hydraulic system is 0.056 Kw and Heat pipe of above size able to dissipate heat up to 18 Watts so three Heat pipes are suitable to transfer the heat load.

The above calculations shows that heat generated by hydraulic system is 0.056 kW and heat flux obtained from the analysis data is 156.20 W/m^2 so the system is safe and will not overheat

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