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Design development and analysis of novel intergral heat pipe cooling system for hydraulic power pack tanks

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ABSTRACT

Hydraulic power packs are most commonly used power sources in industry. The progress in recent years has offered high efficiency and reliable hydraulic components, yet hydraulic tank design is often neglected part of the development. Hydraulic power units are types of equipment, from which the user expects an energy saving and reliable operation with minimum maintenance problems. One aspect of the hydraulic tank design is prevention of overheating of the hydraulic oil.. Letting oil temperature rise beyond recommended limits can reduce the life of a system due to poor lubrication, higher internal leakage, a higher risk of cavitation, and damaged components. Keeping temperatures down also helps ensure the oil and other components last longer. Excess heat can degrade hydraulic oil, form harmful varnish on component surfaces, and deteriorate rubber and elastomeric seals. Operating within recommended temperature ranges increases a hydraulic system's availability and efficiency, improving equipment productivity .Finally, with more machine uptime and fewer shutdowns, it reduces service and repair costs Considering the benefits coolers offer, it's apparent that accurately sizing them is a paramount concern for design engineers. Under sizing obviously allows higher-than-recommended oil temperatures. But over sizing hurts system efficiency as well, by reducing temperatures below the recommended range and increasing costs with a larger-than-necessary purchase. Objective of this paper is to develop an integrated cooling system in the hydraulic tank itself by use of heat pipes and innovative fin structures. The hydraulic tank is to be fitted with oil cooler modules arranged in series on the tank surface lined along the wall of the tank. The use of heat pipe will result into better overall heat transfer whereas the innovative fin structure will offer maximum surface area in minimal space. A dedicated pump system with minimal power consumption is provided with system for effective flow of oil through the oil cooler system. Here the individual modules will cooled by a dedicated fan.

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I. INTRODUCTION

All electronic components, from microprocessors to high end power converters, generate heat and rejection of this heat is necessary for their optimum and reliable operation. As electronic design allows higher through put in smaller packages, dissipating the heat load becomes a critical design factor. Many of today's electronic devices require cooling beyond the capability of standard metallic heat sinks. The heat pipe is meeting this need and is rapidly becoming a main stream thermal management tool.Heat pipes have been commercially available since the mid 1960′s. Only in the past few years, however, has the electronics industry embraced heat pipes as reliable, cost-effective solutions for high end cooling applications. The purpose of this work is to explain basic heat pipe operation, review key heat pipe design issues, and to discuss current heat pipe electronic cooling applications.

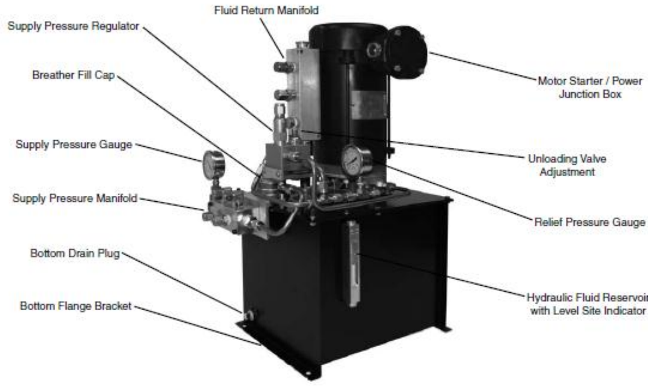

Fig.1. Hydraulic Power Pack[12]

The Hydraulic Power Pack (HPP) is stand alone unit with no assembly required other than filling the hydraulic reservoir with fluid. The unit is located as close as possible to the valve it will operate. For the protection against exposure to standing or runoff water, the unit is fixed on a flat level hard surface, such as concrete. The bottom flange bracket provide four bolt holes which should be used to fixed the unit place, minimizing vibration.[12]

Fill the reservoir to the midpoint of the hydraulic tank. Monitor the fluid level during startup of the system. Alternative hydraulic fluid can be used if they fall within the viscosity range in the operating temperature range of the system.[12]

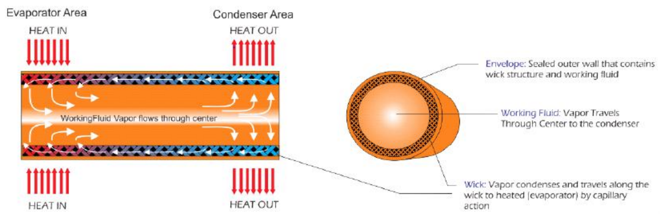

Fig.2. Heat Pipe Operation[1]

Heat pipes are passive two-phase heat transfer devices that attain low thermal resistance by exploiting the thermophysical properties of a working fluid. The working fluid operates inside a sealed envelope, typically copper for electronics cooling applications. A wick structure lines the interior wall to pump the liquid along the length of the pipe via capillary force. The copper tube is drawn under a vacuum, thus the fluid inside the pipe exists at the boundary between its liquid and vapor state,known as the saturation curve. Any amount of heat input through the copper wall vaporizes the liquid that is contained in the wick structure in the region known as the evaporator. The higher local pressure of this region drives the vapor and its sequestered heat to the colder, lower pressure region of the pipe known as the condenser. Here, the vapor condenses into liquid on the copper wall, passing off its latent heat of vaporization in the process. The wick structure then pumps the liquid back to the evaporator to absorb more heat. This process loops continuously as long as a temperature gradient exists between two points along the length of the heat pipe.[1]

II. LITERATURE SURVEY

In view of proposed paper work concerned, following few are the researchers have done their experimental study and investigated results which have been review as follows:
Darren Campo et al [1] studied, the enhancing thermal performance in embedded computing for ruggedized military and avionics applications. This experiment concluded that,the direct heat pipe integration or heat pipe bolt-on solutions give suppliers great flexibility to meet thermal requirements without compromising other design goals like size, weight, or device capabilities.
Dan Pounds et al [2] studied experimentally, the high heat flux heat pipes embedded in metal core printed circuit boards for LED thermal management. This experiment can be concluded that these novel low evaporative resistance wick structures will enable high heat flux dissipation at the circuit board level with the use of embedded heat pipes. These advanced heat spreaders will provide means of PCB level thermal management for next generation of high brightness LEDs.
G. Canti et al [3] studied, the transient behaviour of a heat pipe with extracapillary circulation. The result of study shows that the system can approach steady state condition,at a pressure of 4 bar and with a heat flux transferred of about 150 W/sq.cm, supporting an electic power step of about 1.8 kW.R K Sarangi et al [4] studied, the experimental investigations for start up and maximum heat load of closed loop pulsating heat pipe. It was observed that start up heat load does not vary with fill ratio. The optimum fill ratio depends on thermo physical properties of working fluid, operating temperatures and PHP parameters.
S.M. Peyghambarzadeh et al [5] evaluated, the thermal performance of different working fluids in a dual diameter circular heat pipe. In this study, the heat transfer performance of a 40 cm-length circular heat pipe with screen mesh wick is experimentally investigated. Results demonstrate that higher heat transfer coefficients are obtained for water and ethanol in comparison with methanol.
R. Yogev et al [6] evaluated, the PCM storage system with integrated active heat pipe. Experimental results indicate that, the active heat pipe configuration of PCM thermal storage has a potential to mitigate the effect of low thermal conductivity of the PCM.
William G. Anderson et al [7] studied,the intermediate temperature heat pipe life tests and analyses. The results indicate that the tested envelope materials and working fluids can form viable material/working fluid combinations.
CalinTarau et al [8] investigated,the variable conductance heat pipe operated with a stirling convertor. This investigation concluded that the VCHP was successfully tested with a high temperature Stirling convertor, all test objectives were achieved demonstrating proof-of-concept of ACT’s heat pipe.
Katharina Morawietz et al [9] studied, the integrated development and modeling of heat pipe solar collectors. This study concluded that the integrated development approach proposed represents a promising method to overcome current drawbacks of heat pipe solar collectors sustainably and thus exploit their potential successfully.
Steffen Jack et al [10] evaluated, the flat plate aluminum heat pipe collector with inherently limited stagnation temperature. . The study concluded that, this kind of collector a simpler hydraulic interconnection of the collector

array without problems of nonuniform flow, a longer lifetime of the solar fluid, a smaller expansion vessel and overall less expensive components inside the solar loop due to lower stagnation temperatures can be achieved.

Senthilkumar R et al [11] studied, the effect of inclination angle in heat pipe performance using copper nanofluid. The obtained experimental results depict that the nanofluids have a great potential for heat transfer which makes them suitable for use in many applications than the conventional cooling mediums.

III.EXPERIMENTAL SETUP

The testing setup is shown in fig. 3a and fig. 3b with the innovative fin structure and heat pipe modules. Three numbers of module are mounted on the wall of the hydraulic tank in series. Here the individual module are cooled by the dedicated fan. A dedicated pump system with minimum power consumption is provided with system for effective flow of oil through the oil cooler system.

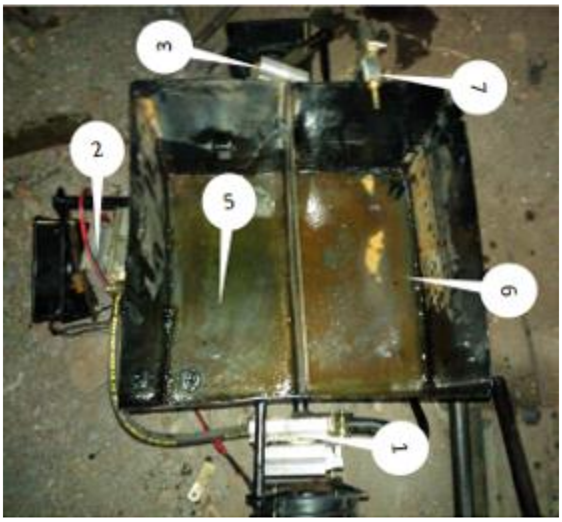

Fig. 3. Hydraulic tank with innovative fin structure and heat pipe module on the wall.

The test setup shown in fig. 3 with the innovative fin structure and heat pipe module. The 3 modules are mounted on the wall of tank in series. Here the individual module are cooled by dedicated fan. A dedicated pump system with minimum power consumption is provided with system for effective flow of oil. The hot oil from the system are collected in tank and with the help of pump the oil is supplied towards the heat pipe module. After flowing through the three module the cold oil is stored in another part of tank and then supplied towards the system.

The test setup shown in fig. 3 contain fin and heat pipe module (1,2,3), fan(4), hot oil chamber(5), cold oil chamber(6), flow control valve(7), oil flow channel(8) and pump(9).

The study is embodied as,

$$q = mc_p\Delta T = UA\Delta T_{lm} \tag{1}$$

Where,
qis heat transfer rate
m is mass flow rate
$c_p$is specific heat of fluid
ΔT is temperature difference
U is overall heat transfer coefficient
A is area

$$LMTD = \frac{\Delta T_I - \Delta T_{II}}{\ln(\Delta T_I/\Delta T_{II})} \tag{2}$$

Where,

$$\Delta T_I = T_{hi} - T_{co} \tag{3}$$

$$\Delta T_{II} = T_{ho} - T_{ci} \tag{4}$$

$T_{hi}$is hot oil inlet temperature
$T_{ho}$is hot oil outlet temperature
$T_{ci}$is cold oil inlet temperature
$T_{co}$is cold oil outlet temperature

$$C = \frac{(mc_p)min}{(mc_p)max} \tag{5}$$

Where,
C is capacity ratio

$$\varepsilon = \frac{T_{hi} - T_{ho}}{T_{hi} - T_{ci}} \tag{6}$$

Where,
$\varepsilon$is effectiveness

IV.RESULT & DISCUSSION

The results obtained from the study are given below,

Table I
Results of test setup

T_{hi}	T_{ho}	T_{ci}	T_{co}	m (Kg/s)	U (W/m^2k)	LMTD	q (W)
90	53	28	36	0.005	185.62	37.65	314.5
90	51	28	36	0.0058	235.27	36.32	384.54
88	52	29	35	0.0063	238.46	35.93	385.56
89	54	26	36	0.0065	245.83	34.96	386.75
88	48	28	36	0.0082	370.10	33.48	557.6

With increase in flow rate, LMTD decreases. Because of this the overall heat transfer increases which results the maximum heat dissipation from the system.

From above results following graphs are obtained,

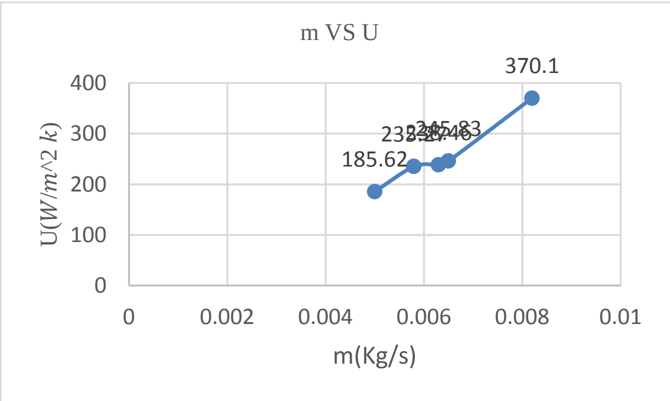

Fig. 4. A graph of flow rate (m) vs overall H.T. coefficient

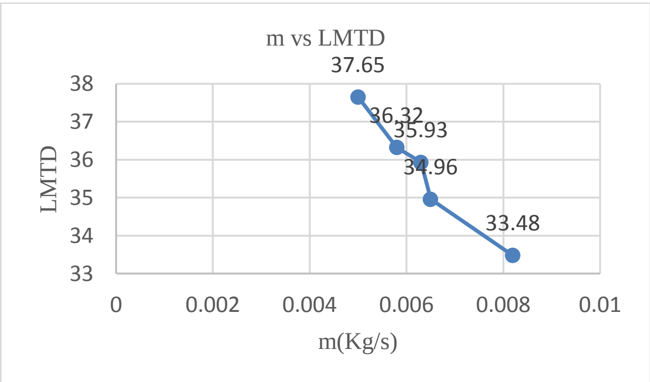

Fig. 5. A graph of flow rate(m)vs LMTD

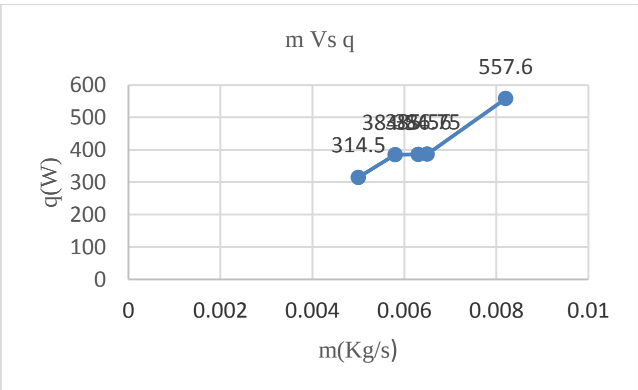

Fig. 6. A graph of flow rate(m)vsq

V.CONCLUSION

The above study concludes, the heat pipe and innovative fin structure module used in hydraulic tank increase heat dissipation from the system where it use. Because of this the life of parts in system increases which decreases the maintenance cost of the system. Because of maximum heat dissipation the time cycle of wax formation of oil increases that reduce the electricity cost. The above setup used in power pack of press machine and earth moving equipment, CNC machine controller cooling, this are the future scope of above study.

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