International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Experimental Analysis of Hybrid Vortex Cooling System

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Abstract: ***For an electronic system thermal management is a serious issue for maintaining its performance and reliability. Hot-spots is the other problem which causes damage to the system. In this section an experimental analysis is performed to eliminate the hot-spots by considering SWaP. A hybrid system is designed by using water and air as cooling fluid with the consecutive heat transfer mode such as conduction, convection and multiphase. The experimental heat inputs are 100W, 250W and 500W which are being dissipated by using 12W of axial fan. This system successfully reaches the room temperature at the expense of 30seconds. The heat dissipation enhancement by using this system is 28% over liquid cold plate with the Reynolds Number 6000-16000.***

Keywords: Liquid cold plate, embedded heat pipe, vortex generators, multiphase heat transfer.

1. Introduction

The thermal damage and performance of the system can be protected by using cooling system to remove high heat flux from computer chips. However, equally important field of high-power electronic devices has been experiencing a major paradigm shift from air cooling to liquid cooling over the last decade. Cooling technologies and development related to high power electronic devices include a variety of process ranging from phase-change cooling, forced convection cooling, natural convection cooling and micro heat exchanger cooling cooling.

The maximum limited temperature that can be borne by a silicon chip in electronic components is 120°C. The reliability of electronic components drops by 10% for each increase of 2°C in a normal operating temperature, and high temperature is a major reason for the malfunctioning or shortening life of electronic components. Thus, it is necessary to quickly remove high heat generated by electronic components for a normal operating temperature of under 70°C.

The methods used for solving the heat capacity of electronic components are forced convection, extended surfaces by enhancing their capacity as per applications. They can reduce the total thermal resistance from 0.6°C/W to 0.3°C/W. Increasing the surface area of fins results in an increase in cost and boosting the fan speed results in noise, vibration and more power consumption, which increases the probability of failure to electronic components. From various papers it comes to a conclusion that a combination of heat pipe and heat sink i.e. embedded heat pipe is one of the best solution.

In a heat sink with embedded heat pipes, the use of heat pipes to rapidly transfer heat from the heat source to the fins, without increasing the surface area of the fins or increasing the speed of the fan makes it possible to reduce the thermal resistance to under 0.3°C/W. From various papers it comes to a conclusion that a combination of heat pipe and heat sink i.e. embedded heat pipe is one of the best solution.

Thermal cooling for increasing heat fluxes and power loads in compact electronic packages is driving thermal solution designers away from the limitations of air cooling to liquid cooling in many demanding applications. To satisfy critical thermal management needs in applications as diverse as military/aerospace, medical equipment, power electronics, lasers, renewable energy and transportation. Liquid cold plates provide the top performance and reliability designers trust. Liquid cooling component cold plates include tube-in-plate, aluminum vacuum-brazed and copper brazed types for various applications. Tube-in-plate cold plate materials consist of copper or stainless steel tubes pressed into a channeled aluminum or copper extrusion or machined plate. Finally, copper cold plates that incorporate vertical fin technology (e.g. micro-channel technology) or for higher performance, specialized powdered metal construction. Liquid cold plate assemblies are designed specifically for each application's unique thermal/mechanical requirements. Liquid cooled cold plates can be engineered to perform with diverse coolants, including water, water/glycol solutions, dielectric fluids, oils and synthetic hydrocarbons, Polyalphaolefin (PAO).

Embedded heat pipe heat sink solutions produce excellent spreading of heat along the length of heat pipes embedded within a heat sink. Incorporating two-phase heat transfer principles means more efficient cooling. Heat pipes remove “hot spots” from the heat sink base, sending the heat across the heat sink base and maximizing air side fin efficiency. Designers also get high-heat flux heat dissipation capability (>300 W/cm2) with sintered heat pipes. And embedded heat pipes can offer a thermal performance improvement of up to 20% compared with typical aluminum or copper base spreaders — particularly in applications like electronics or computers, where the heat source is small relative to the area for fins. Thermal architects have more flexibility, too, because embedded heat pipes don't require changing the geometry of the heat sink. Heat pipes can be mounted to the base in several ways, including direct soldering into grooves on the heat sink base with the heat pipes in direct contact with heat source, or embedded into holes using own proprietary expansion process that gives an extra-efficient metal to metal thermal interface. Because of our pliable sintered powder metal wick structure. Heat pipes are effectively bent, shaped, flattened and configured to fit into the tightest of applications. To make the best thermal contact, the heat pipes are soldered or adhesively bonded into the metallic heat sinks. Procedures for making these solder or adhesive bonds and the material used have been proven over and over again to withstand and survive the toughest temperature extremes and vibration environments.

Heat spreader cold plate solutions offer several options to obtain the optimum thermal performance for protecting hi-tech equipment and electronics. Heat spreader cold plates gives high-efficiency heat transfer without moving parts in space and weight-constrained applications through compact. Heat spreader cold plates transfer heat from sources such as electronic components, rejecting it to ambient air (through forced or natural convection) or liquid coolants (water, glycol/water mixtures, dielectric fluids, polyalphaolefin or PAO). These types of cold plates are well suited for operating in harsh environments, including extreme temperatures/humidity, shock and vibration. Heat spreader cold plates can offer from two to 50,000+ times the thermal conductivity of solid materials like aluminum and copper.

2. Experimental Method

Experimentation is in order to get performance of liquid cold plate with spiral grooved over liquid cold plate attached to embedded heat pipe.

A. Experimental set up

The construction of the cooling system is designed considering the heat source of Nichrome wire Honeycomb 100W, 250W, 500W, heater of 100×100mm. This cooling system consists of cooling fluid tank, hose, flow regulator, spiral grooved liquid cold plate, heat pipe, spiral radial fins and air axial fan.

The temperature of the heater reaches to 90° C when the heater is fully heated. The cooling system is arranged on the top surface of the heater. The cold plate is screwed with the heater and thermal grease is applied to prevent thermal resistance and air gap in between. The cold plate of 100×100×25mm is spiral grooved made-up of Aluminum of h=20W/m^{2}K the grooves are continuous to provide flow path to fluid and to cover the heat source surface area completely. This grooves path is obstructed by inserting ribs as a vortex generator and flow diversion. The plate is attached with the centrally grooved for heat pipe, immersing evaporating section in the water of 15mm depth. The diameters of spiral grooves are for fluid flow is of 16mm pitch and a 32mm is centrally grooved for assembling heat pipe at center. Cold plate is provided with diagonal inlet and outlet for the liquid coolant. The heat pipe has total length of 75mm and diameter of 32mm.

A spiral radial fin is used for providing condensing cooling of heat pipe made up of aluminum (h=20W/m^{2}K of material). Heat pipe and fins are press fitted and thermal grease is applied to seal them perfectly. Fin is selected through its geometry as it is easy to assemble due to central hole and maximum diameter of fins is 90mm with the surface area 0.256m^2, total number of fins are 56 with fin width 3mm, gap between fin is 5mm and length of fin is 26mm. the height of heat pipe at condensing section is covered by fins which reduces the total height of the assembly to 85mm. The 12W axial fan is used for providing forced convection to the fins with the varying volume of air between 80-90CFM. Fan is mounted axially facing to the fins to blow the air on the fins to enhance cooling rate of fin. The height of fan is 115mm from fins. Axial fan is fitted at this height to provide the uniform distribution of air in the block. This cooling assembly is enclosed in the box of 100×100×200mm block with at its top the fan.

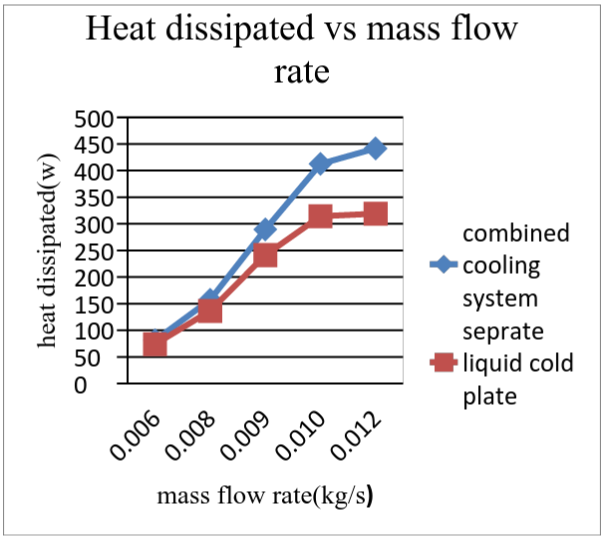
This system is supplied with the liquid coolant from the cooling fluid tank of capacity 4L assembled at a height of 500mm from the liquid cold plate. Liquid is circulated externally over the heat source in the liquid cold plate. The hose of 25mm in diameter is used to supply the coolant from tank to plate.

B. Experimental Procedure

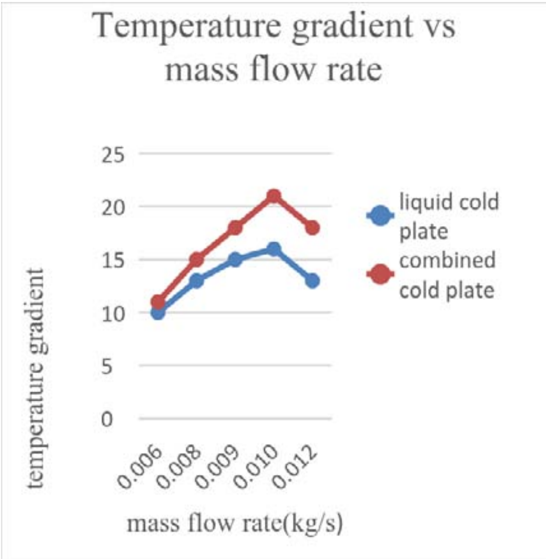
The cooling liquid, water is filled with coolant and heater is put to heat. The flow regulator allows the fluid to flow through the hose and enter to the spiral grooved aluminium plate. The water is allowed to flow through the spiral grooved path of the cold plate to absorb heat of the heater and the hot water is drain out. When the water is circulated through the plate the heat transfer from the water to the evaporation section of heat pipe is supplied. The heat from the evaporation section of the heat pipe is given out to the fins at the condenser section of heat pipe and the atmospheric air is blown on the fins to provide forced convection.

The heat transfer from the heater is given to atmosphere at two points viz., at water outlet and at atmospheric air through axial fan.

C. Results and discussion



A graph is plotted of heat dissipation against mass flow rate of the water (kg/s). it is observed from the following graph that amount of heat dissipated by the separate cooling system at the same mass flow rate is lesser than the amount dissipated in the combined cooling system (Hybrid cooling system). The amount of heat dissipation by separate system is degrading with the increasing mass flow rate from 0.26W to 0.6792W in comparison with the combined system with heat dissipation of 0.2926 to 0.92186W. As the mass flow rate is increasing the performance of combined system is improving then seperate liquid cooling system.



A mass flow rate is kept constant and the temperature at inlet and outlet of water is measured and difference between them is calculated. The temperature gradient by using the same mass flow rate and same set-up is recorded and it is observed that the temperature at the outlet of the liquid is increased. The water absorbs heat more than the heat in separate case. The performance of the liquid cold plate is enhanced when it is used in combination with the embedded heat pipe system. The performance of liquid cold plate in separate system decreases gradually as the mass flow rate is increased after 0.0103kg/s. the nature of the linear trendline shows is divergence as the mass flow rate increases the temperature gradient of the combined liquid plate system increases than in separate system.

3. Conclusion

In present work theoretical and experimental study carried out.

1) The heat dissipation rate increases than the individual system performance. A liquid cooling system gives a maximum enhancement of 28% than using individual liquid cold plate to hybrid cooling system.
2) As mass flow rate of water is increasing the temperature of hot water at outlet is increased.
3) Maximum temperature gradient in water jacket in combined case is 18 degree.
4) Maximum heat dissipated by water jacket system in separate case is 133.56 KW/hr
5) Maximum heat dissipated by water jacket system in combined case is 184.94 KW/hr

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