International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 2, February- 2013

Experimental Investigation Of Liquid Cooling System For Electronics Cooling

Chandra Sekhar P[1], A Ramakrishna[2]

PG Student [1], Professor [2]
Department of Mechanical Engineering, BVC Engineering College, Odalarevu - 533 210, Andhra Pradesh, India

Abstract

The electronic components have been ruling the world since few decades. Heat dissipation in the electronic components is being a critical issue with the development of chip integrated circuits. Gradual decrease in size of the components has resulted in drastic increase of the amount of heat generation per unit volume. In the present work a copper water block is used as heat sink having overall dimension 38×38×2.5 *mm. Diluted Ethylene glycol at volume fractions of 20%, 40%, 60% and 80% and pure water are used as cooling fluids. The surface temperature of the aluminum block is tested at different flow rates of water and diluted ethylene glycol. The temperature of the block is maintained below 45°c when water is used. The convection heat transfer coefficient of water flowing through the copper tubes is increased with increasing the flow rate is observed. The effect of Ethylene glycol is compared with pure water.*

In the present work

Nomenclature

d = inner diameter of copper tube, m
Q = heat transfer rate to the water, W
Q_{loss}= loss of heat energy, W
Q_{input} = heat input to the heater, W
m = mass flow rate of water, Kg/s
C_p = Specific heat, Kj/(kg-k)
ΔT = Temperature difference, K
T_i = inlet Temperature of water, K
T_o= outlet Temperature of water, K
h_w = convection heat transfer coefficient, W/m^2K
k = thermal conductivity, W/mK
Nu = Nusselt number
Re = Reynolds number
V = velocity of fluid, m/s
EG = Ethylene glycol
l = litres

Subscripts
i = inlet
o = outlet
w = water

Greek
μ = absolute viscosity of fluid [kg/ms]
ρ = fluid density [kg/m^3]

1. Introduction

With the development of microprocessors, heat dissipation problems become more and more serious. They have made its way into practically every aspect of modern life, from toys and appliances to high speed computers. An electronic component depends on the passage of electric current to perform their duties, and they become potential sizes for excessive heating since the current flow through a resistance is accompanied by heat generation.

According to Moore's law the number of transistors mounted on a chip gets doubled for every two years. As the number of transistors increase with development of chip integration technology increases the power draw and heat load to dissipate during operation increases. With the development of chip integrated circuits gradual decrease in size of the components has resulted drastic increase in the amount of heat generation per unit volume. Unless they are properly designed and controlled high rates of heat generation result in the failure of electronic component due to high operating temperature. The failure rate of electronic components increase with increase in temperature. A hot spot created within the electronic components due to low transfer rates seems to be major failure problem. Therefore thermal control has become increasing important in the design and operation of electronic equipment.

As a result of increasing heat loads and heat fluxes conventional cooling technologies such as fan heat sink are unable to absorb and transfer the excess heat. As a result it requires large fans and large heat sinks or new techniques are needed to improve the heat removal

ISSN: 2278-0181
Vol. 2 Issue 2, February- 2013

capacity. The heat density of the new-generation chips is predicted to exceed 100 W/cm^2 in the near future .As a result, it will be very difficult for the traditional air cooled heat sinks to keep the junction temperature below acceptable values. Another concern is the relatively large size of the air cooled heat sinks which defies the market demand for more compact electronics devices [1]. It will be directed toward micro channels, which invariably involve cooling channels in blocks, as opposed to mini and larger diameter channels that have individual confining walls and are usually thermally well controlled. Using commonly accepted definitions of micro channels, the hydraulic diameter will be in the range 10–200 mm. The length of the flow passages will be on the order of 10 000 micro meter [2].

Steinke and Kandlikar presented a comprehensive review of conventional single-phase heat transfer enhancement techniques. They discussed several passive and active enhancement techniques for minichannels and micro channels. Some of their proposed enhancement techniques include fluid additives, secondary flows, vibrations, and flow pulsations [3]. The volumetric heat dissipated by computer equipment at each level of the package from the chip to the chassis is having a tremendous impact on the thermal management of computer equipment. Because of the consumer's insatiable desire for increased performance, the competitive pressures are driving the computer manufacturer to pack as much processor/memory performance within the smallest volume possible. The consumer views high performance in a compact package as a benefit. These market pressures seem to be in direct conflict with the desire to continue to provide air cooling solutions for the foreseeable future. Because of these trends in power and package design, other cooling technologies beside air are now becoming viable, techniques, but each must be weighed with many other factors that influence the cooling technology selected. These factors will be discussed along with two specific IBM server packages and their associated cooling technology employed. Finally a microprocessor liquid cooled minichannel heat sink will be described and its performance presented as it applies to a current microprocessor (IBM Power4) chip [4]. Cooling a Microprocessor Chip-Heat spreading, choice of thermal interface materials and proper heat-sink design can enhance cooling of microprocessor packages and systems [5]. The flow of a locally heated liquid film moving under the friction of gas in a channel is considered through theoretical and numerical modelling and conducting experiments. Theoretical investigation predicts that at $Re_l/Re_g < 0.35$ the main driving force for the film is the friction at the liquid – gas interface. In experiments it was revealed that a liquid film driven by the action of a gas flow in a channel is stable in a wide range of liquid/ gas flow rates. A map of isothermal flow regimes was plotted and the lengths of smooth region and region of 2D waves were measured. It was found that the critical heat flux at which an initial stable dry patch forms for a shear-driven liquid film can be several times higher than that for a vertical falling liquid film, which makes shear driven liquid films more suitable for cooling applications. Temperature distribution at the film surface was measured by an infrared scanner and it was found that thermo capillary tangential stresses may exceed tangential stresses caused by the friction of the gas, which indicates a significant Marangoni effect on the film dynamics [6].

Saturated critical heat flux (CHF) is an important issue during flow boiling in mini and micro channels. To determine the best prediction method available in the literature, 2996 data points from 19 different laboratories have been collected since 1958. The database includes nine different fluids (R-134a, R-245fa, R-236fa, R-123, R-32, R-113, nitrogen, CO_2 and water) for a wide range of experimental conditions. This database has been compared to 6 different correlations and 1 theoretically based model. For predicting the non-aqueous fluids, the theoretical model by Revellin and Thome [Revellin, R., Thome, J.R., 2008. A theoretical model for the prediction of the critical heat flux in heated micro channels. Int. J. Heat Mass Transfer 51, 1216–1225] is the best method. It predicts 86% of the CHF data for non-aqueous fluids within a 30% error band. The data for water are best predicted by the correlation by Zhang et al. [Zhang, W., Hibiki, T., Mishima, K., Mi, Y., 2006. Correlation of critical heat flux for flow boiling of water in mini channels. Int. J. Heat Mass Transfer 49, 1058–1072]. This method predicts 83% of the CHF data for water within a 30% error band. Some suggestions have also been proposed in this paper for the future studies [7].

The interface temperature decreases with increasing the volume flow rate and convective heat transfer coefficient increases with increasing the flow rate [8].

2. Experimental setup

The general layout of experimental setup is shown in Fig.1. The major components are heated aluminium block, heat sink made with copper plate and copper tubes, pump, high density cartridge heater and air cooled cross flow heat exchanger. An aluminium block of size 38 × 38 × 70 mm which simulates the heat generated by any electronic equipment is used as the heated block. A hole is precisely machined in the aluminium block to insert the high density cartridge heater of capacity 150 W. Any air gap between the heater and the hole would damage the heater, so heater is fitted in to the hole carefully such that there is no air gap between the two. For heat sink copper tubes are brazed to the copper plate. The numbers of copper tubes are 18.The length of each copper tube is 40 mm having inner diameter 0.36 mm. The overall dimension of copper plate is 38 × 38 × 2.5 mm. The top surface of aluminium block and bottom surface of copper plate are polished to minimise the gaps. Two K type thermocouples are inserted into the surface of the aluminium block at different locations to measure the surface temperature of the heated aluminium block. Another two K type thermocouples are used to measure the outlet temperature of fluid from the heat sink and inlet temperature to the heat sink.

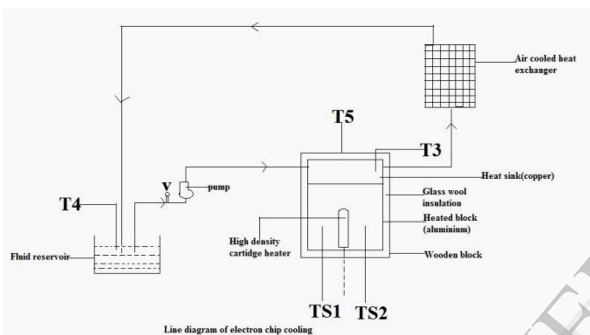

Fig.1. Line diagram of experimental setup

Copper heat sink is placed firmly on the top surface of the aluminium block by using spring force to decrease the thermal resistance. To improve the thermal conductance between the heat sink and heated aluminium block, thermal interface material (TIM) is applied. To minimise the thermal losses to the surroundings glass wool of thickness 40mm is provided all around the heat sink and heated aluminium block assembly. The whole assembly is placed inside a wooden box of size 120×120×150 mm. One more thermocouple is attached to the wooden box to find out the temperature of the insulation provided. The inlet and outlet diameters of heat sink are 10 mm and 7 mm. A pump having capacity 4 l/min is used to circulate the fluid. A valve is provided between the pump outlet and heat sink inlet to regulate the flow of fluid. An air cooled cross flow heat exchanger is used to decrease the temperature of the hot fluid to room temperature. A dimmer stat is used to supply electric current through the high density cartridge heater at any required voltage. By using voltmeter and ammeter the supplied voltage and current to the heater is measured. A plastic vessel of 5 l capacity is used as a reservoir.

2.1Details of heat sink and aluminium heated block

The heat sink and aluminium heated block is shown in Fig .2 and Fig.3 respectively. 18 number of copper tubes were brazed on to the copper plate of overall dimension 38 × 38 × 2.5 mm. The inner and outer diameters of the copper tube are 0.36 mm and 1.0 mm respectively. The length of each copper pipe is 40 mm. The copper tubes were inserted in to two more copper tubes of having inner diameter 5 mm. The fluid enters into one copper tube (larger diameter) and leaves from the other tube after flowing through the copper tubes of smaller diameter.

Fig.2. Copper heat sink

A solid aluminium block of overall dimensions 38 × 38 × 70 mm is used as heated block to simulate any electronic device. A hole was precisely machined in the aluminium block at the bottom surface to insert the high density cartridge heater. The diameter and length of the heater is 10 mm and 40 mm respectively. To measure the surface temperature of the heated aluminium block two K type thermocouples were inserted in to the top surface of the aluminium block.

Fig.3. Heated aluminium block

3. Experimental procedure

Initially the setup is tested to ensure that there is no leak in the circuit. For this without giving any heat flux the setup is run with pure water. By using dimmer stat constant heat flux is applied to high density cartridge heater. The applied heat input is 106 W. Flow rate of water is regulated by using a control valve and the flow rate is measured by using a measuring jar. The flow rate is in between 0.3 to 1.4 litres per minute. For each flow rate the inlet and outlet temperature of water, surface temperature of aluminium block and surface temperature of wooden box are taken periodically by using digital temperature indicator. The readings are taken till the system reaches steady sate. Ethylene glycol is diluted with water at different volume fractions of 20%, 40%, 60% and 80%. For each volume fraction the surface temperature of the aluminium block is measured at different flow rates. The results are compared with that of pure water. The Experimental setup is shown in Fig.4.

Fig.4. Experimental setup

3.1 Calculations

Heat loss is calculated from energy balance equation and the loss is 4% of the heat supplied. Heat energy carried away by water is given by

$$Q = m\, c_P\, \Delta T = m\, c_P\, (T_o - T_i) \quad (1)$$

Heat loss is calculated by using

$$Q_{loss} = Q_{Input} - Q \quad (2)$$

Reynolds number is given by

$$Re = (d_i V \rho)/\mu \quad (3)$$

Convective heat transfer co efficient is calculated from Nusselt number which is the function of Reynolds number and prandtl number.

$$h_w = (Nu \times K)/d_i \quad (4)$$

4. Results and Discussions

The surface temperature of the aluminium block is the indication of performance of the cooling system. The surface temperature of the aluminium block at different flow rates of water is shown in Fig.5. From the graph the surface temperature of the aluminium block decreases with increase in flow rate.

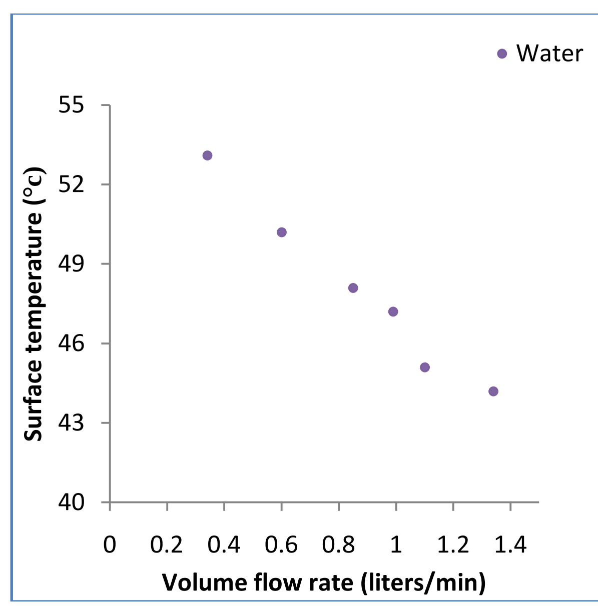

Fig.5. Effect of volume flow rate of water on surface temperature.

From the Fig.5 the surface attain a temperature of 44.2^{0}C when the volume flow rate of water is 1.34 litres per minute. Highest surface temperature is obtained at a flow rate of 0.34 litres per minute. In the present work a temperature reduction of 8.9^{o}C is obtained at 1.34 l/min when compared to the flow rate of 0.34 l/min.

The surface temperature of aluminium block is shown in Fig.6 diluted ethylene glycol is used. From the graph it is clear that the surface temperature increases when ethylene glycol diluted with water is used but the surface temperature is below the optimum temperature of the electronic equipment.

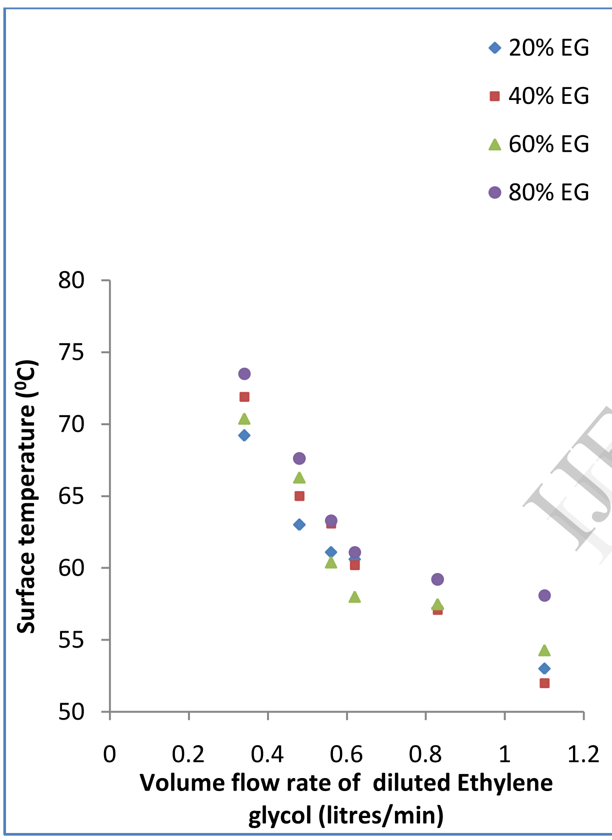

Fig.6. Effect of volume flow rate of diluted ethylene glycol on surface temperature.

From the Fig.6 the lowest surface temperature is 52^{o}C when the volume flow rate of 40% diluted Ethylene glycol is 1.1 litres per minute. When compared to water the surface temperature of the aluminium block is increased by 7^{o}C at this flow rate. The highest surface temperature of 73.5^{o}C is obtained at volume flow rate of 0.34 litres per minute with 80% diluted Ethylene glycol.

The effect of volume flow rate on convective heat transfer coefficient of water is shown in Fig.7. From the graph we can conclude that the convective heat transfer coefficient increases with volume flow rate.

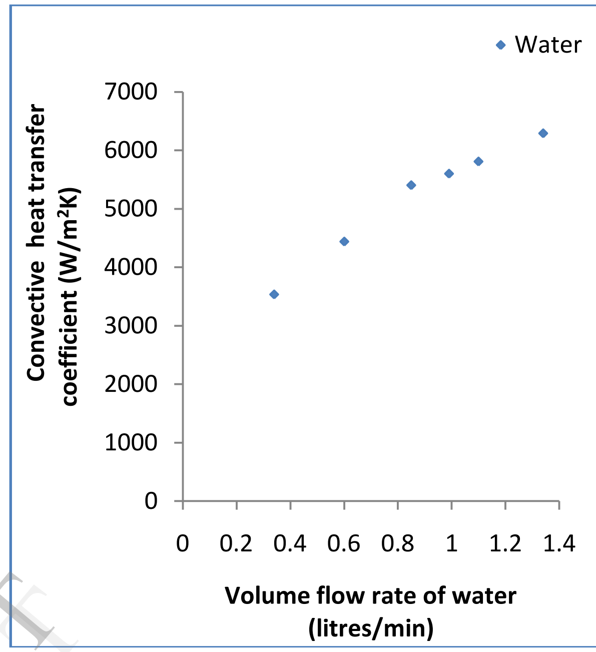

Fig.7. Effect of volume flow rate of water on convective heat transfer coefficient.

The convective heat transfer coefficient increases from 3533W/m^{2}K to 6290 W/m^{2}K when the volume flow rate changes from 0.34 litres per minute to 1.34 litres per minute.

5. Conclusion

The effect of volume flow rate on surface temperature of the aluminium block which simulates any electronic device is studied with pure water and diluted Ethylene glycol. The effect of the volume flow rate on convective heat transfer is studied. When the flow rate changes from 0.34 to 1.34 litres per minute, 16.76% reduction in surface temperature is observed. 43.83% increase in convective heat transfer coefficient is observed when the flow rate changes from 0.34 to 1.34 litres per minute. There is an increase in surface temperature when diluted ethylene glycol is used as cooling medium when compared to water.

7. References

1. M. E. Steinke and S. G. Kandlikar, "Single-phase heat transfer enhancement techniques in micro channel and minichannel flows," in *Proc. 2nd Int. Conf. Micro channels Minichannels*, Rochester, NY, Jun. 17–19, 2004, pp. 141–148.

2. Heat Transfer Engineering, Volume 25, Issue 3 April 2004, pages 3 – 12

3.Heat Transfer International Research Institute of Universite Libre de Bruxelles and Institute of Thermo physics of Russian Academy of Sciences, Av. Roosevelt 50, B-1050 Brussels, Belgium Accepted 24 May 2006. Available online 27 September 2006.

4. Université de Lyon, CNRS INSA-Lyon, CETHIL, UMR5008, F-69621, Villeurbanne, France; Université Lyon 1, F-69622, Villeurbanne, France

5. Electrometric micro channel cooling system for microprocessor by Kenneth Heat Transfer Engineering, Volume 25, Issue 3 April 2004 , pages 3 – 12

6. Heat Transfer International Research Institute of Universite Libre de Bruxelles and Institute of Thermo physics of Russian Academy of Sciences, Av. Roosevelt 50, B-1050 Brussels, Belgium Accepted 24 May 2006. Available online 27 September 2006.

7. Goodson, juan suntiago,Thomas Kenny , linan jinag

8. P. Selvakumar, S. Suresh, Convective performance of CuO/water nanofluid in an electronic heat sink, Exp.Therm.Fluid.Sci.(2012),doi:10.1016/j.expthermflu sci.2012.01.033