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Study of Heat Transfer Characteristics of A Multiple Jet Cooling

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Abstract: In this work an experimental study of cooling capabilities of impinging water and air jet array is presented. Investigations were carried out using electrically heated test plate. Heat flux in the range of 25 to 200W/cm^2, which is a typical requirement for cooling high power electronic components was dissipated using 0.25mm and 0.5mm diameter water and air jets arranged in 7X7 array with a pitch of 3mm. Tests were performed in the Reynolds number range of 1200 to 4500. Results shows higher values of heat transfer coefficient are obtained.Theeffect of positioning of jets are insignificant**.**

Keywords: Multiple jet cooling, Heat transfer enhancement, working fluids

I. INTRODUCTION

In the Todays life, electronic equipments have made their way in to practically every part, which is from electronic gadgets to high power computers. Electronic components have become probable sites for high heating, because of the heat generation due to resistance to current flow. The miniaturization of electronic system has caused significant increase in the heat generation per unit volume. If not properly designed and controlled there is risk of its reliability and safety. Increased operating temperature of electronic systems exponentially increases the failure rate of electronic equipments. The effective cooling and thermal control of electronic components has become important in the design and working of electronic equipments. The power consumption and heat dissipation from the electronic components is very vital. The restrictions in both speed and size of the electronic components compelled to upgrade the circuit design and materials to decrease power dissipation considerably through cooling technologies such as free convection and forced convection. More numbers of industries are interested in high speed computing. Most of the industries considered the cooling of electronic components as a thermal management problem and tried to solve it by incorporating the heat sinks. The requirements of high speed initiated smaller devices and systems. The speed of the personal computers is increasing constantly and is reaching a point where traditional cooling methods are insufficient. Because of this concern, the electronic world is looking for new and more effective cooling techniques. The solution to this problem may be through the introduction of new materials, latest cooling technologies and change in cooling technology concepts and methods of execution.

Brian p., Whelan. A.J., Robinson [1] have conducted experiments with a square array of 45 jets with a jet diameter of 1mm and pitch of 5mm to study the cooling capabilities of multiple water jets. They have used 6 types of nozzle geometries and a power density of 26 W/cm^2 for the investigation. The water jets were made to impinge on a heated copper circular surface of 32mm diameter. A constant jet-to-target distance of 2mm was used for the confined-submerged jet arrays and 20mm jet-to target distances were used for the free surface jets. All the jets were tested in the Reynolds number values between 800 to 10000. Higher heat transfer co-efficient were obtained with the confined submerged jets as compared to free jets. Contouring and chamfering the nozzle inlets showed a noticeable decrease in the pressure drop across the nozzle plate and increase in the surface averaged heat transfer co-efficient. A nozzle that gives the highest heat transfer was identified for a given pumping power.

The heat transfer study for a single water jet was carried out by Elison.B, Webb B.W [2]. The jet diameters of 0.584, 0.315 and 0.246mm were tested. The jets are designed in such a way that the jets were enough to provide a completely developed velocity profile. The Reynolds number (Re) is varied from 300 and 7000. Nusselt number varied as $Re^{0.8}$, the earlier studies have revealed that Nusselt number is proportional to $Re^{0.5}$. The heat transfer enhancement is due to the surface tension effects at the exit of the jet. The heat transfer co-efficient increases with increase in jet diameter.

II. NOMENCLATURE

A	Test plate surface area (cm^2)
d	Jet nozzle diameter (mm)
h	Heat transfer coefficient (W/cm^2C) ($q / (T_c - T_w)$)
k	Thermal conductivity(W/mK)
Nu	Nusselt number (hd/k)
P	Total heat transfer (W)
q	Heat flux (W/cm^2) (P/A)
Q	Total flow rate (ml/min)
R_e	Reynolds number (Vd/ν)
T_b	Bulk fluid temperature (^0C)
T_c	Test surface temperature (^0C)
T_a	Inlet air temperature (^0C)
V	Jet velocity (m/s)
ν	Kinematic viscosity (Ns/m^2)
Z	Nozzle height from chip surface (mm)
ΔT	Difference in temoerature between the test surface and air at inlet ($T_c - T_a$) (^{0} C)

III. EXPERIMENTAL APPARATUS AND TEST PROCEDURE

The Schematic arrangement of experimental setup is shown in Fig. 1. The experimental setup is designed and fabricated to carry out tests using different types of jet nozzles with the varying positions for horizontal and vertical positioning of jets. It consists of an air compressor auxiliary reservoir ,flow control valve and the test chamber. The test plate is made of copper and is heated using the heater. The test chamber consists of the test plate, jet nozzle block and the heating element. The variable voltage transformer, control system and display system are provided to control power supply to the heater. The test plate represents the surface of a typical electronic component and is made of Copper. Copper is selected because of its high thermal conductivity. The test plate is of 20mm x 20mm size and thickness 1mm. The heating element is a Nichrome wire of 16 gauge, 2 ohm, and wattage capacity of 1 kW. Two thermocouples arefixed on the test plate on the centre line.These thermocouples also provide indication of the surface temperature uniformity on the plate. The complete test assembly is mounted and insulated using a Teflon jacket. The leads from the thermocouples are connected to the control and display system. The functions of the control and display system includes (a) To vary the heat input to the test plate using the transformer (b) To display the test plate surface temperatures, input voltage and current using digital temperature indicator, voltmeter and ammeter and (c) Limit the maximum surface temperature and automatically cut off the power supply when the test plate temperature exceeds the set value. The flow rate from the receiver is varied using the regulator. The flow rate is measured using the water manometer.The experiments were conducted for vertical and horizontal positioning of jets

The jet nozzle block is made of stainless steel and it consists of the nozzle chamber and jet nozzle plate. The jet nozzle plate is made of 3mm thick stainless steel plate. The jet nozzle plate is designed to cover the nozzle chamber making it a single leak proof unit. Two jet nozzle plates having 0.25mm diameter holes were used. The holes are laser drilled and arranged in a square array of 7X7 with a pitch distance of 3mm between the holes. The distance between the jet nozzle plate and the test plate surface is maintained at 20mm. The test chamber includes a base tray, mounting plate, test plate and positioning screw held together by vertical support rods. The nozzle block is attached to the jet nozzle plate which could be moved verticallyand horizontally.

The water flow rate,air flow rate, power input and distance between nozzle exit and test plate were varied during the experiments. The test plate is allowed to reach a steady state before the acquisition of test data on water flow rate, power dissipation and test plate temperatures.Experiments were conducted by positioning the jets and the test plate in both horizontal and vertical positions. The values of test parameters used in the present study are given below:

- Jet diameter = 0.5mm and 0.25mm
- Heat flux range =25 to 200W/cm^2
- Flow Reynolds number range =1200 to 4500
- Distance between the nozzle head and test plate = 20mm
- Working fluid= Water and air

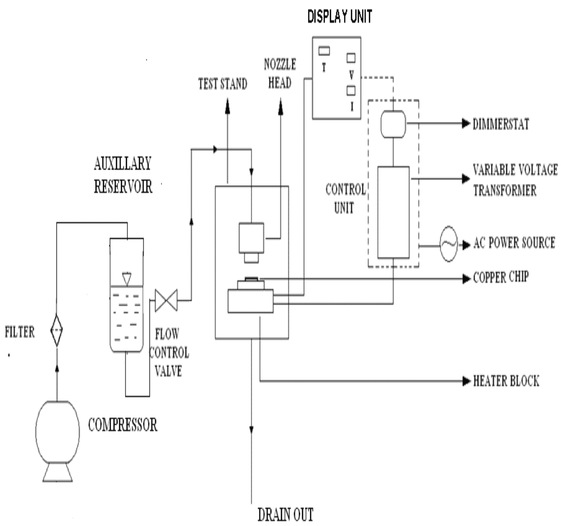

Fig1: Schematic diagram of multiple jet experimental setup

IV. RESULTS AND DISCUSSIONS

Fig 2Shows variation of heat transfer co-efficient with heat flux for different flow rates at d=0.5mm for water and air as a fluid. The flow rate varied and jet diameter to jet exit-to-test plate surface distances (Z) was kept at 20mm. The study of different working fluids were tested and the heat transfer coefficient increases with increase with flow rate in allworking fliuds.

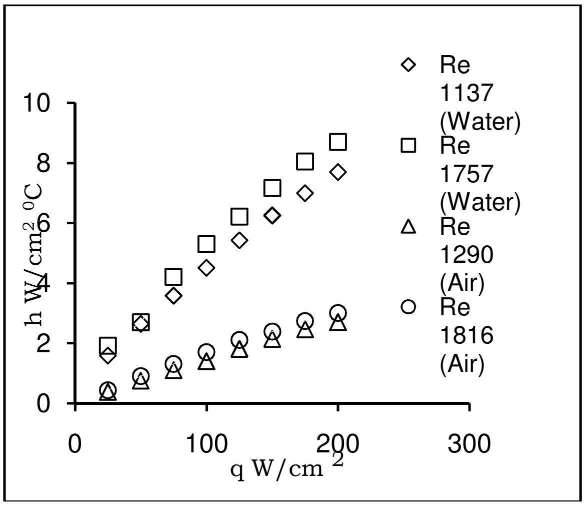

Fig 2: Variation of heat transfer co-efficient with heat flux for different flow rates at d=0.5mm for water and air as a fluid.

Fig 3 Shows variation of heat transfer co-efficient with heat flux for different flow rates at d=0.25mm for water and air as a fluid. The flow rate varied and jet diameter to jet exit-to-test plate surface distances (Z) was kept at 20mm. The study of different working fluids were tested and the heat transfer coefficient increases with increase with flow rate in all working fliuds.

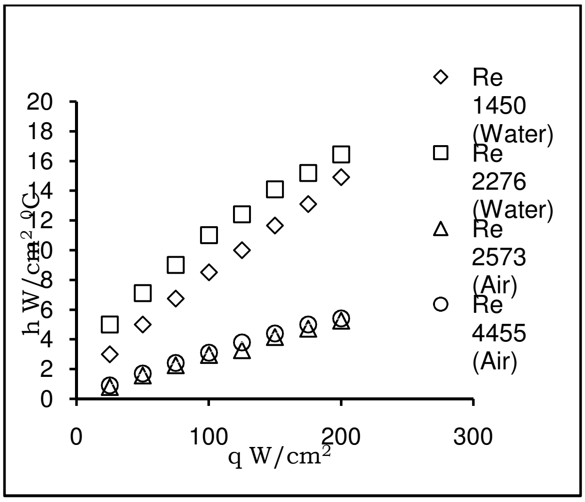

Fig 3: Variation of heat transfer co-efficient with heat flux for different flow rates at d=0.25mm for water and air as a fluid.

Fig 4 and 5 shows the variation of temperature differences between the test surface and the fluid inlet(Δt) as a function of heat flux . The study of different coolants were tested. Results have been plotted for the jet diameter of 0.5mm and 0.25mm. Thus, For a given value of (Δt), the heat transfer co-efficient increases with the increase in flow rate. It should be noted that the heat flux is also increasing with the variation of flow rate at the constant temperature difference (Δt).

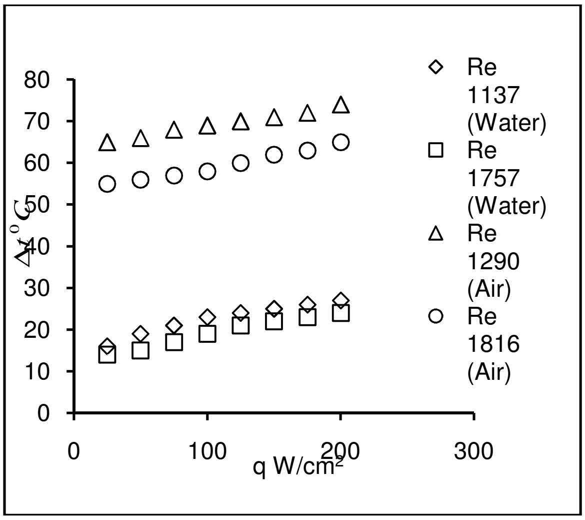

Fig 4: Variation of temperature differences with heat flux for different flow rates at Z=20mm and d=0.5mm for water and air as a working fluid.

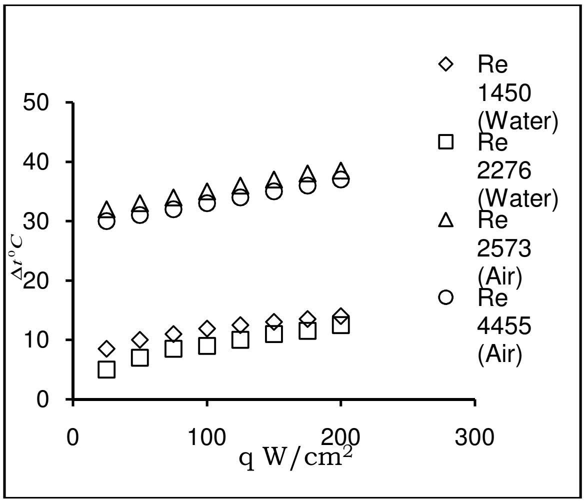

Fig 5: Variation of temperature differences with heat flux for different flow rates at Z=20mm and d=0.25mm for water and air as a working fluid.

V. .CONCLUSION

Experiments were conducted to study the enhancement of heat transfer using impingement of multiple water and air jets on an electrically heated test plate. Heat flux in the range of 25 to 200W/cm^2,which is typical for high power electronic components, was dissipated using multiple air jets of 0.5mm and 0.25mm diameter. Tests were conducted by varying the heat flux, water flow rate, airflow rate, distance between the heated test plate and the nozzle exit and by keeping the jet nozzle in both horizontal and vertical positions.

REFERENCES

I. Brian P., Whelan. A.J., Robinson. "Nozzle Geometry Effects in Liquid Jet Array Impingement" Applied Thermal Engineering, Vol. 29, Issue 11-12, (2009), pp. 2211-2221.
II. Elison. B, Webb B.W. "Local Heat Transfer to Impinging Liquid Jets in the Initially Laminar, Transitional and Turbulent Regimes." International Journal of Heat and Mass transfer, Vol. 37, no 8, (1994), pp.1207-1216.
III. MatteoFabbri, Shanjuan Jiang, Vijay K. Dhir. "Comparative Study of Spray and Multiple Micro Jets Cooling for High Power Density Electronic Applications". ASME International Mechanical Engineering Congress and Exposition, Washington, D.C., (Nov 2003).

IV. Jiji.L.J, Dagan.Z. "Experimental Investigation of Single-Phase Multi Jet Impingement Cooling of an Array of Micro Electronic Heat Sources". Proceedings of the International Symposium on Cooling Technology for Electronic Equipment, Hemisphere Publishing Corporation, Washington, D.C., (1987), pp. 333–351.

V. Wang.E.N, Zhang.L, Jiang.L, Koo.J.M, Goodson.K.E, Kenny.T.W, Maveety.J. G, Sanchez.E.A. "Micro-machined Jet Arrays for Liquid Impingement Cooling of VLSI Chips" Solid-State Sensor,Actuator and Microsystems Workshop; Hilton Head Island, South Carolina, June 2-6, (2002).

VI. Niranjan Murthy., V.Krishnan., A. Chennakesava Reddy. "Experimental Investigation of Heat Transfer Enhancement Using Impingement of Multiple Water Jets" International Journal of Heat transfer-Asian Research, Vol 39(4), [2010], PP 222-231.

VII. Niranjan Murthy., V.Krishnan., A. Chennakesava Reddy. "Parametric Study of Heat Transfer Enhancement Using Impingement of Multiple Water Jets" International Journal of Applied Engineering Research, ISSN 0973-4562,Vol 5 No 21, [2010], PP 3553-3564.

VIII. Dr. Niranjan Murthy, "***Heat Transfer Augmentation with array of multiple water jets*** ", February 2016 Volume 4 Issue S.I (01) , International Journal Advanced Technology in Engineering and Science (IJATES), ISSN: 2348-7550, PP: 41– 47 Impact factor: 2.870

IX. DrNiranjanmurthy"Optimized heat transfer for electronic cooling with impingement of multiple liquid jets"International journal of advanced management, Technology and engineering sciences, (IJAMTES) PP 1-10 Volume 7,Issue10, Oct2017. Impact Factor: 4.8 THOMSON Reuters research ID: H-2418-2017 Indexed Journal , Scopus suggested journal ID:50e4CF07B9164F83

X. MatteoFabbri, Shanjuan Jiang, Vijay K. Dhir. "Comparative Study of Spray and Multiple Micro Jets Cooling for High Power Density Electronic Applications". ASME International Mechanical Engineering Congress and Exposition, Washington, D.C., (Nov 2003).

XI. Jiji.L.J, Dagan.Z. "Experimental Investigation of Single-Phase Multi Jet Impingement Cooling of an Array of Micro Electronic Heat Sources". Proceedings of the International Symposium on Cooling Technology for Electronic Equipment, Hemisphere Publishing Corporation, Washington, D.C., (1987), pp. 333–351.

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