iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 Issue: IV Month of publication: April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4803

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Experimental Investigation of Multi Jet Air Impingement on Circular Pin Fin Heat Sink for Electronic Cooling

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Abstract: Pin fins are widely used as elements that provide increased cooling for electronic devices. Increasing demands regarding the performance of such devices can be observed due to the increasing heat production density of electronic components. For this reason, extensive work is being carried out to select and optimize pin fin elements for increased heat transfer. The work reported in this paper is an attempt to enhance heat transfer in electronic cooling appliances with use of multi jet air impingement on circular pin fin heat sinks under unconfined semi confined flow arrangement. In this study the effect of reynolds number, jet to jet spacing and nozzle plate to target surface heat sink (z/d), pin fin heat sink array, and height of pin fin heat sink on average nusselt (nu_a) are studied.an experimental investigation has been carried out for heat transfer enhancement over pin fin heat sink using 4×4 nozzle array of air jet impingement. Experimental study carried out on pin fin heat sink of 5×5 with fin diameter 4, 5, 5.5mm fitted on 60×60×6 aluminum heat sink for z/d ratio 5.5, 6, 7.experimental analysis for the reynolds number range from 6000 to 20,000 for constant heat supply of 10 , 20 , 30 w.the results revels that the air at smaller z/d ratio heat transfer is more effective. The multi jet air impingement shows average heat transfer coefficient increases with increase in reynolds number, total thermal resistance decreases with increase in reynolds number.

Keywords: Pin fins heat sink, electronic cooling, multi jet impingement, heat transfer

Nomenclature

A_{plate}	Area of Test plate (Ai plate), m^2
D	Nozzle diameter, m
Z	Nozzle to target surface spacing, m
C_d	Discharge Coefficient of air
C_p	Specific heat of air at constant pressure, J/KgK
d_o	Diameter of Orifice, m
g	Acceleration due to gravity, m/s^2
h	Heat transfer Coefficient of air, W/m K
h_{air}	Height of air column, m
h_w	Height of water column, m
K_a	Thermal conductivity of air, W/m^2K
M_a	Mass flow rate of air, kg/s
Q	Convective heat transfer to air, W
T_m	Mean Temperature, °C
T_{12}	Ambient temperature

Dimensionless Parameter

N_u	Nusselt Number
R	Reynolds Number
P_r	Prandal Number

I. INTRODUCTION

Today's rapid IT development like internet PC is capable of processing more data at a tremendous speed. This leads to higher heat density and increased heat dissipation, making CPU temperature rise and causing the shortened life, malfunction and failure of CPU.

Electronic portable devices, especially desktop PC, CPU have become challenging and popular nowadays (1). The new wave of computer technology making a crucial impact on modern world and desktop computer is widely employed in state-of-the-art industry. The failure rate of electronic components grows as an exponential function with their rising temperature [1].With the increase in heat dissipation from microelectronics devices and the reduction in overall form factors, thermal management becomes a more important element of electronic product design. Both the performance reliability and life expectancy of electronic equipment are inversely related to the component temperature of the equipment. The relationship between the reliability and the operating temperature of a typical silicon semi-conductor device shows that a reduction in the temperature corresponds to an exponential increase in the reliability and life expectancy of the device. Therefore, long life and reliable performance of a component may be achieved by effectively controlling the device operating temperature within the limits set by the device design engineers.

A. Literature Review

Luis A. Brignoni and Suresh V. Garimella Conducted a variety of nozzle configurations were tested to characterize and optimize the performance of confined impinging air jets used in conjunction with a pin-fin heat sink. Four single nozzles of different diameters and two multiple-nozzle arrays were studied at a fixed nozzle-to-target spacing, for different turbulent Reynolds numbers (5000<Re<20, 000). Enhancement factors were computed for the heat sink relative to a bare surface, and were in the range of 2.8–9.7, with the largest value being obtained for the largest single nozzle (12.7 mm diameter). Average heat transfer coefficients and thermal resistance values are reported for the heat sink as a function of Reynolds number, air flow rate, pumping power, and pressure drop, to aid in optimizing the jet impingement configuration for given design constraints[11]. Hani A. El-Sheikh and Suresh V. Gabriella, A variety of pin-fin heat sinks were mounted on the heat source and the resulting enhancement studied. Average heat transfer coefficients are presented for a range of jet Reynolds numbers (8000 Re 45000) and orifice diameters (12 7 38 1 mm). A total fin effectiveness was computed for the pinned heat sinks relative to the unpinned ones, and was in the range of 2.4 to 9.2; the highest value was obtained for the largest nozzle diameter. Results for the average heat transfer coefficient were correlated in terms of Reynolds number, fluid properties and geometric parameters of the heat sinks[12]. C.J. Kobus , T. Oshio, A comprehensive theoretical and experimental study was carried out on the thermal performance of a pin-fin heat sink. A theoretical model was formulated that has the capability of predicting the influence of various geometrical, thermal, and flow parameters on the effective thermal resistance of the heat sink[16]. N. K. Chougule G. V. Parishwad,, The work reported in this paper is an attempt to enhance heat transfer in electronic devices with use of multi air jet impingement on pin fin heat sinks with effusion slots on the nozzle plate. In this study the effect of nozzle jet exit velocity, heat sink array, and the height of pin fin on the average Nusselts number (Nu_a) are studied. Numerical investigation is carried out on multi air jet array of 3x3, 5x5 and 10x10(nozzle diameter 5, 3 and1.5mm) impinging on aluminum pin fin heat sink (pin fin array 4x4, 6x6 and 11x11 respectively) for H/d ratio of 3, 4 and 5 keeping the nozzle exit to pin fin tip distance 1d for each case[8] Jim G. Maveety they have investigated on square pin fin heat sink under jet impingement cooling. They investigated on Experimental and numerical results are presented for heat transfer from a C4 mounted organic land grid array (OLGA) thermal test chip cooled by air impingement. Five heat sink geometries were investigated for Reynolds numbers ranging from 9,000 to 26,000. The dimensionless nozzle-to-heat sink vertical spacing was varied between 2 and 12[9]. Akın Burak Etemoglu, he provides a comparative survey of advanced methods of cooling for electronic systems and an economical analysis of cooling electronic equipments using slot and circular jets[7]. Koonlaya Kanokjaruvijit, Ricardo F. Martinez-botas they studied on eight-by-eight jet array impinging onto a staggered array of dimples at Reynolds number 11,500 was investigated by the transient wide band liquid crystal method. The distance between the perforated plate and the target plate was adjusted to be 2, 4 and 8 jet diameters to examine its effect on the heat transfer performance[13].

II. PROBLEM DESCRIPTION

The schematic of a 4×4circular multi nozzle jet impinging on a 5×5 pin fin heat sink array which is to be analyzed is shown in Fig.1. The air jet is discharged through the round nozzle having length l and diameter d is directed normally towards the pin finned target plate with base 60 x 60 x 6mm, the pin fin are provided on top of plate on 50 x 50mm area, the sink is subjected to constant heat input (10, 20,30W) from bottom and except top surface all other walls are adiabatic. The material of the heat sink is Aluminum.

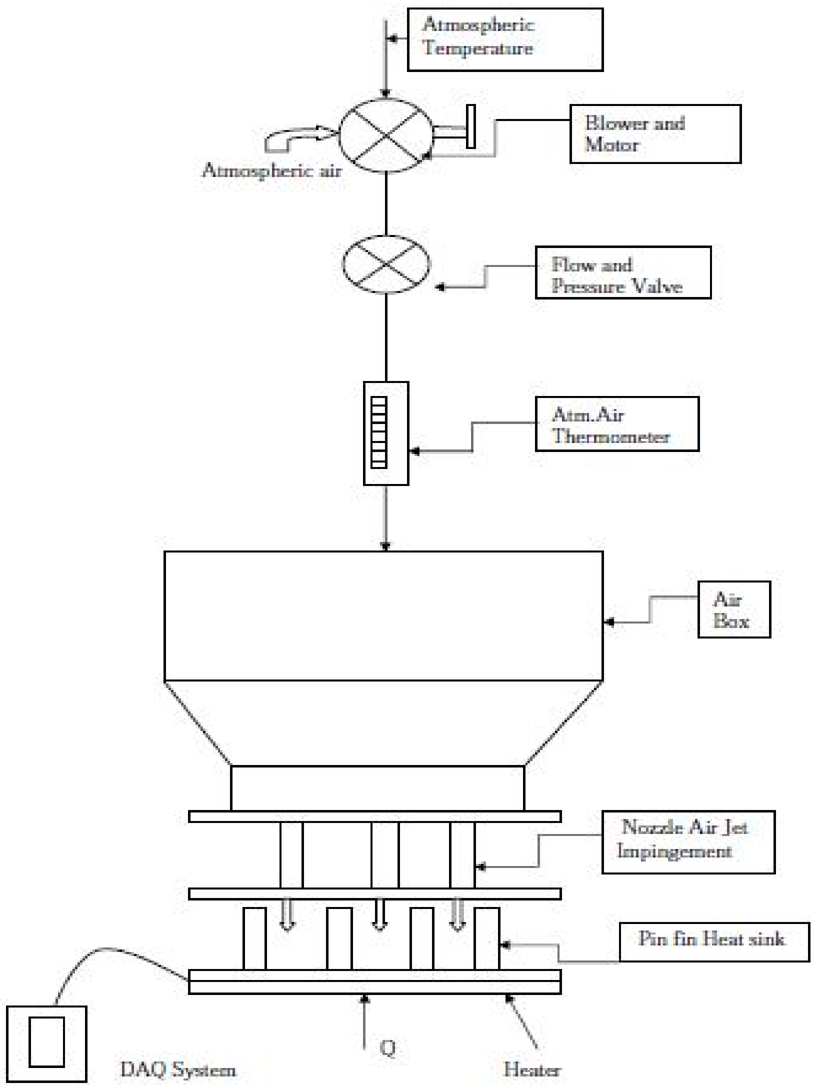

Fig.1.Vertical Air flow Bench

III. EXPERIMENTAL SET UP AND DETAILS

The experimental apparatus used to measure the performance of pin fin heat sink is vertical air flow bench.Fig.1. Shows the experimental set up& apparatus. The experimental set up consists of pin fin heat sink, 100W capacity electric heater, 4×4 arrays nozzle jets assembly. The experimental set up includes the 5×5 array circular pin fin aluminum heat sink of size 60×60×6 mm base dimensions. One 3 mm thickness, 100 W capacities 60×60mm square electric heater was used to heat pin fin base. Due to the same base dimensions of the heat sink and electric heater same heat distribution at the base of the heat sink. Back side and 4 edges of the heater and pin fin heat sink covered with the asbestos 7 mm thickness insulator at the base and 3 mm at each edge of the heat sink and heater to avoid heat loss at the bottom side and edges. Air ambient condition drawn from the variable speed generating blower. The air flow measured by the use of pitot tube manometer difference. Air from the air box flow through honeycomb comes out to through the 4×4 nozzle exit. The nozzle to the target plate or fin base Spacing is maintained by using spacers. Experiments Carried out for 3 different Z/D ratios says 5.5,6&7 for two different flow configurations unconfined , semi confined at constant heat flux supply10,20 30 W.The average heat transfer coefficient for the heat sinks was calculated according to Newton's laws of cooling,

Temperature measurement on the heat sink was at six different locations at the base and one at the pin fin tip. Due to use of 3×3 multi jet air impinging along the fin base temperature distribution is same due to the symmetry of the heat sink area, nozzle spacing, and constant heat flux supply from the base The thermocouples mounted at one corner of the heat sink equally spaced. For measurement of the temperature T-type thermocouple were used.

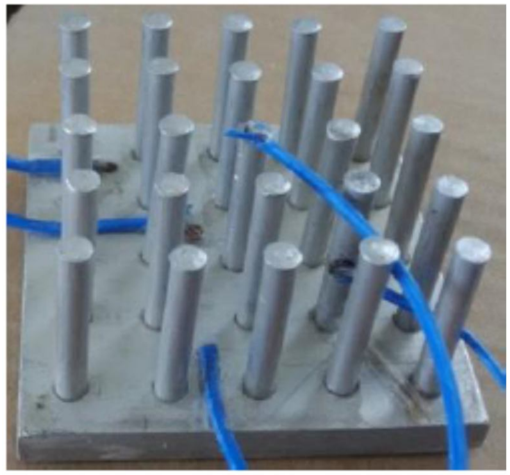

Fig.2 Pin Fin Heat sinks with thermocouples

Pin-fin heat sinks provide a large surface area for the dissipation of heat and effectively reduce the thermal resistance of the package at the cost of higher pumping power. They often take less space and contribute less to the weight and cost of the product.

After mounting the whole assembly with air flow bench exit section, heating of the flat plate or Pin fin heat sink is done by the heater. Heat supplied at the bottom side of the flat plate heat sink or pin fin heat sink. Electronic instrumentation parts for measurement of heat supplied digital voltmeter (0-230V), ammeter (0-5A), Autotransformer (0-300V), Temperature measurement circuit with Data Acquition system. There are 6 thermocouples mounted on the pin heat sink or flat plate .From that 6 thermocouple are at base at the quarter side of heat sink and 1 at the pin tip to measure temperature. Made heater on for heating heat sink at the base simultaneously also made air flow bench on. Select manometer head for particular butterfly valve position (for six Reynolds numbers). The ambient temperature was measured using a thermometer and the Data acquisition system. All experimental data are saved directly by data Acquition system. After getting final steady state make heater off and make cool heat sink by opening butterfly valve fully at atmospheric temperature

IV. RESULTS AND DISCUSSION

The effects on the results of varying this spacing (Z/D Ratios) as well as the Reynolds Numbers were studied with the heat sink on to the heat source. The 4×4 nozzle array with diameter of nozzle d=5mm used for experimentations. Pin fin heat sink used were 5×5 array with diameter of pin fin D= 4,5,5.5 mm height of fin Hp = 30mm, pitch Xp=Yp=15 mm [2][3].Experiments were performed for Reynolds numbers ranging from 6000 to 20 000 with the nozzle-to-target plate spacing fixed at Hp= 30 mm.

A. Comparison Between z/d ratios for all heat Energy Inputs & both Arrangements: for z/d ratios 5.5,6,7 for all side open arrangement.

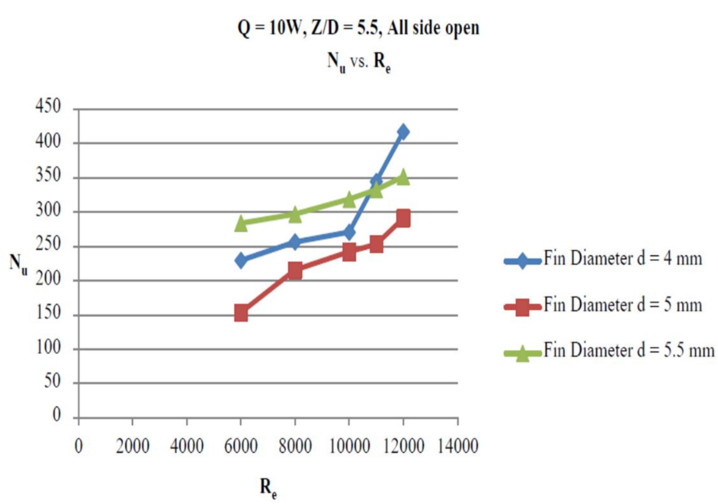

Fig.3 Nu Vs Re for Z/D=5.5 Q= 10W all side open

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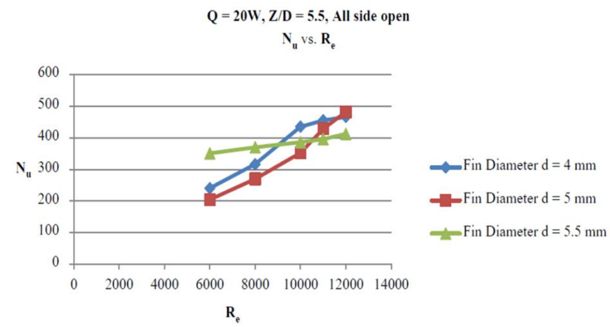

Fig.4 Nu Vs Re for Z/D=5.5 Q=20W all side open

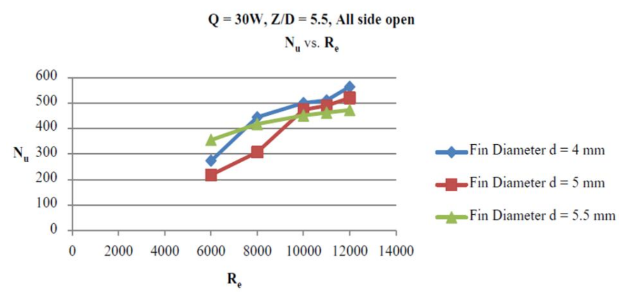

Fig.5 Nu Vs Re for Z/D=5.5 Q=30W all side open

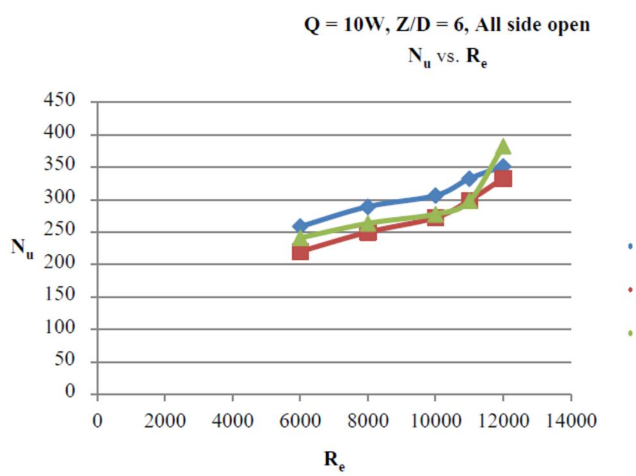

Fig.6 Nu Vs Re for Z/D=6 Q=10W all side open

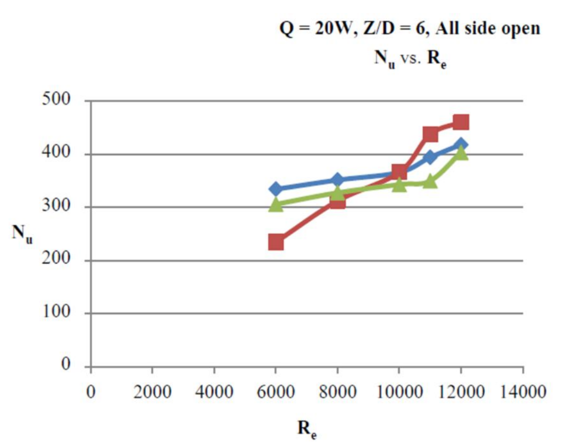

Fig.7 Nu Vs Re for Z/D=6 Q=20W all side open

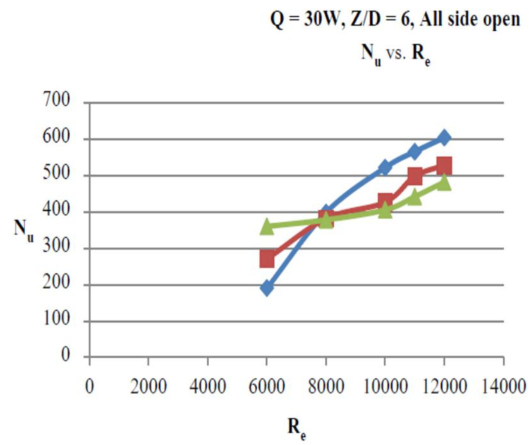

Fig.8 Nu Vs Re for Z/D=6 Q=30W all side open

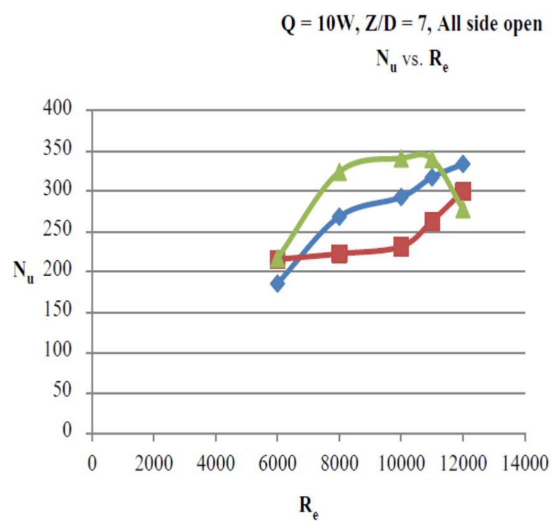

Fig.9 Nu Vs Re for Z/D=6 Q=30W all side open

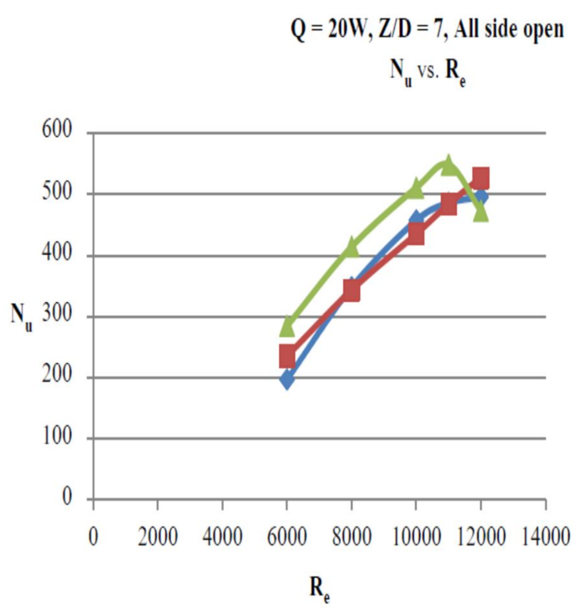

Fig.10 Nu Vs Re for Z/D=6 Q=30W all side open

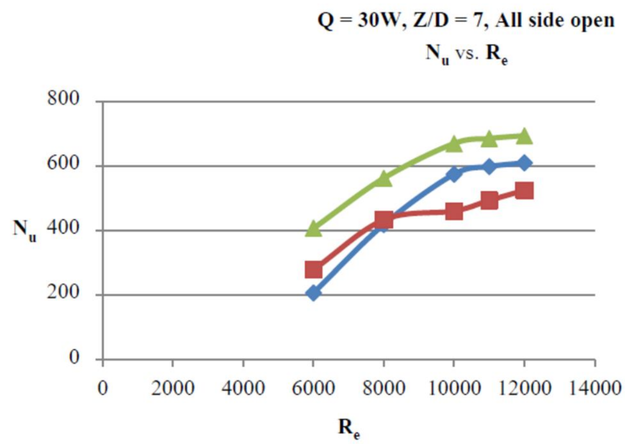

Fig.11 Nu Vs Re for Z/D=6 Q=30W all side open

Above Fig. shows that Nu Vs Re for Z/D=5.5,6 7, all side open arrangement Nusselts Nu number increases with increasing Reynolds number Re. For Z/D=6 highest Nusselts Nu number is 482.02 but for Z/D=5.5,7 as Nu number sudden decreases. Comparatively Nu number for UC, at Z/D=5.5,7.

B. Semi Confined Arrangement

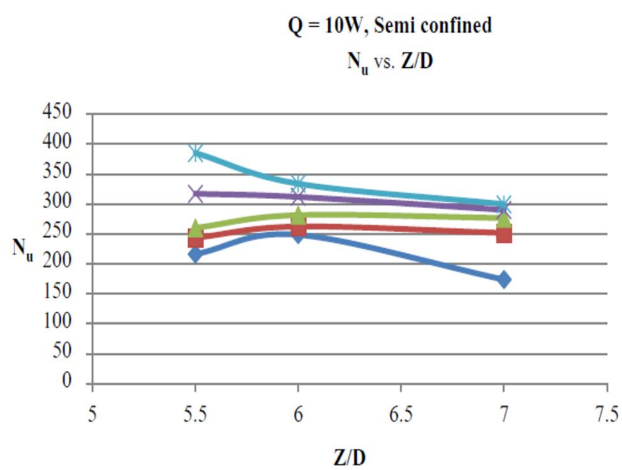

Fig.12 Nu Vs Re for Z/D=6 Q=10W Semi confined open

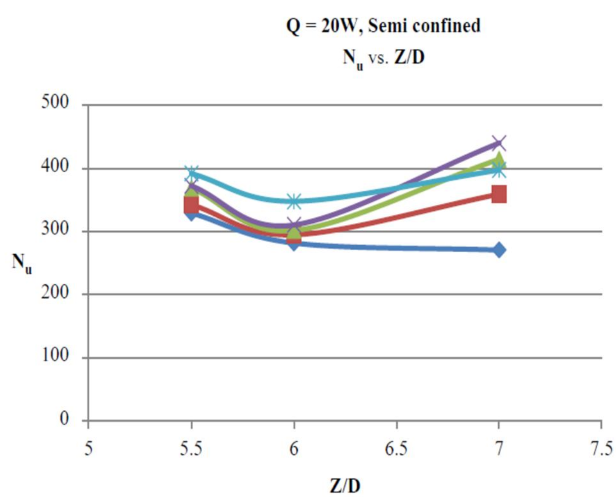

Fig.13 Nu Vs Re for Z/D=6 Q=20W Semi confined open

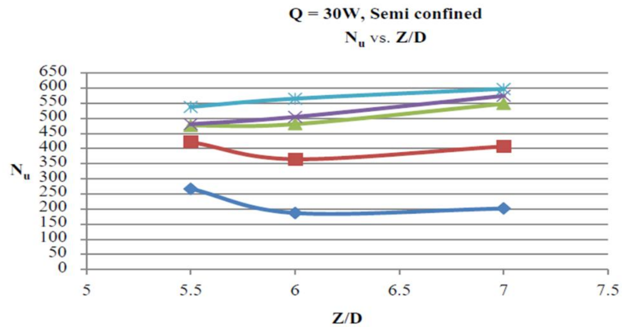

Fig.14 Nu Vs Re for Z/D=6 Q=30W Semi confined open

Above graphs gives information about the Unconfined(UC) and semi confined (PC)cross flow arrangment for different Z/D ratios (5.5,6,7) on heat sink.comparision with unconfined and semi confined flow arrangement experimental graph shows that Unconfined cross flow arrangment(all side open) is better than semiconfined cross flow because Nu number.

V. CONCLUSTION

In the experimentation, the effects of various design parameters like Z/D ratio, Re on Nu for heat sinks having circular pin fins of different diameters were systematically analyzed. The following conclusions can be derived from the results,

From the graph of Nu vs. Re , it is observed that for all fin diameters (d), the all side open configuration gives better results over semi-confined arrangement for all (Z/D) ratios.

From the graph of Nu vs. (Z/D) ratio, for different Re it is concluded that, For heat input Q = 10W, Z/D = 6 gives optimized results for all side open and semi-confined arrangement.

For heat input Q = 20W and Q = 30W, Z/D = 7 has been proved to be better over other Z/D ratios for all side open and semi confined arrangement.

The plot of Nu vs. Re reveals that,

For Z/D = 5.5, 6 and all heat inputs, the fin diameter d = 4 mm yields best for all side open and semi-confined arrangement giving higher Nusselt number(Nu). For Z/D = 7 and all heat inputs, the fin diameter d = 5.5 mm gives higher Nu for both all side open and semi-confined arrangement.

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