*Proceedings of Conference On Insights in mechanical Engineering (IME-19)*
*In Association with Novateur Publications IJIERT-ISSN No: 2394-3696*
*ISBN. No. 978-93-87901-04-9*
*March, 1st March 2019*

**Paper ID HP 04**

# EFFECT OF H/D RATIO ON HEAT TRANSFER CHARACTERISTICS OF CONFINED AIR JET IMPINGEMENT

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**ABSTRACT**

Impinging jet can be defined as a high-velocity coolant mass ejected from a hole or slot that impinges on the heat transfer surface. A characteristic feature of this flow arrangement is an intensive heat transfer rate between the application and the fluid. Jet impingement is an attractive cooling mechanism in which we are going to achieve maximum possible heat transfer rates. A confinement is provided to have recirculation of fluid resulting in more heat transfer. In following paper heat transfer characteristics of confined air jet impingement have been studied. It is found that for H/d ratio 6 maximum heat transfer takes place.

**KEYWORDS—**Confined, Air Jet, H/D ratio

## INTRODUCTION

Jet impingement heat transfer has become well established as a high performance technique for heating, cooling, or drying a surface. Engineering applications of jet impingement include annealing of metal, tempering of glass, drying of paper, cooling of electronic equipment, freezing of tissue in cryosurgery, anti-icing system for forward facing surfaces of civil aircraft, cooling of gas turbine components and the outer wall of combustors. Both empirical and theoretical studies in the topic are unabated and may have even accelerated in recent years, mainly stimulated by the need of higher temperatures in the gas turbine industry. Direct impingement of turbulent jets onto a surface leads to high local heat transfer rate. It is often employed to achieve rapid heating or cooling.

Jet impingement heat transfer has been extensively studied to determine both the peak and the spatial heat transfer distribution for various configurations of jets and surface. The impingement of unconfined axisymmetric (circular) and slot (two-dimensional) jets on a flat surface have received most of the research attention. A measurement of the local Nusselt number of a confined circular air jet vertically impinging on a flat plate is performed. The jet flow, after impingement, is constrained to exit in two opposite directions. Part of the impinging surface is maintained at a constant heat flux condition and the rest is adiabatic. The constant surface heat flux condition is modeled by conducting electricity through a thin stainless foil with a thickness of 0.01 mm. The heating oil was given constant heat flux values of 500, 1000, 1500 and 2000 W $m^{-2}$. Four diameters of the impinging jet 3, 4, 6 and 9 mm are considered individually. The jet Reynolds number is in the range of 30,000-67,000. The Hd is2.0. The recirculation and mixing effect on the heat transfer is investigated by varying the jet diameter, surface heat flux, Reynolds number and surface heating width. The correlations of the local Nusselt number and the jet-to-adiabatic wall temperature difference were obtained.[1]

Thermal-fluid characteristics of solid and perforated pin fin heat sinks cooled by confined air jet impingement were investigated numerically. The SST k-ω turbulence model was used to predict the turbulence flow parameters. The numerical model was verified with previously published experimental data. Flow and heat transfer characteristics are presented for the impinging Reynolds number, Re= 5000 to 25000 having constant impingement distance (Y/D = 8), fin width (W/L = 0.1) and height (H/L =0.5). The main objective of study was to examine the effects of fin perforations on the thermal performance of pin fin heat sinks. Results show that thermal resistance decreases and fin efficiency increases with the increase of Reynolds number due to perforation. Thus, this kind of heat sink equipment reduce cooling power consumption rate.[2]

In this study, air jet impingement on flat, triangular-corrugated, and sinusoidal-corrugated surfaces was numerically investigated. Bottom surface was subjected to constant surface temperature. Air was the working fluid. The air exited from a rectangular shaped slot and impinged on the bottom surface. The Reynolds number was changed between 125 and 500. The continuity, momentum, and energy equations were solved using the finite volume method. The effect of the shape of bottom surface on heat and flow characteristics was investigated in detail. Average and local Nusselt number were calculated for each case. It was found out that Nusselt number increases by increasing the Reynolds number. The optimum conditions were established to get much more enhancement in terms of performance evaluation criterion (PEC). It was revealed that the shape of the cooling surface (bottom wall) influences the heat transfer substantially.[3]
The flow characteristics of both confined and unconfined air jets, impinging normally onto a flat plate have been experimentally investigated. The mean and turbulence velocities, and surface pressures were measured for Reynolds numbers ranging from 30,000 to 50,000 and the nozzle-to-plate spacing's in range of 0.2–6. Smoke-wire technique is used to visualize the flow behavior. The effects of Reynolds number, nozzle-to-plate spacing and flow confinement on the flow structure are reported. In the case of confined jet, sub atmospheric regions occur on both impingement and confinement surfaces at nozzle-to-plate spacing's up to 2 for all Reynolds numbers in consideration and they lie up to nearly the same radial location at both surfaces. However, there is no evidence of the sub atmospheric region in unconfined jet. It is concluded that there exists a linkage among the sub atmospheric region, turbulence intensity and the peaks in heat transfer coefficients for low spacing's in impinging jets.[4]
From the review it is understood that Confined air jet impingement provides more heat transfer. So in this work, heat transfer enhancement by using confined air jet is studied. The H/d ratio is selected as 2, 4, and 6,8,10 from the literature. Also to confinement is provided so that mixing recirculation of air will enhance the cooling effect.

**EXPERIMENTAL ANALYSIS**

Fig.2a Actual Setup

The experimental set up is shown in Fig. 2a. Air is supplied by an air blower. The flow rate is controlled by valve. Nozzle is made of copper with decreasing cross section to increase Mach number of exiting air. Dimension of nozzle are Length: 8.5cm, Overall Diameter: 6 cm, Inlet diameter: 4cm, Outlet diameter: 1cm. Heater is used to raise the temperature of heat plate more than 200 $^0$C.The heat plate is made up of Aluminum. The heat plate is fixed to the heater by using Screw. Holes are drilled in the slots. The diameter of the heat plate is 175 mm.Mass of the heater plate is 1Kg.The target plate assembly is as shown in Fig. 2b.


Fig 2b.Target Plate

Heat transfer takes place through conduction from heater to the heat plate. With the help of rack and pinion vertical distance of heat plate can be vary.

Air is trapped between the impeller pockets of the rotating impeller and is then accelerated centrifugally causing air to come out of the blower at high velocity then that high velocity air passes through the pipe consisting of flow control valve to control the flow rate of air stream. This air is then forced into a convergent nozzle which will reduce the pressure and further increase the velocity of the air.. Our application is a heater over which an aluminum plate is fixed with nut and bolt. Heater heats the aluminum plate and cooling of this plate is done by the blower, nozzle arrangement. Over the aluminum plate thermocouples are attached along the X,Y axes equidistantly resulting in observation of temperature at various locations on temperature indicator while cooling. Use of dimmer stat helps us to vary the voltage and thus varying the power input to the heater which further enhances our accuracy of observation. There is rack and pinion arrangement is provided for varying the distance between the air flow coming out of the nozzle and the application for observing the idle distance for cooling. Confined plate is fixed to the nozzle with the help of nut and bolt. Confined plate is formed with the galvanized iron sheet .The GI sheet is having the same diameter as of heat plate.

Blower produced high velocity air . The high velocity air is passed through PVC pipe. The PVC pipe is having uniform cross sectional area. The velocity of air will be constant throughout the pipe. After pipe the air will enter into the nozzle. Hence, the heat reduction the heat plate takes place. The confined plate will force the air to go back again to the heater. It actually helps the air to reach to its maximum capacity.

**RESULTS**

To understand the heat transfer of the impinging jet of various fluid flow of air the heat transfer measurements have been carried out along the X-axis and Y-axis of plate. The heat transfer from air flow is compared varying H/d ratio for each flow measurement was carried. The heat transfer for air flow for H/d=(10,8,6,4,2) we used dimmer to regulate the voltage and fixed it to 90volt and thus the application temperature corresponding to the voltage was to be found nearer to 190 $^0$C was measured and graph was plotted.

Graphical analysis of Nusselt Number for Air as working fluid

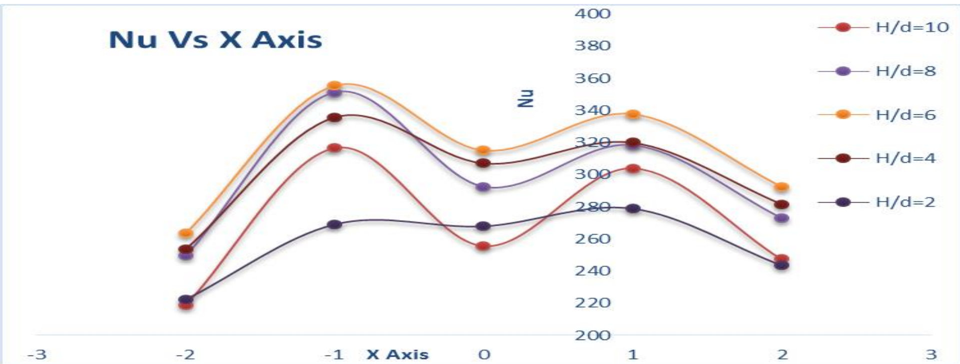


Fig.3a

From Fig 3a it is For H/d ratio 6 maximum heat transfer takes place ,then for H/d ratio 4 ,8.It is Surprising to note that least heat transfer takes place at H/d ratio 2.Also at Point of Impingement for all H/d ratio heat transfer is less. At the farther end from impinged point heat transfer is very less. For Y/d ratio of 1,-1 there is increase in heat transfer.

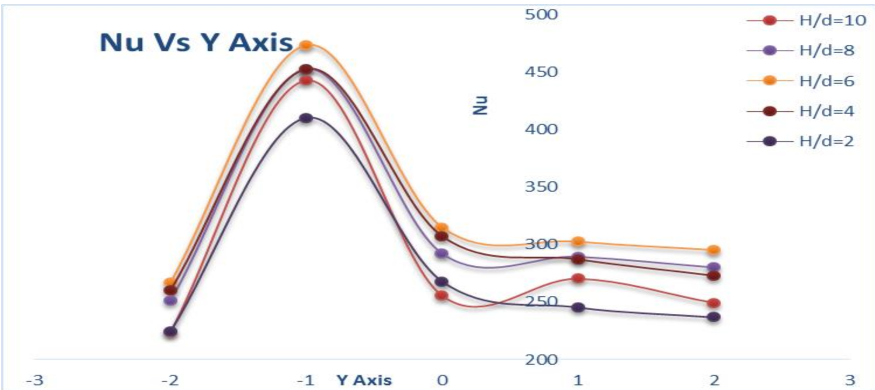


Fig.3b

## CONCLUSION

Effect of H/d ratio on heat transfer in confined jet impingement cooling is studied. Results reveal that for X, Y axes pattern of heat transfer is different.in X axis analysis Because of confinement maximum heat transfer occurs at H/d ratio of 6.So as H/d ratio increases heat transfer increases this is not happening in this case. Also for Y axis All H/d ratio give same pattern here also H/d ratio 6 gives maximum heat transfer. Also for Y/d=-1 a peak is formed which may be result of confinement.

Results show that more work is needed in confined jet impingement.

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