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Comparison Study of Confined and Unconfined Flow of Wall Static Pressure Distribution on Convex Surface for Turbulent Flow by Air Jet Impingement from an Orifice

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***Abstract:** Jet impingement is a well known method of heating and cooling of surfaces. This type of impingement allows small distance with high heat transfer rate. This heat transfer coefficient depends upon static pressure. Therefore in our work, we are involved in a determining a distribution of static pressure over a convex surface made of acrylic with confined flow. This experiment is conducted by varying Reynolds number from 10000 to 40000, orifice to target surface distance (z/d)1 to 4, and curvature angle(Ɵ) from 0 to 30°. From the study we come to know that there is no influence of Reynolds number on the value of Cp. The value of Cp decrease with increase in the curvature angle. The value of Cp is higher for the confined flow of jet when compared to unconfined flow of jet.*

***Keywords:** Static pressure distribution, Jet impingement, Vena Contracta, Stagnation Point, confined flow, atmospheric region, Potentiocore region.*

I. INTRODUCTION

Jet impingement is one of the well defined or well established technique for heating, cooling and drying of surfaces. This type of impingement allows short flow path on the surfaces relatively with high heat transfer rates.The impinging jets can be classified by their boundary as confined or unconfined flow fields. The unconfined geometries were frequently used in the earlier studies on impinging jets. Confined geometry, where the radial spread of the jet is bounded by a confinement plates due to which the loss of air is minimized. The confined flow jets have found ore applications. Some of the industrial applications of the air jet impingement are gas turbine blade cooling, glass tempering and annealing, paper and cereal drying. Since the local heat transfer coefficient and stagnation point is mainly depends on the flow of characteristic and the vena contracta between the orifice diameter to the target surface. Static pressure distribution depends on various parameters like Reynolds number, jet-to-tube spacing, radial distance from stagnation point, target plate inclination, confinement of the jet, nozzle geometry, curvature of target plate, roughness of the target plate and turbulence intensity at the nozzle exit. Therefore the present work carried out for determination of static pressure coefficients on convex surface due to impingement of air jet from an orifice nozzle for confined flow.

In 1969, Raymond E Chupp experimentally investigated static pressure coefficient by proposing correlation for stagnation strip by resistance heater by varying parameters like Reynolds number, jet to target surface distance, nozzle to target distance[1]

In 1994,D. Lytle and B. W. Webb., “Air jet impingement heat transfer at low nozzle-plate spacings” studied about radial distribution of the recovery factor and also about local heat transfer for axisymmetric impinging air jet for a smooth nozzle.

In 2006 -2007, Ramkumar and Prasad conducted same experiment by using one row of jet and five row of jet(multiple jet) by varying a parameter like nozzle to plate distance, Reynolds number, and jet to target distance . The static pressure taps and micro manometers are used to find static pressure developed and local pressure , and heat transfer coefficient distribution showed presence of secondary peaks corresponding up to wash due to jet interactions.[5]

In 2013,Dr. Vadiraj katti have done experiment on the pressure distribution due to the rows of jet impingement on a concave surface and study the various parameters like jet to jet distance, Reynolds number, nozzle to target distance and they found there is a decreasing in wall static pressure coefficient with higher jet to jet distance and secondary peaks are found on adjacent sides[7]

In 2016, Mr.Karthik.N.R.et.all has done experimental investigation of Static pressure distribution on concave target surface for confined flow by varying Reynolds number and proved that the static pressure for confined flow is more than that of the free flow.[8]

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In 2018, Prof. A M Hanchinal et.al Experimentally determined the effect of jet to test section spacing and Reynolds number on wall static pressure distribution on convex curved surface due to an air jet impingement from an orifice for unconfined flow for different geometrical and flow parameters are studied. After number of experiments at steady state condition.[9]

Hence, the present work is focused on coefficient of static pressure distribution on Convex surface for both confined and unconfined flow due to the air jet impingement from an orifice of diameter 14mm. The work is processed by varying the various parameters like Reynolds Number (Re=10000 to 40000), Z/d (1 to 4)and curvature angle ϴ (0 to 30°). The conclusion from this work plays very important role while designing the blades of the gas turbines, deciding of air craft systems.

II. NOMENCLATURE

Symbols	Description	Units
Z/d	Nozzle to target plate distance	m
Re	Reynolds Number	-
Vj	Velocity of the jet	m3/Sec
ρ	Density	m3/Kg
Cp	Coefficient of pressure	-
Cp_o	Static pressure coefficient	-
Tj	Temperature of the jet	°C
Patm	Atmospheric Pressure	Pa
m	Mass Flow rate	Kg/Sec
V	Voltage	mV
A	Area of nozzle	m2
a1 and a2	Area of Throat and Divergent	m2
Q	Discharge	m3/Sec
Ha and Hw	Manometer Head	m
Δp	Pressure	Pa
ϴ	Curvature angle	degrees

III. EXPERIMENTAL SETUP AND PROCEDURE

A. *Specifications Of Experimental Setup*

Blower capacity	3.0 m^3/min
Venturimeter C_d	0.92±2%
Orifice diameter	14mm
Pipe Used	PVC
Pressure gauge range	0-2.1 bar
Valve type	Ball Valves
Stand Supports	MS

B. *Description of Target Plate*

Target type	Convex surface
Material of target	Acrylic
Length	220mm
Inner and Outer diameters	50mm×60mm
Thickness	5mm
Hole diameter	2mm

The complete experimental procedure setup is as shown in fig (1) The blower with capacity of 3.0 m^3/min and maximum supply of power 240 W used for the supply of air jet. And the calibrated Venturimeter with coefficient of discharge C_d of 0.92±2% is used to adjust the flow of jet, Calibrated K type thermocouple is used to measure the jet temperature considering the Ice-water equilibrium

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and mercury setup arrangement and the ends of the thermocouple are connected to the millivoltmeter. The other parameters taken under consideration are as per the steady state conditions.

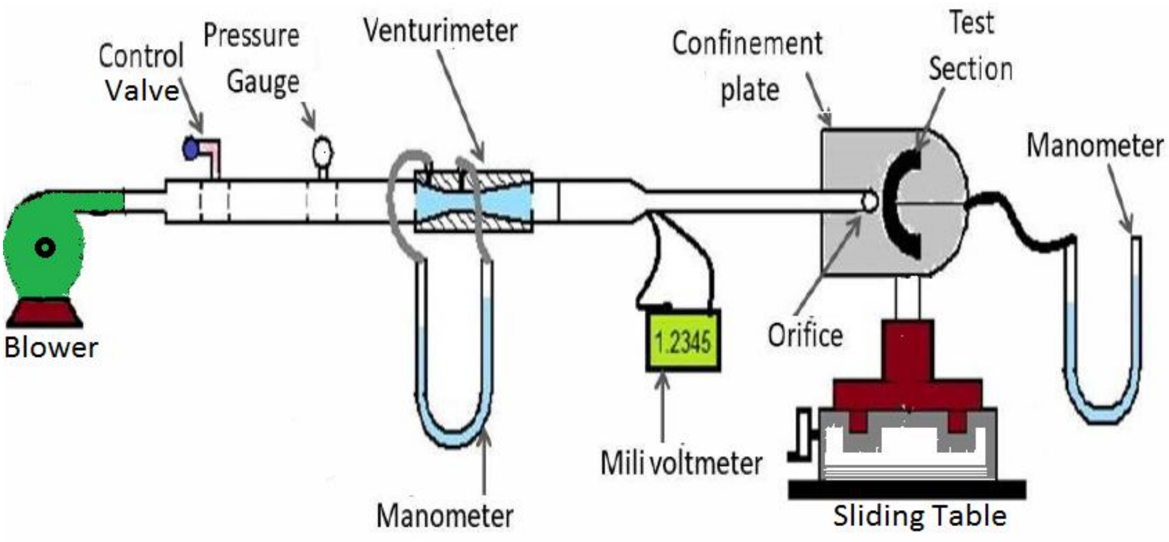


Figure 1 Schematic Layout of the Experiment

The target surface i.e convex surface with internal diameter 50mm and external diameter 60mm with thickness of 5mm and length 220mm, with a hole of 2mm at the centre of the convex surface. And the target surface is mounted in a square wooden box at particular position. The target plate is confined using two acrylic plates which are drilled at the centre such that the target surface can easily slide through them. The Z/d i.e the ratio of distance between the target surface and orifice to the diameter of orifice is varied by changing the pipe length between 1 to 4 as of Z/d and the curvature angle(0 to 30°) is changed by rotating the target surface.

The blower which has a motor of power 1hp and has a speed of 13000rpm blows the air with a very high velocity to the venturimeter through a ball type control valve. The control valve helps in setting up of the Reynolds number by regulating the control valve. The air with higher velocity and at the desired Reynolds number hits the target surface that is placed at particular distance through the orifice of diameter 14mm. The flow of jet is confined to required length. The target surface may be placed at a distance i.e, z/d=1,2,3,or 4. Target surface is connected with a pressure tap which in turn connected to one of the ends of the manometer and other end of the manometer is open to atmosphere.

IV. DATA REDUCTION

1) Reynolds number is defined on the basis of orifice diameter and is estimated using the following equation.

$$Re = \frac{4 \times m}{\pi \times d \times \mu}$$

2) Temperature of the jet at the exit of orifice

$$T_j(°C) = (23.188 \times \upsilon) + 3.843$$

3) Density of air jet

$$\rho = \frac{Patm}{0.287 \times (T_j + 273)}$$

Static Pressure and Atmospheric pressure

$$\Delta P = 1000 \times 9.81 \times H_w$$

4) Coefficient of Pressure

$$C_p = \frac{\Delta P}{0.5 \times \rho_a \times V_j^2}$$

V. RESULTS AND DISCUSSIONS

A. Influence of Reynolds Number on Cp

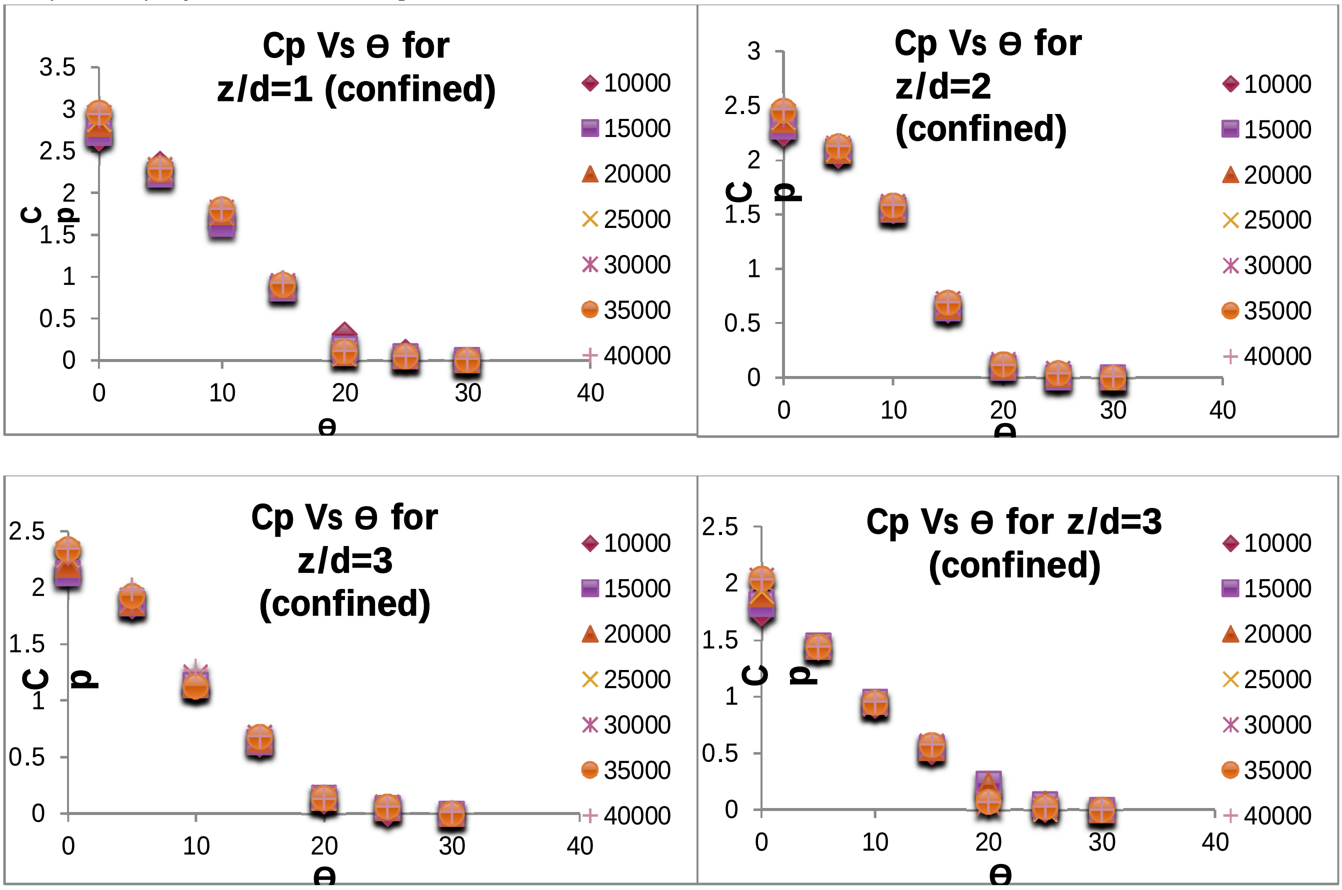


Figure 2 Influence of Reynolds Number on Cp

From figure2, i.e the graph showing the relation between the static pressure coefficient Cp with the curvature angle ϴ for all the Reynolds Number i.e Re=10000 to 40000, curvature angle ϴ=0 to 30° and z/d ratio from 1 to4. The value of Cp is maximum at the stagnation point due to high velocity of jet and it is almost atmospheric when curvature angle ϴ is increased more than 20°. The value of Cp is equal to zero at 30°. From this data, it clears that the trend for all the Reynolds Number is similar or same though the jet of air is confined. So the further study will be carried out for a representative Reynolds Number Re=25000.

B. Effect Of Z/D Ratio On CP When Confined In Comparison With Unconfined

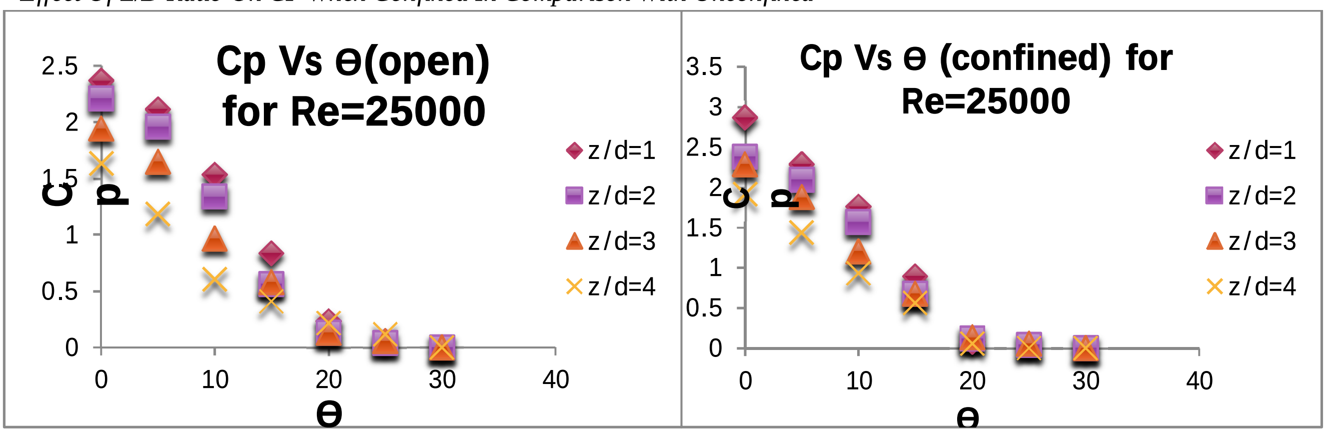


Figure 3 Comparison between the value of Cp for confined and unconfined flow and for all the z/d ratio

Figure 3 shows the variation of Cp with Ө for z/d=1,2,3 and 4 and also the above figure gives comparison between open and confined flow of jet. From the data, it can be observed that the valve of Cp is higher for the confined flow of jet at all the curvature angles. Due to confinement of the jet, the loss of air jet is reduced and maximum amount of air hits the target and the velocity of the jet gets converted into pressure energy and hence the value of Cp is more for confined flow when compared with the open flow. And also the value of Cp is maximum at the stagnation point due to the high velocity of the jet. The value of Cp is more or less uniform from 0 to 5°, because there is no much spread of the jet over the convex surface. The value of Cp is appreciably decreased when the curvature angle is increased from 5° to 15° due to the higher spread of the jet. Further increase in the value of curvature angle results in the atmospheric condition of the Cp. This is because the jet completely spreads over the convex surface.

C. Effect of Confinement of the jet on the Value of Cp

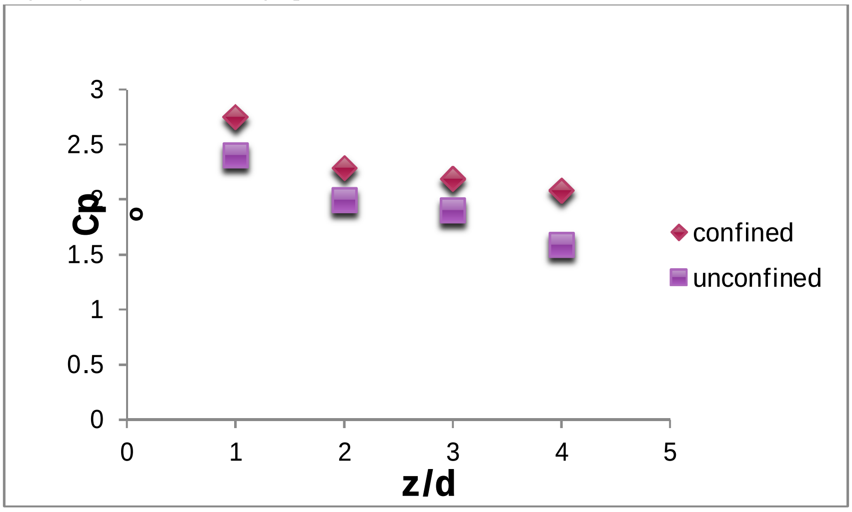


Figure 4 Comparison of values of Cp for confined and unconfined flow for all z/d ratios at stagnation point

The figure 4 shows comparison of the value of static pressure for the Confined and Unconfined flow and the Reynolds number is 25000. Since the flow is confined, there is minimum loss of air when compared to the unconfined flow, so the maximum air hits the target surface and the velocity of jet gets converted into the pressure energy, thus the value of static pressure at stagnation point when the flow is confined is more than the value of Cp at stagnation point when flow of jet is unconfined. For unconfined and confined flow the value of Cp for z/d=1 is maximum due to shorter distance between the target and orifice. For unconfined flow the value of Cp between z/d=2 and z/d=3 is almost uniform because the target surface is placed in the potential core region of the jet. And for confined flow due to confinement of the jet the potentio core length is increased and thus the value of Cp is almost uniform between z/d=2 to z/d=4. Due to the higher distance between target surface and the orifice, the jet spread is more and hence the value of Cp for the z/d=4 is very less. From the above data we can conclude that the value of Cp decreases with increase in the distance between target surface and the orifice.

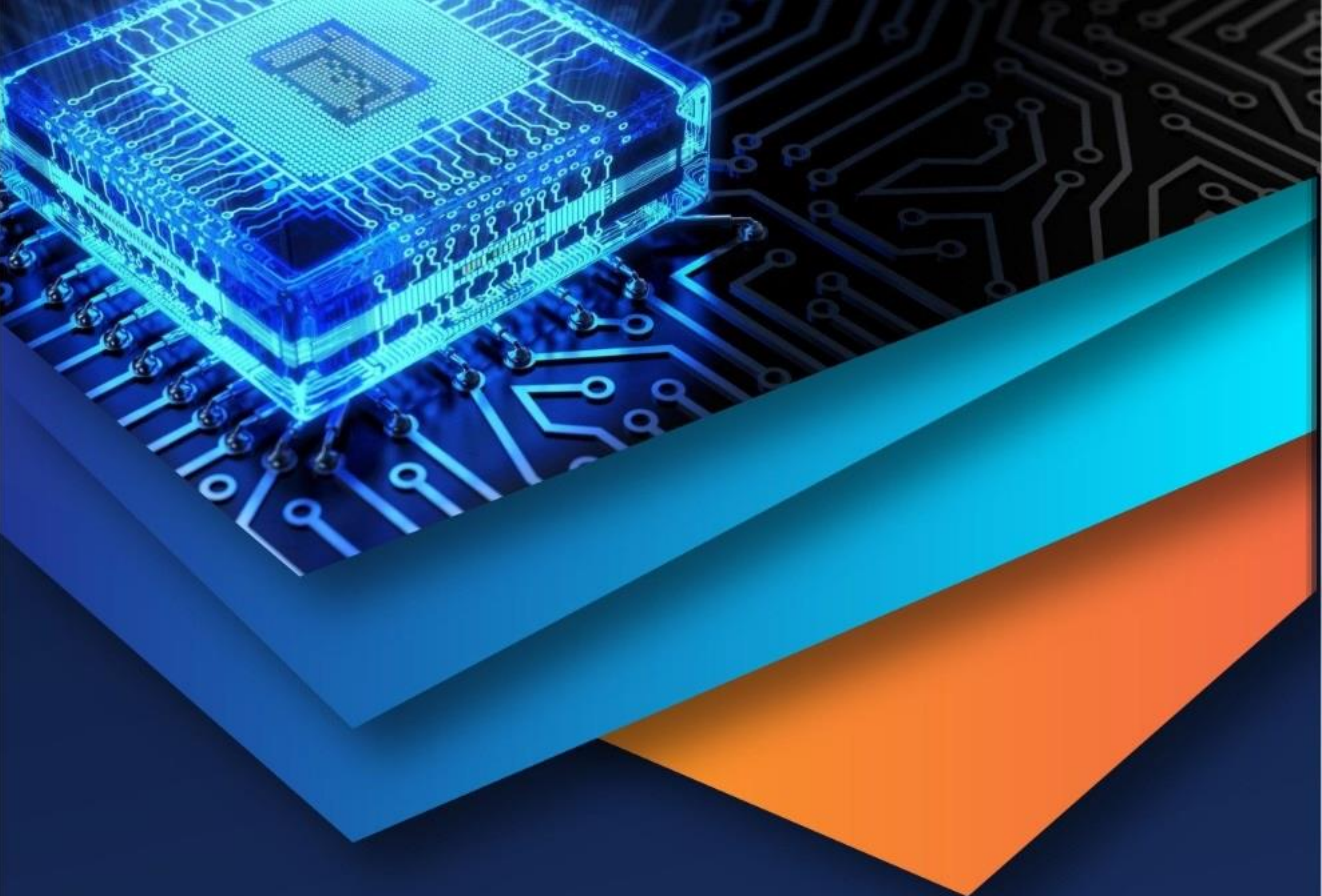
VI. CONCLUSIONS

After all the experimental investigations of air jet impingement for both unconfined and confined flow on Convex surface by varying the Reynolds number from 10000 to 40000 for various curvature angles and z/d ratio's, the study hence reveals the following conclusions.

A. There is no influence of Reynolds number on the value of coefficient of static pressure for both confined and unconfined flow.
B. The values of coefficient of static pressure at stagnation point are higher for confined flow in comparison with unconfined flow due to the effect of vena contract.
C. There is an increase in the length of potentio core region of the jet for confined flow due to the minimum loss of air when compared to the unconfined flow.
D. The value of coefficient of static pressure is more for the confined flow when compared with the value of static pressure for unconfined or free flow.

REFERENCES

[1] Reymond E. Chupp, Harold E. Helms and Tony R. Evaluation of internal heat transfer coefficient for impingement – cooled turbine airfoils, J aircraft, Vol 6,No 3, May-June 1969.
[2] R. J. Goldstein et al., "Stream wise distribution of the recovery factor and the local heat transfer coefficient to an impinging circular air jet" Int. .J. Heat Mass Transfer. Vol. 29, No. 8. pp. 1227-1235 (1986).
[3] D. Lytle and B. W. Webb., "Air jet impingement heat transfer at low nozzle-plate spacings" Int. J. Heat Mass Transfer. Vol. 37, No. 12, pp. 1687-1697, (1994).
[4] D.W. Zhou et al., "Radial heat transfer behavior of impinging submerged circular jets" International Journal of Heat and Mass Transfer (2005).
[5] B.V.N. Rama Kumar and B.V.S.S.S., Experimental and computational study of multiple circular jets impinging on a concave surface, 33rd national and 3rd International Conference on FMFP,Dec-2006,IIT Bombay, India.
[6] Quan Liu, A.K. Sleiti , J.S. Kapat., "Application of pressure and temperature sensitive paints for study of heat transfer to a circular impinging air jet" International Journal of Thermal Sciences 47, 749–757 (2008).
[7] Vadiraj Katti , S.Sudheer , S.V.Prabhu , Pressure distribution on a semi-circular concave surface impinged by a single row of circular jets, Exp.Therm. Fluid Sci. (2013)
[8] Karthik Ramadurg , R.N.Patil ,and Vadiraj.V.Katti.(2016), "Experimental investigation of distribution of coefficient of static pressure on the concave curved surface due to impingement of air jet from an orifice for confined flow", Journal of Advances In Science & Technology Vol.12,Issue No.25,(Special Issue)December-2016, ISSN2230-9659.
[9] A M Hanchinal, Akshay Biradar "Distribution of Wall Static Pressure on Flat Plate by Impenjing Air Jet from Orifice for Turbulent Flow" ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887Volume 6 Issue VI, June 2018.



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