

# “STATIC PRESSURE DISTRIBUTION ON PLANE FLAT PLATE SURFACE BY AIR ORIFICE JET IMPINGEMENT FOR FREE FLOW $D=16\text{mm}$ ”

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**ABSTRACT:-** A review of Air Jet impingement for flow characteristics of free air jet and confined air jet 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 involving in a determining a distribution of static pressure over plane flat plate surface made of acrylic with a opened flow. This experiment is conducted by varying Reynolds number based on nozzle discharge condition from 6000 to 40000, and nozzle to target plate distance ( $Z/d$ ) 1 to 4 and Stagnation point surface to the orifice diameter i.e  $x/d$  between 0.8 to 2.4. By considering all the acceptable criteria our work results the static pressure distribution by free orifice jet of potential core region and structure of zone of jet.

**KEY WORDS -** Static pressure distribution, Jet impingement, Vena contract, Stagnation Point, Plane Flat plate Surface, Potential Core region.

## 1. INTRODUCTUION

Air Jet Impingements are used in many industrial oriented applications would like to achieve extreme coefficients for convective heating, cooling or drying. Applications involved such as Glass plate tempering, Sheet metal annealing, Textile and Paper Dryings, De-icing of aircraft systems and cooling effect for heated elements, Cryogenic tissue freezing and others. In addition to their important applications, impingement jets have many interesting fluid dynamics and heat transfer features.

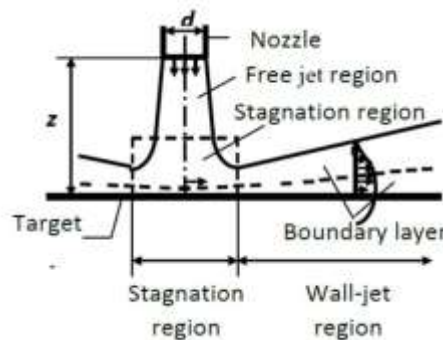


Fig:1 Structure of Jet

Unconfined jet impingement system is one in which jet after impingement on a surface is exited without confinement shows the flow of field of an impinging jet on to an plate . The flow structures of impinging axi - symmetric jet can be sub divided into three characteristic regions -

1. Free jet region
2. The stagnation floe region
3. The wall jet region

In Gas turbine Systems, Jet impingement cooling is found that increased use as higher turbine inlet temperatures are utilized. For turbine components includes turbine rotor blades, turbine guide vanes, discs and the wall of the turbine. in

which impingement cooling is provided to prevent the over heating. Structure of jet Fig(1) Shows that behaviour of air jet impingement after the striking of jet to the target surface from the nozzle.

In recent years many studies and researches are done on these topics. In 1969 <sup>[1]</sup>Reymond E. Chupp, Harold E. Helms and Tony R, experimentally investigated static pressure coefficient for stagnation strip by resistance heater by varying parameters like Reynolds number, jet to jet distance, nozzle to plate distances and proposed correlation of local heat transfer coefficient. <sup>[2]</sup>B.V.N. Rama Kumar and B.V.S.S.S., Experimental and computational study of multiple circular jets impinging on a concave surface by using one row of jet and five row of jet i.e. multiple jet by varying a parameter like nozzle to plate distance, Reynolds number, and jet to jet distance. The static pressure taps and micro manometers used for 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 to jet interactions. <sup>[3]</sup>Vadiraj Katti, S.Sudheer, S.V. Prabhu, Pressure distribution on a semi-circular concave surface impinged by a single row of circular jets and study the various parameters like jet to jet distance, Reynolds number, nozzle to plate 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. <sup>[4]</sup>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 Static pressure distribution for confined flow is more compare to unconfined on concave surface by varying Reynolds number. <sup>[5]</sup>G. W. Lowery and R. I. Vachon, The effect of turbulence on heat transfer determine the effect of turbulence shows the intensity on the overall or average heat transfer were partially successful. <sup>[6]</sup>M. Fenot, J.-J. Vullierme, E. Dorignac, Local heat transfer shows the independence of heat transfer coefficients and effectiveness from the jet injection temperature within the range studied. The influence of confinement on heat transfer coefficient is weak, but it has a great impact on effectiveness.

## 2. NOMENCLATURE

Symbols	Description	Units
X/d	Stagnation point surface to the orifice diameter	m
Z/d	Nozzle to target plate distance	m
Re	Reynolds Number	-
V <sub>j</sub>	Velocity of the jet	m/Sec
ρ	Density	m <sup>3</sup> /Kg
C <sub>p</sub>	Coefficient of pressure	-
C <sub>p0</sub>	Static pressure coefficient	-
T <sub>j</sub>	Temperature of the jet	°C
P <sub>atm</sub>	Atmospheric Pressure	P <sub>a</sub>
m	Mass Flow rate	Kg/Sec
V	Voltage	mV
A	Area of nozzle	m <sup>2</sup>
a <sub>1</sub> and a <sub>2</sub>	Area of inlet pipe and throat	m <sup>2</sup>
Q	Discharge	m <sup>3</sup> /Sec
H <sub>a</sub> and H <sub>w</sub>	Manometer Head	m
Δp	Pressure	P <sub>a</sub>

## 3. EXPERIMENTAL SETUP AND PROCEDURE

The complete experimental procedure setup is as shown in fig (2) The blower with capacity of 3.0 m<sup>3</sup>/min and maximum supply of power 240 W used for the supply of air jet. And the calibrated Venturimeter with coefficient of discharge Cd of 0.92 is used to adjusted the flow of jet, Calibrated K type thermocouple is used to measure the room temperature considering the Ice-water equilibrium temperature with jet temperature connected with the milli voltmeter and mercury setup arrangement. In were the other parameters are taken under consideration as per the steady state conditions.

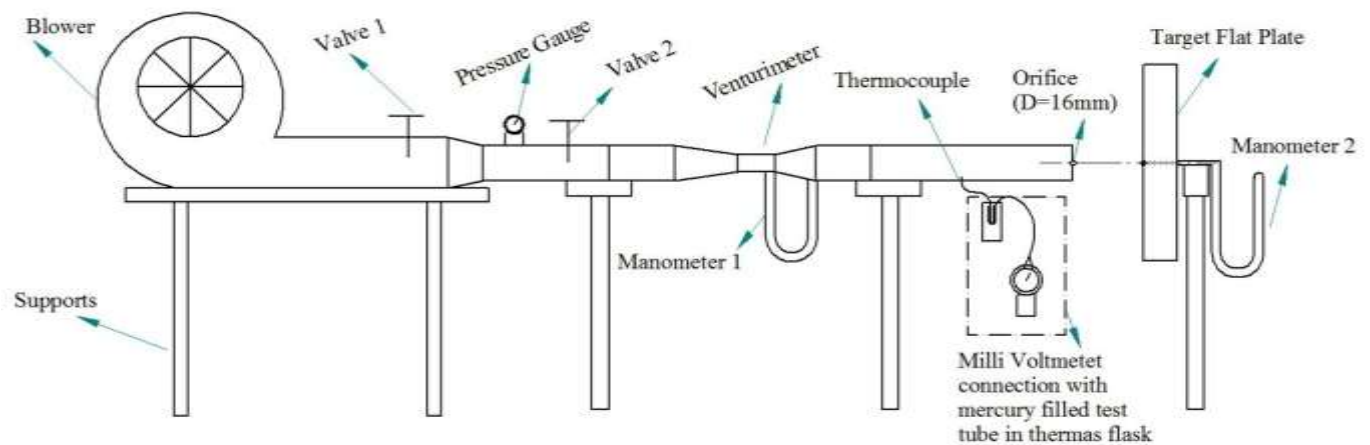
The target surface i.e plane flat plate acrylic sheet is of 6mm thickness with length 220mm, height 90mm with the centre 2mm hole. And is fixed at the square mounted box at particular position. The Z/d i.e the distance between orifice diameter to the target plate is varies with the help of by changing the pipe length between 1 to 4 as of Z/d. And another parameter i.e x/d distance between the stagnation point surface to the orifice.

**i. Specifications of Experimental setup**

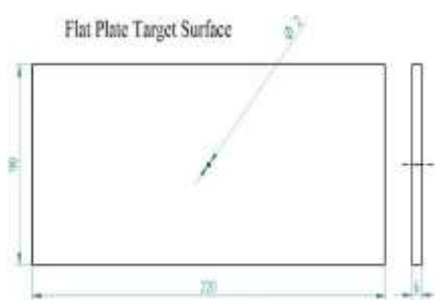
Blower capacity	3.0 m <sup>3</sup> /min
Venturimeter Cd	0.92±2%
Orifice diameter	16mm
Pipe Used	PVC
Pressure gauge range	0-2.1 bar
Valve type	Ball Valves
Stand Supports	MS

**ii. Description of Target Plate**

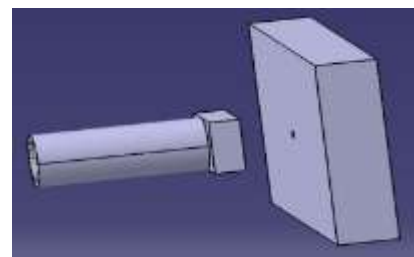
Plate type	Plane Flat Plate
Material of Plate	Acrylic
Length	220mm
Height	90mm
Thickness	6mm
Hole diameter	2mm



**Fig: 2** Schematic Layout of the Experiment



**Fig: 3** Description of target plate



**Fig: 4 (3-d)** View of target plate

The air is blown through the venturimeter with orifice diameter of 16mm over the unconfined free flow plane flat plate surface at a certain particular Reynolds Number of flow at the exit of the orifice. Reynolds Number is set at that particular point with the help of U- Tube manometer connected to the venturimeter and the static pressure distribution is measured by U -Tube Manometer and water is used as a fluid of manometer.

#### 4. DATA REDUCTION

- Head of manometer after target plate

$$H_a = \left[ \frac{1000}{\rho} - 1 \right] * \frac{H_w}{1000} \dots\dots\dots (m)$$

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

$$R_e = \frac{\rho * v_j * d}{\nu * 10^{-3}}$$

- Temperature of the jet at the exit of orifice

$$T_j(^{\circ}C) = (23.188 * \nu) + 3.843 \dots\dots\dots(^{\circ}C)$$

- Density of air jet

$$\rho = \frac{P_{atm}}{0.287 * (T_j + 273)} \dots\dots\dots Kg/m^3$$

- Mass flow rate

$$m = \frac{Q}{\rho} \dots\dots\dots m/s$$

- Discharge through Venturimeter

$$Q = \frac{a_1 a_2 \sqrt{2 * 9.81 * H_a}}{a_1^2 - a_2^2} * C_d \dots\dots\dots m^3/s$$

- Area of nozzle

$$A = \frac{\pi d^2}{4} \dots\dots m^2$$

- Velocity of jet

$$V_j = \frac{\text{Mass flow rate}}{\text{Area of nozzle} * \rho} \dots\dots m/s$$

- Static pressure

$$\text{Static Pressure} = \frac{H_w}{\text{Magnifying factor}}$$

- Pressure

$$P = \frac{\text{Static pressure}}{9.81}$$

- Coefficient of Pressure

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

5. RESULTS AND DISCUSSIONS

i. Influence of Longitudinal distance from point of impingement  $x/d$  on Static pressure  $C_p$  for various  $Z/d$  ratios for  $Re$  6000 to 40000

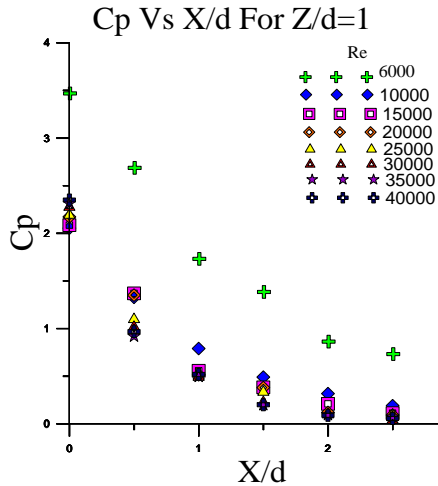


Fig.5 (a)  $z/d=1$   $x/d=0.8$  to  $2.4$   $Re$  6000 to 40000

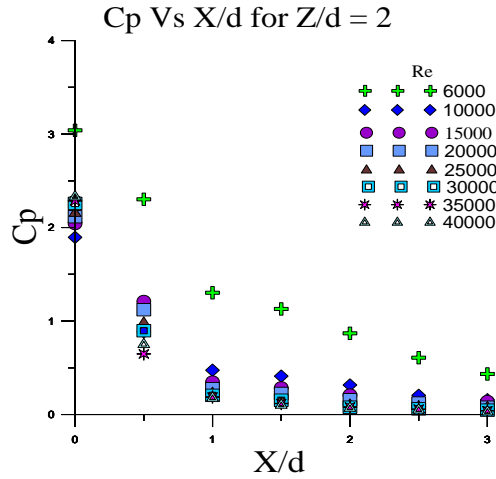


Fig.5 (b)  $z/d=2$   $x/d=0.8$  to  $2.4$   $Re$  6000 to 40000

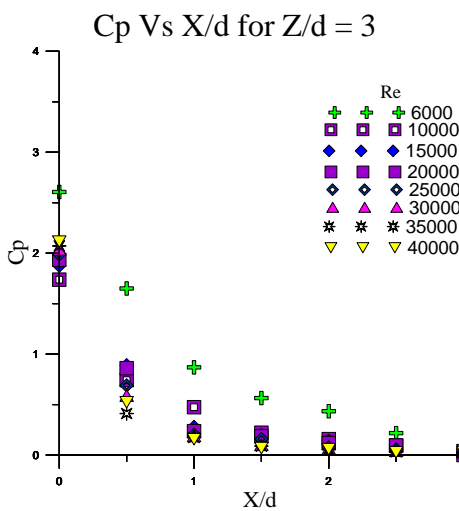


Fig.5 (c)  $z/d=3$   $x/d=0.8$  to  $2.4$   $Re$  6000 to 40000

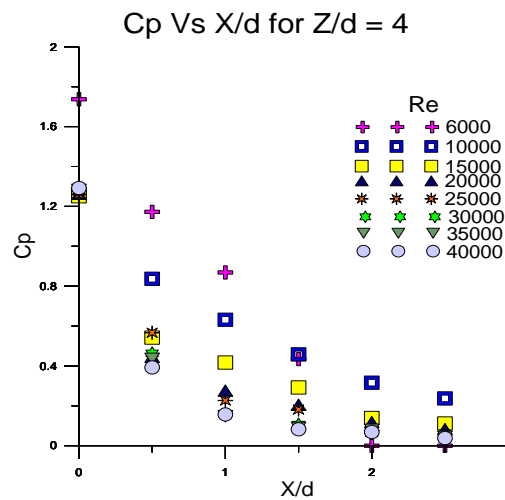


Fig.5 (d)  $z/d=4$   $x/d=0.8$  to  $2.4$   $Re$  6000 to 40000

The above figures show that the effect of the static pressure  $C_p$  with the longitudinal distance  $X/d$ . From Fig.5 (a, b, c, d)  $z/d = 1$  to  $4$  considering Reynolds number varies from 6000 to 40000 the pressure coefficient is maximum at the stagnation point at  $x/d = 0$  and it decreases with increase in  $x/d$  ratio 0.8 to 2.4 hence it becomes null as  $x/d$  nearly reaches 2.4. The appreciable decrease of  $C_p$  and  $C_{p_0}$  value is observed for further decrease in  $Z/d$  ratio. As the distance from the nozzle increases the velocity goes on decreasing monotonically due to spreading of jet.

Which results the effect of Vena contract is the point in a fluid stream where the diameter of the stream is the least, and fluid velocity is at its maximum, such as in the case of stream issuing out of nozzle. It is a place where the cross section area is minimum. The above trend is same for all the  $Z/d$  ratios i.e. ( $Z/d=1, 2, 3, 4$ ). Therefore, it is clear that there is no influence of the Reynolds number on Static pressure ( $C_p$ ).

ii. Influence of Longitudinal distance orifice to flat plate distance  $Z/d$  on Static pressure  $C_p$  for various  $Z/d$  ratios for  $Re$  6000 to 40000 considering  $Re = 30000$ .

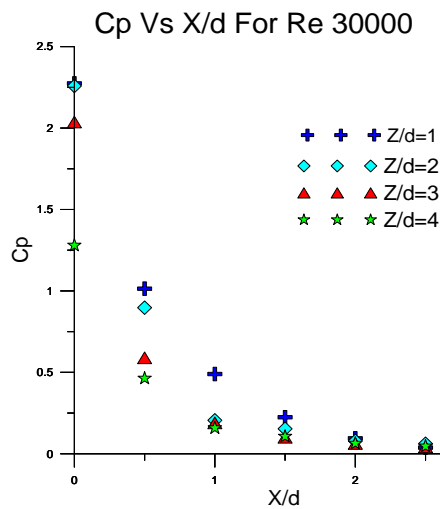


Fig.5 (e)  $z/d=4$   $x/d=0.8$  to  $2.4$   $Re$  6000 to 40000

The above figure reveals that the variation of the static pressure  $C_p$  with the Longitudinal distance i.e. orifice to flat plate distance  $Z/d$  having the maximum  $C_p$  value at  $z/d=1$  being the 2.27407 and it maximum at stagnation point  $X/d=0$ . Since the jet and pressure tap are co-axial hence the kinetic energy of the jet is completely converted into the potential energy i.e. pressure energy. As the  $Z/d$  ratio varies from 1 to 4 the gradual decrease in  $C_p$  value takes place, at  $Z/d = 4$   $C_p$  value is 1.27913.

Hence by increasing  $X/d$  and  $Z/d$  ratios for the various Reynolds number the atmospheric conditions on the flat plate reaches the sub atmospheric entities.

From the graph of  $C_p$  Vs  $x/d$  and  $C_p$  Vs  $Z/d$  for various Reynolds Number, it is observed that, coefficient of static pressure  $C_p$  is independent of Reynolds Number as curves overlaps to each other and same trend is observed for all  $Z/d$  ratio.

iii. Influence of  $Z/d$  ratios on the static pressure at stagnation point

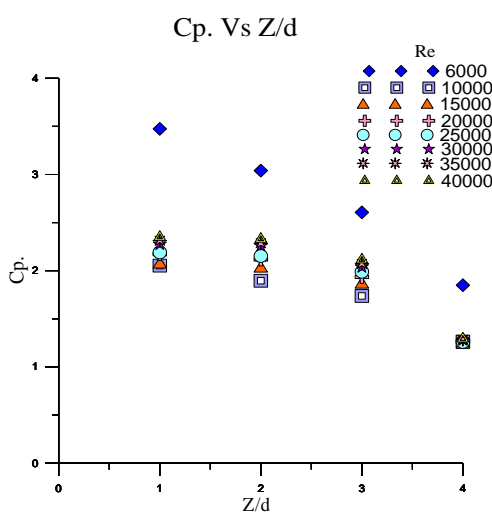


Fig.6(a)  $z/d=1$  to  $4$   $x/d=0$   $Re$  6000 to 40000

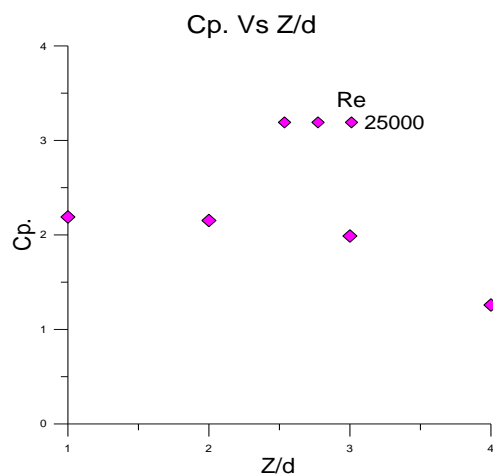


Fig.6(b)  $z/d=1$  to  $4$   $x/d=0$   $Re$  25000

The above **Fig.6(a)** completely reveals that for  $C_p$  value of  $Z/d$  ratios of  $Re$  varies from 6000 to 40000. The Static pressure coefficient is maximum, Where as Vena contract is located.  $C_p$  is completely depends on the  $z/d$  ratio where the potential core region is defined in between the  $z/d= 1$  to 2 and then gradual decreases at certain point it becomes zero at  $z/d=4$ . The above **Fig.6(b)** illustrates that for  $Re$  25000 characteristic of  $C_p$  Vs  $Z/d = 1$  to 4 Shows that Potential core region is holds from  $z/d =1$  to 2 where the  $C_p$  value is maximum, when the distance of  $z/d$  increases the potential energy decreases .Hence the Kinetic energy is completely converted into potential energy.

## 6. CONCLUSIONS

After all Experimental iterations of air jet impingement on plane flat plate surface by various  $Re$  from 6000 to 40000 for different  $X/d$  and  $Z/d$  distances. Hence reveals that the following conclusions may be drawn from this study:

- Reynolds Number is completely independent on Static pressure distribution on the plane flat plate surface.
- The Values of the Stagnation points are higher compare to other  $x/d$  values due to the influence of maximum velocity that is because of the effect of vena contract.
- Potential Core region is maximum for small  $z/d$  distance where as it becomes null value due increasing the  $z/d$  distance.
- The velocity of the jet is also affects the values of the pressure distribution.

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