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Influence of Confinement Effect on Fluid Flow Characteristics of Multiple Impinging Jets on the Flat Surface

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Abstract—*Multiple impinging jets are used in many industrial applications to achieve enhanced coefficients for convective heating, cooling or drying. Few industrial processes which employ impinging jets are drying of food products, textiles, films and papers; processing of some metals and glass, cooling of gas turbine blades, outer wall of the combustion chamber; cooling of electronics equipments and many more. From the literature review it is observed that not exhaustive work has been reported over the flow characteristics of the multiple jets impinging over the flat surface, hence the topic chosen for the study. The flow characteristics of an impinging jets are affected from a number of parameters such as the nozzle geometry, the jet-to-target spacing (Z/d), Jet Reynolds number (Re), radial distance from stagnation point (r/d) etc., Experimental set-up consists of an air blower, a calibrated venturimeter, a control valve, multiple jets plate, Target plate, 2D-Traverse system, static pressure tap and single water column manometer (or differential pressure transducer).The experimental parameters include, jet plate to target plate distance (Z/d =1.0, 2.0 and 3.0), stream wise pitch (p = 2d,4d & 6d) and Reynolds number (Re =10000 to 20000).Multiple air jets at a specified Reynolds number impinges on the flat surface. Wall static pressure is measured using a static pressure tap and single water column manometer. It is observed that maximum wall static pressure coefficient (Cp) value at all jet centre's for all Z/d studied. Secondary peaks occurred between adjacent jets due to formation of wall jets.*

Keywords: *Multiple impinging jets, stagnation point, Flat target plate, Wall static pressure coefficient.*

1. INTRODUCTION

Impinging jets are used in many industrial applications to achieve enhanced coefficients for convective heating, cooling or drying. Few industrial processes which employ impinging jets are drying of food products, textiles, films and papers; processing of some metals and glass, cooling of gas turbine blades, cooling of a circular furnace, outer wall of the combustion chamber; cooling of electronics equipments and many more.

(Y.S. Chung et al., 1999) Experimentally investigated to study the wall Pressure coefficient distribution (C_p) on without the rib (smooth surface) and with the rib-roughened convex surface(rib type C) by the impinging of axisymmetric jet at different nozzle-to-convex surface distances (*L/D=6 and 10*) and at a fixed Reynolds number of *Re=23000*. Observed that for smooth surface case C_p gradually decreases from its maximum value at the stagnation point to zero C_P at $r/d \approx 1.5$ to slight negative C_p in the region beyond $r/d=1.5$ and the pressure recovers to positive value at $r/d \approx 5.5$. But for the rib-roughened surface case, the pressure suddenly increases when the flow collides on the upstream of the rib. As the fluid flows over the rib, the flow separation occurs on top of the rib, which in turn creates a low pressure region downstream of the rib. However, although we can see a tiny but finite change in pressure coefficient around $r/d \approx 6.0$ for the rib-roughened surface, the pressure coefficient is hardly changed in the region beyond $r/d \approx 6.0$. This may be attributed to a drastic decrease of the flow momentum in the region far away from the stagnation point when the fluid flows over the curved surface.

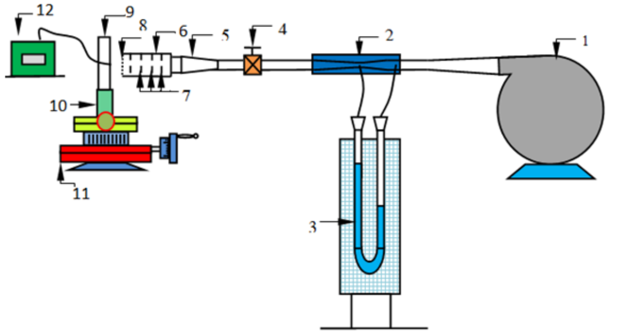
Vadiraj Katti et al., (2008) In this paper measurements for the static wall pressure distribution on smooth flat surface due to impinging circular air jet at different jet-to-plate spacing(*Z/d=0.5 and 6.0*), at a fixed Reynolds number of *Re=23000* were made. Observed that at the stagnation point, the wall static pressure is highest and higher than the atmospheric pressure. This results in a favorable pressure gradient along a direction parallel to the target surface in the stagnation region. Finally, the flow over the target surface forms the wall jet region. The wall jet adheres to the surface and flows over the plate interacting with the surrounding air. $\Delta p/\Delta p_0$ monotonically decreases from its maximum value at the stagnation point to zero at $r/d \approx 1.1$.

Raman Kumar and Prasad(2006) Experimental and computational study of multiple circular jets impinging on a concave surface from this author observed that Peak values of static pressure at the stagnation point and decrease in static pressure with distance from stagnation point are observed and high localized static pressure was observed in case of single row of jets and uniform distribution by using multiple row of jets and concluded that The length of potential core varied from 0.2 to 3 times the jet diameter as h/d varies from 1 to 6.

Katti and S V Prabhu(2008) Conducted experimental study and theoretical analysis of local heat transfer and fluid flow distribution between smooth flat surface and impingement from a circular straight pipe nozzle ,author varied parameter ranges from (Re_j =12000to28000) and jet to plate spacing(z/d=0.5to8) from this observed that peak of wall static pressure coefficient (C_p) at stagnation point and also they observed three regions stagnation regions ($0 \le r/d \le 1.0$),transition region($1.0 \le r/d \le 2.5$),wall jet region ($r/d \ge 2.5$)

2. EXPERIMENTAL SETUP & METHODLOGY

A schematic layout of the experimental set-up is shown in Fig.1. Air is supplied by a blower through a calibrated venturimeter. The air flow is regulated by a control valve located on downstream of the venture meter to obtain the required Reynolds number. Air is discharged through the multiple circular jets on flat surface (target plate) which is mounted on a 2-D traverse system to vary the impinging distance systematically.



1) Blower 2) Venturimeter 3) U tube manometer 4) Control valve 5) Diffuser 6) Air plenum chamber 7) Flow strengtheners (mesh) 8) Jet plate 9) Target plate10) Support 11) 2-D Traverse system Differential pressure transducer or Single water column manometer

Fig. 1: Layout of Experimental set-up for Fluid Flow study

During experimental investigation of wall static pressure coefficient (C_p) distribution using multiple circular impinging jets on a flat surface (smooth surface). Jet air temperature is measured using a calibrated thermocouple placed in the pipe. To obtain the axial and radial variations of static pressure on the flat surface, a static pressure tap (inner diameter of 0.5 mm) is mounted in a hole drilled on the flat surface. Pressure readings are recorded using static pressure tap and single column manometer.

I. Data reduction:

a) Flow rate through Venturimeter:

$$Q_{act} = C_d \frac{a_1 a_2 \sqrt{2gH}}{\sqrt{a_1^2 - a_2^2}} \qquad \text{Eq(1)}$$

Where, Q_{act} = actual flow rate of air (m^3/sec), C_d = coefficient of discharge,

a_1 = cross sectional area at inlet section (m^2) a_2 = cross sectional area at throat section (m^2), g = acceleration due to gravity = 9.81 m/s^2 H = equivalent head = $\left[\frac{\rho_w}{\rho_a} - 1\right] X$

ρ_w = density of water or manometer fluid (kg/m^3), ρ_a=density of pipe fluid (kg/m^3),

X = manometer deflection (m)

b) Average centerline velocity of jet (u):

$$u = \frac{Q_{act}}{A} \qquad \text{Eq(2)}$$

Where Q_{act} = actual discharge of air (m^3/sec), A = cross section area of jet (m^2)

c) Jet Reynolds number (Re):

$$\text{Re} = \frac{\rho u d}{\mu} \qquad \text{Eq(3)}$$

Where ρ_a = density of pipe fluid (kg/m^3),
u= average centerline velocity of jet (m/s), d = diameter of jet (m),
μ = dynamic viscosity (kg/m.sec)

d)Wall static pressure coefficient (C_P):

$$Cp = \frac{\Delta p}{0.5 \rho_a u^2} \qquad \text{Eq(4)}$$

Where Δp =Difference between the wall static pressure on flat surface and atmospheric pressure, i.e ($P - P_\infty$) (Pa), P = Wall static pressure on flat surface (pa), P_∞=Atmospheric pressure (pa) , ρ_a = density of air (kg/m^3), u = average centerline velocity of jet (m/s)

3. RESULTS AND DISCUSSION

I. Influence of Reynolds number on wall static pressure coefficient (C_p) :

Fig. 2 shows distribution of *Cp* for different jet Reynolds number (*Re=10000 to 20000*). It is observed that *Cp* distribution for different *Re* almost collapse; hence the *Cp* distribution may be considered independent of the jet Reynolds number in the range chosen for study.

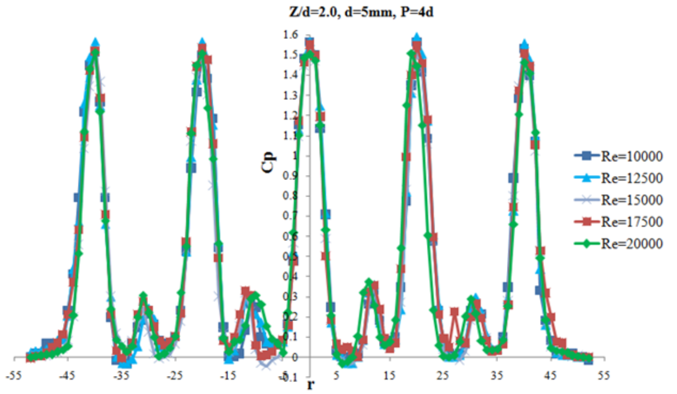


Fig. 2: Reynolds number independency test

II. Influence of Z/d on wall static pressure coefficient (C_p) for stream wise pitch p =4d:

Fig. 3 shows wall static pressure coefficient (C_p) on a flat plate along radial direction (r) at Re = 10000 and *Stream* wise pitch P = 4d for different Z/d. It is observed that maximum C_p value occurs at all jet centres. Secondary peaks occurred between adjacent jets due to formation of wall jets. As Z/d increases Cp value decreases with corresponding radial distance. Also primary peaks shifts down and secondary peaks shifts up.

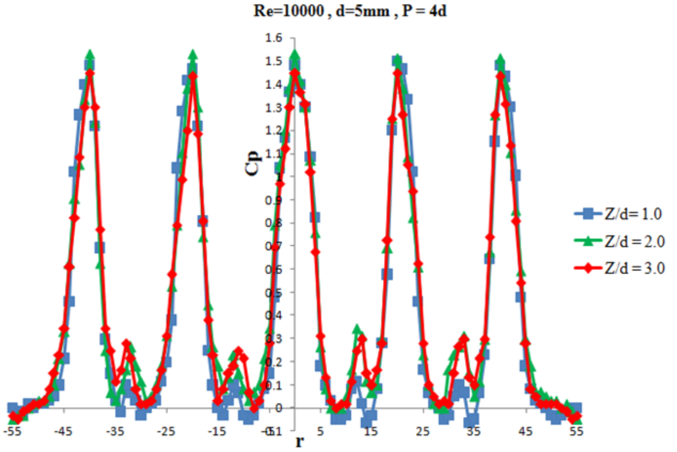


Fig. 3: Wall static pressure coefficient distribution for different Z/d

III. Influence of Z/d on wall static pressure coefficient (C_p) for stream wise pitch p =6d:

Fig. 4 shows wall static pressure coefficient (C_p) on a flat plate along radial direction (r) at Re 10000 and Stream wise pitch P = 6d for different Z/d. It is observed that maximum C_p value occurs at all jet centres. Secondary peaks occurred between adjacent jets due to formation of wall jets. As Z/d increases Cp value decreases with corresponding radial distance. Also primary peaks shifts down and secondary peaks shifts up. The values of wall static pressure coefficient (C_p) at primary and secondary peaks are decreased with increase in stream wise pitch, due to less interaction between adjacent jets.

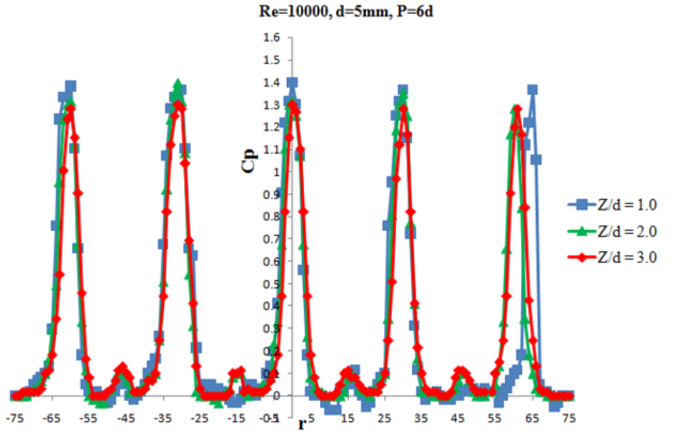


Fig. 4: Influence of Z/d on wall static pressure coefficient (C_p) for stream wise pitch p = 6d

4. CONCLUSION

An experimental investigation is carried out to study the distribution of wall static pressure (C_p) on a flat surface impinged by the multiple circular jets. The influence of the geometric parameters like *Z/d,* stream wise pitch *P* on wall static pressure coefficient distribution is studied. The wall static pressures are measured on the flat surface at different radial distance at a fixed Reynolds number of 10000. Following conclusions may be derived from the present study:

- The maximum wall static pressure coefficient (*Cp*) occurs at all jet centres for all *Z/d* studied due to coincidence of jet axis and static pressure tap axis.
- Secondary peaks occurred between adjacent jets due to formation of wall jets.
- As Z/d increases Cp value decreases with corresponding radial distance due to decay of jet velocity with increase in axial distance from jet exit to target plate.
- The values of wall static pressure coefficient (C_p) at primary and secondary peaks are decreased with increase in stream wise pitch, due to less interaction between adjacent jets.

Future work

- Wall static pressure coefficient (C_p) distribution on rough flat surface by using ribs
- Influence of ribs(surface roughness) configuration on C_p distribution

REFERENCES

1) D. H. Lee, Y. S. Chung, D. S. Kim, “Turbulent flow and heat transfer measurements on a curved surface with a fully developed round impinging jet”, ELSEVIER International Journal of Heat and Fluid flow18 (1997) 160–169.

2) D.H. Lee, Y.S. Chung, S.Y. Won, "The effect of concave surface curvature on heat transfer from a fully developed round impinging jet", PERGAMON International Journal of Heat and Mass Transfer (1999) 422489-2497.
3) Vadiraj Katti, S.V. Prabhu, "Experimental study and theoretical analysis of local heat transfer distribution between smooth flat surface and impinging air jet from a circular straight pipe nozzle", ELSEVIER International Journal of Heat and Mass Transfer 51 (2008) 4480–4495.
4) Y.S. Chung, D.H. Lee, J.S. Lee, "Heat transfer characteristics of an axisymmetric jet impinging on the rib-roughened convex surface", PERGAMON International Journal of Heat and Mass Transfer 42 (1999) 2101-2110.

Nomenclature

C_p	Wall static pressure coefficient defined in Eq (4)
d	Circular jet diameter, m
P	Wall static pressure on flat surface, pa
P_∞	Atmospheric pressure, pa
u	Average centerline velocity, m/s
Re	Jet Reynolds number
Z	Distance along a jet axis from a jet exit to a stagnation point on a flat surface (target plate), m
Z/d	Non dimensional distance along a jet axis from a jet exit to a stagnation point on a target plate
r	Radial distance from axis of a circular jet to a stagnation point on a target plate ,m
r/d	Non dimensional radial distance from axis of a circular jet to a stagnation point on a target plate
A	cross -section area of jet , m^2
	Greek Symbols
ρ_a	Density of air, Kg/m^3
ρ_w	Density of water, Kg/m^3
μ	Dynamic viscosity of air, Ns/m^2
	Subscripts
a	Air
∞	Atmospheric
w	Water