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Pressure Disrtribution on the Concave Curved Surface Due To Impingement of Air Jet from an Orifice for d=10mm for Confined Flow

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Abstract:- **Jet impingement is is one of the all around characterized techniques for cooling, warming and drying of surfaces. Few industrial processes which make use of impinging jets are drying of food products, films and papers, textiles, processing of some metals and glass, outer wall of the combustion chamber and cooling of gas turbine blades . The present work is to study experimentally the distribution of static pressure on the concave curved surface due to air jet impingement from an orifice for d=10mm for confined flow. The experimental includes measurement of static pressure difference on concave curved surface for various parameters such as d=10mm (diameter of orifice), Z/d=1to 4(non dimensional distance between orifice exit plane and curved surface plane) θ=00 to 400 (circumferential location indicated as angular position on concave curved surface measured from the direction of jet impingement at the centre of curvature) for Reynolds number of flow 5000 to 45000. It is observed that coefficient of static pressure Cp is independent of Reynolds number. The results revels that higher value of CP are observed up to θ=00 and decreases along the circumferential location .Higher values of Cp are observed at lower Z/d ratio as the velocity decay is minimum at this position.**

Keywords:-- **jet impingement. Static pressure. Confined flow. Concave surface.**

I. INTRODUCTION

Jet impingement is one of the all around characterized techniques for cooling, warming and drying of surfaces. Such impingement permits small flow path on the surfaces with relative high heat transfer rates. Since local heat transfer coefficient depends on flow characteristics such as static pressure distribution, Few industrial processes which make use of impinging jets are drying of food products, films and papers, textiles, processing of some metals and glass, outer wall of the combustion chamber and cooling of gas turbine blades . Heat transfer rates in case of impinging jets are affected by various parameters like radial distance from stagnation point, roughness of target surface , jet to plate spacing ,target plate configuration, confinement of jet, nozzle geometry, and turbulence intensity at the nozzle exit. The present work is to study experimentally distribution of static pressure on the concave curved surface due to air jet impingement from an orifice for confined flow. Researches in these topics have accelerated in recent years because of its high potential local heat transfer enhancement. Application of jet includes thermal management of electronics equipment, glass tempering and annealing, paper and ceral drying, in gas turbine industry impingement cooling use in cooling of blades, vanes, of gas turbine. There are many innovative work in JET impingement method over a most recent couple of decades and maximum work conducted is related to flat surface however just few works are done on curved surface. The high heat transfer rates connected with impinging air jet is wel recognized and recorded for many years. Review of the experimental work on impinging jets is reported by Jambunathan K. et al.[1]. Taslim[3] et al used one row of jet for both rough and smooth surface and he came to conclusion that there is heat transfer enhancement benefit in roughening the target surface Tabakoff, W. and Clevenger, W[4] have done study on this topic by using slot jet on the curved surface and they expressed that static pressure decreases along the curvature at higher at lower ratios of diameter of curved surface of slot width. Ramkumar and Prasad[5] have done experiment by using one row of jet and five row of jet(multiple jet) by changing a parameters like Reynolds number, nozzle to plate distance, and jet to jet spacing. And they come to conclusion that local pressure and heat transfer coefficients distribution showed the presence of secondary peak corresponding to the up to wash jet to jet interaction recently Vadiraj Katti et al, [6] have done experiment using single row of multiple jet on concave curved surface and stated

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that coefficient of static pressure decreases at higher jet to plate distance. And a secondary peak is seen between adjacent jets.

Hence the present work concentrates on static pressure distribution on confined concave curved surface due to impingement of air jet from an orifice for d=10mm. The work is carried out for various geometrical parameters such as Reynolds number (5000 to 45,000), Z/d (1 to 4) and with confinement. The results from experiments could find a significant role in modifying and designing the gas turbine blades.

Nomenclature

d	Diameter of orifice (m)
Re	Mean jet Reynolds Number
ρ_a	Density of air (kg/m^3)
H_w	Manometer head (m)
Z	Distance between nozzle exit plane and curved surface plane(m)
Z/d	Non dimensional distance between nozzle exit plane and curved surface plane
T_j	Jet air temperature (°C)
ρ_a	Density of air at nozzle exit (kg/m^3)
μ	Absolute viscosity of air (kg/ms)
C_d	Co-efficient of discharge of venturimeter
V_j	Velocity of jet(m/s)
θ	Circumferential location indicated as angular position on the concave curved surface with respect to centre of curvature measured from direction of impingement of jet(°)
C_p	Static pressure coefficient
C_{po}	Stagnation pressure coefficient
m	Mass of air(kg/s)
ΔP	Difference between gauge wall static pressure and atmospheric pressure

II. EXPERIMENTAL SETUP

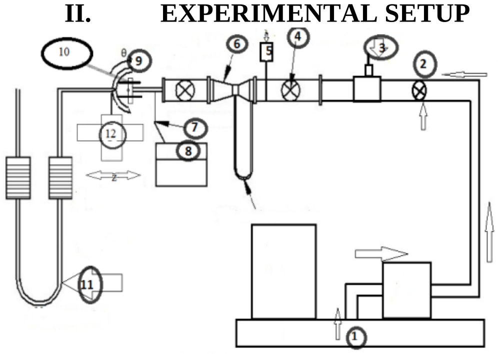


Fig.1. Experimental setup (1) ELGI Airmate, Air screw compressor with refrigeration unitwith capacity of 1.1m^3/min and maximum supply pressure of 7 bars), (2) ball valve (3) pressure regulator, (4) flow control valves, (5) pressure gauge,(6) venturimeter, (7) calibrated K-type thermocouple, (8) millivoltmeter, (9) curved surface, (10) confinement plates, (11) calibrated double bulb micro mano meter (12) calibrated compound sliding table

The Venturimeter is designed and calibrated whose co-efficient of discharge C_d is found to be 0.92 ±2%. The flow rate is adjusted by flow control valves, the Reynolds number is set by adjusting the flow rate with the calibrated venturimeter. The temperature of room temperature and jet temperature is measured by calibrated K type thermocouple placed near nozzle exit. In addition, all experiments were performed under a steady state. The target surface of inner diameter 50mm and 10mm thickness is used as concave curved surface as shown in Figure.2. The total length of target surface is 300mm including the slider. Confinement plates of 150mm length and 70mm width and one end with curvature of 50mm which provides confinement flow for the jet, for different Z/d (i.e Z/d=1 to 4)different confinement plates are used and these confinement plates are attached to concave curved surface with help of Anna bond as adhesive, the care has to be taken to maintain the smooth concave surface while attaching these confinement plate and also there is no stepped surface created between the slider and reaming part of target surface, the movement of slider along circumferentially must be smooth. The curved surface is mounted on calibrated compound sliding table so that it can be fixed at a particular *Z/d* position and curved surface can also be moved circumferentially at a particular angular position with respect to centre of curvature, measured from the direction of impingement θ. The Slider of 15mm width with 0.5mm diameter hole at the centre used as pressure tap to measure stagnation pressure, and this slider is inserted at the middle of the target surface to measure the pressure at different Circumferential angles (θ=0-40°). The air is blown through orifice of diameter 10mm over the confined concave curved surface at a particular Reynolds number of flow at the orifice exit. The static pressure difference is measured by double bulb, two fluid micro manometer using benzyl alcohol and water as manometer fluids, with magnification factor 14.59. Janatics air-pressure regulator is used to regulate air pressure.

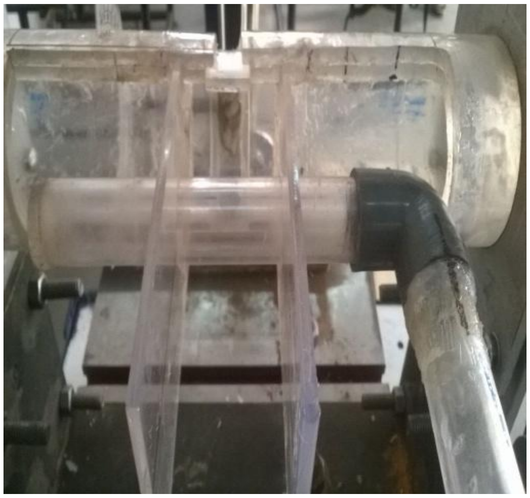
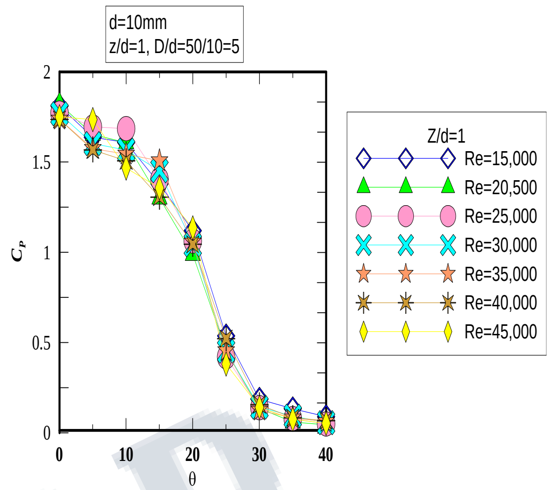
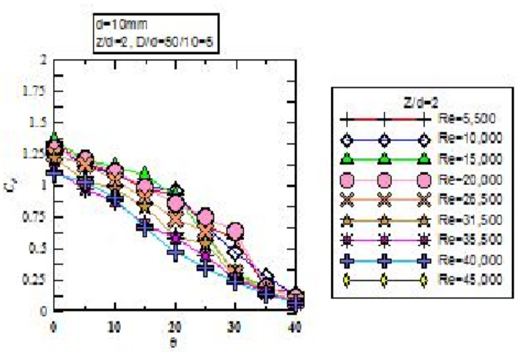
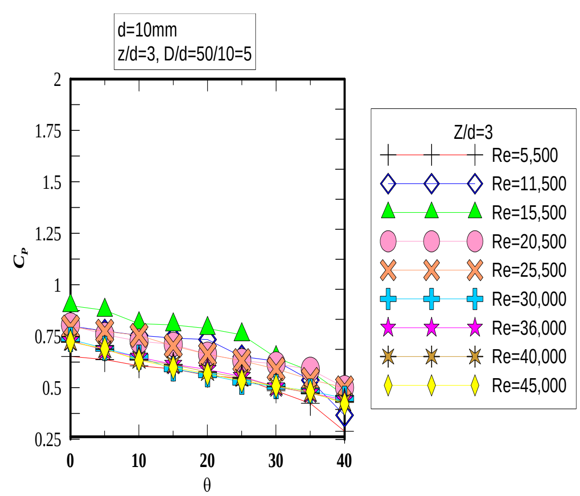


Fig.2.An Image of Concave Curved Surface with Confinement plates







III. DATA REDUCTION

The jet Reynolds number is defined on the basis of orifice diameter and is estimated using the following equation

- $$\mathrm{Re} = \frac{4 \times m^{\cdot}}{\Pi \times d \times \mu}$$
  d = Nozzle Diameter
  m =actual mass inflow rate
- μ = coefficient of dynamic viscosity
- Temperature of jet at exit of orifice in (c^0)
- $T_j(^0C) = 23.188 \times v + 3.843$
- Density of Air from jet in (kg/m^3)
- $$\rho = \frac{P_{atm}}{0.287 * (T_J + 273)}$$
- Difference between gauge wall static pressure and atmospheric pressure in (Pascal's)
- $$\Delta p = 1000 * 9.81 * H_w$$

IV. RESULTS AND DISCUSSION

An experiment is conducted on the concave curved surface to determine coefficient of static pressure distribution ($C_p = \Delta p / 0.5 \rho A V_j^2$) by impinging jet of air through an orifice (for d=10mm) for confined flow at steady state, for different geometrical parameters.

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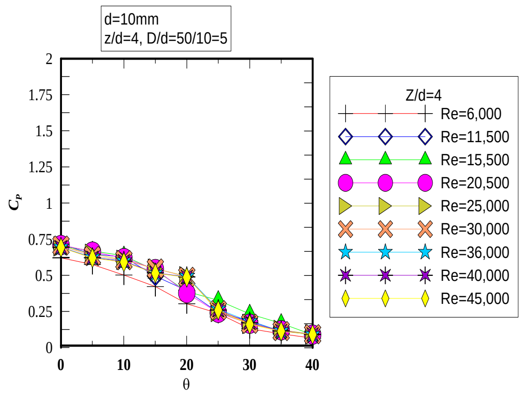

Fig.4. . C_p v/s θ for various Reynolds number at different Z/d where d=14

The Static Pressure co-efficient C_p for different Reynolds numbers are determined for *Z/d* 1, 2, 3&4. From the Figure 4, **C_p v/s Ө,** it is observed that co-efficient of static pressure *Cp* is independent of Reynolds number as the curve overlaps to each other and same trends observed for all *Z/d*. Hence further analysis is carried out for one representative Reynolds number (Re =40000).

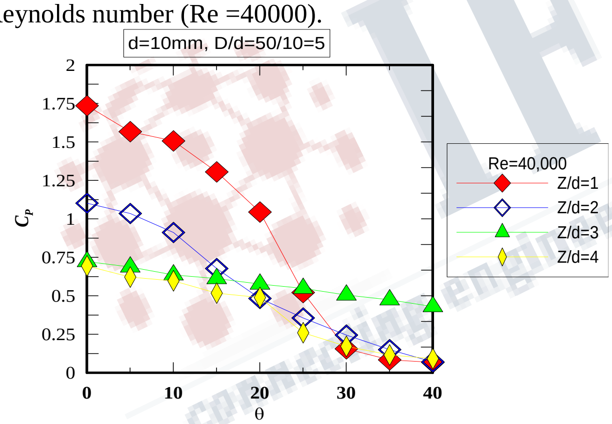

Fig .5. C_P v/s θ at Re=40000 for various Z/d

From the Figure 5, Static pressure co-efficient **C_p vs. Ө**, the higher values of C_p are obtained at *stagnation* because of higher center line velocity. The value of C_p decrease steadily up to Ө=15^0 and decrease considerably for higher Value of Ө. The value of Cp varies from 1.75 to 0.2. As the Z/d ratio increases from 1 to 4 at stagnation point (Ө=0).

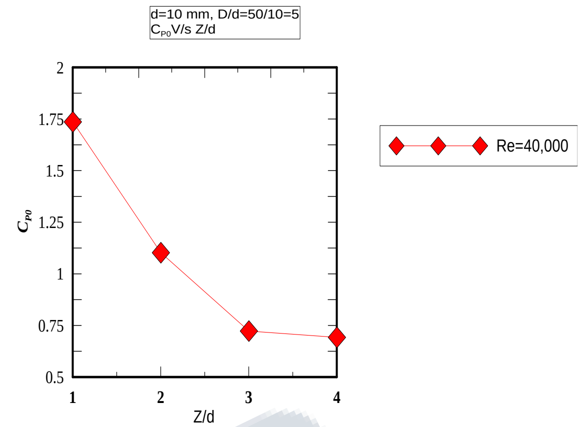

Fig.6. C_{po} v/s Z/d at Re=40000

From the Figure 6, of Stagnation pressure co-efficient C_{po}v/s *Z/d*, revels that stagnation pressure co-efficient are higher at lower Z/d ratio. It decreases from *Z/d* 1 to 4. So the value of C_{po} is 1.75 to 0.75 for the *Z/d* = 1 to 3, this is due to target surface is located within the potential core of free jet. Then the noticeable decrease of C_{P0} is observed for further increase of Z/d ratio. As the distance from the orifice increases the velocity goes on decreasing due to spreading of jet.

V. CONCLUSIONS

The Coefficient of static pressure C_p is experimentally investigated for different Reynolds number of flow at steady state. The followings are the main conclusions that may be drawn from this study The static pressure distribution on the target surface due to impingement of air jet is independent of Reynolds Number of flow.

- The Static Pressure (C_P) on the concave curved surface are almost uniform up to θ=15^0 & decreases considerably for higher value of θ.
- The values of Stagnation pressure co-efficient (C_{po}) is higher at lower *Z/d* ratio and they decreases considerably for higher value of *Z/d* this is because decay of velocity of jet after the potential core region.
- The potential core of free jet is observed for the *Z/d* ratio between 1 & 2. The velocity decay is minimum for this range of *Z.*

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