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Effect of Jet to Test Section Spacing on Wall Static Pressure Disrtribution on the Concave Surface due to an Impingement of a Submerged Circular Air Jet

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Abstract: Jet impingement is one of the well-defined methods used for heating or cooling of surfaces. Such impingement allows narrow path on the surface with relative high heat transfer rate. The different flow and geometric characteristics such as wall static pressure distribution, Jet to test spacing, Reynolds Number, circumferential angle ect influences the local heat transfer coefficients. The present work the experiments are conducted to know the effect of Jet to test section spacing on coefficient of static pressure distribution on the concave curved surface due to impingement of air jet from a circular nozzle of diameter 15mm for unrestricted flow is studied in details for different flow and geometric parameters such as orifice diameter (d=15.5 mm), Curvature ratio (D/d=3.23), Circumferential angle (θ=00 to 350) and Reynolds number of flow (Re=10000 to 45000). It is observed that coefficient of static pressure Cp is independent of Reynolds number and also results revels that value of Cp & Cpo is higher at θ=00 for lower Z/d ratio and it decreases along the circumferential location.

Keywords: Jet impingement. Static pressure. Curvature ratio. Concave curved surface.

I. INTRODUCTION

Jet impingement is one of the best methods for cooling and heating of surfaces. Jet impingement creates a small flow path on the surfaces with relative high heat transfer rates. Since static pressure distribution plays important role in local heat transfer coefficient. The present work is to conduct experiment to study the distribution of static pressure due to impingement jet from an orifice for confined flow on the curved surface.

Researches in these topics have accelerated in recent years because of its high potential local heat transfer enhancement. There have been indefinite researches works and developments in jet impingement technique over last few decades by many research scholars on Curved surfaces, that too with confined flow are of countable number. In the year 1972 Tabakoff W. and Clevenger W[1] done study on this topic by using slot jet to impinge on the curved surface and they stated that the wall static pressure decrease along the curvature at higher flow rate at lower ratios of diameter of curved surface to slot with. Later in the year 2008 Fenot et al. [2] carried out experimental on heat transfer due to a row of air jets impinging on a concave semi-cylindrical surface. The jets are issued from round tubes and flow to the supply channel is normal to the concave surface. In 2010 Vadiraj V. katti and S.V Prabhu[3] done research on this topic by using single row of multiple jet on concave curved surface and studied the heat transfer distribution along the stagnation line in both span wise direction and along the curvature. Recently in 2014 Dr V.V. Katti and R.N. Patil[4] conducted experiment on static pressure distribution due to impingement of jet on target surface they optioned result, the values of Cp at stagnation are higher due to higher centerline velocities and it is almost uniform up to curvature angle of 5°, and decrease appreciably for circumferential angle θ. In 2017 A Hanchinal et al, [5] done study by impinging air jet from orifice on concave surface for confined flow they revealed that the wall static pressure is effected by curvature ratio and confinement. Higher value of C_p are seen for confined flow and at Lower higher Curvature ratio. In further study they revealed that the stagnation pressure is high for Z/d ratio the potential core is seen from Z/d 1 to 2 [6][7].

Hence the present work focused on distribution of static pressure on confined concave curved surface due to impingement of air jet from an orifice. The work is carried out for various geometrical parameters such as Reynolds number (10000 to 45,000), Z/d (0.5 to 8) and influence of curvature angle θ= (0^0 to 35^0) with confinement. The results from experiments could find a significant role in modifying and designing the gas turbine blades and also provides bases for further researches.

II. NOMENCLATURE

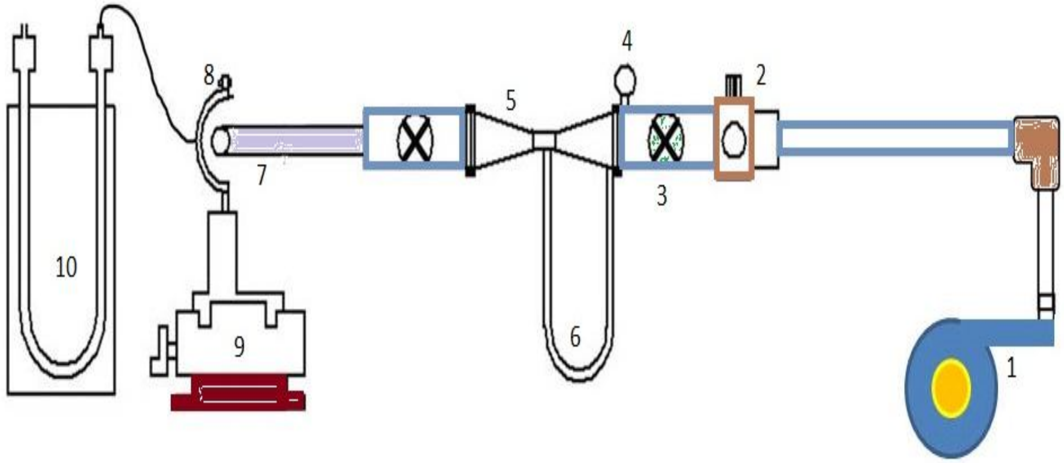
D	Orifice diameter (m)
D_h	Hydraulic diameter (m)
Re	Mean jet Reynolds Number
ρ_a	Density of air (kg/m^3)
H_w	Manometer head (m)
Z	Distance between curved surface plane and nozzle exit plane (m)
T_j	Jet air temperature (°C)
ρ_a	Density of air at nozzle exit (kg/m^3)
µ	Absolute viscosity of air (kg/ms)
C_d	Co-efficient of discharge of venturimeter
V_j	Velocity of jet (m/s)
Θ	Circumferential angle
C_p	Static pressure coefficient
C_{po}	Stagnation pressure coefficient
M	Mass of air(kg/s)
ΔP	Pressure difference between wall static pressure and atmospheric pressure

Abbreviation

Z/d	Non dimensional distance between nozzle exit plane and curved surface plane
D/d	Curvature ratio

III. EXPERIMENTAL SETUP AND PROCEDURE

The schematic lay-out of the experimental set-up is shown in Fig. 1. The experimental set up consists of Air blower of 600 watts capacity (Make- AEG GM 600E), 6 speed controller with flow rate varying from 0.36 m^3/min to 2.8 m^3/min. The venturimeter is designed for this flow range and throat and inlet diameters are 16 mm and 25.4 mm. The venturimeter is calibrated with water for the Reynolds Number. 10000-100000 whose Cd found to be 0.92±2%. the flow of jet and jet temperature and surrounding temperature is measured by calibrated K type thermocouple. In addition, all experiments were performed under a steady state.



1. Blower, 2.Pressure Regulator, 3.Control Valve, 4.Pressure Gauge, 5. Venturimeter, 6.Maometer, 7.Nozzel, 8.Test saection, 9.Sliding Table, 10.Micromanomter

Fig.1. Schematic layout of the complete experimental

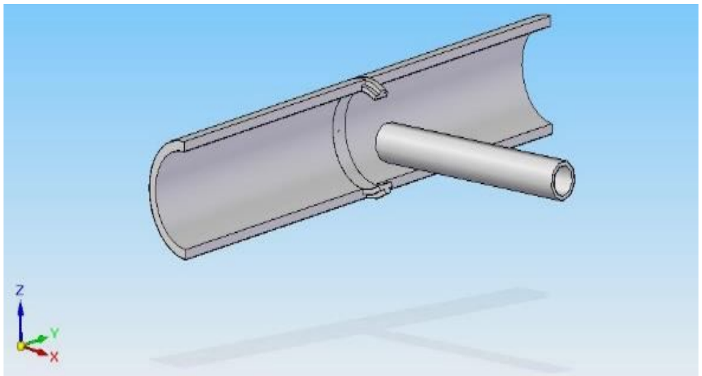
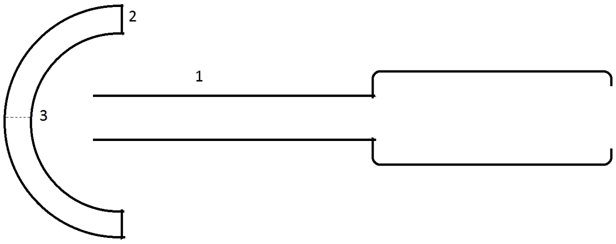


Fig.2. An Isometric view of Target surface with Nozzle



1. Nozzle, 2. Concave Curved Surface, 3.Pressure Tap at center
Fig.3. Schematic layout of Target surface with Nozzle

The semi cylindrical tube of inner diameter 50mm and outer diameter of 60mm and length 275mm is used as the target surface, the care has to be taken to maintain the smooth concave surface which is shown in Figure.2. This target surface will be fixed on calibrated compound slide table. with this compound slide any particular Z/d position of test section will be adjusted. To measure wall static pressure along the circumference of surface the Slider with 0.5 mm diameter hole at the centre used as pressure tap, this slider is placed at the middle of the target surface to measure the static pressure at different Circumferential angles varying θ=0°-35° and the movement of slider along circumferentially must be smooth. The micro manometer with magnification factor 14.59 is used to measure static pressure difference. The two different fluids benzyl alcohol and water are used as manometer fluids in micro manometer. The experiment is performed under a steady state for various flow parameters and results are tabulated to draw different graphs for further study.

IV. DATA REDUCTION

The jet Reynolds number (Re)

$$\mathrm{Re} = \frac{4 \times \mathrm{m}^{\cdot}}{\Pi \times \mathrm{d} \times \mu}$$

1) Temperature of jet at exit of orifice in (c^0)

$$T_j({}^0C) = 23.188 \times v + 3.843$$

2) Density of Air from jet in (kg/m^3)

$$\rho = \frac{P_{atm}}{0.287 * (T_j + 273)}$$

3) Co-efficient of Pressure

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

V. RESULTS AND DISCUSSION

An experiment is conducted for various flow and geometric parameters on the concave curved surface to determine the effect of Jet to test section spacing on wall static pressure distribution ($C_p = \Delta p / 0.5 \rho A V_j^2$) by impinging jet of air through an circular nozzle at steady state conditions and the following results are obtained which are discussed in details below.

Influence of Reynolds number

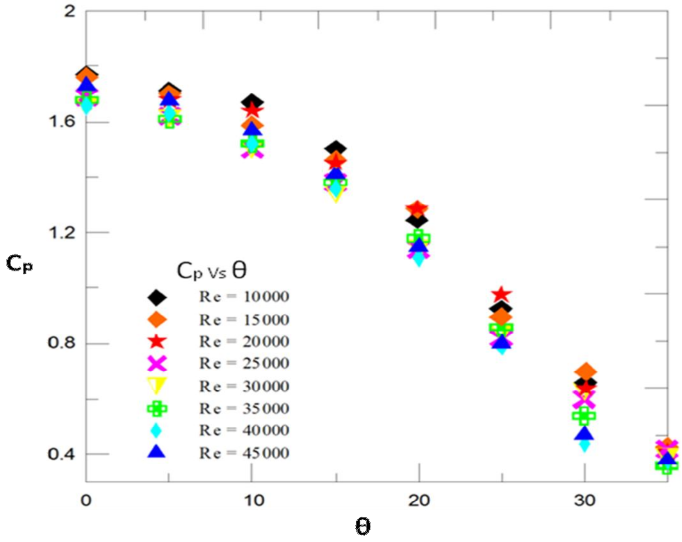


Fig.4. Cp v/s θ for various Reynolds number

From the Figure. 4, **C_p v/s θ** for various Reynolds number at Z/d 0.5. 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 0.5 to 8. Hence further analysis is carried out for any one representative Reynolds number (Re =30000).

Effect of jet to test section spacing on wall static pressure:

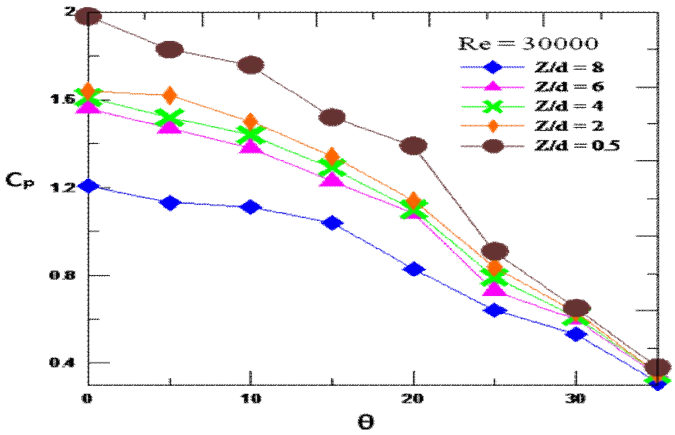


Fig .5. C_p v/s θ at Re=30000 for various Z/d

Figure.5 gives the variation of wall Static pressure co-efficient along circumferential angle θ at curvature ratio D/d=3.23 for various Z/d ratios (0.5 to 8). From graph it is seen that, the higher values of C_p are obtained at stagnation point that is $\theta = 0^0$ because the velocity at the center of jet is high. This increase in the C_p value is also due to vena contraction effect. The value of C_p decrease value up to $\theta = 10^0$ and decrease considerably for higher value of θ at 35^0. The same trend is seen for all Z/d and Reynolds number of flow. This decrease in the Cp is due to the decay of jet as jet comes out of the potential core zone.

Effect of jet to test section spacing on Stagnation pressure:

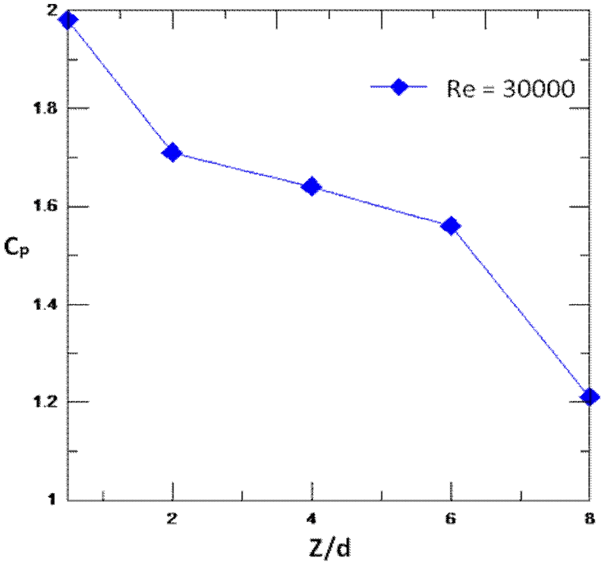


Fig.6. C_{po} v/s Z/d at Re=40000

Figure 6 C_{po} v/s Z/d, gives variation of Stagnation pressure co-efficient for curvature ratio(D/d)= 3.23 for different Z/d ratio varying from 0.5 to 8 at one particular Reynolds number. The above graph revels that stagnation pressure co-efficient are higher at lower Z/d ratio. It decreases gradually from Z/d 1 to 4. So the value of C_{po} is 1.83 to 1.2 for the Z/d = 1 to 2, this is due to target surface is located within the potential core of free jet.

VI. CONCLUSION

The Experimental study results on static pressure distribution on concave curved surface due to an air jet impingement from circular submerged jet for open flow for different geometric and flow parameters gives flowing conclusions which would be useful for further research and development of Turbine blades and heat transfer applications.

A. The independency of wall static pressure distribution is observed for various Reynolds Number of flow on impingement of circular jet on curved surface as all the curves follows same trend.

B. The value of C_p remains uniform to circumferential angle $\theta=10^0$ on the concave curved surface & decreases considerably for higher value of θ

C. The value of C_p and C_{po} are high at lower Z/d = 0.5 they decreases considerably for higher value of Z/d as the decay of jet take place in impinging zone.

D. At Lower Z/d ratio the potential core of free jet is observed. As jet velocity decay is minimum for this range of Z.

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