NUMERICAL ANALYSIS OF HEAT TRANSFER FROM FLAT PLATE TO ORTHOGONALLY IMPINGEMENT AIR JET

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Abstract— ***The heat transfer distribution between the orthogonally impingement jet on a heated flat plate is studied numerically. Using FLUENT 15.0 numerical study and 3-D simulation is carried out, to observed the impact of spread between nozzle exit and plate, Reynolds number on characteristics of heat transfer. Turbulence model used is standard κ-ε. In this paper, results for various jet exit to plate spread from 0.5 to 8 are presented. For Z/d=0.5 to 8 numerical result vary significantly from experimental results having Reynolds number 12000, 20000 has been studied.***

Keywords: Jet impingement, heat transfer, air jet, orthogonal impingement jet

I. INTRODUCTION

Impingement heat transfer is one of the cooling methods. Because of various range of application, Jet impingement heat transfer attracted wide attention of researches in recent year. Applications such as nuclear reactor safety, plastic, steel rolling industries, electronic equipment's cooling etc. Many industrial processes involving heat transfer at high rates using impingement jet. In jet impingement, various factors influence heat transfer rates such as spacing of jet nozzle-plate, Reynolds number, radial spread from stagnation point, geometry of nozzle, turbulent intensity at nozzle exit etc. In literature, many studies are on flat plate air jet impingement. In this present paper heat transfer for case of orthogonally impingement air jet on flat plate is discussed.

II. LITERATURE REVIEW

Many previous studies are done on vertical air jet impingement on a horizontal flat plate. Experimental work review done on heat transfer to impingement jet by Livingood and Hrycak[9], Jambunathan[8],Said that the distribution of heat transfer between jet and plate for nozzle plate spacing is greater than two times the diameter of jet. For the measurement of local heat transfer distribution from constant temperature plate, specially designed heat flux gage was used. Lyttle and Webb [3] studied nozzle-plate spacing of 0.1-0.5 for air jet impingement. Katti and Prabhu [2] experimentally study the air jet impingement by circular nozzle on flat plate subjected to constant heat flux. Gardon and Akfirat [4] studied the turbulence role on the characteristics of heat transfer by impinging jet. Abhishek bhagwat and arunkumar [1] studied V2F turbulence model predicts Nu number distribution over plate is in good arrangement with experimental of katti and prabhu[2].Brignoni and Garimella[5] studied chamfering and without chamfering nozzle inlet effects on pressure drop and characteristics on heat transfer in limited air jet impingement by choosing nozzle length to diameter ratio equal to 1.And finally they conclude that inlet chamfering to nozzle is reduces the pressure drop without affecting much to the heat transfer characteristics. In this paper, to compute the flow of jet over the flat plate and to analysis heat transfer from the surface, ANSYS FLUENT 15.0 was used. Modeling and meshing was done in ANSYS Workbench 15.0.

III. MATERIALS AND METHODS

The nozzle is of diameter 7.35mm and $\frac{l}{d}$ ratio of 83, which is like that used by Katti and Prabhu [2]. Geometric center of plate having dimension of 160×80mm through which circular tube nozzle passes. Velocity at circular nozzle inlet is 23.84m/s,39.747m/s with corresponding to Re number 12000 and 20000.Temperature of nozzle exit is assumed as 300K. Constant heat flux 1500W/m^2 was maintained while validation the result for case of horizontal steel flat plate.

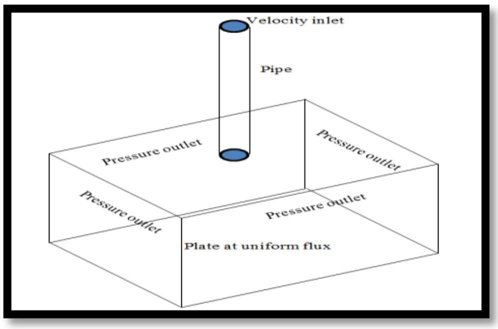

Fig. 1: Isometric view of the geometry(1)

Nozzle is made of steel; outer surface is of adiabatic wall and pressure outlet boundary to all other surfaces. Meshing of the model was tried with ANSYS Workbench 15.0, and interval size kept as 0.0005m. Hexahedral element is used for meshing because of that meshing get smooth and it covers all critical area properly. Commonly used k-epsilon model is used in this paper. SIMPLE scheme is used for pressure and velocity. The Nu number is determined for the surface by equation (1),

$$\text{Nu} = \left(\frac{h \times d}{k}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

$$\text{Re} = \left(\frac{\rho v d}{\mu}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

Z/d	Reynolds Number(Re)
0.5,2,4,6,8	12000,20000

Table 1. Listing of Reynolds number and Z/d parameters

IV. RESULTS AND DISCUSSION

Relation between Turbulent Intensity and Nu number

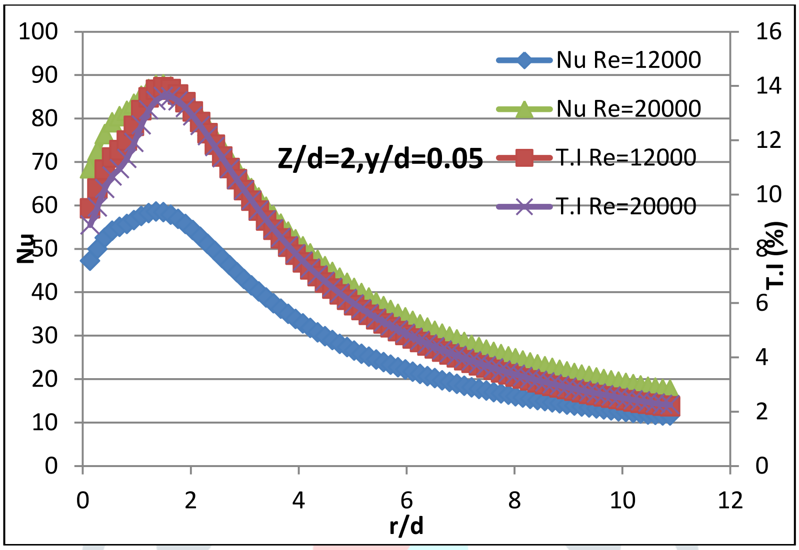

Fig.2 Variation of Nu number and T.I over the plate

On the Y-axis left and right side of plot represent Nu number over plate and variation of T.I at spread 0.05 times nozzle diameter from plate surface. It shows that, due to little intermixing of outside air into the jet core, T.I is low at axis of jet. Outside air enter in the jet shear layer for r/d>1 and due to that suddenly increases in T.I and then start decreases, velocity far from the jet axis is lower for r/d>2 because air from outside is mix with wall jet.

Increases in turbulence intensity because flows go through transition region from laminar to turbulent boundary layer. This result shows the secondary peak in Nu number distribution over flat plate surface.

Results of varying Z/d at constant Re number

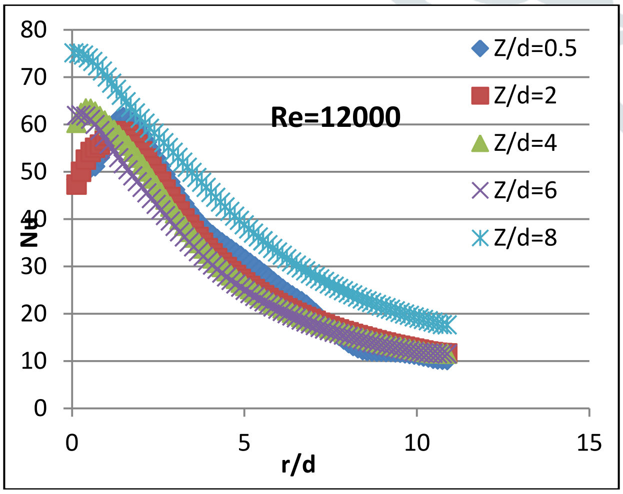

Fig.3 Results of varying Z/d for Re=12000

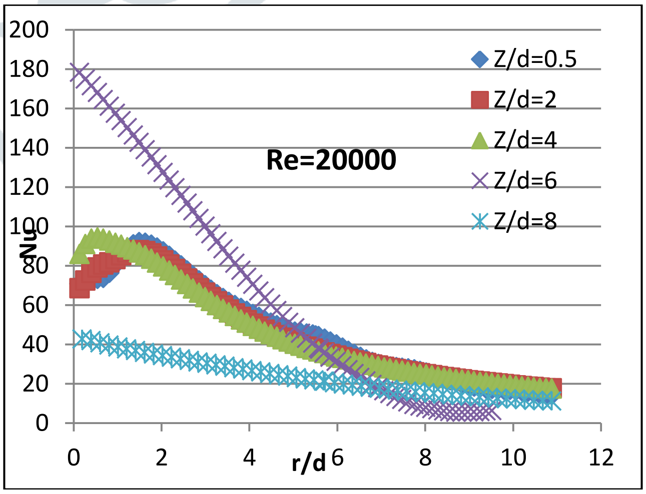

Fig.4 Results of varying Z/d for Re=20000

In above fig.3 and fig.4 result of varying Z/d at constant Re number is shown. Nu number for r/d > 3 is same for 0<Z/d<8.Figure 4 indicates that Z/d from 0.5 to 6, Nu number is increasing for given Re number. After that decrease in Nu number, because intermixing of air jet to surrounding air. Due to increases in turbulent intensity, increases in Nu number for Z/d=4 at r/d=1 and for Z/d=0.5 at r/d=2.Figure indicates that secondary peak is exists for 0.5<r/d<4 and peak is absent for Z/d>6. For Z/d=6 Nu number is maximum at stagnation point is observed.

Results of varying Reynolds number at constant Z/d

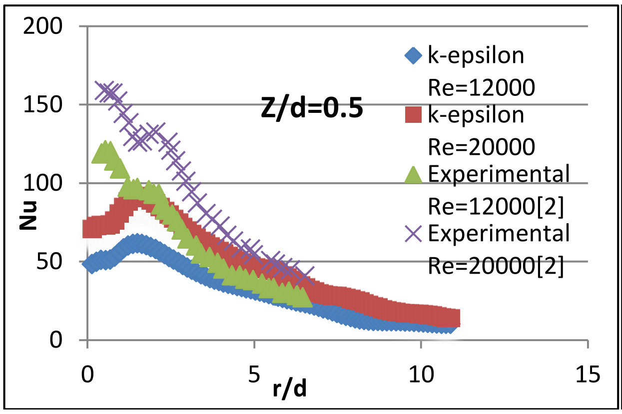

Fig.5 Results of Nu number for Z/d=0.5

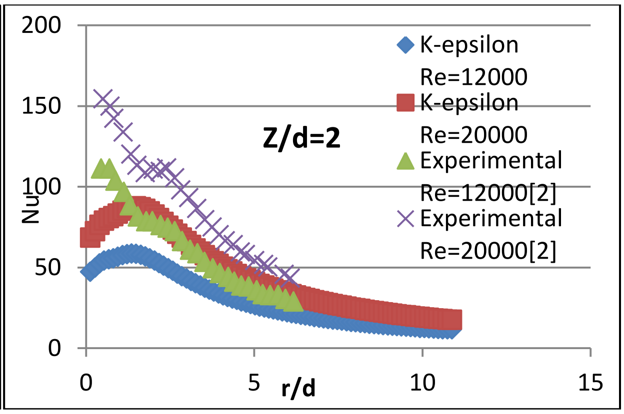

Fig.6 Result of Nu number for Z/d=2

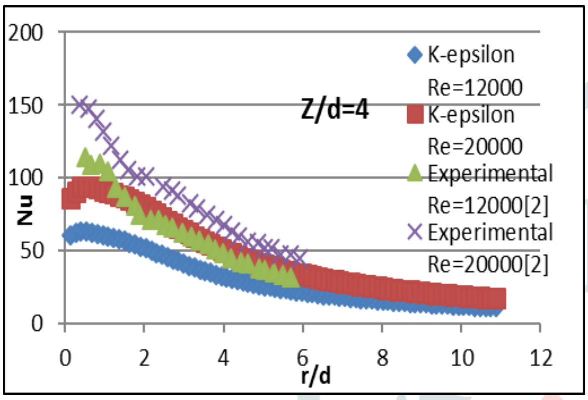

Fig.7 Result of Nu number for Z/d=4

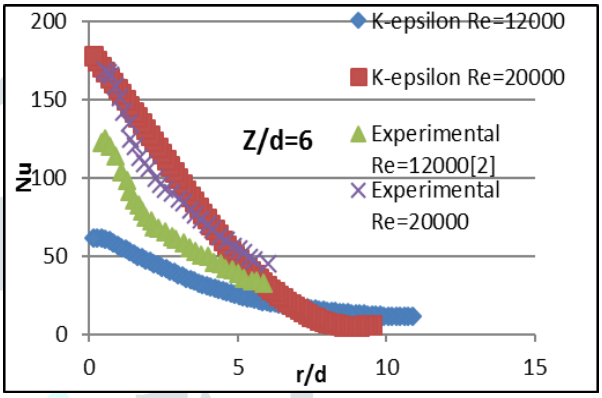

Fig.8 Result of Nu number for Z/d=6

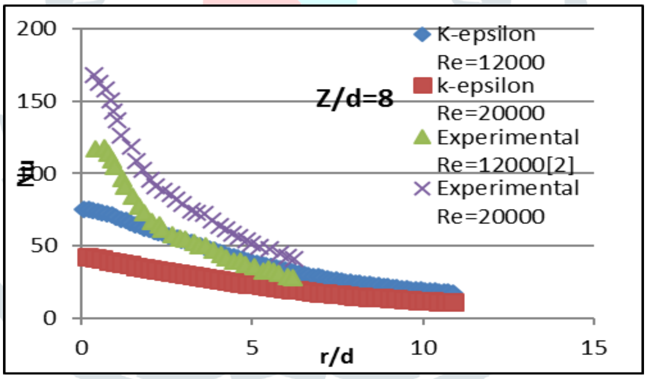

Fig.9 Result of Nu number for Z/d=8

At all radial locations increase in heat transfer coefficient with increases in Re number. Nu number is higher for given Re number at stagnation point. For Z/d lower than 4, Re number decreases from stagnation point and increases to secondary peak. Monotonically decreases Nu number further in downstream is observed. With decreases in Re number location secondary peak shifts towards stagnation point. Nu number at secondary peak due to high turbulence in boundary layer. For Z/d=0.5,at r/d=2 secondary peak is observed. For Z/d=4 secondary peak is disappeared and sharp decrease in slope of distribution of Nu number is observed. For all Reynolds number heat transfer coefficient is decreases monotonically in radial direction far from stagnation point for Z/d= 6, 8 are observed.

V. CONCLUSION

To study the distribution of heat transfer on flat plate by impingement of air jet from nozzle, a numerical investigation was performed. In this study Re number is varied from 12000, 20000 based on jet diameter and Z/d ratio is also varied from 0.5 to 8. The conclusions of present study are as follows:

- Turbulence intensity is low at jet axis due to less intermixing of surrounding air, in shear layer surrounding air entrains and then sudden rise in T.I for r/d>1 and then decreases for r/d>2 is observed.
- For a given Z/d, increase in Re number increases the heat transfer at all radial locations.
- Nu number at stagnation point increase with increases in Z/d from 0.5 to 6, then decreases in Nu number is observed, for a constant Re number. This is due to increases in turbulence intensity with increases in spacing between jet to plate.
- For all Z/d below 4, secondary peak of Nu number is observed and secondary peak location is shifted towards stagnation point with decreases in Z/d.
- K-epsilon turbulence model predicts Nu number distribution over plate in good arrangement with experiments for range of parameters studied.

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