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NUMERICAL INVESTIGATION OF L/D RATIO OF NOZZLE ON HEAT TRANSFER CHARACTERISTIC OF A CIRCULAR JET ON FLAT PLATE

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ABSTRACT
Numerical investigation is performed to study the effects of the L/d of the nozzle and jet-to-plate spacing on the local heat transfer distribution to normally impinging submerged air jet on smooth and flat surface. (v2-f model) has been used to simulate the flow and heat transfer in circular unconfined impinging jet configurations. The model has been validated against available experimental data sets, Four different nozzles each with an equivalent diameter of 16 mm are used during this study and jet-to-plate spacing from 0.5 to 12 nozzle diameters. Length-to-diameter ratio (L/d) of 0.5, 1, 2, and 4 is chosen for each nozzle configuration. Results have been obtained for a range of jet Reynolds number of 30000 and jet-to-target distances. The effect of confinement on the local heat transfer behavior has been determined. The local heat transfer characteristics are estimated Local and average Nusselt number on the impinged surface are presented for all the nozzle configurations investigated. In contrast the flow characteristics in the nozzle strongly affects the heat transfer rate

Keywords: CFD, Transition, v2-f model, Turbulence.

1. INTRODUCTION
Impinging jets have received considerable attention due to their inherent characteristics of high rates of heat transfer besides having simple geometry. Such impinging flow devices allow for short flow paths and relatively high rates of cooling from comparatively small surface area. Various industrial processes involving high heat transfer rates apply impinging jets. 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 and outer wall of the combustion chamber, cooling of electronic equipments, etc. Heat transfer rates in case of impinging jets are affected by various parameters like Reynolds number, jet-to-plate spacing, radial distance from stagnation point, Prandtl number, target plate inclination, confinement of the jet, nozzle geometry, curvature of target plate, roughness of the target plate and turbulence intensity at the nozzle exit.

Many earlier investigations focused on characterizing the flow experimentally by Puneet Gulati, Vadiraj Katti, & S.V. Prabhu did the Investigation on Influence of the shape of the nozzle on local heat transfer distribution between smooth flat surface and impinging air jet. Three different nozzle cross-sections, circular, square, and rectangular are used during their study and concluded that heat transfer characteristics of square and circular jets show much similarity. There is a distinct difference between distribution of Nusselt numbers along the major and minor axis for rectangular jet and Pressure loss coefficient is lowest for the circular jet and highest for rectangular jet.

Y. Ozmen, E. Baydar did the Investigation on Flow structure and heat transfer characteristics of an unconfined impinging air jet at high jet Reynolds numbers and concluded that At spacing up to 3, both near wall turbulence intensity and local Nusselt number along the impingement surface have second peak the location of second peak represents a dependence on Reynolds number and nozzle-to-plate spacing. This has been due to the high heat transfer rates of jet impingement. There are numerous papers dealing with this problem both numerically and experimentally. A number of reviews have also appeared, amongst which some of the more recent are Jambunathan et al. (1992), Viskanta (1993) and Webb and Ma (1995). There are a number of parameters which can affect the heat transfer rate in a jet impingement configuration. For instance, the jet-to-target distance not only affects the heat transfer rate, but also has a significant effect on the local heat transfer co-efficient distribution . For the design and optimization of jet impingement cooling or heating systems, it is essential that the effects of these important parameters are identified and understood. In some of previous studies these effects have been examined; however, experiments performed by different investigators have sometimes been contradictory, due to the differences in the experimental conditions. In their review, Jambunathan et al. (1992) clearly point out this problem and note that for a better understanding of the jet impingement heat transfer process, the details of the geometry and turbulence conditions are required; only then can a comparison be made between di€erent experimental data sets.

Due to the difficulties in performing and comparing experiments, a numerical study of the problem holds promise for quantifying the effects of the various parameters of interest. However, turbulent impinging jets have complex features due to entrainment, stagnation and high streamline curvature. These features prove to be somewhat difficult to represent with most existing turbulence models which are essentially devel- oped and tested for flows parallel to a wall. Craft et al. (1993) have demonstrated some of the problems in these turbulence models; most importantly they obtained a substantial over- prediction of the heat transfer in the stagnation region with a widely used low Reynolds number k-є turbulence model. Due to its complexity, this flow has been chosen as a challenging test-case for the validation of turbulence models. A number of investigators have gauged the success of their models on this ¯flow. However, turbulence modelers encounter numerous difficulties due either to the fact that the details of most of these experimental data sets are not known, or to the fact that the geometry and boundary conditions are not well posed. We have used a few experimental data sets on axisymmetric turbulent jets impinging on a plate to validate the v2-f turbulence model. For this purpose, we chose those data obtained in a fully developed impinging jet configuration (i.e. Puneet Gulati, Vadiraj Katti, & S.V. Prabhu). Subsequent computations were performed to assess effecects of important parameters such as jet-to-target distance, geometry and Reynolds number, as well as to examine the influence of jet configuration
The objective of the present paper is to study the influence of the L/d of the nozzle on the local heat transfer distribution to normally impinging submerged air jet on smooth and flat surface and the effect of jet to plate spacing (0.5 to 12 nozzle diameters) are validated with available experimental results for all the nozzles investigated.

2. NUMERICAL PROCEDURE

2.1. Turbulence model

Most predictions of jet impingement heat transfer in industry involve the use of standard or modified versions of the v^2-f turbulence model, available in many existing CFD packages. These models have usually been developed, calibrated and validated using flows parallel to the wall. Physical phenomena involved in impinging flows on a solid surface are substantially different and have been considered as highly challenging test cases for the validation of turbulence models

An attractive alternative to the k-ε model is the v^2-f turbulence model (Durbin, 1991). In this study important effects of near-wall anisotropy are represented. However, the v^2-f model has the advantage of solving the mean flow with an eddy viscosity at stagnation zone, which avoids some computational stability problems encountered with the full k-є models. It is a general geometry turbulence model, valid right up to solid walls. It does not need wall functions whose universality is increasingly being called into question, especially in impinging regions.

2.2. Numerical method

The impinging jet conditions are mainly steady; consequently, steady flow conditions are considered in the analysis, provided that the compressibility effect and variable properties are accommodated. The jet impinging onto a flat plate is simulated. The heat source with a constant heat flux (220 mm × 75 mm; 0.06 mm thick foil) is considered at the wall surface according to geometrical model of . The geometric arrangements of nozzles for different jet to spacing is Z/d=0.5,3,6,9,12, while the nozzle configurations are The length-to-diameter ratios (*L/d*) of nozzles are with 0.5, 1, 2, & 4. The specifications of the different types of nozzles tested. The exit areas of the nozzles are kept constant according to model geometry configurations , The exit diameter of the pipe is 25mm. This computational study was carried out using STAR-CCM , a finite-volume code. The RANS based V2f turbulence model was utilized for simulations. The use of this turbulence model was based on having provided good correlation with the experimental results when used in earlier studies of Jambunathan. Details of the numerical model are consistent with what was used in earlier studies and need not be repeated here. The solution was declared convergent when the maximum

The flow conditions at the nozzle exit may affect the computed flow field. Therefore, for validation purposes, we chose the case of a jet being issued from a long pipe, so that nozzle- exit conditions are fully turbulent and well defined. A fully developed turbulent pipe flow was first computed in a preliminary computation, and then interpolated onto the full grid to provide the inlet condition of the jet. The computational domain began 1 to 2 pipe diameters to the jet spacing (depending on Z/D), so that the pipe flow profiles may evolve in the nozzle as the flow approaches to the nozzle outlet. It is noted that prescribing the inlet conditions as mass flow through the pipe.

3. RESULTS & DISCUSSIONS

The effect of L/d of the nozzle on the local Nusselt number distribution at Reynolds number of 30000 for nozzle-to-plate spacing *(z/d)* of 0.5 to 12.0 are validated numerically . Figs.1 & 2 show the local distribution of Nusselt numbers along the horizontal line through the stagnation point for nozzles of four different L/d,

Local Nusselt number distributions at *z/d* = 0.5 are shown in Fig. 1. It is observed that with increase in the L/d, Nusselt number increases at stagnation region and 2nd peak observed for all the nozzles configurations at radial locations R/d=2. At this location Nusselt number is higher as compared to stagnation region In the stagnation region i.e., up to R/*d* of 1.0, the Nusselt numbers decrease monotonically for all nozzles

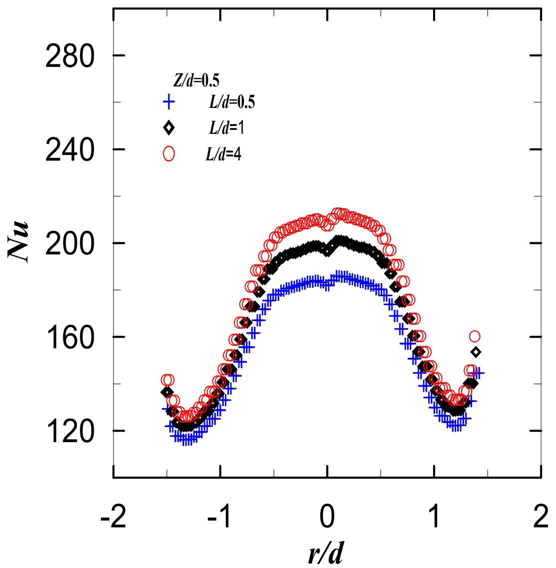

Fig 1. Influence of *L/d* of the nozzle on the local Nusselt number distribution at a *Z/d* of 0.5, *Re* = 30000

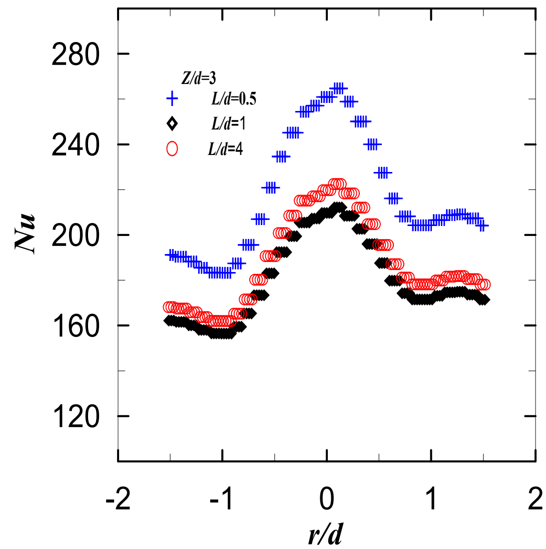

Fig 2. Influence of *L/d* of the nozzle on the local Nusselt number distribution at a *Z/d* of 3, *Re* = 30000

In the fig 2 shows the distribution of local Nusselt numbers for various L/d at *z/d* = 3. However, the stagnation point Nusselt number values are almost same for L/d= 1, 2, 4 nozzles. The distributions of the local Nusselt number for these three nozzles are almost same The secondary peak is distinctly observed where in case of L/d=0.5 is absent from the fig observed that at stagnation region L/d=0.5 has a maximum value of Nusselt number and as R/d increases it decreases monotonically. As the Z/d increases the secondary peak of Nusselt number disappears

4. CONCLUSION

The effects of the L/d of the nozzle on impinging jet heat transfer is numerically investigated at different nozzle-to-plate spacing. The following are the main conclusions that may be drawn from this study. The heat transfer characteristics of nozzles L/d= 1, 2, 4 show much similarity. It is observed that Nusselt number secondary peak, upto *z/d* of 3, and at this location L/d=0.5 has a higher stagnation Nusselt Number. As z/d increases secondary peak disappears.The model was first validated against available experimental data. It was shown to perform very well in a range of Z/D and Re, in order to give confidence in its use as a predictive tool. Three regions on the impingement surface are identified based on flow characteristics of impinging jet. They are stagnation region ($0 \leq R/d \leq 1.0$), transition region ($1.0 < R/d < 2.5$) and wall jet region ($R/d > 2.5$). The effects of confinement and nozzle-exit characteristics were then studied. Confinement was shown to have little effect on the heat transfer coefficient, except for very low nozzle-to plate distances. Intensity in the nozzle have a strong influence on the quantitative and qualitative Nu distribution.

5. REFERENCES

[1] Y. Ozmen, A. E. Baydar (2008), Flow structure and heat transfer characteristics of an unconfined impinging air jet at high jet Reynolds numbers, Heat Mass Transfer DOI 10.1007/s00231-008-0378-4.

[2] Y. Ozmen E. Baydar, An experimental and numerical investigation on a confined impinging air jet at high Reynolds number. Applied Thermal Engineering 25 (2005) 409–421

[3] Gao N and Ewing D, "Investigation of the effect of confinement on the heat transfer to round impinging jets exiting a long pipe", Int. J. Heat Fluid Flow, 27 (2006) 33-41

[4] Suresh V. Garimella and Boris Nenaydykh (1995), Nozzle geometry effects in liquid jet impinging heat transfer. Int. J. Heat Mass Transfer. Vol. 39, No. 14, pp. 2915-2923, 1996.

[5] D. W. Colucci, R. Viskanta (1996), effect of nozzle geometry on local convective heat transfer to a confined impinging air jet, Experimental Thermal and Fluid Science 1996; 13:71-80.

[6] Jungho Lee, Sang-Joon Lee (1999), The effect of nozzle aspect ratio on stagnation region heat transfer characteristics of elliptic impinging jet, Heat and Mass Transfer 43 (2000) 555-575

[7] Jungho Lee, Sang-Joon Lee (1999), The effect of nozzle configuration on stagnation region heat transfer enhancement of axisymmetric jet impingement, Heat and Mass Transfer 43 (2000) 3497-3509.

[8] Luis A. Brignoni, Suresh V. Garimell (1999), effects of nozzle-inlet chamfering on pressure drop and heat transfer in confined air jet impingement, Heat and Mass Transfer 43 (2000) 1133-1139

[9] Dae Hee Lee, Jeonghoon Song and Myeong Chan Jo (2004), The effects of nozzle diameter on impinging jet heat transfer and fluid flow, 554 / Vol. 126, AUGUST 2004

[10] Puneet Gulati, Vadiraj Katti, S.V. Prabhu (2008), Influence of the shape of the nozzle on local heat transfer distribution between smooth flat surface and impinging air jet. THESCI:2807

[11] M. Attalla., M. Salem.," Effect of nozzle geometry on heat transfer characteristics from a single circular air jet " Applied Thermal Engineering 51 (2013) 723-733

[12] Abdullah Abbas Kendoush "Theory of stagnation region heat and mass transfer to fluid jets impinging normally on solid surfaces" Int. J. Heat Fluid Flow (1991)

[13] SHIAN GAO(1998) "Numerical study of heat transfer from an impinging jet" Int. J. Heat Fluid Flow (1998)

[14] M. Behnia a, S. Parneix "Numerical study of turbulent heat transfer in confined and unconfined impinging jets" , Int. J. Heat Fluid Flow (1998)