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Research Article

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Heat Transfer into Impinging Plate with Differences Nozzle Shapes

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Abstract The effect of nozzle shape on heat transfer from hot impinging plate is studied experimentally. Four nozzle shapes (circular, square, elliptic, rectangular, and triangular) are considered. The hydrologic diameter is constant for all types of 10 mm. The Reynolds number is varied from 5000 to 1000. The result showed that, the heat transfer for circular jet is better than other jets. In addition at high separation distance ($H/D_h = 4$), the value of increment ratio for elliptic je EJ is higher than TJ and RJ. Where the value of ratio for EJ is 88 %. On the other hand the value for RJ and TJ are 86 % and 85.5 % respectively.

Keywords circular, square, elliptic, rectangular, triangular Jets, Local and average Nusselt number

1. Introduction

Impinging jets have received considerable attention due to their inherent characteristics of high rates of heat transfer besides having simple geometry. Various industrial processes involving high heat transfer rates apply impinging jets [1-9]. Few industrial processes which employ impinging jets are drying of food products, textiles, films and papers; processing of some metals and glass and cooling of gas turbine blades and outer wall of the combustion chamber; cooling of electronic equipment's, etc. Heat transfer rates in case of impinging jets are affected by various parameters like Reynolds number, nozzle 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, low scale turbulence intensity, i.e., turbulence intensity at the nozzle exit 2-6]. Also in laser or plasma cutting process, the impinging jet is used to cool down the products locally in order to avoid deformation.

1.1. Round Jet

The influence of nozzle profile on heat transfer for compressible subsonic jets has been studied by [1]. Three different circular profiles namely contoured nozzle, orifice and pipe are selected for the present experimental study. For each nozzle profile, Reynolds numbers are around 48000, 82000 and 120000. Appropriate diameters for these nozzles are chosen to maintain nearly same Reynolds number. Pressure distribution in the stagnation regions is measured for all the cases. Correlations for local heat transfer distribution over the surface are presented in this study. Pipe nozzle provides higher heat transfer coefficient compared to contoured nozzle and orifice.

The effects of nozzle geometry on local and average heat transfer distribution in unconfined air jet impingement on a flat plate [2]. Experiments have been conducted with variation of exit Reynolds number, Re, in the range of $6000 < Re < 40{,}000$ and plate surface spacing to nozzle diameter, H/d, in the range of $1 < H/d < 6$ for single nozzle with square edge (non-chamfered) and chamfered nozzles of the same diameter, 5 mm. The chamfered length, Lc is varied from 1 mm to 3.65 mm with constant chamfered angle and length to diameter ratio of 50 is chosen for each nozzle configuration. It is observed that the local and average Nusselt numbers have the highest value for square edge inlet nozzle when compared with other nozzle configurations. For chamfered edge nozzles, the value of average Nusselt number is depend on jet Reynolds number, separation distance and chamfered length. The influence of three different injections: a tube used as a reference, a round orifice, and a cross-shaped orifice perforated on a hemispherical surface [3-6]. All nozzles possess the same free area, and the equivalent diameter is D = 14 mm. Experiments have been conducted for Reynolds numbers 23,000 6 Re 6 45,000, for orifice-to-plate distances 1.6≥ H/D≥ 6.5. Aerodynamic results indicate that the hemisphere produces a ‘‘vena contracta” effect, which is greater in the round than in the cross-shaped orifice. The velocity profile at the jet exit (X/D = 0.1) presents a parabolic shape for the tube and an inverted parabolic shape for the round orifice, while the presence of two shear layers renders the cross-shaped orifice more complex and three-dimensional. Thermal results also show that a round orifice on the hemisphere causes higher heat transfer rate than the other injections.

1.2. Slot Jet

An experimental study on heat transfer behaviors of a confined slot jet impingement [10-11]. The parametric effects of jet Reynolds numbers and jet separation distance on heat transfer characteristics of the heated target surface are explored. As for the investigation of heat transfer behaviors on stagnation, local and average Nusselt number, it is evident that the effect of jet separation distance is not significant; while the heat transfer performance increases with increasing jet Reynolds number. Comparisons of the present experimental data with the existing numerical and experimental results are made. Besides, two new empirical correlations for stagnation and average Nusselt numbers on the heated target surface are also reported in the study. The conducted an experimental study for jet impingement cooling on a semi-circular concave surface when jet flow were ejected from three different slot nozzles, round shaped nozzle, and rectangular shaped nozzle [13]. Experiments have been conducted with variations of nozzle exit Reynolds number (Re 5920 to 25500). Markedly different flow and heat transfer characteristics have been observed depending on different nozzle shapes as shown in Fig. 1.

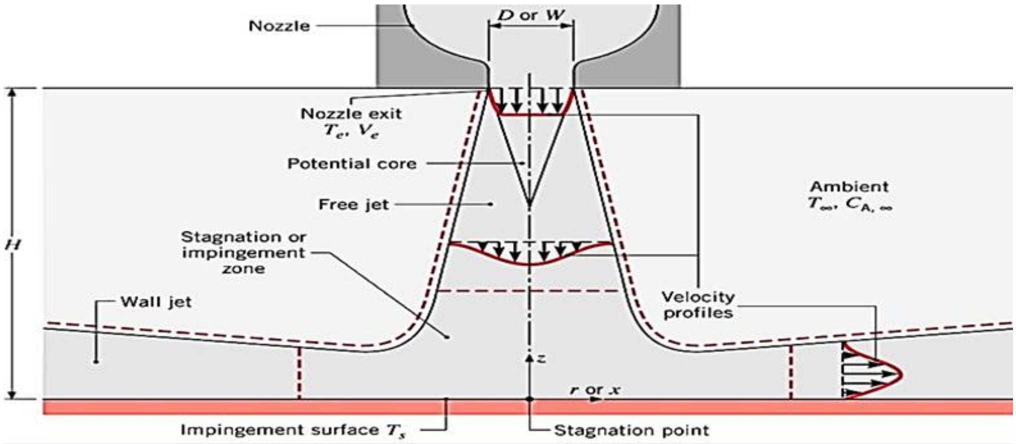

Figure 1: Different nozzle exit geometry [13]

The present study carried out to investigate the effect of different nozzle shape on local and average heat transfer from impingement hot plate. The mail objective can be summarized as the following:

Effect of local and average Nusset number on flat plate under Reynolds number ranged from 15000 to 1000 from different nozzle shapes (Circular jet Square jet – Elliptic Jet – Rectangular Jet – and Triangular Jets). The separation distance is varied of (H/D_h = 1, 2, and 4).

The effect of Stagnation Nusselt number under is showed under the same parameters.

2. Experimental Set-up

A single jet with different shapes was used as shown in Fig. 2. Each nozzle was formed by a free tube with a developing flow length exceeding fifty hydraulic diameters. The inner diameters for the nozzles were selected of 10 mm. the specification of jets is showed in table 1. The level of the nozzle field could be regulated to adjust different spacing between it and impingement sheet (separation distance H). This distance varied between 1Dh to 4Dh. The nozzles field were conducted in an aluminium frame. The infrared thermo camera was arranged vertically at a distance of 800 mm under the metal sheet to measure the bottom surface temperature.

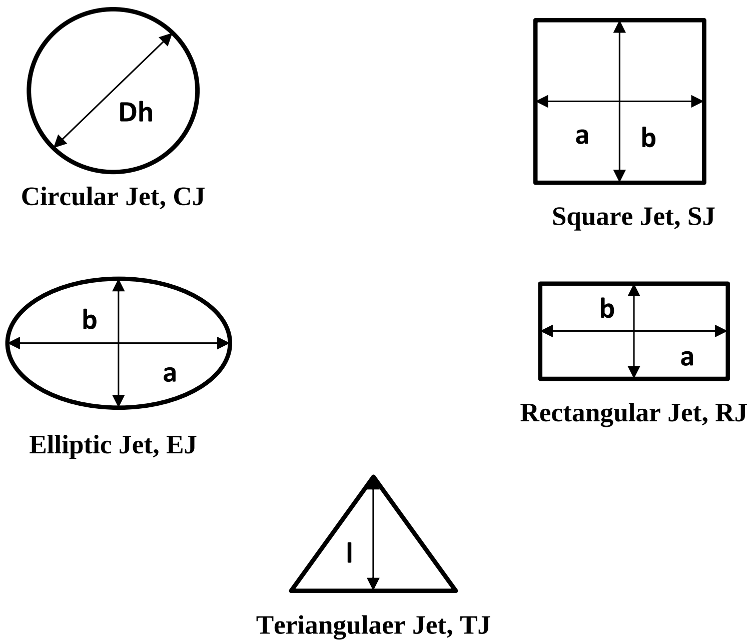

Figure 2: Jets Formation

Table 1: Specification of jets

Shape	Hydraulic diameter, D_h	a	b	l
Circular Jet, CJ	10 mm	--	--	--
Square Jet, SJ	10 mm	10 mm	10 mm	--
Elliptic Jet, EJ	10 mm	5 mm	10 mm	--
Rectangular Jet, RJ	10 mm	5 mm	10 m	--
Triangle Jet, TJ	10 mm	--	--	15.7 mm

Figure 1: Nozzle shape (circle, triangle, rectangle, square and ellipse)

3. Results and Discussion

3.1. Local Heat Transfer Coefficient

The local Nusselt numbers over impinging flat plate for five jets (CJ, SJ, EJ, RJ, and TJ) are showed in this section. The Reynolds number is varied from 15000 to 1000, separation distance H/Dh varied (1, 2, and 4). The effect of jet shape, Reynolds number, and separation distance are description through this work.

Fig. 3 to Fig. 7 shows the Nusselt number distribution for Cj, SJ, EJ, RJ, and TJ respectively at Reynolds number of 15000 and separation distance H/Dh of 1. At all jets (CJ, SJ, EJ, RJ, and TJ), the Nusselt number distribution are same from. Where, the maximum value at the stagnation point and decreases gradually with increase of redial direction (R/D_h). Where the turbulent intensity is stronger at the center of jet (Stagnation Point), then weakness along the wall. This result due to the friction between the flow and wall is increase with increase the radial distance (R/D_h) [15-17]. Also the flow is outside the wall region, where the flow in this region is under the pack pressure. Also, the figures showed that the local Nusselt number is nearly constant in the radial direction of $1 \leq R/D_h \leq 2.25$, for separation distance of $H/D_h = 1$, and 2. With increase of separation distance to $H/D_h = 4$, the constant region is shifted to outward direction $1.8 \leq R/D_h \leq 2.3$. This result due to the secondary flow is more effect for case of low separation distance ($H/D_h = 1$, and 2). Where the flow is backing to perforate holing after impinging with plate. For case of separation distance increase to $H/D_h = 4$, in this case the distance is enough to flow back to perforate [18-19]. For increase the separation distance the secondary flow has leas effect on the main flow comes out from the holing.

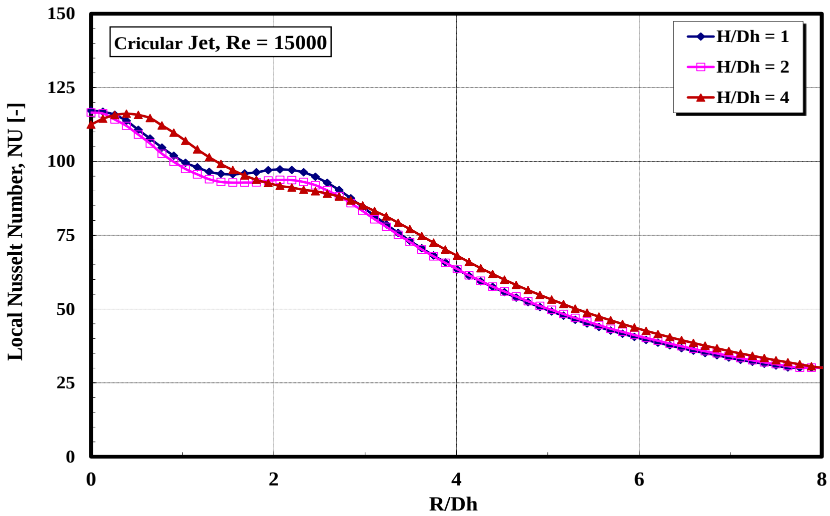

Figure 3: Local Nusselt Distribution verses redial direction for circular jet at Re = 15000

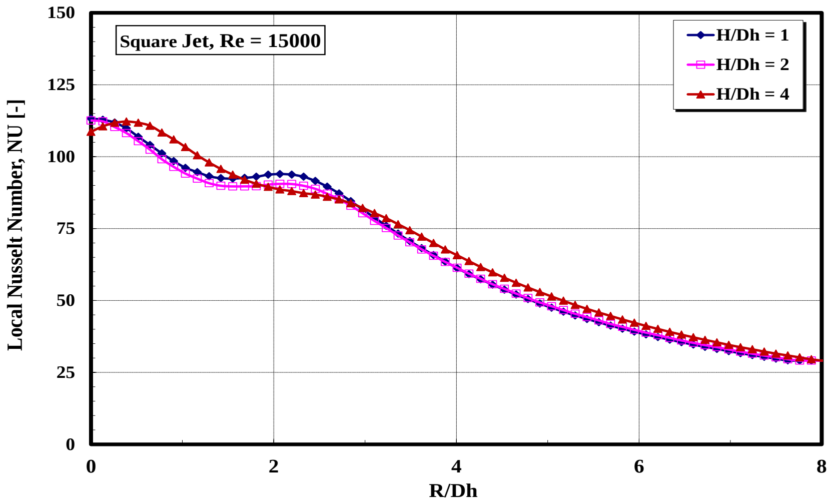

Figure 4: Local Nusselt Distribution verses redial direction for square jet at Re = 15000

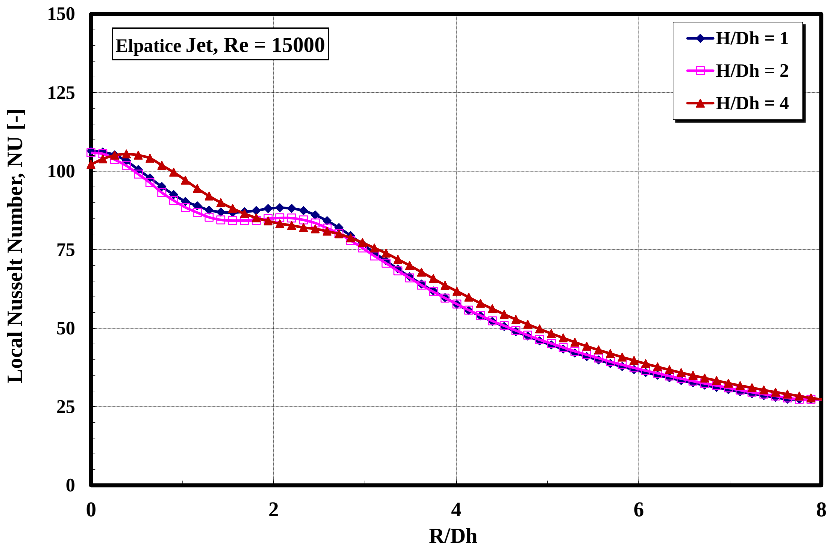

Figure 5: Local Nusselt Distribution verses redial direction for Elliptic jet at Re = 15000

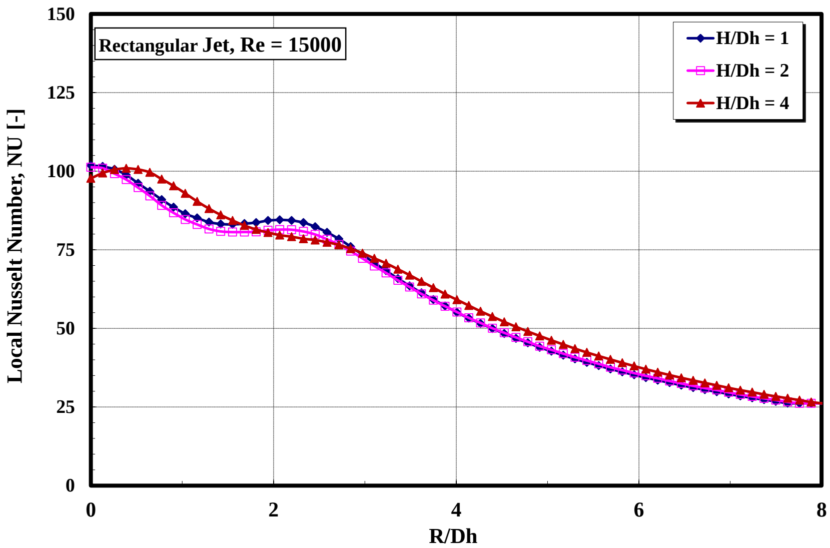

Figure 6: Local Nusselt Distribution verses redial direction for Rectangular jet at Re = 15000

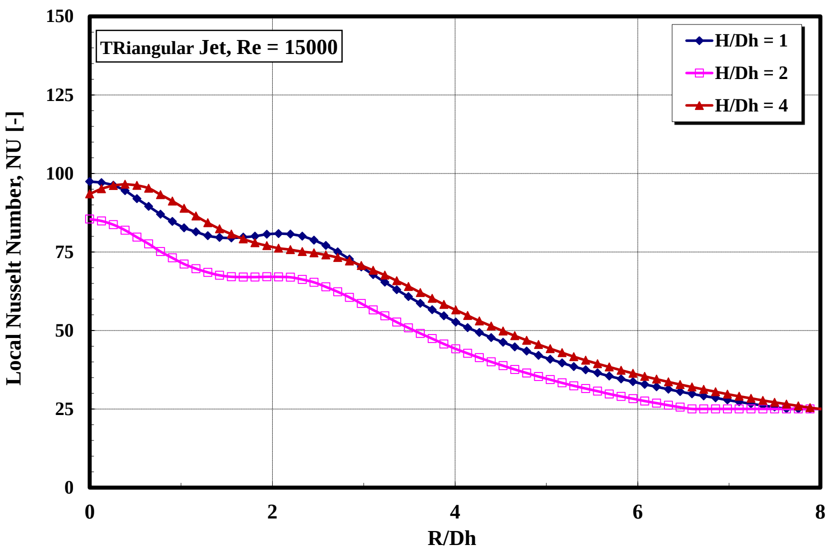

Figure 7: Local Nusselt Distribution verse redial direction for Triangular jet at Re = 15000

4. Conclusions

The main conclusions are summarized as the flowing:

1- The local and average Nusselt number for CJ is showed better than other jets.
2- The value of local and average Nusslet number is nearly constant in the separation distance of less than 4 (H/Dh ≤ 4). For case of separation distance of (H/Dh > 4), the value local and average Nusselt number is decreases for all jet types.
3- The stagnation Nusselt number for CJ is enactment by 15 % for CJ at high Reynolds umber and high separation distance.

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