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Research Article

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Effect of Pair Chevron Impinging Jets on Heat Transfer Coefficient

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Abstract Influence of pair chevron nozzle on local heat transfer distribution over a flat plate impinged by air jets is studied for Reynolds numbers of 5000, 4000, 3000, 2000, and 1000.Three different chevron nozzle configurations are studied with a pipe diameter of 9 mm. Thin metal sheet technique is used with IR camera to measure the wall temperature at nozzles to separation distances (H/d = 1) and spacing distance (S/d = 8). It is observed that the nozzle with (N = 0) provides best heat transfer performance.

Keywords Pair Jets, Chevron, Heat Transfer Coefficient

Introduction

Impinging jets are used in a wide variety of applications such as cooling of electronics and turbine blades, and in the heating, cooling, or drying of pulp, paper, textile, food, and chemicals. The ability to control heat transfer from the surface by varying flow parameters such as jet exit velocity and flow temperature, and geometrical parameters such as jet exit opening, nozzle-to- surface spacing, and nozzle-to-nozzle spacing in arrays, are some of the key factors that have led to the sustained and widespread use of jet impingement technologies [1-5].

Singh [6] performed numerical simulation to analyse the heat transfer performance of an incompressible hot jet by a chevron nozzle on a flat surface. Influence is studied at the nozzle to plate distance (z/d) 8 for three Reynolds numbers of 28,000, 35,000 and 40,000. The results indicated an increase in the Nusselt number of plate by impingement of chevron jet as compared to the circular jet due to turbulence generated by chevrons. It was found out that with the increase in Reynolds number the Nusselt number increase at any given nozzle to plate distance (z/d) [7].

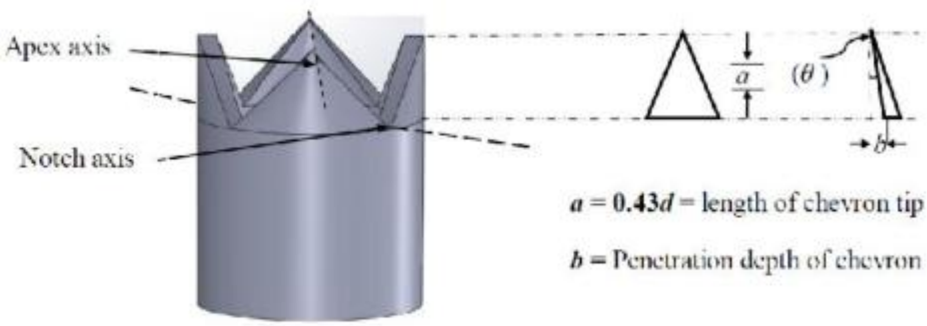


Figure 1: Chevron nozzle profile that investigated by [7]

Trinh, Fénot and Dorignac [8] analyzed 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. 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.

Kito et al. [9] reported the local Nusselt number (Nu) distributions on the target plate were obtained for Re = 5000 (based on the hydraulic diameter of the slot nozzle, Dh), the nozzle-to-plate spacing (H/Dh = 2), the nozzle-to-nozzle spacing (L/Dh=3, 5 and 7) and various twin-jet angles (θ=0, 15, 30 and 45°). For θ=0°, two primary stagnation points having maximum Nu numbers appeared at the geometrical impingement points of the each jet. A secondary stagnation point occurs in the mid-point between jets at L/Dh=5 and 7. However, the secondary stagnation disappeared at lower nozzle-to-nozzle spacing (L/Dh=3) [10-13].The primary Nu peak shifts away from the geometrical impingement point and the value of the primary Nu peak decreased as the inclination angle increased. When two jets were inclined in the same direction, the decrease in the first peak was smaller than that in the second peak with the increasing angle of the jets [14-16]. On the other hand, the values of both peaks' Nu were almost the same when two jets were inclined to face each other [17-18].

The present study investigated the effect of chevron number (N) on heat transfer. The number of chevron is ranged (N= 0, 4, and 6). The Reynolds number is considered depended on mass flow rate from jet and varied from 5000 to 1000.

Experimental set-up

The two jets with chevronnozzle are shown in Fig. 2. Where the number of chevron is N = 0, 4, and 6. The length of tube is 40 cm to insure the low is fully develop flow. The metal sheet is used with (20 mm* 20 mm) is heat by Dc (5 A and 100 V). The IR camera is arranged under metal sheet to measure the temperature distribution over the plate.

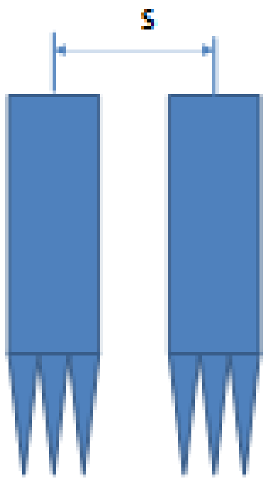


Figure 2: Two Chevron Nozzles

Data Reduction

In the present study the heat losses from the impinging plat by free convection is very small compared to heat flux [7].

The local convective heat transfer coefficient of the target surface is estimated based on the following equations.

Heat transfer coefficient:

$$h = \frac{q_{conv}}{T_s - T_j} \quad (1)$$

Where: *Ts*= Surface temperature (K); *jr*= jet temperature (K),

$$q_{con} = q_{ele} - q_{loss} \quad (2)$$

Where

$$q_{ele}\, q_{rad} + q_{nat} \quad (3)$$

$$q_{ele} = VI \quad (4)$$

Where: V= Supply voltage (V); I = Supply current (Amp

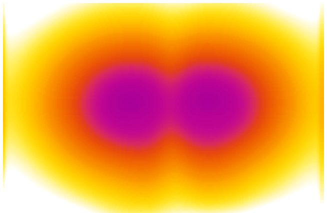
The Reynolds number could be calculate by the flowing equation

$$\mathrm{Re} = 4\dot{m}/\pi.\mathrm{d}.\mu \quad (5)$$

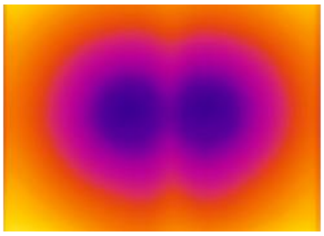
Results and Discussion

Temperature Contours

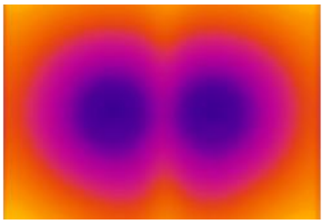
Figure 3 shows the influence of two jets on the local temperature distribution contour for different Reynolds number (Re = 1000, 2000, 3000, 4000 and 5000) with a separation distance (H/d = 1) and spacing distance (S/d = 8). It is observed that the temperature distributions are symmetrical around the stagnation point for all cases of Reynolds number. This result is due to the symmetric geometric structure of the circular nozzle in x and y directions [7, 4, 14]. In addition, the color of contours becomes darker with increasing the Reynolds number. This result is due to the growth of the jet momentum with increasing Reynolds number, and consequently the cooling efficiency increases [14].



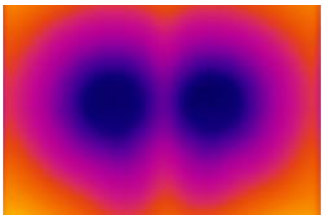
Re = 1000, θ = 0



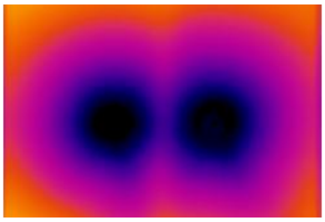
Re = 2000, θ = 0



Re = 3000, θ = 0



Re = 4000, θ = 0



Re = 5000, θ = 0

Figure 3: Temperature contours for Pair jets (N = 0)

Local Heat Transfer Coefficient

Fig. 4 to Fig. 7 shows local heat transfer coefficient distribution for different nozzles. The Reynolds number varied from 5000 to 1000. The two chevron jets are arranged as perpendicular over the flat plate. The spacing and separation distances are 8 and 1 respectively. The local heat transfer is measured along the axis passing through the notch for all nozzle configurations from N= 0, N= 4, N = 6, and N= 8. Due to this acceleration of the fluid, heat transfer rate increases resulting in a secondary peak in the heat transfer distribution as also reported by [12]. Among all cases, highest heat transfer coefficient is measured at the stagnation point (r/d = 0) and z/d = 1. This heat transfer coefficient distribution may be due to uniform velocity profile and the absence of disturbances for large nozzle to plate distances (z/d ≥ 1) as reported by [11]. At z/d of around six nozzle diameter (6d), highest heat transfer coefficient is measured for N10 at stagnation point (around 30%greater compared to N1 nozzle).

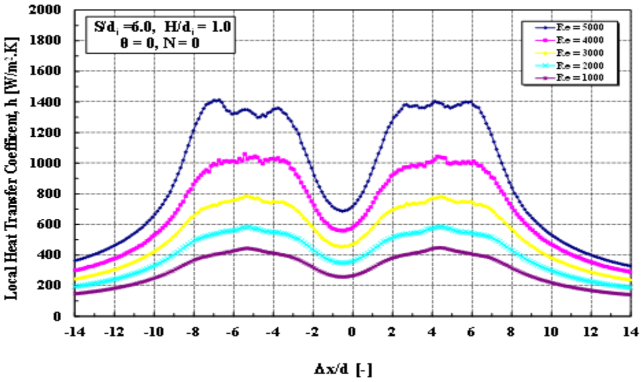


Figure 4: Local heat transfer coefficient of 0 angle, N = 0

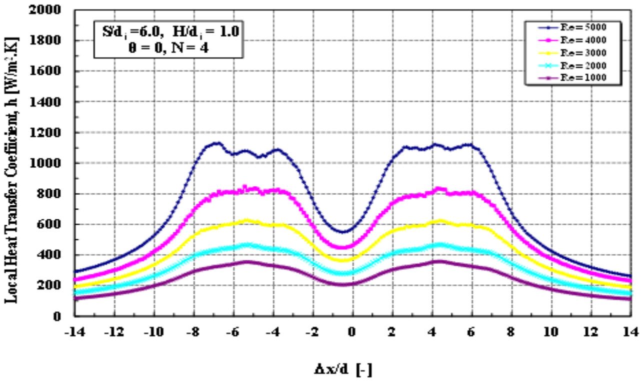


Figure 5: Local heat transfer coefficient of 0 angle, N = 0

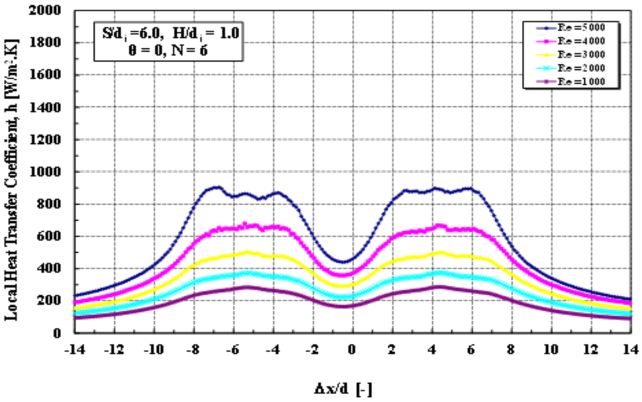


Figure 6: Local heat transfer coefficient of 0 angle, N = 6

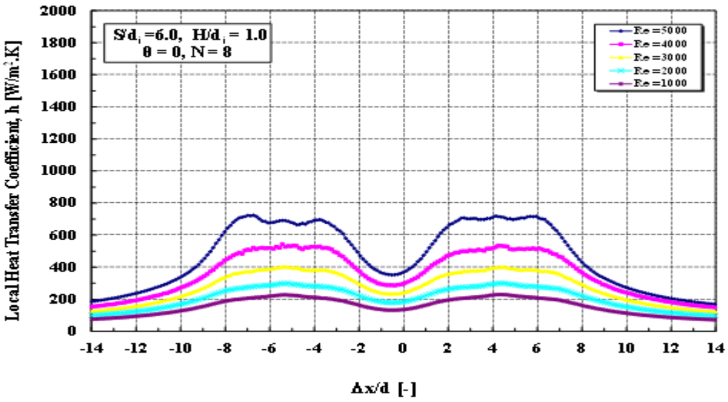


Figure 6: Local heat transfer coefficient of 0 angle, N = 8

Conclusions

The effects of nozzle chevron number on heat transfer coefficient over the smooth plate are considered through this study. The parameters are number of chevron jets (N= 0, 4, 6, and 8). The Reynolds number varied from 1000, 2000, 3000, 4000 and 5000. The spacing and separation distances are constant of 6 and 1 respectively. The main conclusions from this study are flowing:

- Heat transfer coefficient increase with increase of Reynolds number for all nozzle chevron and inclined angles. This result due to increase of turbulent intensity.
- For case of two jets with zero chevron angels, the heat transfer coefficient is considered two jets. On the other hand for case of nozzle with chevron of N= 4, 6, and 8, the nozzle considered one jet. This result due to interaction between two jet and the sheer stress is increase in these cases.
- The heat transfer coefficient is increase with decrease of nozzle chevron angle. This result may be due to the sheer stress is increase between flow and pipe steel.

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