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Research Article

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Effect of Aspect Ratio on Heat Transfer for Slot Impinging Jet

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Abstract The present study investigated the effect of aspect ratio on heat transfer performance of slot impinging jet into flat plate. The experimental study carried out under different conditions such as, Reynolds number varied from 3000, 6000, 9000, 12000, and 15000. The aspect ratios are varied from 1, 0.75, 0.5, and 0.25. The distance between slot jet and impinging plate is varied from 0.5, 1, 1.5, and 2, therefore this problem is considered confined impinging jet. The impinging plate is heated by DC current (10 V and 20 A). The temperature distribution is measure by IF camera arranged bottom the impinging plate.

Keywords Heat Transfer, Slot Impinging Jet

1. Introduction

The industrials applications used different methods to increase intensity of heat transfer are from impinging jet. The impinging jet is widely used in various industrial processes thermal control applications such as electronic and gas turbine components, metal annealing, textile drying, glass tempering and quenching, and many more [1]. Also, the discussed method is often used in food industry [2] for e.g. freezing [3], drying [4], and baking [5]. The most commonly used jet openings are slots and circular holes. For applications requiring highly localized heating or cooling a single circular jet may suffice. For long, but very narrow areas a single row of circular jets or a single slot jet may be appropriate [4]. The single row or slot may also be adequate, in some cases, for treating sheets of material which can be moved continuously past the row or slot. However, where all portions of a surface of larger expanse must be continuously heated or cooled, multiple slot jets or two-dimensional arrays of jet orifices are required [1-6].

To a great extent, performance of flow depends on the shape of the nozzle, from which the jet outflows. Among others, [8] studied this phenomenon. Using numerical simulations, nine jet exit geometries were examined, beginning from axisymmetric, through elliptic and finally rectangular with different aspect ratios. As proved by experimental studies of [9], slot jets generate more uniform convective heat transfer conditions when compared to circular jets. Jet impingement technique is widely used for point, linear or local cooling of surfaces that generate relatively large heat flux. The area of micro jet flow (Fig. 1) can be divided into four main regions [6]. First of them is the free flow region, with a uniform velocity distribution; the second one is the decaying region, where spreading of the jet occurs; the third one is the stagnation region at the site of jet impingement; and the fourth one is the near-wall flow. However, in the work of [7] another four regions at the place of contact between the fluid and the flat surface were defined. For each of them, analytical relations that should be used when describing the border conditions of numerical models were given.

The collision of wall jets leads to an interesting flow feature. [11] presents an investigation of three impinging jets related to the operation of the aircraft. He identified the existence of an upwash flow between two adjacent impinging jets. A schematic of such a flow is given in Figure 1. The upwash flow is a result of the above mentioned collision of wall jets. It affects the entrainment of the impinging jets and provides two mechanisms for the discharge of exhaust air [12]. Part of the exhaust air in the upwash flow is entrained into the adjacentjets, while the other part is discharged along the nozzle plate, avoiding the adjacent jets.

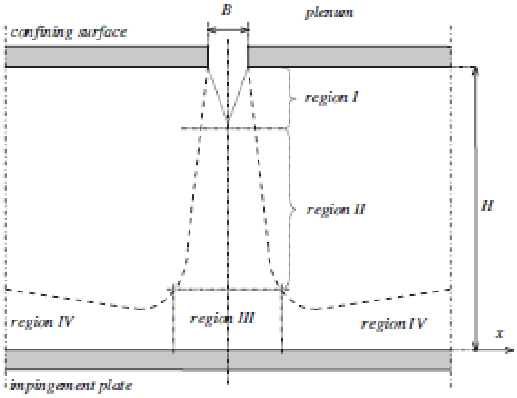

Figure 1: Flow characteristics and interactions of slot jet impingements [11]

Wen, He and Ma, [13] investigated the effects of nozzle arrangement on the convective heat transfer uniformity of multiple impinging jets. A simplified physical model with the size of 200 mm ×200 mm ×50 mm is built and the shear-stress transport (SST) k-ω turbulence model is used in the calculation. The nozzle quantity is varied from 8 ×8 to 32 ×32 for uniform nozzle arrays with a fixed total area of the nozzles. The corresponding numerical results of uniform nozzle arrangements are analysed in details. Based on the 16 ×16 uniform arrangement results, the effects of diameter varying nozzle arrangements on heat transfer uniformity are further examined.

Wae-Hayee, Tekasakul and Nuntadusitb [16] investigated the effect of jet arrangements on flow and heat transfer characteristics was experimentally and numerically investigated for arrays of impinging jets. The air jets discharge from round orifices and perpendicularly impinge on a surface within a rectangular duct. Both the in-line and staggered arrangements, which have an array of 6×4 nozzles, were examined. A jet-to- plate distance (H) and jet-to-jet distance (S) were fixed at H=2D and S=3D, respectively (where D is the round orifice diameter). The experiments were carried out at jet Reynolds number Re=5,000, 7,500 and 13,400. The results revealed that the effect of crossflow on the impinging jets for the staggered arrangement is stronger than that in the case of in-line arrangement. In the latter case of in- line arrangement, the crossflow could pass throughout the passage between the rows of jets, whereas in the former case the crossflow was hampered by the downstream jets. The average Nusselt number of the in-line arrangement is higher than that of the staggered arrangement by approx. 13-20% in this study.

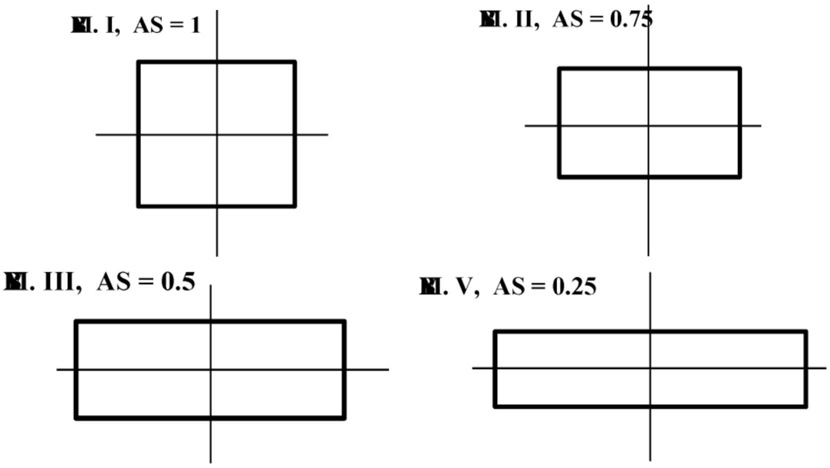

Figure 2: Four models of aspect ratio

The main objective of this study is to examine the heat transfer of heat transfer of slot jet with different aspect ratio (1, 0.75, 5, and 0.25). th Reynolds number based on flow out from jet depend hydraulic diameter. To achieve this goal, the characteristics of heat transfer over impinging plate will be studied therefore the local heat transfer will be estimated. This result carried out under different conditions such as, Reynolds number varied from 3000, 6000, 9000, 12000, and 15000. The separation distance (H/d = 0.5, 1, 1.5, and 2) as shown in Fig. 2.

2. Result

Fig. 3 shows the local Nusselt number for nozzle with aspect ratio of 1, therefore the nozzle considered a square nozzle. This figure show the local Nusslet number is decreases gradually with increase the redial distance.

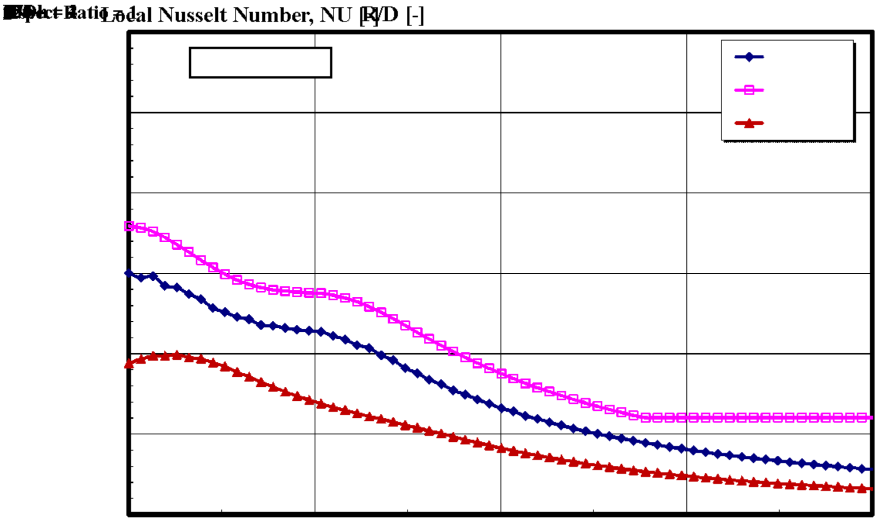

Figure 3: Local Nusselt number distribution over radial distance for aspect ratio of 1

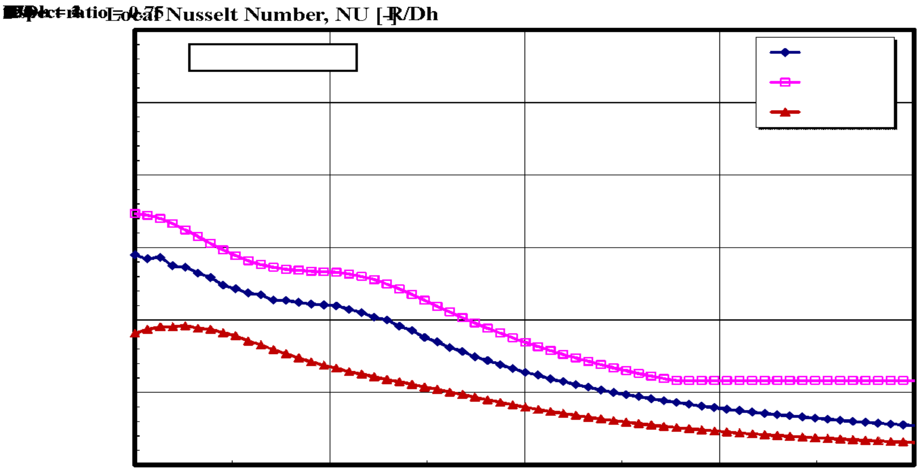

Figure 4: Local Nusselt number distribution over radial distance for aspect ratio of 0.75

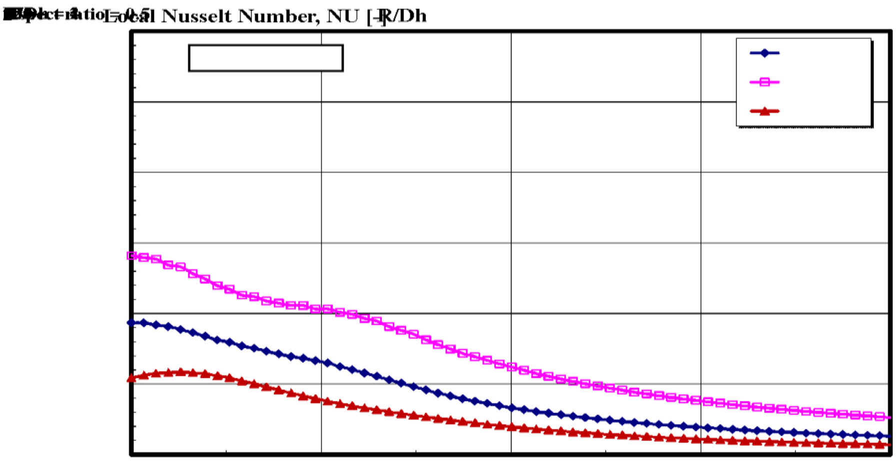

Figure 5: Local Nusselt number distribution over radial distance for aspect ratio of 0.5

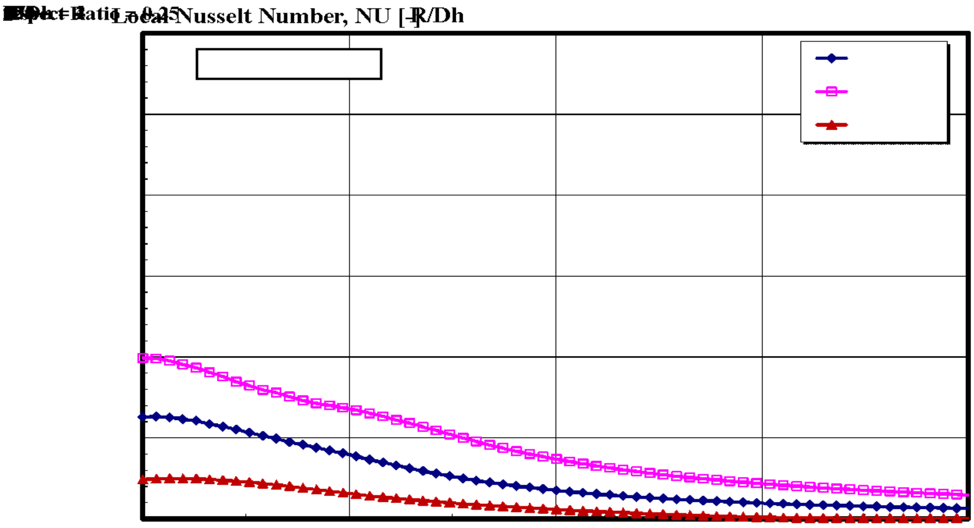

Figure 6: Local Nusselt number distribution over radial distance for aspect ratio of 0.25

In case of aspect ratio of 0.75, 0.5 and 0.25 are shows in Figs. 4, 5, and 6. The local Nusselt number distributions are the same of aspect ratio of 1. In addition the value of local Nusselt number is maximum value for aspect ratio of 1. Where the value of Nusselt number is 95 at R/Dh = 0 for aspect ratio of 1. For aspect ratio of 0.75, 0.5, and 0.25, the value of local Nusselt number are 92, 76, and 55 at separation distance of H/D = 1 respectively.

The main conclusion as the flowing:

- The local Nusselt distributions are same for all aspect ratio.
- The maximum value of local Nusselt number is found at aspect ratio of 1.
- The local Nusselt number is decrease with increase of separation distance.

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