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Research Article

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Effect of Inclined Angle on Local Nusselt Number of Impingement a Pair Slot Jets

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Abstract Effect of inclined angle on heat transfer by two air jets is studied. The inclined angel is varied from 0, 10, 15, and 20. The Reynolds numbers of 5000, 4000, 3000, 2000, and 1000. The spacing distance is ranged from 2 to 8. The result showed that the heat transfer is enhancement by using the incline angle of (θ = 10) than vertical position (θ = 0) at spacing distance (S/D =4). With spacing distance increase to (S/D $\geq$ 6), the heat transfer is maximum value at vertical positions.

Keywords Inclined Angle, Local Nusselt Number, Pair Slot Jets

1. Introduction

Inclined jet impingement is utilized in many industrial applications due to its ability to produce high rates of heat transfer. It is being used in inclined turbine blade, film cooling, bearing cooling, electronics cooling, automobile windshield deicing/defogging, drying of paper, and glass tempering [1–3]. A considerable number of research studies on impingement heat transfer, both in numerical and experimental aspects, have been published [4–18]. The majority of the available information on the heat transfer characteristic of impinging jets is for normal impingement of jet on the flat surface.

However, the studies of heat transfer for an inclined jet to a surface have received relatively little attention. This is perhaps a reflection of the fact that normal impingement has more extensive applications. Fundamental understanding of the complexities of heat transfer of the impingement process attributable to the inclined jet is unexplained [6,7].

A few studies have investigated the effect of jet inclined angles on flow field and heat transfer. The heat transfer from a flat plate to an air jet impinging obliquely from a circular nozzle using the preheated wall, transient liquid crystal technique is studied by [2]. Their results showed that the point of the maximum heat transfer shifts away from the geometrical impingement point toward the uphill side of the plate. The fluid flow and heat transfer distribution to an obliquely impinging air jet is reported by [4]. They proved that the velocity stagnation point (zero velocity) shifted to an uphill direction with a decreasing inclined jet angle[6]. In addition, the surface heat transfer decreases sharply toward the uphill direction and more gradually in the downhill direction. The wall pressure and shear stress in the impingement region of an oblique circular turbulent jet is investigated [8]. The jet Reynolds number ranged from 35,000 to 10,000. The results showed that the shear stress components normal to the radial plane were small [19-20].

The present paper studied the effect of inclined angle on heat transfer rate of pair impinging jets. Four angle are considered (0, 10, 15, 20), spacing distance (S/D = 2, 4, 6, and 8). In present study the two jets is considered confined jets, therefore the vertical distance between jets and impinging plate is constant (H/D = 2). Reynolds number (Re) is varied from 1000, 2000, 3000, 4000, and 5000.

2. Experimental Set-Up

The main part of the experimental test section is consisting on some parts as shown in Fig. 1. The two jets are formed from perforated plate with 10 mm thickness. The inner diameter of two jets is 10 mm. the spacing distance between jets (S) are varied (20 mm, 40 mm, 60 mm, and 80 mm). The two jets are formed by drilling with four difference inclined angle (θ)(0- considered a vertical position, 10, 15, and 20).

In the present study three zones are developed on impinging plate. The first zoon is interaction zoon, and can be defined the zoon between two jets. Second zoon is called downhill zoon, and last zoon is uphill zoon. Because the nozzles are not perpendicular on plate, so the geometry points I and II are shown in present study. These two geometry points are shafted to uphill zoon.

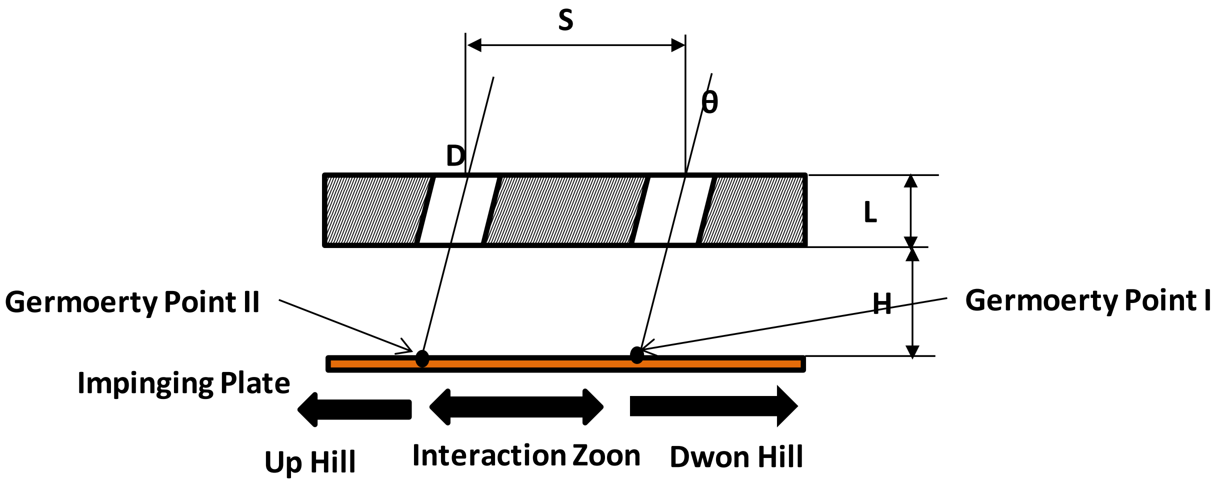

Figure 1: Schematic diagram of Test Section

The local Nussel number over the impinging plate could be calculating by the following equation;

$$Nu = \frac{h.d}{k} \quad (1)$$

where h is the heat transfer coefficient (W/m^2.K), calculated by the following equation:

$$h = \frac{Q_{con}}{T_s - T_j} \quad (2)$$

where T_s and T_j are surface and jet temperatures, respectively.

The heat transfer rate between the impinging jet and target plate Q_{conv} is estimated as

$$Q_{Con} = Q_{ele} - Q_{loss} \quad (3)$$

Where

$$Q_{loss} = Q_{ra} + Q_{lonatss} \quad (4)$$

$$Q_{ele} = VI \quad (5)$$

$$Q_{rad} = \varepsilon\sigma(T_s^4 - T_\infty^4) \quad (6)$$

3. Results and Discussion

The present study carried out to invest aged the effect of inclined angle on average Nusselt number of a pair jet impinging into flat plate. The average Nusselt number is considered the main value at middle point in the hot sheet (inter action zoon).

The distribution of average Nusselt number versus inclined angle (θ) at three practical Reynolds number (Re = 1000, 3000, and 5000) with differences spacing distance (S/d = 2, 4, 6, and 8) are observed in Fig. 1, Fig. 2, and Fig. 3, respectively.

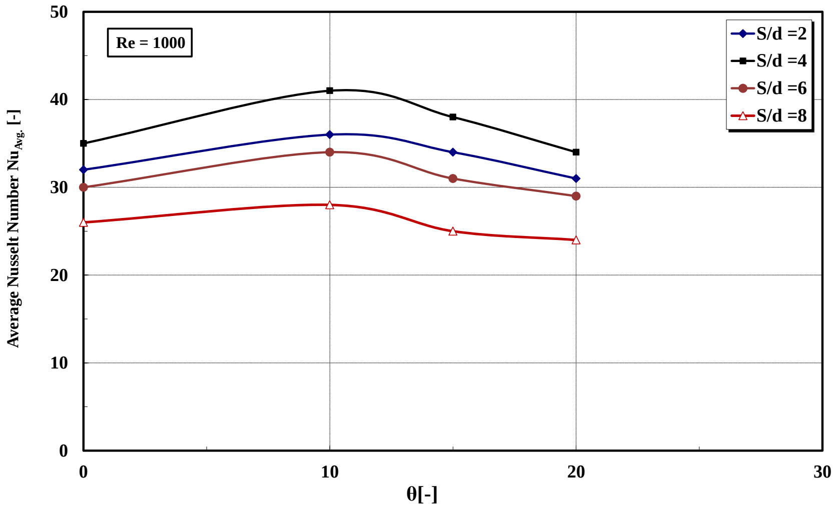

Figure 1: Average Nusselt number versus inclined angle with different spacing distance a Reynolds number of 1000

It can be observed that there exists a maximum value of average Nusselt number for inclined angle of θ = 10. Where the value of average Nuuselt number is 26 for spacing distance of S/d = 8 at inclined angle of θ = 0 (vertical position). This increase with inclined angle increase utile θ = 10. Then this value of average Nusselt number decreases with increase of inclined angle. The value of average Nusselt numbers at incline angle of 10 are 28, 34, 36, and 41 for spacing distance of S/d = 2, 4, 6, and 8 respectively. For inclined angle increase to θ = 20, the values of average Nusselt number are 24, 29, 31, and 34 for same spacing distance (2, 4, 6, and 8) respectively. For case of Reynolds number increase to Re = 3000, the value of average Nusselt number increase also as shown in Fig. 2. Where the value of average Nusselt number is 158 for spacing distance of S/d = 8 and inclined angle of θ = 10. On the other hand, the value of average Nusselt number decrease to 141 for inclined angle of θ = 15.

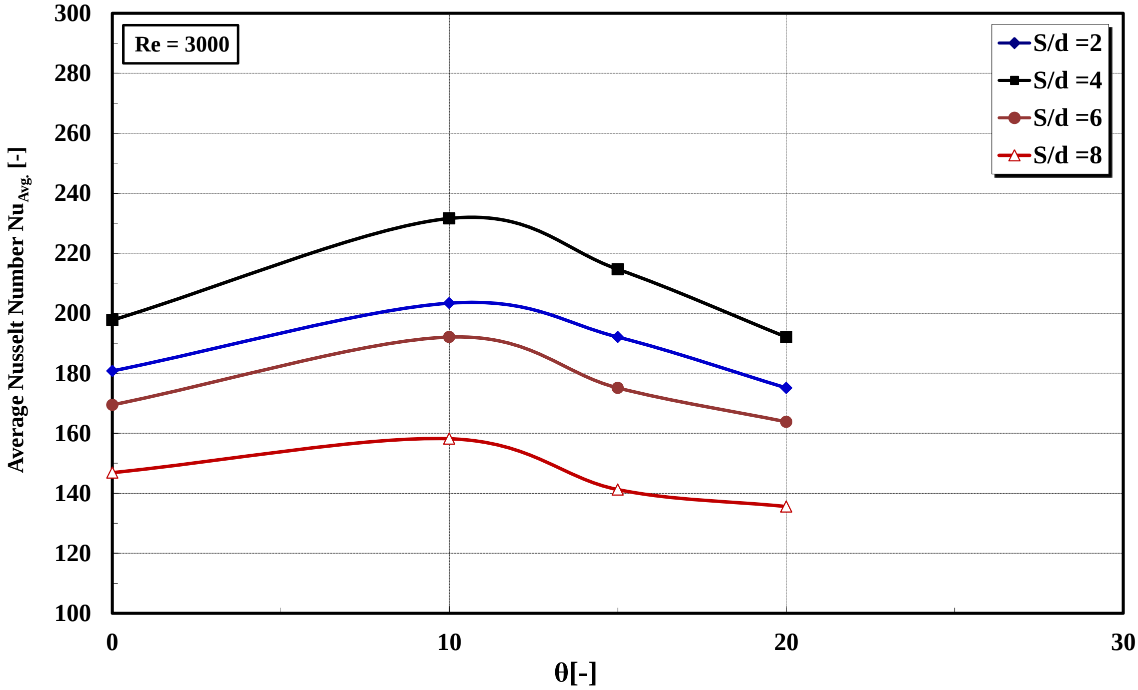

Figure 2: Average Nusselt number versus inclined angle with different spacing distance a Reynolds number of 3000

For case of spacing distance of S/d = 4, 6, and the values of Nusselt number are increasing to 192, 203, and 231 at incline angle of θ = 10 respectively. T incline angle increase to θ = 15, the values of average Nusselt number are decreases slowly. Where the values of average Nusslt numbers are 141, 175, 192, and 219, for spacing distance of 2, 4, 6, and 8 respectively.

For case of Reynolds number increase to Re = 5000, the trend of average Nusselt number is the same of Re = 1000, 3000 as shown in Fig. 3.

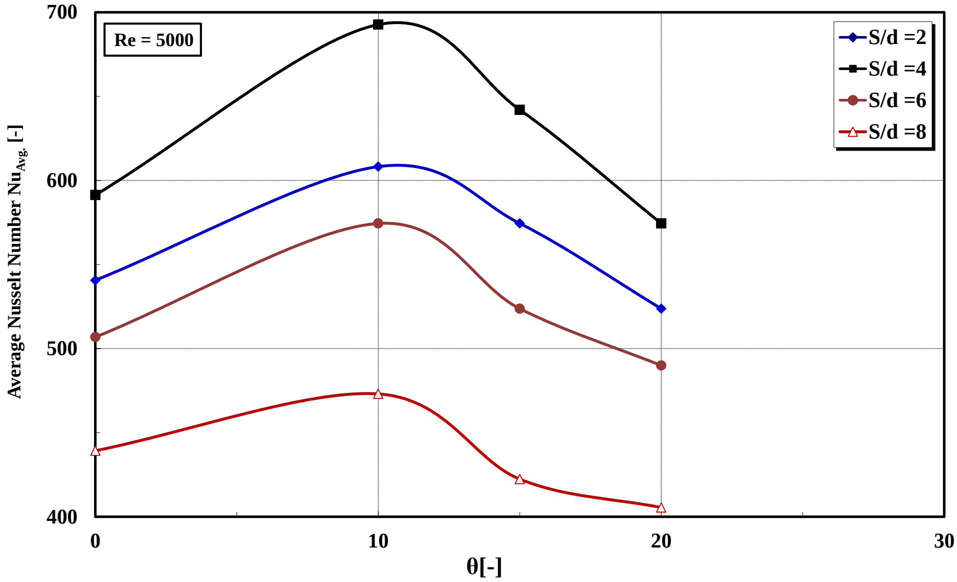

Figure 3: Average Nusselt number versus inclined angle with different spacing distance a Reynolds number of 500

The effect of spacing distance S/d on heat transfer rate at different inclined angle for three Reynolds umber of 1000, 3000, and 5000 respectively is shown in Fig. 4. Where the value of average Nusselt number is showed maximum value for spacing distance of S/d = 4, for all values of Reynolds number and inclined angles. Where the value of average Nusselt is 36, 231, and 691 for three Reynolds number of 1000, 3000, and 5000 respectively at inclined angle of θ = 10 at spacing distance of S/d =4. In addition it can be seen that, the value of average Nusselt number is increase with increase Reynolds number.

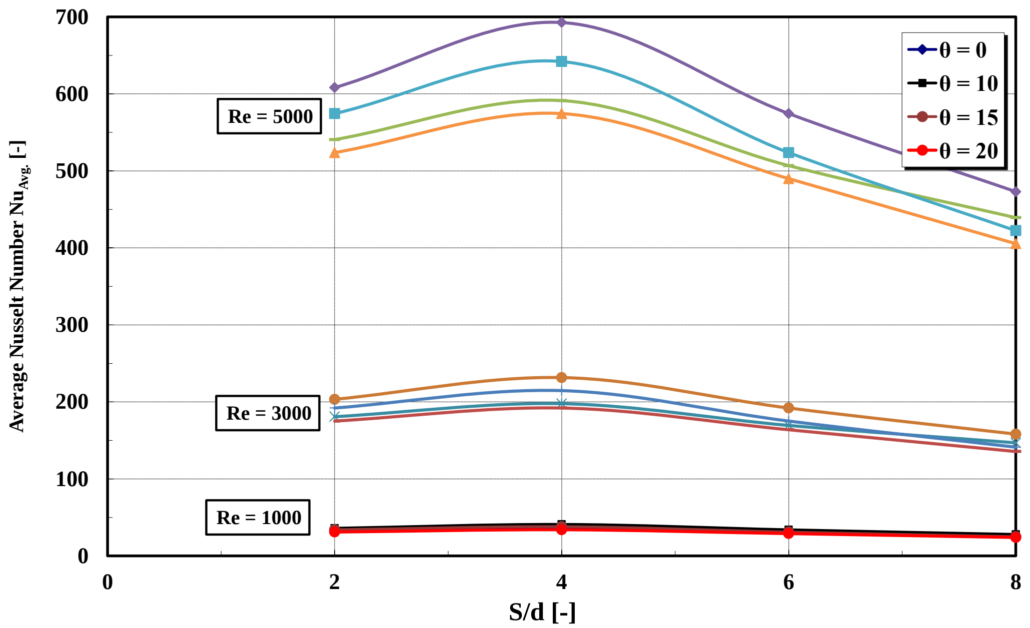

Figure 4: Average Nusselt number versus spacing distance with inclined angleat difference Reynolds numbers

4. Conclusions

The effect of inclined angle on heat transfer of two impinging jets is experientially studied. The main conclusion can be summarized as flowing:

- The average Nusselt number increase with increase Reynolds number for all value of inclined angles and spacing distance.
- The average Nusselt number is improved by 9.4 % of incline angle of θ = 10 than vertical positions. For case of inclined angle of θ = 15, the value of average Nusselt number decrease about 2.5 % than vertical positions.
- The average Nusset number is enhancing by 12.5 % when used spacing distance between jets is S/ =4 than other spacing distances and inclined angle of θ = 10.
- Finally, the best conditions for two inclined impinging jet are spacing distance od S/d = 4 and inclined angle of θ = 10.

References

[1]. Amini, Y. et al. (2015) ‘Heat transfer of swirling impinging jets ejected from Nozzles with twisted tapes utilizing CFD technique’, Case Studies in Thermal Engineering. doi: 10.1016/j.csite.2015.08.001.

[2]. Attalla, M. (2014) ‘Stagnation Region Heat Transfer for Circular Jets Impinging on a Flat Plate’, Experimental Heat Transfer, 28(2), pp. 139–155. doi: 10.1080/08916152.2013.829134.

[3]. Attalla, M. and Salem, M. (2013) ‘Effect of nozzle geometry on heat transfer characteristics from a single circular air jet’, Applied Thermal Engineering, 51(1–2), pp. 723–733.doi: 10.1016/j.applthermaleng.2012.09.032.

[4]. S. Beltaos, Oblique impinging of circular turbulent jets, J. Hydraulic Res. 14(1976) 17–36.

[5]. R.J. Goldisten, M.E. Franchett, Heat transfer from a flat plate to an oblique impinging jet, J. Heat Transfer 110 (1988) 84–90.

[6]. Bergman, T. L. et al. (2011) Fundamentals of Heat and Mass Transfer, Aerospace Engineering.

[7]. Miyazaki, H. and Silberman, E. (1972) ‘Flow and heat transfer on a flat plate normal to a two-dimensional laminar jet issuing from a nozzle of finite height’, International Journal of Heat and Mass Transfer. doi: 10.1016/0017-9310(72)90034-8.

[8]. Rasool, A. A. A. and Hamad, F. A. (2013) ‘Flow structure and cooling behavior of air impingement on a target plate’, Central European Journal of Engineering, 3(0), pp. 400–409. doi: 10.2478/s13531-013-0103-z.

[9]. Reodikar, S. A., Chand, H. and Prabhu, S. V (2016) ‘International Journal of Thermal Sciences In fluence of the ori fi ce shape on the local heat transfer distribution and axis switching by compressible jets impinging on fl at surface’, 104, pp. 208–224. doi: 10.1016/j.ijthermalsci.2016.01.013.

[10]. San, J. Y. and Chen, J. J. (2014) ‘Effects of jet-to-jet spacing and jet height on heat transfer characteristics of an impinging jet array’, International Journal of Heat and Mass Transfer, 71, pp. 8–17. doi: 10.1016/j.ijheatmasstransfer.2013.11.079.

[11]. Singh, D., Premachandran, B. and Kohli, S. (2015) ‘Effect of nozzle shape on jet impingement heat transfer from a circular cylinder’, International Journal of Thermal Sciences. doi: 10.1016/j.ijthermalsci.2015.04.011.

[12]. Singh, H. and S. C. (2018) ‘CFD Analysis of Effect of Reynolds Number on Local Heat Transfer Distribution for Jet Impingement on Smooth Plate by Incompressible Chevron Jet’, International Journal of Engineering Technology Science and Research, 5(3), p. 6. Available at: www.ijetsr.com.

[13]. Transfer, H. and Insert, T. T. (2011) ‘Heat Transfer and Friction Factor in a Tube Equipped with U-cut Twisted Tape Insert’, Jordan Journal of Mechanical and Industrial Engineering, 5(6), pp. 559–565.

[14]. Trinh, X. T., Fénot, M. and Dorignac, E. (2016) ‘The effect of nozzle geometry on local convective heat transfer to unconfined impinging air jets’, Experimental Thermal and Fluid Science. doi: 10.1016/j.expthermflusci.2015.08.006.

[15]. S. Roy, K. Nasr, P. Patel, B. Abdul Nour, An experimental and numerical study of heat transfer off an inclined surface subject to an impinging airflow, Int. J. Heat Mass Transfer 45 (2002) 1615–1929.
[16]. S. Roy, P. Patel, Study of heat transfer for a pair of rectangular jets impinging on an inclined surface, Int. J. Heat Mass Transfer 46 (2003) 411–425.
[17]. X. Yan, N. Saniei, Heat transfer from an obliquely impinging circular air jet to a flat plate, Int. J. Heat Fluid Flow 18 (1997) 591–599.
[18]. T.S.O. Donovan, D.B. Murray, Fluctuating fluid flow and heat transfer of an obliquely impinging air jet, Int. J. Heat Mass Transfer 51 (2008) 6169–6179.
[19]. K. Nakabe, E. Fornailk, J.F. Eschenbacher, Y. Yamaoto, T. Ohta, K. Suzuki, Interaction of longitudinal vortices generated by twin inclined jets and enhancement of impingement heat transfer, Int. J. Heat Fluid Flow 22 (2001)287–292.
[20]. M. Kito, T. Matsumoto, T. Shakouchi, K. Tsujimoto, Heat transfer characteristics for inclined twin jet impingement, Adv. Comput. Method Exp. Heat Transfer XII (2012) 169–180.