



Experimental Analysis of Heat Transfer from Round Jet Impinging to Asymmetric Concave Surface

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ABSTRACT: This study is an experimental effort to investigate the heat transfer from the asymmetry concave surface. For this purpose, an asymmetric cylindrical surface with curvature radiuses of 8 and 12 cm has been considered. Constant heat flux of 2000 W/m² is applied on the concave surface using a silicon rubber heater mat. In the steady-state condition, the temperature distribution of the concave surface is measured with an infrared camera. The asymmetric distribution of Nusselt number is compared with two symmetrical concave surfaces with curvature radiuses of the 8 cm and 12 cm. In this study, the effects of jet Reynolds number and jet to surface distance on Nusselt number distribution are investigated. The study of asymmetric flow and heat transfer in symmetric and asymmetry surfaces have been carried out for three Reynolds numbers of 23000, 35000 and 50000 and three jet-to-plate distance of 2, 4 and 6. Results show that the concave surface with the curvature radius of 8 cm has more values of Nusselt number distributions in comparison to the surface with the curvature radius of 12 cm. The present results confirm that the Nu distribution is asymmetry along the S axis. In the axial direction, symmetry distribution is observed for the Nusselt number. Also, by reducing the distance of jet from the surface the Nusselt number increases across the asymmetric concave surface.

1- Introduction

Jet impingement cooling is widely used in many applications since it is comparatively inexpensive, effective and easily adjustable [1-3]. Cooling of electronic parts, combustion chamber wall, and drying of papers are some cases of a wide variety of impingement jet applications [4]. The foregoing examinations indicate that the jet impingement cooling in the steady state depends on different parameters such as jet Reynolds number, jet-to-surface spacing, and the surface curvature. This study is a new effort to investigate the heat transfer from the asymmetry concave surface. For this purpose, an asymmetric cylindrical surface with curvature radiuses of 8 and 12 cm has been considered.

2- Experimental equipment

Fig.1 shows the equipment employed in the present study. This equipment includes a control box, a high-pressure fan, a temperature sensor, a flow controller valve, the concave surface with constant heat flux and an infrared camera. Constant heat flux of 2000 W/m² is applied on the concave surface using a silicon rubber heater mat. In the steady-state condition, the temperature distribution of the concave surface is measured with an infrared camera. As the heat flux and the temperature distributions of the surface are given, Nusselt number distribution is obtained by the equation below [5]:

$$Nu = \frac{q''}{T_s - T_{jet}} \frac{D_{jet}}{k} \quad (1)$$

3- Procedure

This experiment is aimed to determine the Nusselt and heat transfer from the asymmetric concave surface and its

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Fig. 1. Experimental apparatus

comparison with the symmetric one. Hence, the surfaces with characteristics previously described were considered. The tests are performed for three Reynolds numbers and two impingement distances.

4- Results and Discussion

Velocity distribution of the jet impinging to the asymmetric surface is illustrated in Fig. 2. It can be obviously seen that the velocity distribution along the curvature is asymmetric for the asymmetric surface. The results show that the velocity magnitudes are higher in the surface with lower relative curvature

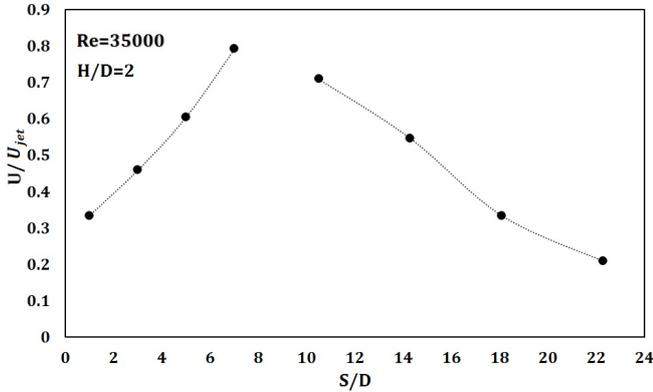


Fig. 2. Velocity distribution along the curvature

Fig. 3 illustrates the comparison of Nusselt numbers in asymmetric and symmetric surfaces. Since the surfaces with the constant curvature radius are geometrical symmetric, only half of Nusselt distribution is plotted. Fig. 3 shows that Nusselt distribution along the curvature is not symmetric. In symmetric surfaces, the Nusselt value is higher in the surface with higher relative curvature ($Cr=0.15$) than the surface with less relative curvature ($Cr=0.1$).

The comparison of average Nusselt numbers on symmetric and asymmetric surfaces is shown in Table 1. The average Nusselt number for an asymmetric surface with relative curvatures of 0.1 and 0.15 is predicted between the Nusselt number of symmetric surfaces with the relative curvature of 0.1 and 0.15. This behavior can be seen in all Reynolds numbers and jet-to-surface distances in the present study. For the given Reynolds numbers, a decrease in jet-to-surface distance leads to an increase in the average Nusselt number.

Table 1. Comparison of the averaged Nusselt number.

Re	H/D	Cr=0.1	Cr=0.1-0.15	Cr=0.15
23000	2	95.12	112.33	150.62
23000	4	80.91	105.95	141.87
35000	2	115.25	150.75	177.87
35000	4	112.04	133.12	160.83
50000	2	125.21	154.95	194.33
50000	4	120.31	139.50	170.39

5- Conclusion

The purpose of this paper is to analyze experimentally the jet impinging on an asymmetric concave cylindrical surface. The obtained results of symmetric surfaces compared with the results of the surfaces for two different curvatures. In this research, three parameters (surface curvature, the relative distance of jet to surface and Reynolds number) were varied to determine the effects of two curvature radiuses (8 and 12cm) on Nusselt distribution. The noteworthy conclusions of this study are as below:

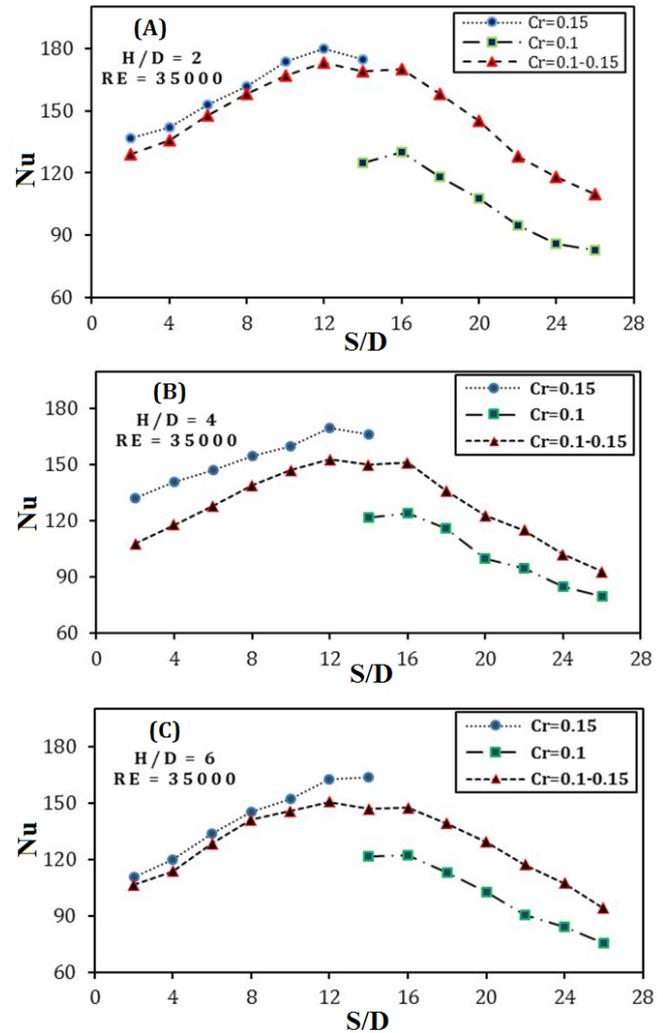


Fig. 3. Effect of jet-to-surface distance on the Nusselt number

- Examination of Nusselt number for asymmetric surface showed that the surface with higher relative curvature ($Cr=0.15$) has a higher Nusselt number compared to the surface with lower relative curvature ($Cr=0.1$).
- Examination of Nusselt number for asymmetric surface showed that the surface with higher relative curvature ($Cr=0.15$) has a higher Nusselt number compared to the surface with lower relative curvature ($Cr=0.1$).
- Axial distribution of Nusselt number is almost symmetric for asymmetric surface ($Cr=0.1-0.15$) and it has a value between the values of the higher and lower relative curvature.
- The comparison made between the symmetric and asymmetric surfaces indicates that average Nusselt number with the asymmetric surface for the relative curvature of 0.1 and 0.15 is in the range of the Nusselt number of the symmetric surface with relative curvatures of 0.1 and 0.15.

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