Enhancement the Heat Transfer Characteristics in Heat Exchanger

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Abstract—In the paper heat transfer characteristics is experimentally analyzed, due to practical importance of heat transfer enhancement a need is felt to analyze in a representative element of heat exchanger. The experiment involves determination of the heat transfer characteristics in a trapezoidal shaped channel with sharp edged wavy plate. The experimental study provides actual information of temperature distribution along with the effect of different parameters on heat transfer enhancement. In this study attempt has been made to enhance the heat transfer using a trapezoidal channel with sharp edged wavy plate at the height of 15mm over the base plate in a turbulent flow. The obtained results were compared with the heat transfer characteristics of plane plate, trapezoidal channel without sharp edged wavy plate and with sharp edged wavy plate. And the effects on different Reynolds number by changing the air flow velocity and different heat fluxes was also investigated.

Keywords—Turbulent flow, Reynolds number, Nusselt number, heat flux.

I. INTRODUCTION

In present time there is great need to focus on heat transfer characteristics of heat exchanger for its efficient work, day to day many attempts have been made to improve it. We also try our best to enhance the heat transfer characteristics of heat exchanger. In this paper some experiments were performed on three test plates, first one was plane plate, second trapezoidal plate and third trapezoidal plate with SEWP. The comparison of heat transfer enhancement between the plates has been done in this experiment. We use Reynold’s number and Nusselt number in this experiment on the behalf of these number we enhance the heat transfer characteristics. Here the computations have been done assuming flow regime to be turbulent.

II. LITERATURE REVIEW

Nishimura, Ohori and Kawamura [1] numerically investigated flow characteristics in channel with symmetric sinusoidal wavy wall, which has geometry similar to that of the Oxford membrane blood oxygenator.

He found at Re = 1 stream lines were symmetrical about max cross-section of the channel, but stream lines became asymmetrical with Re increases. The flow observations were performed in the Reynolds number range 100 to 10000.

Sparrow and Comb [2] the effects of varying the spacing between the corrugated walls was examined in the Reynolds number range of 2000 to 27000. The increase of the inter-wall spacing gave rise to 30% increase in the fully developed Nusselt number compared with that of Re, 1500 to 25 000, but the friction factor was more than doubled.

Stone and Vanka [3] studied developing flow and heat transfer in wavy passages. It was observed that the flow was steady in part of the channel and unsteady in the rest of the channel. As the Reynolds number was progressively increased, the unsteadiness was onset at a much earlier location, leading to increased heat transfer rates. Varying the channel spacing alters the heat transfer and pressure drop characteristics, as well as the transition Reynolds number.

Esam M. Alawadi et al [4], numerical investigation has been performed on forced convection flow in horizontal channel. The channel contains heated blocks on both internal walls, with a wavy plate at its centre line. Wavy plate increases heat transfer characteristics of the heated blocks up to 50% through modification of the core flow pattern. He also found, increasing the waviness of the wavy plate has positive effect on heat transfer of heated blocks. Bahaidarah and Anand [5] numerically investigated two-dimensional steady developing fluid flow and heat transfer through periodic wavy passage and compared to flow through a corresponding straight channel. In this work, sinusoidal and arc-shaped configurations were studied for a range of geometric parameters. The effects of the Reynolds number (Re), length ratio (L/a), and height ratio (Hmin/Hmax) on the developing velocity profiles, streamlines, isotherm, pressure drops, and Nusselt number were examined.
Bahaidarah et al. [6] studied numerically a two-dimensional steady developing fluid flow and heat transfer through a periodic wavy passage (sharp edge-shaped configurations), with and without horizontal pitch. In this work four different types of wavy geometry, triangular without horizontal pitch ($l/L = 0$) and triangular horizontal pitch ($l/L = 0.1, ¼, \text{ and } ½$) were considered. Triangular wavy channel without horizontal pitch ($l/L = 0$) provide lower normalized pressure drop values when compared to triangular wavy channel with horizontal pitch and it keep increasing as the ($l/L$) increases. The module average nusselt number increases monotonically with Reynolds number increases.

Paisarn et al [7] numerically studied on the heat transfer and flow distributions in the channel with various geometric configurations under constant heat flux conditions and effects of geometry configuration of wavy plates, wavy plate arrangements, and air flow rates on the temperature and flow developments were considered in this study, he found that the sharp edges of wavy plate has significant effect on the flow structure and heat transfer enhancement as compared to trapezoidal shaped wavy plate.

### III. EXPERIMENTAL SETUP

The experimental set up for the present study is presented in Figure 1.1. The experimental apparatus consist of a rectangular duct which was made up of plywood. The total length of the duct is 1750 mm, the apparatus consist of four parts, first part is the inlet section having length of 500 mm, width 200 mm, height 120 mm. A straightener is used in the inlet section up to a length of 200 mm to minimize the turbulence in the air and to keep a uniform air flow before entering the test section. A port is made in the top part of the inlet section for the measurement of velocity by hot wire anemometer. Second part of the duct is the test section having the overall length of 600 mm, width 200 mm, height 120 mm. Test section consist of a rectangular plate made up of aluminum, having dimension of 300x150x6 mm.

The pictures of the experimental set-up are shown below.

**Actual View of Experimental Apparatus**

The actual picture of experimental setup is shown in figure 1.2 ply woods is the material used to fabricate this setup. The total length of this is 1750mm, height 120mm and width 200mm. As shown in Fig. 1.2.
Test Section

It is the central part of the wind tunnel having the overall length of 600mm; width 200 mm, height 120 mm, where test specimen is placed over which experiment is to carried. The side view of this section is made up of Plexiglas so that the interior par of section can be seen to analyze the exact location of the test specimen.

IV. RESULT AND DISCUSSION

In this experimental study the observations were carried out in an open type wind tunnel of cross-section 200x120mm and length 1750mm for various test specimens (configurations). The test specimens were placed in a test section one by one to analyze the heat transfer enhancement under various heat flux and flow conditions and then observations were carried out by varying the heat flux i.e. (10.88, 25, 44.16, 68.8watt) and Reynolds number (17037.1, 19799.9, and 26246.3) for plane plate. After completing over plane plate it was replaced by the trapezoidal plate having 11mm grooves on 17 mm plate plane (Aluminium). The observations regarding heat transfer and pressure drop were carried out over trapezoidal plate on same conditions of heat flux and Reynolds number. And then a sharp edged wavy plate was placed over trapezoidal plate in centre at 15mm height. The variation in the heat transfer characteristics is compared with all type of channel configurations.

Validation of Plane Plate

Experimental results for the plane plate have been made by placing it in the test section of open type wind tunnel. From fig 3.1 it has been observed that the Nusselt number increases with increase in Reynolds number. It is also clear from fig 4.1 the variation of Nusselt number obtained from the present work with the correlation i.e. \( \text{Nu} = 0.036 \text{Re}^{0.8} \text{Pr}^{0.33} \) recommended by the Nusselt himself for turbulent flow through non circular pipes. The experimental results agree well within ±15% for Nusselt number with plane plate.
Variation of Average Plate Temperature with Reynolds Number for different heat flux

As the heat flux increases the outlet air temperature increases for particular Reynolds number, because with increase in heat flux the surface temperature of plate further increases which rises the outlet temperature of air.
4.4 Variation of Nusselt Number with Reynolds Number at Different Heat Flux and Comparison between the Three Cases under Study:

Validation of Pressure Drop with Empirical Relation

Figure 4.5 shows the variation of pressure drop across the test section with plate plane, the pressure drop calculated by using Correlation of Blasius i.e. $f = 0.316Re^{-0.25}$ for turbulent flow $Re<10^5$. In this study the obtained pressure drop is reasonably agree well within ± 25% of pressure drop which is calculated by using above relation. As shown in Figure the pressured drop increases with increase in Reynolds number, due to the turbulence effect in the air flow increases which leads to increase in pressure drop.
Variation of pressure Drop with Reynolds Number

Figure 4.6 shows the variation of pressure drop with Reynolds number for plane plate, trapezoidal plate and trapezoidal plate with SEWP. Due to the presence of waviness in trapezoidal plate causes disturbance, induced breaking and destabilizing, recirculation as air flows through such surfaces in the main flow, the pressure drop is 75-90% more as compared to plane plate. From fig it is observed that the pressure drop continues to increase with Reynolds number. Fig 4.7 also shows maximum increase in pressure drop with SEWP as compared to rest of the two in this study.

V. CONCLUSIONS

In the present experimental work, experiments were performed on three different test plates, first one was plane plate, second trapezoidal plate and third trapezoidal plate with SEWP. The comparison of heat transfer enhancement between these plates has been done in this experimental study.

On the basis of the results obtained the following conclusions are made:

1. Due to the presence of waviness in trapezoidal plate significantly enhances the heat transfer from the plate. Nusselt number for the trapezoidal plate is enhanced by 40-55% at 10.88 watt, 45-65% at 25 watt, 30-45% at 44.16 watt, and 25-35% at 68.8 watt in the Reynolds number range of present study.

2. The Nusselt number increases with increase in Reynolds number and the air outlet temperature decreases with Reynolds number in spite of increase in heat transfer.

3. The enhancement in heat transfer for trapezoidal plate reduces the plate temperature by 7-10% as compare to plane plate.

4. By introducing a SEWP over the trapezoidal plate further enhances the heat transfer. The Nusselt number for such plate is enhanced by 70-85% at 10.88 watt, 65-80% at 25 watt, 50-65% at 44.16 watt, and 35-50% at 68.8 watt in the Reynolds number range of present study, in this way trapezoidal plate with SEWP has found better heat transfer characteristics.

5. The average plate temperature with SEWP is low as compare to plane plate. This is because of augmentation in Nusselt number.

6. The enhancement of heat transfer achieved by using a SEWP over trapezoidal plate is associated with an increase in pressure loss and also pressure drop increases with increase in Reynolds number.

REFERENCES