CHAPTER - 7

EXPERIMENTAL INVESTIGATIONS ON HEAT TRANSFER ENHANCEMENT IN PLAIN TUBE FITTED WITH LOUVERED STRIP INSERTS

From the literature, it was found that, most of the studies focused on the turbulent flow heat transfer enhancement and the results of those studies had shown that although heat transfer efficiencies were improved, the frictions of tube were also considerably increased. Hence, in the present work, a novel concept to augment heat transfer efficiency using louvered strip inserts was developed and experimentally investigated. The strips provided high turbulent and circulation flow, resulting in an excellent rate of heat transfer.

Previous studies have addressed the heat transfer in tubes with elliptical shaped louvered strip inserts while the experimental investigations with circular, square and trapezoidal shaped louvered strip inserts in turbulent flow regime are not reported so far. For the cases of longitudinal strip and mesh inserts, a good agreement was found between numerical and experimental results as discussed in the previous chapters. Hence, in the present work, heat transfer and friction factor characteristics of air in the presence of louvered strip inserts are determined based on experimental investigations only. Three kinds of louvered strip inserts namely: circular, square and trapezoidal shaped
inserts were used for study. The Reynolds number ranged from 7000 to 14000. In the presence of inserts, both Nusselt number and pressure drop increased.

7.1 DESCRIPTION OF LOUVERED STRIP INSERTS AND EXPERIMENTAL PROCEDURE

Louvered strip insert of square geometry is shown in figure 7.1. Louvered strips, made of copper, were mounted on copper core rod with an inclined angle of $60^0$, as shown in the figure. Smith et al. [115] in their work with elliptical shaped louvered strip inserts concluded that, with the increase of the strip angle, Nusselt number could be increased. Hence, in the present work, inclined angle of strip with core rod is chosen as $60^0$ for experimental investigations. The diameter of the core rod is 2 mm. The distance between two adjacent louvered strips (pitch) is fixed at 50 mm.

Fig 7.1: Square shaped louvered strips of 22 mm effective diameter
The distances measured parallel to and perpendicular to the axis of the horizontal tube are 5.7 mm and 10 mm respectively for all (circular, square and trapezoidal shaped) louvered strips of 22 mm diameter. A typical case of square shaped louvered strip insert is shown in the figure 7.1. As the core rod diameter is 2mm, strips are mounted on both sides of the core rod (10 mm +10 mm+2 mm), louvered strips of 22 mm diameter are obtained.

Similarly all louvered strip inserts of 26 mm diameter are fabricated. A typical case of 26mm effective diameter square shaped louvered strip insert is shown in the figure 7.2.
Plate 7.1: Photograph of circular shaped louvered strip inserts
Plate 7.2: Photograph of square shaped louvered strip inserts
Plate 7.3: Photograph of trapezoidal shaped louvered strip inserts
Plate 7.4: Photograph of all louvered strip inserts
Plate 7.5: Photograph of trapezoidal shaped louvered strip insert (26 mm effective diameter) being placed inside the horizontal tube
In the previous chapter, using mesh inserts fitted inside the horizontal tube, a maximum increase in Nusselt number of approximately 1.87 and 2 times was obtained for mesh screen diameters of 22 mm and 26 mm respectively with the distance between screens (pitch) equal to 50 mm. At larger mesh screen diameters (i.e., 22 and 26 mm), the obstruction to airflow increased which caused turbulence within the test section leading to rapid mixing of the flow especially at lower pitch diameters. As a result, more heat was carried away by air, which resulted in increase of Nusselt number. Hence, in the present work using louvered strip inserts, 22 and 26 mm diameters each with a pitch of 50 mm are selected for experimental investigations.

Table 7.1: Louvered strip inserts characteristics

<table>
<thead>
<tr>
<th>S.No</th>
<th>Type of inserts</th>
<th>Effective diameter (mm)</th>
<th>Pitch (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Circular</td>
<td>22 26</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>Square</td>
<td>22 26</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>Trapezoidal</td>
<td>22 26</td>
<td>50</td>
</tr>
</tbody>
</table>
Experimental procedure is given below:

1. The test section is disconnected from the orifice plate. The louvered strip insert is inserted into the pipe axially as shown in the photograph and the pipe is refitted.

2. The heat input and the Reynolds numbers at which experiments are conducted are same as that of plain tube experiment. The pipe section is heated to the preset value, 40 W, which is adjusted using a dimmerstat on the instrumentation panel.

3. Temperatures T1 to T6 are noted from the temperature indicator at a time interval of 5 minutes until steady state is reached and the steady state readings are tabulated.

4. The above process is continued for different mass flow rates of air.

5. Steps 1 to 5 are repeated for all louvered strip inserts.

### 7.2 HEAT TRANSFER CALCULATIONS

Calculation of Nusselt number and friction factor for air in plain tube fitted with louvered strip inserts is given below:

Velocity of airflow,

\[ U_i = \frac{d}{A_{fr}} \] (m/sec) \hspace{1cm} (7.1)

Friction factor,

\[ D_h = 4 \frac{A_{fr}}{Wetted \ perimeter} \] (m) \hspace{1cm} (7.2)
Reynolds number,

\[ Re = \frac{U_i D_h}{v} \]  

(7.3)

Experimental heat transfer coefficient for air in plain tube fitted with louvered strip inserts is calculated by using the Eqs. 4.13 to 4.17.

\[ Nu = \frac{h D_h}{k} \]

(7.4)

Eq. (7.4) gives Nusselt number in the presence of louvered strip inserts

\[ f_i = \frac{\Delta P_i}{\left( \frac{L}{D_h} \right) \left( \frac{\rho_a U_i^2}{2} \right)} \]

(7.5)

Eq. (7.5) gives friction factor in the presence of louvered strip inserts

**7.3 RESULTS AND DISCUSSION**

Experiments were conducted with 22 mm and 26 mm effective diameter louvered strip inserts. Figures 7.3, 7.4 and 7.5 indicate the variation of average surface temperatures of horizontal tube in the presence of louvered strip inserts.
Fig 7.3: Surface temperature variation with Reynolds number for circular strips of 22 mm and 26 mm effective diameters

Fig 7.4: Surface temperature variation with Reynolds number for square strips of 22 mm and 26 mm effective diameters
Fig 7.5: Surface temperature variation with Reynolds number for trapezoidal strips of 22 mm and 26 mm effective diameters

Presence of all 22 mm diameter louvered strip inserts indicated higher tube wall temperatures compared to 26 mm effective diameter inserts. This is due to lesser obstruction created for air in the tube in the presence of 22 mm louvered strip inserts causing an increase in tube surface temperatures.

Maximum average tube surface temperatures were 55.4°C, 54.2°C and 53.1°C respectively for circular, square and trapezoidal inserts. Trapezoidal inserts showed lesser wall temperatures compared to other two inserts. This is due to more heat carried away by air causing decrease in tube surface temperature in the presence of trapezoidal insert. Maximum air outlet temperatures in the presence of circular, square and trapezoidal inserts were 54°C, 55.1°C and 56°C respectively.
Highest heat transfer rates were observed in the presence of trapezoidal insert due to the increase of strong turbulence intensity.

Fig 7.6: Variation of Nusselt number with Reynolds number for strips of 22 mm effective diameter

Fig 7.7: Variation of Nusselt number with Reynolds number for strips of 26 mm effective diameter
Figures 7.6 and 7.7 show the variation of Nusselt number ($Nu_i$) with Reynolds number for louvered strip inserts of 22 mm and 26 mm effective diameters respectively. It is observed that 26 mm diameter insert yielded the highest value of Nusselt number in each case. This is due to the strong turbulent intensity generated by 26 mm diameter insert leading to rapid mixing of the flow. It is observed that the Nusselt number is maximum for insert with trapezoidal geometry in each case. This is due to the geometry of trapezoid, with gradually increasing cross-sectional area, which could drive the air towards the tube wall leading to better mixing of fluid between the core and the tube surface regions. Maximum Nusselt number increase compared to plain tube is 294%, 301% and 323% for circular, square and trapezoidal inserts respectively.

![Graph showing the variation of friction factor with Reynolds number for strips of 22 mm effective diameter](image)

Fig 7.8: Variation of friction factor with Reynolds number for strips of 22 mm effective diameter
Fig 7.9: Variation of friction factor with Reynolds number for strips of 26 mm effective diameter

Figures 7.8 and 7.9 indicate the variation of friction factor ($f_i$) with Reynolds number for 22 mm and 26 mm effective diameters respectively. The friction factor, which is high at lower Reynolds number, tends to reduce with the increase of Reynolds number. Friction factors with all louvered strip inserts were observed to be higher than plain tube at all Reynolds numbers. Maximum values of friction factors were observed in the case of 26 mm square louvered strip inserts.

Maximum friction factor increase compared to plain tube is 250%, 280% and 261% for circular, square and trapezoidal inserts respectively. Friction factors for circular inserts are less compared to those of square and trapezoidal strip inserts. This may be due to the contour of circular strip offering lesser resistance to airflow. Highest friction factor ratio is
obtained for square strip insert. This is due to the obstruction caused to airflow at the corners of square leading to higher friction factors.