Review of Forced Convection Heat Transfer through Rectangular or Square Duct Provided with Different Configurations of Rib Turbulators

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Abstract- **Heat transfer enhancement technology is the process of improving the performance of a heat transfer by increasing the convection heat transfer coefficient. Generally the main objective is to reduce the size and costs of heat exchangers. General techniques for enhancing heat transfer can be divided in two categories. One is passive method such as twisted tapes, helical screw tape inserts, rough surfaces, extended surfaces, additives for liquid and gases. The other is active method, which requires extra external power, for example mechanical aids, surface fluid vibration, use of electrostatic fields. Passive methods are found more inexpensive as compared to active methods.**

Rib is a popular heat transfer enhancement device used in various heat-exchanging channels. The flow blockages such as ribs increase the pressure drop and leads to increased viscous effect because of reduced fluid flow area. Flow around ribs includes recirculation, reattachment and secondary flow. The secondary flow further provides a better thermal contact between surface and fluid as secondary flow creates swirl. This results in mixing of fluid that enhances the thermal gradient which ultimately enhances the heat transfer coefficient.

Keywords- Square Duct, Forced Convection, Rib, Nusselt number, Reynolds number, Friction factor, convective heat transfer coefficient, heat transfer enhancement

I. INTRODUCTION

Heat exchangers have been widely employed in several industrial and engineering applications. The design of heat exchangers needs exact analysis of heat transfer rate and pressure drop estimations. The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment. The heat transfer rate can be improved by introducing a disturbance in the fluid flow, but in the process pumping power may increase significantly and ultimately the pumping cost becomes high. Square ducts are widely used in heat transfer devices such as in compact heat exchangers, gas turbine cooling systems and nuclear reactors.

II. LITERATURE REVIEW

The effects of the various inserts, rib arrangement and configuration on the heat transfer performance have been investigated by many researchers. Recent work that has been carried out related to study of convective heat transfer from rectangular and square duct provided with different types of inserts is reviewed as follows:-

Ray et al. [1] numerically predicted characteristics of laminar flow and heat transfer through square duct with twisted tape insert. The heat transfer characteristics are predicted under axially and peripherally constant wall heat flux conditions. Correlations for friction factor and Nusselt number are developed from the predicted data. The agreement between the correlation and experimental data for friction factor is found to be excellent.

Giovanni Tanda et al. [2] carried out an experimental investigation of Heat transfer in rectangular channels with transverse and V-shaped broken ribs. The ribs, having rectangular or square sections, were deployed transverse to the main direction of flow or V-shaped with an angle of 45 or 60 degree relative to flow direction. The effect of continuous and broken ribs was also considered. Local heat transfer coefficients were obtained at various Reynolds numbers, within the turbulent flow regime. Maximum heat transfer is attained for 60 degree V-shaped ribs.

Sujoy Kumar Saha et al. [3] studied experimentally the heat transfer and the pressure drop characteristics of laminar flow of viscous oil through rectangular and square ducts with internal transverse rib turbulators on two opposite surfaces of the ducts and with wire coil inserts. The transverse ribs in combination with wire coil inserts have been found to perform better than either ribs or wire coil inserts acting alone.

Giovanni Tanda [4] performed an experimental work to investigate forced convection heat transfer in a rectangular channel with angled rib turbulator, inclined at 45°. The angled ribs were deployed with parallel orientations on one or two surfaces of the channel. Superior heat transfer performance was found at the optimal rib pitch to height ratio of 13.33 for the one-ribbed wall channel and at rib pitch to height ratio of 6.66 for the two-ribbed wall channel.

M. Udaya et al. [5] performed an experimental study of heat transfer enhancement in square duct with inserts under turbulent flow condition and constant heat flux. It is seen that for an increase Reynolds number up to 15%; Nusselt number increased by 30%. It is observed that experimental heat transfer coefficient of air increases by inserting the different inserts in square duct.

Pankaj et al. [6] carried out an experimental analysis to study turbulent flow heat transfer in rectangular duct with and without internal ribs. The effects of internal ribs on the heat transfer coefficient and friction factor are compared with the result of smooth duct under similar flow conditions. Experimental results show that the local Nusselt number distribution is strongly depended on the position, orientation, and geometry of the ribs. Also the discrete V- shaped ribs produce overall less heat transfer enhancement than the continuous V- shaped ribs. However, the increased heat transfer enhancement in the continuous V- shaped ribs came at the cost of an increased pressure penalty.

Yongsiri et al. [7] carried out a numerical study of turbulent flow and heat transfer in a channel with inclined detached-ribs. The effects of the inclined detached ribs with different attack angles on the heat transfer, friction factor and thermal performance behaviors have been investigated numerically for Reynolds numbers from 4000 to 24,000. Among the ribs examined, the one with ϴ=60° yield comparable heat transfer rate 1.74 times of those in the smooth channel and ϴ=120° yield thermal performance factor 1.21 which are higher than those given by the others.

Sagar et al. [8] carried out a numerical analysis of heat transfer for three different angles of w-shaped turbulators placed at the bottom side wall of square duct. From the numerical analysis of it is found that Nusselt number and friction factor in duct with W-rib insert increases as compare to smooth duct without insert.

Priyank et al. [9] carried out a two-dimensional CFD investigation to study forced convection of fully developed turbulent flow in a rectangular duct having ribs on the underside of the top wall. The effect of Reynolds number and relative roughness pitch on the heat transfer coefficient and friction factor have been studied. It is observed that the roughened duct having circular and square rib with highest relative roughness height provides the highest Nusselt number at a higher value of Reynolds number. Square sectioned rib provides higher value of enhancement as compared to circular rib at a higher value of Reynolds number.

III. PROPOSED WORK:

Following work will be carried out during the experimentation:

Theoretical Work:

Review of previous work on study of forced convection heat transfer in a rectangular and square duct provided with different type of turbulators

1) To take decision about dimensions of different configurations of rib turbulators that are to be provided in square ducts

Experimental Work:

1) Fabrication of experimental set-up
2) To conduct the experiment for different configurations of rib turbulators and noting down the set of readings for each configuration to calculate Reynolds number, Nusselt number, convective heat transfer coefficient and overall enhancement ratio

Validation:

After performing the experiment, calculation of the heat transfer coefficient of air by using correlation method will be done. Finally the comparison of the results of experimental investigation with the results obtained by using correlation method will be done.

IV. PROPOSED EXPERIMENTAL SET-UP

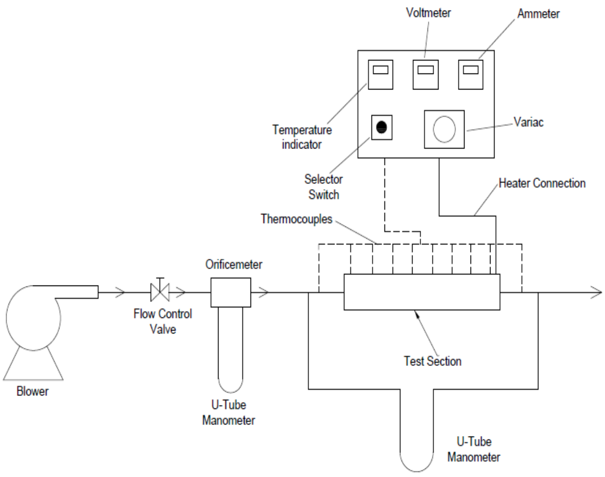

Fig.1- Proposed experimental set-up

Proposed experimental set-up for investigation of forced convection heat transfer in a square duct provided with rib turbulators is as shown in fig.-1.

In this set-up, two opposite walls of square duct will be provided with the different configurations of rib turbulators. The square duct is surrounded by band heater. Eight thermocouples are embedded on the test section and two thermocouples are placed in the air stream at the entrance and exit of the test section to measure air inlet and outlet temperature. The temperatures can be read directly from the temperature indicator by using selector switch. Air flow is controlled by a flow control valve and is measured with the help of orifice meter and manometer. Heat input can be set with the help of variac provided on control panel and same can be read out digitally with the help of voltmeter and ammeter.

The different configurations of rib turbulators to be provided on the two opposite walls of the square duct are as shown in fig.-2.

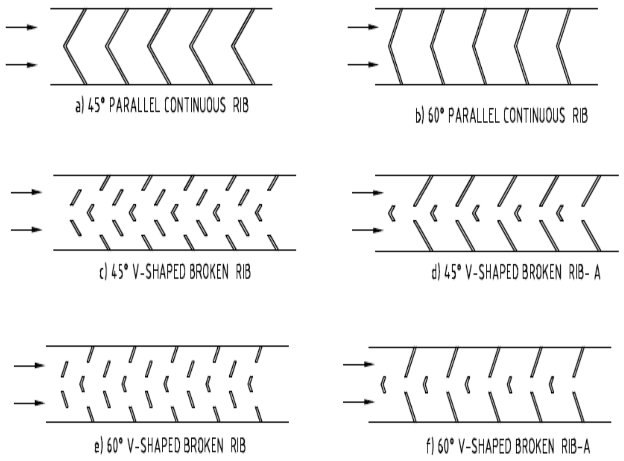

Fig.2- Rib Turbulator Configurations

V. CONCLUSION

1) Heat transfer rate is increased by using square ducts with inserts, because inserts increase the turbulence of the flow.
2) The heat transfer characteristics are mainly dominated by turbulent transport and secondary flow induced by geometrical features.
3) Ribs installed at an acute angle provide better heat transfer performance than orthogonally installed ribs. These angled ribs generate strong secondary vortices adjacent to the channel surface as the flow moves in the direction of the ribs. The vortices sweep the surface, and locally intensified heat transfer occurs in these regions. Moreover, parallel ribs installed on opposite channel surfaces generate a rotational flow, which promotes mixing of the fluid.

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