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Heat Transfer Enhancement in Tube Using Circular Square Cut Inserts

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ABSTRACT

An experimental investigation is carried for heat transfer enhancement with the help of square cut circular insert for heat exchanger applications. This experimental investigation is for measuring tube side heat transfer coefficient friction factor, Reynolds number of air for tuebulent flow in circular tube fitted with square ut circular ring insert. An experimental setu consist of blower, flow control valve to maintain measured quantity of flow, orifice meter is used for flow measurement, pressure drop is measured along test section and orifice plate with 2 U-tube manometers. A stainless steel tube of SS304 material having 40mm I.D and 50mm O.D and 1250mm length is used. A mild steel plate of 5mm thickness square cut with 10mm width and 10mm depth is used as the insert.A 10mm hole is drilled in the centre of the circular disc. The enhancement devices of the square cut insert show a considerable improvement of Nusselt number and friction factor relative to the plain section without inserts and smooth tube acting alone. The Nusselt number is found to increase with increase in the Reynolds number of individual iterations of 6 inserts, 5 inserts. The highest Nusselt number is found to be 63.83 for 6 circular square cut inserts in the tube with alternate angles of 18° and Reynolds number of about 14000. The friction factor is found to increase with decrease in the Reynolds number and vice versa. The friction factor is maximum for the tube with 6 inserts and about 0.0294 and lowest for the tube without inserts of about 0.027. The friction factor is found to be maximum at the lowest Reynolds number value of about 13400. The heat transfer coefficient for convective transfer of heat is found out to be maximum for the tube with 6 inserts. The maximum value of h is 43.24 W/m²K for a Reynolds of about 13400.
Keywords : Circular square cut insert, Dimensional analysis, Heat transfer augmentation, Nusselt no, Reynolds no.

I. INTRODUCTION

Heat transfer occurs due to temperature difference between the two systems. In daily life, there are lots of engineering systems in which heat transfer plays very important role. Heat exchangers, boilers, condensers, radiators, heaters, furnaces, refrigerators, solar collectors etc. are the equipments of engineering systems in which heat transfer occurs. In past few years various researchers research on heat transfer augmentation. Heat transfer augmentation techniques are used to improve performance of heat exchangers. Improving the performance of heat exchangers led to saving of energy. Therefore total energy required to the system decreases. So, heat exchanger becomes compact and material required for heat exchangers is low. Energy efficient heat exchanger gives high performance. The techniques used to improve performance of heat exchangers are called as heat transfer augmentation or heat transfer enhancement techniques. Various researchers used different techniques like passive, active, compound etc.

A) Passive Techniques:

Heat transfer augmentation achieved by using inserts or introducing additional devices. External power input is not required in passive techniques. There are various passive techniques as given below:

(a) Treated Surfaces: Treated surfaces are used in condensing and boiling and this technique includes application of coating.

(b) Extended Surfaces: Fins are the example of extended surfaces and fins are used in heat exchanger to enhance heat transfer.

(c) Displaced Enhancement Devices: These devices are used in forced convection. Various inserts are inserted to displace fluid from core to surface side.

(d) Swirl Flow Devices: Rotating type of flow generated by using these devices. Inlet Vortex

Generators, Twisted Tape Inserts are the different types of swirl flow devices.

B) Active Techniques:

For heat transfer enhancement, there is external power input is required. This technique is more difficult to design and there are very less applications. Mechanical Aids, Injection, Surface Vibration and Electrostatic Fields are different examples of active techniques.

C) Compound Techniques:

Combination of active techniques and passive techniques is called as compound techniques. Its purpose is to improve thermo hydraulic performance of a heat exchanger.

Inserts have been utilized as one of the enhancement techniques and are widely utilized in heat transfer equipments. They show several advantages in relation to other enhancement techniques:

1) Easy installation and removal.
2) Simple manufacturing process with low cost.
3) Preservation of original plain tube from mechanical strength.
4) Possibility of installation in an existing smooth tube heat exchanger.

II. EXPERIMENTAL SETUP

Figure 1. Photograph of the experimental setup.

Geometries of the inserts:

The circular square cut insert used in this project work is discussed in the following.All inserts used in experiments are made up of mild steel sheet of 5mm thickness. The square cuts on the circular sheet has dimensions: 10mm breadth and 10mm deep cuts. 4 square cuts are made on the circular sheet each 90degrees to the other. The circular sheet diameter 40mm is used with a centre hole of 10mm diameter.The square cut shape on the circular mild steel disc is given by using laser cutting machine. By using laser cutting machine the required profile was obtained with greater accuracy. The circular diameter of insert is 40mm and also square cut of width 10mm and depth10mm. The 4 square cuts angled at 90° apart from each other on insert. After achieving the required shape of insert, these inserts were welded on a circular mild steel rod of diameter 10mm. The length of the circular rod is 1250mm and this 6 circular square cut inserts are mounted on equi-distant of 250mm. Then these inserts were spot welded on the circular rod. To obtain better swirl flow turbulence of air, an angle between each consecutive insert was adjusted to 18°. This increased the turbulence in the direction of the flow. The inserts were mounted on the rod by spot welding for easy removal while taking experimental readings in decreasing order of number of inserts used

Figure 2. Photograph of circular square-cut insert

III. GRAPHICAL RE PRESENTATION

1) Graphical analysis of Nusselt number:

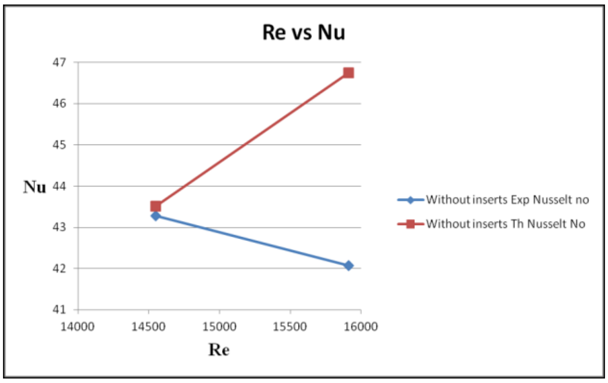

Figure 3. Verification of Nusselt number for plain tube

2) Graphical analysis of Nusselt number for 6 inserts:

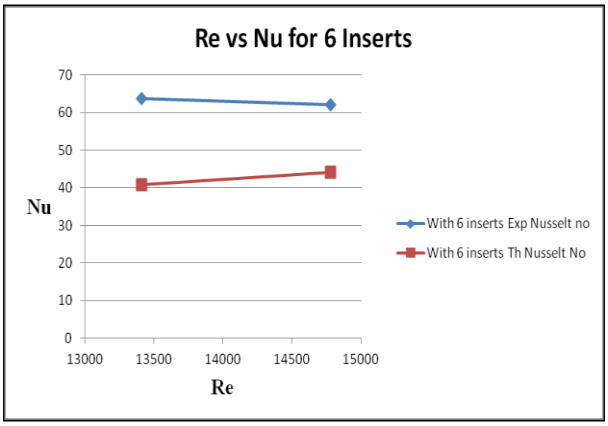

Figure 4. Verification of Nusselt number for 6 inserts

3) Graphical analysis of Nusselt number for 5 inserts:

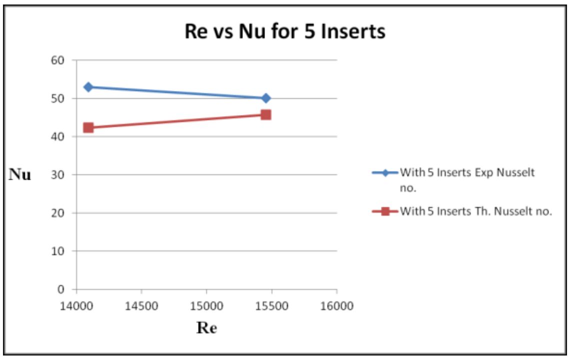

Figure 5. Verification of Nusselt number for 5 inserts.

4) Graphical representation of overall Nusselt number:

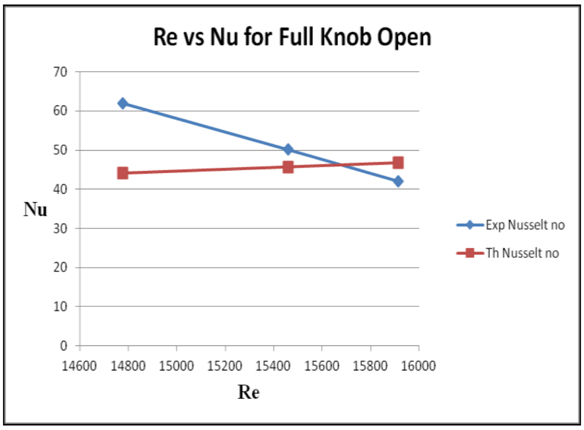

Figure 6. Verification of Nusselt number for Full knob open

5) Graphical representation of overall Nusselt number(Half Knob Open):

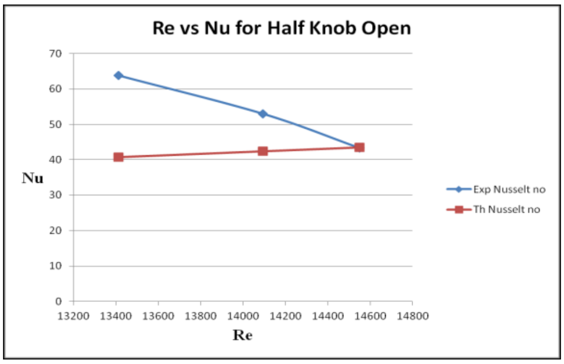

Figure 7. Verification of Nusselt number for Half knob open

6) Graphical representation for Reynolds number vs Friction factor:

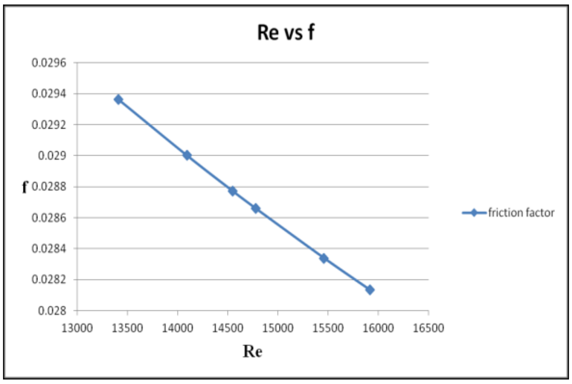

Figure 8. Comparison of Friction factor for various values of Reynolds number

7) Graphical representation of Convective heat transfer coefficient:

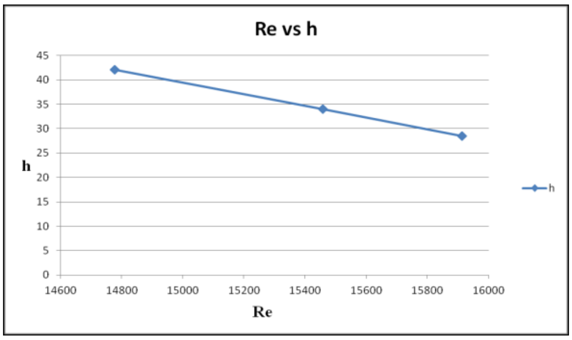

Figure 9. Comparison of convective heat transfer coefficient wrt Reynolds number

8) Graphical representation of Mass flow rate:

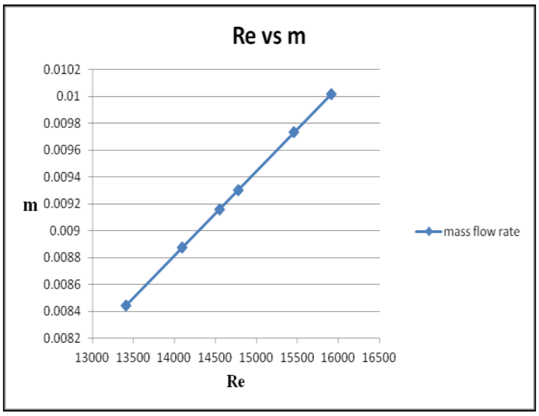

Figure 10. Comparison of Mass flow rate

IV. CONCLUSION

Heat transfer enhancement in a tube inserted with circular square cut inserts at 18° angle from each other to generate swirl flow is studied experimentally in this present study. The work has been conducted in the turbulent flow regime (Reynolds number in between 12000 to 16,000) using air as the working fluid. The findings of the work can be drawn as follows:

1. The enhancement devices of the square cut insert show a considerable improvement of Nusselt number and friction factor relative to the plain section without inserts and smooth tube acting alone.
2. The Nusselt number is found to increase with increase in the Reynolds number of individual iterations of 6 inserts, 5 inserts. The

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