Enhancement in Heat Transfer by Forced Convection Technique

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ABSTRACT

The enhancements of heat transfer characteristics in a uniform heat flux circular tube fitted with inserts creating annular blockages are experimentally investigated in this paper. This paper, is outcome of experimental study conducted to compare the rate of heat transfer with annular blockages in a tube. Blockages are created by using insert rings of aluminum of various inner diameter creating 22%, 44% 48% and 64% of blockage in tne tube. It is found that each application of the % blockages can help to increase considerably the heat transfer rate over that of the plain tube by about 278% and 206%, respectively. Nusselt number, Heat transfer raet,Reynolds number are determined with the experimental data. It was found that the use of the annular blockage of 48% leads to a maximum heat transfer rate that is up by 316%. Whereas on increasing the blockage upto 64% the heat transfer rate goes on reducing.

Introduction

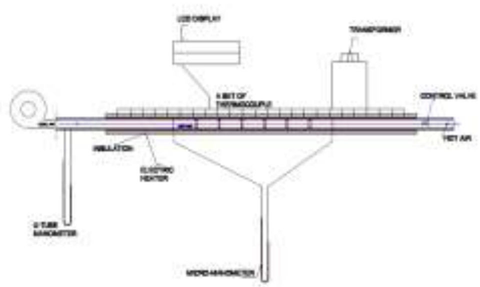
The science and engineering of air-side heat transfer enhancement plays a critical role in the design of various engineering equipments. Recently surfaces imprinted with dimples or concave indentations have been researched extensively. In the past researches, Royds (4) was the first to prove the useful effects of turbulence flow generators on heat transfer in 1921 with many experiments and types of turbulators. Kreith and Margolis (5),Kreith and sonju(6) proposed that heat transfer can be enhanced by introducing swirl flow in the heat exchanger with tangential injection of the fluid at various locations along the tube axis. Marner and bergles(7) reported experimental data for laminar flows of ethylene glycol and polybutene with twisted tape in an isothermal tube. In general twisted tape insert can help to generate the swirl flow and stronger turbulence in the tubes. This causes a thinner boundary layer and longer resident time of the flow leading to an increase in the heat transfer coefficient. However an increase pressure drop is the penalty of the twisted tape technique. The straight tape twisted in geometry form of helical tape with similar geometry of the screw tape, called the helical tape was introduced in a research study [8].

The swirl flow generator is also used in augmenting heat transfer in many engineering applications. Filament inserts are widely used for enhancing heat transfer rate. The Filaments inserts with holes, twisted tapes etc are the examples. After extensive literature reviewed, the use of annular blockages inserts replacing the filament inserts is discussed in the paper. To verify the enhancement in heat transfer experimentations is required This work is the outcome of an experimental work. So in the work, Test section were made with the arrangement of ring inserts for creating blockages. Heat transfer rates, heat transfer coefficients are compared with plain tube and various blockages.

EXPERIMENTATION

An experimental setup of circular tube with is developed and discussed below (fig 1).

2.1 Experimental Setup: Figure 1 shows the setup of Forced convection Heat transfer from circular tube with annular blockages.



The Cast iron tube has a test section length of L=500mm, with 25mm inner diameter and 28mm outer diameter. The tube was heated by continually winding flexible electrical wire provided a uniform heat flux boundary condition. The electrical output power was controlled by a variable transformer to obtain a constant heat flux along the entire length of test section and by keeping the current less than 3amps.

The outer surface of the test tube was well insulated with glass wool to minimize convective heat loss to surroundings and necessary precautions were taken to prevent leakage from the system. The inner and outer temperatures of bulk air were measured at certain points with multi-channel temperature measurement unit in conjunction with the copper-constantan thermocouples .Six thermocouples were tapped on the local wall of the tube and the thermocouples were placed round the tube to measure the circumferential temperature variation, which was found to be negligible. The mean local wall temperature was determined by means of calculations based on the reading of copper –constantan thermocouples.

2.2 Test Procedure

The test procedure was started with 0% blockage ie.plain tube and gradually increased blockages were introduced with aluminum ring inserts. The maximum % blockage attempted was 64% with the inner diameter of 1.5mm.The plain circular tube without blockages was supplied with heater input 25,50,75 and 100watt and flow from blower and the temperature are recorded at each thermocouple. the same procedure is repeated with various blockages of 22%,44%48% and 64%

3.0 RESULT & DISCUSSION

Using the data obtained from experiments, Rate of heat transfer, Heat transfer coefficient, Nusselt Number and ratio of Nusselt number to base line Nusselt Number for different heat input and for different mass flow rate of air are discussed in the following subsections.

3.1 Approach

Enhancement of heat transfer has been studied for different ring inserts made of aluminum. Performance graphs have drawn for
1) Heat transfer coefficient and mass flow rates
2) Logarithmic graphs for Nusselt numbers and Reynolds numbers
3) Pressure drops and Reynolds numbers.
The drop for plain tube (without insert) is measured for given range of heater inputs .

Heat transfer coefficients and mass flow rates have been noted for plain tube for various ranges of heater inputs. Also analytical heat transfer coefficients calculated by Dittus- Boelter equation. Increasing the diameter of insert rings, creates blockages in flow. Four ranges of annular blockages were used, as the blockages were increasing from plain tube (without blockage) to 64% of the blockage the flow becomes more turbulent. Thus higher the Reynolds number the greater would be the Nusselt number.

The contact between rings and circular tube wall from inside is inevitable and consequently heat transfer will exist due to heat conduction through some contacted insert rings. It can be attributed that the use of ring inserts can cause the turbulence and uniformity of temperature and pressure gradient in radial direction. The boundary layer along would be thinner with the increase of turbulent flow and pressure resulting in more heat flow through fluid. In addition to this due to the contact of six rings with hot inside tube wall there would be better heat transfer due to conduction.

3.2 Results for Plain tube

Heat transfer coefficients and mass flow rates have been noted for plain tube for various ranges of heater inputs. Also analytical heat transfer coefficients calculated by Dittus- Boelter equation. Performance curves for Nusselt number for various heater input are shown below. The maximum Nusselt number achieved is 57.16 at 12564 Reynolds number.

3.2.1 Performance Curves for Verification of Nusselt Number

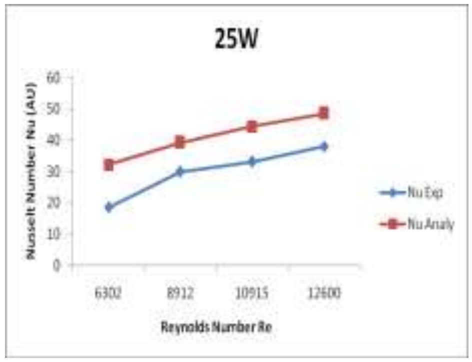


Fig. 3.2 (a)- Verification of Nusselt number for Plain tube for reading for 25 watts.

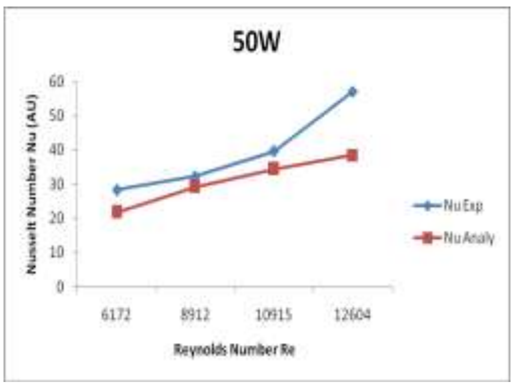


Fig. 6.2 (b) - Verification of Nusselt number for Plain tube for reading for 50 watts.

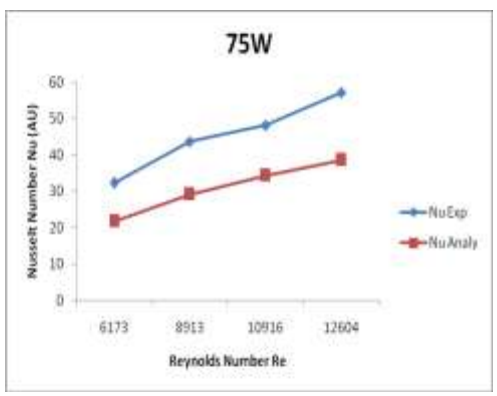


Fig 6.2 (c) - Verification of Nusselt number for Plain tube for reading for 75watts.

6.3 Results for 22.56 % Blockages in tube

For the annular blockage of 22.56% the flow of air through the tube is get distributed and it has to travels through the rings getting blocked for ring diameter and again getting widened with this the boundary layer will be thin and turbulent flow gets created. With increase in turbulence the Nusselt number is increasing resulting in enhances heat transfer coefficient than plain tube. The maximum Nusselt number observed is 97 at the Reynolds number 13286. Whereas for Plain tube 57.16

.6.3.1 Performance curves for Heat Transfer coefficient

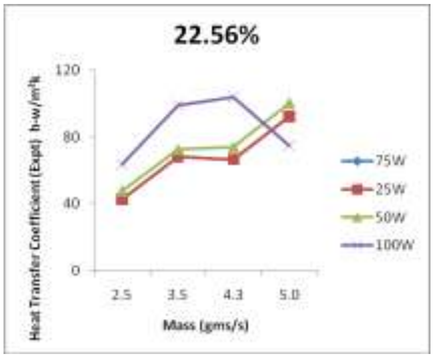


Fig. 6.3(a) Enhancement of heat transfer for 22.56% blockage

6.4 Results for 42.24 % Blockages in tube

The annular blockage of 42.24% causes the thinner boundary layer along the tube with the increase of turbulent flow and pressure resulting more heat flow through fluid as the blockages is increased. The flow of air through the tube is get narrower distributions and it has to travels through the rings getting more blocked for ring diameter and again getting widened, which creates more turbulent flow. With increase in turbulence the Nusselt number is increasing resulting in enhances heat transfer coefficient than plain tube.

The maximum Nusselt number observed with this blockage is125 at the Reynolds number 15286. This is more than for 22.56% blockage and for Plain tube without blockages.

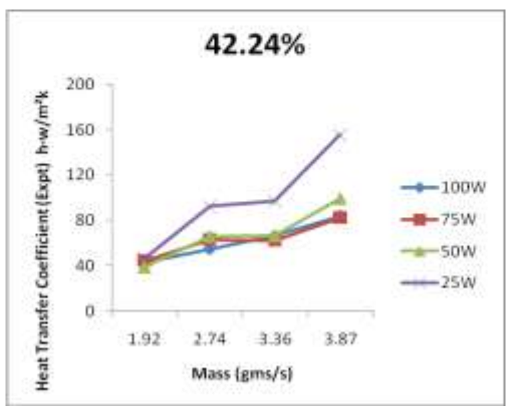


Fig.6.4(a) Enhancement of heat transfer for 42.24% blockage

6.5 Results for 48.16 % Blockages in tube

The annular blockage of 48.16% causes the same effect as with earlier blockages for 42.56% blockage. But as the flow is getting more restricted in this arrangement the velocity of flow is increasing and also the turbulent flow and pressure resulting more heat flow through fluid. With increase in turbulence the Nusselt number is increasing resulting in enhances heat transfer coefficient than plain tube.

The maximum Nusselt number observed is 161 at the Reynolds number 190925 this is more than other two blockages and plain tube without blockages.

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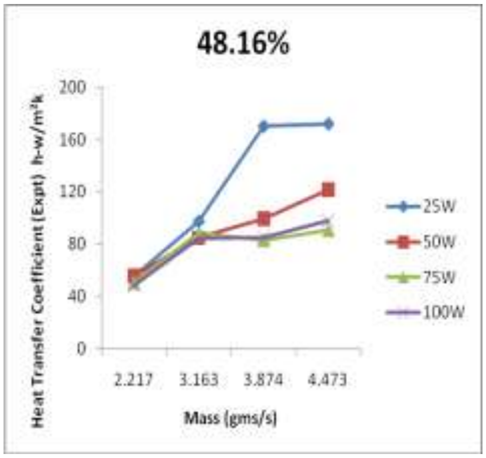

Fig 6.5 (a) Enhancement of heat transfer for 48.16% blockages

6.6 Results for 64 % Blockages in tube

The annular blockage of 64% cause the formation of boundary layer along the tube with the reduction of turbulence in the flow and increasing pressure due to increased blockage resulting in less heat flow through fluid. The flow of air through the tube is get narrower distributions and it is getting more blocked for ring diameter of 1.5id. With increase in turbulence the Nusselt number is increasing resulting in enhances heat transfer coefficient than plain tube. But it is less than other three blockages ie 22.54%, 42.24% and 48.16%. The maximum Nusselt number observed is 90 at the Reynolds number 8860.

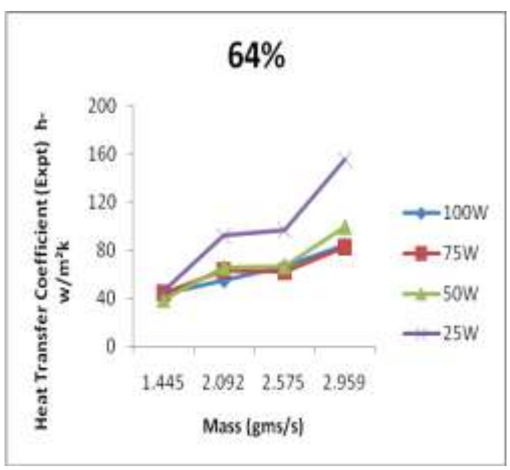

Fig 6.6 (a) Enhancement of heat transfer for 64% blockage

6.7 Performance Curves for Nusselt Number and Reynolds Number

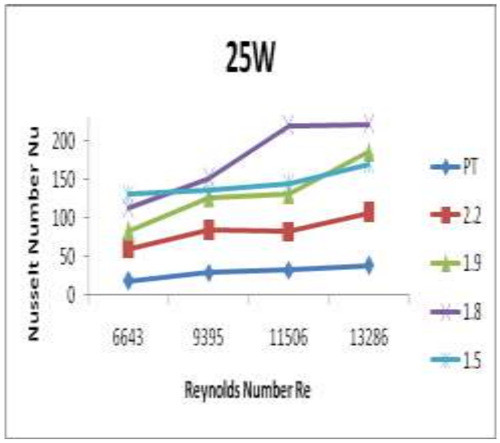

Fig. 6.7 (a) – 25W Curve

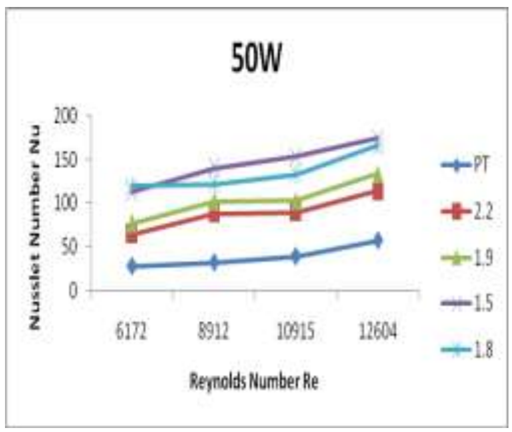

Fig. 6.7 (b) – 50W Curve

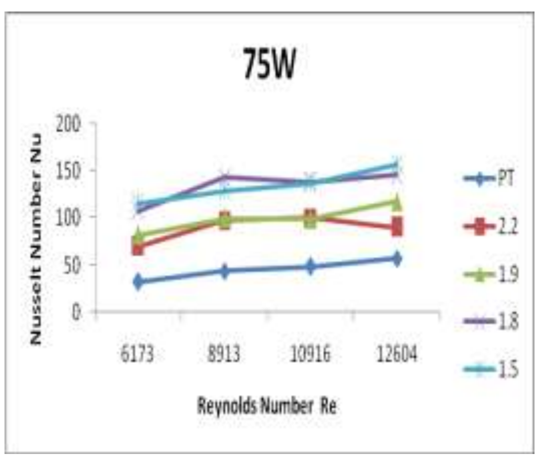

Fig. 6.7 (c) – 75W Curve

6.11 Pressure drop and friction factor

The pressure drop for air flowing through plain tube is measured for given range of Reynolds numbers. The maximum pressure drop observed is up to 50 Pascal which is measured by micro manometer. The pressure drop noted for flow with ring inserts is 550 pascals. It is oblivious that the use of inserts blockages gives higher pressure drop than that of plain tube due to larger contact surface areas. The pressure drop for various % blockages is different as flow gets change.

4 CONCLUSIONS

An experimental study of the flow of air through tube with annular blockages, subjected to different heat input has been performed. The effect of different annular blockages arrangement on the rate heat transfer, heat transfer coefficient, Nusselt number and Reynolds number has been studied. Experimental results measured on annular blockages test tube are given for heat input from 25 watts to 100 watts. Results have been compared within those of a plain tube,22% blockage,42%blockage,48.12%blockage and 64%blockage under similar flow conditions to determine enhancement in heat transfer coefficient.

Following conclusions have been drawn:
1) The rate of heat transfer for 48.16% blockage arrangement seems to have maximum value than all other arrangements. The rate of heat transfer is about 23% more for 48.16% blockage arrangement than plain tube without blockage at mass flow rate of 4.473gm/sec The 48.16% blockage arrangement has rate of heat transfer 12 % more than plain tube and all other blockages.
2) The rate of heat transfer for 42% blockage arrangement is less than 48% blockages but more than plain tube and all other arrangements. The heat transfer coefficient for 42.24% is 20% more than plain tube for mass flow rate 3.8 gm/s and 100w heater input.

6 References:

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