HEAT TRANSFER ENHANCEMENT USING TWISTED TUBE INSERTS IN A TUBE EXCHANGER

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ABSTRACT

A heat exchanger is a device used to transfer thermal energy between two or more fluids, at different temperatures in thermal contact. Enhanced heat transfer is a heat transfer that has been improved. The study of improved heat transfer performance is referred to as the heat transfer enhancement, augmentation or intensification. Heat exchangers have special and practical applications in the feed water cooler in the process industries, power plants, chemical plants, refineries, process applications as well as refrigeration and air conditioning industry. Experimental investigation has been carried out to study the effect of overall heat transfer coefficient in twisted tube heat exchanger. The main aim of this experimentation is to determine the overall heat transfer coefficient and friction factor of twisted tubes in multipass arrangement, with water as a working fluid. The experimental model was validated with the computational model.

Keywords: Twisted tube heat exchanger, CFD, Reynolds Number, Friction factor

INTRODUCTION

The cause of heat transfer is through the transmission of energy from one region to other is due to the temperature difference between two regions. Heat transfer or transfer of thermal energy is of great importance to engineers and in many branches of science and engineering. It is important to know the feasibility, the cost and the size of the equipment for better knowledge of heat transfer. So, the optimal heat transfer for engineering applications is necessary for effective working of system.

Enhanced heat transfer is a heat transfer that has been improved. The study of improved heat transfer performance is referred to as the heat transfer enhancement, augmentation or intensification. The various engineering problems involving the heat transfer are:-

- Gas turbine
- Wall of I.C. engine
- Heat exchanger
- Automobile engine

- Refrigeration, heating and ventilation

Heat transfer enhancement in heat exchangers is gaining industrial importance. It creates the opportunity to achieve these advantages:-

- Increase heat duty for fixed surface area
- Reduce heat exchanger size and numbers
- Reduce heat transfer surface area

Compact heat exchanger

Compact heat exchangers arespecial purpose heatexchanger which endeavors toachieve a very large transfer surface area per unit volume of heat exchanger. They are generally used when convective heat transfer coefficient of one fluid is much smaller as compared to the other fluid. Sometimes fins are used on the side corresponding tosmall heat transfer coefficient. Greater compactness is necessary wheresevere space and weight limitations are involved as in aircrafts ancillaries to accomplish the necessary rateof heat transfer as in generator. Compact lightly constructed heat exchangers are also often used where pressure are low. The period of use should be short and the cost of manufacturing is to below.

Twisted tube heat exchanger

A twisted tube heat exchanger is a passive heat transfer enhancement device comes under the category of swirl flow device. Swirlflowdeviceconsistsofvarietyof geometric flow arrangements that produce forced vortex fluid motion in confined flows. The enhancement occurs due to the rigid agitation and mixing induced by the swirl flow. These heat exchangers are extremely efficient due to the induced turbulence in both shell and tube side flow, and has added the advantage of substantial reduction of the amount of fouling. The innovativetubegeometryallows true counter-current flow andremarkableimprovement in heat transfer coefficient. This enhances heattransfer in shell side and tube side. Fluid in the tube side is swirled hence affectedby wall turbulence and different fluid layer velocities. A secondary circulation generated by the centrifugal force of swirling which affects in bundle flow. Inside and outside helical shaped tube accounts for doubling of the overall heat transfer rate but hydraulic resistance is also increased to double fold. A simple use ofsuch tubes in side ofstraight tube is equivalent to a 30% reduction of heat exchangersize.

LITERATURE REVIEW

The heat exchanger is an important device in almost all mechanical as well as process industries. Hence from long time it has been keen interest of researchers to improve the performance of heat exchanger by enhancing heat transfer rate within the limits of certain pressure drop. The review of such techniques keeping focus on passive augmentation techniques is focus of all these papers. The twisted tapes were also been tasted by many of them for different twist ratios. These inserts are tasted individually and in different form and the results were compared.

Azmi et al. carried out the experimental investigation on forced convection heat transfer of nano-fluids along with twisted tape insert in a plane tube. Reynolds number range was varied from 5000 to 25000 with bulk temperature of 30oC in the investigation. The experiments were conducted for flow in a circular tube with twisted tapes of different twist ratios. The conclusion shows that the heat transfer coefficient of nano-fluids with twisted tape is higher in the water flow for the same twist ratio. The maximum heat transfer enhancement with twisted tape for TiO_2/water and SiO_2/water nano-fluids was in the range of 1% and 3% volume concentration.

Gawandare et al. different square jagged copper twisted tape inserts 3mm with 5.2, 4.2 and 3.2 twists respectively were experimentally studied for the heat transfer enhancement. The inserts create a high degree of turbulence resulting in an increase in the heat transfer rate and the pressure drop. The Reynolds number is varied from 5000 to 16000. The work includes the determination of friction factor and heat transfer coefficient for various twisted wire inserts with varying twists and different materials. The 3mm thick with 3.2 twists copper insert shows increase in Nusselt number values by 76% along with increase in friction factor by only 19.5% as compared to the smooth tube values.

Eiamsa-ard.et.al. the thermal performance assessment of the heat exchanger tube equipped with regularly spaced twisted tapes was studied. The full length twisted tapes with two different twist ratios ($y = p/w = 6.0$ and 8.0), and the regularly-spaced twisted tape (RS-TT) with two different twist ratios ($y = 6.0$ and 8.0) and three free space ratios ($s = S/P = 1.0$, 2.0, and 3.0) were employed for comparative study. The heat transfer rate and friction increased with decreasing twist ratio and space ratio. Full length twisted tapes ($s = 0$) recorded higher heat transfer rate, friction factor and thermal performance factor than RS-TT ones ($s = 1.0$, 2.0 and 3.0).

Nanan et al. studied the influence of perforated helical twisted-tapes (P-HTTs) on the parameters of thermal performance, heat transfer and friction loss characteristics under a uniform heat flux condition. The P-HTTs were obtained by perforating typical helical twisted-tapes (HTTs) with a view to obtain reduction in friction loss of fluid flow. Three P-HTT's of different diameter ratios (d/w) 0.2, 0.4 and 0.6, and three different perforation pitch ratios (s/w) 1, 1.5 and 2 were used in the experiment. The helical pitch ratio and twist ratio were fixed at $P/D = 2$ and $y/w= 3$. The range of Reynolds number were chosen between 6000 and 20,000. The experiments were repeated in the plain tube and the tubes with HTTs for assessment. The experimental results show that the use of P-HTTs helps the reduction of friction loss as compare to HTT. Thermal performance, heat transfer and friction factor increase as d/w decreases and s/w increases.

M. Bhuiya et al studied through experimentation the heat transfer and friction factor characteristics in turbulent flow for a tube fitted with perforated twisted tapes inserts with four different porosities of $Rp =$ 1.6, 4.5, 8.9 and 14.7%.Herethe experiments were conducted in a turbulent flow regime with Reynolds number ranging from 7200 to 49,800 using air as the working fluid under uniform wall heat flux boundary condition. Nusselt number, thermal performance and friction factor in the tube with perforated twisted tape inserts was found to be 110 –340, 28–59% and110 – 360 higher than those of the plain tube values respectively.

Eiamsaard et al. reports an experimental investigation on heat transfer along with pressure drop characteristics of turbulent flow in a heating tube equipped with perforated twisted tapes with parallel wings (PTT). Reynolds number between 5500 and 20500 was recorded. The parameters investigated were the hole diameter ratio (D/W= 0.11, 0.33 and 0.55) and wing depth ratio (w/W = 0.11, 0.22 and 0.33). Heat transfer enhancement from 190% to 208% was reported in an assessment. Compared to the plain tube, the tubes with PTT and TT yielded. The evaluation of overall performance under the same pumping power reveal that the PTT with d/W= 0.11 and w/W = 0.33, gave the maximum thermal performance factor of 1.32, at Reynolds number of 5500.

Dr. Abdullah et al. effect of different geometry twisted tapes in circular tube for turbulent flow heat transfer enhancement was experimentally tested. Effect of different geometry twisted tapes in circular tube for turbulent flow heat transfer enhancement. Use of Six types of twisted tapes with total length of 1200mm and diameter of 50mm were chosen for experimentation such as normal twisted tape regularly spaced twisted tape, triangular-cut twisted tape, and rectangular-cut twisted tape, and semi-circular-cut twisted tape, and drilled twisted tape. Variation of range of Reynolds number lies between 4500 to 23500. It was observed that the enhancement of heat transfer coefficient increases as the type of twisted tape changes from one to six, respectively.

Promvonge and Suwannapan a numerical analysis of laminar periodic flow and heat transfer characteristics was presented for a constant temperature-surface square channel mounted with 30° angled baffles of various pitches. The computations here were based for finite volume method for SIMPLE algorithm implementation. The heat transfer and fluid flow characteristics were presented for Reynolds number ranging from 100-2000in the channel hydraulic diameter. A pair of stream-wise counter– rotating vortex flow was generated by placing angled baffles repeatedly on the lower and upper channel walls with in–line arrangement. Effects of different pitch ratios (PR=P/H) with a single baffle height ratio of 0.2 on heat transfer and pressure loss in the channel were examined. The computation revealed that the pair of vortex flow leads to substantial increase in heat transfer rate over the test channel. The decrease in the PR also led to the rise of friction factor. The result showed that the optimum thermal performance enhancement factor of about 3.78 is found at PR=2.5.

Naga Sarada et al. experimental investigations display the results obtained of the augmentation of turbulent flow heat transfer in a horizontal tube of varying width twisted tape inserts with air as the working fluid. To get reduce reasonably sufficient pressure drops associated with full width twisted tape inserts and corresponding reduction in heat transfer coefficients, reduced width twisted tapes of widths ranging from 10 mm to 22 mm, in the tube having inside diameter of 27.5 mm were used. Experiments were conducted for plain tube with/without twisted tape insert at constant wall heat flux and different mass flow rates. Three different twist ratios (3, 4 and 5) each with five different widths (26-full width, 22, 18, 14 and 10 mm) respectively were used. The Reynolds number variation was calculated from 6000 to 13500. The enhancement of heat transfer with twisted tape inserts as compared to plain tube varied from 36 to 48% for full width (26mm) and 33 to 39% for reduced width (22 mm) inserts.

METHODOLOGY

Model strips

The material choose for making the model strips is aluminium. Different configurations of the model twisted strips are fabricated viz. Twisted strips, twisted strips with rectangular cut, twisted strips with triangular cut and twisted strips with semi-circular cut. The configuration indicates the number of twist over the length of strips. For this purpose aluminium flat dimension 450*25*4 mm is taken. Then strips are being twisted in certain proportion and cut is given (same area is cut of different geometry). Thus different twisted strips are considered for experiment. During twisting, twisted length on the strips is chosen such that from both sides 75 mm length is left. Thus the twisted length on each strip is 300 mm.

The model strips are thus fabricated and these are used for experimentation. The geometry of the strip is thus simple, an aluminium flat twisted strips into constant pitch helix. The different geometry of the strips is shown in figure given below. The ratio of p/w is taken to represent the different configuration.

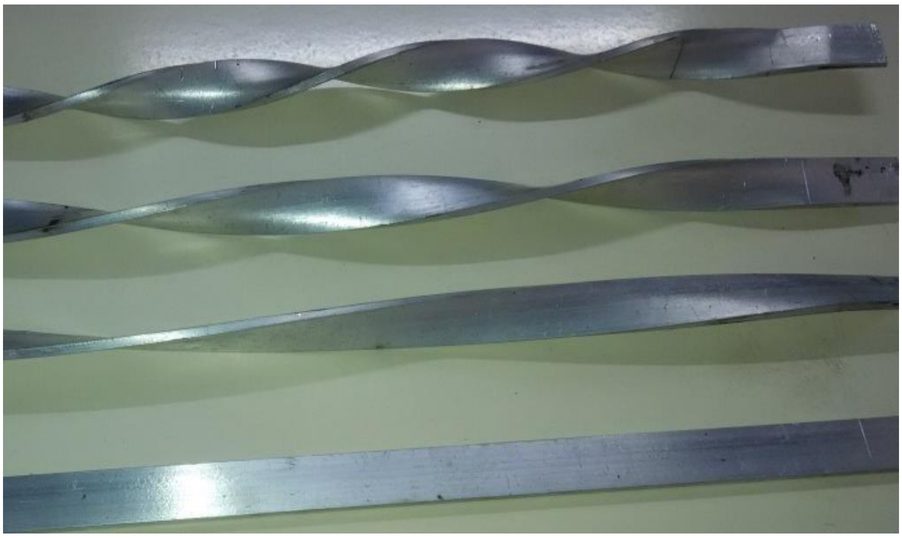

Figure 2: Model strips without cut

Duct

The duct is required for the experimentation with forced convection mode of heat transfer and the photograph is given in appendix. It consists of one fan rigidly fix at one end in such a way that air will flow equally on entire strip. First velocity of air at strip position is measured with the help of an anemometer.

Thermocouple and thermocouple circuit

The thermocouple circuit is as shown in fig. Three thermocouples are attached to each model strips by fixing there bid ends using an araldite adhesive. One thermocouple is fixed in the reference junction (cold junction) by immersing its bid in ice. The entire constantan end is attached to each other to form a common end. The free copper ends of v thermocouples attached to the model strips are soldered to the selector switch. The positive pole of the digital panel meter is connected to the selector switch. The free copper end of the reference junction is connected to the negative pole of digital panel meter which gives reading in terms 0c.

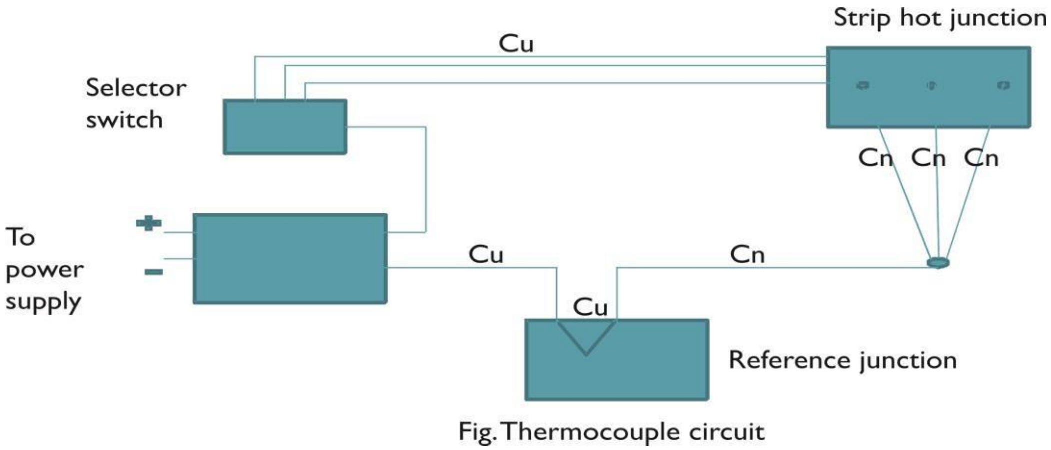

Figure 3: Thermocouple circuit

Experimental Procedure

For conducting the experiment on forced convection, a duct is used for supplying uniform flow of air over the strips during the experiment. Now the strips are placed during the experiment. First the velocity of air at the strip position is measured with the help of anemometer. At the outlet of duct, strip position is fixed such that air is supplied over the strip. The set-up is arranged as shown in fig. all the electrical connections are checked to find them right. Thermocouple circuit is arranged as shown in fig. for each strip thermocouple is used. It is checked whether the reference junction thermocouple is completely immersed in cold ice. Now power supply is given to heat the strips. A stage comes when the temperature of the strip remains constant with respect to time. This indicates the steady state situation. At this time the reading of thermocouples are noted from the digital panel meter which gives the output in degree Celsius. The atmospheric temperature is also recorded during the experimentation. The procedure is repeated for ten different heat supplied from 50 watt to 140 watt. Each time the reading of thermocouples is noted down. First the experiment is carried out for straight strip and then for different configuration of twisted strips having p/w ratio 12, 6, 4, 3. After carrying out experiment all the readings are tabulated. Reynolds number for each reading is calculated, then overall heat transfer coefficient and Nusselt number is also calculated.

The experiments were carried out in M.I.E.T. Gondia in Heat Transfer Lab.

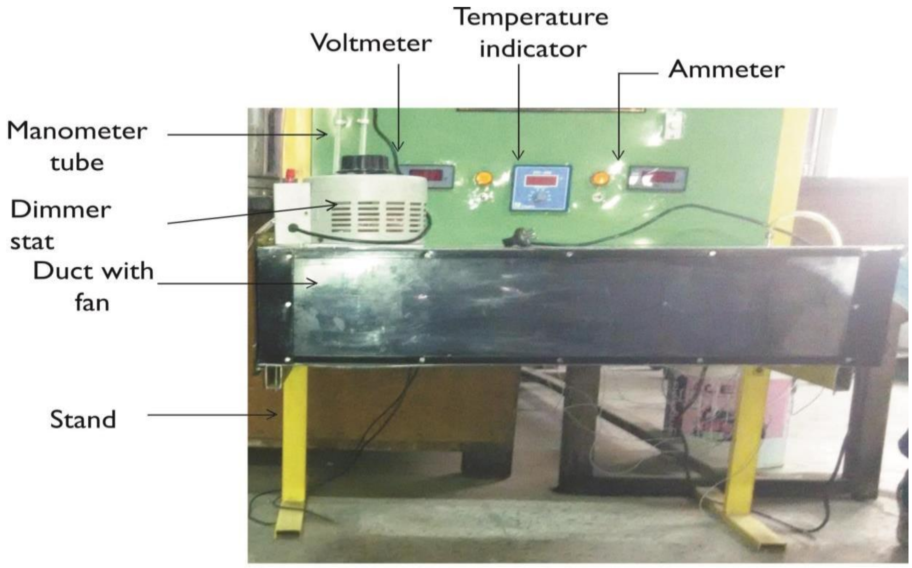

Figure 4: Experimental Setup

RESULT DISCUSSION

From the analysis it is found that Reynolds number (Re) in each case does not vary much which lies in the range of 5.21% and mean value of Re is 5485. Hence, the graphs are plotted by taking Re as constant.

The graph is plotted for each configuration of TT

- Heat transfer coefficient and heat input
- Heat transfer coefficient and p/w ratio
- Nusselt number and heat input
- Nusselt number and p/w ratio
- % increase in Nusselt number and p/w ratio

For plotting Nusselt number and heat transfer coefficient mean value of Nusselt number and heat transfer coefficient for different p/w ratio is considered. Similarly for plotting percentage increase in Nu, mean value of percentage increase in Nu for different p/w ratio is considered.

Graphs for TT without cut

The following fig. shows the variation of heat transfer coefficient for the different values of heat input. The heat transfer coefficient increases as the pitch to width ratio decreases i.e. when number of twist increases. The maximum value of heat transfer coefficient is for twisted tape with four twist (p/w = 3) and minimum value is for straight strip. Twisting effect enhances the heat transfer coefficient.

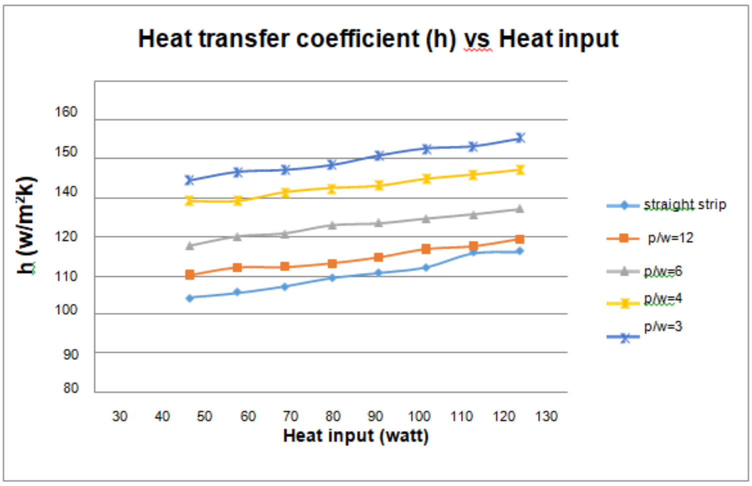

Figure 5: Variation of heat transfer coefficient for different heat input

The following fig. shows the Nusselt number variation with the heat input. The maximumvalue of Nuseeltnumber is obtained for p/w = 3 i.e. for TTwithfour twist and minimum value is for straight strip. This is dueto the twisting effect which enhances the Nusseltnumber.

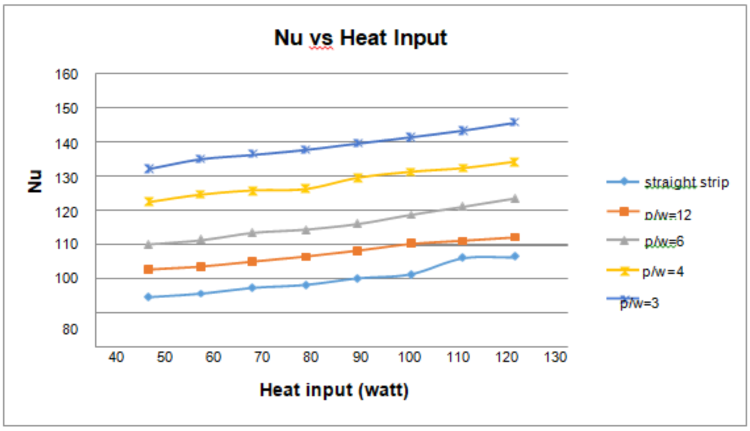

Figure 6: Variation of Nusselt number with heat input

TT with triangular cut

The following fig. shows the variation of heat transfer coefficient for the different values of heat input. The heat transfer coefficient increases as the pitch to width ratio decreases i.e. when number of twist increases. The maximum value of heat transfer coefficient is for twisted tape with four twist (p/w = 3) and minimum value is for straight strip. Twisting effect enhances the heat transfer coefficient. The heat transfer coefficient obtained here is more than the twisted tape without cut.

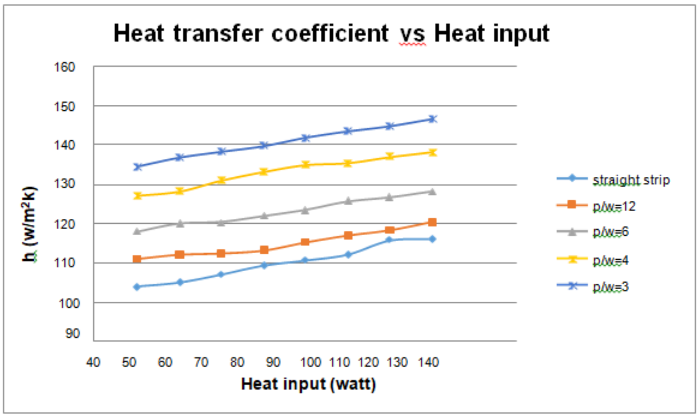

Figure 7: Variation of heat transfer coefficient for different heat input

The following fig. shows the Nusselt number variation with the heat input. The maximum value of Nuseelt number is obtained for p/w = 3 i.e. for TT with four twist and minimum value is for straight strip. This due to the twisting effect and the triangular cut which enhances the Nusselt number.

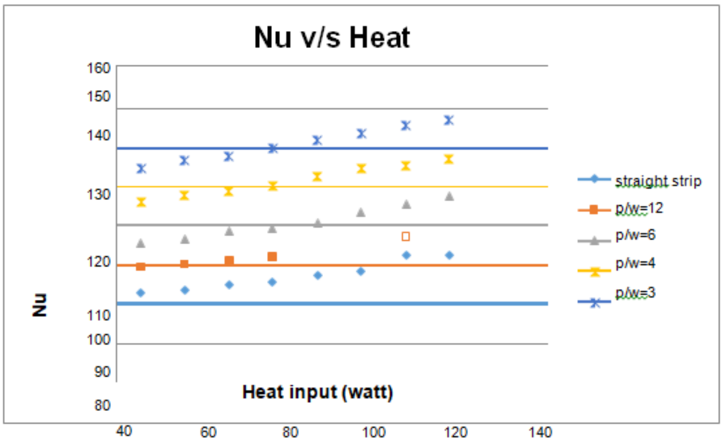

Figure 8: Variation of Nusselt number with heat input

TT with rectangularcut

The following fig. shows the variationof heat transfer coefficient for the different values of heat input. The heat transfer coefficient increases as the pitch to width ratio decreases i.e. when number oftwistincreases. The maximumvalueofheattransfer coefficient is for twisted tape with four twist (p/w = 3) and minimum value is for straight strip. Twisting effect enhances the heat transfer coefficient. This modified geometry improves the heat transfer coefficient than TT with no cut and TT with triangularcut.

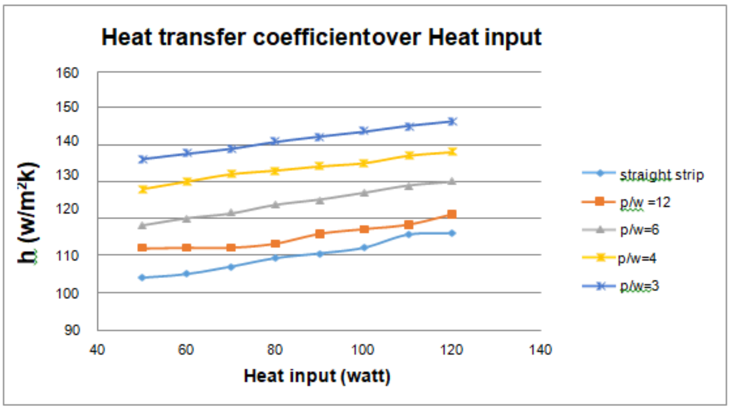

Figure 9: Variation of heat transfer coefficient for heat input

The followingfig.shows the Nusselt number variation with the heat input. The maximum value of Nuseeltnumber is obtained for p/w = 3 i.e. for TT with four twistand minimum value is for straight strip. This due to the twisting effect and the rectangular cut which enhances the Nusseltnumber.

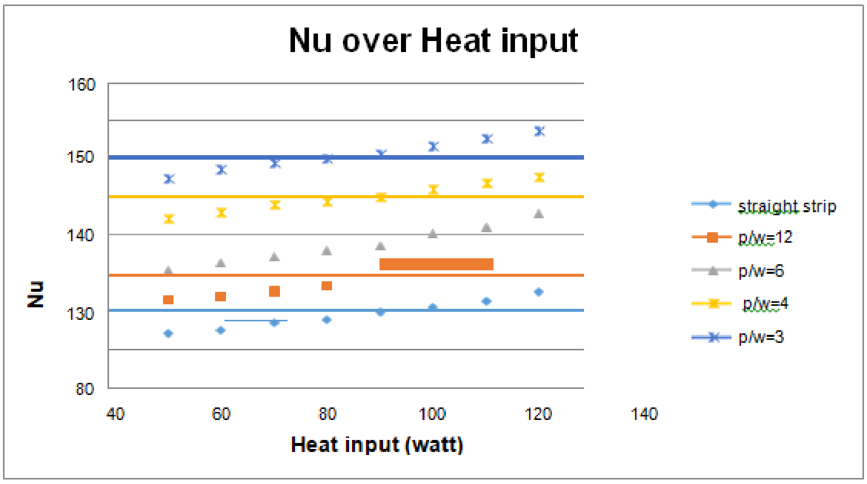

Figure 10: Variation of Nusselt number with heat input

CONCLUSION

As per the results obtained from the experiment conducted on various configuration of twisted strips for forced convection mode of heat transfer, it can be concluded that

- As a twist increases from one twist to four twists and pitch to width ratio decreases from 12, 6, 4 and 3 respectively. Hence there is increase in Nusselt number and hence, the heat transfer coefficient.
- In experimental results value of Reynolds number variation 5482 to 5496 which is variation in Reynolds number is +5 %.
- For the same mass flow rate of air and for the same area of cut, the increasing value of Nu is 94.47 to 108.3 for Straight strip, 102.56 to 113.1 for p/w = 12, 110 to 125.3 for p/w = 6, 122.18 to 135.63 for p/w = 4, 131.9 to 147.8 for p/w = 3 and the increasing value of heat transfer coefficient is observed for TT without cut.

- For same mass flow rate of air and for the same area of cut, the increasing value of Nu and heat transfer coefficient for TT with triangular cut, TT with rectangular cut and TT with semi-circular cut respectively.
- Nusselt number in case of straight strip (94.47 to 108.3) increase up to 29.48% (for p/w = 3) when compared to case of TT with semi-circular cut (134.8 to 148.8).

The experimentation can be done with the help oftwisting parameters to compare the valueof heat transfer coefficient for forced and natural convection mode. Vary the pitch to width ratio and geometry configuration and observe their effect on Nu and heat transfercoefficient.

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