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Experimental Performance of Double Pipe Heat Exchanger using Rectangular-Cut Twisted Tape with Wire Coil Inserts

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Abstract— Heat transfer is the phenomena, of transfer energy (thermal energy) in between the systems or system and surroundings. And heat exchanger is the main device which is used for transfer of heat (thermal energy) in many industries like food industries, chemical industries, thermal power plant, air conditioning equipment etc. So because of heat exchanger importance, many heat enhancement techniques are adopted to improve the performance of heat exchanger. An experimental investigation has been done for a double pipe heat exchanger for plain pipe and pipe with Rectangular cut with wire coil. Experiments were done for plain pipe, Rectangular cut twisted tape and Rectangular cut with wire coil to measure the Nusselt number, and friction factor with and without augmentation. All experiments done with hot water passing in the inner pipe and cold water in the annulus with varies Reynolds numbers.

Keywords— **Friction Factor, Heat Exchanger, Pressure Drop, Twisted Tape Insert, Wire Coils**

I. INTRODUCTION

Heat transfer is used to forecast energy transmit that might receive place among the two bodies temperature variation. Thermodynamics instruct the transfer of energy a form of temperature. The technology inquires about to give explanation of energy transfer. The energy transfer is preferred purpose of examination of thermodynamics and heat. It can be employed to envisage of entire energy necessary to modify a structure one things leads to another; Heat transfer supplement values of heat and work by provided that extra investigational system employed to set up transfer of heat. As thermodynamics technology, an experimental system used basis of heat transfer simple and easily extended to include a different practical situation. In forced type of convection allow transfer heat from some fluid to other fluid in a presence of flow. Convection through a pipe it is assorted with stream and flow of stream remove a heat. This is because due to preserve temperatures slope among the couple of fluids. An experiment of double'- pipe heat exchangers was most commonly used method is heat exchanger. Because hot fluid flowing inner tube and the cold fluid flowing among outer and inner tube and another tube that around a first. There are two flow configurations: the two streams' co-current flows with similar direction, while a stream flows with opposed directions. The scenario changes tubes: temperatures flow, fluid characteristics, liquid structure excreta. This short conduct leads to process temperature modifications that will lead to a stage where the supply of temperature becomes constant. This changes the temperature of the liquids when heat opens to transfer. The hot method flow of fluid throughout internal pipe its hot water throughout external pipe during the device.

A system is stable condition until the flow speed and entry temperature difference change. This modification of circumstances caused differences with change of temperature achievement of stable position of time. Once an inlet and outlet temperatures for the method are stable, the coolant becomes steady. In reality, Temperatures determination in no way is entirely stable; although by means of adequate variations in entry temperatures and flow, it is possible to observe a relatively stable state.

II. LITERATURE REVIEW

The present paper give an overview of work carried out on heat enhancement techniques. The purpose of this study is to provide an outline of the research that has been done on heat augmentation strategies.

M.M.K. Bhuiya et al. [1] 2013 investigated the Nusselt number, friction factor, and thermal performance factor in a circular tube with perforated twisted tape with four different porosities of 1.6, 4.5, 8.9, and 14.7 percent porosity. The experiment was conducted in a flow state. Nusselt number, friction factor, and thermal performance factor were found to be 110-340, 110-360, and 28–59% higher than plane tube values. And the findings with a porosity of 4.5 percent were better than the results with other porosities. Paisarn Naphon [2] 2006 conducted an experiment in a double pipe heat exchanger with twisted tape to anticipate heat transmission and pressure decrease. Aluminium twisted tape with a thickness of 1mm and a length of 2000mm. The findings obtained with twisted tape are compared to those obtained with a plain tube that does not have twisted tape. The findings revealed that twisted tape had a significant impact on heat enhancement. The rate of heat transmission and the pressure decrease both increased.

P. Bhardwaj et al. [3] 2009 used a spirally groove tube with twisted tape insert with twist ratios of y = 10.15, 7.95, and 3.4 to test the heat transfer characteristics of water. And the results were compared to those obtained using a planar tube. Heat transfer augmentation was 400 percent in the laminar regime, 140 percent in the turbulent regime, and a reduction in heat transmission in the 2500 Re 9000 regime in tube without twisted tape, according to the results. With twisted tape, it's 600 percent in the laminar regime and 140 percent in the turbulent. For regime 6000 Re 13000, there was a decline in heat transmission with y = 10.14. Among the three twist ratios, the heat transfer routine of twisted tape with twist ratio y = 7.95 was found to be the best. zhang [4] CUI Young In 2010, researchers used edge fold twisted tape (ETT) and spiral twisted tape to conduct experiments and simulations to forecast heat transmission and pressure drop in a circular tube (STT). The RNG turbulence model and pressure velocity approach were used to simulate pressure drop and heat transfer characteristics. Heat transfer was shown to be greater with ETT inserts than with STT inserts. The twist angle and the distance between the tube and the inserts were two elements that affected heat transfer. Twist ratios ranging from 5.4 to 11.4 were used, with Re ranging from 2500 to 9500. ETT inserts had a Nusselt number and friction factor of 3.9 percent -9.2 percent and 8.7 percent -74 percent greater than STT inserts in tube.

Bodius Salam et al. [5] 2013 conducted a study to measure the heat transfer coefficient, friction factor, and heat transfer efficiency of water in a tube with a rectangular cut twisted tape insert. The stainless steel twisted tape had a twist ratio of 5.25. Nusselt numbers increased by 2.3 to 3.9 when a rectangular cut twisted insert was used in place of a plain tube. In comparison to plane tube, twist tape increased friction factor by 1.4 to 1.8 times. Heat transfer efficiency ranged from 1.9 to 2.3 and improved as Reynolds Number climbed. M.M.K. Bhuiya et al [6] 2013 tested the effect of triple twisted tape inserts with twist ratios of 1.92,2.88, 4.81, and 6.79. Thermodynamic enhancement efficiency, heat transfer rate, and friction factor in tubes The Nusselt number, friction factor, and thermal enhancement efficiencies attained with triple twisted tape inserts were 1.73 to 3.85 times higher, 1.91 to 4.2 times higher, and 1.10 to 1.44 times higher than plain tube values, respectively. In the turbulent area of 2000 Re 12000, P.Murugesan et al[7] 2011 conducted an experiment to predict heat transfer and friction factor of a circular tube equipped with plain twisted tape (PTT) and U – cut twisted tape (UTT) with twist ratios of 2.0, 4.4, and 6.0. The results of the UTT experiment were compared to those of the plain tube and the tube with PTT. UTT has a higher Nusselt number and friction factor than plain tube and PTT. The heat transfer enhancement provided by UTT is superior to that provided by plain tube and PTT.

Chinaruk Thianpong et al.[8] 2009 used two dimple tubes (PR = 0.7, 1) and three twisted tapes with twist ratio y = 3, 5, 7 to anticipate the influence of pitch and twist ratio on heat transfer coefficient and pressure drop. The results from the plain tube and the dimple tube were compared. Dimpled tube with twist tape had increased heat transfer and friction factor than plain tube, ranging from 1.66 to 3.03 and 5 to 6.31, respectively. P.Eiamsa-ard et al. [9] carried out an experiment to anticipate heat transfer enhancement and friction factor in a tube with rectangular – winged twisted tape (TT- RWs). The wing depth ratio was altered from 0.1 to 0.3 throughout the experiment, while the twist ratio remained constant. The working fluid was water, and the Re number ranged from 5500 to 20200. When compared to TT, TA, and plain tubes, tubes having TT-RWs performed better. The nusselt number and thermal performance of 1.86 were higher in TT-RWs with = 0.3. The effect of louvered strips in a double pipe heat exchanger on friction factor and heat transfer performance was calculated by Somsak Pethkool et al [10] 2006. Brass strips with a thickness of 0.5mm and a width of 9mm were used.

III. EXPERIMENTAL SET UP

An experimental configuration comprises of electrical geyser, pressure indicator, sensor to measure heat, flow gauge, water pumps and twisted tape insert heat exchanger. An experimental arrangement demonstrates in Fig. The test section is insulated with insulated material in a device for exchanging to decrease heat flow to environment. It involves two concentrated pipes hot fluid flowing throughout internal pipe with cold water flowing outer pipe through annulus. Water passes through a pipe, geyser is placed in controlled water supply path by altering the electrical energy, an agitator with flow indicator. Thermometers employed to assess temperature of fluids and surface temperatures were revealed and data were gathered by means of supply unit. From the cold storage tank, water has fed into the outside pipe and from geyser liquid has fed into inner pipe. To evaluate the flow of mass rate of water, use flow indicator and pressure gauge was used. Before the inlet ports, control valves adapted and experimental reading with separate flow rates will be performed to obtain the variety of experimental records.

To start the water supply and adjust the water supply on hot and cold water sides and keep the valves open and closed for correct arrangement of the parallel flow type heat exchanger. The switch on the electric heater and desired temperature maintained by controlling the heater with a temperature controller. The cold water pump is switched on, flow adjusted and control by means of valve. A cold water flow outer side tube in the test section through the valve control. The hot water pump is switched on; the flow rate will be adjusted and hot water supply inner tube of the test section. After sometimes the temperature of the water was start to rising, after temperatures becomes stable condition. The opening temperature chill fluid maintained constant condition and heating water maintained range from 65 -70 degree Celsius. Once a stable state attains, entire water temperatures are noted. The rate of flow both fluid data are collected under the turbulent conditions. After the data gathered, to work out all performance characteristics were considered with different flow rate by hot and cold water for plain tube, R-CTT and R-CTT with wire coil inserts. The experiment was carried out with different mass flow of fluid under turbulent condition and reading was be taken with different surface temperature as displayed in the display unit.

Fig.1. Heat exchanger

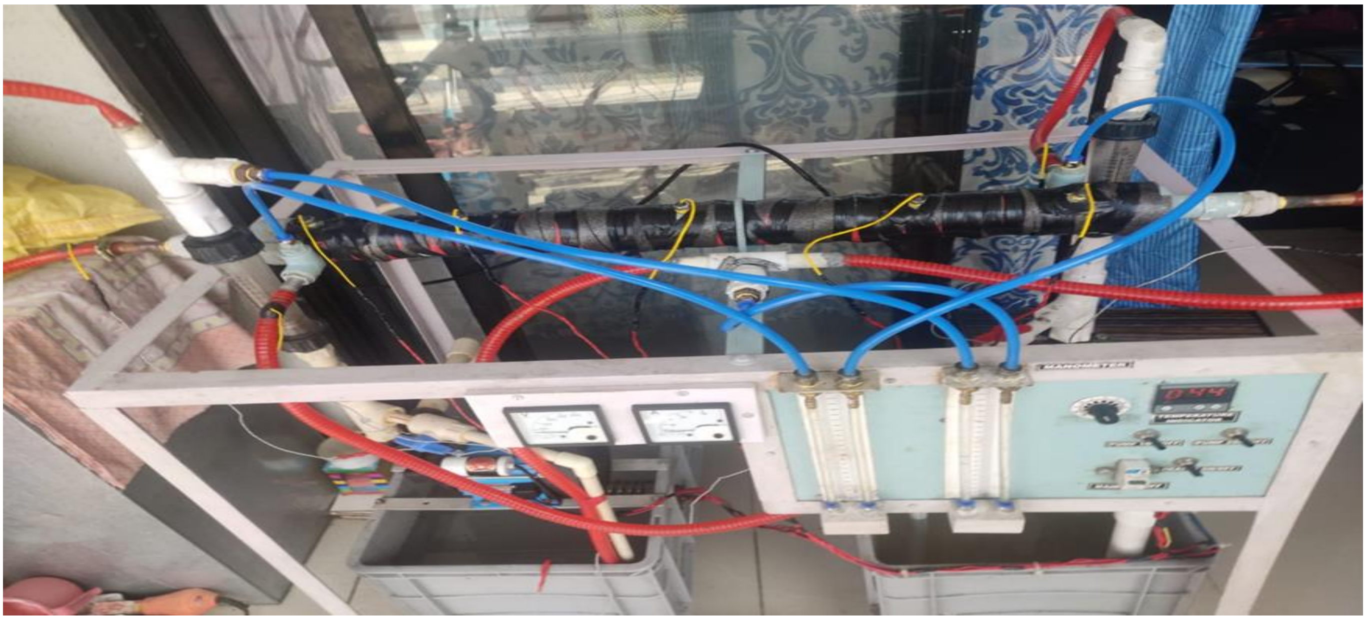

Fig 2 - Experimental Setup

TABLE I
GEOMETRICAL CONFIGURATIONS

Length of tube, L	1000mm
Inner diameter of inside pipe, d_i	0.20 m
Outer diameter of inside pipe, d_o	0.22 m
Inner diameter of outside pipe, D_i	0.54 m
Outer diameter of outside pipe, D_o	0.60 m

IV. RESULTS AND DISCUSSION

A. Validation of plain pipe

The experimental set up was adjusted and verified through the heat transfer and pressure drop experiment using plain tube.

The experimental data of heat transfer in the present work carried for the Reynolds number in the range of 2200 to 15500, are compared with those predicted by the Dittus-Boelter correlation as follows,

Nu=0.023(Re)0.8(Pr)0.4 --------For Heating

Nu=0.023(Re)0.8(Pr)0.3 --------For Cooling

The comparison of Nusselt number calculated using experiment and those above correlations is shown in Fig. The results of validation test show the good agreement with Dittus-Boelter equation which is within ±7.5%.

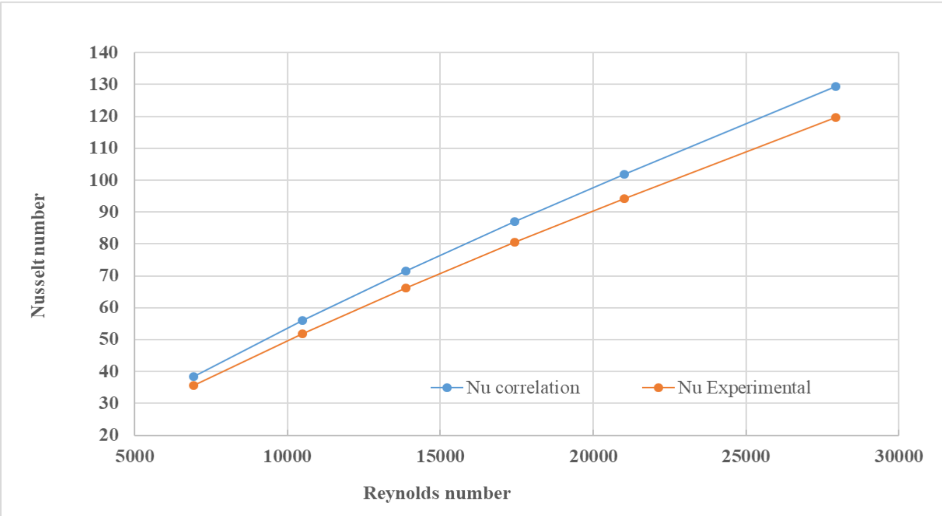

Fig. Verification of Nusselt number for plain tube

The experimental results of the friction factor of plain tube are compared using correlation given by Petukhov and Blasius correlation. Petukhov correlation is as follows-

$f = (0.790\ln Re)^{-2}$ ……………… For $3000 \leq Re \leq 5X10^6$

The comparison of friction factor calculated using experiment and using above correlations is shown in fig. It is observed that the deviation of experimental results with Petukhov correlation is within ±9.5% respectively.

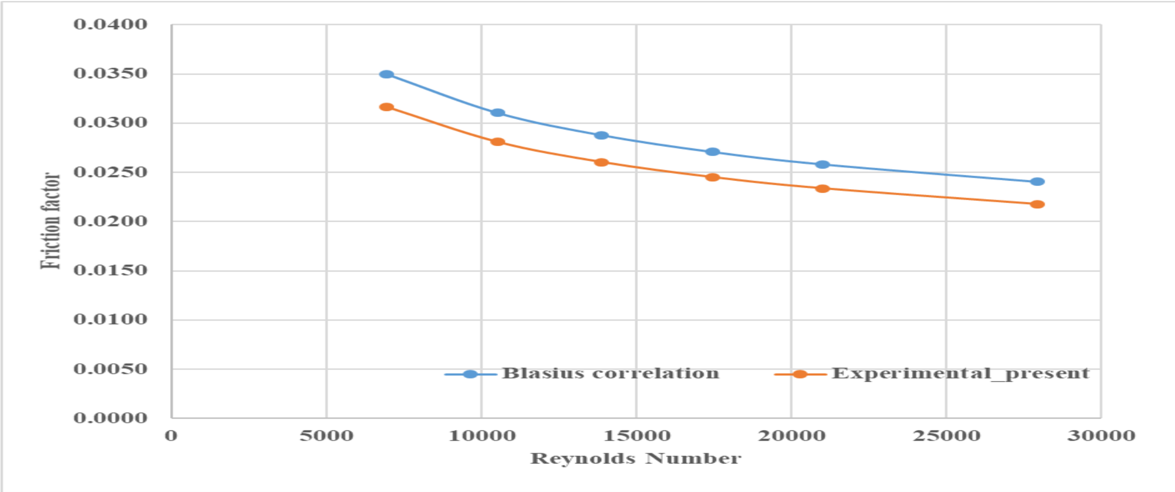

Fig. Verification of Friction factor for plain tube

The above data shows that the experimental system is reliable and can be used to measure the performances of the enhanced tubes.

b. Heat Transfer Performance

The most important principle is exploring performance of heat flow and fluid flow characteristics of variant shape of tape by turbulent flow conditions. The different twisted tape inserts are plain tube, R-CTT, R-CTT with wire coil were used. Figure shows the comparison between plain tube, R-CTT, R-CTT with wire coil for Nusselt number. It can be observed clearly all the twisted tape the number of Nusselt rises with the number of Reynolds as shown in figure. The present examination of the Nusselt number result reveals that RCTT with wire coil gives higher than that the plain tube and R-CTT. Because RCTT with wire coil inserts provides an additional fluid mixing and cuts makes the secondary flow in between tube and tape. This Nusselt number increases due to the viscous fluid strength as the amount of Reynolds number rises. The final conclusion of Nusselt value variation by Reynolds value increases of RCTT with wire coil inserts was enhanced by 1.37 times as compared with R-CTT and 1.85 times as compared to plain pipe. Heat transfer rate increases on average 130% of pipe with triangular fins as compared to plain pipe.

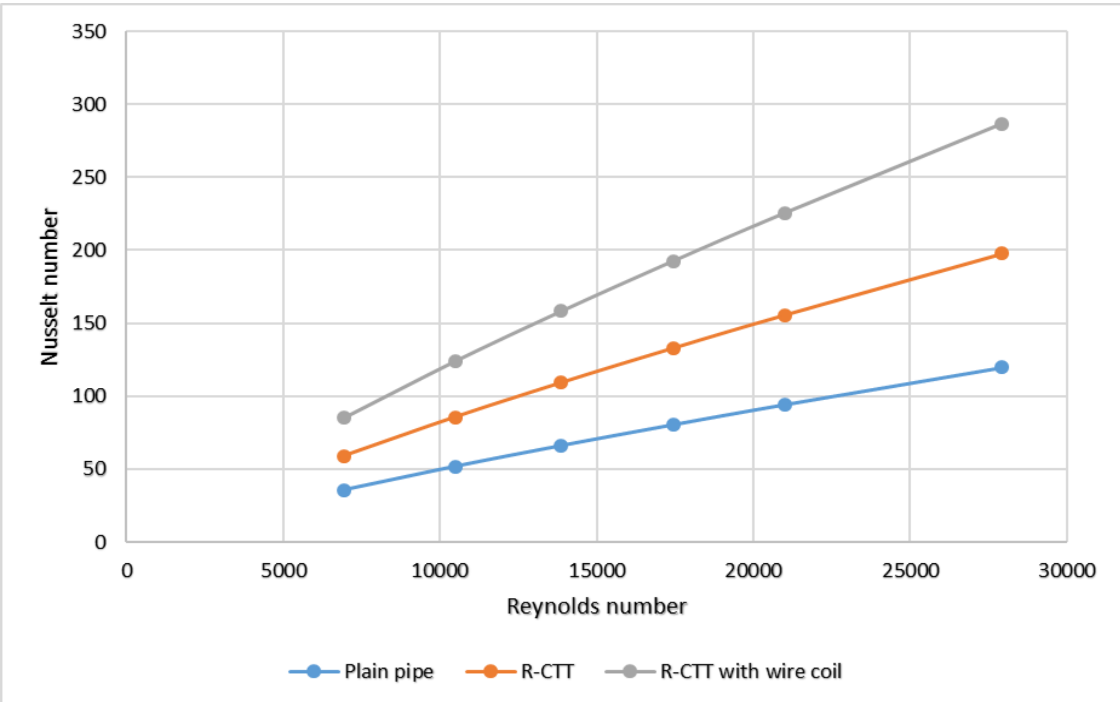

Fig. Nusselt number with Reynolds number

C. friction factor

The Reynolds number and friction factor of different geometry of inserts shows figure. The result can have derived that plain pipe the friction value falls in tube, which happen by tapes blocking flow with decreasing momentum of flow. The RCTT friction factor 1.3 to 1.8 times that of the plain pipe (PT) is also collected. The number of Reynolds improved with the decrease of the friction factor and the greater number of Reynolds offers the increase of lower friction. This is because at the decreased amount of Reynolds the thrust of stream was lesser and hence flow becomes more resistant causes by the presence of cut, which create the pressure. The percentage of the friction factor increases of RCTT with wire coil with decreasing Reynolds number; this occurs with tape that caused swirl. It was primarily owing to collective impact fluid turbulence produced in alternates cut in the twisted tape.

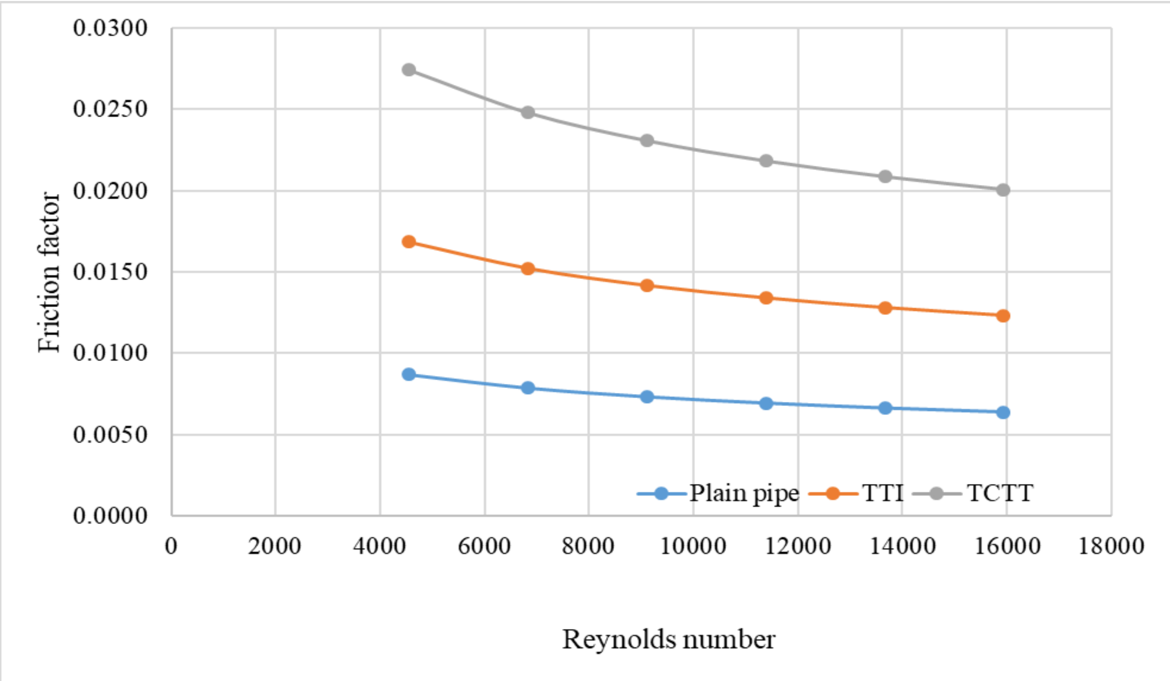

Fig. Friction factor with Reynolds number

d. Thermal performance Factor

The proper evaluation is important for comparing the performance of enhanced tubes. There are several performances criteria to evaluate the thermal performance of enhanced tubes proposed by Bergle's and Webb. For constant pumping power,

$$(V\dot{\Delta}P)_{plain} = (V\dot{\Delta}P)_{inserts}$$

The thermal performance factor of the heat exchanger for constant pumping power is defined as the ratio of convective heat transfer coefficient of pipe with inserts and those of plain pipe. The thermal performance factor of the system was determined using following equation

$$\eta = \left(\frac{Nu_{inserts}}{Nu_{plain}}\right)\left(\frac{f_{inserts}}{f_{plain}}\right)^{-\frac{1}{3}}$$

The thermal performance of pipe with R-CTT and R-CTT with wire coil, and these are observed that performance ofr R-CTT with wire coil is higher and equals to from 1.32 which is found to be maximum in comparison with plain pipe (Thermal performance ration for plain pipe is 1.00) and R-CTT (Thermal performance ration for R-CTT is 1.142)

V. Conclusions

An experimental investigation has been done for a double pipe heat exchanger for plain pipe and pipe with Rectangular cut with wire coil. Experiments were done for plain pipe, Rectangular cut twisted tape and Rectangular cut with wire coil to measure the Nusselt number, and friction factor with and without augmentation. All experiments done with hot water passing in the inner pipe and cold water in the annulus with varies Reynolds numbers.

•The heat transfer shows 130% when the Reynolds number of the hot water is high whereas that the cold water is minimum.

•The heat transfer rate for a Rectangular cut with wire coil show a 1.85 times over the plain pipe.

•The friction factor for the cold water decreases with increasing Reynolds number.

It can be concluded that heat transfer rate increases with using augmentation (with Rectangular cut with wire coil) as well as friction factor increases. All those lead to increase the pumping power. Therefore, it is highly recommended to select the optimum Reynolds number with suitable fins to gain a moderate heat transfer rate with suitable pressure drop.

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