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Thermal Performance and Fuzzy Logic Modelling for Wavy Twisted Tape Inserts in Single Phase Flow.

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*Abstract— **The designing of heat exchangers is quite complicated, as it needs correct analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. In order to obtain above objective the current experimental investigation has been carried out which shows that heat transfer enhancement take place with increase in turbulent flow where Reynolds number varies from 4000 to 9500 and turbulent flow is developed due to twist tape wavy inserts , the twists ratio are 8.33, 9.79 & 10.42. Performance parameter like pressure drop and heat transfer coefficient is calculated. The obtained results are compared with various combinations such as smooth tube versus twisted tape inserts & plain tape inserts. The above obtained results are studied using a fuzzy inference system named Mamdani and used to expect the output membership functions be fuzzy sets.***

Keywords: Enhancement efficiency, turbulence, varying wave-width, TR

I. Introduction

1.1 Heat Transfer Enhancement

Heat exchangers are widely used in various industrial processes for heating and cooling applications. The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate with less pumping power.Various techniques have been proposed in recent years and are discussed under.Passive Techniques: These techniques do not require any direct input of external power; rather they use it from the system itself which ultimately leads to an higher fluid pressure drop. They geometrical alteration to the flow channel by incorporating inserts or additional devices like twisted tapes, twisted wires, circular rings etc. Active Techniques: External power is brought into action for the desired flow modification and the relative improvement in the rate of heat transfer. Enhancement of heat transfer can be achieved by(i) Mechanical Aids: (ii) Surface vibration:

1.2 Fuzzy Logic

Fuzzy logic is a method which can be used to model the experiments, and it has been introduced for the first time in 1965 by Zadeh . Modeling of experiments can be helpful to reduce its costs. By using the models, we can predict results of experiments, which have not performed, or are not possible to perform due to some restrictions. In this study, the fuzzy logic methodology has been used in order to model and predict the experimental results. A simple fuzzy consists from four major parts: Fuzzification interface, Fuzzy rule base, Fuzzy inference engine, and defuzzification interface. A fuzzification operator has the effect of transforming crisp data into fuzzy sets. A fuzzy rule represents a fuzzy relation between two fuzzy sets. It takes a form such as; *if x is A then y is B*. Each fuzzy set is characterized by suitable membership functions. A fuzzy rule base contains a set of fuzzy rules, where each rule may have multiple inputs and multiple outputs. Fuzzy inferencing can be realized by utilizing a set of fuzzy operations. The defuzzification interface mixes and converts fuzzy membership functions into significant numerical outputs. Depending on the types of inference operations upon a simple condition rule *if-then*, two types of fuzzy inference systems have been widely employed in various applications such as automation, data sorting, analysis of decision, expert systems, and computer vision: Mamdani fuzzy models and Sugeno fuzzy models, which is similar to the Mamdani model. It includes fuzzy inference process, fuzzy the inputs and apply fuzzy operator, are similar. The differentiation between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant . The fuzzy system which has been used here is Mamdani which is the most commonly seen fuzzy methodology

II. Experimental set up

The schematic diagram of experimental set-up is given in Figure 1.

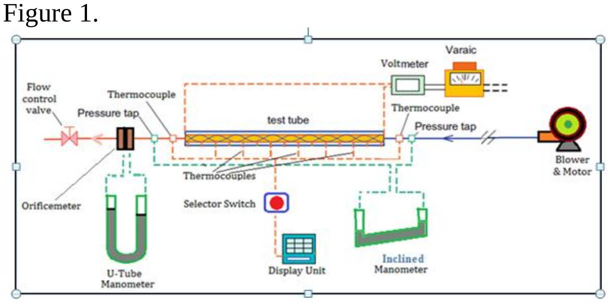

Fig-1*:* Experimental setup of Forced Convection .

The researchers have used twisted tape with varying pitches where they are getting higher friction factor of about 30% to 50 % hence an attempt have to be made to reduce this friction factor. This attempt can be done by changing the shape of

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insert and also by using various materials. The inserts used for the experiment are wavy twisted tape with different wave-widths and pitches as there is no work done on such type of insert.

The work includes the following:

1. Determination of friction factor and Nusselt number for smooth tube and for various wavy twisted tape inserts with varying pitches and wave-widths.
2. The results of Nu, f and PEC for all the aluminum wavy twisted tape inserts are plotted on the graph and compared with the values for the smooth tube.
3. Similarly all the above parameters for copper wavy twisted tape inserts are plotted on the graph and compared with the values for the smooth tube.
4. To observe the effect of varying twists and wave-widths, another set of graphs are plotted for copper and aluminum inserts.
5. Two materials are chosen for the experiment hence to find an optimum value in terms of the above mentioned parameters ,combined graphs are plotted for copper & aluminum to find an optimum out of the two materials that can be used for this experimental set up.
6. Comparing results of wavy twisted tape with plane tape

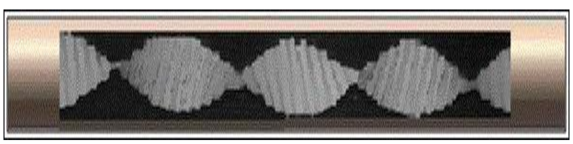


Fig- 2: Schematic of test tube with wavy tape inserted

The wavy twisted tapes contained in the experimental study are shown in Figure 3.

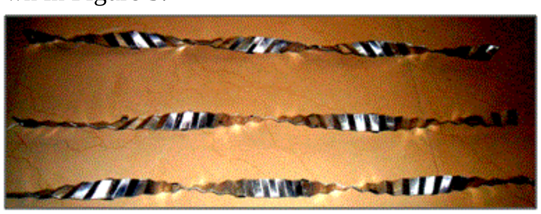


Fig-3: Actual view of wavy twisted tape inserts

III. Results & Discussions.

The Nusselt number, friction factor are the important parameters which decides the success of any experimentation work as both parameters are opposite to each other. The Nusselt number shows the percentage increase in heat transfer enhancement when inserts are placed inside a test pipe due to increase in heat transfer coefficient by comparing it, without inserts. The Nusselt number and the friction factor are obtained for a smooth tube to validate the experimental procedure used before the experiments with twisted wire inserts. The results of Nusselt number and friction factor for smooth tube are compared with the results obtained from the well-known steady state flow correlations of Dittus Boelter and Pet equation, for the developed turbulent flow in circular tubes. The figures shown below shows the comparison between the results of the present smooth tube and the correlations of Dittus Boelter and Petukov equation.

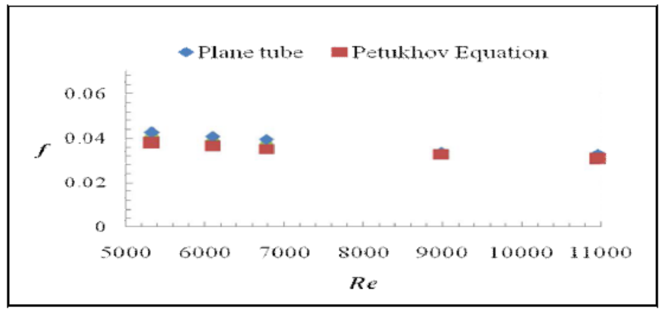


Figure 3.1: Validation results for friction factor

The comparisons of Nusselt number and friction factor for the present plain tube with existing correlations are shown in Figs. 3.1 and 3.2, respectively. These figures shows that validation experiments of heat transfer in terms of Nusselt number and friction factor for the plain tube are in good agreement with the results obtained from Dittus-Boelter and Petukhov equations. The results of present plain tube and previous equations are nearly the aame. Thus, this accuracy provides reliable results for heat transfer and friction factor in a tube with twisted tape inserts in this present study.

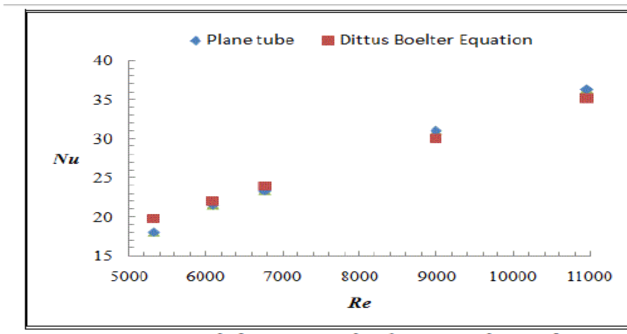
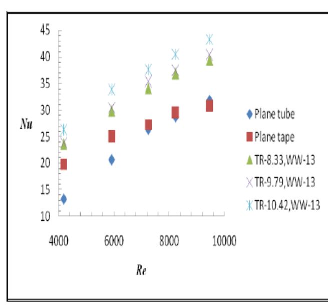


Figure 3.2: Validation results for Nusselt number



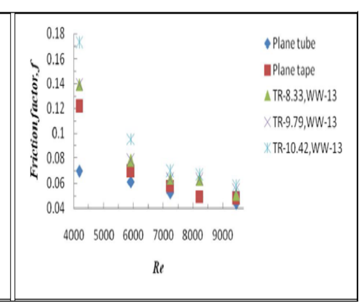


Fig 3.3 Fig.3.4

Figure 3.3: Variation of Nusselt number for different insert configurations

Figure 3.4: Variation of friction factor for different insert configurations

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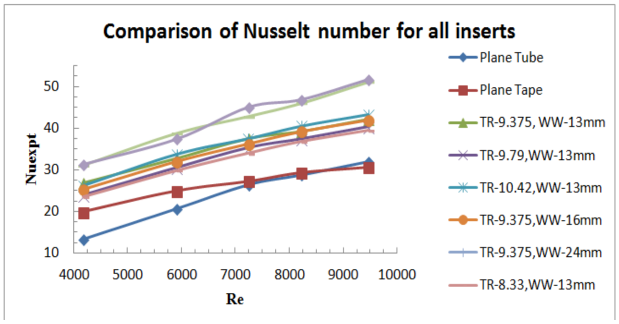

Figure no.3.5: Comparison of Nu all tapes

When inserts are placed it is been observed that Nuth of copper is higher than the aluminum but the Nusselt no. without inserts are proved to have lower value than the aluminum and copper for all the inserts. From these graphs it's been observed that the Nu increases 2 times than smooth tube for Aluminium of all the inserts for TWIST RATIO 9.375 & WW-13mm and for Copper it increases by upto 2.35 times than smooth tube for TWIST RATIO 9.79 & WW-16mm. Copper inserts shows better result in terms of Nusselt number than Aluminium, hence insert with Copper is preferred

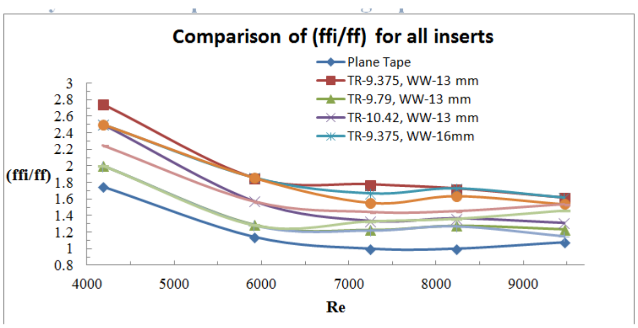

Figure 3.6: Friction factor comparison for all inserts & without insert

When inserts are placed it is been observed that friction factor of aluminium is higher than the copper insert used but the friction factor without inserts are proved to have lower value than the aluminum and copper for all the inserts. From these graphs it's been observed that the friction factor increases 2.75 times than smooth tube for Aluminium of all the inserts and for Copper it increases by only upto 2 times than smooth tube for Twist ratio-9.79 & Wave width-16mm. Copper inserts shows better result in terms of friction factor than Aluminium, hence insert with Copper is preferred

IV. Fuzzy Logic Modelling

The aim of this Fuzzy logic is to consider the effect of two main factors, Reynolds number , Number of twists and the surface temperature of the tube through which the heat exchanges. In order to perform fuzzy logic, input and output variables and their levels must be determined. Reynolds number (Re) in 3 levels ranging from 4500 to 9000, temperature in three levels from 320 K to 330 K, Number of twists from 8.33 to 10.5, as input variables and friction factor , Nusslet No as output variable were chosen. The Mamdani inference system used in this study is shown in Figure. 4.1. Symmetric triangular membership functions for output and input variables were defined. Figures 4.2 , show membership functions for input variables, i.e. Reynolds number, and temperature. The membership functions of friction factor and Nusslet No. are brought in Figure 4.3. Some parts of rules, which were chosen for the fuzzy model, are shown in Fig 4.4 & Fig. 4.7. Therefore experimental results are modelled by fuzzy interference system, which shows that, the fuzzy logic is a reliable method to model & predict the heat transfer coefficient. According to fuzzy logic, with Reynolds number is directly proportional to heat transfer coefficient increases. This result may be explained by the generation of stronger turbulence intensity and more rapid mixing of flow created by twisted wire insert.

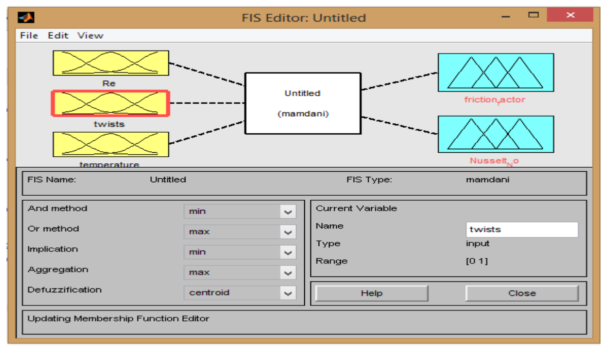

Figure . No 4.1 Mamdani system used entire system

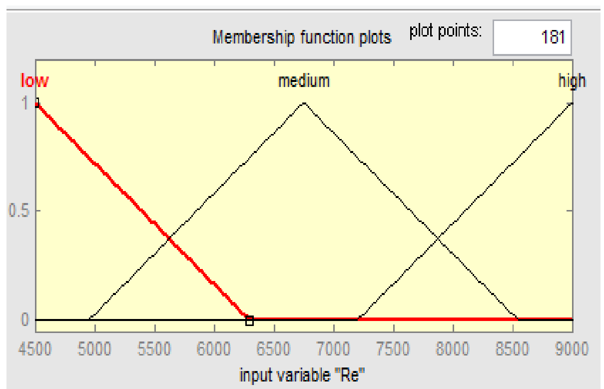

Fig- 4.2 Member function for Re

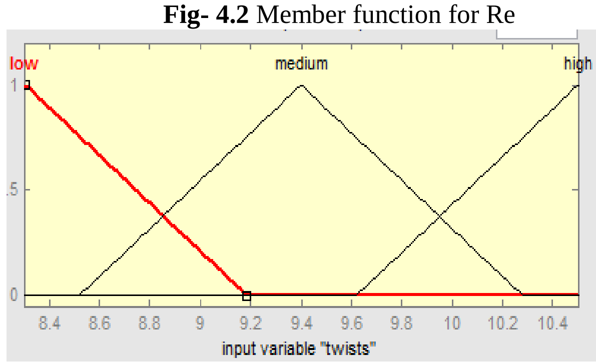

Fig-4.3. Member function for twists

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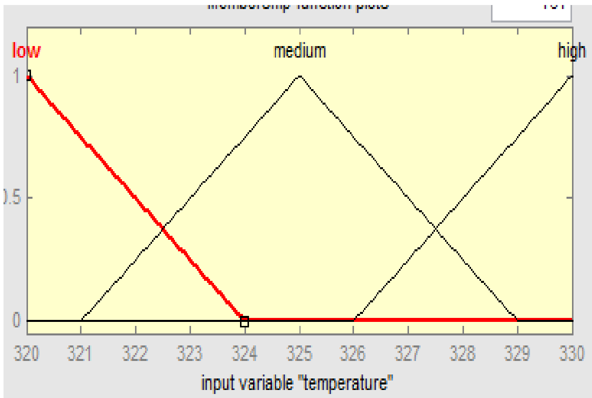

Fig-4.4. Member function for temperature

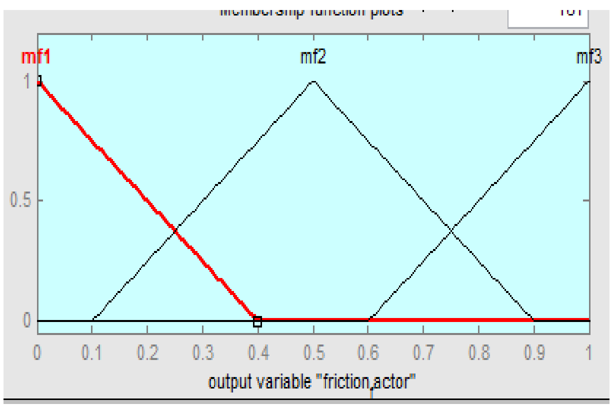

Fig-4.5. Member function for output friction factor

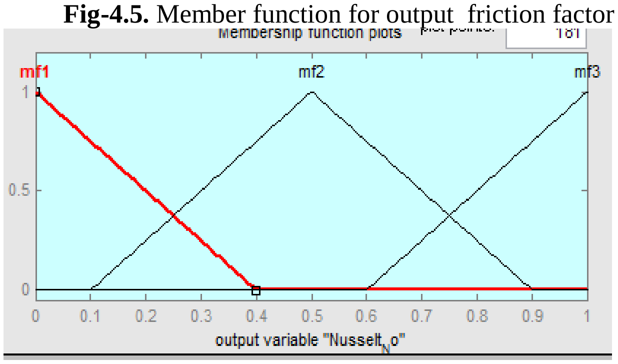

Fig-4.6. Member function for Nusselt No.

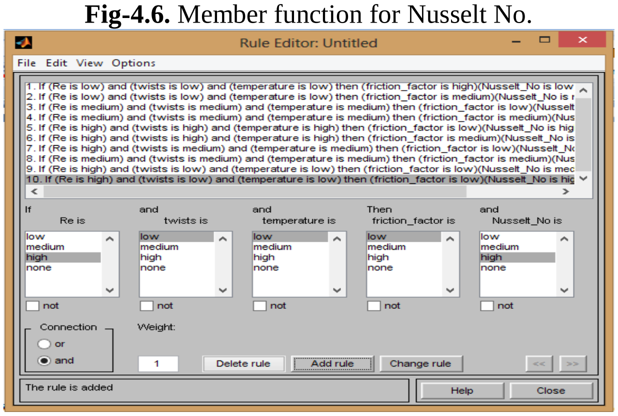

Fig 4.7. Rule Editor Window

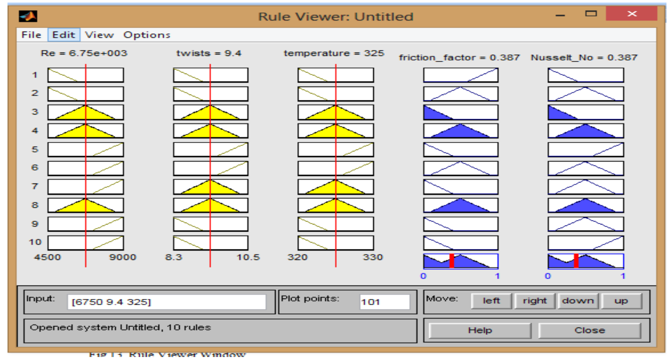

Fig 4.8. Rule Viewer Window

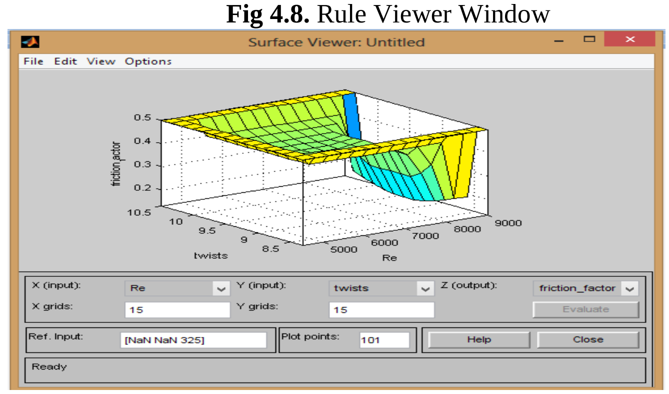

Fig. 4.9. Input Vairable Reynolds number , twists and with output variable friction factor

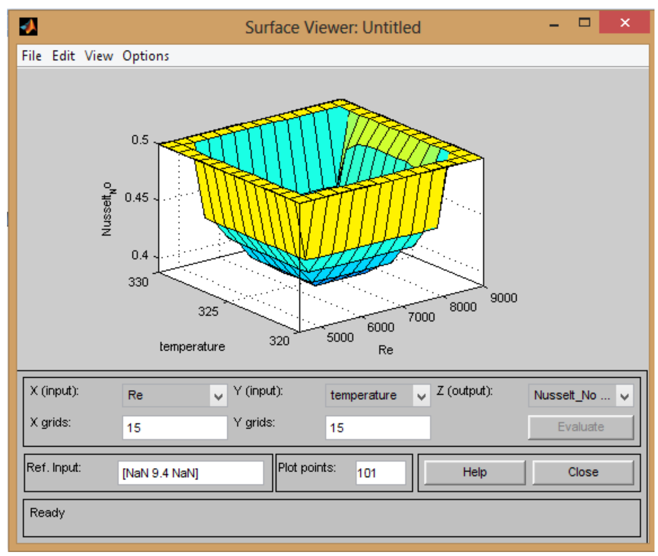

Fig- 4.10. Input Vairable Reynolds number , temperaturfe and with output variable Nu

V. Conclusions

1. It is observed that with an increase in the ranging from 4000 to 9500, the heat transfer coefficients increases by 60% to135% for copper and 23% to 101% for Al with respect to plain tube whereas the friction factor decreases.

2. It is found that copper wavy twisted tape with twist ratio 9.79 & Wavy width 16mm gives highest enhancement of 50 %.

3. The copper wavy twisted tape with twist ratio 9.79 & wave-width 16 mm gives 135% rise in Nu.

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