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Execution of a Smart Prediction Tool to Evaluate Thermal Performance in a heat exchanger by using Single Elliptical Leaf Strips with altered Angle

J. Bala Bhaskara Rao, Ramachandra Raju

Abstract ***Heat exchangers are prominent industrial applications where engineering science of heat transfer and Mass transfer occurs. It is a contrivance where transfer of energy occurs to get output in the form of energy transfer. This paper aims at finding a solution to improve the thermal performance in a heat exchanger by using passive method techniques. This experimental and numerical analysis deals with finding the temperature outlets of cold and hot fluid for different mass flow rates and also pressure drop in the tube and the annular side by adding an elliptical leaf strip in the pipe at various angles. The single elliptical leaf used in experiment has major to minor axes ratios as 2:1 and distance of 50 mm between two leaves are arranged at different angular orientations from 0^0 to 180^0 with 10^0 intervals. Since it's not possible to find the heat transfer rates and pressure drops at every orientation of elliptical leaf so a generalized regression neural network (GRNN) prediction tool is used to get outputs with given inputs to avoid experimentation. GRNN is a statistical method of determining the relationship between dependent and independent variables. The values obtained from experimentation and GRNN nearly had precise values to each other. This analysis is a small step in regard with encomiastic approach for enhancement in performance of heat exchangers.***

Keywords: heat transfer rate, pressure drop, heat exchanger, Elliptical leaf strip, Generalized Regression Neural Network

I.INTRODUCTION

Heat transfer is a broad area of study in engineering science where many topics are learnt with reference to transfer of heat as a form of energy causing major changes in the universe. Indirectly or directly the changes in atmosphere, temperature regulations and flow of winds entirely depends on the heat transfer principles. Hence heat transfer subject is a great path in the field of research. An influential topic in the heat transfer is the study of heat exchangers. Heat exchangers are the devices where the energy flow in the form of heat is transferred from one part to another utilizing which large energy transformations is possible .These energy transfers causes great outputs to industrial applications actually applied in real life. Hence heat exchanger output causes a mighty difference to the society. Hence with this approach various

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Using counter flow configuration on a single phase water to water heat transfer was performed by varying the mass flow rates of annulus and the inner tube. [2] Performed the task of researchers have done research with the motto of increasing the output of heat exchangers. [1]Various bended strips were used and an experiment was performed on tube in tube out heat exchanger. shot blasting to increase the heat transfer. In this experiment analysis the roughness of outer surface of inner pipe was changed which gave the results of increased heat transfer rate by 43%. [3] They used the finite difference calculus to model the temperature profiles across heat exchangers. [4] They found a method to determine the pipe sizes, pipe lengths, number of bends. The performance was determined by using heat exchanger effectiveness and the fouling factor. [5] Conducted experiment on nanoparticle's concentration effect on Nusselt number and heat transfer characteristics with baffles and without baffles which resulted in enhancement up to 12% for 0.2 % concentration and enhancement up to 22% for 0.1% concentration .All these results were obtained when baffles were used in the experimentation. [6] This paper suggested inserting twisted tape in double pipe heat exchangers which gave positive results of heat transfer coefficient on both tube side and annulus side of heat exchanger. After finding this they even further tested the characteristics of heat transfer enhancement with pressure drop characteristics where there was a negative result for pressure drop with enhancement in heat transfer rates.[7]Proposed the use of circular and square longitudinal strips to find the effect on Nusselt number ,Pressure drop & overall heat transfer coefficient in a double pipe heat exchangers. The results ascertained the increase in heat transfer rate with increase in mass flow rate and size of the strips. [8] They studied about the use of twisted tapes to increase the heat transfer rates. The results gave the increase in heat transfer rates by using twisted tapes. [9]They found the effect of condensation heat transfer rate by introducing twisted tape. It created swirl generation which increased the contact area resulting in the increase of condensation heat transfer coefficient for steam. [10] Used the technique of baffle spacing in finding better thermal performances. They used the triangular baffles of 100 and 50 mm pitches which increased the values by 1.42 & 1.62 in parallel flow and 1.338 & 1.62 times in counter flow heat exchanger. [11] wrote a review paper on the augmentation of Active, passive and compound techniques. In a plain tube the use of passive and compound techniques produced better results, by using helical tubes also better heat transfer rates and pressure drops was given. [12] studied about the enhancement techniques of double pipe heat exchangers which

indicated the enhancement of heat transfer coefficient at 7.69 twist ratio for a range of Reynolds's number (2300-10000) .It also stated that swirl flow also improved the conductive heat transfer in double pipe heat exchanger.[13] found the effect of twisted tape, trapezoidal cut on double pipe heat exchanger using al203water based nano fluids. From this experiment they found the friction factor required for performance analysis. [14] Used the passive heat transfer, method in concentric heat exchanger for different fin profiles for rectangular, parabolic and triangular shape. The results showed that concave parabolic fins had minimum pressure when compared with other two. [15] Found the design criteria required for hot fluid flowing in a double pipe heat exchanger. It showed that with more pressure drop more temperature difference occurred between the fluids. [16] Tried to find the enhancement of heat transfer rate by using triangular fins which gave the results as increase in effectiveness of heat transfer rate by inserting fins to the outer surface of the copper tube. [17] Found a numerical simulation of Nano fluids flow in a double pipe heat exchanger using porous baffles. The solution was found in a finite volume method. [18] They analyzed the heat exchanger analysis in a double pipe heat exchanger where the heat transfer coefficient was found to be higher for a laminar flow [19] used a rotor inserted tube to get high turbulent flow in a counter flow heat exchanger and found the numerical and experimental values. [20] They analyzed a horizontal triple tube heat exchanger having internal threaded pipes. The heat transfer analysis was found on a triple tube heat exchanger.

Based on this survey from various sources passive method was used for experimentation. In this investigation novelty stands for the utilization of an elliptical leaf in the pipe for heat transfer rate. Since the elliptical shape is preferred for better flow in ducts so keeping this as reference an elliptical shaped leaf is used for allowing better flow of fluids in the pipe. So in this passive method an elliptical leaf strip insertion placed at various orientations provides the rate of heat transfer and pressure drop. After the experimentation a prediction tool is used known as GRNN (Generalized Regression Neural Network) for finding the formulation between inputs and outputs. The inputs such as different elliptical leaf angles, mass flow rates of hot and cold fluids and inlet temperatures are taken to give outputs such as outlet temperatures of hot and cold fluid and pressure drops in tube and annular side. This analysis is an insight to open a pathway for various analyses in the applications of heat transfer for a wide range in the upcoming days.

II. EXPERIMENTAL SETUP

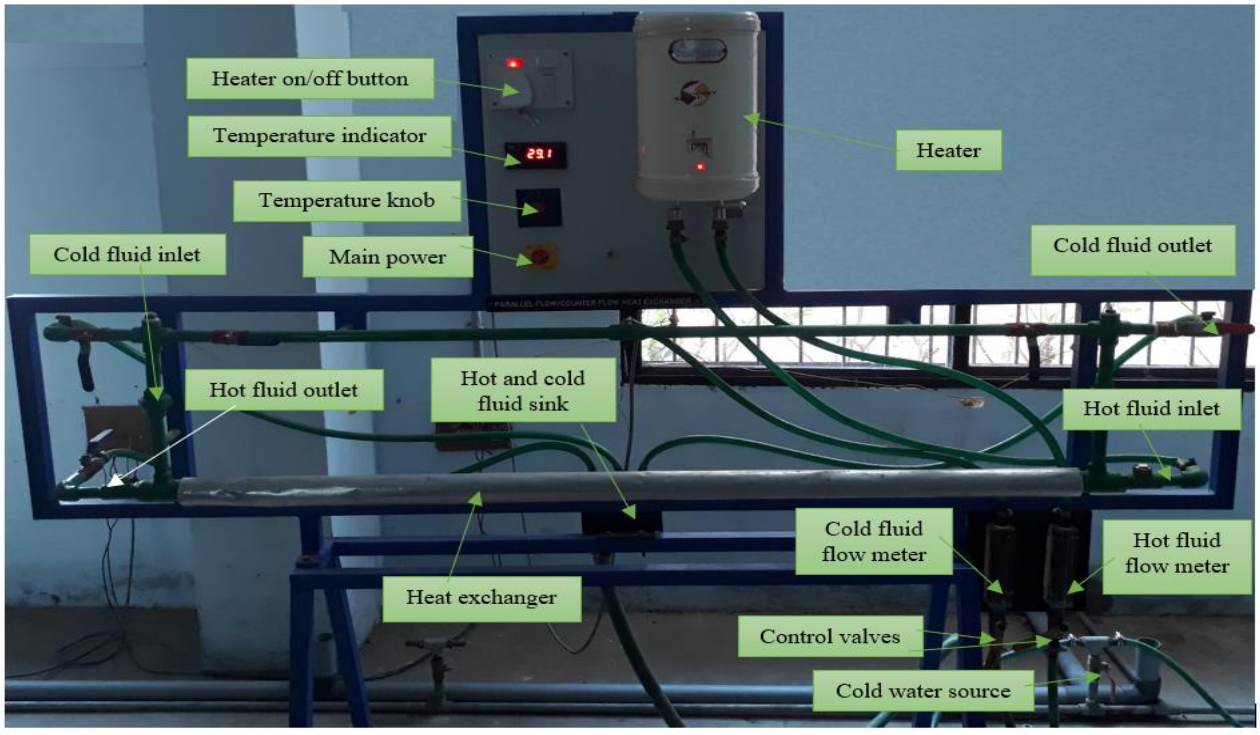

Fig.1 Experimental setup of double pipe heat exchanger

The experimentation started with the utilization of double pipe heat exchanger with inner and outer pipe made up of copper and steel respectively as shown in Fig.1. The fluid flow is incompressible and turbulent in the pipes. Here the experimentation is conducted based on 19 scenarios where the elliptical leaf strips are placed at different angles from 0^0 to 180^0 at 10^0 intervals as shown in Fig.2. The elliptical leafs are designed as major to minor axes as 2:1 and the thickness is 1mm. These elliptical leafs are located at 50mm distance at 90^0 rotation towards the shaft. Since the fluid taken is water which is arriving from the tank where it is divided into two streams comprising of cold fluid going through the annular side and hot fluid passing through the tube side which is heated by an electrical heater and sent in to it. All the values are taken after a steady state is attained.

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The specifications for the experiment are taken as following for hot water inner pipe temperature is 348 K for different mass flow rates of 0.15785, 0.3827, 0.55763 & 0.71782 kg/s & cold water inner pipe is at 298 K with mass flow rates of 0.34589,0.8403, 1.2245 & 1.5762 Kg/s. Certain accessories are used for measurement during these fluid flows such as thermo couples for temperature measurements at inlet and outlet of the pipes, flow meters to measure the volume flow rates at the stream division. Both thermo couples and Rota meters where calibrated before experimentation to obtain accurate results. The atmospheric pressure is defined as the pressure boundary at the outlets. While analysis is done constant temperatures of hot and cold fluids are considered for the design modifications of double pipe heat exchanger. Reynolds number is calculated using different mas flow rates at shell side and tube side fluids. It indicates whether the flow is laminar or turbulent. In this analysis, turbulent flow is considered for both the pipes and accordingly calculations are performed. The numerical analysis results are obtained from fluent and indicated from Fig.3 to Fig.6.

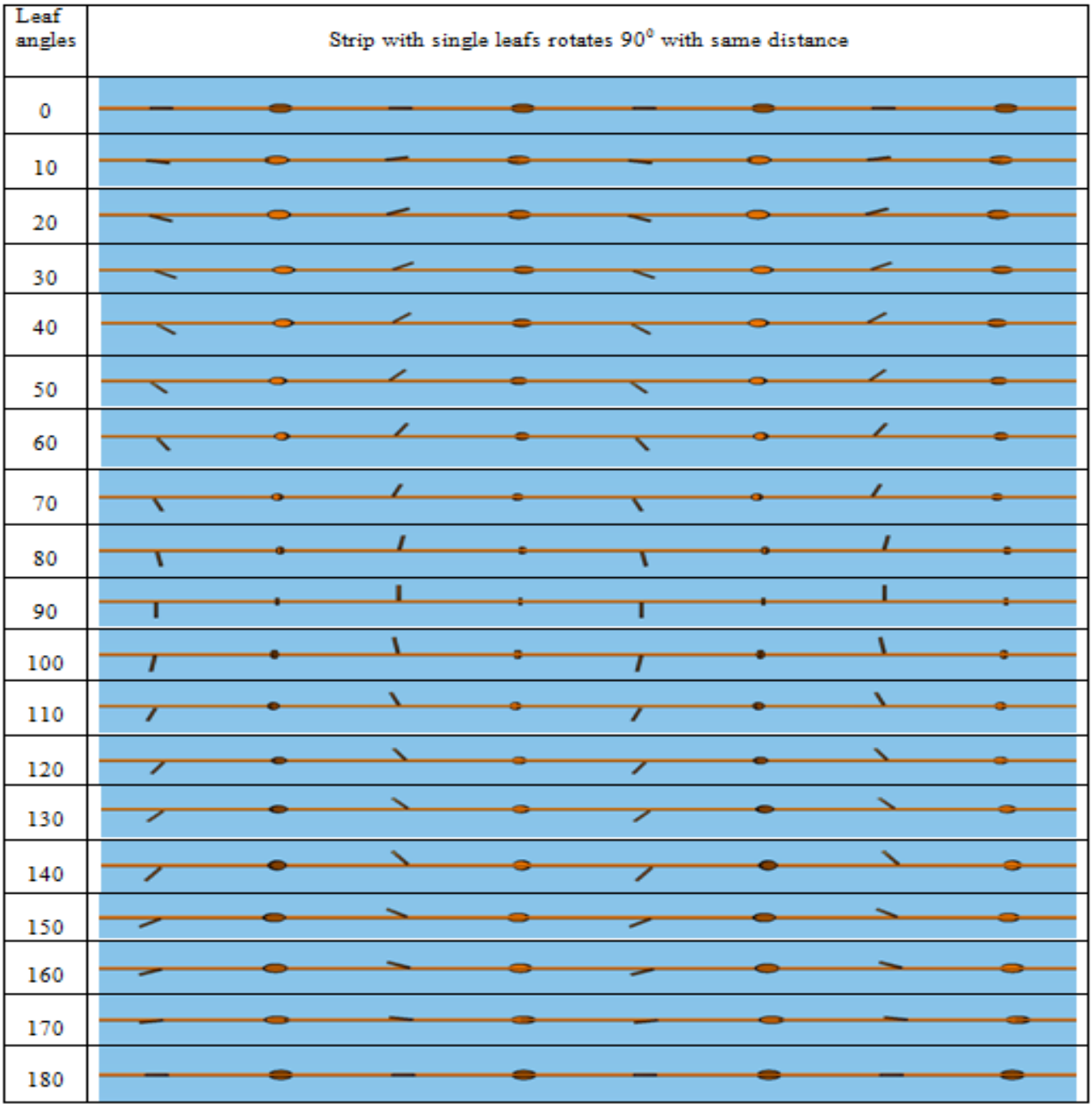


Fig.2 Different strips with elliptical leaf positioning

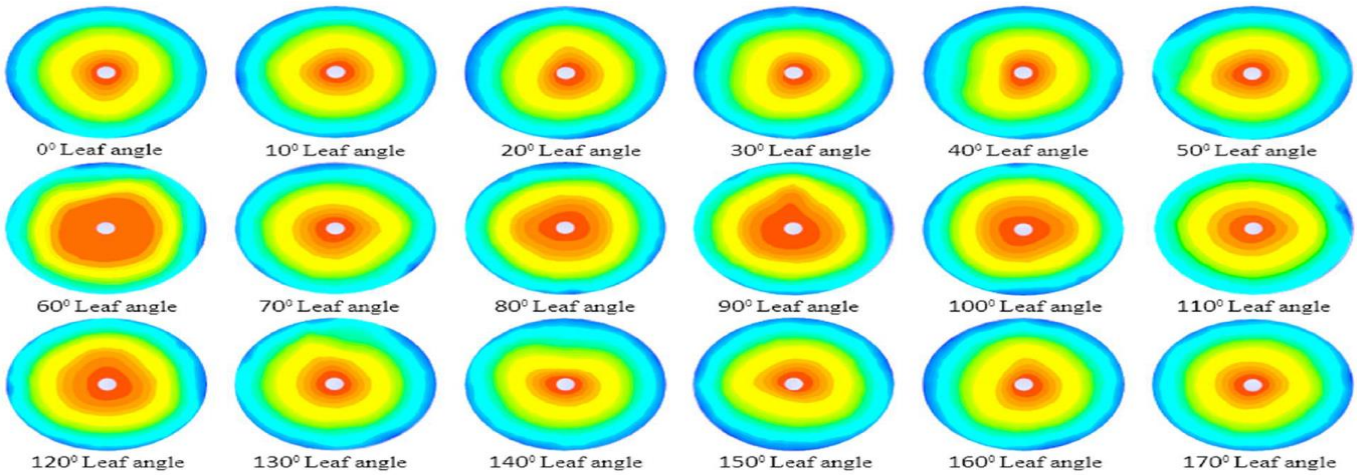


Fig.3 Temperature contours of elliptical leafs at different inclinations

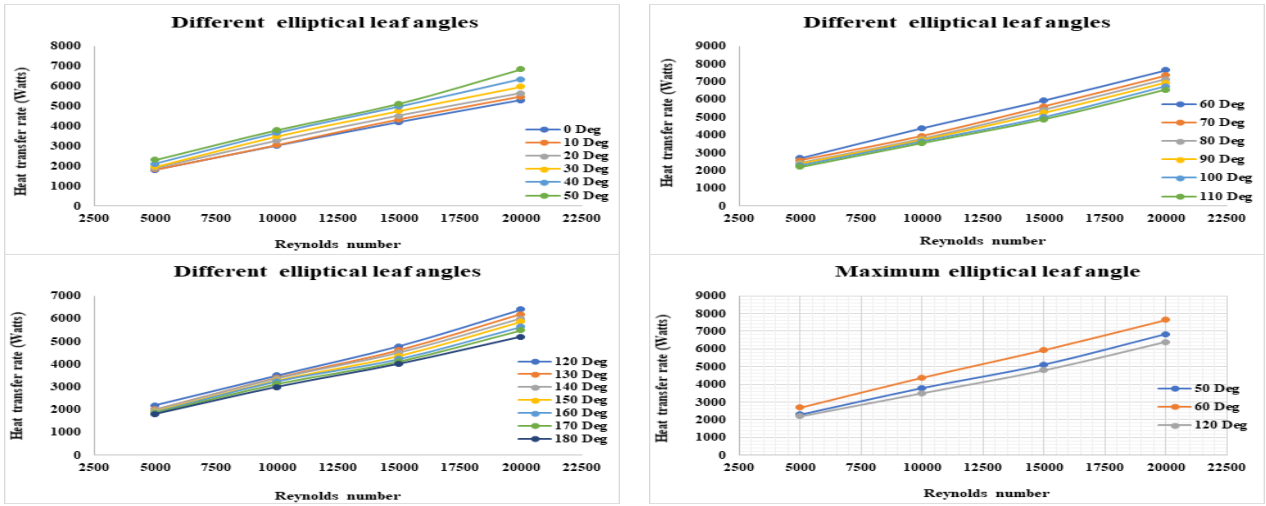


Fig.4 Heat transfer variation at different elliptical leaf angles

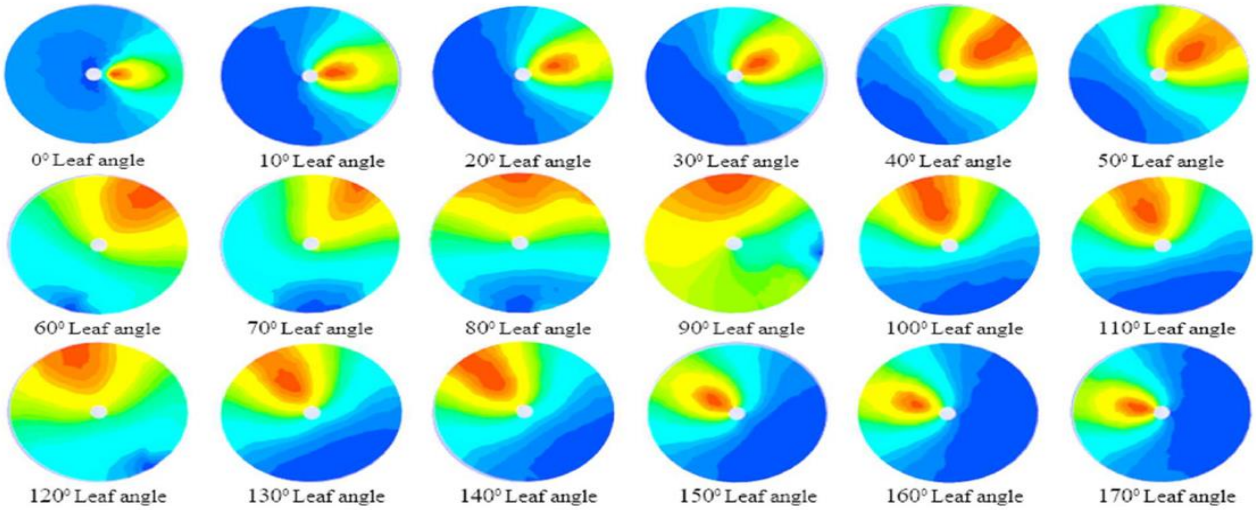


Fig.5 Pressure contours at different elliptical leaf angles

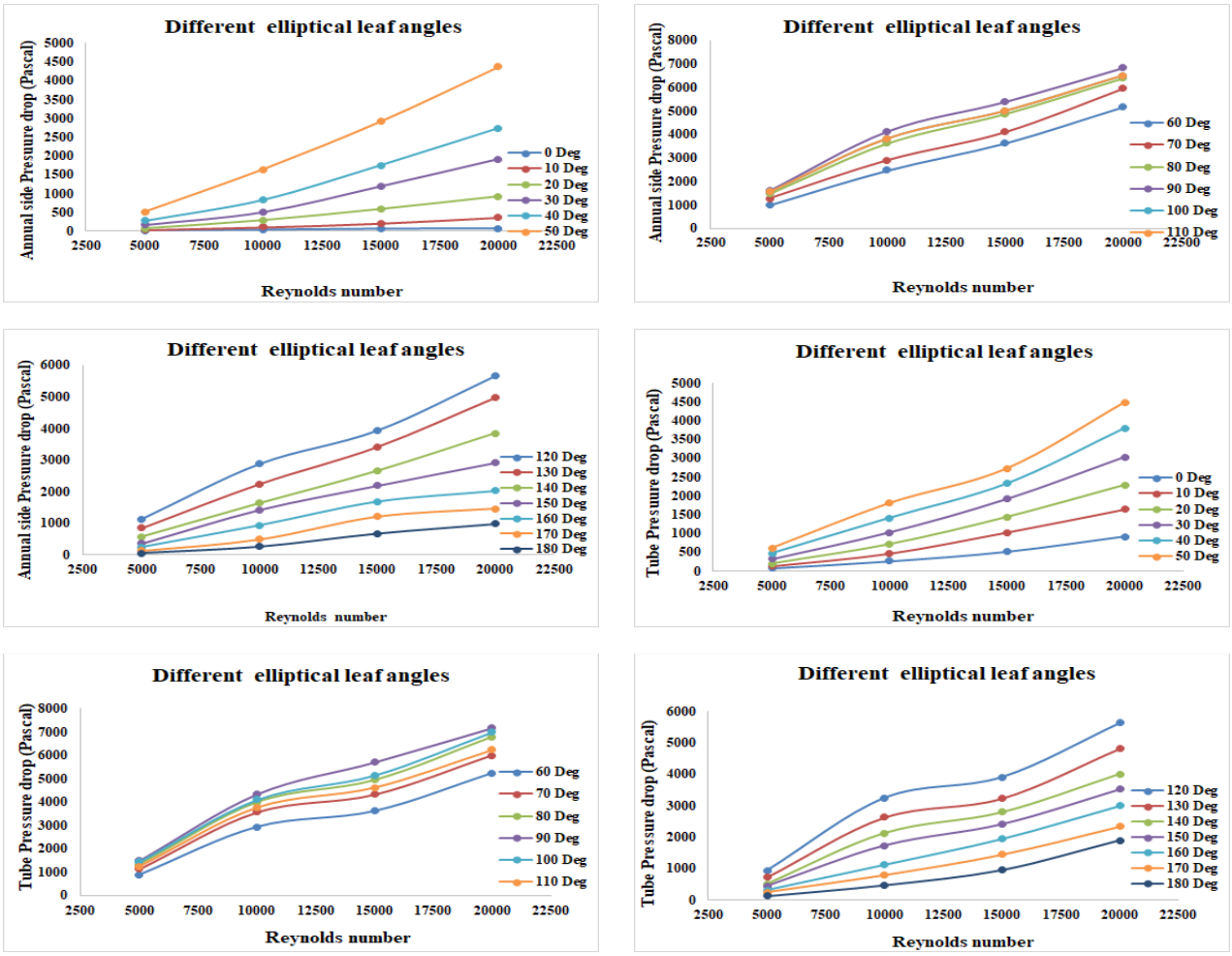


Fig.6 Annular and Tube side pressure drop variation at different elliptical leaf angles

III.GRNN IMPLEMENTATION

GRNN is a statistical tool used to measure certain outputs by giving some known inputs from Tab.1. Here to find an arbitrary random value say "Y" from a measured reading of "X" of a random variable "x" where mean is utilized in the equation and this is known as regression "y" on "x" given as

$$E(y/X) = \frac{\int_{lower}^{upper} yf(X,y)dy}{\int_{lower}^{upper} f(X,y)dy}$$

$$(X) = \frac{\sum_{i=1}^{n} \exp[-\frac{(X-X_i)^T}{2\sigma^2}(X-X_i)]}{\sum_{i=1}^{n} \exp[-\frac{(X-X_i)^T}{2\sigma^2}(X-X_i)]} \frac{\int_{-\infty}^{\infty} y \exp\left[-\frac{(Y-Y_i)^2}{2\sigma^2}\right]dy}{\int_{-\infty}^{\infty} \exp\left[-\frac{(Y-Y_i)^2}{2\sigma^2}\right]dy}$$

The above two equations are used for a continuous function of f(x, y). Investigation shows us that the above inputs and outputs are nonlinear and we cannot find a specific relation for input and output Hence they are converted into another statistical equation and combined with artificial neural network

$$Y = \frac{\sum_{i=1}^{n} Y_i e^{(D_i^2/2\sigma^2)}}{\sum_{i=1}^{n} e^{(D_i^2/2\sigma^2)}}$$

Tab.1 GRNN input and output weights

Demonstration	Input	Weight of input
X1	Elliptical leaf angle (θ)	($0^0 - 180^0$)
X2	Inlet cold water temperature (Tci)	298 K
X3	Inlet hot water temperature (Thi)	348 K
X4	Cold water mass flow rate (Mc)	0.223883 Kg/sec 0.447766 Kg/sec 0.671649 Kg/sec 0.895532 Kg/sec
X5	Hot water mass flow rate (Mh)	0.032683 Kg/sec 0.065366 Kg/sec 0.098049 Kg/sec 0.130731 Kg/sec
Demonstration	**Output**	**Weight of output**
Y1	Cold fluid outlet temperature (Tco)	As per investigation
Y2	Hot fluid outlet temperature (Tho)	As per investigation
Y3	Tube side pressure drop (ΔPt)	As per investigation
Y4	Annual side pressure drop (ΔPa)	As per investigation

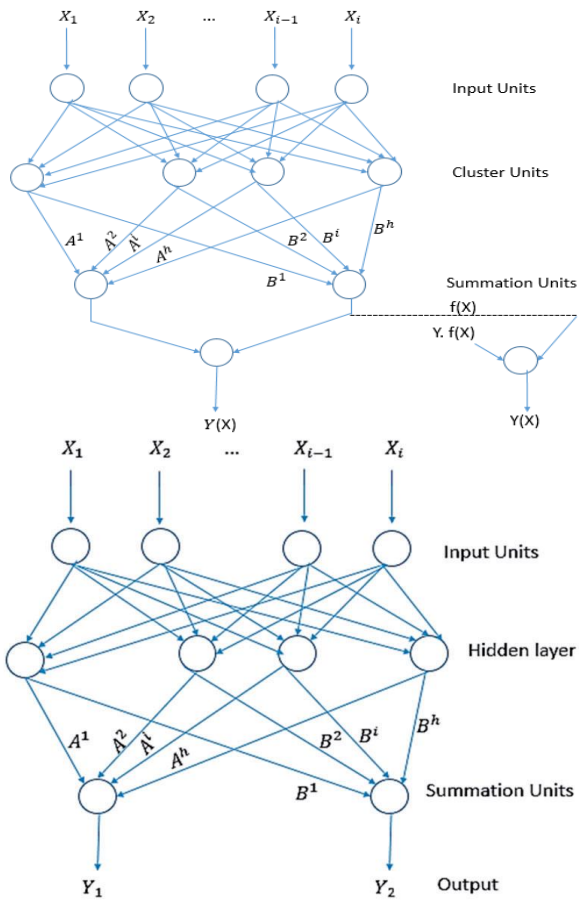
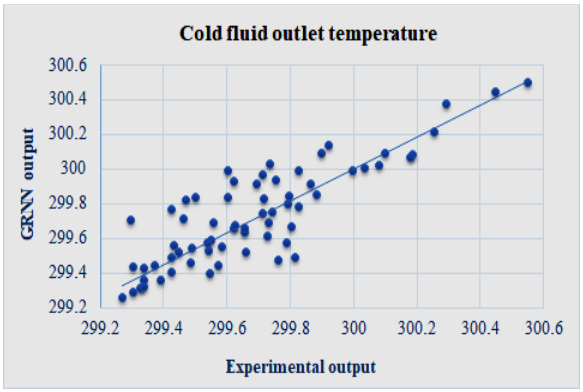


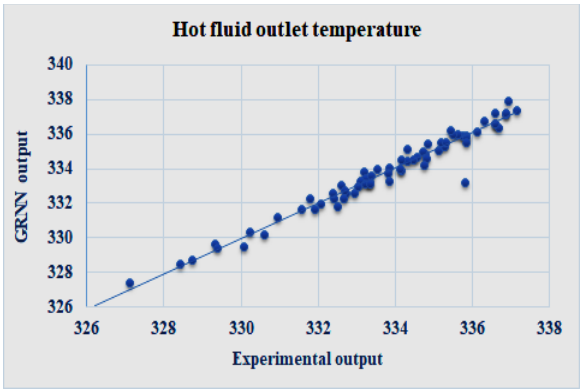
Fig.7 clustering process of ANN to GRN

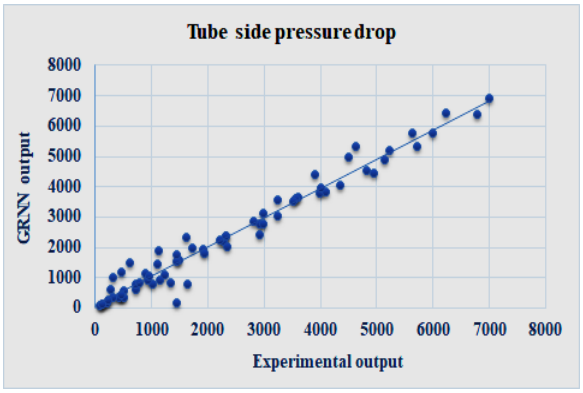
Hence to get a relation for the nonlinear results clustering operations is chosen to measure the output values from Fig.7 .By performing the clustering operation through various processes the system yields us desired outputs. This clustering technique is done by ANN (Artificial neural network) in this experiment.

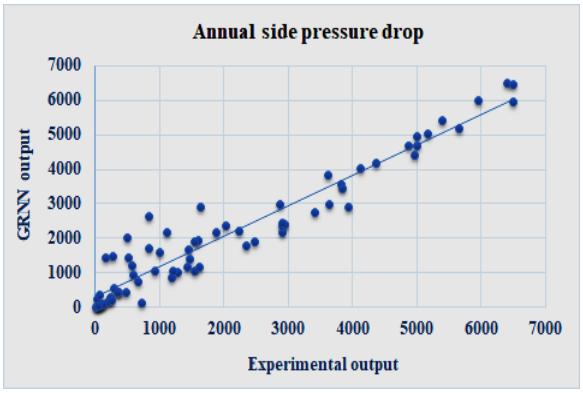
$$\text{GRNNoutput } (Y_{GRNN}) = \frac{\sum_{i=1}^{68} Y_i e^{(D_i{}^2/2\sigma^2)}}{\sum_{i=1}^{68} e^{(D_i{}^2/2\sigma^2)}}$$

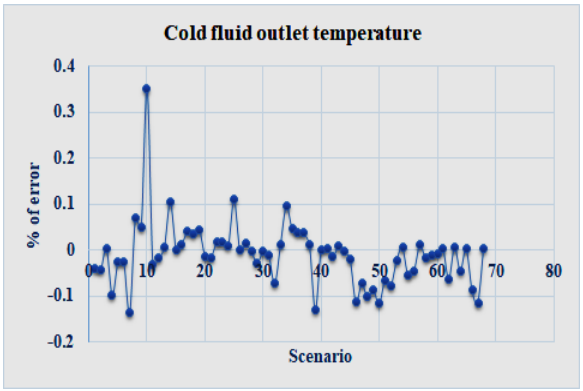
As this experiment deals with finding the heat transfer rate and pressure drop rates so in this regression method taking the values of temperatures and mass flow rates outputs of pressure drop is found out .Hence in this model we used "68" experimental data sets "trainee data" sets are chosen & "8" "test data "sets are chosen randomly to find the results and to match them and get the results more accurately. Based on the equation used the pressure drops at both the pipes and temperatures at cold and hot fluid are represented as outputs. Once the values are calculated they are checked with the experimental results to find the accuracy of this regression analysis from Fig.8. From the graphs the value obtained between the experimental sets and regression analysis gave us a humongous accuracy.

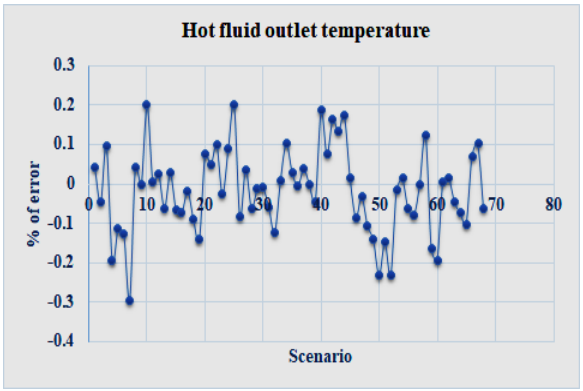


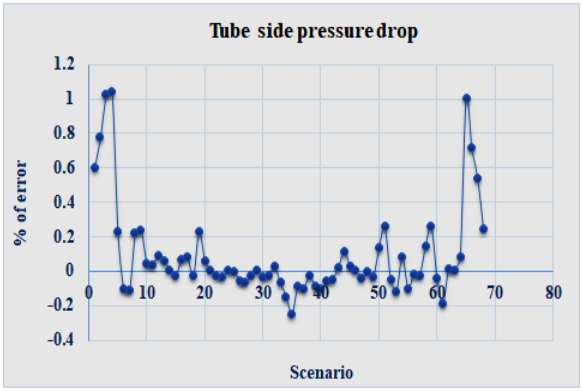












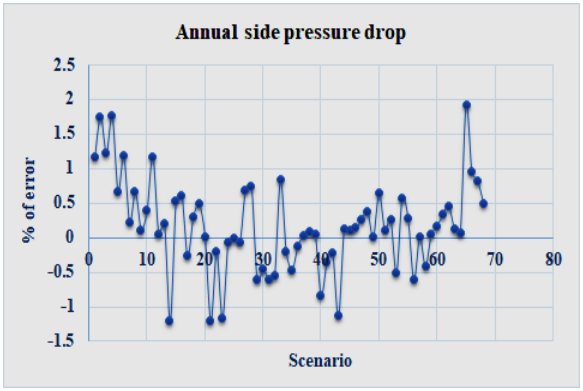


Fig.8 Comparision between experimental and GRNN outputs for trainee,tested and percentage of error data sets

IV.CONCLUSION

In this analysis statistical tool generalized regression neural network is used to find a relation between desired outputs and known inputs. The basics of heat exchanger teaches that the common method of enhancing heat flow rate is utilizing different baffle arrangement in a heat exchanger. Hence the idea of enhancing the area (inserting elliptical leaf strip) in the pipe for improvement in the heat transfer rates motivated for this experimentation.

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In this investigation elliptical leaf strips with aspect ratio 2:1 were inserted in the inner pipe at different orientation with equidistant space are utilized to improve the performance of the double pipe heat exchanger. During experimentation there was difficulty in finding the process parameters at every angle and the input and output parameters are non-uniform so the prediction tool of GRNN is used to find the solution. By using this smart tool one can easily identify and vary various parameters and get their desired outputs with 2% error between experimental and GRNN values. Although the experimental and GRNN outputs have converged solutions with each other, it is difficult to find the optimum values from this prediction tool. Hence the future work includes the implementation of some optimization techniques to get the optimum values of process parameters.

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