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Evaluation of a Double Pipe Heat Exchanger by using Double Elliptical Leaf Strips with Opposite Orientation and Same Direction and Executing with a Smart Prediction Tool of GRNN

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Abstract: ***The world is full of applications with heat exchangers. From the moment a person wakes up to the end of the day everyone is surrounded by heat exchangers. The refrigerators, Air conditioners, automobile radiators, geysers, Sea breeze etc., are the common applications of heat exchangers .Since we are followed by various devices of heat exchangers so change in the output of heat exchangers would gear up the entire applications and change the society into a new phase. This paper aims at one such augmentation method of insertion of elliptical leaf strip in a heat exchanger equipment for the enhancement of thermal performance of the heat exchanger. From the obtained results of experiment a statistical tool of GRNN is used to compare them. Based on both the available values plotting is done to find the percentage of errors between the calculated values.***

Keywords: Heat exchangers, elliptical leaf, insertion, GRNN, percentage of error.

1. INTRODUCTION

Analysis of double pipe heat exchangers state that the thermal performance can be improved by various methods like introducing twisted tapes of the tube and pipe, semicircular disc baffles ,mechanical turbulators , corrugated twisted tapes .[1]Analysis of spiral tube heat exchangers were studied after experimenting them [2] . Comparing heat transfer by analyzing and experimenting and finding the difference between those values. [3]Improvement in effectiveness was studied by introducing triangular fins, trapezoidal cut twisted tape inserts, conical strips, louvered strip .[4] Thermal performance on U bend heat exchanger was studied by introducing twisted tapes turbulators .[6]Various techniques to improve efficiency in double pipe heat exchangers was studied. [8]

Various parameters of double pipe heat exchanger of hot fluid side inner pipe was studied. Modelling and simulation of overall heat transfer characteristics in a double pipe heat exchanger was studied using a black box approach, holed twisted tape. Heat transfer enhancement in circular double tube heat exchanger was studied. [5] Numerical analysis of double pipe
heat exchanger with & without strips was analyzed [7] Pipe in pipe heat exchanger was experimented and analyzed by designing it. [9] Multiple shell and tube heat exchangers was studied. [10]Various augmentation techniques was studied for double pipe heat exchangers. Effect of helical tape inserts was studied in this paper. The CFD analysis of double pipe heat exchanger using Nano fluids was studied here. A concentric tube heat exchanger was studied along with its effect when twisted tape inserts are placed. Heat transfer analysis using artificial neural networks approach was studied. [11] Heat transfer was analyzed using prediction tool on various heat exchangers. [12][13] The effect of generalized predictive control was studied [14]. The novelty of this investigation is on the use of a statistical tool named GRNN. (Generalized Regression Neural Network) uses neural network principles giving certain known inputs and finding the outputs. [15]A comparison of the obtained experimental values and GRNN values are made to find the percentage of error from this technique.

Based on these literature survey the passive method of augmentation is used for enhancement of thermal performance in this paper. Two elliptical leaf strips are placed in the tube with same orientation but opposite direction and experimental analysis are done to obtain results. Our novelty is in the implementation of GRNN. A neural network based statistical tool which is used to get outputs by giving predefined inputs. The regression of a dependent variable Y with independent variable X is computed over here. X consists of different mass flow rates, inlet temperatures whereas Y is the outlet temperature.

II. EXPERIMENTAL SETUP

Here a double pipe heat exchanger is used for experimentation made of steel for the outer pipe
& copper as the inner pipe.

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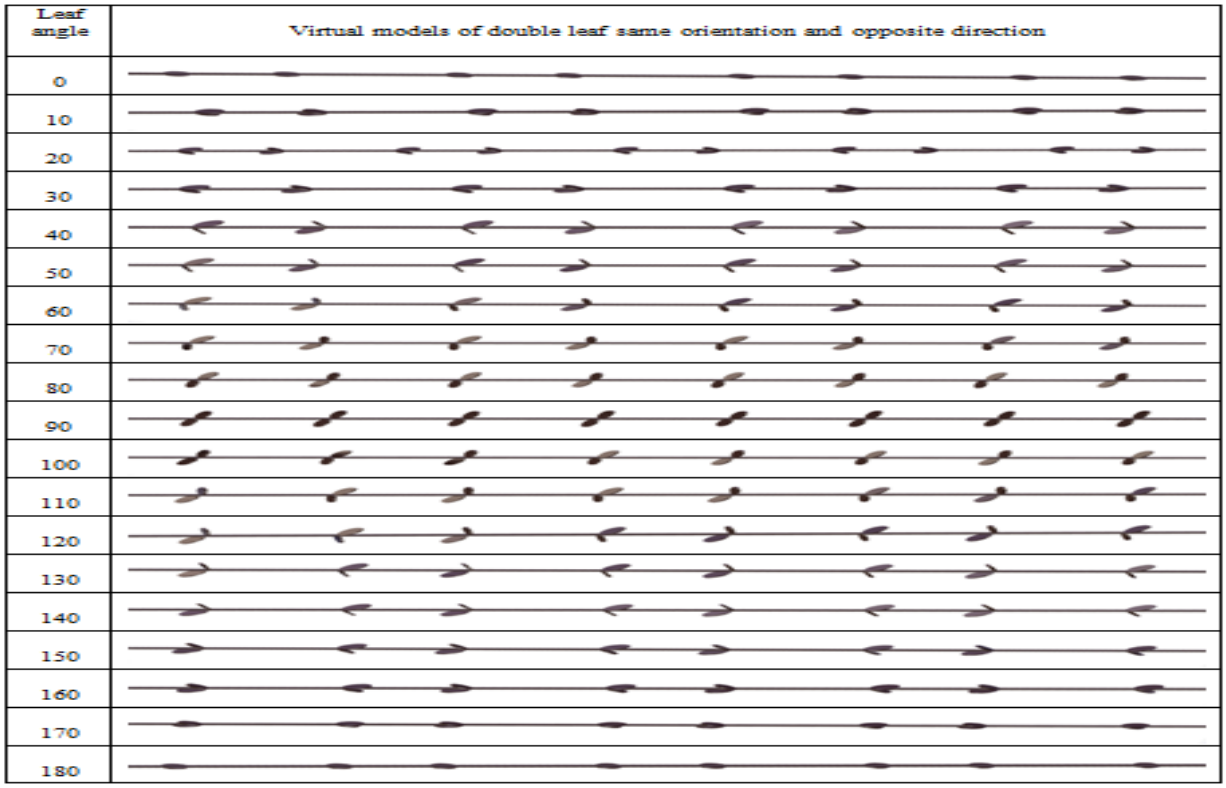
Water is taken as the working fluid and the equipment is designed as follows. Water is taken from a pump & made to flow into pipe side and annulus side respectively. The hot water at inlet side is obtained by heating it with a heater and allowing it to pass into the tube. Various accessories are placed at different points to measure temperature, fluid flow rate etc. The experiment is conducted by placing two elliptical leaf strips with the following inputs. The leaves strip inserted are designed with major to minor axis as 2:1with thickness of 1 mm. For the entire length of the pipe with a distance of 50 mm the leaves are located with 90 ^{0} rotation towards the shaft. For experimentation purpose the strips are placed along the opposite direction but same orientation as shown in figure -2. The experiment is conducted by placing two elliptical leaf strips with the following inputs. The leaves strip inserted are designed with major to minor axis as 2:1with thickness of 1 mm.For the entire length of the pipe with a distance of 50 mm the leaves are located with 90 ^{0} rotation towards the shaft. Both the leaves are placed along the same orientation, opposite direction along the flow of fluid. The working fluid used is water which is incompressible and turbulent in the pipes. The fluid flow is represented as water running from a tank is extracted and divided into two streams consisting of cold and hot fluid passing through annular side & tube side respectively .Before reaching the tube side the working fluid is heated in an electrical heater & made to enter as hot water in the tube side. The experiment is started once steady state is achieved .The experimental conditions of mass flow at steady state are as follows 0.15785, 0.3827, 0.55763 & 0.71782 kg/s for the hot side & 0.34589,0.8403, 1.2245 & 1.5762 Kg/s along the cold side . The passive technique of elliptical leaf strip insertion is taken in this case .The condition utilized here are insertion of elliptical double leaf strip with same orientation and opposite direction. The elliptical leaf strips are placed on the pipe and the fluid is allowed to flow and at steady state the readings are taken for calculation. The fluid flow is incompressible and turbulent in the pipes. 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 figure.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 Figure.2. The elliptical leafs are designed in 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. The atmospheric pressure is defined as the pressure boundary at the outlets. While analysis is done constant temperatures of hot and cold fluids are assumed for the design modifications of double pipe heat exchanger. Using Turbulent flow by finding the Reynolds number analysis is made. From the obtained Reynolds's no. analysis is done to get thermal performance.



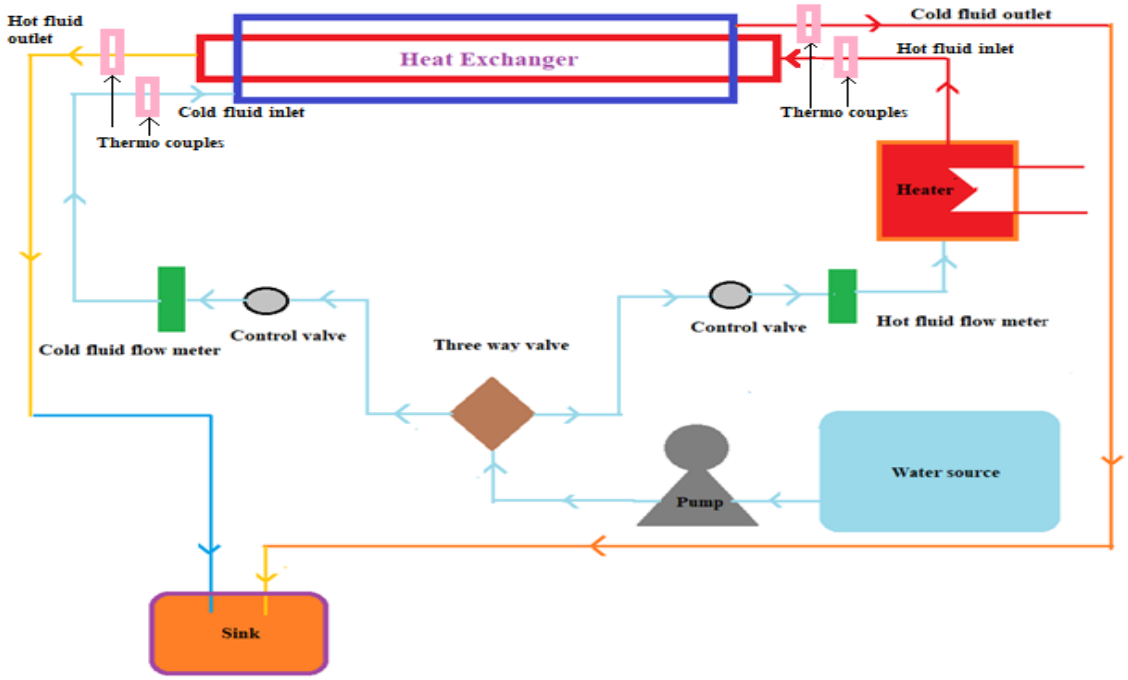


Fig.1 Experimental setup of heat exchanger and different elliptical leafs.

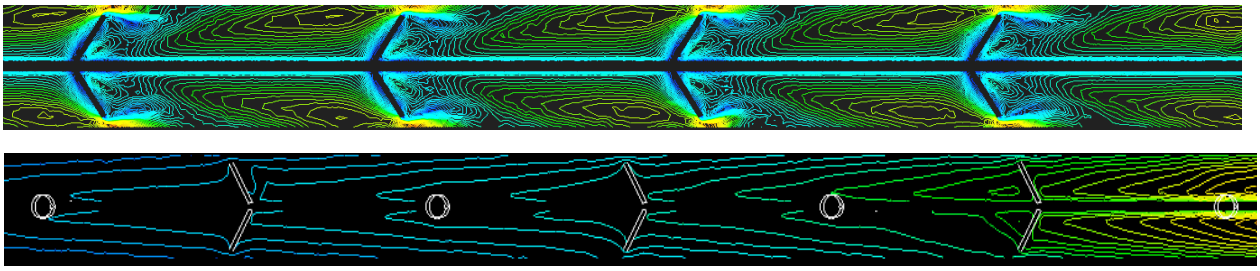


Fig.2 Velocity and temperature stream lines of heat exchanger

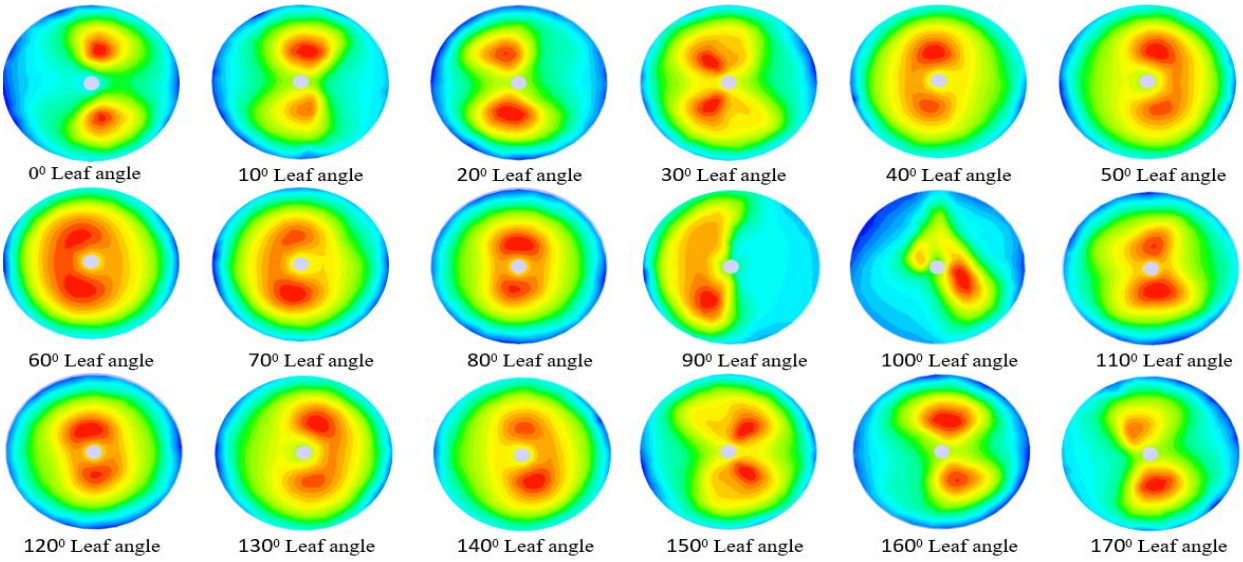


Figure.3 Heat transfer contours at different elliptical leaf angles

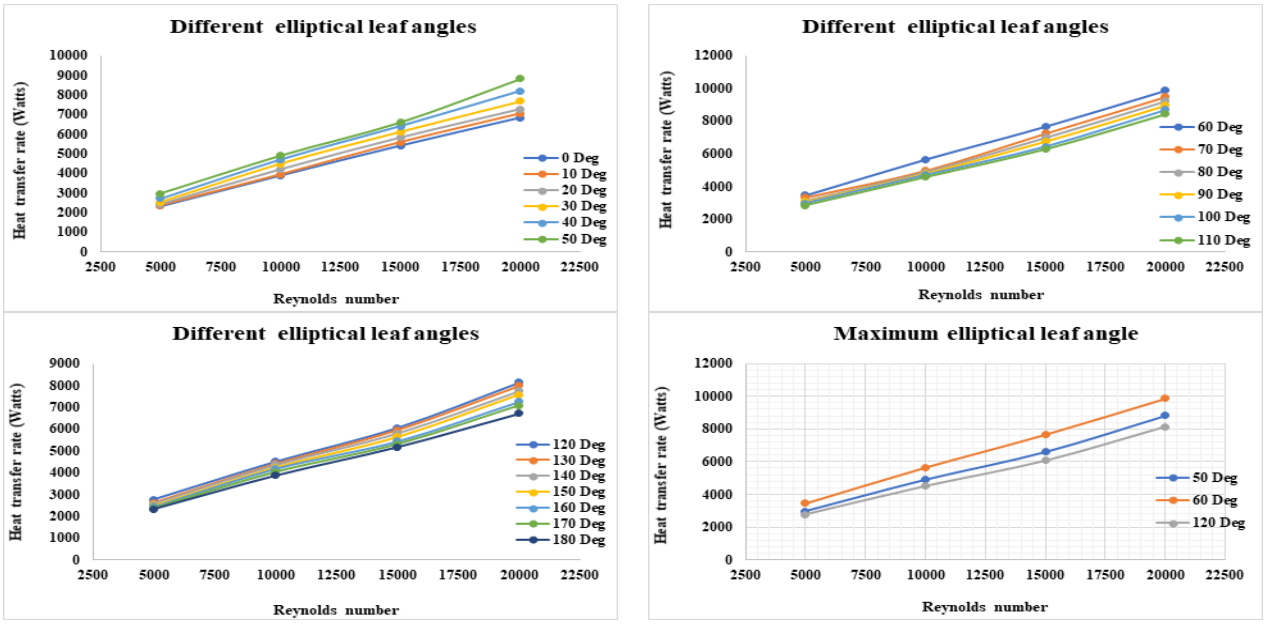


Figure 4 : Heat transfer variation at different elliptical leaf angles

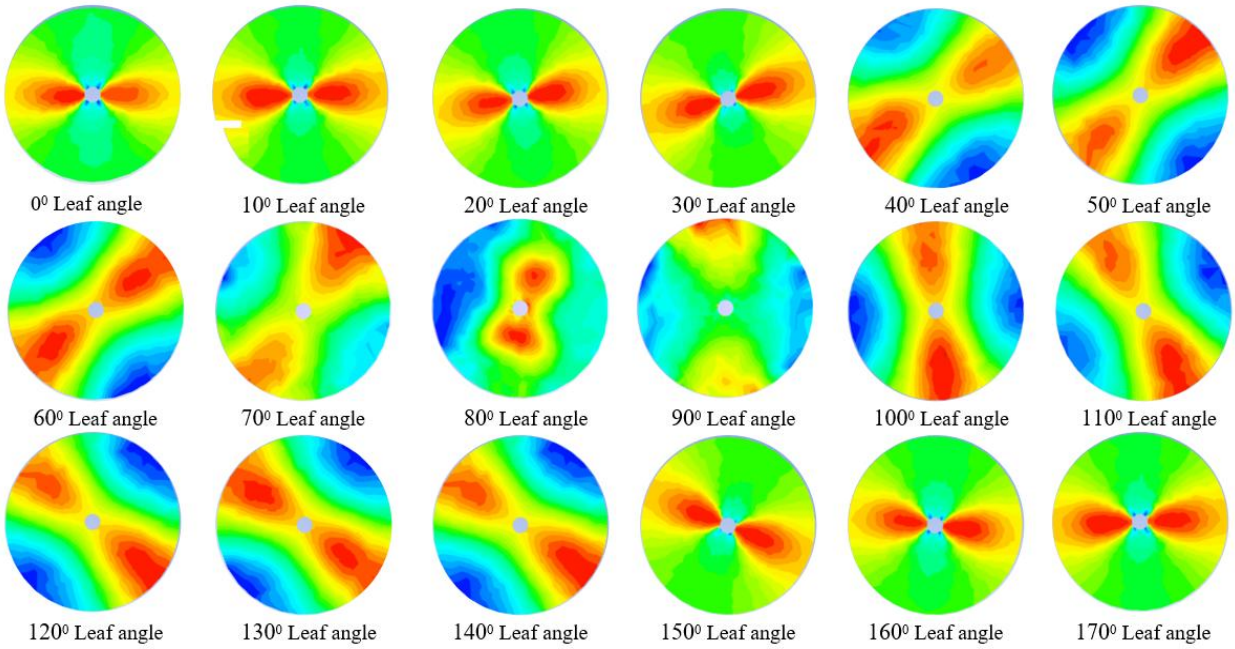


Figure.5 Pressure contours at various elliptical leaf angles

III. GRNN IMPLEMENTATION

GRNN is a statistical tool used to measure certain outputs by giving some known inputs. 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

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

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

In combination with the artificial neural network as shown in Fig.6 a new assumption is made to find a linear relation between the output and inputs which is given by

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

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 as shown in Table.1 .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 from Fig.7. 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 the graphs the value obtained between the experimental sets and regression analysis gave us good accuracy.

Table.1 Input and output weights of GRNN

Demonstration	Input	Weight of input
X1	Elliptical leaf angle (θ)	(0^o – 180^o)
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

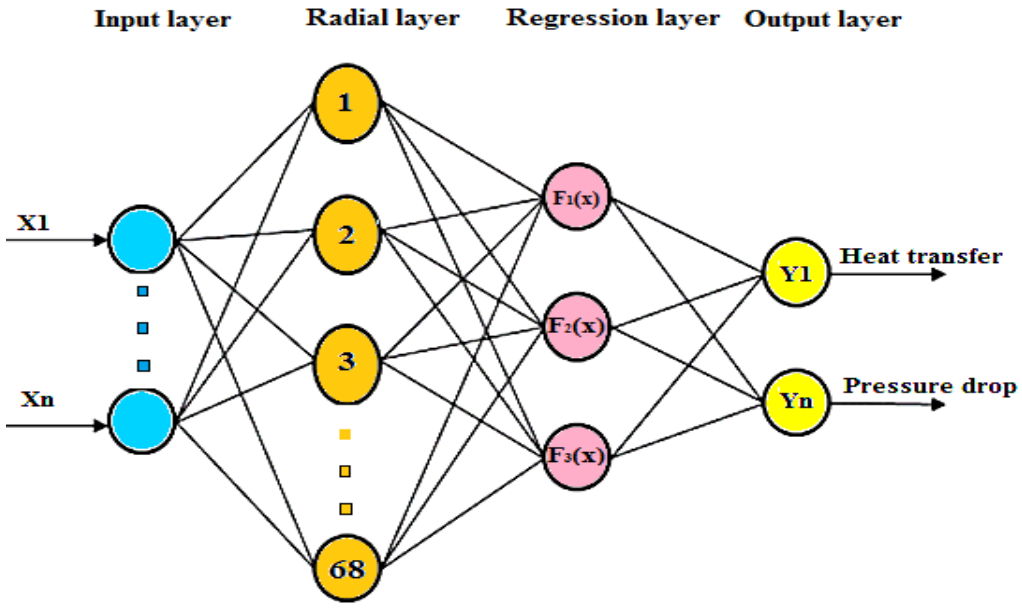


Fig.6 Implementation of neural network

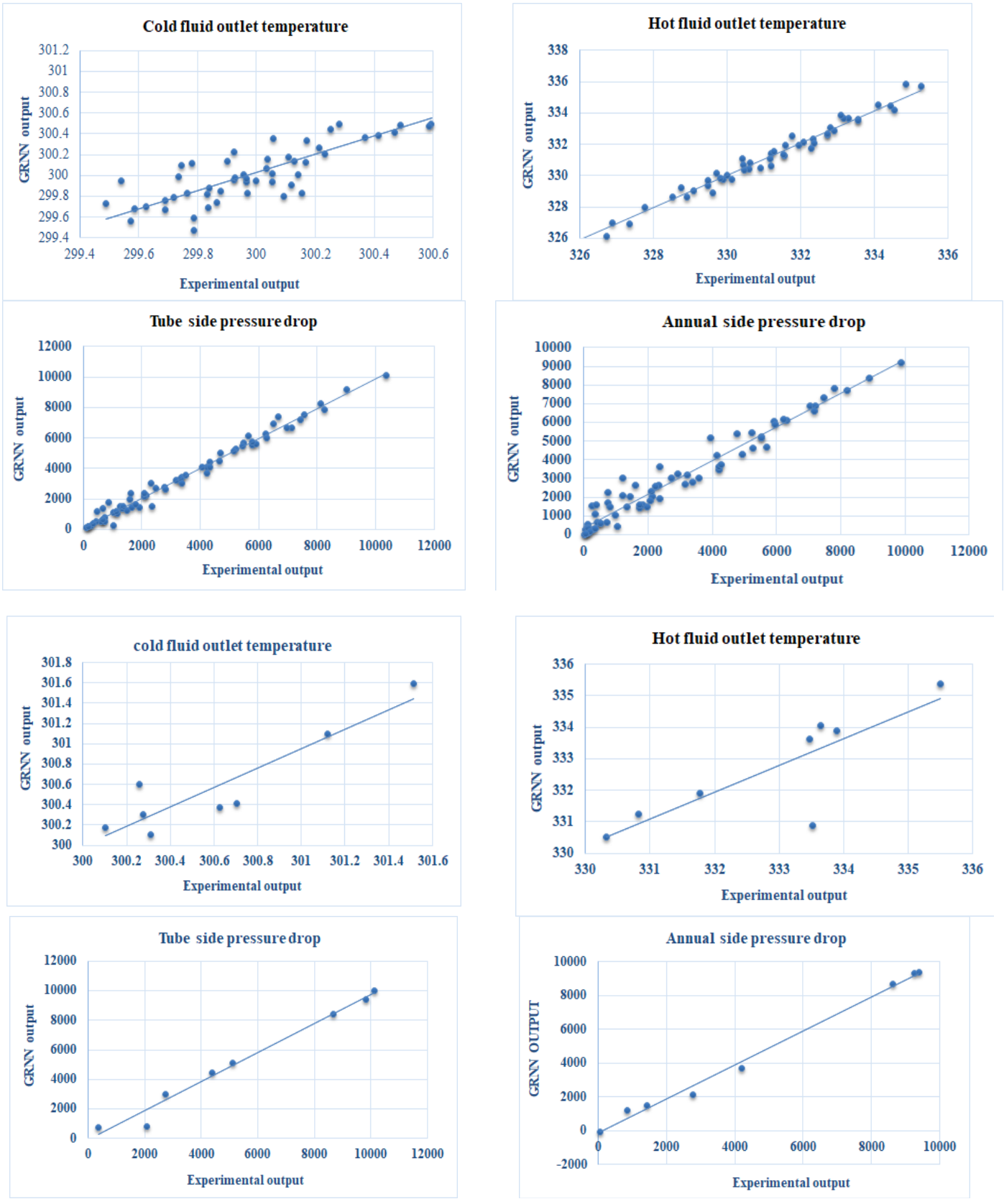


Fig.7 comparisons of GRNN and experimental values of trainee and tested data

IV. CONCLUSION

Enhancement in output of heat exchanger would bring a revolutionary change in this world. Keeping this in mind this paper aimed at improvement of heat transfer rate & decrease in pressure of fluid flow. This is achieved by introducing a double elliptical leaf strip in the pipe side. The strips are placed at same orientation & opposite direction of fluid flow. With these inputs experimental values are taken and plotted for best angle of orientation for this flow. For these obtained values a statistical tool named GRNN (generalized regression neural network) is used to get values. In this tool leaf angles, inlet temperatures & mass flow rates are considered as inputs. Outlet temperatures & pressure drops are given as outputs .To obtain a clear conclusion plotting was done for 68 trainee data and 8 tested data. From the obtained graphs a final plot for percentage of errors are drawn and final conclusion is drawn to be convergence between these two values with error percentage less than 2% for the obtained GRNN values.

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