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Using a Generalized Regression Neural Network Prediction Tool to Estimate Thermal Performance in A Heat Exchanger By using Triple Elliptical Leaf Angle Strips with Opposite Orientation and Same Direction

J. Bala Bhaskara Rao, Ramachandra Raju

Abstract: ***In our day to day hectic schedule humans have got so adaptive to technology that tremendous pressure is built on researchers to produce better equipment with greater output & easier way of human usage. One among these is Heat exchanger which is a device for trading heat and providing comfortable environment either for humans or the equipment .This paper aims at finding a solution in improvement of the thermal performance of the heat exchanger by implementing a statistical tool derived from Artificial Neural Network. The name of the tool is GRNN. (Generalized Regression Neural Network) From a sparse data of inputs (Temperatures, Angle orientation & mass flow rates) the outputs of (outlet temperatures & drop in pressure) are found out using this tool. An experiment is also conducted to find the heat transfer rates and pressure drops. To enhance the heat transfer rate three elliptical shaped leaf strips are introduced in the tube with opposite orientation and same direction. The results obtained from both the sources are compared and the percentage of error is calculated.***

Keywords: Thermal Performance, ANN, GRNN, Elliptical shaped leaf strips, percentage of error

I.INTRODUCTION

Heat exchanger is an inimitable arrangement which has the capability of improving many industrial applications by enhancing the characteristics affecting its performance. [2] Using hexagonal & semicircular fins comparison was made between different heat exchanger devices. The usage of corrugated twisted pipes in place of a normal pipe yields better results in tubular heat exchangers. Introduction of Turbulators in heat exchangers causes drop in fluid pressure. A study of nanoparticle concentration was done on Nusselt number and to find the heat exchange characteristics introducing the baffles and without it. [4] Heat transfer behavior with different boundary conditions of friction factor, pumping power, pressure drop variation were found by doing a numerical investigation. [5] In a heat exchanger the comparison between convective theoretical film coefficient & experimental film coefficient is done. enhancing heat transfer by utilizing fins in a heat exchanger was discussed in this paper. [7] Experimentation on triple tube & double tube heat exchanger was performed and heat transfer characteristics was found. The process of shot blasting was used in this experiment to increase the roughness of the internal pipe's external diameter surface causing a change in rate of heat transfer in a double pipe heat exchanger. [8]Effect of triple tube heat exchanger having internal threaded pipe was performed and analyzed .Tube in tube heat exchanger was numerically analyzed. The effect of plain twisted tapes, semicircular tapes, were compared with the heat transfer rates & pressure drops in heat exchangers. [3]Applications in industry based on counter or parallel flow was determined by using various graphs. Using Solid works, experimental and computational methods double pipe heat exchanger was studied [1] Concentric tube heat exchanger with various fins was studied [6] Using enhancement liners double pipe heat exchangers was studied. [9] [10] Investigation of heat transfer coefficient Using artificial neural networks was studied. Cross flow heat exchanger was studied and analyzed using neural networks. Thermal characteristics of a plate fin heat exchangers was studied. Based on these survey from various sources we implemented a passive form of elliptic leaf strip insertion method to find the thermal performance on a heat exchanger. The experimentation outcomes were compared based on the orientation of these elliptical leaf strips at various angles from 0 to 180 at 10 intervals. Heat transfer analysis using artificial neural networks approach was studied. [12] Heat transfer was analyzed using prediction tool on various heat exchangers. [13][14] The effect of generalized predictive control was studied [15] 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. A comparison of the obtained experimental values and GRNN values are made to find the percentage of error from this technique.

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II. EXPERIMENTAL SET UP

Here investigation is done on a double pipe heat exchanger with inner pipe made of copper and outer one made of steel connected with different devices as shown in the figure -1. The experiment is conducted by placing three 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. The leaves are placed along the same orientation and same 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.

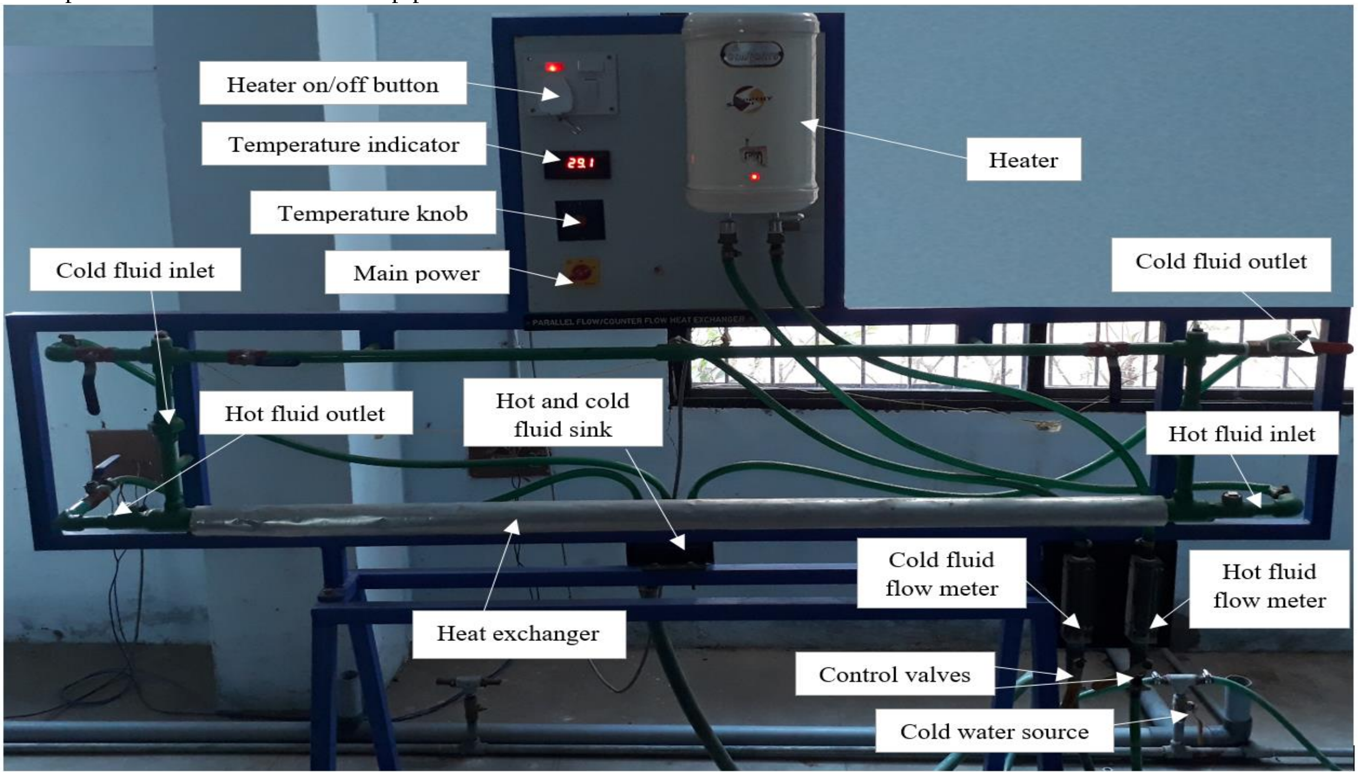

Fig.1 Double pipe heat exchanger experimental setup

The experimental conditions at steady state are as following hot water inner pipe temperature is 348 K with different mass flows of 0.15785, 0.3827, 0.55763 & 0.7182 kg/s & the cold fluid mass rates to be 0.34589, 0.8403, 1.2245& 1.5762 kg/s with inlet temperatures of 298 K .To measure these the following devices are used thermocouples for temperature measurement, Flow meters for volume flow rates giving us the mass flows. All the devices were calibrated for obtaining accurate results. The pressure boundary at the outlet is considered as atmospheric pressure. For analysis purpose the heat content of the fluids are assumed to be constant throughout the experiment .Using turbulent flow in both the pipes calculations for thermal performance are done. The turbulent flow condition is obtained by calculating the Reynolds's number from altered mass flow rates at tube and pipe sides in the double pipe heat exchanger. Elliptical leafs are arranged at an inclination of 0^0 to 180^0 (0^0 – 180^0) at 10^0 intervals as shown in Figure.2. The parameters are calculated by

Tube side Reynolds number (Ret) = $\frac{\rho v_{D_e}}{\mu}$ (1)

Where ρ = Density of inner fluid in Kg/m^3

V = Velocity of inner fluid in m/sec

D_e = Hydraulic diameter of pipe in meters

$= \frac{4\,A_c}{P_h} = d$

d = Inner diameter of inner pipe in meters

μ = Dynamic viscosity of inner fluid Kg/m-sec

Annual side pressure drop (Re a) = $\frac{\rho v De}{\mu}$ (2)

Where ρ = Density of annual side fluid in Kg/m^3

V = Velocity of annual side fluid in m/sec

De =Hydraulic diameter of pipe in meters

$= \frac{4\,A_c}{P_h} = \frac{D_i^2 - d_0^2}{d_0}$

$A_c = \frac{\pi}{4}(D_i^2 - d_0^2)$ & $P_h = \Pi d_0$

A_c = Minimum flow area in m^2

P_h = Wetted perimeter in meters

D_i = Inner diameter of outer pipe in meters

d_0 = Outer diameter of inner pipe in meters

μ = Dynamic viscosity of annual side fluid Kg/m-sec

The thermal performances are found from the initial values of the mass flow rate, temperature at entrance of shell & tube side and exit temperature of shell & tube side. The heat transfer rate is obtained by the following equation.

$$Q = AU\Delta T_m \quad (3)$$

Where Q=average heat flux between the cold and the hot fluid in watts = $(Q_C + Q_h)/2$

$$Q_C = m_c\, c_{pc}\, (T_{co} - T_{ci}) \quad (4)$$

$$Q_h = m_h\, c_{ph}\, (T_{hi} - T_{ho}) \quad (5)$$

m_c, m_h cold and hot fluid mass flow rates in kg/sec.

c_{pc}, c_{ph} are specific heats under constant pressure of cold and hot fluids in kj/kg k.

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A= surface area based on the tube outside diameter in m^2
ΔT_m=logarithm mean temperature difference for hot and cold fluid in (kelvins)

Tube side pressure drop $((\Delta P_t)$ = $f.\frac{2l}{d_e}$ $\frac{\rho\, u_m{}^2}{2}$ N_{hp} (6)

Annulus side pressure drop $((\Delta P_a)$ = $f.\frac{2l}{d_e}$ $\frac{\rho\, u_a{}^2}{2}$ N_{hp} (7)

Where (f) = $(3.64\log_{10} Re - 3.28)^{-2}$ (8)

Where f= friction factor and N_{hp} = number of hair pins

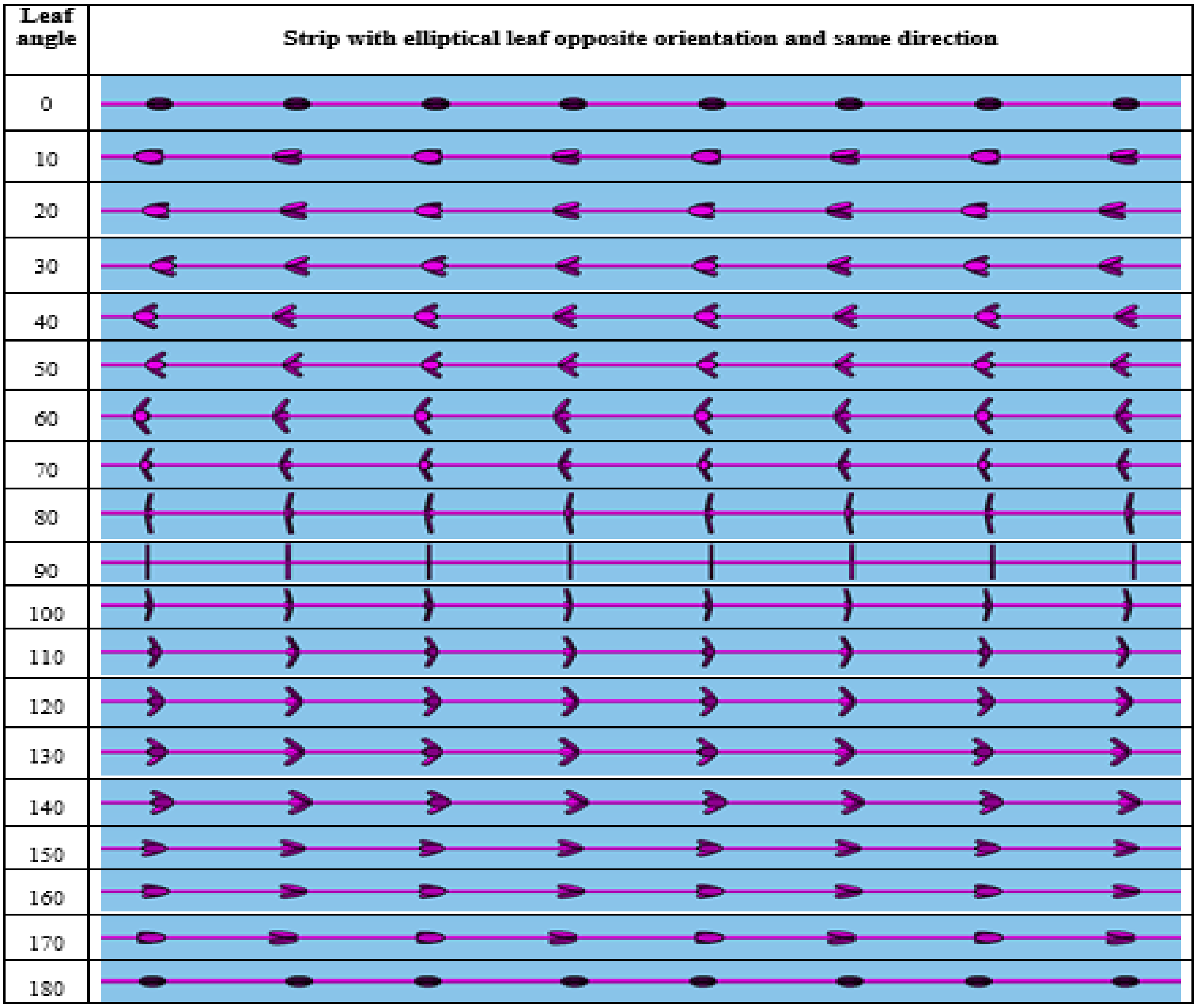

Fig.2 Different elliptical leaf angle strips

III.RESULTS AND DISCUSSIONS

To begin the FLUENT analysis of temperature difference in fluid flow, the base conditions must be analyzed as shown in Fig.3 to Fig.5. The first condition is that of fluid flowing through a tube with constant wall heat flux condition. In this analysis turbulent incompressible fluid flow was considered in tube side with 19strips with different elliptical leaf angles to evaluate thermal analysis in double pipe heat exchanger.

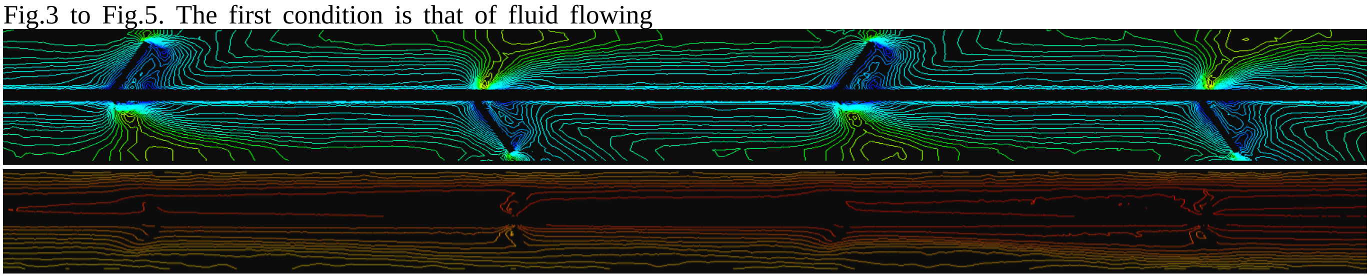

Fig.3 Velocity and temperature contours of triple elliptical leaf angle strips

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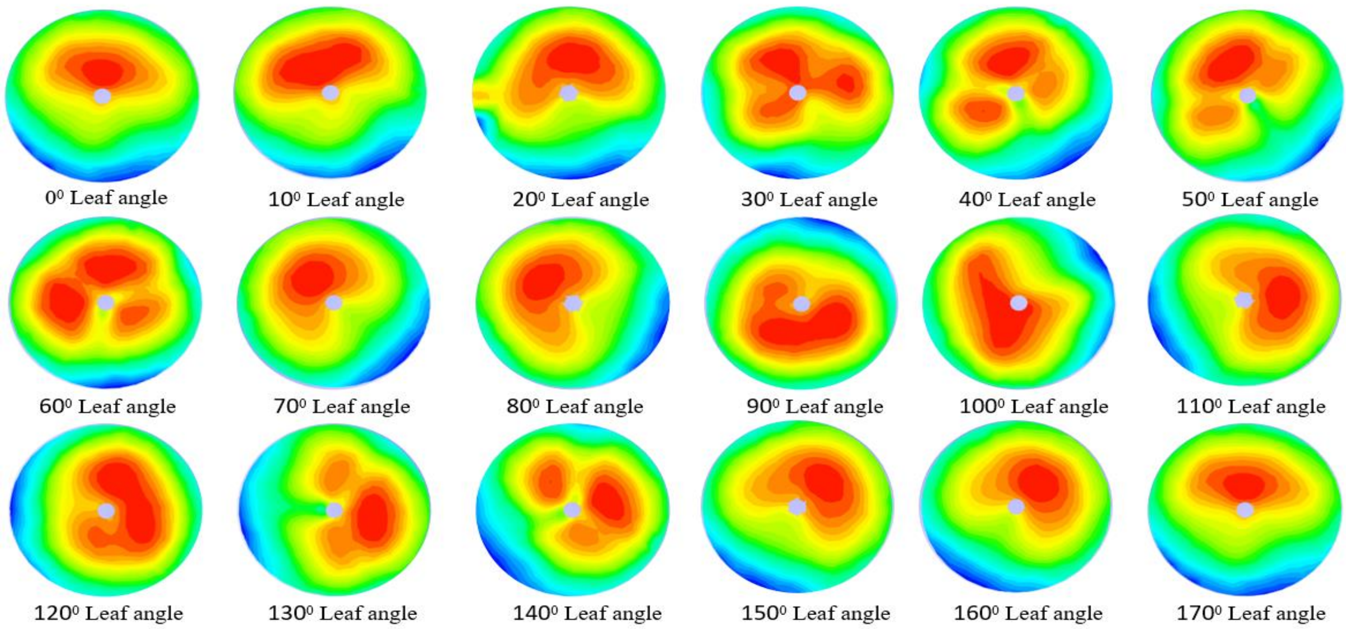

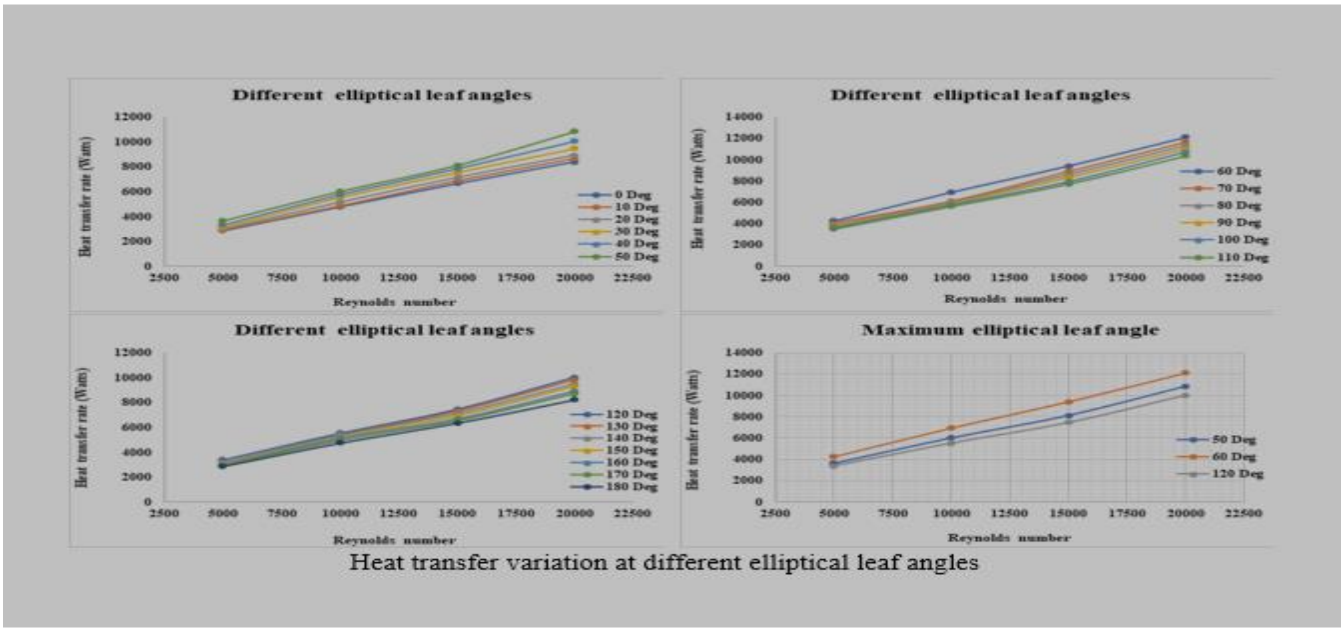

Fig.4 Heat transfer variation at different elliptical leaf angles

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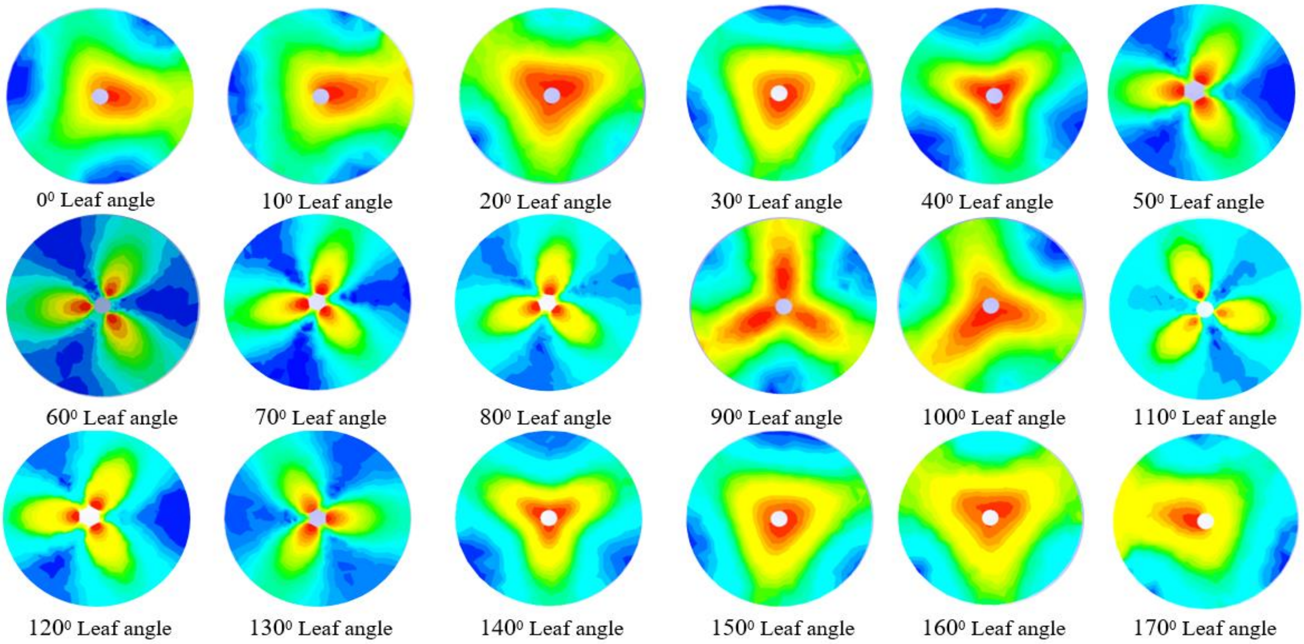

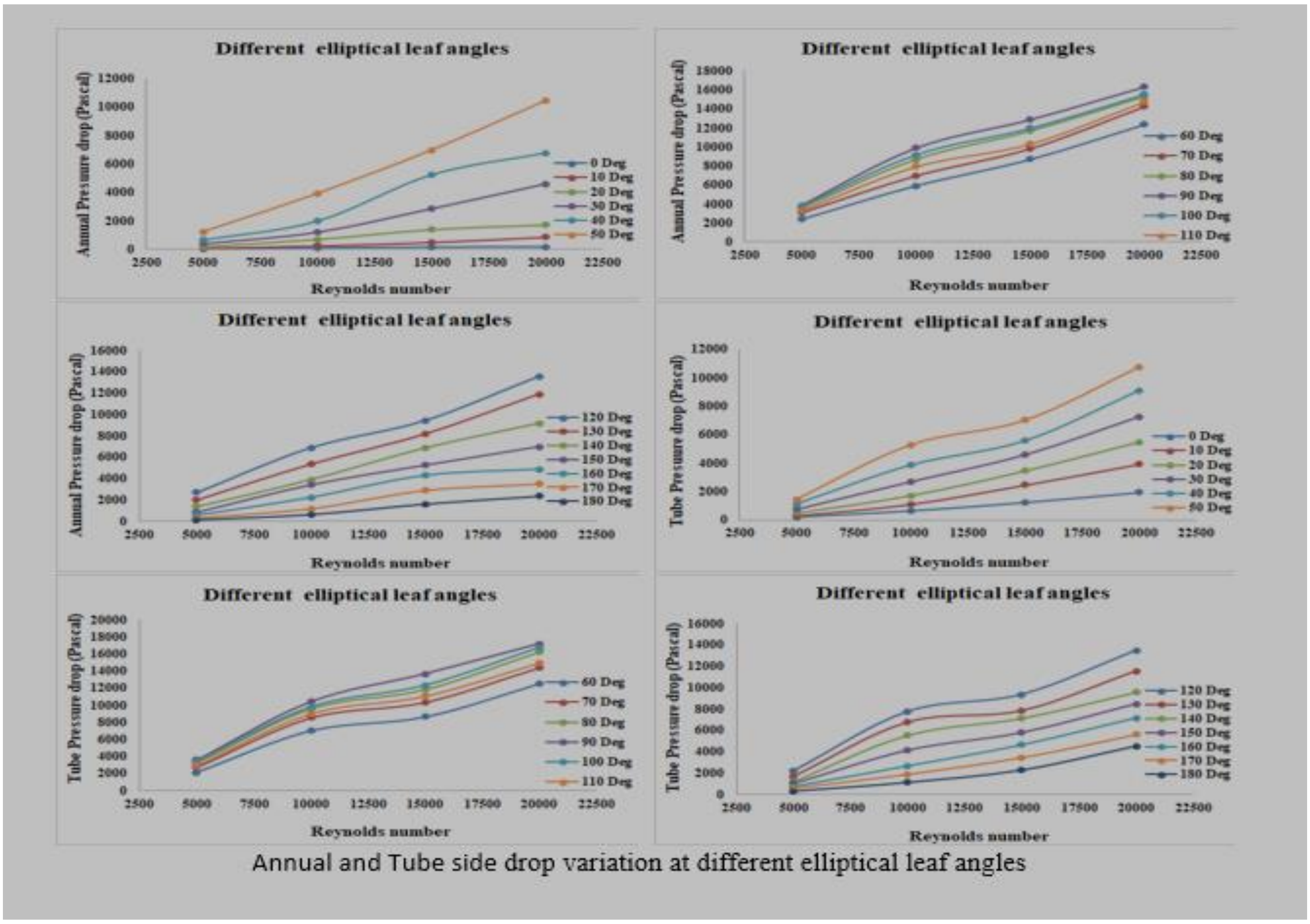

Fig.5 Pressure drop variation at different elliptical leaf angles

IV.GRNN DESIGNING

GRNN or Generalized Regression Neural Network is an algorithm based tool used to find continuous variables .The model is generally of two types 1) A predictor model 2) A system model.

If the outputs to be estimated are future values it is a predictor model. If the variables to be estimated relates outputs it is a system model. Once a system is modelled it would define a control function. Hence by using this tool a linear relationship can be obtained for nonlinear outputs. The neural regression of independent variables (Y) on dependent variables (X) for this analysis is given by

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

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

In combination with the artificial neural network a new assumption is made to find a linear relation between the output and inputs which is given by

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

Final output for the GRNN inputs and outputs are obtained from the following equation after clustering as shown in Fig.6.

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

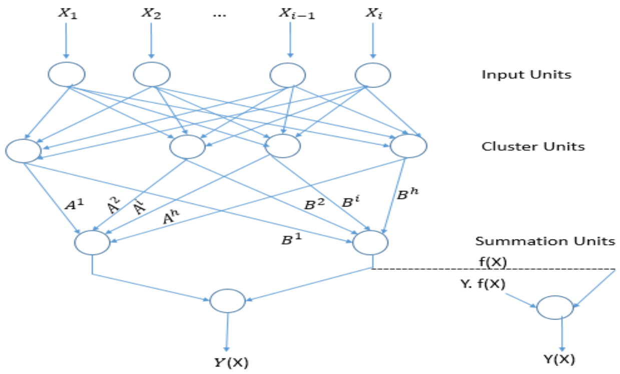

Fig.6 Clustering of ANN to GRNN

In this analysis heat transfer rates and pressure drops are found as outputs with mass flow rates, angles of orientation, inlet temperatures at both the pipes are taken as inputs as shown in Table.1. Here a total of 68 experimental data sets & 8 test data sets are used. Using the GRNN analysis the results are obtained for these entire trainee data and test data. After obtaining the results from GRNN and experimental values both are compared to find the error concentration between experimental and GRNN tool as shown in Fig.7.

Table.1 GRNN inputs and outputs

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

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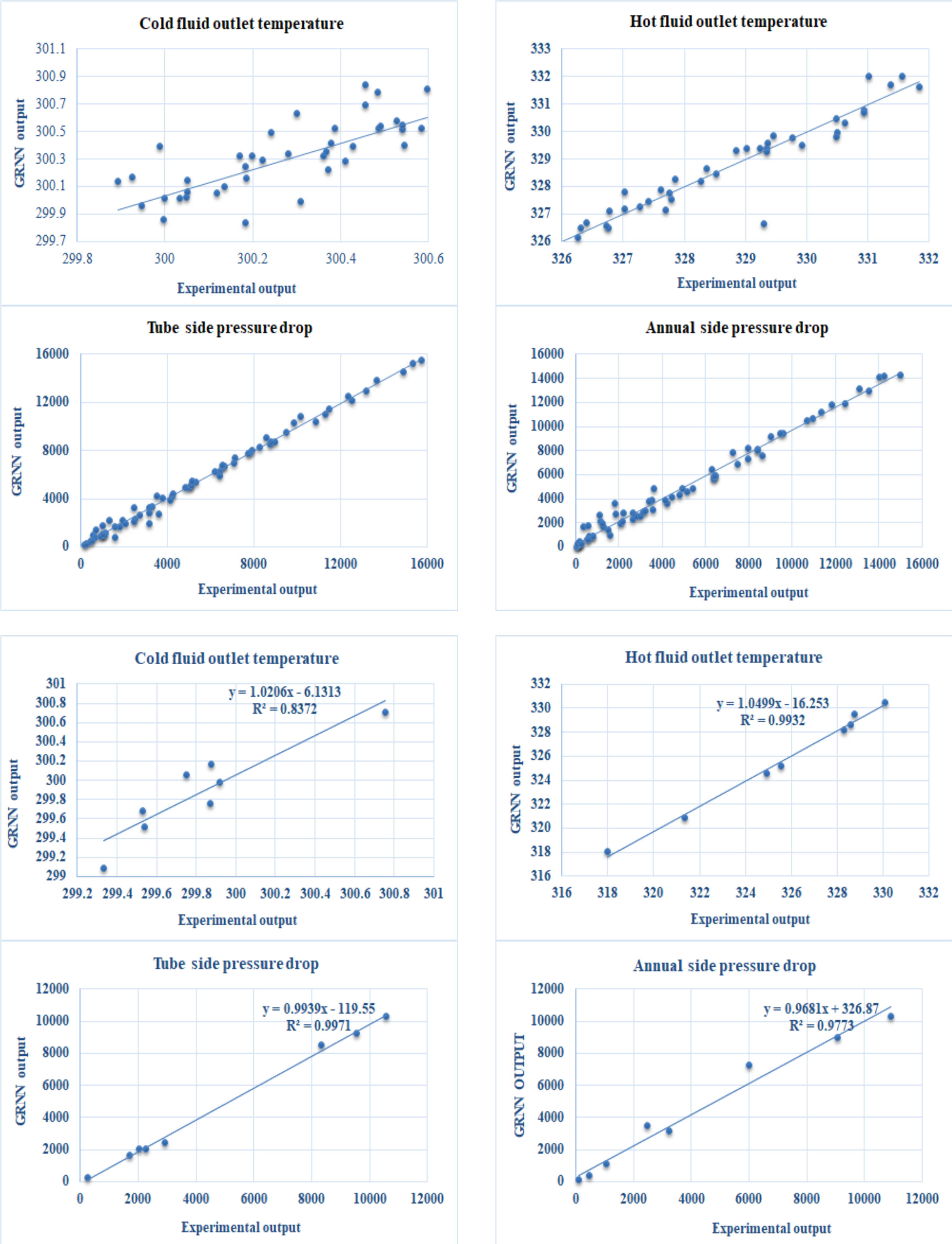

Fig.7 comparison of GRNN and experimental values of trainee and tested data sets

V.CONCLUSION

In this investigation statistical tool of generalized regression neural network is used which is an application of artificial neural network. Using GRNN various outputs can be obtained by adding few inputs. Here experimentation part was done by adding three elliptical leaves strips in the pipe with emphasis on increasing the heat transfer rate of double pipe heat exchanger. From the results of experimentation a nonlinear relation was obtained between inputs and outputs hence GRNN was implemented to get a relationship between input and output parameters. Utilizing GRNN gave faster and better results with errors less than 2%.Hence this paper could be used to find the relationship for different types of heat exchangers with inputs and outputs which is the proposed future work .Hence to conclude with GRNN tool will be very helpful in finding various outputs of many engineering applications in the near future.

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