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Implementation Of A Neural Network Tool For Evaluation Of Thermal Performance In A Heat Exchanger By Using Double Elliptical Leaf Angle Strips With Same Orientation And Same Direction

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Abstract*: Exchange of energy in all processes generally occur in the form of heat & work. The exchange of heat is determined by the rate of heat exchange between hot and cold body or cold and hot body. To exchange this heat we need two energy stacks such as a source & sink. So, whenever heat is rejected or accepted the energy change occurs identically i.e. amount of heat rejected is equal to amount of heat gained in an ideal case but when heat transfer rate is analyzed it is different fsor different processes such as vaporization is an instantaneous process whereas the condensation is slower and takes much more time so, with this idea that heat transfer rate can be altered individually in different processes an idea of analyzing heat exchanger by introducing elliptic double shaped leaf strips within the double pipe heat exchanger and the rate of heat transfer and pressure drop in is planned at various orientations of angles . From these obtained results neural network tool was designed for evaluating the thermal performance named the generalized regression neural network (GRNN).In this process certain input parameters are given (temperatures, mass flow rate) and instantly predefined output parameters (heat transfer rate, pressure drop) are obtained.

Keywords: leaf strips, heat exchanger, orientation, GRNN, heat transfer, drop in pressure.

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 shell and finned tube exchanger. The usage of corrugated twisted pipes in place of a normal pipe yields better results in tubular heat exchangers.[1] 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. [6] Heat transfer behavior with different boundary conditions of friction factor, pumping power, pressure drop variation were found by doing a numerical investigation. [7]In a heat exchanger the comparison between convective theoretical film coefficient & experimental film coefficient is done· [8] Enhancing heat transfer by utilizing fins in a heat exchanger was discussed in this paper· [9] Experimentation on triple tube & double pipe heat exchanger was performed and heat transfer characteristics was found [4]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 heat exchanger. Effect of triple tube exchanger having internal thread 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 thermal values in heat exchangers. [5] 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. [3]Concentric tube heat exchanger with various fins was studied. Using enhancement liners double pipe heat exchangers was studied· Investigation of heat transfer coefficient Using artificial neural networks was studied. Cross flow heat exchanger was studied and analyzed using neural networks [7] Thermal characteristics of a plate fin heat exchangers was studied [10]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. [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.

II. EXPERIMENTAL SET UP:

Here investigation is done on a heat exchanger with inner pipe made of copper and outer one made of steel connected with various accessories as shown in the fig.1.

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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.

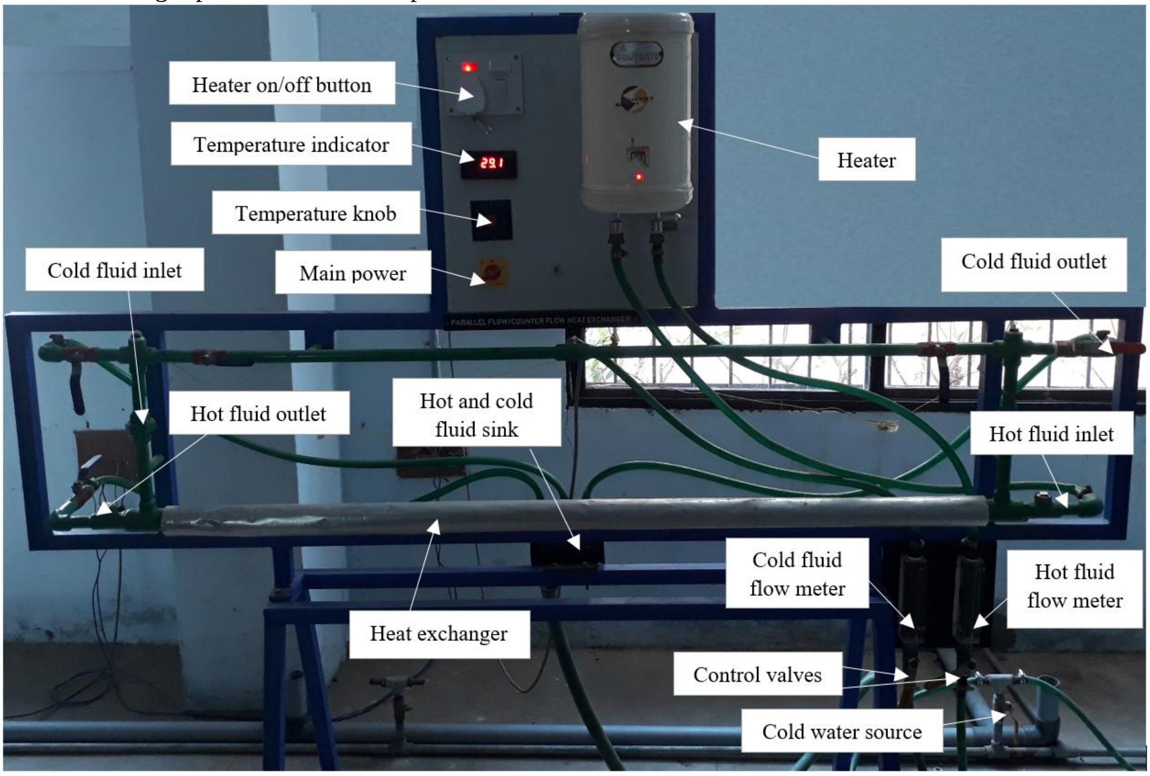

Fig.1 Experimental arrangement of heat exchanger

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 and same direction along the flow of fluid. The working fluid used is water which is incompressible and turbulent. 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 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 Fig.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 = Outer pipe inner diameter in meters
d_0 = Inner pipe outer diameter in meters
μ = Dynamic viscosity of annual side fluid Kg/m-sec

The thermal performance is studied from the preliminary proceedings permitting to the flow rate, inlet and outlet temperature at shell & tube side. The heat transfer rate is achieved by the subsequent equation.

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

Where $Q = (Q_C + Q_h)/2$

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

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

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

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

A= surface area in m^2

ΔT_m=logarithm mean temperature difference 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 pin

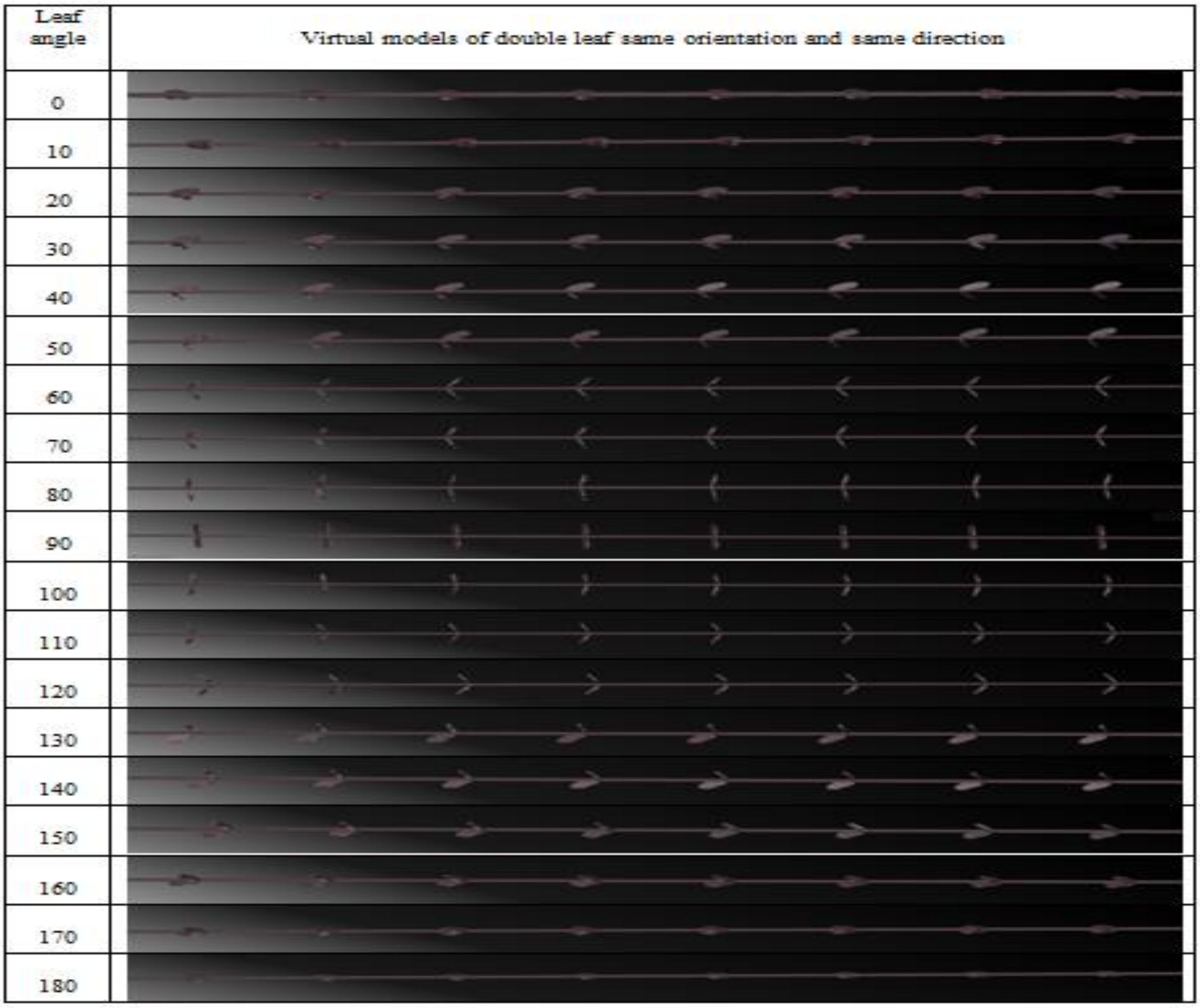

Fig.2 Positioning of double elliptical leaves with same orientation and direction

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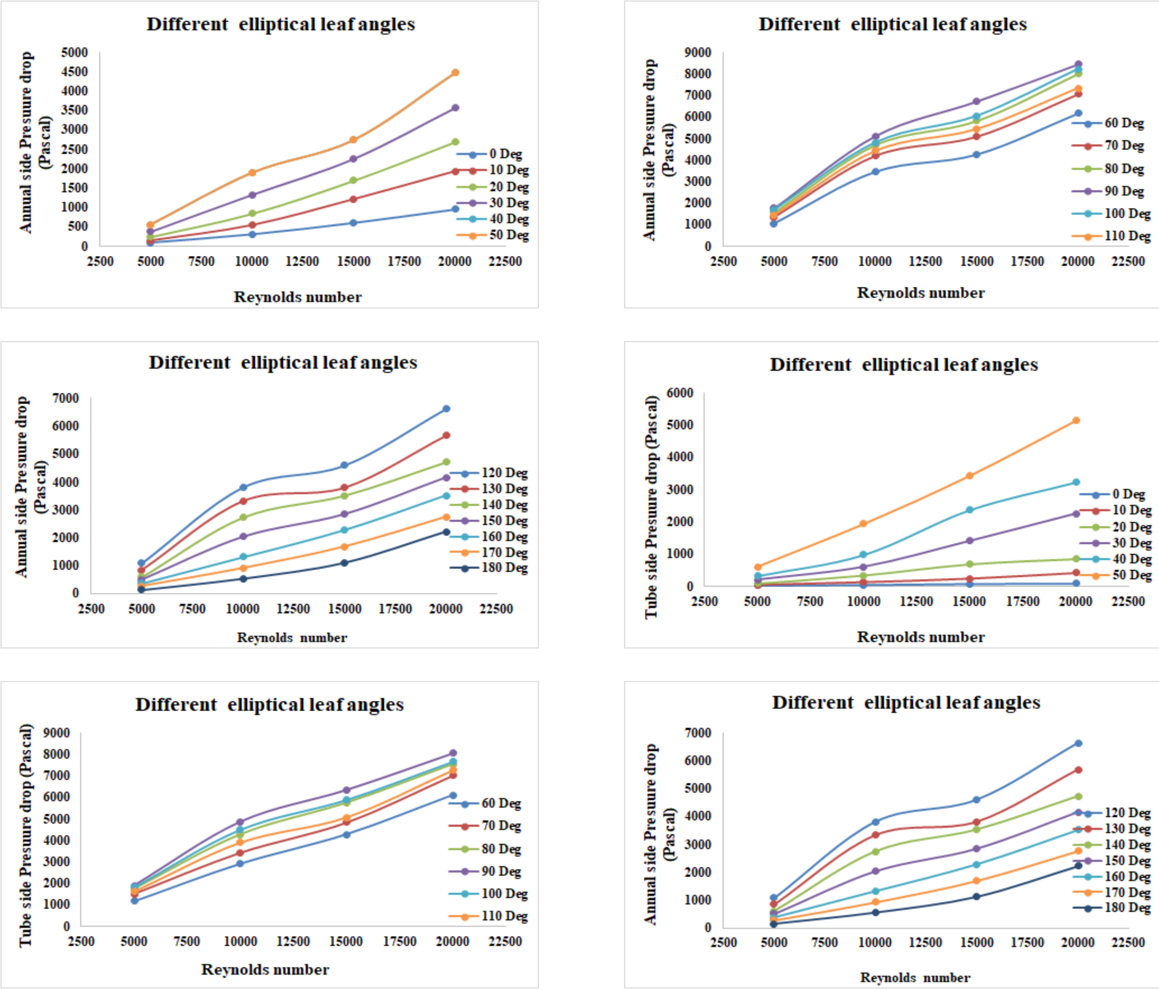
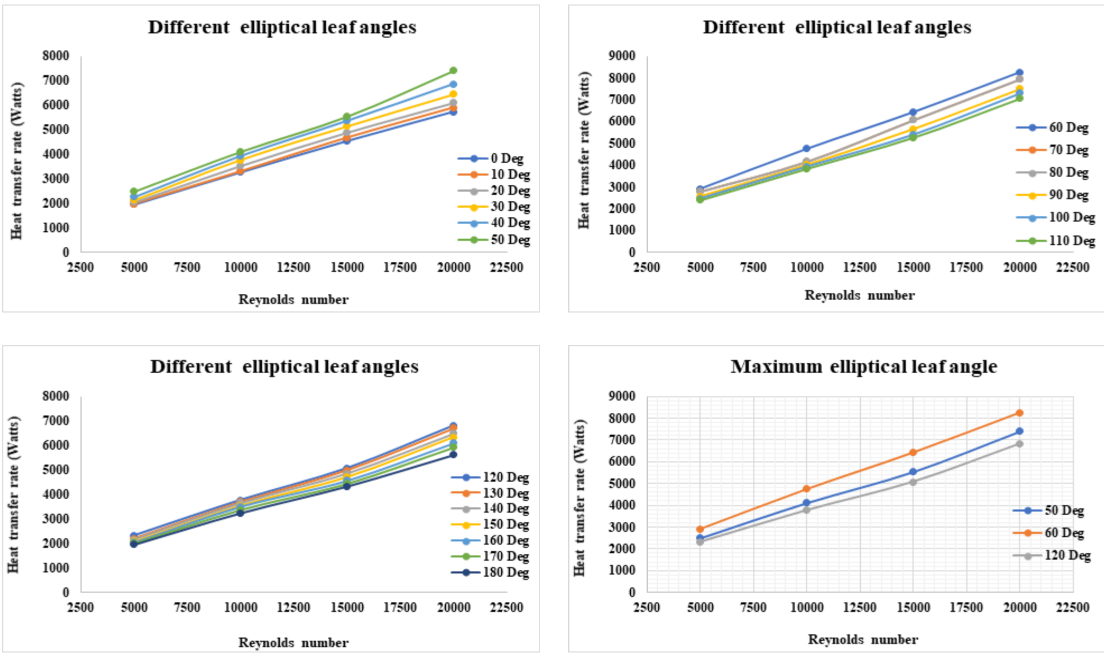


Fig.3 Tube side and annular side pressure drop deviations at various elliptical leaf angles



Fig,4 Heat transfer variation at different elliptical leaf angles

III. GRNN IMPLEMENTATION:

Generalized regression neural network is a probabilistic neural network which is very helpful in finding outputs by inserting few inputs. Its basic advantage over other statistical tools are its ability to add extra variables which are required by user without any additional input by user in fig.5. The neural regression of independent variables (Y) on dependent variables (X) for this analysis is given by

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

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

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

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

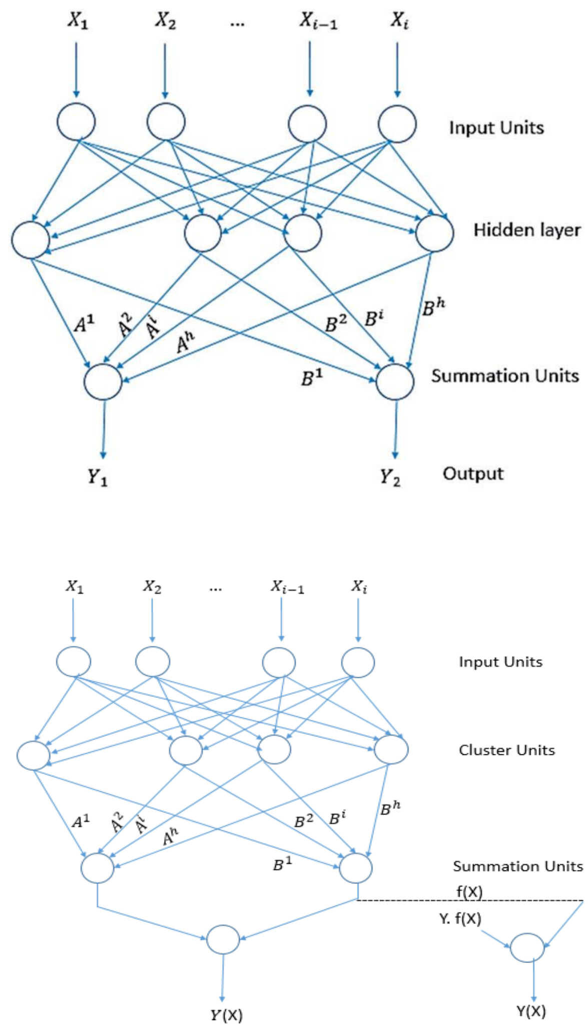


Fig.5 GRNN Implementation Into Clustering Methods Of ANN

Final output for the GRNN inputs and outputs are obtained from the following equation after clustering

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

In this analysis the thermal performance values are found as outputs with mass flow rates, angles of orientation, inlet temperatures at both the pipes are taken as inputs. Here a total of 68 experimental data sets & 8 test data sets are used in tab.1. 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 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 and represented form Fig. 6 - Fig.8.

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 a humongous accuracy.

Tab.1 GRNN datasheet

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

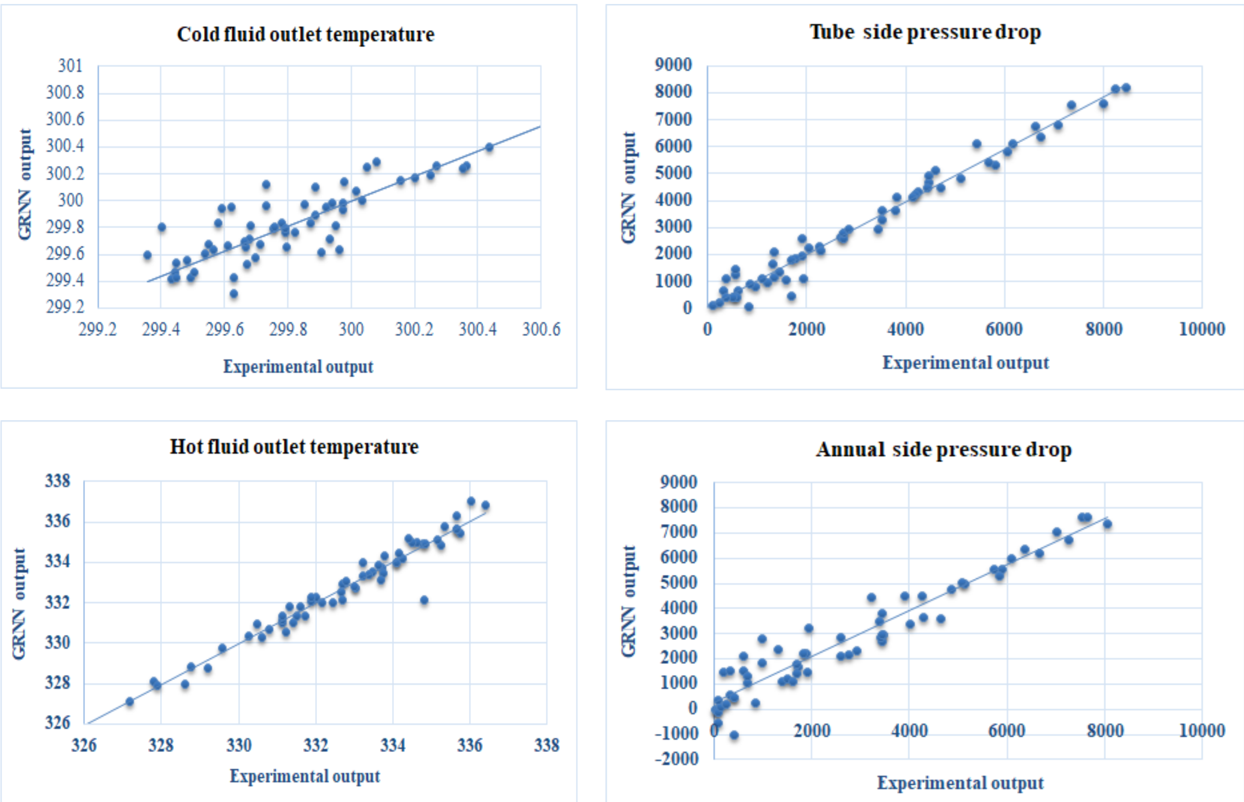


Fig.6 Error percentage between experimental and GRNN outputs for 68 trainee data sets

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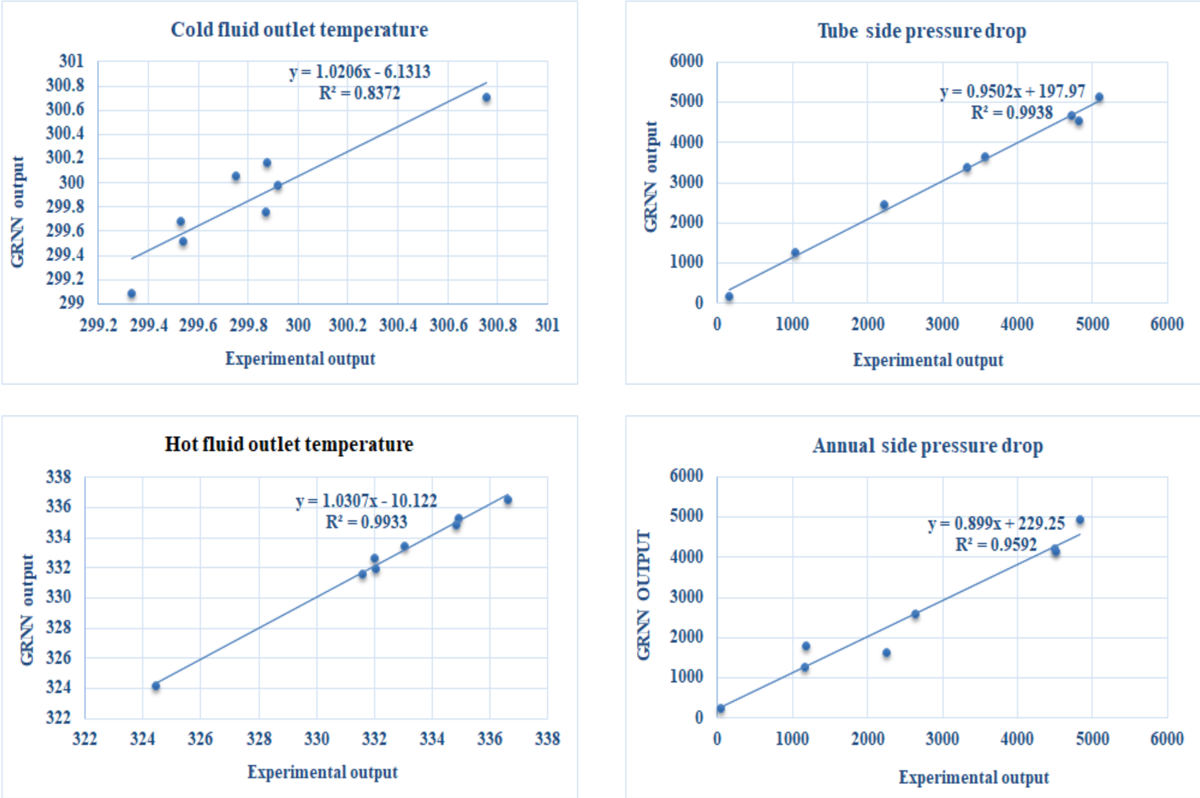

Fig.7 Comparision between experimental and GRNN outputs for 8 tested data sets

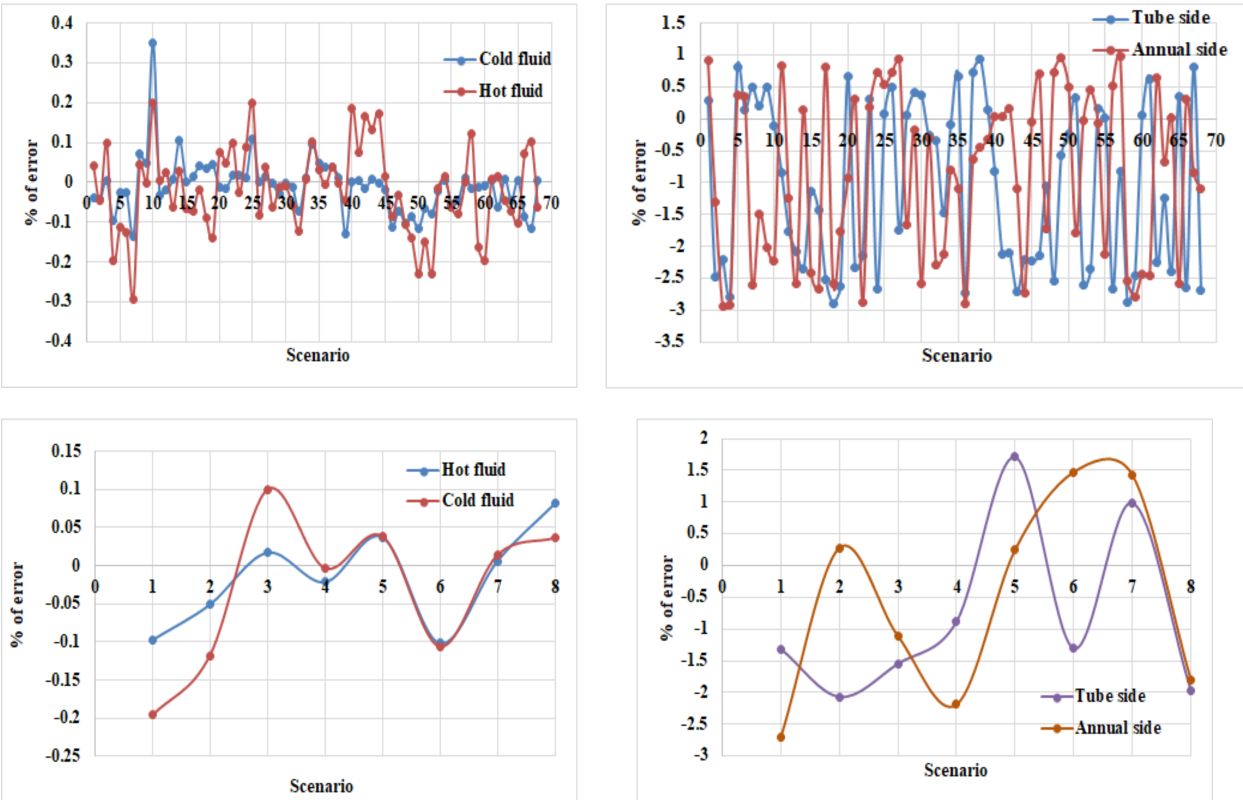

Fig.8 Error percentage between experimental and GRNN outputs for 8 tested data sets

IV. 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 double elliptical leaves strips in the pipe with emphasis on increasing the thermal performance.

From the results of experimentation a nonlinear relation was obtained between inputs and outputs hence GRNN was executed to get an association among input and output parameters. Utilizing GRNN gave faster and better results with errors less than 1%.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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