

# Implementation of GRNN for Evaluating the Pressure Drop and Heat Transfer in a Heat Exchanger

## By Utilizing Triple Elliptical Leaf Angle Strips With Same Orientation and Opposite Direction

J. Bala Bhaskara Rao, Ramachandra Raju



**Abstract:** Heat exchangers are the basic devices which are used in many areas wherever applications of heat flow occurs. Its usage varies from common domestic devices to mighty industrial applications. The performance of the heat exchanger shows a very important role for its utilization in many aspects. This performance is not dependent on the design parameters in a particular relationship hence experimental values for thermal performance are taken by utilizing three elliptical leaf strips in a tube and pipe heat exchanger. The three elliptical leaves 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  $0^{\circ}$  to  $180^{\circ}$  with  $10^{\circ}$  intervals. The leaves are placed in the tube side with same orientation and opposite direction of flow and experimentation is conducted to obtain the values. Based on these datasets available a statistical tool is utilized known as GRNN for the comparison between these obtained experimental values & GRNN values. From this comparison the percentage of error between the values is identified as result.

**Keywords:** Performance, opposite orientation, elliptical leaf strips, GRNN.

### I. INTRODUCTION

Heat exchanger is an 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 the shell and finned tube heat exchanger. 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. [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. Enhancing heat transfer by utilizing fins in a heat exchanger was discussed in this paper. Experimentation on triple tube heat exchanger was performed and heat transfer characteristics was found [4] [5]. 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 performance in a double pipe heat exchanger. [8] Effect of triple tube heat exchanger having inner threaded pipe was performed and analyzed [1]. Tube in tube heat exchanger was numerically analyzed. The effect of plain twisted tapes, semicircular tapes, were compared with the performance in heat exchangers. 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 [6]. Using enhancement liners double pipe heat exchangers was studied [9]. Investigation of heat transfer coefficient Using artificial neural networks was studied. [13] Cross flow heat exchanger was studied and analyzed using neural networks. Thermal characteristics of a plate fin heat exchangers was studied and 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. [10][11][12] Heat transfer was analyzed using prediction tool on various heat exchangers. [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.

### II. EXPERIMENTAL SET UP

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

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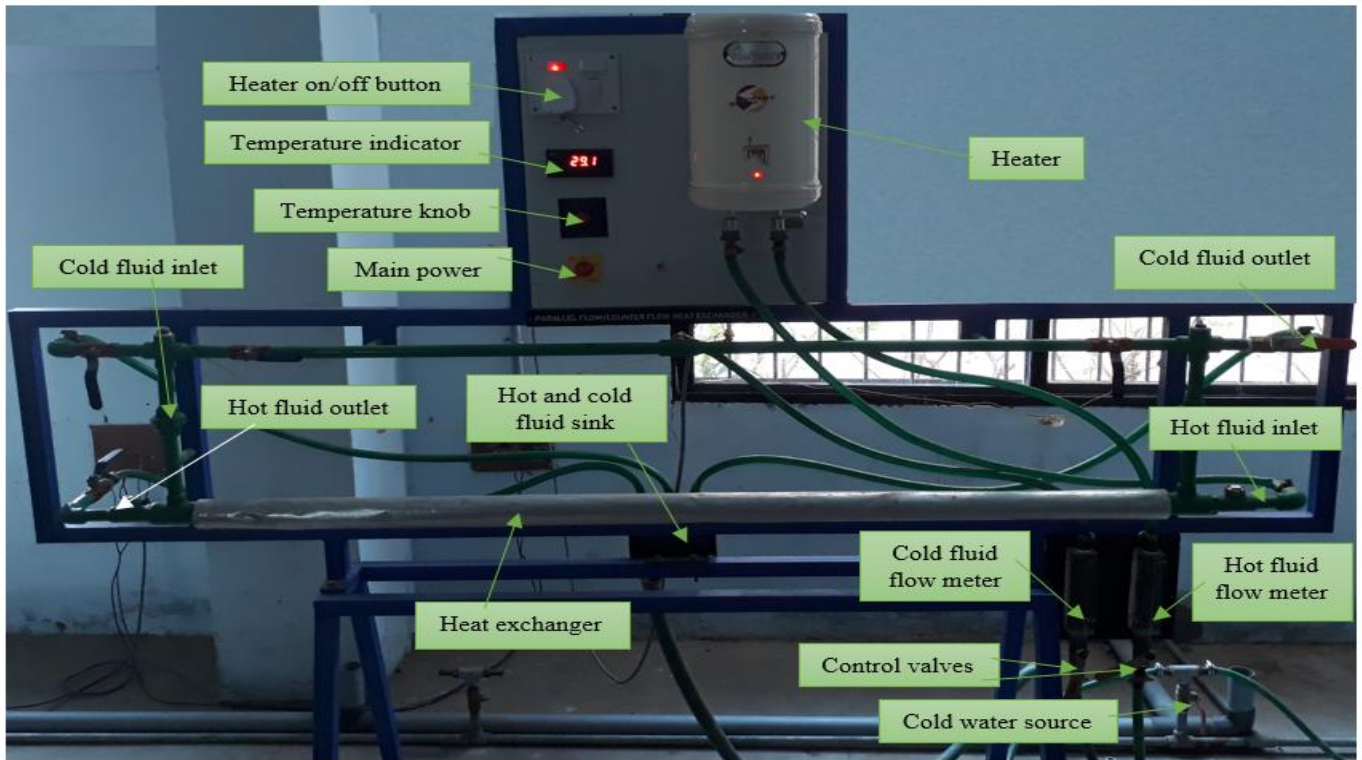
## Implementation of GRNN for Evaluating the Pressure Drop and Heat Transfer in a Heat Exchanger By Utilizing Triple Elliptical Leaf Angle Strips With Same Orientation and Opposite Direction

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 2:1 with thickness of 1 mm. For the entire length of the pipe with a distance of 50 mm the leaves are located with  $90^\circ$  rotation towards the shaft. All the leaves are placed along the same orientation and 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 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.

Leaf angle	Strip with elliptical leaf with same orientation and opposite direction
0	
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	
130	
140	
150	
160	
170	
180	



**Fig.1 Experimentation on heat exchanger and elliptical leaf strip with different angles.**

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. Using Reynolds Number the mass flow rates for different turbulent conditions are identified and experiment is performed. Elliptical leaves 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

$$(Re_t) = \frac{\rho v D_e}{\mu} \quad (1)$$

Where  $\rho$  = Density of inner fluid in  $\text{Kg/m}^3$

$v$  = Velocity of inner fluid in  $\text{m/sec}$

$D_e$  = Hydraulic diameter of pipe in meters

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

$d$  = Inner diameter of inner pipe in meters

$\mu$  = Dynamic viscosity of inner fluid  $\text{Kg/m-sec}$

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

Where  $\rho$  = Density of annual side fluid in  $\text{Kg/m}^3$

$v$  = Velocity of annual side fluid in  $\text{m/sec}$

$D_e$  = Hydraulic diameter of pipe in meters

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

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

$A_c$  = Minimum flow area in  $\text{m}^2$

$P_h$  = Wetted perimeter in meters

$\mu$  = Dynamic viscosity of annual side fluid  $\text{Kg/m-sec}$

The heat transfer rate is calculated 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 fluids in  $\text{kg/sec}$ .

$c_{pc}, c_{ph}$  are specific heats in  $\text{kJ/kg k}$ .

$A$  = surface area in  $\text{m}^2$

$\Delta T_m$  = logarithm mean temperature difference for hot and cold fluid in (kelvins)

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

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

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

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



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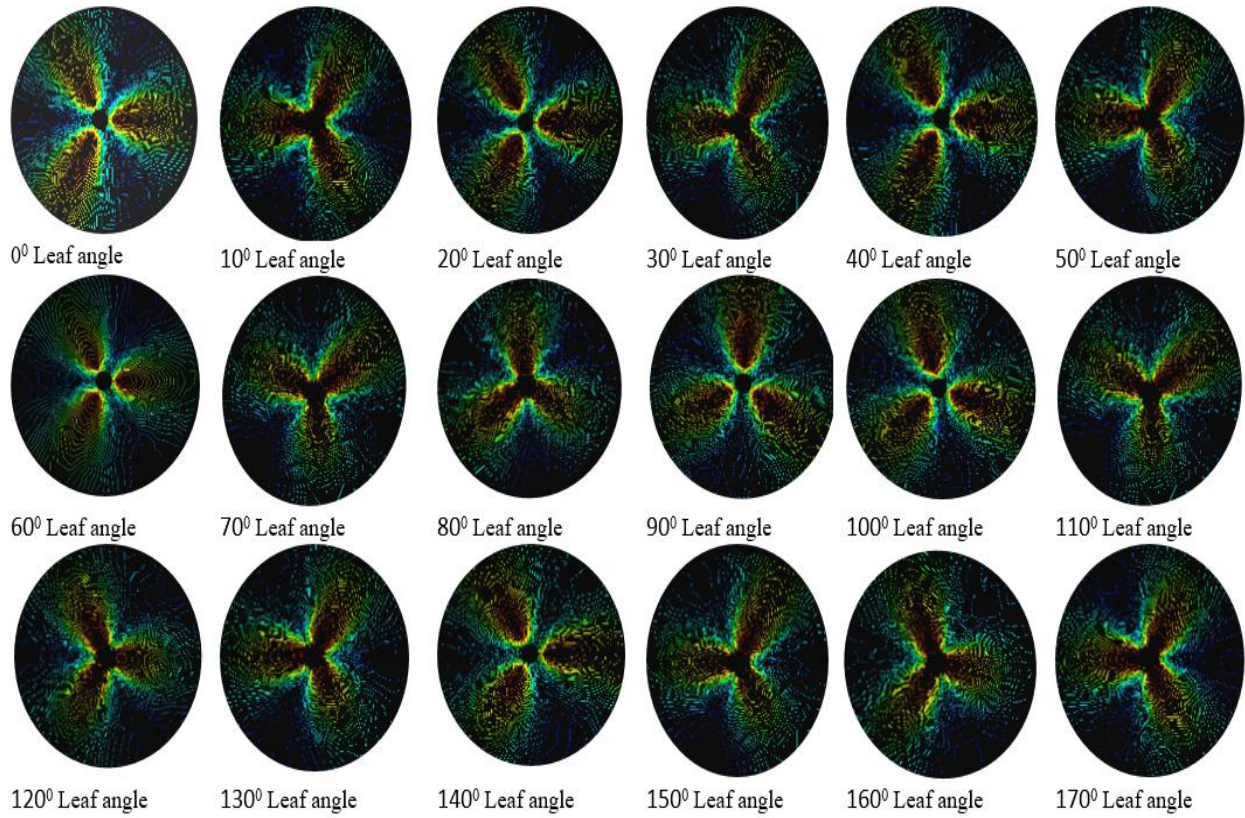


Fig.2 Fluent results of pressure variation at different elliptical leaf angles

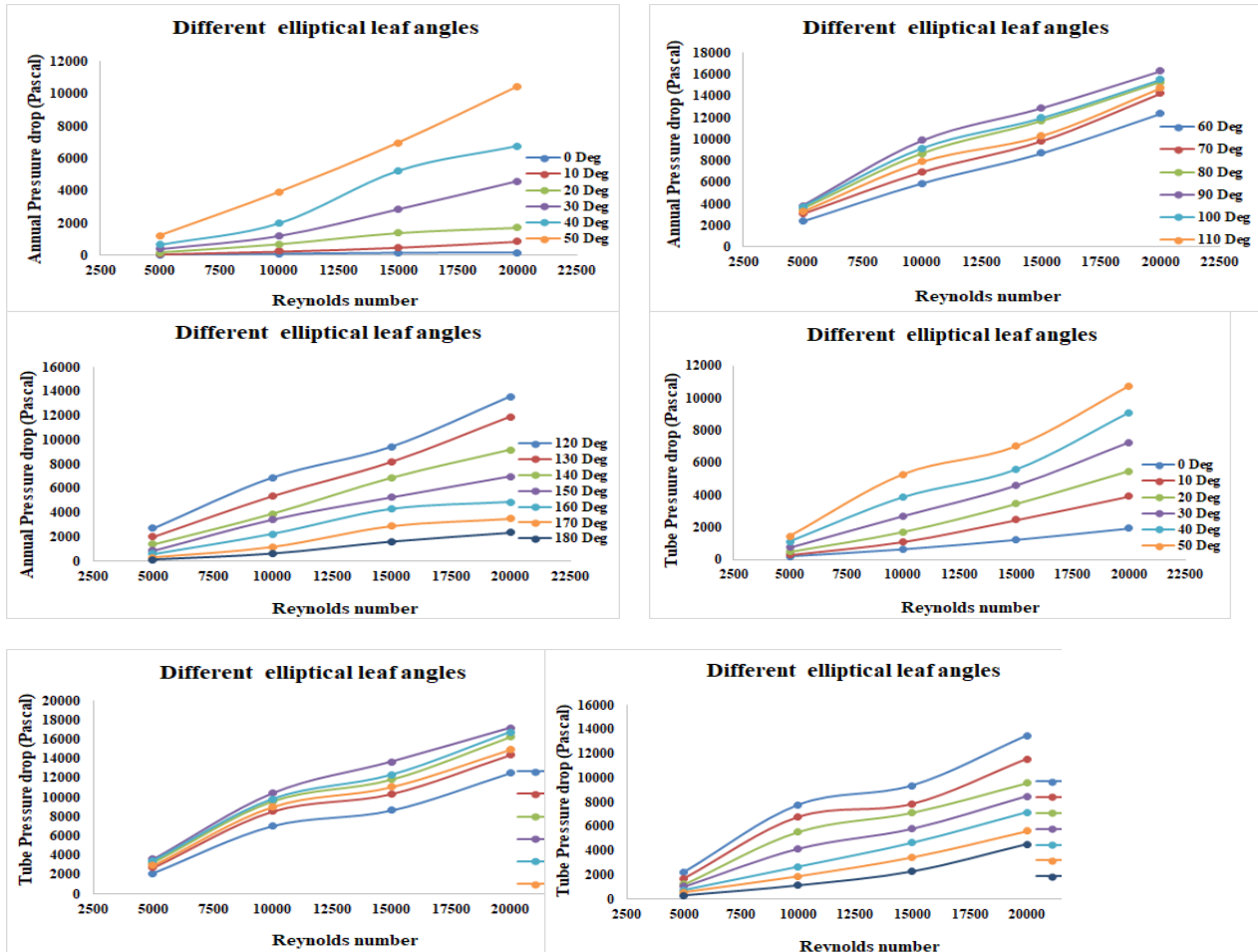


Fig.3 Annual and Tube side drop variation at different elliptical leaf angles

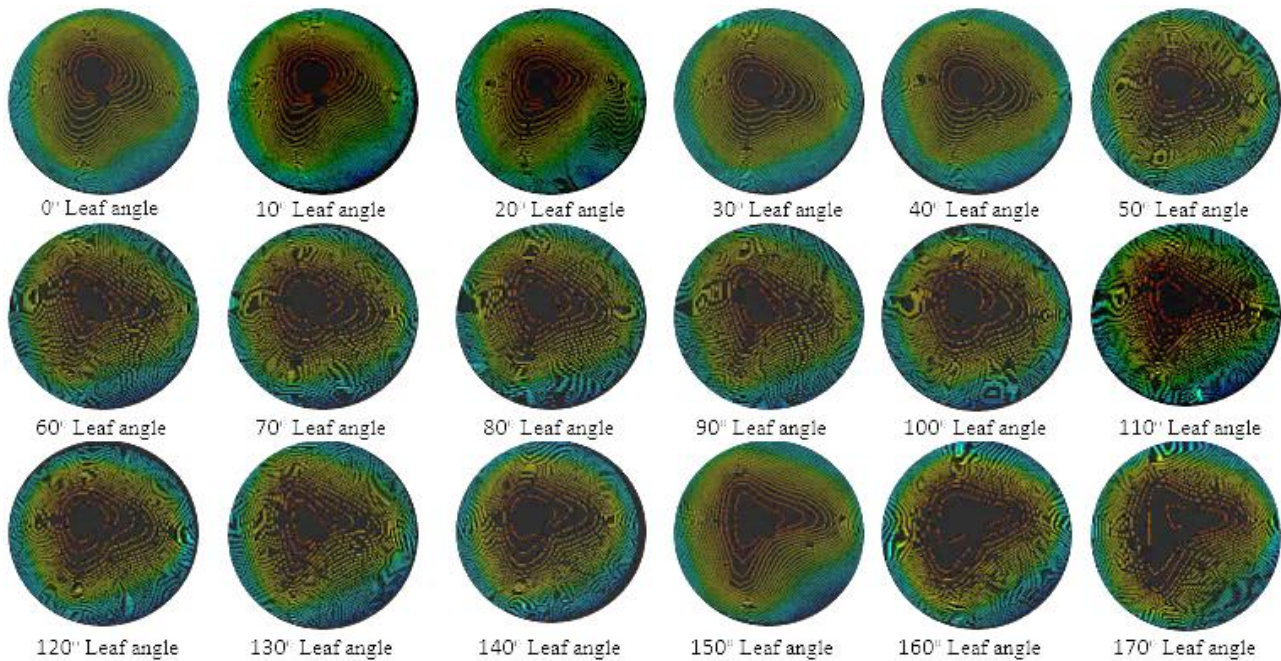


Figure.4 Temperature variations of three elliptical leaf at various inclinations

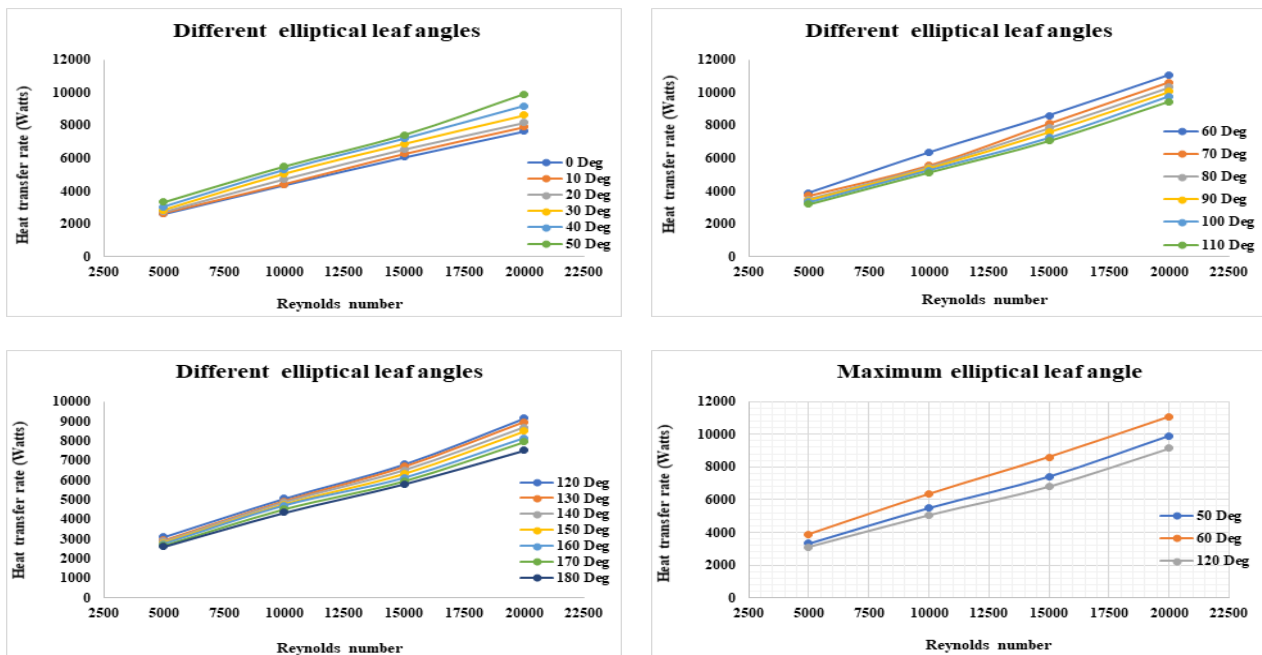


Figure.5 Heat transfer variation at different elliptical leaf angles

### III. MODELLING OF GRNN

In Generalized Regression Neural Network the regression of reliant variable Y (outputs) on X (inputs) which are independent variables computes the most appropriate values of Y for each value of X. Assumption of some unknown parameters in the function form is required for system identification. The input and output data sets are considered on fluent results from Fig.2 and Fig.5. Hence the modelling is done by the following equation

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

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

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



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

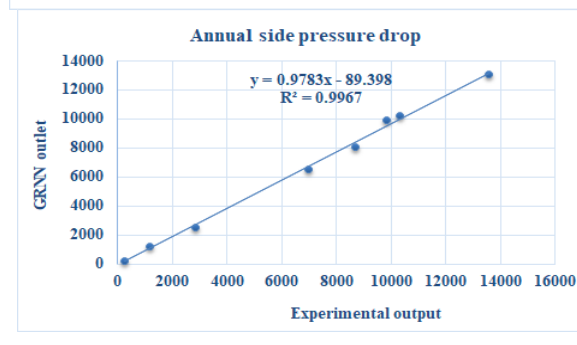
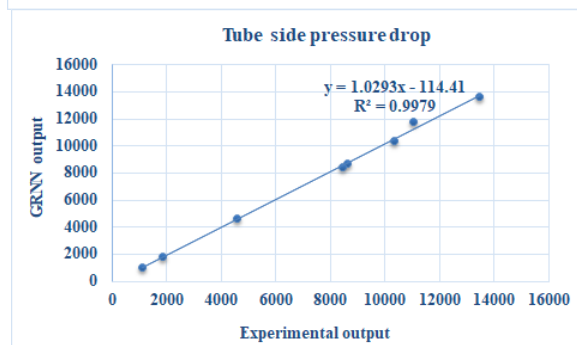
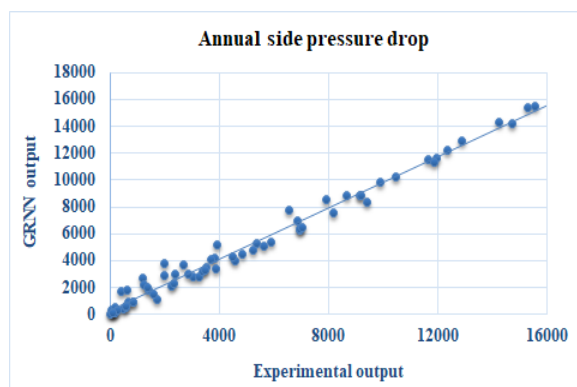
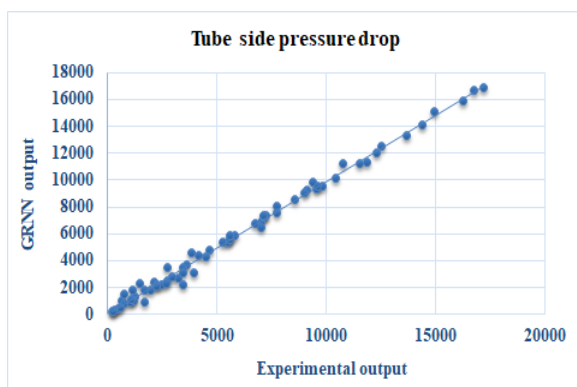
As this experiment deals with finding the performance so in this regression method taking the values of temperatures and mass flow rates outputs of pressure drop is found out .Hence in this model we used “68” experimental data sets “trainee data” sets are chosen & “8” “test data “sets are chosen randomly 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 the graphs the value obtained between the experimental sets and regression analysis gave us good accuracy.

Tab.1 GRNN input and output weights

Demonstration	Input	Weight of input
X1	Elliptical leaf angle ( $\theta$ )	( $0^\circ - 180^\circ$ )
X2	Inlet cold water temperature ( $T_{ci}$ )	298 K
X3	Inlet hot water temperature ( $T_{hi}$ )	348 K
X4	Cold water mass flow rate ( $M_c$ )	0.223883 Kg/sec
		0.447766 Kg/sec
		0.671649 Kg/sec
		0.895532 Kg/sec
X5	Hot water mass flow rate ( $M_h$ )	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 ( $T_{co}$ )	As per investigation
Y2	Hot fluid outlet temperature ( $T_{ho}$ )	As per investigation
Y3	Tube side pressure drop ( $\Delta P_t$ )	As per investigation
Y4	Annual side pressure drop ( $\Delta P_a$ )	As per investigation



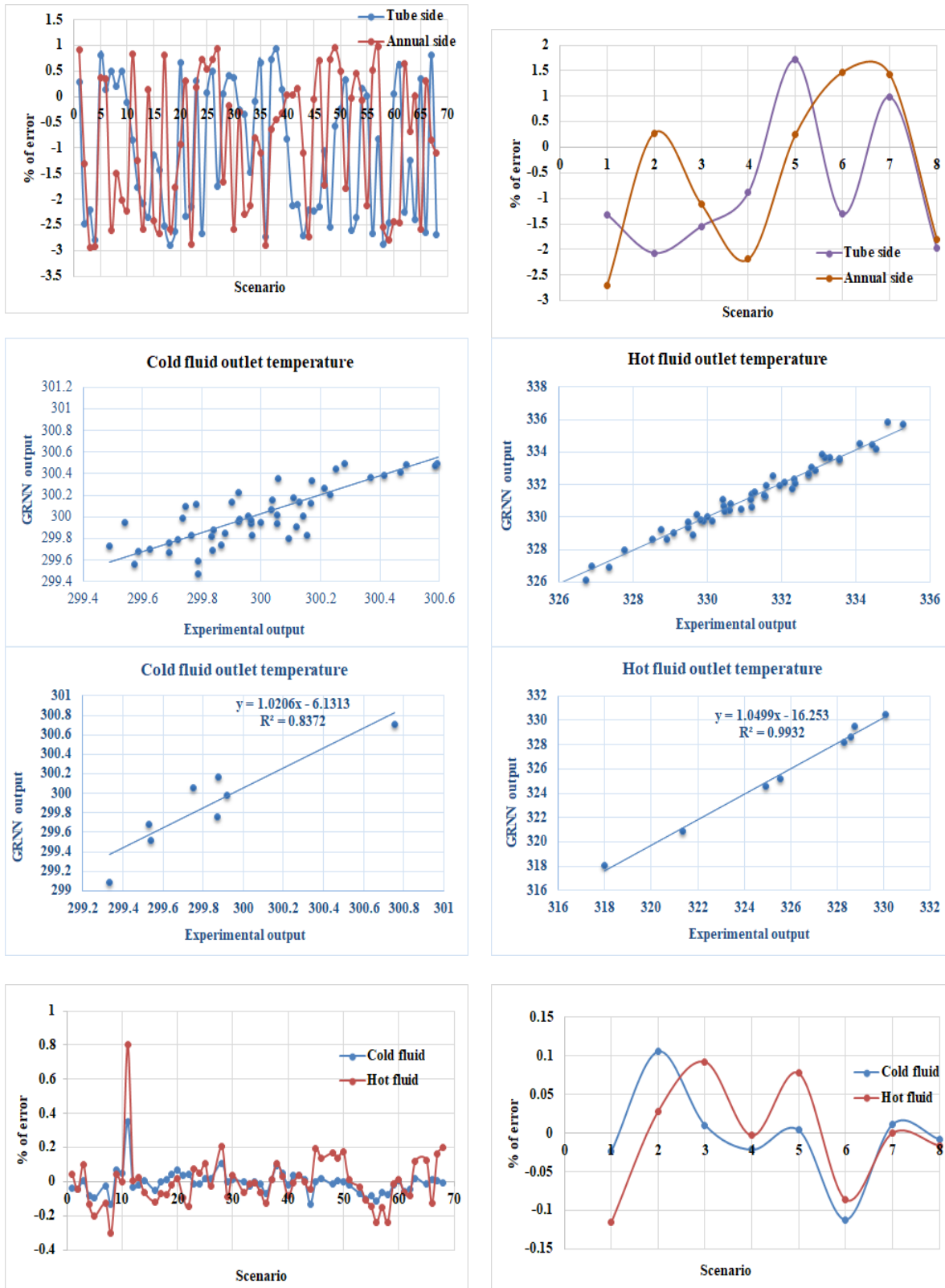


Fig.4 Comparison of GRNN and experimental for both trainee and tested data sets

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 three elliptical leaves strips in the pipe with emphasis on increasing the heat transfer rate. From the results of experimentation a nonlinear relation was obtained

between inputs and outputs hence GRNN was used to get a relationship between dependent & independent variables. 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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