

# Execution of a Modern Prediction Tool for Evaluation of Thermal Performance in a Heat Exchanger by Expending Triple Elliptical Leaf Angle Strips with Altered 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 plays 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 different 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 results.

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

## I. INTRODUCTION

Human comfort is the basic theme for human existence. Heat exchangers plays a very important role in achieving this comfort conditions. To improve the performance of heat exchangers various methods and experimentation were done.

A double pipe heat exchanger was analyzed by adding porous baffles twisted tapes bent strips, shot blasting heat transfer enhancement liners & turbulators to find it's thermodynamic & hydrodynamic performance. [1] Experimental analysis was done on concentric tube heat exchangers using various fins configuration. [2] Using twisted pipe heat exchangers numerical and experimental analysis was done on heat exchangers. [3] Using Nano fluids and baffles the double pipe heat exchangers were numerically & experimentally analyzed. [5]

A tube in tube out heat exchanger with helical coil was analyzed to obtain the heat transfer rate. [7] Fabrication and standardization of double pipe heat exchanger for laboratory scale was performed. [8] Experimental performance of a triple tube heat exchanger was done using a dimple tubing. [10] Using different flow configurations experimental & computational technique were investigated on a double pipe heat exchangers. Augmentation in heat transfer coefficient using twisted tape and semicircular cut insert were studied. [4] Experimental analysis of heat exchanger was analyzed using Solid works software. Numerical analysis of triple tube heat exchanger was performed using ANSYS software. Condensation heat transfer enhancement of steam at low pressures were experimentally analyzed. [6] Analytical study of reliable compartmental model for double pipe heat exchangers were studied. In a helical flow duct a numerical investigation on heat transfer enhancement & flow characteristics were studied fouling in a double pipe heat exchanger was studied in this paper. [9] Heat transfer analysis of helical strip insertion with spaced cut sections are studied in a circular pipe. A review on double pipe heat exchanger with CFD analysis was performed in this study. Enhancement of heat transfer rate in a shell and tube heat exchanger using conical tapes were studied. Two phase Nano fluids were studied with twisted tape and helical insertion in the tubes.

Manuscript published on 30 September 2019

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Based on the literature survey the methods utilized were focused on improvement of thermal performance of the heat exchangers. <sup>[11][12]</sup> Heat transfer was analyzed using prediction tool on various heat exchangers. <sup>[13][14]</sup> The effect of generalized predictive control was studied <sup>[15]</sup> 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.

So in this paper concentration is on improvement of thermal performance. The enhancement in performance is done by using three elliptical shaped leaf strips in the tube at different orientation and different direction for the flow of working fluid which is the novelty of this experimentation. 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. Once the steady state is achieved the experimental values are noted for all the angles position. A

statistical tool of Regression analysis is introduced to find the output values for a known input values.

## 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. Water is taken as the working fluid and the equipment is designed as follows. Water is pumped from a storage tank & it is divided into two streams for the 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 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. For experimentation purpose the strips are placed along the opposite direction and opposite orientation as shown in fig.2. The experiment is conducted by placing three elliptical leaf strips with the following inputs.

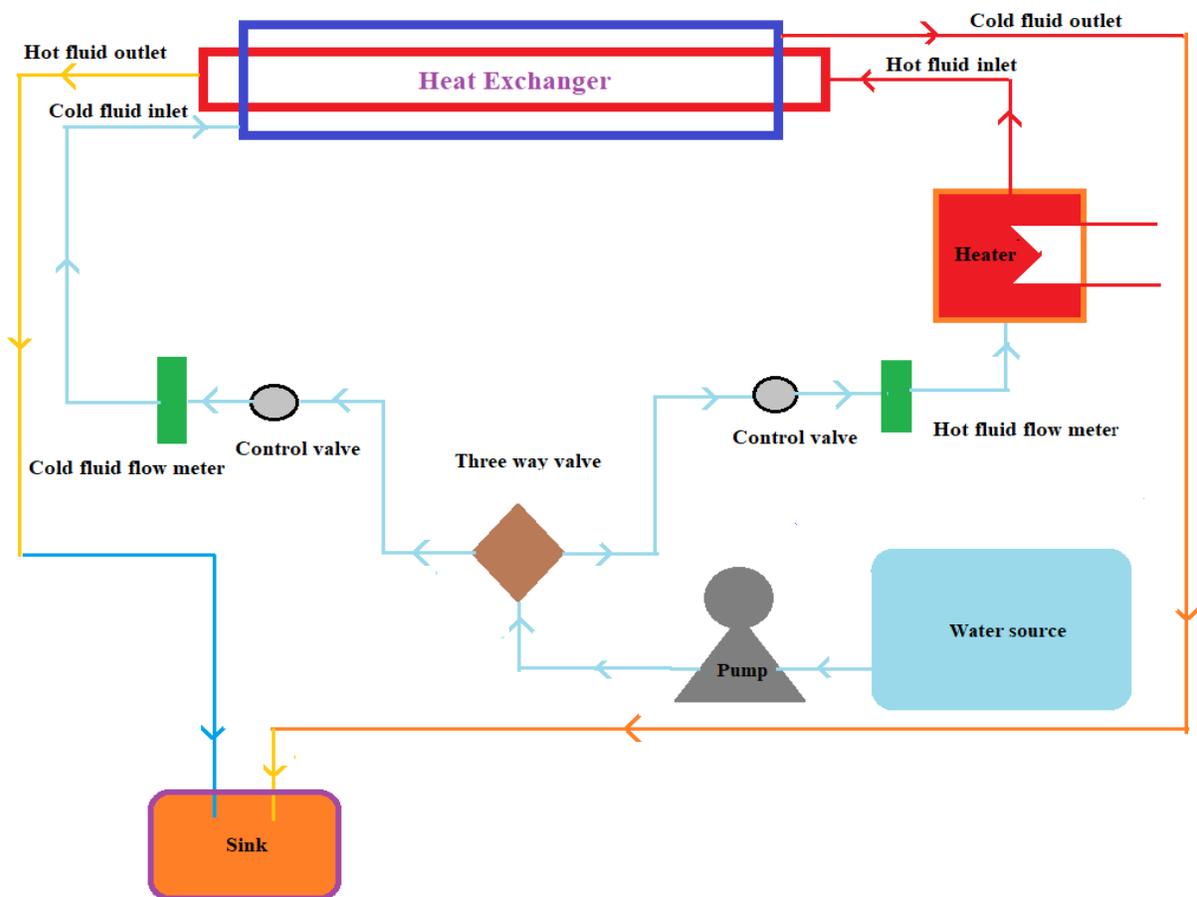


Fig.1 Experimental set up of double pipe heat exchanger

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° rotation towards the shaft. Both the leaves are placed along the opposite 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 annulus side & tube side respectively. Before reaching the tube side the working fluid is heated in an electrical heater &

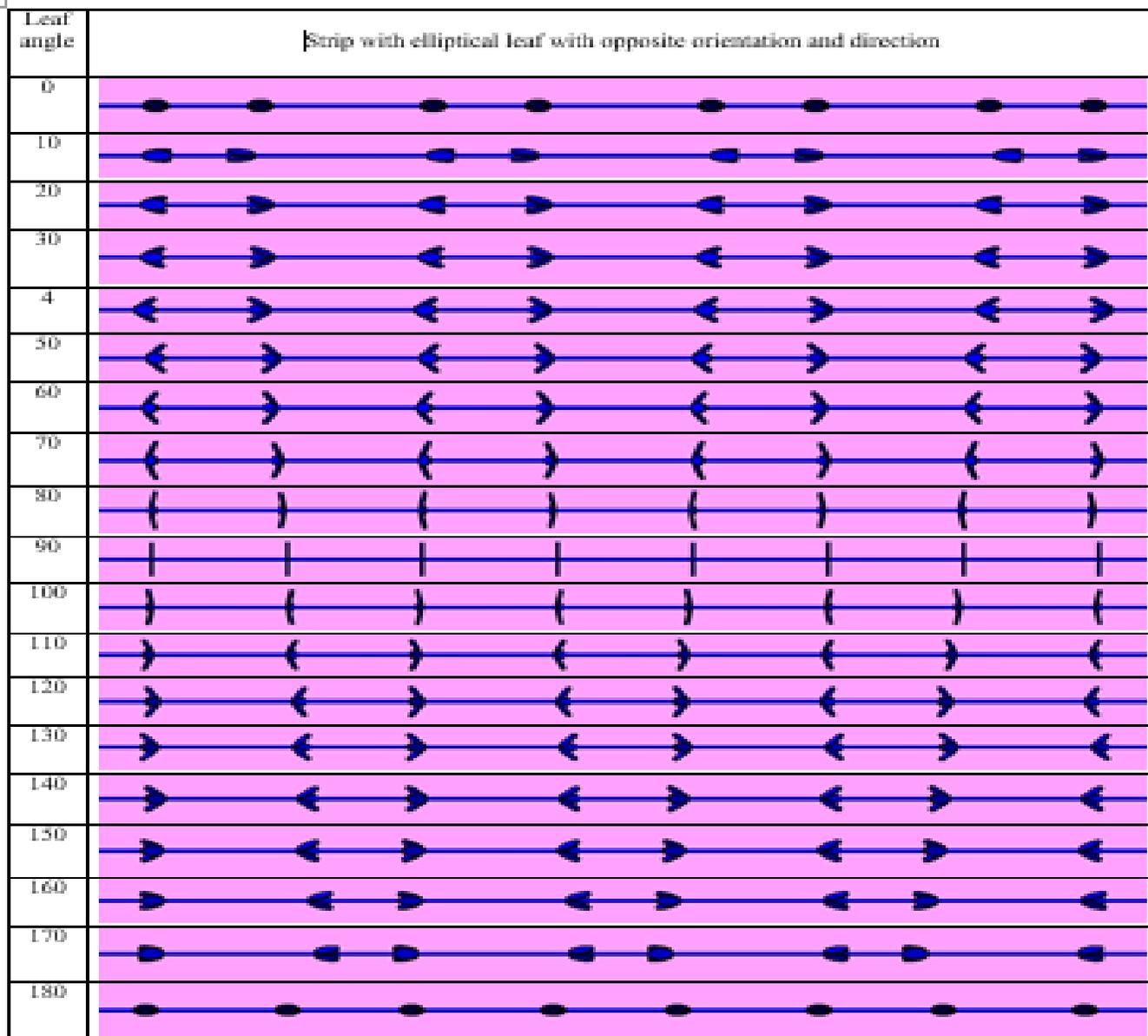


Fig.2 Placement of three elliptical leaf strips with opposite orientation and direction

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 triple leaf strip with different 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

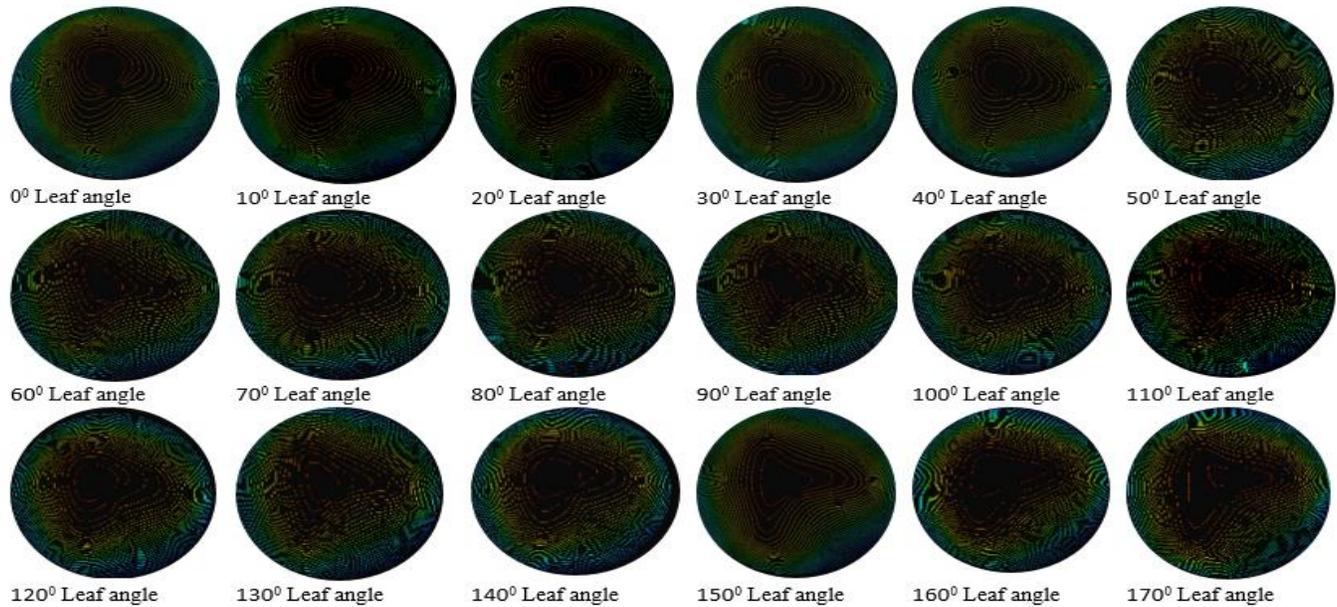
readings are taken for calculation. The fluid flow is incompressible and turbulent in the pipes. The experimentation started with the utilization of double pipe heat exchanger with inner and outer pipe made up of copper and steel respectively as shown in figure.1. The fluid flow is incompressible and turbulent in the pipes.

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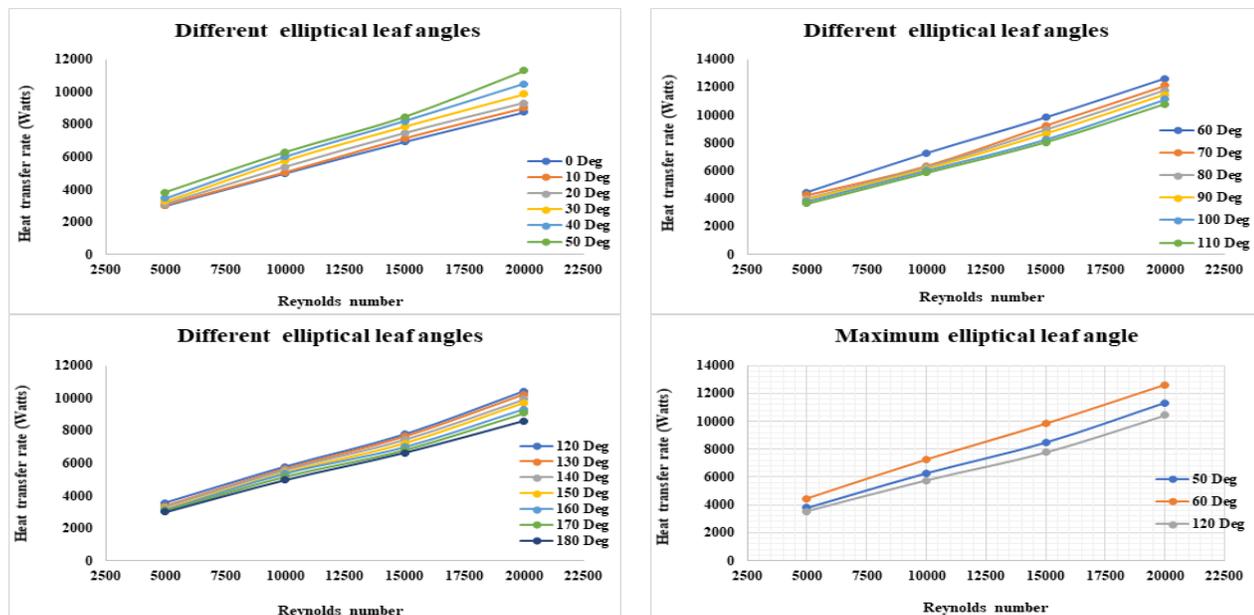
Here the experimentation is conducted based on 19 scenarios where the elliptical leaf strips are placed at different angles from  $0^{\circ}$  to  $180^{\circ}$  at  $10^{\circ}$  intervals as shown in Fig.2. The elliptical leaves are designed in major to minor axes as 2:1 and the thickness is 1mm. These elliptical leaves are located at 50mm distance at  $90^{\circ}$  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 in Fig.1. The Reynolds number is calculated using different mass flow rates obtained at shell

side and tube side. In this analysis, turbulent flow is considered for both the pipes and accordingly calculations are performed. From the obtained Reynolds's no. analysis is done to get the heat transfer rates and pressure drops.

From the obtained results of heat transfer rates and pressure drops comparison is done with the values of GRNN & the percentage of error is calculated. The numerical analysis are conducted and tabulated from fig.3 to fig.6. The variations of heat transfer and pressure drop are shown in diagrams.



**Fig.3 CFD analysis of heat transfer at different angles of three elliptical leaf strips**



**Fig.4 Heat transfer variation at different elliptical leaf angles**

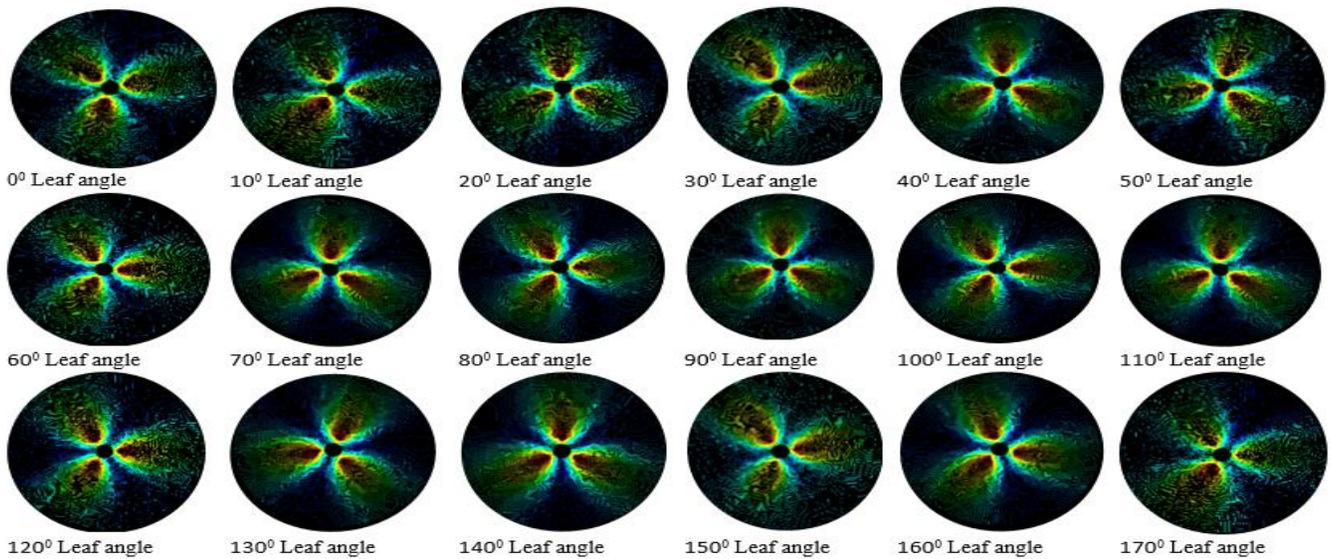


Fig.5 CFD analysis of pressure drop at different angles of three elliptical leaf strips

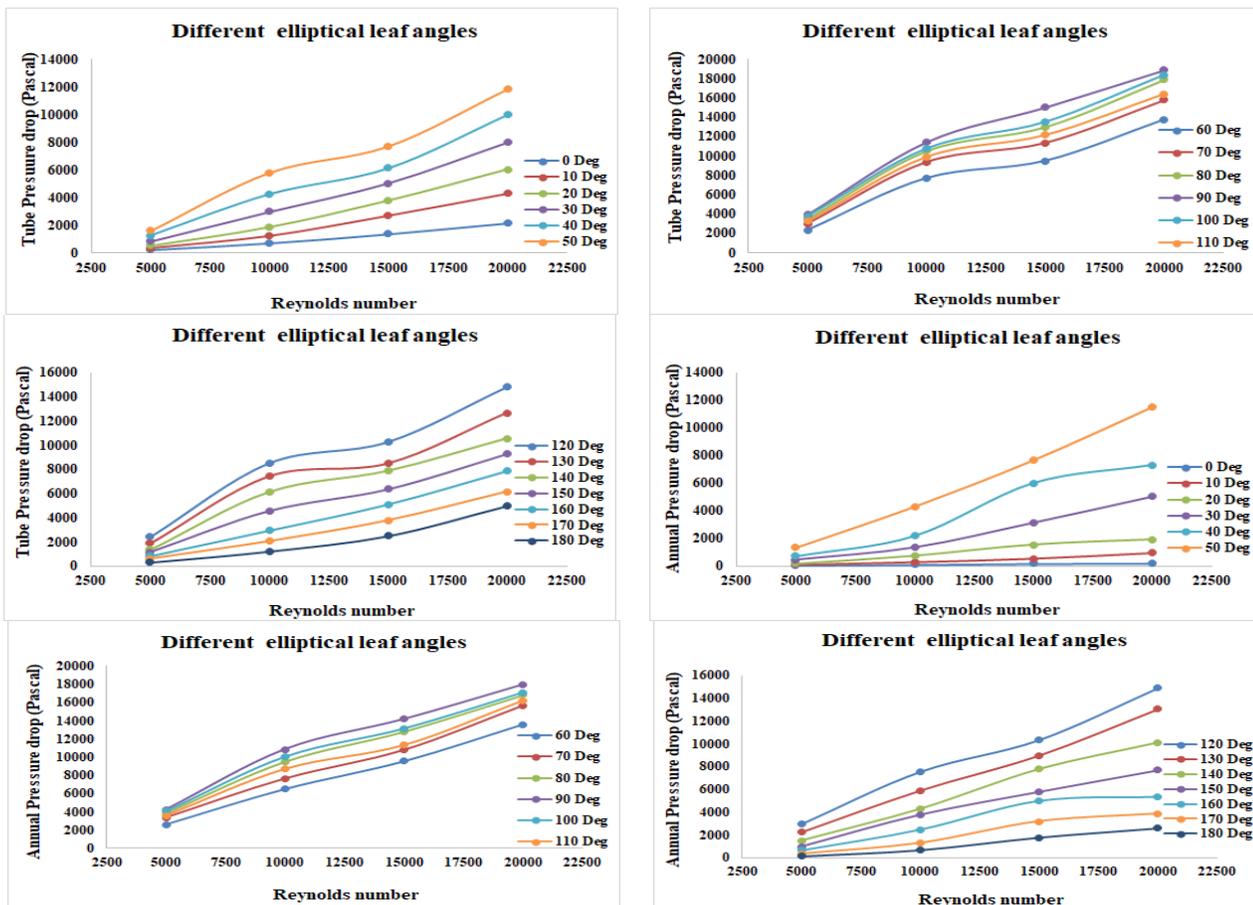


Fig.6 Annual and tube side pressure drop variation at different elliptical leaf angles

### III.GENERALISED REGRESSION NEURAL NETWORK

It is a one pass neural network learning algorithm used to find continuous variables as outputs. The basic advantage of using

this statistical tool is by having sparse inputs outputs can be developed by this algorithm and tabulated in tab.1.

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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

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

(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

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

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 .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 and 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 good accuracy.

**Tab.1 GRNN inputs & outputs**

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

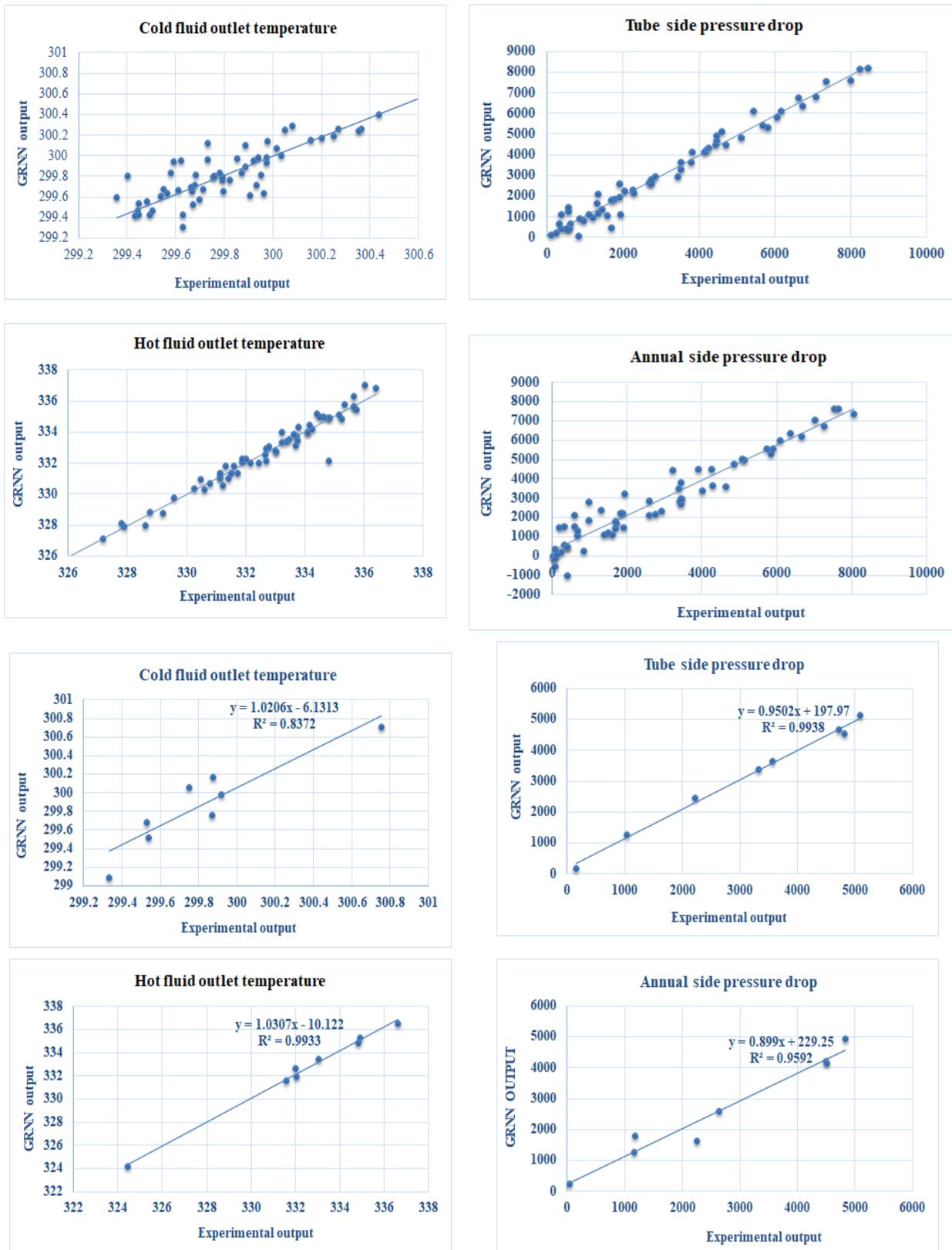


Fig.7 Temperature & pressure values comparison with GRNN & experimental for both trainee and tested data

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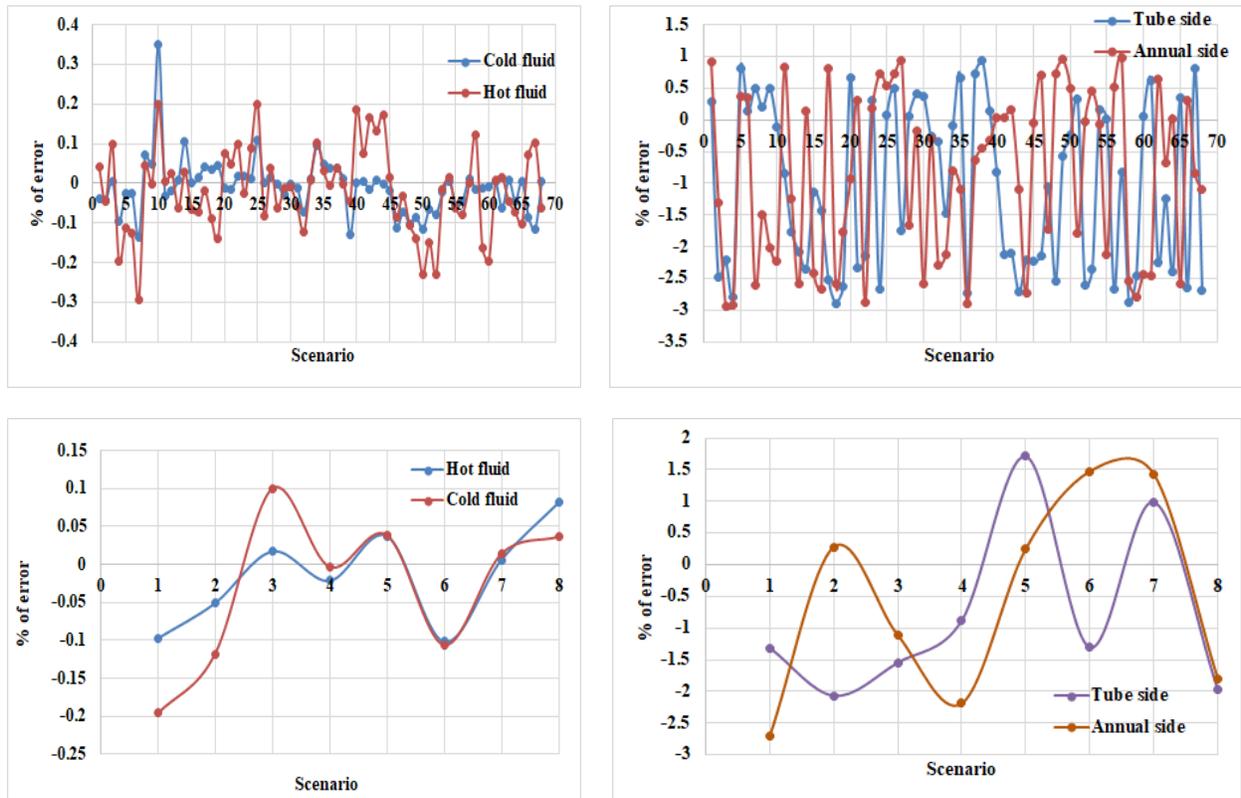


Fig.8 percentage of errors between GRNN and experimental values for trainee and tested data

## IV.CONCLUSION

Updating in the current era has become daily task in our day to day life .Engineering based applications are getting interconnected with each other and getting updated to meet the mammoth expectations of current customers. A few such examples of it are using electronics in the automobile field where sensors have taken a leading edge in the entire automobile sector. Applications of IOT (internet of things) over daily used equipment has made it a bare necessity. Similarly this paper is a combination of experiment and statistical tool of GRNN to obtain the thermal performance of double pipe heat exchangers. A comparison between these two obtained values are plotted to obtain the percentage of errors. After getting the plot it is noted that these values are in good convergence with each other since the obtained accuracy is around 98% in this case. The proposed future work may include the same work performed on different fluids and finding the values once again or using the experimental analysis for different orientations of leaf strips added.

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