CHAPTER 3

OBJECTIVES

3.1 OBJECTIVES

On the strength of the exhaustive review of the work done by previous researchers, it is found that only countable work has been done on Spiral plate Heat Exchangers (SHE). However, it is evident that most of the work focussed only on developing correlations between the dimensionless parameters viz. Reynolds Number, Nusselt Number, etc. From the literature, it is also observed that the research focus was not much on optimising the overall heat transfer coefficient and pumping power in a Spiral plate Heat Exchanger using RSM technique. The numerical analysis based on Computational Fluid Dynamics (CFD) modelling for spiral plate heat exchangers is seldom reported. Also, not much work was reported about intelligent modelling to predict the unseen data. The emphasis given to the application of intelligent modelling techniques like Artificial Neural Networks (ANN), Adaptive Network based Fuzzy Inference System (ANFIS) and Gustafson-Kessel (G-K) clustering techniques for spiral plate heat exchangers is not overwhelming. Thus, the author is motivated to carry out the research in the areas which seem to have the potential, yet unattended. Hence, the performance analysis of SHE is carried out by implementing RSM optimisation, CFD modelling and Intelligent modelling techniques. Hence, the objectives of the research work are framed to fill the gap sensed.
The objectives of the investigations to be carried out in this work can be summarised as follows:

- To design the experimental conditions based on the Design of Experiments (DOE) technique using Response Surface Methodology (RSM) for the process fluids, Water, Sea Water (3%), Sea Water (12%), Methanol, Butanol and Biodiesel based on their industrial applications.

- To conduct the experiments on a spiral plate heat exchanger using the six fluid systems, namely, Water-Water, Water-Sea Water (3%), Water-Sea Water (12%), Water-Methanol, Water-Butanol and Water-Biodiesel. The experimental conditions are to be designed based on the experimental conditions proposed by the Box-Behnken design.

- Evaluation of the overall heat transfer coefficient and the pumping power for all the six fluid systems corresponding to the variables namely, hot fluid flow rate, cold fluid flow rate and hot fluid inlet temperature.

- Optimisation of the process variables to obtain the maximum possible overall heat transfer coefficient by consuming the minimum possible pumping power using MINITAB software.

- Experimental validation of the RSM predicted results.

- To perform numerical validation of the experimental results by creating a three dimensional CFD model of the spiral plate heat exchanger in GAMBIT 2.4 software.

- To predict the unseen data in order to throw more light on the overall behaviour of the individual fluid systems using ANN, ANFIS and G-K clustering techniques.

- To compare the results of the proposed intelligent models with experimental results and RSM predictions in order to find the best performing model.
3.2 ORGANISATION OF THE THESIS

This thesis is divided into nine Chapters. The organisation of every Chapter is briefly described below:

Chapter 1 presents a brief introduction of heat exchangers. The description of the elementary construction of a spiral plate heat exchanger is given with the specific flow paths of hot and cold fluid. The advantages and applications of spiral heat exchangers are listed.

Chapter 2 presents the review of the past research works of the scholars. The literature is reviewed in four broad categories, namely, Heat Exchangers with specific attention to geometries, Response Surface Methodology, CFD Modelling and Intelligent Modelling.

Chapter 3 presents the list of objectives of this research work. The chapter organisation is also given.

Chapter 4 presents the detailed methodology of both the experimental research work to be carried out and the proposed modelling techniques in flow charts.

Chapter 5 presents the needs and ways of the optimisation of the process parameters, namely, hot fluid flow rate, cold fluid flow rate and hot fluid inlet temperature for a spiral plate heat exchanger. The basics of Response Surface Methodology with specific reference to the Box-Behnken design is discussed.

Chapter 6 presents the description of the experimental set up and the procedure of experimentation. The dimensions of the spiral plate heat exchanger are tabulated. The variables chosen are also tabulated with their respective experimental ranges. The results of both the overall heat transfer coefficient (U) and pumping power (W_p) for the Box-Behnken design based experiments for all the six fluid systems are tabulated. The RSM predicted values of ‘U’ and ‘W_p’ are also tabulated. The ANOVA analysis for both ‘U’ and ‘W_p’ is carried out and the fitting models are developed. Also, the quadratic equations to predict U and W_p are also formulated individually. The optimal conditions proposed by RSM to obtain the maximum possible overall heat transfer coefficient with minimum pumping power consumption are graphically and numerically displayed for all the fluid systems. The validation of the proposed
optimisation parameters is carried out by conducting verification experiments and the results are presented.

**Chapter 7** presents the governing equations for the proposed numerical model with discretisation methods. The geometry of the spiral plate exchanger is created in GAMBIT environment and is imported into FLUENT software to predict the temperature profiles of the spiral plate heat exchanger. Simulations are carried out for all the six fluid systems in all the cases (15 cases per fluid system). The temperature data for the outlet conditions are computed and the corresponding temperature profile of the particular experimental condition is also obtained. The predicted temperature profiles are compared with those of the experimental data in order to validate the generated CFD model.

**Chapter 8** presents the development of intelligent modelling techniques, namely, ANN, ANFIS and G-K cluster for the spiral plate heat exchanger. For every technique, individual models are developed for the overall heat transfer coefficient (U) and pumping power (W_p) with the three inputs viz. cold fluid flow rate (m_c), hot fluid flow rate (m_h) and hot water inlet temperature(T_{h,in}) for Water-Water, Water-Sea Water (3%), Water-Sea Water (12%), Water-Methanol, Water-Butanol and Water-Biodiesel systems. The data required to train the models are obtained from the experimental data based on Response Surface Methodology (RSM). The ANN models are developed using Back Propagation Network (BPN) algorithm, incorporating Levenberg-Marquardt (L-M) training method. The fuzzy clustering models are developed based on Gustafson-Kessel (G-K) algorithm. The ANFIS models are developed based on the advanced neural-fuzzy technology. The accuracy of the ANN, G-K clustering and ANFIS models are verified according to their ability to predict unseen data by minimising the performance measures like root mean square error (RMSE), average percentage error (APE) and correlation coefficient (%R^2) value.
Detailed algorithms for ANN, G-K fuzzy clustering and ANFIS techniques are given in this Chapter. Results are presented and discussed. The performance measures like percentage error, APE, RMSE and Correlation coefficient ($%R^2$) are calculated and tabulated for $U$ and $W_p$ for all the fluid systems by implementing ANN, ANFIS and G-K clustering models and compared with those of experimental values and RSM model output. From the results, G-K is found to be the best model for the analysis of SHE.

Chapter 9 presents the conclusions drawn from the experimental work and modelling techniques of the research. The scope for the future work is also presented.