CHAPTER - 6
SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.0 SUMMARY

In the present study, optimization of shell and tube heat exchangers is carried out using three different methods. They are as follows:

- Kern method
- Bell-Delaware method
- Pressured drop model using FEM.

Optimization is performed for different configurations on STHXs using evolutionary algorithms such as genetic algorithm, cuckoo search algorithm, bat algorithm, flower pollination algorithm. Since the behaviour of each algorithm is different due to their habitats and biological process in the nature. Therefore, different algorithms give different optimal values having one or the other advantages. A case study from the open literature for a shell and tube heat exchanger is optimized using flower pollination algorithm and bat algorithm by the simplest method called Kern method. The effects are discussed and the results are compared with the literature. Further, the bat algorithm is used for multi-objective optimization by Bell-Delaware method and it is compared with genetic algorithm to find optimal geometrical values for the heat exchanger so as to obtain best thermo hydraulic performances. The genetic algorithm is used to overcome the drawbacks of the previous work from the literature. The cuckoo search algorithm is used to compare the results of multi-objective and single objective optimization by Bell-Delaware method. In this study, a new model pressure drop based on FEM method is used for optimization on shell and tube heat exchanger. This model proved that its theoretical values are quite matching with the experimental values.
6.1 CONCLUSIONS

In this chapter, conclusions will be discussed individually for each models from 1 to 7.

6.1.1 MODEL-1: OPTIMIZATION OF SHELL AND TUBE HEAT EXCHANGERS USING FLOWER POLLINATION ALGORITHM. (SINGLE OBJECTIVE FUNCTION i.e. TOTAL COST).

6.1.2 MODEL-2: OPTIMIZATION USING BAT ALGORITHM ON SHELL AND TUBE HEAT EXCHANGERS BY KERN METHOD. (SINGLE OBJECTIVE FUNCTION i.e. TOTAL COST).

6.1.3 MODEL-3: OPTIMIZATION OF SHELL AND TUBE HEAT EXCHANGERS BY MINIMIZING THE ENTROPY GENERATION USING BAT ALGORITHM. (SINGLE OBJECTIVE FUNCTION i.e. ENTROPY GENERATION).

6.1.4 MODEL-4: MULTI-OBJECTIVE OPTIMIZATION USING GENETIC ALGORITHM ON SHELL AND TUBE HEAT EXCHANGER BY BELL-DELAWARE METHOD.

6.1.5 MODEL-5: A COMPARISON BETWEEN MULTI-OBJECTIVE AND SINGLE OBJECTIVE OPTIMIZATION USING GENETIC AND CUCKOO SEARCH ALGORITHMS BY BELL-DELAWARE METHOD.

6.1.6 MODEL-6: MULTI-OBJECTIVE OPTIMIZATION USING BAT ALGORITHM ON SHELL AND TUBE EXCHANGER BY BELL-DELAWARE METHOD. (MULTI-OBJECTIVE FUNCTIONS).
6.1.7 MODEL-7: OPTIMIZATION OF SHELL AND TUBE HEAT EXCHANGER USING FEM BASED PRESSURE DROP MODEL.

6.1.1 MODEL-1: OPTIMIZATION OF SHELL AND TUBE HEAT EXCHANGERS USING FLOWER POLLINATION ALGORITHM. (SINGLE OBJECTIVE FUNCTION i.e TOTAL COST).

A new meta-heuristic search algorithm FPA is employed into optimization process for designing two types of STHE’s. The optimization process is based on the minimum of the total cost including the capital investment and operating expenses. It is observed that there is reduction in optimized total cost of about -21.63% compared to original design for case study 1. The total cost is decreased by -15.23% compared to original design [110] for case study 2. Note that the total cost obtained from FPA was much lesser than BBO. The convergence takes place for 25 iterations for the case study 2 which saves computational time. Hence FPA approach proved to be a superior to GA, CSA, PSO, BBO, ABC approaches. The results tabulated from FPA are quite closely matching with other methods in the literature. Further, the FPA algorithm allows a rapid solution for the design problem and enables to examine a number alternative solution giving the designer more degrees of freedom in the final choice with respect to traditional methods. The algorithm proposed here may provide a basis for determination of the optimal performance for the domestic and commercial heat exchangers.
6.1.2 MODEL - 2: OPTIMIZATION USING BAT ALGORITHM ON SHELL AND TUBE HEAT EXCHANGERS BY KERN METHOD. (SINGLE OBJECTIVE FUNCTION i.e. TOTAL COST).

The total cost is minimum compared to original design and it is quite matching with other algorithms. Furthermore, the BA algorithm allows for rapid solution for the design problem. Because the number of iterations took for convergence is less than 10 and it saves the computational time. It enables to examine a number of alternative solutions of good quality, giving the designer more degrees of freedom in the final choice with respect to traditional methods. Hence the present algorithm can be used for any optimization applications more confidently.

6.1.3 MODEL- 3: OPTIMIZATION OF SHELL AND TUBE HEAT EXCHANGERS BY MINIMIZING THE ENTROPY GENERATION USING BAT ALGORITHM. (SINGLE OBJECTIVE FUNCTION i.e. ENTROPY GENERATION).

The number iterations for convergence are found to be less than 10 iterations as shown in the convergence graph and its computational time is also less compared to other algorithms. Hence, this algorithm can be effectively applied for optimization applications. The reduction of modified entropy indicates that pumping power increases.

6.1.4 MODEL- 4: MULTI-OBJECTIVE OPTIMIZATION USING GENETIC ALGORITHM ON SHELL AND TUBE HEAT EXCHANGER BY BELL-DELAWARE METHOD.

The results from the Pareto front curves clearly reveal that $45^0$ tube layout is more suitable for the case study because effectiveness ($\varepsilon$) is higher than $30^0$ and $90^0$ tube layout patterns. If cost is slightly manageable of about $2500 - $3000 than more
advantageous can be obtained i.e. higher heat quantity and higher heat transfer on shell side and also higher exit temperature and less exit temperature on shell side. It is not only the decision variables like baffle cut, baffle spacing, pitch, tube length and number of tubes has a conflict between the two objective functions. The tube arrangement also has the conflict between two objective functions.

6.1.5 MODEL-5: A COMPARISON BETWEEN MULTI-OBJECTIVE AND SINGLE OBJECTIVE OPTIMIZATION USING GENETIC AND CUCKOO SEARCH ALGORITHMS BY BELL-DELAWARE METHOD.

The results from the Pareto front curves clearly reveal that 45° tube layout pattern is more suitable for the case study. The results from GA are cross verified with CSA and the inference drawn from both algorithms are same. For comparison, 45° tube layout of baffle cut is considered. The point at which the effectiveness and the total cost start in Pareto front GA refers the same the point (or values) in cuckoo search graph. Similarly, the end point of the two objective functions of Pareto front GA refers same the result in cuckoo search graph. Hence, it can be concluded that the behaviour of the design variables like baffle cut, baffle spacing, pitch and number of tubes from Pareto front GA is similar in nature with cuckoo search graph. Hence the inference drawn from both algorithms are same. Hence CSA can be used more confidently for optimization in place of multi-objective optimization.

6.1.6 MODEL-6: MULTI-OBJECTIVE OPTIMIZATION USING BAT ALGORITHM ON SHELL AND TUBE EXCHANGER BY BELL-DELAWARE METHOD. (MULTI-OBJECTIVE FUNCTIONS).

The results of GA are cross verified with BA and the inferences obtained from both algorithms are same. The optimization is carried out using two different techniques such as genetic and bat algorithm. The effects of other tube layouts like
and $90^0$ are exclusively shown on every Pareto front along with $45^0$ tube layouts. The following conclusions can be drawn from this investigation are

The $45^0$ tube layout is the best among $30^0$, $45^0$, and $90^0$ tube layouts. Since the effectiveness, quantity of heat and heat transfer coefficient is higher for $45^0$ than $30^0$ and $90^0$ tube layout. On increasing design variables like baffle spacing, baffle cut and pitch both effectiveness and total cost decreases. As the tube length variable increases, both effectiveness and total cost increases. The proposed method BA finds more efficient than GA for the following reasons:

- Pareto front generated by BA is similar in nature with genetic algorithm.
- Cpu time taken by BA is 0.56 times less than GA. However, the number of iterations in BA is more.

Hence BA can be used more confidently for accurate value, quick convergence in place of multi-objective optimization of GA.

6.1.7 MODEL-7: OPTIMIZATION OF SHELL AND TUBE HEAT EXCHANGER USING FEM BASED PRESSURE DROP MODEL.

The pressure drop is determined using FEM method and it is quite matching with the experimental results given in Parkishit et al. [38]. It is found that the optimized pressure drop value is 109 kPa which is near to the literature value. The deviation is found to be only -0.026% when compared with [6]. Hence, it can be said that this method can be used effectively for determining pressure drop and also for optimization in the place of other methods like Bell-Delaware, Gaddis et al. [30], Kapale et al. [114].
6.2 RECOMMENDATIONS

The following are the suggestions that can be applied for future work:

i) The bat algorithm is a multi-objective function algorithm. It can be easily applied to any equipment’s where design and manufacturing are involved. It can also be applied in other fields where contradiction of variable occurs.

ii) Optimization of pressure drop using F.E.M is a new model since it gives better results, it can be applied to other heat exchangers like plate and frame, plate fin, compact heat exchangers etc. and other applications where pressure drop is critical.

iii) Optimization can be carried out using several other evolutionary algorithms available in the biological systems in order to obtain best thermo hydraulic performances.