Optimization of Helical Coil Tube Heat Exchanger: A Systematic Review

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Abstract: Helical coil heat exchanger is used in the food industries, air cooling industries etc., due to its advantage of structural compact and high heat transfer coefficient. Many existing researches have been carried to improve the heat transfer efficiency and pressure drop. Mathematical model of the heat exchanger has been used to validate the performance of the heat exchanger. This paper involves in review the researches related to the optimization of helical coil tube heat exchanger. Some of the optimization methods such as Taguchi method, Genetic Algorithm (GA) and Multi-Objective Genetic Algorithm (MOGA) is used. From the analysis, Artificial Neural Network (ANN) and GA method has efficient performance in modelling and optimization of heat exchanger. Although, some methods involved in economic optimization of heat exchanger and these method has lower performance.

1. Introduction
Helically coils are vastly used as an efficient heat exchanger due to their compactness and high heat transfer coefficients. The helically coiled heat exchangers are used in numerous applications such as air conditioning systems, refrigeration systems, thermal power plants systems, chemical processing, food processing and medical equipment [1]. The study of the thermal performance of these types of heat exchangers was extensively performed in the past years. Many researchers have studied thermal performance and frictional characteristics of these types of heat exchangers and proposed various correlations for Nusselt numbers and friction factors of both sides [2]. Optimization of energy consumption is one of the most important subjects in the engineering and process design. Therefore, investigations on heat transfer enhancement (HTE) methods are quite important [3]. The experimentally analyzed the effects of the geometrical parameters on heat transfer performance. And they found that the structural parameters have significant effects on flow and heat transfer [4]. With the development of CFD technology and computers, the numerical investigations on heat exchangers are more and more popular [5].

Recently, various researchers have studied the thermal characteristics of these kinds of heat exchangers for use with different applications [6]. They obtained the impact of various operational and geometrical parameters and proposed correlations for estimation of the Nusselt numbers, thermal and exergy efficiency, optimal and critical values of operational and geometrical parameters and entropy generation rate [7]. With advantages of larger heat transfer area, higher heat transfer coefficient, and more uniform heating, helically coil-tube heat exchangers can enhance heat transfer performance [8]. This phenomenon is not consistent with the entropy generation minimization principle. Thus, the optimization with only entropy generation rate as the optimization objective function has its limitations [9, 10]. In this paper, the researches related to the Helical Coil Tube Heat exchanger were reviewed. The analysis shows that the ANN and GA method has the higher efficiency in modelling and optimization of heat exchanger.

The paper is organized as review on Helical Coil Tube Heat exchanger is provided in section 2, comparative analysis of optimization of Helical Coil Tube Heat exchanger is provided in section 3 and conclusion is provided in section 4.
2. Review on Helical Coil Tube Heat exchanger

Helical Coil Tube Heat exchanger has been used in many industrial applications such as air conditioning system, food industries etc. Many researches have been carried out to improve the helical coil tube heat exchanger. These methods involves in applying mathematical model to validate the performance of heat exchanger. Artificial Neural Network is used to model the heat exchanger to analyse the effect of input parameters. The optimization methods such as GA, PSO is applied to find the optimal performance of the heat exchanger. Computational Fluid Dynamics (CFD) is applied to simulate the heat exchanger to evaluate the performance. The major objectives of the method are to find the optimal design parameter to provide higher heat transfer efficiency and lower pressure. The general block diagram of the helical coil heat exchanger is shown in Figure 1.

![General block diagram of optimization of Helical coil tube heat exchanger](image)

Figure 1. The general block diagram of optimization of Helical coil tube heat exchanger

Baqir, et al. [11] applied the optimization method to enhance the thermal performance and reduce the cost of the helical coil heat exchanger with air injection technique. The economic optimization is based on the optimal air flow and shell-side flow rate of the exchanger. The experimental result shows that parameters such as injected air flow, shell-side flow and coil-side flows has the impact on effectiveness. The effectiveness of the exchanger is increased in this method and has considerable economic performance. The efficiency of the method can be improved by using optimization methods such as Genetic algorithm and Particle Swarm Optimization.

Campet, et al. [12] optimize the internal shape of single-started helical coil tube heat exchanger. In order to improve heat exchanger efficiency, the inner surface of channel feature rounded rib. The Gaussian process regression and efficient global optimization are used in this method for optimization. The optimization method involves in improve the heat transfer efficiency for similar pumping power. The experimental result shows that the method increases the heat transfer efficiency. The mathematical model has been used in this research to analyse the performance. The optimization performance can be improved by efficient optimization method.

Sharifi, et al. [13] applied Artificial Neural Network (ANN) and Genetic Algorithm (GA) for the optimization of the heat exchanger. The ANN method was used to analyse the performance of the heat exchanger for various input variables. The GA is used to find the optimal performance of the heat exchanger in the method. The experimental result shows that the developed method has the higher performance in the optimization of heat exchanger. The experimental analysis shows that selection of wrong wire insertion affects the overall performance of heat exchanger. The optimization performance can be increased by using PSO method.

Mohapatra, et al. [14] uses the three fluid heat exchanger to analyze the performance of the design
parameters. Taguchi based optimization method was used to find the optimal parameter for the higher efficiency and lower pressure. The experimental result shows that flow rate of hot water is the important parameter for heat transfer and tube size is the important parameter for pressure drop. Effective optimization methods like GA can be used to improve the performance.

3. Comparative Analysis

Helical Coil Tube Heat exchanger has been used in many industries such as food, refrigeration, aerospace etc., due to its compact structure, ease of manufacturing and high heat transfer efficiency. Some of the researches involves in optimizing the Helical coil tube heat exchanger to improve the efficiency and reduces the cost. The recent research in the optimization of helical coil tube heat exchangers are reviewed in this section. The comparative analysis of the recent researches in helical tube heat exchanger is shown in Table 1.

Table 1. Comparative analysis of optimization method in Helical Coil Tube Heat Exchanger

| Author(s)            | Methods                                           | Advantages                                                                 | Limitations                                                                 |
|----------------------|---------------------------------------------------|-----------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Han, et al. [15] (2020) | Multi-Objective Genetic Algorithm (MOGA)          | Design parameters are analysed under equal Reynolds number.                 | The energy saving is required to improve in the design.                    |
|                      |                                                   | Provides the better performance than existing method.                       |                                                                            |
| Wang, et al. [16] (2019) | Two-layered Multi-Objective optimization          | The experimental and numerical analysis was carried out.                   | The performance of the optimization is required to be improved.           |
|                      |                                                   | The analysis shows that the performance is improved in the method.          |                                                                            |
|                      |                                                   | The optimal structural parameter is provided in this method.               |                                                                            |
| Gord, et al. [17] (2016) | The optimal geometry and operational conditions are analysed using second law of thermodynamics | Four important parameter are consider in this method for the optimization. | The economic analysis is also can be considered to reduce the cost.       |
|                      |                                                   | To optimize the geometry, the fixed optimal condition is considered in this method. |                                                                            |
| Alimoradi, et al. [18] (2017) | Numerical investigation of heat transfer intensification via installing annual fins on outer surface of the helical coil. | Two methods were used to analysis the design.                              | Efficient optimization method can be applied to improve the performance.  |
|                      |                                                   | The numerical analysis shows that the method has the considerable performance. |                                                                            |
|                      |                                                   | For prediction of heat transfer performance, optimal cases and condition has been achieved. |                                                                            |
| Wang, et al. [19] (2018) | Numerical analysis has been made to study the effect of fin geometry and inlet mass flow rate. | The analysis shows that the developed method has the considerable performance. | The performance of the method is low and various parameters are required to be considered. |
|                      |                                                   |                                                                            | Pressure drop is slightly affected by this method.                       |
| Miansari, et al. [20] (2019) | Numerical analysis has been carried out to evaluate the effect of circular grooves on exchanger. | The geometric parameter of qualitative and quantitative analysis shows that the performance is increased. |                                                                            |
|                      |                                                   |                                                                            |                                                                            |
|                      |                                                   | The grooves are created in different height for the analysis.              |                                                                            |
| Authors                  | Methodology                                                                 | Results                                                                 |
|-------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------|
| Etghani, et al. [21] (2017) | Taguchi method was used to analyse the different parameters.             | The numerical analysis shows that the important parameter for optimal performance. |
|                         | Numerical analysis has been carried to analyse the exchanger.               | The performance of optimization is need to be increased.               |
|                         | Four important parameter are considering to improve the performance.        |                                                                        |
|                         | Taguchi method was used to find the optimal design performance.             |                                                                        |
| Han, et al. [22] (2019)  | Multi-objective optimization is applied using Markowitz effective boundary theory. | The developed method has the higher performance than existing method.   |
|                         | The Mathematical analysis has been carried out to evaluate the method.      | The error value of the developed method is low.                        |
| Alimoradi, et al. [23] (2017) | Numerical model has been carried out to analysis the effect of parameters. | The method provide the optimal design for the model.                   |
|                         | The development method has the higher performance than existing method.     | The performance of optimization is low and need to consider various parameters. |
|                         | The error value of the developed method is low.                            |                                                                        |
| Kareem, et al. [24] (2016) | The optimization and CFD is analysed in this method.                       | The simulation result shows that the developed method has the higher performance. |
|                         | The various cross-section is analysed in this method.                      | Pressure drop is required to be considered in this method.             |

4. Conclusion

Helical Coil Tube Heat Exchanger has been used in food industries, air conditioning industries etc., due to its advantages of structural compact and high heat transfer coefficient. Many researches have been carried out to improve the heat transfer efficiency and reduces the pressure in the heat exchanger. This paper review the researches involves in the optimization of the helical coil heat exchanger with its advantages and limitations. From the analysis, the methods such as ANN and GA has higher efficiency in modelling and optimization of heat exchanger. Some researches involved in economic optimization of heat exchanger to reduce the cost and improve the efficiency. These methods have the lower efficiency in the optimization and requires effective method for higher performance.

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