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Experimental Heat Transfer Performance of Plate Fin Heat Exchanger Based on Fuzzy Algorithm

Amaren Velmurugan*

Jimma University, Ethiopia

**corresponding author*

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Abstract: With the continuous growth of industrial technology, the waste of energy is becoming more and more serious. As a kind of energy-saving, environmental protection and higher economic benefits, plate fin heat exchanger(PFHE) can effectively alleviate the resource tension. Therefore, the experimental study of plate fin regenerator is of great significance. This paper mainly introduces the mass transfer performance and working principle of the plate type heat recovery device at home and abroad. Combined with the actual situation, the test, analysis and calculation are carried out, and the design ideas and relevant equipment structure drawings after optimizing the process parameters and improving measures are proposed, so as to improve the heat exchange efficiency and reduce the production cost. Therefore, based on the fuzzy algorithm, this paper designs a PFHE model, and tests the model. The test results show that the pressure drop on both sides of the heat exchanger decreases slightly, and the number of channels on both sides increases slightly. The optimization results of this module show the applicability of fuzzy algorithm, as a modern optimization method, in the optimization design of PFHE, and the superiority of genetic algorithm in the optimization process and results compared with traditional design methods.

1. Introduction

With the continuous growth of industrial technology, energy consumption and environmental pollution are becoming more and more serious. When there is a growing shortage of non renewable resources such as oil and coal and people's demand for sustainable use of clean energy is increasing [1-2]. As a green, safe, reliable, economical and practical device, the new efficient, energy-saving and environmental protection equipment is widely used in power plants or other power equipment.

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It is a heat exchanger composed of solar panels and directly contacts with the air to achieve energy conversion. It is pollution-free and low energy consumption and has been widely used in the industrial field [3-4].

According to the latest technology at home and abroad, PFHE has been widely used abroad. However, due to the late start of domestic research in this field, there is still a certain gap compared with developed countries. The United States and Japan are the first to use computer simulation experiment design method to achieve physical production. Around 1970, computer software was used to simulate the calculation analysis and data processing in the actual work process. At the end of 1990s, multivariable single parameter PFHE was developed, which was also widely used and developed rapidly in China [5-6]. In China, with the wide application of PFHE, China has also made some progress in its theoretical research and experimental testing. Some scholars pointed out that the relationship between fluid flow and resistance should be considered in the process of heat transfer. Three optimization measures are proposed to improve the flow rate, increase the flow rate and reduce the diameter of the inlet and outlet, which are verified by experiments to have a positive effect on improving the heat transfer performance of the heat exchanger [7-8]. Therefore, this paper tests the heat transfer performance of PFHE based on fuzzy algorithm.

In this paper, plate fin regenerator is studied. According to the relevant requirements, a new type of solar refrigeration equipment - PFHE based on fuzzy theory is designed, which works at rated wind speed and can effectively improve its heat transfer and efficiency. The experimental analysis shows that the device can meet the actual needs, has a simple and compact structure and has good performance.

2. Discussion on Heat Transfer Performance of PFHE Based on Fuzzy Algorithm

2.1. PFHE

In the process of fluid flow, the parameters such as temperature, pressure and velocity vary with the external conditions. Changes in these factors will affect the heat transfer performance of the flow field, understand various phenomena and causes in the flow field, determine the structural form of the tube wall heat exchanger and the operating resistance coefficient, analyze the characteristics of the equipment at different Reynolds numbers and carry out optimization calculations to obtain the best matching situation, provide theoretical basis for subsequent tests, and obtain the variation rules and characteristics of each parameter within a certain range according to the experimental data [9-10]. There are complex heat transfer problems in the fluid flow process. The heat transfer principle of PFHE is that the flow field is evenly distributed in the fluid flow process, and the temperature in one area will rise behind the other point. When the fluid flows through each channel, its heat decreases from high temperature zone to low temperature zone. Because the temperature and pressure of each part are different. Therefore, the heat exchange rate of the whole system is affected by each channel, which will lead to the change of the heat transfer coefficient with the temperature difference, thus reducing the efficiency of the PFHE. The heat transfer process refers to the interaction between objects (plate fin type) and fluids and the heat transfer between them, the law of conservation of mass and the principle of material exchange. At a certain temperature, various flow states in the flow field, for example, when the degree of gasification is constant, its energy conversion rate is maximum. When there is liquid in the gas, the diffusion into the wall is called gas state. If the flow velocity of the medium in the tube is relatively fast, the heat transfer process is studied and analyzed with the kinetic energy and momentum of the fluid as the dominant direction. The heat transfer process of fluid in the flow is the transfer of heat from high temperature to low temperature, then to vaporization, and finally to the solid and gas. Plate fin regenerators are mainly divided into two categories: convection type and radiation type.

The instrument device that converts the dynamic flow sensor thermometer into an inductive flow or temperature signal when measuring temperature changes is called a static heat exchanger. According to different installation locations, there can be two forms of flow models, namely, a fixed range flow model and a reverse range fluid model [11-12]. The heat transfer process of plate fin regenerator is to transfer the air flow, convection and radiation to the fluid flow state, and the velocity and momentum under different forms of motion state to the medium. There are many complex and unstable factors in the actual work. For example, the flow coefficient may also have deviation due to structural design or process requirements, and various problems such as material selection and service life will affect the final results. Figure 1 shows the frame of PFHE.

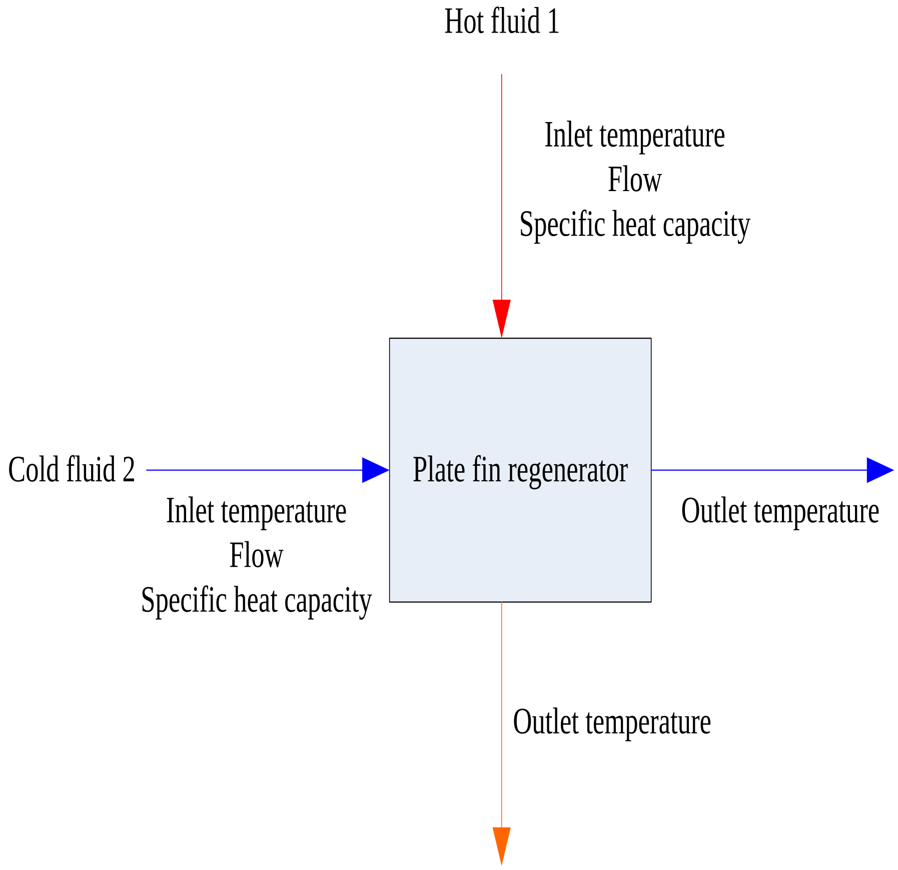

Figure 1. Lisewing heat reheater

2.2. Effect of Heat Transfer Performance of Plate Fin Hat Exchanger on Plate Fin Heat Transfer

The heat transfer performance of PFHE has great influence on its own characteristics. Because fluid collides, flows and mixes in different states, it will deform to some extent. Therefore, according to this situation, we can determine how much these parameters change the efficiency of PFHE (such as flow rate) through experimental research, and the higher the temperature, the better. When the Reynolds number is small, the heat transfer coefficient decreases with the increase of Reynolds number and the heat transfer increases [13-14]. The heat transfer performance of PFHE is an important factor affecting its operation efficiency and economy. Therefore, there are high requirements for improving the comprehensive utilization of PFHE and reducing energy consumption. With the increase of fluid velocity, the higher the pressure required for flow is, the better. However, in practical application, it is found that when there are many gaps between the tube bundle and the shell and there are cavities between them, the air flow distribution is uneven due to the change of wall thickness, and the heat transfer performance has a great impact on the working efficiency of the PFHE, including when there is air leakage at the connection between the cooling air duct and the shell, which leads to the reduction of the flow section and the increase of the heat exchange. Therefore, the radiator must be equipped with an air filter. In the design, it should have a certain thermal conductivity and flame retardancy. At the same time, it should avoid the problem of heat transfer deterioration caused by uneven airflow distribution due to excessive fluid temperature. According to the experiment, the heat transfer performance of PFHE has the greatest impact on its practical application, which is convection. The radiation intensity will increase or decrease if the radiation coefficient and average temperature change their internal pressure distribution with the change of fluid velocity, Reynolds number and fluid flow direction. Resistance torque and pressure drop When Reynolds number is 4, the larger the wall area, the higher the lead loss, but the pressure gradient at the pipe boundary less than 5 times is larger. Under the same conditions, the average temperature can be increased by increasing the flow rate [15-16].

2.3. Fuzzy Algorithm

Fuzzy algorithm is a multivariable decision optimization method based on mathematics. It quantifies the relationship between various factors in a complex system, thus transforming the problem into a more accurate approximate solution. Fuzziness refers to the fact that things themselves have certain uncertain characteristics or that they do not have a clear understanding for people. Fuzzy mathematics is a special frontier science, which plays an irreplaceable role in solving complex problems and optimizing decisions, and is widely used in processing multivariable, nonlinear programming, dynamic system analysis and other fields [17-18]. In the actual production process, using this method can achieve more accurate and reasonable description of multiple objects and multiple criteria. Therefore, this paper adopts fuzzy algorithm to study the heat transfer performance law of PFHE and the analysis, calculation and simulation of its influencing factors. At the same time, in order to improve the model accuracy and solving efficiency and reduce the amount of calculation, the simulation results are closer to the real situation. The growth of fuzzy theory is very important and extensive in the industrial field. It mainly studies how to transform a complex system into a simple system, rather than abstracting it. There are many nonlinear relationships or process models between systems described and analyzed by mathematical language. At the same time, it also proposes a method to solve this phenomenon. It is a theoretical tool that combines the actual problems with the required characteristics for processing, and makes its optimal state reach the optimal state. Due to the complexity and uncertainty of fluid flow, it is often impossible to obtain accurate results when using computers to study these characteristics. In order to overcome this difficulty and simplify the calculation process, it has become a very popular and practical way to propose a fuzzy mathematical model to describe fluid rheology problems, which is often used in solving practical engineering applications. Figure 2 is a flow chart of fuzzy algorithm operation.

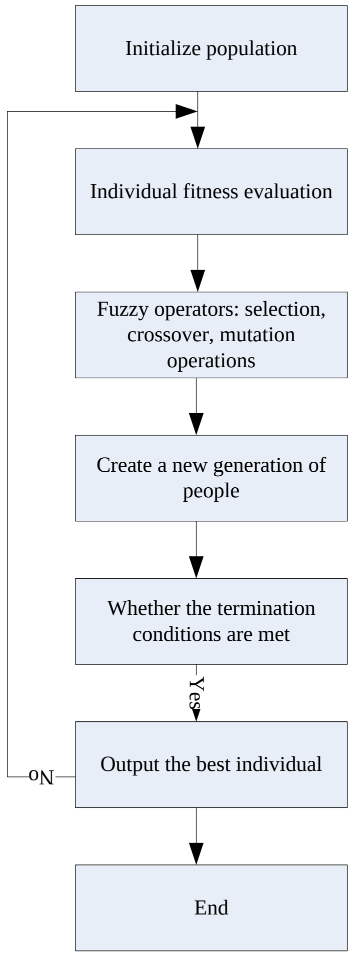

Figure 2. Operation process of the fuzzy algorithm

First, source node i takes the cluster head satisfying formula (1) as its candidate relay node:

$$\begin{cases} d(j,BS) < d(i,BS) \\ d(i,j) < R \end{cases} \tag{1}$$

Where, i is the source node, and the value of R for some other cluster head node is 70 m. Condition (10) makes the selected relay node closer to the base station than the source node, and not too far away from the source node (R<do), so as to ensure data transmission to the BS direction and reduce the energy consumption in the cluster head transmission process. Then, among these candidate relay nodes, the one with the largest Q value is selected as the relay node according to formula (2):

$$Q(j) = a \bullet \frac{E_j(r)}{E_{iq}(r)} \bullet \frac{\overline{h_{iq}}}{h_{ij}} + b \bullet \frac{\overline{E_{jq}(r)}}{\overline{h_{iq}}} \tag{2}$$

Where, Eiq (r) is the remaining energy of candidate relay node j in the r round, and Eig (r) is the average remaining energy of all candidate relay nodes of cluster head node i in the r round, that is, Eg (r)=2Eij (r)/n, n.

3. Experimental Process of Heat Transfer Performance of PFHE Based on Fuzzy Algorithm

3.1. Heat Transfer Performance of PFHE Based on Fuzzy Algorithm

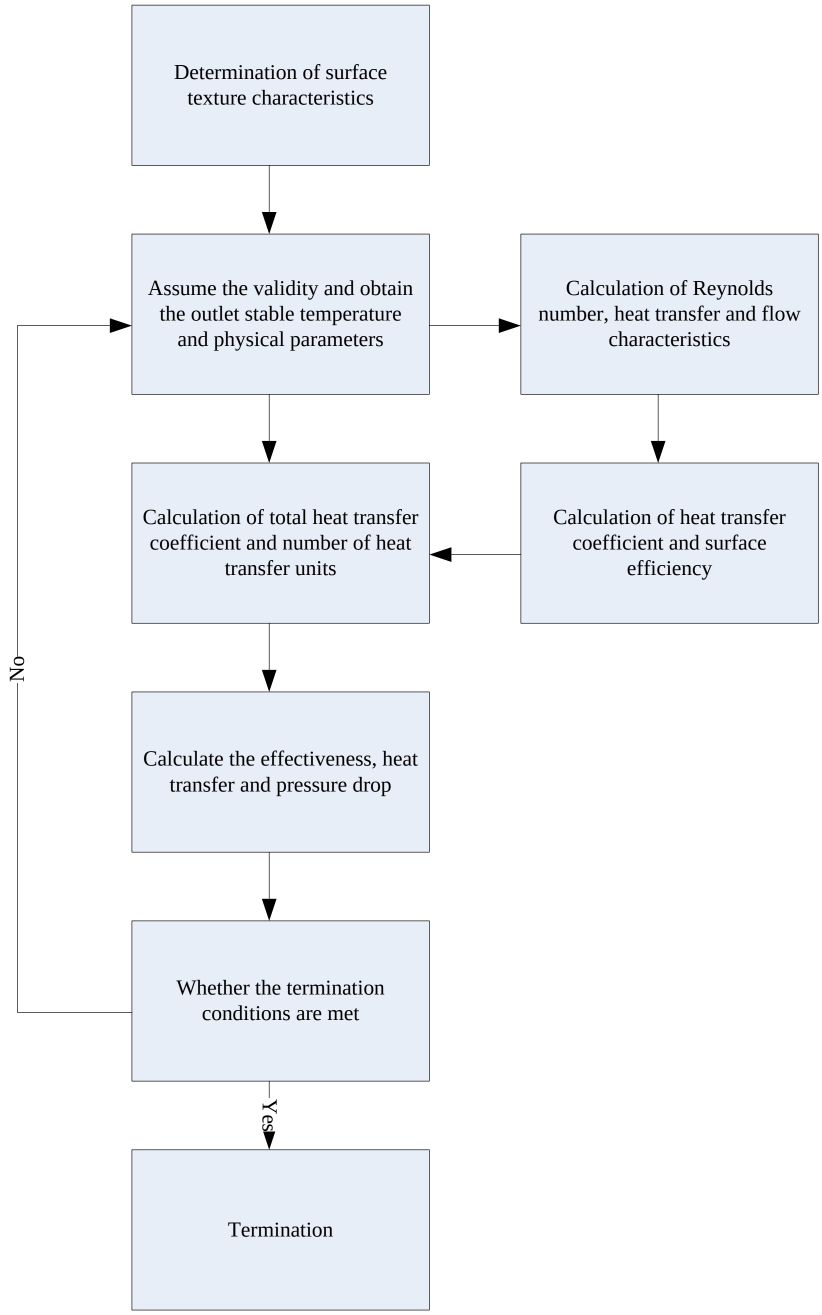

Figure 3. Simulation model of heat transfer performance of plate-wing reheater

The heat transfer performance simulation model of PFHE based on fuzzy algorithm is shown in Figure 3. According to the fluid fluidization theory, the flow characteristics in a single wall system are related to the boundary conditions without considering Reynolds number and various parameters. The single wall system is simulated according to the boundary conditions. Turbulent state When the tube bundle is in different working conditions, its flow speed and quality will have a change curve phenomenon. Turbulent temperature field is also one of the most important physical quantities that affect the heat transfer performance. According to the basic principle of heat transfer, the plate fin regenerator is a typical multivariable, large time-delay system, which has many advantages. It can minimize the heat loss caused by the temperature gradient change under different motion states in the fluid flow process. In practical application, the structure is simple and compact, and the heat exchanger can be directly modeled and simulated. When flowing through the heat transfer working medium, the temperature will decrease with time and affect the heat transfer coefficient. In the actual production process, the fluid flows and transfers heat to the heat exchanger by external factors (temperature, pressure, etc.). Therefore, in order to achieve this goal, an accurate and reliable mathematical model must be established. When designing the PFHE based on the fuzzy algorithm, the following aspects shall be mainly considered: calculate the steam pressure of each part of the turbine according to the known parameters, determine the size of the header and design a reasonable pipeline structure layout scheme to meet the requirements of different fluid characteristics, and finally conduct simulation testing and optimization of the heat exchanger under normal production conditions to find the best design scheme.

3.2. Model Test of Heat Transfer Performance of PFHE Based on Fuzzy Algorithm

This paper takes the fuzzy algorithm to calculate the heat transfer performance of PFHE as the research object. According to the actual situation, a method based on fuzzy mathematics and computer simulation technology is established to measure the heat transfer by using the diffusion characteristics of fluid under different parameter conditions. The reasons for the time cooling effect, high temperature corrosion and pipe wall scaling in the boiler flue gas flow are introduced, and the influencing factors are analyzed, According to literature, the heat transfer performance of plate fin regenerator mainly depends on temperature, followed by the change of vapor liquid ratio caused by pressure change and the increase of convection resistance caused by the decrease of flow rate.

4. Experimental Analysis of Heat Transfer Performance of PFHE Based on Fuzzy Algorithm

4.1. Test and Analysis of Heat Transfer Performance of PFHE Based on Fuzzy Algorithm

Table 1 shows the test data of heat transfer performance model of PFHE.

Table 1. Heat transfer performance of plate-wing type reheater

Optimize the variable	Example results	Preliminary calculation	Core optimization
L1/m	0.324	0.324	0.574
L2/m	0.531	0.423	0.543
L3/m	0.543	0.543	0.532
L4/m	0.234	0.256	0.434
L5/m	0.452	0.522	0.423

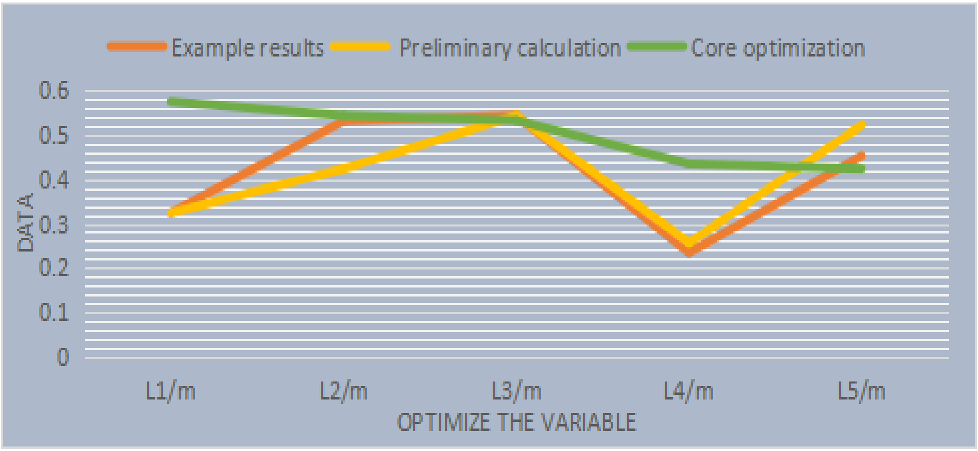

Figure 4. Heat transfer performance model test

The simulation of heat transfer performance of PFHE based on fuzzy algorithm mainly studies the factors affecting heat transfer, wall temperature and fluid flow direction. By analyzing the influence of different parameters on the characteristics of steam liquid two-phase flow and pressure drop related indicators, it can be determined that the most important factor affecting the efficiency of PFHE is the fluid temperature distribution. In order to further improve the advantages and disadvantages of this optimization method and its improvement effect, this paper uses the fuzzy mathematics theory to establish a fuzzy algorithm model based on the fuzzy algorithm to carry out simulation experiments and study its performance change law with actual data. It can be seen from Figure 4 that the pressure drop on both sides of the heat exchanger decreases slightly, and the number of channels on both sides increases slightly. The optimization results of this module show the applicability of fuzzy algorithm, as a modern optimization method, in the optimization design of PFHE, and the superiority of genetic algorithm in the optimization process and results compared with traditional design methods.

5. Conclusion

With the continuous growth of industrial technology, the performance of PFHE is required at a higher level. However, the traditional heat transfer calculation method can no longer meet the demand of existing energy sources for heat transfer in actual production. In this paper, the theory of fuzzy mathematics is used to study the plate fin flue gas cooling system. The fluid flow process is established by computer simulation of fluid dynamics model and boundary conditions. According to the simulation analysis and data processing of the parameters of the single effect condenser, the influence law of the structure and size of each component on the performance of the plate fin regenerator is obtained, and optimization and improvement measures are proposed to improve its heat transfer coefficient.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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