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Effectiveness Comparison of Shell and Tube Heat Exchanger

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ABSTRACT

An overview of the research on shell and tube heat exchangers is given in this article. For applications like heat transmission in the industries, heat exchangers are used extremely often. In comparison to other types of heat exchangers, shell and tube heat exchangers offer higher surfaces for the transmission of heat between the two fluids. For applications like liquid-to-liquid heat transfer with high-density working fluid, shell and tube heat exchangers are widely used. In this work, convective heat transfer of tap water, cold water and hot water is analysed with various parameters such as mass flow rate, heat transfer rate, overall heat transfer coefficient and effectiveness with constant temperature in shell and tube heat exchanger. The Effectiveness of the experiments came out to be 46% for Hot vs Room temperature condition, 35% for Room temperature vs Cold condition and 68% for Hot vs Cold condition.

1. INTRODUCTION

A heat exchanger is an apparatus that enables the transmission of heat between two fluids that are at various temperatures. Due to its varied function and construction, Heat exchangers are commonly used in industry in heat transfer processes for generating conventional energy, such as condensers, heaters, boilers, or steam generators. They offer adequate surface area for heat conduction, and high pressure and high temperature operations are possible due to their mechanical and thermal characteristics. Shell and tube heat exchangers in a variety of design variations are the most common and commonly utilized basic heat exchanger configuration in industry. A shell-and-tube heat exchanger's total number of shell and tube passes is further divided into categories. Heat exchangers with a shell and tube design are frequently used in high-pressure applications. When the tube bundle is placed inside a shell, the secondary fluid flows through the shell and over the surface of the tubes. In nuclear engineering, this type of heat exchanger is frequently used, for example in steam generators that convert feed water into steam using the heat generated in a nuclear reactor core. To increase the amount of heat transmitted and the amount of electricity generated, the heat exchange surface must be greater. Through the front header, fluid enters the exchanger's tube side. It is occasionally referred to as the Stationary header. The rear header is where the tube side fluid leaves the exchanger or is returned to the front header in exchangers with several tube side passes. To keep the bundle together, a tube bundle is made up of tubes, tube sheets, baffles, and tie rods, among other things. The shell houses the tube bundle.

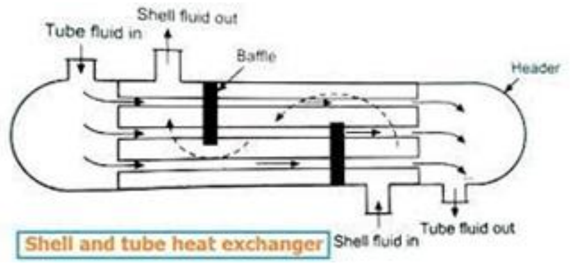

Figure 1: Shell and Tube Heat Exchanger

2. Related Work

[1] (SANDEEP, Chowdary and Babu, 2020) The report's central idea is to investigate the LMTD (logarithmic mean temperature difference), Heat transfer coefficient, & Effectiveness (ε) of a combination of heat exchanger employing an acetoacetate/water combination as a function of various mass flow rates. This work investigates the effects of acetoacetate/water mixture on heat transfer coefficient, LMTD, productivity, and total heat transfer coefficient in 3 distinct heat exchangers: tubes in tube, shell and tube, and combination heat exchangers. The exploratory examination of the forced convective heat transfer and flow properties of a 25% acetoacetate containing 75% water is summarised in these conducting tests. Assuming laminar flow conditions, the acetoacetate/water mixture flows in a parallel, counter-clockwise direction in the tube in tube, shell and tube heat exchanger, and combination of heat exchanger. The largest increase in the coefficient of convective heat transfer was 56.3 percent, with 49.6 percent effectiveness. Based on a multi-pass flow of Acetoacetate/water, integrated heat exchangers give greater heat transfer characteristics than parallel & counter flow tubular & shell and tube heat exchangers

[2] Zahid H. Ayub: A new chart method is presented to calculate single-phase shell side heat transfer coefficient in a typical TEMA style single segmental shell and tube heat exchanger. A case study of rating water-to-water exchanger is shown to indicate the result from this method with the more established procedures and softwares available in the market. The results show that this new method is reliable and comparable to the most widely known HTRI software.

[3] (Singh and Kumar, 2014) The tube and shell heat exchanger are among such kinds of heat exchanger in which hot water flows inside one tube and coldwater flows over the other. The heat exchanger is simulated using a CFD technique, which is a computer-based simulation that involves fluid movement and heat transmission. For determining the temperature gradients, pressure distribution, as well as velocity vectors, CFD resolves the entire heat exchanger in discrete elements. For correct CFD results, the turbulence model k- is being used. Temperature differences are estimated for parallel and counter flow by adjusting the mass flow rate of fluid of 2L/min and 3L/min, which is regulated by a rota metre, and temperature variations are detected by sensors mounted at the inlet and exit of tube. The solid geometry is created in SOLID WORKS and then loaded into GAMBIT, which is the ANSYS 13.0 pre-processor for meshing the geometric shapes. The simulated results, such as temperature contours, pressure contours, and velocity vectors, are generated using the post processor FLUENT.

[4] The heat transfer tube was analysed in this article using various parameters. The thermal analysis of shell and tube heat exchangers was performed in ANSYS utilising varied thermal loads and streams of water and steam. The computation was done in C code, which is useful for thermal analysis. Various materials have compared and contrasted different thermal materials. According to the findings, steel has a superior shell structure than cooper for tubes and baffles. The LMTD and surface area change as the water temperature rises. When the fouling factor of the oil increases, the total heat transfer coefficient decreases

[5] An increase or improvement in energy savings is always a major aim for the industrial sectors to attain. Because of the present energy prices, the need for energy conservation is growing. In the refrigeration, automotive, chemical, and process sectors, heat exchangers are the most significant device. In the industrial industry, there is a desire for cost-effective, more efficient, and smaller heat exchangers due to the danger of rising energy consumption. As a result, this article presents a detailed analysis of the experimentation as well as computations based on the experiment. This experimental examination of heat exchangers and their calculations aided in the development of some efficient and more effective new basics that may be utilised in the future to preserve heat and

save energy. There is potential for growth in the future

[6] This paper consists of extensive thermal analysis of the effects of severe loading conditions such as various flow condition using different insulations, under various ambient temperature and also they tried to create the turbulence by closing the pump opening and observed its effect on its effectiveness. To serve the purpose a simplified model of shell and tube type heat exchanger has been designed using kern's method then steady state thermal analysis is done on ANSYS 14.0, practical working model of the same has been fabricated using the components of the exact dimensions as derived from the designing. Heat exchanger. The Result of the above experiment show that the insulation is a good tool to increase the rate of heat transfer if used properly well below the level of critical thickness. Amongst the used materials the cotton wool and the tape have given the best values of effectiveness. Moreover the effectiveness of the heat exchanger also depends upon the value of turbulence provided. The ambient conditions for which the heat exchanger was tested do not show any significant effect over the heat exchanger's performance.

A. Pignotti [7] in his paper established relationship between the effectiveness of two heat exchanger configurations which differ from each other in the inversion of either one of two fluids. This paper provides the way by which if the effectiveness of one combination is known in terms of heat capacity rate ratio and NTUs then the effectiveness of the other combination can be readily known.

3. Proposed Methodology

No	Parameter	Shell	Tube (61 tubes)
1	Outer diameter (mm)	75 mm	6 mm
2	Material	Casted Aluminum	Brass
3	Length	16 inch	15 inch

In this experimentation, three fluids i.e., Cold water, Hot water and Room temperature water has been considered.
In the first case of determining the effectiveness, Heat loss and heat transfer co efficient we have taken room temperature water versus Hot temperature water. While experimentation the system is NOT insulated
The hot water is passed through the shell and room temperature water is passed through the tubes

The readings are as follows

Time	Room Temp. Initial	Room Temp. Final °C	Hot Initial °C	Hot Final °C
FIRST 30 SEC	°C	33	56.4	53.3
1 MIN	26.8	36.4	55.1	50.1
1 MIN 30 SEC	26.3	38.7	53	47.6
1 MIN 52 SEC	26	41.3	51.7	43.3

In the second case the experimentation is done between Room Temperature Water And Cold temperature Water
Where the cold water is passed through the tubes where as the Room temperature water is passed through the shell

Time	Hot Initial(°C)	Hot Final(°C)	Cold Initial(°C)	Cold Final(°C)
FIRST 30 SEC	59.3	45.6	10.8	17
1 MIN	57.8	43.8	12.1	17.8
1 MIN 30 SEC	52.3	37.6	14	18.7
2 MIN	50	32.4	14.8	20.5
2 MIN 30 SEC	47.6	28.3	15.9	22.1
3 MIN	46.8	26.3	16.6	24.2

The effectiveness of a heat exchanger, it is the total heat transfer rate to the temperature of the inlet and outlet fluid, the overall heat transfer coefficient, and the total surface area for the heat transfer rate. The heat transfer equation between hot fluid and cold fluid is equilibrium. The rate of heat transfer between hot fluids and cold fluids and by ignoring the heat transfer that occurs in heat exchangers on the environment, ignoring changes in potential energy and kinetic energy, and by applying steady energy equations, and in the case of this fluid does not under a phase change and assumed the condition of constant specific heat, then the equation,

$$q = \dot{m}hcph\ (Thi - Tho) \qquad 1$$

$$q = \dot{m}ccpc\ (Tco - Tci) \qquad 2$$

If the direction of flow of the two fluids inside the heat exchanger is parallel. This means that both fluids enter on one side and exit from the other side flowing in the same direction. If the flow graph is parallel equation will be obtained,

$$q = \dot{m}hcph(Thi - Tho) = \dot{m}ccpc(Tci - Tco) \qquad 3$$

If the assumption of the value of specific heat capacity (Cp) is cold and hot fluid is constant, there is no loss of heat to the environment and the steady state, then the heat transferred,

$$q = U \, x \, A \, x \, LMDT \quad 4$$

$$LMDT = (\Delta T1 - \Delta T2) \, / \, ln \, (\Delta T1 / \Delta T2) \quad 5$$

Counter flow, that is if both fluids flow in opposite directions and exit on the opposite side If the flow graph is parallel equation will be obtained,

$$q = \dot{m}hcph(Thi - Tho) = \dot{m}ccpc(Tco - Tci) \quad 6$$

Cross Flow, This means that the direction of the second flow of fluid intersects. The NTU effectiveness method is a method based on the effectiveness of heat exchangers in removing certain amounts of heat. Where the effectiveness of the method has several. The advantages for analyzing the problems which we have to compare different types of heat exchanger in order to choose the best kind to carry out a specific task for heat. The effectiveness of heat exchangers with the following equation:

$$\text{Effectiveness} = \frac{\text{The actual heat transfer Rate}}{\text{The rate of heat transfer possible}}$$

$$= \frac{\text{Qactual}}{\text{Qmaximum}}$$

Condition	Q1 (Kw)	Q2 (Kw)	Effectiveness
Room vs hot	5.676	8.075	46%
Room vs Cold	4.915	3.461	35%
Hot vs Cold	8.602	13.78	68%

Conclusion

The results show that the heat transfer characteristics is increased/enhanced hot water and cold water compared to room temperature water. It is found that heat transfer rate is high in the process of hot water and cold water compared to tap water. It also found that heat transfer rate is decreasing with decrease in temperature. It is found that effectiveness is high in hot water versus cold temperature water (68 %) compared to room temperature water and cold water (35%) , whereas the effectiveness in the case of normal temperature water versus Hot water is 46% . It is also found that effectiveness is decreasing with decrease in temperature.

Conflict Of Interest

The authors declare that they have no conflict of interest.

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