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Modified on Shell and Tube Heat Exchanger

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Abstract: Heat transfer is one of the most important processes in many industries. For this a heat exchanger is used. There are many different types of heat exchanger available that are double tube heat exchanger, Shell and Tube heat exchanger, tube in tube heat exchanger, Plate heat exchanger, Finned heat exchanger etc. In heat exchanger a fluid is used to cool another fluid which is a higher temperature, this is done either with direct contact between the fluids or indirect contact between the fluids with a surface in between. Most common type of heat exchanger used in industries is Shell and Tube heat exchanger due to its dimension flexibility which is it dose not have any dimension limit to it. As most of the Shell and Tube heat exchanger in the industries are of long lengths and also they are equipped with only single pass of the tube and with either parallel flow or counter flow. They are also equipped with different types of baffle plate at different angles and placing. In this project we have done construction and performance on Shell and Tube heat exchanger which is made in compact size and which is also equipped with parallel flow and counter flow. We have given multiple passing of the tube throughout the shell which results in better cooling of water. The cooling medium used in this project is water at normal room temperature. Because of the compact size of this heat exchanger it can be used in small spaces with availability of water like in small scale industries.
Keywords: Shell and tube heat exchanger, heat transfer, multiple pass, compact size, rotameter, valves

I. INTRODUCTION

A heat exchanger is a system used to transfer heat between two or more fluids. Heat exchangers are used in both cooling and heating processes. The fluids maybe separated by a solid wall to prevent mixing or they may be in direct contact. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Heat exchangers are one of the mostly used equipment in the process industries. Heat exchangers are used to transfer heat between two process streams. One can realize their usage that any process which involve cooling, heating, condensation, boiling or evaporation will require a heat exchanger for these purpose. Process fluids, usually are heated or cooled before the process or undergo a phase change. There are different type of heat exchanger

1) Double Tube Heat Exchangers
2) Shell and Tube Heat Exchangers
3) Tube in Tube Heat Exchangers
4) Plate Heat Exchangers
5) Finned heat exchanger
6) Plate fin heat exchanger
7) Compact heat exchanger
8) Plate shell heat exchanger

Different heat exchangers are named according to their application. For example, heat exchangers being used to condense are known as condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop. A typical heat exchanger, usually for higher pressure applications up to 552 bars, is the shell and tube heat exchanger. Shell and tube type heat exchanger, indirect [6] contact type heat exchanger. It consists of a series of tubes, through which one of the fluids runs. The shell is the container for the shell fluid. Generally, it is cylindrical in shape with a circular cross section, although shells of different shape are used in specific applications. For this particular study shell is considered, which is generally a one pass shell. A shell is the most commonly used due to its low cost and simplicity, and has the highest log-mean temperature-difference (LMTD) correction factor. Although the tubes may have single or multiple passes, there is one pass on the shell side, while the other fluid flows within the shell over the tubes to be heated or cooled. The tube side and shell side fluids are separated by a tube sheet. Baffles are used to support the tubes for structural rigidity, preventing tube vibration and sagging and to divert the flow across the bundle to obtain a higher heat transfer coefficient.

II. PROBLEM DEFINATION

Shell and tube heat exchanger is the most common type of heat exchanger used in industries. In this project, the design of a shell and tube heat exchanger unit has been carried out. The task at hand was to design and fabricate a heat exchanger with minimum cost and a good heat transfer rate. The tests for the heat exchanger are done by experimental method. The shell of the heat exchanger is made from Mild Steel material and the pipes used are made of copper

III. LITERATURE REVIEW

Arjun Kumar Prasad et.al (2020) [1] the study shows that the application of Differential Evolution (DE) for the optimal design of shell-and-tube heat exchangers. The main objective in any heat exchanger design is the estimation of the minimum heat transfer area required for a given heat duty, as it governs the overall cost of the heat exchanger. Many configurations are possible with various design variables such as outer diameter, pitch, and length of the tubes; tube passes; baffle spacing; baffle cut etc. Hence the design engineer needs an efficient strategy in searching for the global minimum. The objective was to design the shell and tube heat exchanger in the way which gives maximum heat transfer between both the fluids.

Ram Kishan et.al (2020) [2] the study shows the CFD analysis of shell and tube heat exchanger model using ANSYS Fluent. The aim of the study is design tube and box heat exchanger with various pattern of tubes and examine the flow and temperature field at inlet and outlet point of tube and container using ANSYS programming tool. From this study copper material is selected for the tubes and stell material for the shell. As per results it is concluded that Zigzag pattern tube design gives better heat transfer in heat exchanger as comparison to others.

P.Mathiyalagan (2019) [3] : the study shows an analysis of outline and forms of heat exchanger, Thermal Design and Mechanical Design using the ASME standard. The construction of STHE, i.e. thermal and mechanical design, was carried out by means of TEMA/ASME specifications, both manually and using software. It is noticed that the construction of STHE accomplished by both methods is very straightforward, basic advancement and time-consuming as a modern heat exchanger.

Pranita Bichkar et.al (2018) [4] the study shows that how design of baffle plates can affect the thermal efficiency of the heat exchanger. . Increasing the number of baffles beyond certain number gives serious effects on pressure drop. So by changing the types of baffles without hampering the other dimensions suggested that single segmental baffles show the maximum pressure drop while it reduced when helical baffles are used. Single segmental baffles show the formation of dead zones where heat transfer cannot take place effectively. This problem is solved by usage of double segmental baffles. It also reduces the vibrational damage as compared to single segmental baffles.

Saurabh Sharma et.al (2018) [5]: the study shows the review about major work done on design of Baffle plates and its different orientations to improve overall performance of shell and tube heat exchanger. From CFD simulation results, for fixed tube wall and shell inlet temperatures, shell side heat transfer coefficient, pressure drop and heat transfer rate values are obtained. So, overall we can say that using heat exchanger with 25% baffle cut percentage with 45° inclination angle will give best result compared to all other design models under study. This results in higher heat transfer rate, greater heat transfer coefficient value and lesser pressure drop of that shell side fluid

Kaushik Parmar et.al (2017) [6] the study shows the l design the heat exchanger by bell delware method to increase heat transfer by using various material and geometries. shell and tube heat exchanger is analyzed using Bell Delaware methods and heat transfer coeffient, Reynold's number, pressure drops are calculated. Also the shell side pressure increase rapidly with increasing flow rate and this increase is again more in Bell Delaware method as compared to others

Sandeep. K. Patel et.al (2016) [7]: the study shows that how to design with optimization of mass flow rate and spacing of baffle. From literature review it can be concluded that, There is increase in pressure drop with increase in fluid flow rate in shell and tube heat exchanger which increases pumping power. Tube pitch ratio, tube length, tube layout as well as baffle spacing ratio were found to be important design parameters which has a direct effect on pressure drop and causes a conflict between the effectiveness and total cost. It is necessary to evaluate optimal thermal design for shell and tube heat exchanger to run at minimal cost in industries.

Moses Omolayo et.al (2016) [8]: the study shows that how different tube layouts affect the pressure drop of fluid flowing through shell. n this study, numerical investigation has been carried out for predicting the performance of shell and tube heat exchangers with three different tube layout patterns. The results showed that much of the heat transfer and pressure drop occur during the cross-flow of shell-fluid through the tube bundles. the STHE_T is more desirable follow by the STHE_C as they exhibit higher heat transfer coefficient than the STHE_RT for the same pressure drop in the shell-side.

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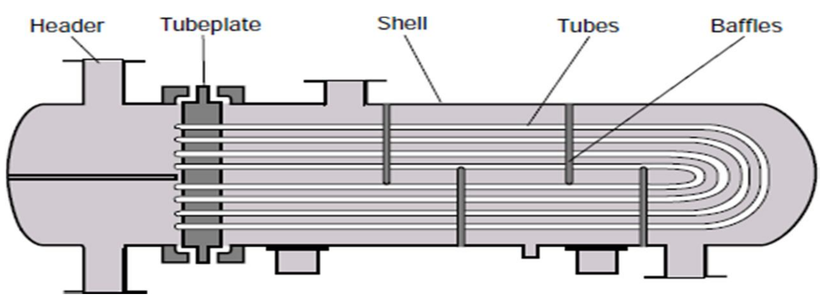
Raj Rajat et.al (2014) [9]: the study shows that how different load conditions and different ambient temperature affect the working of the heat exchanger. a lot of factors affect the performance of the heat exchanger and the effectiveness obtained by the formulas depicts the cumulative effect of all the factors over the performance of the heat exchanger. It may be said 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. However it is also seen that there does not exists direct relation between the turbulence and effectiveness and effectiveness attains its peak at some intermediate value. The ambient conditions for which the heat exchanger was tested do not show any significant effect over the heat exchanger's performance.
P.S.Gowthaman et.al (2014)[10]: the study shows that the analyse of two different baffle in a Shell and Tube Heat Exchanger done by ANSYS FLUENT. Baffle is an shell side Component of shell and tube heat exchanger. The segmental baffle forces the liquid in a Zigzag flow and improving heat transfer and a high pressure drop and increase the fouling resistance and Helical Baffle have a Effective Performance of increasing heat transfer performance. From the Numerical Experimentation Results it is Confirmed that the Performance of a can be improved by Helical Baffles instead of Segmental Baffles. Use of Helical Baffles in Heat Exchanger Reduces Shell side Pressure drop, pumping cost, weight, fouling etc as compare to Segmental Baffle for a new installation. The Pressure Drop in Helical Baffle is Appreciably lesser as Compared to Segmental Baffle heat exchanger.
Majid Amidpour et.al (2011) [11]: the study shows that how the total construction cost for the manufacturing can be reduced by using constructional theory. Shell and tube heat exchangers have been optimized using a new useful method called the constructional theory. The results of design using the constructional theory are heat exchangers with in-series sections which we call constructional shell and tube heat exchangers. In sections of the heat exchanger, optimal values of diameter and length are found by trade-off between operational and capital costs. The series structure of sections of constructional heat exchangers facilitates reparation, maintenance and deposit removal throughout their operation. The case study used in this paper for validation which was taken from one of the renowned reference texts on heat exchanger design represented more than 50% reduction in [10] total cost compared to the usual method of design. Consequently, designing heat exchangers by the use of constructional theory is proposed as a useful method for designers, engineers and researchers.
Uday C. Kapale et.al (2005) [12]: the study shows the effect of pressure drop at the shell side of shell and tube heat exchanger. The present model is developed based on estimated actual flow pattern of the liquid in the shell. The model is simple and based on geometrical and operating parameters of the heat exchanger and covers the Reynolds numbers ranging from 103 to 105. The present model results can be used by designers confidently.

IV. DESIGN METHODOLOGY

Several designs constrain have been implicated in the project they are as follows.



A. Making of Shell

We used a 3mm thick Mild Steel sheet to make the shell. First we took the required size of sheet by cutting it form a standard size sheet available in the market. Then with the help of cold rolling we made a cylinder out of that sheet and then welded the edges together. We welded it through in order to avoid leakage.

B. Making of Tubes

For tube we decided to use Copper tube because the heat transfer rate of copper is more than Mild Steel. We used manual bending with sand filled inside the copper tubes in order to avoid the cracking of tubes which will lead to leakage of hot water in it. We used 20 tubes which go inside of the shell.

C. Rubber Gasket
We have used Rubber Gasket in order to avoid leaks from shell side. The Rubber Gasket cut in circle shape in same size of the outer ring and is fixed between the ring and the side plate of shell. The Rubber Gasket will be fitted on both side of shell.

D. Rotameter
We have installed Mass Flow meter on the hot water inlet side in order to calculate the flow rate of hot water.

E. Pump
We have used small capacity submersible pump of 18W for hot water circulation.

F. Thermometer
We used basic regular thermometer for the temperature measurement of hot and cold water and also to measure the temperature difference.

G. Side Cover
The side cover made of Mild Steel is used to cover both end sides of the shell where the tubes bends are exposed and the outlet of the shell water (cold water) is given in the covering.

H. Flow Control Ball Valve
We have used four Flow Control Ball Valve each before inlet and outlet of both hot water and cold water so that we can set the flow of both hot and cold water and can get higher efficiency. We used PVC ball valve instead of brass to cut the cost.
Types of Shell and Tube Heat Exchanger according to flow arrangement:
1) *Parallel Flow:* In this type the inlets for the hot fluid and cooler fluid are kept at the same end of the heat exchanger and the working medium are allowed to move in the same direction towards the outlet.
2) *Counter flow:* On the same end of the heat exchanger inlet of one pipe and outlet of another pipe is made. Hence by this configuration fluids will be travelling in vice versa direction to each other.
3) *Cross flow:* If fluids are made to move perpendicular to each other this is called cross flow.

I. Material Selection for Tube
Among the two fluids one is made to pass through the tubes so it becomes necessary to choose a tube which is capable of facing every possible condition.
For this the tubes must be having a good thermal conductivity. As the temperature along width of the tube varies thermal stresses are observed by the tubes. So the tubes must be designed in such a way that it can hold the thermal stresses. And the tube material must becompatible with the pH of the fluid. In addition to all this tube must be corrosion resistant. Commonly used tube materials are, aluminium, copper alloy, stainlesssteel, Carbon steel and titanium. Fluoropolymers arealso used viz, Perfluoroalkoxy alkane (PFA) andFluorinated ethylene propylene (FEP).

J. Applications of shell and tube heat exchanger:
These are highly used to make heat transfer possible between two fluids or mediums. These are used in industrial sectors for heating or cooling purpose.

The main applications are:
1) Space heating
2) Refrigeration
3) Air conditioning
4) Power plants
5) Chemical plants
6) HVAC
7) Air processing

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K. Advantages

1) They can be designed and manufactured to bear very high pressures.
2) They have extremely flexible and steady design.
3) They have no dimension limit.
4) Pressure loss is at a minimum and can be maintained at a minimum in line with the process purpose.
5) They can easily be disassembled and assembled back for maintenance, repair and cleaning.
6) Easy maintenance and repair.

L. Limitations

1) Heat exchange effectiveness is less
2) Requires more space
3) Capacity of tube cooler can't be expanded.

V. RESULT

1) Inlet of hot water (t_1)= 50^0C (323K)
2) outlet of hot water (t_2)= 33^0C (306K)
3) Inlet of hot water (t_3)= 30^0C (303K)
4) outlet of hot water (t_4)= 34^0C (307K)
5) Mass flow rate of hot water (m_h) = 2.6l/min (43.3kg/sec), Mass flow rate of hot water (m_h) = 5/min (kg/sec)

VI. CALCULATIONS

1) Length of copper pipe = 762mm
2) Cp of water = 4.182 KJ/KgK
3) (T_h) = $t_1 – t_2$ = 323 – 306 = 17k
4) (T_c) = $t_4 – t_3$ = 323 – 306 = 3k
5) LMTD = T_h-T_c / ln(T_h/T_c)= 8.07K
6) Q= mcp($t_1 – t_2$) = 3.078W
7) A= 3.14.r^2h = 1.11m^2
8) Q = U.A.LMTD
   3.078 = U. 1.11. 283.45
   U=9.78*10^{-3} W/M^2K
9) Efficiency = Q/ Q_{MAX} = $m_h$cp($t_1 – t_2$)/ C_{min}($t_1 – t_3$) = 85%

VII. CONCLUSION

Shell and Tube heat exchanger is very economical and useful in Thermal industries. Due to the size of the Heat Exchanger in industries it cannot be shifted to different locations, but with smaller and compact size it can be moved easily and can be used where ever the users wants to use it.

For this project we have used normal room temperature water as a cooling medium to cool the heated water which will pass through the copper tube.

By doing this we achieved a temperature change of 17°C. If a low temperature cooling medium is used in this project the temperature difference can be much higher.

VIII. FUTURE SCOPE

Due to portability and low cost of this Heat exchanger the demand can be more in the market for it. Because of the portability it can be moved and taken anywhere with very minimum efforts. If a good Cooling medium is used for it the temperature difference can be increased even further and good efficiency will be achieved. To operate this heat exchanger high skilled worker is not required a semi-skilled Worker can operate it easily. The cost of the heat exchanger is less and it can also be used in small scale industries and does not require a separate room to operate.

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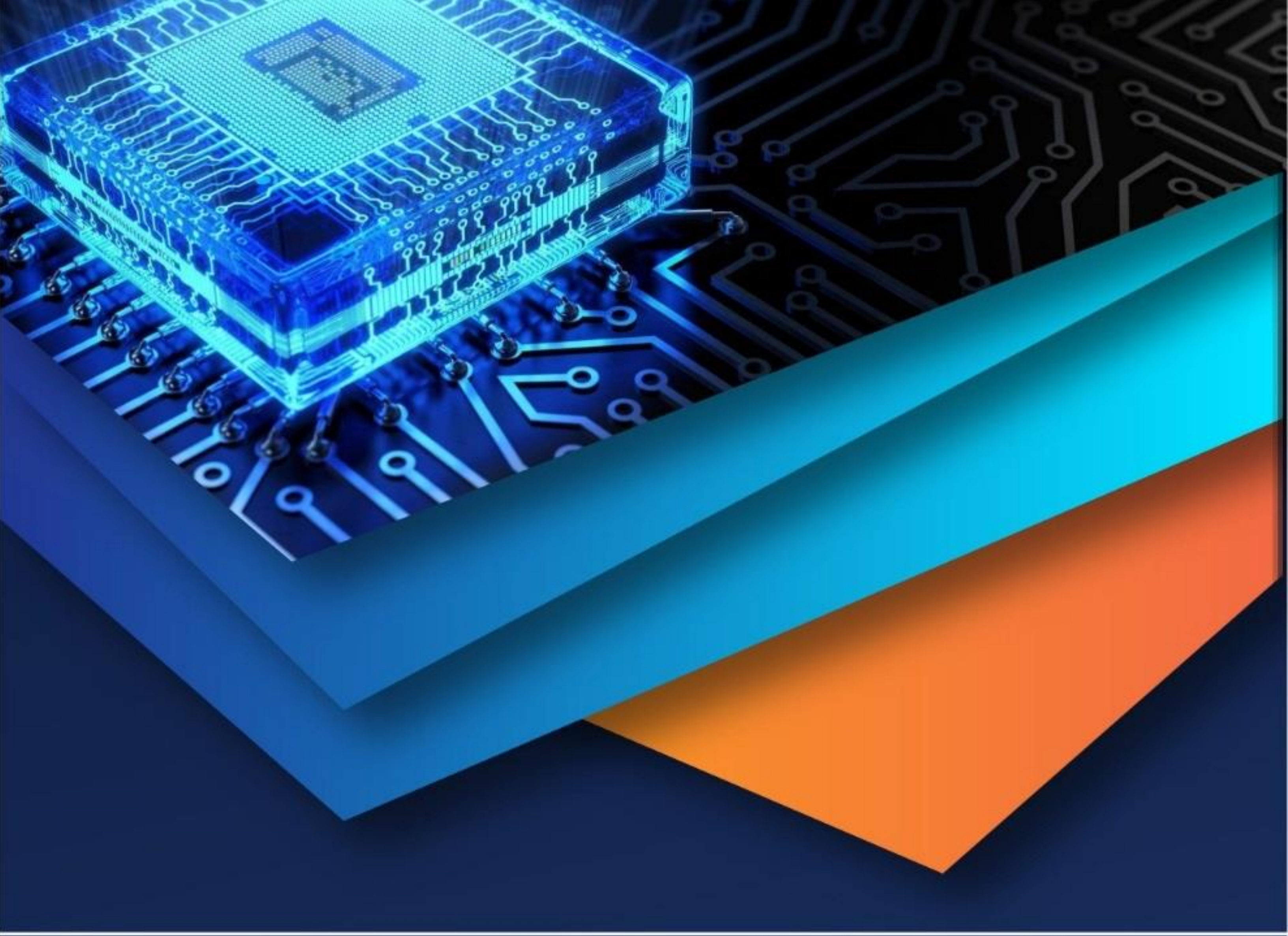

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