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EXPERIMENTALLY ANALYSING THE EFFECTIVENESS OF SHELL AND TUBE HEAT EXCHANGER BY VARYING BAFFLE CONDITIONS

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Abstract— **Heat exchangers are a device that is used to transfer heat from one medium to another. These media can be a gas, liquid, or a combination of both. This paper contains the design and fabrication of shell and tube heat exchanger manually and then the analysis of the effects on heat exchanger by varying conditions such as in this case is number of baffle plates. Designing of heat exchanger is done by using kern's method. In this experiment heat gain of cold water is analysed i.e., change in temperature of cold water with the change in temperature of hot water passed through. Two different setup of heat exchanger was made.In first setup 7 baffle plates were used and in second setup 9 baffle plates were used and in both temperature of cold water passed through was kept same and also all the inlet conditions were also kept similar as in the first setup. Readings were taken such as change in temperature of cold water by change in number of baffle plates. All the observations are discussed in detail inside this paper.**

Index Terms— **Heat Exchanger, Baffle Plates, fabrication, LMTD method, Nusselt number.**

I. INTRODUCTION

Heat exchangers are devices designed to transfer heat between two or more fluids—i.e., liquids, vapours, or gases—of different temperatures. Hence the main function of heat exchanger is to either remove heat from a hot fluid or to add heat to the cold fluid. Depending on the type of heat exchanger employed, the heat transferring process can be gas-to-gas, liquid-to-gas, or liquid-to-liquid and occur through a solid separator, which prevents mixing of the fluids, or direct fluid contact. Other design characteristics, including construction materials and components, heat transfer mechanisms, and flow configurations, also help to classify and categorize the types of heat exchangers available. Finding application across a wide range of industries, a diverse selection of these heat exchanging devices are designed and manufactured for use in both heating and cooling processes

Shell and tube heat exchangers are simply a device that puts two working fluids in thermal contact using tubes housed within an outer cylindrical shell. These two integral pathways are usually built out of thermally conductive metals that allow easy heat transfer. Basic components of shell and tube heat exchanger (STHE) consists of bundle of tubes that are enclosed in shell which is of cylindrical type, one fluid is pass through the tubes and second fluid flows through shell. Most commonly used STHE have large heat transfer efficiency in comparison with others. Shell and tube heat exchangers with segmental straight baffles is largely used in chemical, food industries oil refineries.

II. LITERATURE REVIEW

Rajagopal THUNDIL KARUPPA RAJ and Srikanth GANNE investigated the impacts of baffle inclination angles on fluid flow and its effect on readings of heat exchanger. Three baffle inclinations were at 0°, 10°, and 20° respectively. Simulation based results were analysed, first with segmental baffle plates perpendicular to fluid flow and second with segmental baffles inclined to the direction of fluid flow were compared. study was done on a single shell and single side pass parallel flow heat exchanger.The flow parameters and temperature fields inside the shell were studied using non-commercial computational fluid dynamics software tool ANSYS CFX 12.1. Baffle cut was made 36%.From the computational fluid dynamics simulation results, the shell side outlet temperature, pressure drop, re-circulation near the baffles, optimal mass flow rate and the optimum baffle inclination angle for the given heat exchanger geometry were determined and the conclusion from this investigation was the shell and tube heat exchanger with 20° baffle inclination angle results in better performance compared to 10° and 0° inclination angles baffle plates.

A. Musilim, A. Nwagwo, O. K. Uche computationally investigated the effect of Baffle Cut Sizes on Temperature and Pressure Drop at Various Mass Flow Rate in a Shell and Tube Heat Exchanger.Baffle cut were varied between 25%, 35%, and 45%. Their study showed that increasing baffle cut percentage (i.e. reducing baffle diameters) demonstrates significant improvement on the flow conditions and overall cooling performance of the heat exchanger.

A. GopiChand et.al. a simplified model for the study were made and thermal analysis of shell-and tubes heat exchangers of water and oil type were done. In this paper the thermal analysis by using theoretical formulae were done and for this they chose a practical problem of counter flow shell and tube heat exchanger of water and oil type, by using the data from theoretical formulae, they designed a model of shell and tube heat exchanger with the help of software Pro-E and thermal analysis by using Floefd software. Results were compared which showed that they were getting an error of 0.023 in effectiveness.

A SadikinN Y KhianY P HweyH Y Al-Mahdi computationally analysed the effect of Number of Baffles on Flow and Pressure Drop in a Shell Side of a Shell and Tube Heat Exchangers. In this the number of baffles: 6, 8 and 10 and three cases of baffle orientation angles (45°, 90° and 180°) were done. Results obtained were as the number of baffle increases, the pressure drop and outlet temperature of the shell side increases. As the number of baffles increases, the water also creates a significantly smaller re-circulation zone in the shell and the flow is well developed.

III. CONCLUSION FROM LITERATURE REVIEW

Shell and tube heat exchanger's performance depends on number of factors such as materials used in design, velocity of flow of the fluids, thermal conductivities of fluids ambient temperature, baffle spacing, baffle cutting, number of baffle plates etc. Hence to make heat exchanger with exact outcome is difficult to achieve. However, by certain testing and experiments predictions can be made up to a certain level.
This paper is an attempt to analyse experimentally the outcomes by varying number of baffle plates.

IV. FABRICATION AND METHODOLOGY

Step 1 — **Select the materials which are to be used.**

Step 2 — **Methodology for designing shell and tube heat exchanger.**

Step 3 — **Purchasing the material.**

Step 4 — **Fabrication of heat exchanger with different number of baffles.**

Step 5 — **Performing thermal analysis of heat exchangers.**

Step 7 — **Study the difference between the two heat exchangers**

Step 8 — **Result compilation**

Step 9 — **Conclusion of the research**

V. METHODOLOGY

Designing of shell and tube heat exchanger is done by Kern's Method

Shell and tube heat exchanger are normally designed by two methods first is kern's method and second is Bell-Delaware method. Kern's method is a traditional approach which gives an approximate result. Whereas Bell-Delaware is accurate and gives comparatively good outcomes. Bell-Delaware is mainly focussed on pressure drop which gives accurate heat transfer coefficient but on the same way it is very tedious to design through Bell- Delaware method.

In this paper we have designed a shell and tube heat exchanger with the help of Kern' s method to cool the water from 60℃ to 50℃. This change in temperature is made exact in two different heat exchangers. In first heat exchanger number of baffle plates is 7 and in second heat exchanger number of baffle plates is 9.

Steps of designing are-

i. Energy balance equations to find out the outlet temperature of cold liquid which is water.
For this inlet and outlet condition of hot liquid mass flow rate hot and cold liquidis fixed.

$$Q = m_h c_{ph}(t_{h1}\text{-}t_{h2}) = m_c C_{pc}(t_{c2}\text{-}t_{c1})$$

$$T_{c2} = \frac{(\dot{m}c_p)_h (T_{h1} - T_{h2})}{(\dot{m}c_p)_c} + T_{c1}$$

ii. LMTD method to determine log mean temperature difference

$$LMTD = \frac{\Delta T_a - \Delta T_b}{\ln\left(\frac{\Delta T_a}{\Delta T_b}\right)}$$

ΔT_a = *temperature difference at entrance*

ΔT_b = *temperature difference at exit*

iii. Number of tubes required is calculated as by the given formula

$$N_t = (CTP)\frac{\pi D_s^2/4}{ShadeArea}$$

$CTP = 0.93$ for one-pass exchanger
$CTP = 0.9$ for two-pass exchanger
$CTP = 0.85$ for three-pass exchanger

Where CTP is the tube count constant that accounts for the incomplete coverage of the shell diameter by the tubes, due to necessary clearance between the shell and the outer tube circle and the tube pass lane for multiple pass design.

Here we have used single pass heat exchanger

iv. Now our next is to calculate equivalent diameter of shell for square pitch, tube bundle diameter, area with the help of given formula

$$D_e = \frac{4\left(P_t^2 - \pi d_o^{\,2}/4\right)}{\pi d_o}$$

$$A = \frac{Q}{U_0 \Delta T}$$

v. Baffle spacing is calculated by following correlation

$$B = \frac{L_t}{N_b + 1}$$

Baffle spacing should be more than 40% of shell diameter

vi. Nusselt number in tube and shell is obtained with the help of following correlation

Tube side is calculated by

$$Nu_D = \frac{hd_i}{k_f} = 1.86\left(\frac{d_i \operatorname{Re}\Pr}{L}\right)^{\frac{1}{3}}\left(\frac{\mu}{\mu_s}\right)^{0.14}$$

vii. After strenuous mathematical calculation we have found the following values which are used for the final setup

t_{h1} = 60°C, t_{h2} = 50°C, t_{c1}= 25°C, t_{c2}= 35°C
m_h=m_c=0.222kg/sec
d_i = 19.5 mm, d_o =25 mm
N_t = 11
D_i= 143 mm
D_o = 150 mm
Number of baffles = 7
Baffle diameter = 143 mm
Baffle spacing = 230 mm
Note – segmented baffle plates are used with 30% cut to ensure flow of liquid through shell.

VI. FABRICATION OF EXPERIMENTAL SETUP

Shell and tube heat exchanger with 7 baffle plates

Shell and tube heat exchanger with 9 baffle plates

VII. TESTING AND ANALYSIS

Testing with various flow conditions were performed such as change in mass flow rate, parallel flow, counter flow, without insulation, with 7 baffle plates, with 9 baffle plates and the results obtained are shown below.

VIII. RESULTS AND DISCUSIONS

i. Parallel Flow condition, hot water in shell, 7 baffle plates

S.no.	Cold water at inlet (°C)	Cold water at outlet(°C)	Hot water at inlet (°C)	Hot water at outlet (°C)	Degree of cooling (°C)	Degree of heating (°C)	Effectiveness of heat exchanger
1	22.6	28.4	58.8	50.7	7.9	5.8	0.2182
2	23.2	29.3	57.6	49.9	7.7	6.1	0.2238
3	23.3	28.2	58.1	50.2	7.9	4.9	0.227
4	23.8	29.5	57.4	50.6	6.8	5.7	0.2024
5	22.9	27.7	55.6	49	6.6	4.8	0.2018

Average effectiveness = 0.21464

ii. Counter flow,hot water in tube, 7 baffle plates

S.no.	Cold water at inlet (°C)	Cold water at outlet(°C)	Hot water at inlet (°C)	Hot water at outlet (°C)	Degree of cooling (°C)	Degree of heating (°C)	Effectiveness of heat exchanger
1	23.4	29.1	59.2	50.3	8.9	5.7	0.2486
2	23.8	29.8	58.9	50.3	8.6	6	0.245
3	22.7	28.9	58.4	49.6	8.8	6.2	0.2465
4	23.9	30.2	57.9	49.8	8.1	6.3	0.2382

Average effectiveness = 0.244575

iii. Parallel Flow condition,hot water in shell, 9 baffle plates

S.no.	Cold water at inlet (°C)	Cold water at outlet(°C)	Hot water at inlet (°C)	Hot water at outlet (°C)	Degree of cooling (°C)	Degree of heating (°C)	Effectiveness of heat exchanger
1	24	30.3	61.3	52.6	8.7	6.3	0.2332
2	24.4	30.6	60.8	51.6	9.2	6.2	0.2527
3	23.8	30.7	60.4	52.2	8.2	6.9	0.2240
4	24.7	29.8	59.9	51.8	8.1	5.1	0.2301

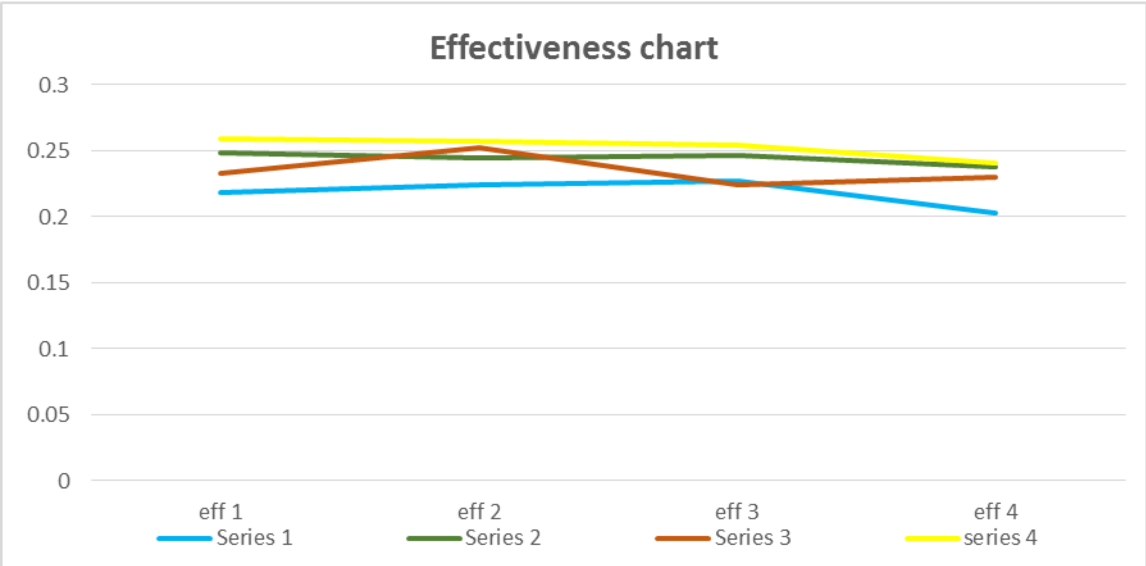
Average effectiveness = 0.235

iv. Counter flow, hot water in tube, 9 baffle plates

S.no.	Cold water at inlet (°C)	Cold water at outlet(°C)	Hot water at inlet (°C)	Hot water at outlet (°C)	Degree of cooling (°C)	Degree of heating (°C)	Effectiveness of heat exchanger
1	25.6	32.9	59.6	50.8	8.8	7.3	0.2588
2	25.4	32.5	58.8	50.2	8.6	7.1	0.2575
3	24.8	32.7	59.4	50.6	8.8	7.9	0.2543
4	24.6	31.8	59.1	50.8	8.3	7.2	0.24058

Average effectiveness = 0.252795

Comparison of effectiveness of heat exchanger with 7 baffle plates and with 9 baffle plates is shown by a chart



Hence it was observed that the effectiveness of heat exchanger increases as the number of baffle plates was increased to nine and approaches nearly to calculated by Kern's method.

Effectiveness of heat exchanger as calculated by Kern's method = 0.2812
Effectiveness of heat exchanger with 7 baffle plates = 02445
Effectiveness of heat exchanger with 9 baffle plates = 0.2528

IX. CONCLUSION

on the basis of above obtained result it can be said performance of heat exchanger and it's effectiveness depends upon number of factors such as ambient temperature, material of the tube and the shell, flow parameters, fouling inside heat exchanger, baffle spacing etc. The results obtained from this study demonstrates that the variation of the baffle spacing in shell and tube heat exchanger has been found to increase in the degree of heating of cold fluid and also the effectiveness of heat exchanger. Hence, further study in this field is likely to reveal more interesting results in heat exchanger design and operation.

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NOMENCLATURE

m= mass flow rate of fluid (kg/sec)
t=temperature of fluid (°C)
$t^{/}$= experimental value of temperature of fluid (°C)
C_p= specific heat of fluid (j/kg- °C)
C=capacity rate of fluid(W/°C)
LMTD=Logarithmic mean temperature difference (°C)
U (or U_o)=overall heat transfer coefficient (w/m^2°C)
A=Area of heat exchanger (m^2)
L= length of heat exchanger (m)
N=number of tubes
B=baffle spacing (mm)
P_r=Prandtl number
R_e=Reynold's number
N_u= Nusselt number
h=heat transfer coefficient (w/m^2 °C)
D_b=tube bundle diameter (mm)
d=diameter of tubes (mm)
D=diameter of shell (mm)
μ_s=viscosity of the shell-side fluid

SUBSCRIPTS

i=inner parameter
o=outer parameter
t=tube side parameter
h=hot fluid parameter
w=wall temperature
s=shell side parameter