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Enhancing the Heat-Transfer Co-Efficient By Using Taguchi Orthogonal Array

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ABSTRACT *:Shell and tube heat exchangers are mainly employed in the industries for its robust design and versatile purposes. Among many problems arise due to its complicated design structure, despite enhance the heat transfer co-efficient and reduce the pressure drop on a shell side is a notable thing. Geometrical parameters are also a cause for this problem. Kern's design procedure is used to solve the analytical calculations. Statistical design procedure is made by using Taguchi orthogonal array.*

KEYWORDS: *Geometrical Parameters, Taguchi Orthogonal Array.*

I. INTRODUCTION

The fulfilment of many industrial services requires the use of large number of double pipe hairpins. These consume considerable ground area and also entail a large number of points at which leakage may occur. Where large heat- transfer surfaces are required, they can best be obtained by means of shell and tube equipment. These exchangers are available in various sizes and used in industrial operations, energy conversion systems etc.

Classification Of Parameters

There are three types of parameters available in the shell and tube heat exchangers. They are geometrical parameters, flow parameters and flow parameters. Geometrical parameter plays a major role in the aspect of heat transfer co-efficient and pressure drop on shell and tube side.In this work, parameters are optimized by using a statistical technique. Besides, heat transfer co-efficient is the problem criteria in this work. So the analytical calculations are done up to the heat transfer co-efficient of the shell side only. The parameters are taken account in this work are number of baffles, shell diameter,
tube pitch and baffle space.

Significance Of The Noted Parameters

It is apparent that higher heat transfer co-efficient result when a liquid is maintained in a state of turbulence. To induce turbulence outside the tubes it is customary to employ baffles, which causes the liquid to flow through the shell at right angles to the axes of the tubes. This causes considerable turbulence even when a small quantity of liquid flows through the shell. Furthermore, baffle spacing also a notable parameter to induce the heat transfer co-efficient whereas, shell diameter and tube pitch are mainly responsible for make the changes in the heat transfer surface area.

Introduction To The Statistical Technique

Taguchi method is one of the best off-line methods for achieving quality control. By using Taguchi approach on problems having less number of parameters is obtaining their feasible solution. By performing the problems by the aid of full factorial design it could take more amount of time. Despite in this work only finite number of parameters is taken. The off-line portion of quality control is addressed in the text because of the paucity of materials on the phase of Taguchimethods and the positive impact on cost that is obtained by improving the quality at the earliest times in product life cycle. It is a powerful tool for the design of high quality systems. The Taguchi approach to experimentation provides an orderly way to collect, analyse and interpret data to satisfy the objectives of the study

PROBLEM DEFINITION AND ASSUMPTIONS

PARAMETER NAME	NOTATION	
Shell size	D_S	0.254M
Tube outer diameter	D_0	0.019M
Tube bundle geometry	_	Square
Tube pitch	P_T	0.0254M
Central baffle spacing	L_B	0.0582M
No of baffles	N_B	6

This problem is taken from the book [1].
Assumptions:
1. Neglect the friction factor on shell side.
2. Water is taken on shell side and taken the average temperature of the fluid as 80^0c.and also assumes that mass flow rate is 1800 Kg/hr.
3. Hot fluid is taken on the shell side.

Design Approach And Kern's Methodology

The prediction of performance and design characteristics of shell and tube heat exchanger is complex due to the shell-side flow conditions. But more than 60 % of the industries are using shell and tube heat exchanger, because of its various ranges and better performance than the other heat exchangers. So the most influencing design parameters have been identified for increasing the performances of the heat exchanger. There are many variables associated with the geometry (i.e. baffles, tubes, pitches, etc.) in a shell and tube heat exchanger in addition to those for the operating conditions. The design calculations are essentially series of iterative rating calculations are made by using KERN'S method. Heat transfer and pressure drop on shell side are significant for rating procedure. The heat transfer co-efficient is computed using available correlations and moreover is used for pressure drop calculations. For designing shell and tube heat exchanger there are numerous design procedures are available. Among them kern's methodology plays a stupendous role in the performance of shell side on shell and tube heat exchanger.

Parameter Level Selection

SL NO	*PARAMETERS*	*LEVEL 1(m)*	*LEVEL 2(m)*	*LEVEL 3(m)*
1	SHELL SIZE(D_S)	0.249	0.254	0.259
2	TUBE OUTER DIAMETER(D_0)	0.014	0.019	0.024
3	CENTRAL BAFFLE SPACING(L_B)	0.0577	0.0582	0.0587
4	TUBE PITCH(P_T)	0.0249	0.0254	0.0259

This parameter selection is based on the resolution level of the Taguchi orthogonal array. For the three level four factor analysis Taguchi preferred L9 and L27. From the above arrays L27 had higher resolution.

2.3 Taguchi Approached Parameter Values

SLNO	*SHELL SIZE*	*TUBE OUTER DIAMETER*	*BAFFLE SPACING*	*TUBE PITCH*	*HEAT TRANSFER COEFFICIENT*
1	0.249	0.014	0.0587	0.0259	1133.96
2	0.249	0.014	0.0582	0.0254	1092.5
3	0.249	0.014	0.0577	0.0249	1059.25
4	0.249	0.019	0.0587	0.0254	1961.62
5	0.249	0.019	0.0582	0.0259	1825.42
6	0.249	0.019	0.0577	0.0249	2119.56
7	0.249	0.024	0.0587	0.0259	5396.16
8	0.249	0.024	0.0582	0.0249	8541.40
9	0.249	0.024	0.0577	0.0254	6687.80
10	0.254	0.014	0.0587	0.0259	1028.270
11	0.254	0.014	0.0582	0.0249	1123.72

12	0.254	0.014	0.0577	0.0254	1085.91
13	0.254	0.019	0.0587	0.0249	2076.81
14	0.254	0.019	0.0582	0.0254	1949.4
15	0.254	0.019	0.0577	0.0259	1853.61
16	0.254	0.024	0.0587	0.0254	6553.04
17	0.254	0.024	0.0582	0.0259	5402.12
18	0.254	0.024	0.0577	0.0249	8488.49
19	0.259	0.014	0.0587	0.0254	1075.65
20	0.259	0.014	0.0582	0.0259	1028
21	0.259	0.014	0.0577	0.0249	1117.05
22	0.259	0.019	0.0587	0.0259	1671.90
23	0.259	0.019	0.0582	0.0249	1991.45
24	0.259	0.019	0.0577	0.0254	1784.65
25	0.259	0.024	0.0587	0.0249	7553.79
26	0.259	0.024	0.0582	0.0254	5997.75
27	0.259	0.024	0.0577	0.0259	4921.19

II. SOLUTION

(TRIAL 1)
Shell size = 0.249 m
Tube outer diameter = 0.014 m
Baffle spacing = 0.0587m
Tube pitch = 0.0249 m
Properties of water at 80^0 C [2]
Density ($\dot{\rho}$) = 974 kg/ m^3
Kinematic viscosity (υ) = 3.64* 10^{-7} sq-m/s
Thermal conductivity (Ꝁ) = 0.6687 w/ m* k
Prandtl number (p_r) = 2.220
Specific heat capacity (c_p) = 4195 J/ kg* k
Dynamic viscosity (µ) =3.54*10^{-4} NS/sq-m
$A_S = (D_S * C * L_B) / P_T$
$A_S = (0.249 * 0.0109 * 0.0587) / 0.0249 = 0.00639\ m^2$.
$G_S = M_S / A_S$
$G_S = 0.5 / 0.00639 = 78.145$ Kg/ s*m^2.
$D_e = 1.27 * (P_T^2 - 0.7854\ D_0^2) / D_0$
$D_e = 0.042$ m.
$R_e = (G_S * D_e) / \mu$
$R_e = 9271.4$
$H = 0.36 * (Ꝁ / D_e) * R_e^{0.55} * pr^{0.33} = 1133.96\ w/m^2 * k$.

From results of the statistical mode the top five results are taken as test case.

Test cases	Heat transfer coefficient(w/ sq-m* k)
Trial no 9	8541
Trial no 19	8488.5
Trial no26	7553.8
Trial no10	6687.8
Trial no17	6553

III. CONCLUSION

The above results exclaimed that parameter is a considerable cause for affecting the equipment performance. The results are sorted in the descending order. Then the average ratio between the shell diameter and baffle space are 4.34 or approximately 4.5. And the ratio between the tube pitch and tube diameter is approximately equal to 1.05. These are the optimum co-relations which enhance heat transfer coefficient.

REFERENCE

[1] “Process Heat Transfer” by Donald .Q. Kern ISBN 0- 07- 085353-3.

[2] “Heat and Mass Transfer Data Book” by C.P. KothandaramanPaperback, Published 2010 by New Age International Pvt Ltd Publishers ISBN-13: 978-81-224-3123-0, ISBN: 81-224-3123-2