Heat Transfer Enhancement Analysis In Shell And Tube Exchanger Using Doughnut And Flower Baffles

S.Akila*, V.K.Bharathikkannan**, S.Kavin**, B.Balaji**

Abstract—Baffles are the essential part of a Shell and Tube Heat Exchanger acting as a tube support as well as used to route the shell side flow which is considered to be the most important to increase the heat transfer rate between hot and cold fluids. Different Baffle sorts have been used in fabrication and their effects have been investigated by many researchers. This study focuses on the performance evaluation of a Shell and Tube Heat Exchanger equipped with flower and doughnut baffles and comparison have been made with conventional segmental baffles and flower baffles. The investigation is carried out by choosing three independent variables (hot water inlet flow rate, cold water inlet flow rate and hot water inlet temperature) and they are varied to verify their interactions on the three responses (Hot water outlet Temperature, Cold water Outlet Temperature and Heat Transfer Coefficient). The results are analyzed statistically by Box Behnken Design and the mathematical models have been developed. It is observed that combination of Flower and doughnut baffles contribute more to the performance of a Shell and Tube Exchanger by increasing the heat transfer coefficient when compared with segmental and flower baffles.

Index Terms – Baffles, Box Behnken Design, Doughnut, Segmental, Shell and Tube Heat Exchanger, Tube support

1 INTRODUCTION

Demand for energy, drastic change in the climatic conditions, green house effect, energy price hike are the alarming challenges throughout the world. These scenarios cater the promotion of new technology to minimize the consumption of energy through eco-friendly energy saving techniques with high effective output. The best way to attain the above target can be done by improvising the geometry of the heat transfer equipments without increasing its complexity of its design. One such highly employed thermal system in Oil Refineries and Chemical Process Industries is Shell and Tube Heat Exchanger (STHE). The enhancement in the thermal performance of STHE could be achieved by focusing on the baffle design. [1-4]

Heat exchanger is a type of heat transfer equipment which provides the transfer of heat energy between two fluids by varying the temperature of the system. STHE’s are classical heatexchangers which are familiar for its accurate design procedure, reliability, adaptability for high pressure operations and better performance. Hence, STHE plays a prominent role in heat transfer process in most of the chemical, chemical based and oil refining industries. [5-8]

The cold fluid flows inside the tube which is called tube side fluid and the hot fluid flows inside the shell which is called shell side fluid at varying temperatures. [9].The factors affecting the performance of a STHE are fluid turbulence, pressure drop in the shell and tube side, individual and overall heat transfer co-efficient, fouling factor, the flow rate of shell side fluid and tube side fluid, length to diameter ratio of heat exchanger and the baffle configuration. The influence of a baffle has a major part in a STHE in which the baffle holds up the tube bundles and creates the turbulent flow on the shell side. Based on the flow of the fluid in the shell, the flow in a STHE can be classified as: longitudinal flow, transverse flow and helical flow. [10-12]

The different types of baffles which are familiar in chemical industries are segmental type, disc and doughnut type, helical type, double helical type, orifice type baffle, horse shoe type baffle, sector shaped plain type baffle and flower segmental baffle. [15]Several problems in a STHE are created when it is used with the commonly used segmental baffles. They are: formation of fouling, creation of high pressure drop which retards the lifespan of STHE, requirement of high energy for pumping the fluid and damages caused due to the vibration in the shell side and increase in the heat load. In order to improve the efficiency of a STHE, a new combination of baffles is used to increase the heat transfer rate and decrease the pressure drop. [12-13]

Experimentally analyzing the flower segmental baffles with the normally used segmental baffles, the flower segmental baffle gives the best result by increase in the heat transfer rate than the segmental baffle. [6]. Also assimilating the doughnut type baffle with the segmental baffle, the doughnut baffle results in the enhancement of overall heat transfer co-efficient and the effectiveness of STHE than the segmental one. This rise is because of the rise in the area of STHE which causes the transfer rate to increase. [14]

In this experimental study, STHE is fabricated in such a way that doughnut and flower segmental baffles are alternatively arranged. The objective is to verify and estimate the individual and overall heat transfer coefficient in comparison with conventional baffles and to check the enhancement in the results between them.
2 DESIGN SPECIFICATIONS

The Shell and tube heat exchanger is designed with both doughnut and flower segmental baffles with the configurations below in table 2.1.1:

Table 2.1.1: STHE specifications

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Tube ID</th>
<th>Tube</th>
<th>Shell ID</th>
<th>Shell OD</th>
<th>Baffle spacing</th>
<th>Tube length</th>
<th>Number of tubes</th>
<th>Number of baffles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10mm</td>
<td>12.5mm</td>
<td>165mm</td>
<td>170mm</td>
<td>76mm</td>
<td>510mm</td>
<td>12</td>
<td>4</td>
</tr>
</tbody>
</table>

3 RESULT ANALYSIS and FIT STATISTICS

3.1 Effect of hot water inlet Flow rate and hot water inlet temperature on hot water outlet temperature

The hot water inlet flow rate is varied from 15 LPM (2680 ml/10 sec) to 40 LPM (6530 ml/10 sec), cold water inlet flow rate is varied from 2 to 8 LPM and inlet temperature of hot water is varied from 45°C to 60°C. Experiments runs are carried out based on the table 2.2.1 generated using BBD statistical analysis technique. The results are presented as 3D Surface Plots (figure 2-4). From the plots it was observed that variation in Hot water inlet flow rate does not have much influence on the outlet temperature of hot water whereas increase in cold water flow rate has a considerable incremental effect on the hot water outlet temperature. On the other hand, Hot water inlet temperature has an appreciable effect on the hot water outlet temperature. The effect of the independent variables (hot water inlet flow rate, cold water inlet flow rate and hot water inlet temperature) on the response 1 (hot water outlet temperature) is given in the ANOVA table (table 3.1.2) and the fit statistics are presented in table 3.1.1. It is evident that R2 value is well within the acceptable limit.
3.2 Effect of hot water inlet flow rate and hot water inlet temperature on cold water outlet temperature

The effect of the independent variables (hot water inlet flow rate, cold water inlet flow rate and hot water inlet temperature) on the response 2 (cold water outlet temperature) is analyzed and the 3D surface plots are given figure (5-7). From the plots all the three independent variables have their appreciable effect on the response. Cold water outlet temperature increases with the increase in hot water inlet flow rate, cold water inlet flow rate and hot water inlet temperature. ANOVA table and fit statistics is given in table 3.1.1 and 3.1.2. The p-value and R2 values are within the limits.

3.3 Heat transfer Coefficient Analysis

The selected variables are investigated to verify their influence on heat transfer coefficient (response 3). All the variables show an appreciable effect on the response. It is observed that there is an increase in the heat transfer coefficient value and this is mainly due to the design modification done in the equipment (i.e., utilization of flower and doughnut baffles). The increase in heat transfer coefficient value is much higher when compared with conventional segmental baffles and flower baffles alone reported by various researchers. ANOVA and Fit statistics are given in the table 3.1.1 and table 3.1.2.
Investigations are carried out by selecting three independent variables (hot water inlet flow rate, cold water inlet flow rate and hot water inlet temperature) and three responses (Hot water outlet Temperature, Cold water Outlet Temperature and Heat Transfer Coefficient). The results are discussed elaborately and it is concluded that usage of flower and doughnut baffles in an alternate fashion increases the heat transfer coefficient in comparison with segmental and flower baffles.

6 REFERENCES


