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Shell and Tube Heat Exchanger Design For Producing Methylaniline

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ABSTRACTS

The aim of this study is to design a heat exchanger. Heat Exchanger (HE) is the most important tool in the process of completing various energy cycles. The heat exchanger is designed with a two-pass shell and tube type to produce methylaniline. This research is studied to obtain several main dimensions of the equipment, such as the heat insulation surface area (A) which depends on other parameters, namely thermal load (Q), overall heat insulation coefficient (U) and logarithmic average temperature difference (ΔTlm). The heat exchanger design is calculated using the Microsoft Excel. The calculation results of heat exchanger design result are a shell length of 16 ft, an inner pipe diameter of 1.12 in, a shell diameter of 17.25 in, and a thickness of 0.65 in. The effectiveness value obtained is 11.62% with an impurity factor of 0.0061. Based on the results of these calculations, although the effectiveness value obtained is still relatively small, the two-pass shell and tube heat exchanger design still meet the criteria or requirements of the TEMA standard.

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1. INTRODUCTION

Heat Exchanger (HE) is the most important tool in the process of completing various energy cycles. The basic principle in the HE system is the completion of the process of transferring heat energy from various parts of the system without physical mixing (Alrwashdeh, *et al.*, 2022). In the industrial sector, especially the chemical industry, HEs have a very important role because they can streamline energy use (Pordanjani, *et al.*, 2019). The types of heat exchangers used in industry are: plate HE (Pandya, *et al.*, 2020; Bhattad, *et al.*, 2019; Fazeli, *et al.*, 2021; Tao & Ferreira, 2019), finned tube HE (Saleh, *et al.*, 2020; Zhang, *et al.*, 2019; Bezaatpour & Rostamzadeh, 2020), and shell and tube HE (Arani & Moradi, 2019; Fares, *et al.*, 2020; Said, *et al.*, 2019; Hojjat, 2020). One type of HE that is widely used in various industries is the shell and tube HE (Rashidi, *et al.*, 2022).

The use of shell and tube type HEs has been widely applied in various industries such as: the food industry (Jafari, *et al.*, 2018), the natural gas industry (Panahi, *et al.*, 2020), power generation (Zhang & Ge, 2021), petroleum industries (Masoud, *et al.*, 2020), refrigeration (Hu, *et al.*, 2018), and many others. HE can be used in the production process of methylaniline in the chemical industry. Methylaniline has been reported to have uses in a variety of applications including making dyestuffs, insecticides, preservatives for epoxy resin systems, and rubber manufacture. In the composition of paint dyes, methylaniline plays an important role as a corrosion inhibitor (Rzayev& İbadov, 2021).

Therefore, the aim of this study is to design a tube and shell type HE to produce methylaniline. This study discusses the process in obtaining several main dimensions of the equipment, such as the heat transfer surface area (A) which depends on other parameters, namely, logarithmic average temperature difference (ΔTlm), overall heat transfer coefficient (U), and thermal load (Q).

2. METHODOLOGY

2.1. Manufacturing of Methylaniline

Methylaniline from Chlorobenzene and Methylamine with the volume of 55,000 tons per year operates for 330 days per year and 24 hours per day. In order to achieve this production volume, 8,024.11 kg/hour of Chlorobenzene is needed and 11,070.08 kg/hour of Methylamine as the main raw materials. The Chlorobenzene and Methylamine reaction took place in a stirred tank flow reactor with Cu_2Cl_2 as catalyst. To remove side products, Methylamine Hydrochloride is reacted with NaOH and produces products in the form of Methylamine and NaCl. Next, the remaining reactants are separated from the products based on their boiling points.

2.2. Mathematical Models for Heat Exchanger (HE) Design

The design of a tube and shell type HE to be operated to produce methylaniline requires a number of assumptions for the fluid used in the equipment. These assumptions are presented in Table 1. There are two types of fluids used, namely: hot fluids and cold fluids. The hot fluid used is methylaniline, while the cold fluid used is water. Hot fluid (methylaniline) is added to the device at 475.16 K (Th in) temperature and leaves at 313.15 K (Th out). Cold fluid (water) is added into the device at 303.15 K ($T_{c\ in}$) and exits at a 323.15 K ($T_{c\ out}$) temperature. The velocity of the hot fluid that enters the tool is 6944.4444 kg/hour, while the speed of the cold fluid that enters the tool is 23.0931 kg/h. To collect the data needed to meet the specifications of the tool, the thermal analysis in this study was calculated using Microsoft Excel and refers to the Standard Tubular Exchanger Manufacturers Association (TEMA).

Table 1. Assumptions for fluid properties working on HE

	Shell Side	**Tube Side**
	Hot Methylaniline (T_h)	**Cold Water (T_c)**
Inlet Temperature, T_{in} (K)	475.16 K	303.15 K
Outlet Temperature, T_{out} (K)	475.15 K	323.15 K
Fluid Flow Rate (kg/h)	6944.4444 kg/h	23,0931 kg/h
Operating Pressure (atm)	1.2 atm	1.2 atm
Specific Heat (BTU/lb/°F)	0.4949 BTU/lb/°F	0.9979 BTU/lb/° F
Density (g/mL)	0.9059 g/mL	0.9979 g/mL

3. RESULTS AND DISCUSSION

The results of manual calculations using Microsoft Excel produce the specifications for shell and tube type HE as follows (Table 2).

Table 2. HE specification based on calculation results

No.	**Parameter**	**Results**
1	Initial Heat Transfer Rate (Q)	2343304.5 kJ/hour
2	Logarithmic Mean Temperature Difference (LMTD)	93.18 ° F
3	Assumed Overall Fluid Coefficient of Water (U_a)	100 btu/hour.ft^2.F
4	Area of Heat Transfer (A)	238.3490 ft^2
5	Number of Tube (Nt)	45.5420
6	CTP	0.9
7	CL	1
8	Total Heat Transfer Surface Area in Tube (at)	0.985 in^2
9	Mass Flow Rate of Water Fluid in Tube (Gt)	279774.1117 lb/hour.ft^2
10	Reynold Number in Tube (Re, t)	201790.0988
11	Prandtl Number in Tube (Pr, t)	16.72394908
12	Nusselt Number in Tube (Nu, t)	95.57
13	Convection Heat Transfer Coefficient in the Tube (hi)	964.7092 btu/hour.ft^2.F
14	Bundle Shell (Db)	16 ft

No.	Parameter	Results
15	Total Heat Transfer Surface Area in Shell (as)	0.1033 ft^2
16	Mass Flow Rate of Water Fluid in Shell (Gs)	148178.6179 lb/hour.ft^2
17	Equivalent Diameter (De)	17.25 in
18	Reynold Number in Shell (Re, s)	10266.8637
19	Prandtl Number in Shell (Pr, s)	6.9564
20	Nusselt Number in Shell (Nu, s)	490.73
21	Convection Heat Transfer Coefficient in Shell (ho)	301.2621 BTU/hour.ft^2.F
22	Actual Overall Heat Transfer Coefficient (Uact)	94.8793 btu/hour.ft^2.F
23	Heat Capacity Rate for Hot Fluid (C_h)	0.4949 BTU/lb.F
24	Heat Capacity Rate for Cold Fluid (C_C)	0.9979 BTU/lb.F
25	HE Effectiveness (ε)	11.62%
26	Number of Transfer Unit (NTU)	469.1617
27	Dirt Factor (Df)	0.0061

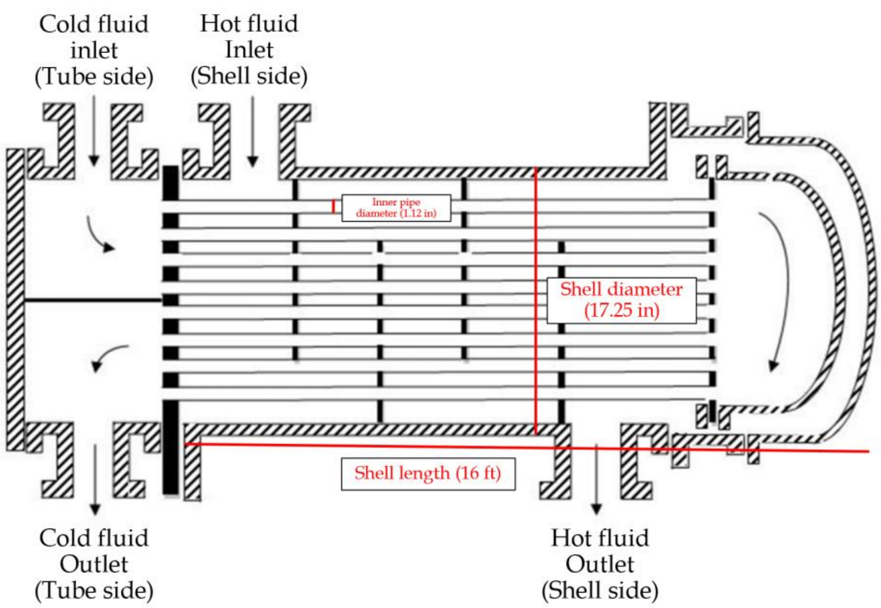

Figure 1. Shell and Tube Heat Exchanger Design

The concept of this heat exchanger (HE) design is to account for the difference in temperature between $T_{h\ in}$ and $T_{c\ in}$ with the apparent effect on the outlet temperature and the apparent effect on the outlet temperature. The value of Q in the shell and tube HE design is 2343304.5 kJ/hour. HE shell and tube turbulent flow

The effectiveness of HE is 11.62% which shows the actual heat transfer rate divided by the maximum possible heat transfer rate. The total performance (efficacy) of the HE, on the other hand, is determined by the working fluid's thermal conductivity, viscosity, density, and specific heat.

Based on the results obtained for the shell and tube and two pass heat exchanger (HE) design, the results have met the standards in accordance with the requirements of TEMA.

4. CONCLUSION

The results of the heat exchanger with shell and tube and two pass types have several specifications. The HE design has specifications for a shell length of 16 ft, an inner pipe diameter of 1.12 in, a shell diameter of 17.25 in, and a thickness of 0.65 in. HE has a turbulent flow type. The effectiveness value obtained is 11.62% with an impurity factor of 0.0061. Based on the results obtained, the HE design is in accordance with the standards that must be met from TEMA.

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