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# Designing of Shell and Tube Heat Exchanger, 1 Shell - 4 Tube with Fixed Tube Head & Counter Current using DWSIM

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**ABSTRACT:** Heating is one of the most crucial phenomena in 21<sup>st</sup> century industrial processes. It can be seen that during the last decade, new methods have been developed to harness heat energy as much as possible. Heat exchanger is one of the most significant and valuable equipment in chemical & allied industries. Designing a heat exchanger is one of the most complex methods and requires accuracy and precision undertaking the conditions in which it will be operated. Shell-and-tube heat exchangers are prevalent in industrial processes. DWSIM is a cape open modelling & simulation software that can be used to design an efficient heat exchanger according to the unit operation. It will be used in modeling and simulation, which helps in solving the problem of designing and testing as it makes the process of designing and testing the designed heat exchanger in a minimal amount of time making the process more economical.

**KEYWORDS:** Designing, DWSIM, Heat Exchanger, Modeling, Simulation.

## I. INTRODUCTION

Most chemical manufacturing processes rely heavily on heat transfer between fluids. [1]. Chemical companies rely heavily on heat transfer devices for controlling stream temperatures. A heat exchanger's geometry can take several forms, including shell and tube, double pipe, and plate and frame designs. The type of heat exchanger chosen will depend on the heat duty needed to bring a stream up to the specified temperature. Since shell and tube heat exchangers (STHE) can transfer a lot of heat while taking up very little room, they find widespread use in a variety of industrial settings. [2].

Many companies are looking for time-saving alternatives to designing shell and tube heat exchangers. Literature and industrial surveys show a need for good shell-and-tube heat exchanger design. The choice of heat exchanger for a specific application depends on various aspects, including the application, available floor space, resources, field connections, cost, and many more. In a competitive setting, the heat exchanger must transport enough heat, occupy less space, weigh less, and be priced competitively [3][4].

Heat transfer is most often used to develop devices to exchange heat between fluids. Heat exchangers distribute heat efficiently. Heat exchangers transmit heat between two or more different-temperature fluids.

Chemical heat transmission must be efficient. Many chemical processes require energy-intensive heat transfer; hence inefficiency can increase costs.

Chemical reactions require heat transfer between fluids. The chemical process relies on thermal processing to cool down a chemical after an exothermic reaction or heat components before commencing a reaction to generate a final product.

Designing an efficient heat transfer system is important to cost-effective chemical manufacture today. According to their use, shell-and-tube heat exchangers need improvement. Shell-and-tube heat exchangers have several workable parameters. Focus on their impact on shell-and-tube heat exchanger performance. In industries, heat exchangers are less efficient and more expensive. Designing process equipment constantly considers cost. Costs are capital and operational. Knowing all the current unsolved heat exchanger challenges, we believe our proposal is good for future [5][6]:

1. The efficiency of heat exchanger
2. The overall cost of a heat exchanger.

Most importantly, we use DWSIM software; significant industrial shell and tube exchanger equipment types can be designed using DWSIM shell and tube exchanger in any combination of processes, including single-phase heating or



cooling, boiling, or condensation. By using DWSIM Exchanger Design & Rating to efficiently design their exchangers, users typically save between 10 and 30% on equipment expenses. The programme does a thorough design search to identify the best cost arrangement that satisfies the process constraints given a process requirement and physical property data [5][7][8].

The programme offers detailed exchangers dimensions and performance information, as well as a specification document, configuration plan, and schematics of the tube layout. Complete mechanical design to meet ASME or other top international design codes can be transferred to DWSIM shell and tube Mechanical using completed designs [9][10].

DWSIM are thorough process modelling tools used in design for simulation process and process optimization. DWSIM offers a wide selection of heat exchanger customization options. Using DWSIM, the challenge of determining the flow velocity of cold and hot streams via the heat exchanger at various stream conditions can be rectified. This software's heat exchangers are highly adaptable, as they can tackle problems including temperature, pressure, heat flow, and the flow of material streams[5][11][12].

In DWSIM, models of heat exchangers can be selected to be analysed. It has the ability to run heat exchangers and simulate how heat transferred inside it. Due to DWSIM's clever design, it helps consumers save the cost of their equipment by 10% to 30%. By giving the physical data for the process requirements, the software may provide an optimal cost arrangement design [5][13][14][15].

## II. MATERIAL AND METHOD

### Steps of modeling and simulation of a shell and tube heat exchanger

In this paper, the problem statement is showed in Table 1 below. Table 2 illustrates various parameters incorporated for the study. Figure 1 shows the simulated design of a shell and tube heat exchanger. In this software, various specifications has been enter as shown in Figure 2.

Table 1:

Compounds	Water	Methanol
Inlet streams	Cold (H <sub>2</sub> O)	Hot (CH <sub>3</sub> OH)
Mass flow	15,000 kg/h	25,000 kg/h
Mole fraction	X (CH <sub>3</sub> OH) = 0	X (CH <sub>3</sub> OH) = 0
Mole fraction	X (H <sub>2</sub> O) = 1	X (H <sub>2</sub> O) = 0
Temperature	10 °C	80 °C
Pressure	1 bar	5 bar

Table 2:

Type of exchanger	2-8 shell % tube
Total no. of tubes	2048
Tube spacing	25 mm
Tube layout	Square
Thermal conductivity	60 W/mk
Tube roughness	0.05 mm
Fouling factor (Tube & shell)	0.00035 km <sup>2</sup> /W
External diameter for tube	20 mm
Tube thickness	2.5 mm
Tube length	5 m
Shell internal diameter	1000 mm
Baffle spacing	250 mm
Baffle cut	25 %
Fluid in shell	Methanol

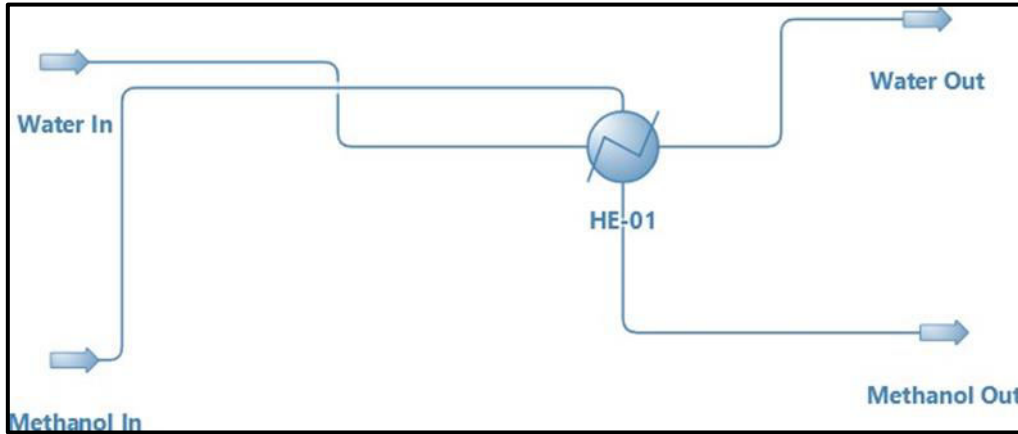
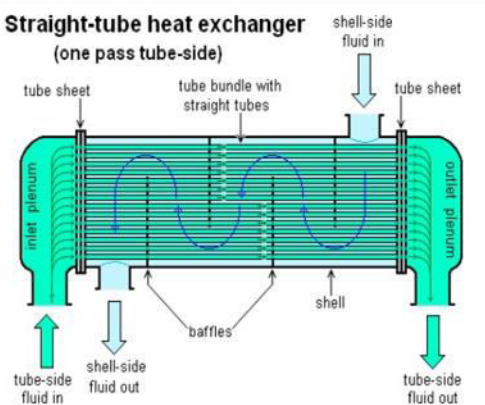


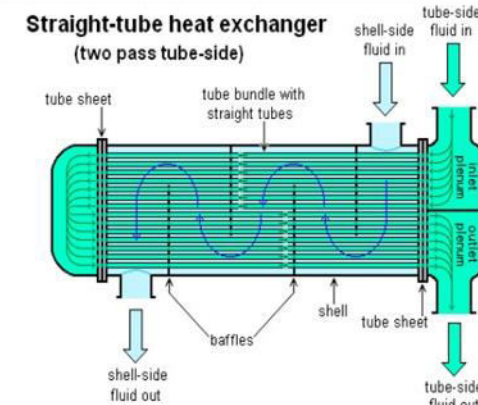
Figure 1: Basic simulated design of shell and tube heat exchanger.

Shell and Tube Exchanger Properties

**Straight-tube heat exchanger (one pass tube-side)**



**Straight-tube heat exchanger (two pass tube-side)**



Shell	
Shells in Series	1
Shell Passes	2
Internal Diameter	1000 mm
Fouling Factor	0.00035 K.m <sup>2</sup> /W
Baffle Spacing	250 mm
Baffle Cut (% diameter)	25 %
Baffle Type	Single
Baffle Orientation	Vertical

Tubes	
Internal Diameter	15 mm
External Diameter	20 mm
Length	5 m
Fouling Factor	0.00035 K.m <sup>2</sup> /W
Roughness	0.05 mm
Thermal Conductivity	60 W/[m.K]
Passes per Shell	4
Tubes per Shell	1024
Tube Spacing	25 mm
Tube Layout	Square
Fluid in Tubes	<input type="radio"/> Hot <input checked="" type="radio"/> Cold

Figure 2: Specifications of shell and tube heat exchanger in Condition 1

### Optimization Procedure

Increasing the no of shell passes to optimize the design of heat exchanger.

$$N_{\text{ShellPasses}} = 2 \text{ to } 4.$$

Apart from the shell passes, some other parameters like Internal diameter, External diameter and tube spacing are altered to get a variety of results in terms of Reynolds no and thermal efficiency, which will help us to draw a conclusion at the end of the designing process. The table below Table 3 shows the different values of Reynolds no and thermal efficiency upon the taken parameters:

Table 3: Values of different parameters obtained at varied shell passes

S. No	Shell passes	Internal diameter	External diameter	Tube spacing	Thermal efficiency, %	Re Shell	Re Tube
1	2	15 mm	20 mm	25 mm	79.06	2655.48	2039.24
2	4	30 mm	40 mm	50 mm	62.97	3349.24	1057.91
3	4	10 mm	10 mm	12.5 mm	83.21	2004.84	4193.25

As, per the results the parameters in condition 3 seems to be most suitable in terms of efficiency and optimization. To increase the efficiency in the results of condition 3 we will not try to optimize the tube length by increasing and decreasing simultaneously to see the effect on the Reynolds no and thermal efficiency. The table 4 below will have results for different values of Tube length keeping the other parameters constant as per condition 3:

Table 4: Values of different parameters obtained at varied length of tube

S. No.	Tube length	U (Overall heat transfer coefficient) W/m <sup>2</sup> k	Thermal efficient. %	Re Shell	Re Tube
1	5 m	373.253	61.93	2004.84	4193.25
2	10 m	373.938	68.23	1958.13	4430.14
3	20 m	373.189	95.41	1935.17	4528.87
4	30 m	372.164	99.30	1910.27	4464.94

The values of overall heat transfer coefficient, thermal efficiency and Reynold’s no of shell and tube for different tube lengths are there in the table above with a phenomenal thermal efficiency of 99% in condition 4 according to the table above at a tube length of 30 m.

**Comparison of Different Designs based on Different Parameters**

When we have compared the results among conditions 1, 2 & 3. We have found out that the condition 3 gives the most optimum results in terms of thermal efficiency and Reynold’s no. However, it still has a scope for further optimization, so we have done some trials with the tube length in condition 3. A detailed comparison of different design dimensions is below in Table 5:

Table 5: Comparison of various factors

Internal diameter, mm	External diameter, mm	Tube spacing, mm	Tube length, m	U (Overall Heat Transfer Coefficient), W/m <sup>2</sup> k	Thermal efficiency, %	Re Shell	Re Tube
7.5	10	12.5	10	373.938	68.23	1958.13	4430.14
7.5	10	12.5	20	373.189	95.41	1935.17	4528.87
7.5	10	12.5	30	372.164	99.30	1910.27	4464.94

**Result and discussion**

In the previous chapter, we have compared the dimensional designs of design no 3.2, 3.3, 3.4. Now we are able to extract the results from the designed heat exchangers of different dimensions. Several different properties of heat exchanger like shell side pressure drop, tube side pressure drop etc. are compared for different designs below in Figures 3 to 8 :



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Figure 3: Design no 3.2

Object	Water Out	Water In	Methanol Out	Methanol In	Unit
Temperture	74.3756	10	33.5039	80	C
Pressure	0.80146	1	4.78517	5	bar
Mass Flow	15000	15000	25000	25000	kg/h
Molar Flow	832.627	832.627	780.229	780.229	kmol/h
Molar Fraction (Mixture) / Methanol	0	0	1	1	
Molar Fraction (Mixture) / Water	1	1	0	0	

Heat Exchanger - Results		
Object	HE-01	Unit
Global Heat Transfer Coefficient (U)	373.395	W/[m <sup>2</sup> .K]
Heat Exchange Area (A)	321.056	m <sup>2</sup>
Heat Load	1123.88	kW
Cold Fluid Outlet Temperature	74.7	C
Hot Fluid Outlet Temperature	34.2977	C
[Shell & Tube] Internal Shell Diameter	1.00E+06	mm
[Shell & Tube] Number Of Tubes	1024	
[Shell & Tube] Tube Pitch	12500	mm
[Shell & Tube] LMTD Correction Factor (F)	0.751649	
Logarithmic mean temperature difference (LM	12.4726	C
[Shell & Tube] Reynolds Number Shell	1958.13	
[Shell & Tube] Reynolds Number Tubes	4430.4	
Thermal Efficiency	91.7348	%
Heat Loss	0	kW
Pressure Drop (Cold Side)	0.19854	bar
Pressure Drop (Hot Side)	0.214828	bar

Figure 4 – Result for Design 3.2

Figure 5: Design no 3.3

Object	Water Out	Water In	Methanol Out	Methanol In	Unit
Temperture	76.8994	10	31.5145	80	C
Pressure	0.604429	1	4.78517	5	bar
Mass Flow	15000	15000	25000	25000	kg/h
Molar Flow	832.627	832.627	780.229	780.229	kmol/h
Molar Fraction (Mixture) / Methanol	0	0	1	1	
Molar Fraction (Mixture) / Water	1	1	0	0	



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Heat Exchanger - Results		
Object	HE-01	Unit
Global Heat Transfer Coefficient (U)	373.311	W/[m <sup>2</sup> .K]
Heat Exchange Area (A)	642.755	m <sup>2</sup>
Heat Load	1169.18	kW
Cold Fluid Outlet Temperature	77.0574	C
Hot Fluid Outlet Temperature	32.1436	C
[Shell & Tube] Internal Shell Diameter	1.00E+06	mm
[Shell & Tube] Number Of Tubes	1024	
[Shell & Tube] Tube Pitch	12500	mm
[Shell & Tube] LMTD Correction Factor (F)	0.512159	
Logarithmic mean temperature difference (LM	9.51394	C
[Shell & Tube] Reynolds Number Shell	1935.71	
[Shell & Tube] Reynolds Number Tubes	4528.87	
Thermal Efficiency	95.4192	%
Heat Loss	0	kW
Pressure Drop (Cold Side)	0.395571	bar
Pressure Drop (Hot Side)	0.424508	bar

Figure 6 – Result for Design 3.3

Figure 7: Design no 3.4:

Heat Exchanger- Stream Wise Results					
Object	Water Out	Water In	Methanol Out	Methanol In	Unit
Temperture	76.1515	10	29.4235	80	C
Pressure	0.405183	1	4.36569	5	bar
Mass Flow	15000	15000	25000	25000	kg/h
Molar Flow	832.627	832.627	780.229	780.229	kmol/h
Molar Fraction (Mixture) / Methanol	0	0	1	1	
Molar Fraction (Mixture) / Water	1	1	0	0	



Heat Exchanger - Results		
Object	HE-01	Unit
Global Heat Transfer Coefficient (U)	372.1	W/[m <sup>2</sup> .K]
Heat Exchange Area (A)	964.454	m <sup>2</sup>
Heat Load	1216.58	kW
Cold Fluid Outlet Temperature	75.6177	C
Hot Fluid Outlet Temperature	29.7047	C
[Shell & Tube] Internal Shell Diameter	1.00E+06	mm
[Shell & Tube] Number Of Tubes	1024	
[Shell & Tube] Tube Pitch	12500	mm
[Shell & Tube] LMTD Correction Factor (F)	0.330586	
Logarithmic mean temperature difference (LM)	10.2545	C
[Shell & Tube] Reynolds Number Shell	1910.27	
[Shell & Tube] Reynolds Number Tubes	4464.94	
Thermal Efficiency	99.3014	%
Heat Loss	0	kW
Pressure Drop (Cold Side)	0.594817	bar
Pressure Drop (Hot Side)	0.634313	bar

Figure 8– Result for Design 3.4

**Results of the most efficient designs**

By analysing the results, it can be clearly established that design no 3.3 and 3.4 are the most efficient ones in the parameters of overall heat transfer coefficient, thermal efficiency and fluid flow profile in tubes and shells. Detailed comparison of the results of two most efficient designs then we have designed during the phase of this work in Figures 9 and 10

Heat Exchanger - Results		
Object	HE-01	Unit
Global Heat Transfer Coefficient (U)	373.311	W/[m <sup>2</sup> .K]
Heat Exchange Area (A)	642.755	m <sup>2</sup>
Heat Load	1169.18	kW
Cold Fluid Outlet Temperature	77.0574	C
Hot Fluid Outlet Temperature	32.1436	C
[Shell & Tube] Internal Shell Diameter	1.00E+06	mm
[Shell & Tube] Number Of Tubes	1024	
[Shell & Tube] Tube Pitch	12500	mm
[Shell & Tube] LMTD Correction Factor (F)	0.512159	
Logarithmic mean temperature difference (LM)	9.51394	C
[Shell & Tube] Reynolds Number Shell	1935.71	
[Shell & Tube] Reynolds Number Tubes	4528.87	
Thermal Efficiency	95.4192	%
Heat Loss	0	kW
Pressure Drop (Cold Side)	0.395571	bar
Pressure Drop (Hot Side)	0.424508	bar



<b>Heat Exchanger - Results</b>		
<b>Object</b>	<b>HE-01</b>	<b>Unit</b>
<b>Global Heat Transfer Coefficient (U)</b>	372.1	<b>W/[m<sup>2</sup>.K]</b>
<b>Heat Exchange Area (A)</b>	964.454	<b>m<sup>2</sup></b>
<b>Heat Load</b>	1216.58	<b>kW</b>
<b>Cold Fluid Outlet Temperature</b>	75.6177	<b>C</b>
<b>Hot Fluid Outlet Temperature</b>	29.7047	<b>C</b>
<b>[Shell &amp; Tube] Internal Shell Diameter</b>	1.00E+06	<b>mm</b>
<b>[Shell &amp; Tube] Number Of Tubes</b>	1024	
<b>[Shell &amp; Tube] Tube Pitch</b>	12500	<b>mm</b>
<b>[Shell &amp; Tube] LMTD Correction Factor (F)</b>	0.330586	
<b>Logarithmic mean temperature difference (LM)</b>	10.2545	<b>C</b>
<b>[Shell &amp; Tube] Reynolds Number Shell</b>	1910.27	
<b>[Shell &amp; Tube] Reynolds Number Tubes</b>	4464.94	
<b>Thermal Efficiency</b>	99.3014	<b>%</b>
<b>Heat Loss</b>	0	<b>kW</b>
<b>Pressure Drop (Cold Side)</b>	0.594817	<b>bar</b>
<b>Pressure Drop (Hot Side)</b>	0.634313	<b>bar</b>

Figure 9 and 10: Master property table of efficient designs.

Keeping the practical working conditions of shell and tube heat exchanger, it were taken as design no 3.3, with a thermal efficiency of around 95 %, will be the most efficient design of the heat exchanger. Design no 3.4 can also be regarded as the most efficiently designed heat exchanger, but the thermal efficiency of 99% is difficult to achieve in actual working conditions.

### III. CONCLUSION

In this work, we designed an shell and tube heat exchanger, using simulation software DWSIM. DWSIM is a CAPE-OPEN compatible chemical process simulator for Windows, Linux, and mac-OS which are open source. DWSIM has a graphical user interface (GUI), advanced thermodynamics calculations, reaction support, petroleum characterization/hypothetical component generation capabilities and developed on the Microsoft NET and Mono platforms. In this design, we have taken the heat exchange problem between methanol and water and then simulated this under specified conditions and dimensions. After that, we found out that the efficiency is around 60% for the initial designs of the heat exchanger, and the value of Reynolds no for the fluids present in both shell and tube is very poor. After using different dimensions to design an efficient heat exchanger for the problem, we got an efficiency of around 80% by altering the internal diameter, external diameter and tube spacing. However, in the hope of better results and to increase the efficiency of the design, we have tried different alternations in the length of the tubes and in this attempt, we can design the two efficient designs of the shell and tube heat exchanger for the above problem. One with the thermal efficiency of around 95 % and 99%, respectively and the fluid flow profile in shell and tube have come out to be laminar and turbulent respectively as we have expected at the start of our simulation. During this project, we have learnt the basics of modeling and simulations which can be further implemented in designing more industrial equipment.

The Future recommendations for this project are as follows: a) In the work of designing more sets of dimensions can also be designed to make the design efficient; b) The cost analysis of the heat exchanger which is designed will be done to get an efficient heat exchanger in the most economical price for the various industries.

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