Numerically and CFD studies on shell and tube heat exchangers

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Abstract - *This study aims to investigate the effect of different baffle layouts on the STHX (rate of heat transmission and pressure loss) of the A tube heat exchanger. The addition of baffles to the tube and shell mechanism enhances the heat switch while also boosting pressure. Best one, doubled, helical, triple section, and flowery baffles are used in tube heat exchangers, and they are designed using SOLIDWORKS go with the flow simulation software (ver. 2015). A single segmental baffle exhibits the best mass price and heat transmission rate on the shell side, according to simulation results. There are almost no stagnation zones inside the helical baffle, which results in significantly less fouling and a longer operating lifetime due to less flow-induced vibration.*

Key Words: Kern's theoretical approach, ASPEN Segmental baffles, Helical baffles, Flower baffles, Heat transfer coefficient, Pressure drop, SOLIDWORKS flow simulation.

1. INTRODUCTION

One of most strongly crucial components of a nation's economic and social development is the production of energy. Demand for natural resources and energy is rising daily as a result of population growth, industrialization, urbanisation, and expanding global trade and production opportunities. The usage of fossil fuels as a source of energy, dependency on foreign sources of fuel, high import costs, environmental issues, and the quick depletion of global fossil fuel reserves all raise the importance of renewable energy sources. Currently, renewable energy sources account for 20% of global energy consumption [1].

A power production system called the Organic Rankine Cycle (ORC) runs at low temperatures and substitutes hydrocarbon-based organic working fluids for water. Models of different complexity levels for shell-and-tube heat exchangers

The study and analysis of several heat exchanger models has been conducted. The general presumptions made by all of the models are outlined in the list below.

1. Radiation and heat transport rates in fluids are insignificant. Axial heat is also negligible in both fluids.

2. The heat capacity of the tube walls is zero in both the normal direction and the direction.

3. The thermal capacitance of the heat transmission shell is disregarded. that is only one dimensional and flow-oriented.

2 Methodologies: the use of heat exchangers

A separate, in-depth research will be needed to cover each area of the application of heat exchangers because it is such a vast topic. Their use is frequently found in home appliances, mechanical equipment, and the process sector. District systems can be heated using heat exchangers, which are increasingly being used nowadays. In order to condense or evaporate the fluid, heat exchangers are utilised in air conditioners and freezers. They also work in pasteurisation units in milk processing facilities. [3].

Heat Transfer Characteristics. The inlet/outlet temperature differential on the shell side, inlet/outlet pressure drop on the tube side, heat transfer area of the working fluid on the shell side, and heat transfer coefficient of the tube wall were all calculated using numerical analysis. First, the temperature difference on the shell side was calculated as the difference between the measured inlet and outlet temperatures. Likewise, the pressure drop was also calculated as the difference between the measured inlet and outlet pressures.

2. Methodology:

2.1 STHX's layout with the simulation tool ASPEN

A heat exchanger can be designed, rated, simulated, and priced using this software. Here, the heat exchanger created using Kern's theoretical approach is simulated using ASPEN. All the information pertaining to the heat exchanger's geometry and the fluid's parameters must be entered into the software's simulation mode. The fluid streams' input temperatures and flow rates must also be specified. It provides a TEMA sheet that shows the heat transfer coefficients, pressure drop both on the shell and tube sides, and other data that are important in heat exchanger design. The input for ASPEN simulation software program in this case is as proven within the following desk 2,

I. ProblemDefinition		
A. ApplicationOptions		
1. General		
Calculation Mode	Simulation	
Location of Hot fluid	Shell-Side	
Select Geometry Based on	SI standards	
Calculation Method	Advanced method	
2. Hot side		
Application	Liquid, no phase change	
Simulation Calculation	Output temperature	
3. Cold side		
Application	Liquid, no phase change	
Simulation Calculation	Output temperature	
B. ProcessData		
Fluid Name	Shell-Side hot water	Tube- Side cold water
Mass flow rate (kg/s)	0.3	0.753
InletTemperature(℃)	90	30
Operating Pressure abs (bar)	1	1
Fouling Resistance (m^2K/W)	0.0002	0.0002
I. PropertyData		
Properties of fluids were imported form ASPEN database		
I. ExchangerGeometry		
A. Shell/Heads		
Front Head Type	B-bonnet bolted or integral tube-sheet	
Shell Type	E-one pass shell	
Rear Head Type	U – U-tube bundle	
Exchanger Position	Horizontal	
Shell Inner diameter (mm)	154.05	
B. Tube		
Number of Tubes	10	
Number of Tubes Plugged	0	
Tube length (mm)	1038	
Tube Type	Plain	

Tube Outside Diameter (mm)	21.34
Tube wall Thickness (mm)	1.65
Tube Pitch (mm)	28.8
Tube Pattern	45
Tube Material	Copper
C. Baffles	
Baffle Type	Single Segmental
Baffle Cut (%)	29
Baffle Orientation	Horizontal
Baffle Thickness (mm)	3.2
Baffle Spacing (mm)	50.8
Number of Baffles	16
D. Nozzles	
Outside diameter of shell side Inlet nozzle (mm)	26.645
Inside diameter of shell side Inlet nozzle (mm)	26.645
Outside diameter of tube side Inlet nozzle (mm)	26.645
Inside diameter of tube side Inlet nozzle (mm)	26.645
V. Construction Specifications	
A. Materials ofConstruction	
Shell	Carbon Steel
Tube-Sheet	Carbon Steel
Baffles	Carbon Steel
Heads	Carbon Steel
Nozzle	Carbon Steel
Tube	Copper
B. Design Specifications	

Table2 Input to ASPEN simulation Software

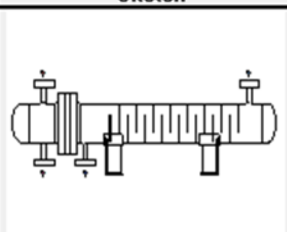
1. Codes and Standards	
Design Code	ASME Code Sec VIII Div 1
Service Class	Refinery Service
TEMA Class	C-General Class
Material Standard	ASME
Dimensional Standard	ANSI - American

Heat Exchanger Specification Sheet

1						
2						
3						
4						
5						
6	Size 152.4 - 1038	mm	Type BEU Hor	Connected in	1 parallel	1 series
7	Surf/unit(eff.) 0.7	m²	Shells/unit 1	Surf/shell (eff.)	0.7	m²
8	PERFORMANCE OF ONE UNIT					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		hot water		cold water	
11	Fluid quantity, Total	kg/s	0.3		0.7533	
12	Vapor (In/Out)	kg/s	0	0	0	0
13	Liquid	kg/s	0.3	0.3	0.7533	0.7533
14	Noncondensable	kg/s	0	0	0	0
15						
16	Temperature (In/Out)	°C	90	70.08	30	37.97
17	Dew / Bubble point	°C				
18	Density Vapor/Liquid	kg/m³	/ 971.8	/ 971.8	/ 984	/ 984
19	Viscosity	mPa s	/ 0.354	/ 0.354	/ 0.725	/ 0.725
20	Molecular wt, Vap					
21	Molecular wt, NC					
22	Specific heat	kJ/(kg K)	/ 4.196	/ 4.196	/ 4.178	/ 4.178
23	Thermal conductivity	W/(m K)	/ 0.67	/ 0.67	/ 0.623	/ 0.623
24	Latent heat	kJ/kg				
25	Pressure (abs)	bar	1	0.98743	1	0.97673
26	Velocity	m/s	0.17		0.75	
27	Pressure drop, allow./calc.	bar	0.11	0.01257	0.20684	0.02327
28	Fouling resistance (min)	m² K/W	0.0002		0.0002	0.00024 Ao based
29	Heat exchanged 25.1	kW		MTD corrected	45.21	°C
30	Transfer rate, Service 790.2		Dirty 790.2	Clean 1206.4		W/(m² K)

Table3.1 Heat Exchanger Specification sheet by ASPEN Simulation

31	CONSTRUCTION OF ONE SHELL				Sketch
32			Shell Side	Tube Side	
33	Design/vac/test pressure:g	bar	3.44738/ /	3.44738/ /	
34	Design temperature	°C	126.67	126.67	
35	Number passes per shell		1	2	
36	Corrosion allowance	mm	3.18	0	
37	Connections In	mm	1 19.05/ -	1 25.4/ -	
38	Size/rating Out		1 19.05/ -	1 25.4/ -	
39	Nominal Intermediate		/ -	/ -	
40	Tube No. 5Us OD 21.34	Tks-Avg 1.65 mm	Length 1038 mm	Pitch 28.8 mm	
41	Tube type Plain	#/m	Material Copper	Tube pattern 30	
42	Shell Carbon Steel	ID 154.05 OD 168.12 mm	Shell cover	Carbon Steel	
43	Channel or bonnet	Carbon Steel	Channel cover	-	
44	Tubesheet-stationary	Carbon Steel -	Tubesheet-floating	-	
45	Floating head cover	-	Impingement protection	None	
46	Baffle-cross Carbon Steel	Type Single segmental	Cut(%d) 29.22 H	Spacing: c/c 50.8 mm	
47	Baffle-long -	Seal type	Inlet	0 mm	
48	Supports-tube	U-bend 0	Type		
49	Bypass seal	Tube-tubesheet joint	Exp. 2 grv		
50	Expansion joint -	Type None			
51	RhoV2-Inlet nozzle 1190	Bundle entrance 15	Bundle exit 1	kg/(m s²)	
52	Gaskets - Shell side	Flat Metal Jacket Fibe	Tube Side	Flat Metal Jacket Fibe	
53	Floating head	-			
54	Code requirements	ASME Code Sec VIII Div 1	TEMA class	R - refinery service	
55	Weight/Shell 122.9	Filled with water 141.2	Bundle	20.2 kg	



TEMA Construction Details of Shell and Tube Heat Exchanger as provided by ASPEN Simulation (Table 3.2).The specification sheet shown in Fig. 3.1 and the TEMA specification sheet shown in Fig. 3.2 are the results of the APSEN Simulation programmed.

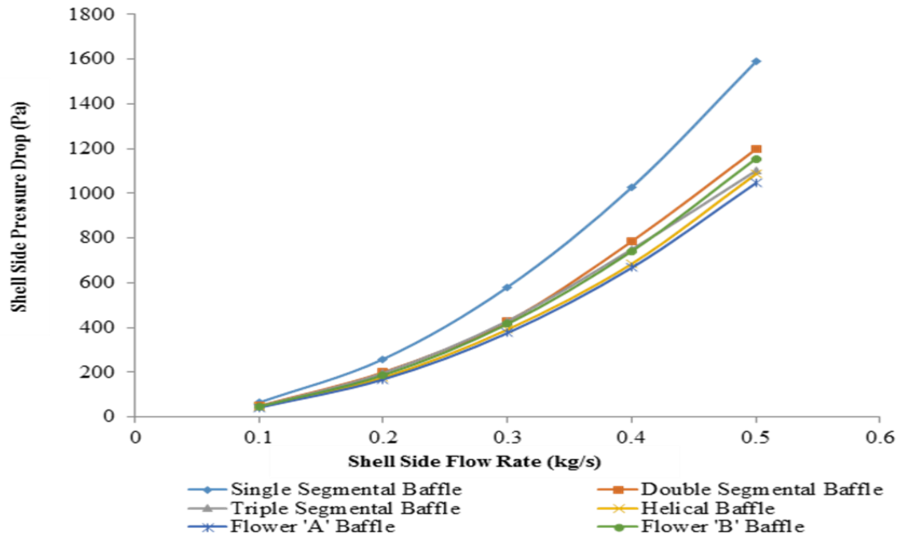


Figure 26 Shell Side Pressure Drop vs. Shell Side Flow Rate

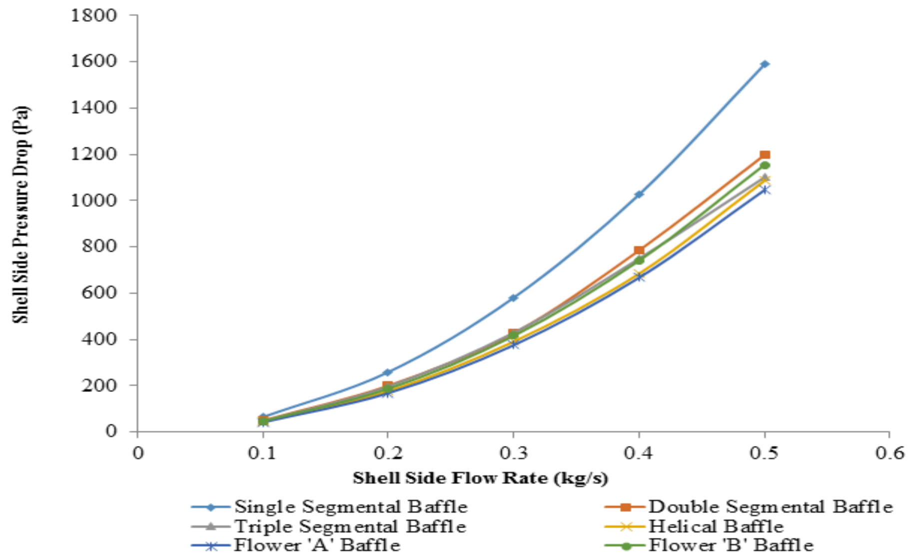


Figure 27 Shell Side Pressure Drop vs. Shell Side Flow Rate

Table3.2:-Data for design of Shell and tube heat exchanger

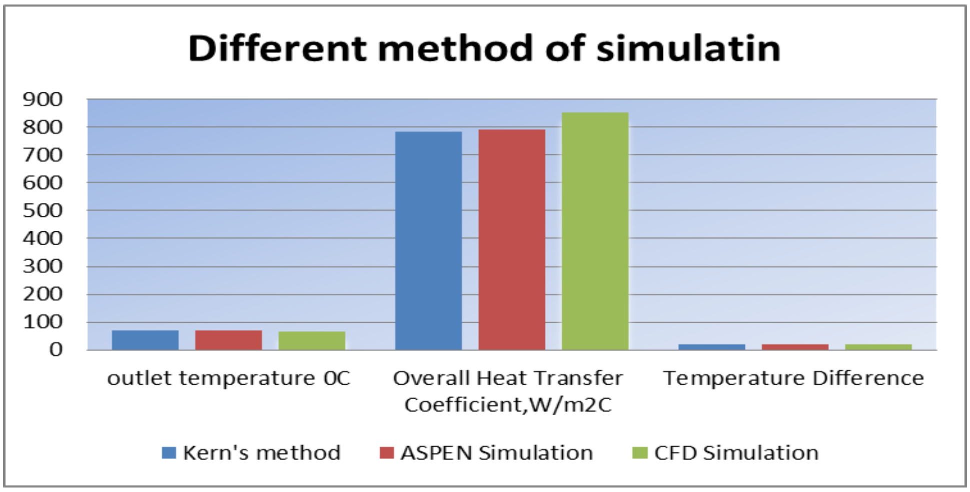
	Shell Side Fluid-Hot Water	
Property	Unit	Value
T_{HI}		90
T_{HO}		70
Density	kg/m^3	971.8
Specific Heat Capacity	kJ/kgK	4.1963
Viscosity	mPas	0.354
Conductivity	W/mK	0.67
Fouling Factor	m^2K/W	0.0002

Flow Rate	kg/s	0.3
Tube Side Fluid-Cold Water		
T_{CI}		30
T_{CO}		38
Density	kg/m^3	984
Specific Heat Capacity	kJ/kgK	4.178
Viscosity	mPas	0.725
Conductivity	W/mK	0.623
Fouling Factor	m^2K/W	0.0002
Flow Rate	kg/s	0.7533

4. RESULTS ANDDISCUSSION

Table 4 assessment of normal heat switch Coefficient, Shell aspect outlet temperature and Shell side temperature difference predictions

Heat Exchanger Design Method	Outlet temperature 0C	Overall Heat Transfer Coefficient,W/m2C	Temperature Difference
Kern's method	70	782	**20**
ASPEN Simulation	70.08	790.2	**19.92**
CFD Simulation	**68.79**	**852.46**	**21.21**



4. RESULT AMD FUTURE SCOPE

With the same input parameters, a Shell and Tube Heat Exchanger was constructed using Kern's method, ASPEN simulation software, HTRI simulation software, and Solid Works Flow Simulation software. The overall heat transfer coefficient values were 782, 790.2, 781.9, and 852.6 W/m2K, respectively. In CFD modelling studies on shell and tube heat exchangers, single, double, triple, helical, flower type A 'type, and flower type B 'type baffle layouts have been employed. The following findings came from these simulation studies: Although single segmental baffles have a lower pressure drop and a higher total heat transfer coefficient, they require more pumping force.

1. Where a little agreement with the outlet temperature is attainable, double-segmented baffles may be used instead of single-segmented baffles since the pressure drop will be decreased by 25% to 30%, making energy savings equal.

2. Helical baffles are effective because they reduce pressure loss by 30% to 35% when compared to single segmented baffles. But there has been a 40% decrease in the overall heat switch coefficient. According to this, in order to cover the area needed to obtain the temperature differential, 40% larger tubes must be introduced. Retrofitting won't be possible in this scenario, but installing a new heat exchanger with helical baffles might be justified on the basis of economics. This setting disables triple segmented baffles.

3. Because flower baffles reduce pressure drop by 25% to 35% while simultaneously lowering the overall heat switch coefficient by 30% to 35% with single segmented buffers, they are the most effective baffles.

4. Flowers Because they lessen pressure, Flower B "baffles" are more effective than Flower B "baffles." A rash is comparable to Flower, except it has better thermal performance.

1. Kern's technique and ASPEN simulation results for a typical heat transfer coefficient are comparable, although reliable Works software values are higher by 9%. When using the software solid works, the shell side temperature drop is increased by 6%.

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