International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
SJIF (2024): 6.623

Design and Comparative Analysis of a Shell and Tube Heat Exchanger using HTRI and Aspen EDR Software

Keval Sanket Bhatt

Mumbai University, Datta Meghe College of Engineering, Bachelors in Chemical Engineering
Email: *kevalbhatt08[at]gmail.com*

Abstract: ***This paper presents the design and performance evaluation of a shell and tube heat exchanger using advance simulation tools – HTRI and Aspen Exchanger Design and Rating (EDR). Heat exchangers are essential to process industries for achieving efficient thermal energy transfer. The objective is to assess and compare the thermal performance, sizing, and optimization capabilities of both tools using a common problem statement involving benzene and water as the working fluids. Key design parameters such as overall heat transfer coefficient, heat transfer area, fluid velocities, and pressure drops were determined using both software platforms. The comparative analysis highlights the advantages and limitations of each, with HTRI offering high - fidelity design accuracy and Aspen EDR providing seamless integration with process simulation environments. This work demonstrates the importance of simulation - driven design in improving heat exchanger efficiency and provides insights into the selection of appropriate design tools in industrial applications.***

Keywords: Shell and Tube Heat Exchanger, HTRI, Aspen EDR, Thermal Design, Simulation - Based Design, Heat Transfer Analysis, Heat Exchanger Optimization, Comparative Software Analysis

1. Introduction

Heat Exchangers are vital components in a wide range of industrial processes, including chemical manufacturing, power generation, and oil refining. Their primary function is to efficiently transfer heat between two or more fluids, thereby heat improving energy utilization and process performance. Among various heat exchanger types, the shell and tube heat exchanger remains the most widely used due to its versatility, mechanical strength, and ease of maintenance.

In modern engineering practice, the design and analysis of heat exchangers have increasingly shifted from manual, empirical methods to simulation - driven approaches. Advanced software tools enable engineers to optimize thermal performance, minimize pressure drops, and ensure operational reliability before physical implementation.

Two such prominent tools are HTRI (Heat Transfer Research Inc.) and Aspen EDR (Exchanger Design Rating). HTRI is known for its high - accuracy, research - based calculations and is widely accepted in industries for detailed performance evaluations. On the other hand, Aspen EDR integrates seamlessly with process simulation software such as Aspen Plus and Aspen HYSYS, offering a streamlined workflow for process engineers.

This study focuses on the design and comparative analysis of a shell and tube heat exchanger using both HTRI and Aspen EDR software. By using a common case study involving water and benzene as the working fluids, the research aims to evaluate and compare the key output parameters from each software, such as heat transfer area, overall heat transfer coefficient, pressure drop and fluid velocity. The objective is to understand the practical difference in how each platform approaches heat exchanger design and highlight their respective strengths and limitations in an industrial concept. Ultimately, this paper contributes to the ongoing evolution of engineering design practices by emphasizing the importance of simulation - based tools in the accurate, efficient, and sustainable design of thermal systems.

2. Literature Review

Shell and tube heat exchangers are widely used in chemical and process industries due to their design flexibility, mechanical durability, and thermal performance. Their efficiency depends on factors such as baffle spacing, tube arrangement, shell diameter, and adherence to standards like TEMA. These factors directly influence pressure drop, fouling, and overall heat transfer rate. [1]

In the study Design and Optimization of Shell and Tube Heat Exchanger Using Aspen EDR, the authors highlighted the role of simulation tools in heat exchanger design. Aspen EDR was used to evaluate key parameters like heat transfer area, pressure drop, and overall heat transfer coefficient, demonstrating its ability to provide reliable and standard - compliant output. [2]

While Aspen EDR is widely used in academic and industrial environments, HTRI software remains less documented in published research due to its proprietary nature. However, it is known for its high accuracy and strong empirical foundation. This paper aims to contribute to the literature by comparing the outputs of both tools under similar conditions, highlighting differences in performance, assumptions, and usability.

3. Methodology

The design and simulation of a shell and tube heat exchanger were carried out using two professional tools: Aspen Exchanger Design and Rating (EDR) and Heat Transfer

Research Inc. (HTRI). The purpose of this analysis was to evaluate and compare the design performance of both tools under the same operating conditions. The exchanger was designed to handle heat transfer between benzene (hot fluid) and water (cold fluid), a typical scenario in chemical processing systems. Key performance indicators such as heat transfer area, overall heat transfer coefficient, pressure drop, and fluid velocity were analyzed. The simulations were conducted under steady - state conditions assuming single - phase flow with no phase change.

3.1 Design and Simulation with HTRI:

HTRI was used to perform the thermal and mechanical design of the shell and tube heat exchanger using the same process inputs defined the project. HTRI is widely known for its detailed empirical correlations, accuracy, and industrial acceptance. The input parameters included hot and cold fluid properties, flow rates, inlet and outlet temperatures, and allowable pressure drops. A counter - current flow configuration was used, and standard design rules were followed for baffle cut (25%) and spacing (around 15% of shell diameter). Additional design inputs such as tube layout, tube passes, tie rod arrangement, and segmental baffle design were configured. HTRI provided a comprehensive thermal rating output, including heat transfer area, overall heat transfer coefficient, pressure losses, and shell - side/tube - side velocities.

Simulation results generated by HTRI software for the shell and tube heat exchanger are shown in Figure 1.

HTRI **Output Summary** Page 1
Released to the following HTRI Member Company:

Xist 9.2 (64 bit) 3/12/2025 16:16 SN: 00061-2038987626 **MKH Units**

Case 2
Rating - Horizontal Multipass Flow TEMA AES Shell With Single-Segmental Baffles

See Data Check Messages Report for Warning Messages.
See Runtime Message Report for Warning Messages.

Process Conditions		Hot Shellside		Cold Tubeside	
Fluid name			Benzene		C.W
Total flow rate	(1000-kg/hr)		21.228		41.038
Inlet/Outlet Y	(Wt. frac vap.)	0.0000	0.0000	0.0000	0.0000
Inlet/Outlet T	(Deg C)	92.00	45.00	26.00	36.00
Inlet P/Avg	(kgf/cm2A)	4.549	4.530	5.603	5.256
dP/Allow.	(kgf/cm2)	0.037	0.703	0.695	0.703
Fouling	(m2-hr-C/kcal)		0.000205		0.002

Exchanger Performance					
Shell h	(kcal/m2-hr-C)	708.89	Actual U	(kcal/m2-hr-C)	224.98
Tube h	(kcal/m2-hr-C)	6029.4	Required U	(kcal/m2-hr-C)	203.88
Hot regime	(--)	Sens. Liquid	Total duty	(MM kcal/hr)	0.4093
Cold regime	(--)	Sens. Liquid	Eff. area	(m2)	62.951
EMTD	(Deg C)	31.9	Overdesign	(%)	10.35

Shell Geometry			Baffle Geometry		
TEMA type	(--)	AES	Baffle type		Single-Seg.
Shell ID	(mm)	435.00	Baffle cut	(Pct Dia.)	25
Series	(--)	1	Baffle orientation	(--)	Perpend.
Parallel	(--)	1	Central spacing	(mm)	350.00
Orientation	(deg)	0.00	Crosspasses	(--)	17

Tube Geometry			Nozzles		
Tube type	(--)	Plain	Shell inlet	(mm)	77.927
Tube OD	(mm)	19.050	Shell outlet	(mm)	77.927
Length	(mm)	6096	Inlet height	(mm)	38.120
Pitch ratio	(--)	1.3333	Outlet height	(mm)	38.120
Layout	(deg)	30	Tube inlet	(mm)	77.927
Tubecount	(--)	174	Tube outlet	(mm)	77.927
Tube Pass	(--)	4			

Thermal Resistance, %		Velocities, m/s	Min	Max	Flow Fractions	
Shell	31.74				A	0.091
Tube	4.79	Tubeside	1.51	1.54	B	0.486
Fouling	62.40	Crossflow	0.12	0.13	C	0.212
Metal	1.07	Longitudinal	0.17	0.18	E	0.078
					F	0.133

Figure 1: HTRI output summary

3.2 Design and Simulation with Aspen EDR:

Aspen Exchanger Design and Rating (EDR) software was used to perform a parallel simulation using the same process conditions and fluid properties as in the HTRI model. Aspen EDR is widely used in both academia and industry due to its integration with Aspen Plus and compliance with TEMA and ASME standards. The heat exchanger was configured with a counter - current flow arrangement, 25% baffle cut, and baffle spacing of approximately 15% of the shell diameter. Inputs such as tube dimensions, layout, pitch, and material were entered based on standard design guidelines. The software generated thermal performance data, including heat transfer area, pressure drops, and overall heat transfer coefficient.

Simulation results generated by Aspen EDR software for the shell and tube heat exchanger are shown in Figure 2.

Paper ID: SE25518171408 DOI: https://dx.doi.org/10.70729/SE25518171408

International Journal of Scientific Engineering and Research (IJSER)
ISSN (Online): 2347-3878
SJIF (2024): 6.623

TEMA Sheet

Heat Exchanger Specification Sheet

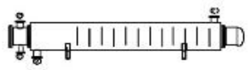
1	Company:					
2	Location:					
3	Service of Unit:	Our Reference:				
4	Item No.:	Your Reference:				
5	Date:	Rev No.:	Job No.:			
6	Size: 432 - 4870 mm	Type: AEM Horizontal		Connected in: 1 parallel 1 series		
7	Surf/unit(eff.) 56 m^2	Shells/unit 1		Surf/shell(eff.) 56 m^2		
8	**PERFORMANCE OF ONE UNIT**					
9	Fluid allocation		Shell Side		Tube Side	
10	Fluid name		Benzene		Cooling Water	
11	Fluid quantity, Total	kg/s	0.0059		0.0115	
12	Vapor (In/Out)	kg/s	0	0	0	0
13	Liquid	kg/s	0.0059	0.0059	0.0115	0.0115
14	Noncondensable	kg/s	0	0	0	0
15						
16	Temperature (In/Out)	°C	92	44.97	26	35.98
17	Bubble / Dew point	°C	/	/	/	/
18	Density Vapor/Liquid	kg/m^3	/ 801.28	/ 851.93	/ 993.09	/ 983.39
19	Viscosity	mPa-s	/ 0.284	/ 0.4702	/ 0.8928	/ 0.7255
20	Molecular wt, Vap					
21	Molecular wt, NC					
22	Specific heat	kJ/(kg-K)	/ 1.829	/ 1.608	/ 4.523	/ 4.522
23	Thermal conductivity	W/(m-K)	/ 0.1206	/ 0.1358	/ 0.6077	/ 0.621
24	Latent heat	kJ/kg				
25	Pressure (abs)	bar	4.46105	4.46104	5.49467	5.49464
26	Velocity (Mean/Max)	m/s	0 / 0		0 / 0	
27	Pressure drop, allow./calc.	bar	0.68941	0	0.703	3E-05
28	Fouling resistance (min)	m^2-K/W	0.00018		0.00172	0.00217 Ao based
29	Heat exchanged 0.5 kW			MTD (corrected) 32.12 °C		
30	Transfer rate, Service 0.3		Dirty 17.5	Clean 18.2		W/(m^2-K)
31	**CONSTRUCTION OF ONE SHELL**				**Sketch**	
32			Shell Side	Tube Side		
33	Design/Vacuum/test pressure:g	bar	5.51581 / /	6.20528 / /		
34	Design temperature / MDMT	°C	132.22 /	71.11 /		
35	Number passes per shell		1	4		
36	Corrosion allowance	mm	3.18	3.18		
37	Connections	In mm	1 154.05 / -	1 102.26 / -		
38	Size/Rating	Out	1 154.05 / -	1 154.05 / -		
39	ID	Intermediate	/ -	/ -		
40	Tube #: 196	OD: 19.05 Tks. Average 2 mm	Length: 4.87 m	Pitch: 23.81 mm	Tube pattern:30	
41	Tube type: Plain	Insert:None	Fin#: #/m	Material:Carbon Steel		
42	Shell Carbon Steel	ID 423	OD 704.85 mm	Shell cover -		
43	Channel or bonnet	Carbon Steel		Channel cover Carbon Steel		
44	Tubesheet-stationary	Carbon Steel	-	Tubesheet-floating -		
45	Floating head cover	-		Impingement protection None		
46	Baffle-cross Carbon Steel	Type Single segmental	Cut(%d) 27.12	Hori Spacing: c/c 300 mm		
47	Baffle-long -	Seal Type		Inlet 292.84 mm		
48	Supports-tube	U-bend 0		Type		
49	Bypass seal		Tube-tubesheet joint	Expanded only (2 grooves)(App.A 'i')		
50	Expansion joint	-	Type None			
51	RhoV2-Inlet nozzle 0	Bundle entrance 0		Bundle exit 0		kg/(m-s^2)
52	Gaskets - Shell side	-	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	13730.2 Filled with water 14340.8	Bundle	1269.3	kg	
56	Remarks					
57						
58						

Figure 2: Aspen EDR output summary

3.3 Comparison of HTRI and Aspen EDR outputs:

The output from HTRI and Aspen EDR software were compared to evaluate the design performance of shell and tube heat exchanger under identical operating conditions. Key design parameters such as heat transfer area, overall heat transfer coefficient, pressure drop, and flow velocity were extracted from both simulations. The purpose of this comparison is to analyze how each software approaches thermal design and to identify practical differences in their results.

Table 1: Comparative Analysis

Parameters	HTRI output	Aspen EDR output
Fluid Pair	Benzene and cooling water	Benzene and cooling water
Heat Duty	0.4093 (mmkcal/hr)	0.5
Overall Heat Transfer Coefficient	224.98 kcal/m^{2}hr. c	18.2
Heat Transfer Area (m^2)	62.95	56
Shell side pressure drop (bar)	0.3703	0.6894
Tube - side pressure drop (bar)	0.695	0.703
Shell Diameter (mm)	435	423
Tube Count	174	174
Baffle Spacing (mm)	350	292.84
Baffle Cut (%)	25	27.12

The outputs from HTRI and Aspen EDR showed generally comparable trends, though notable differences were observed in parameters like heat duty and overall heat transfer area. HTRI estimated a heat duty of approximately 477KW, while Aspen EDR reported a higher value of around 581.5 KW. This difference may result from variations in default assumptions, thermal resistance modeling or input handling. Additionally HTRI a U - value of 941.9 W/m^{2}k, while Aspen output did not clearly display the correspondence value for validation. These observations reflect the importance of understanding each tool's calculation basis and ensuring all the inputs are fully aligned when performing comparative analysis. Both tools remain industry - reliable and demonstrates valid, though not identical, design outcomes.

3.4 Observations on Pressure Drop and Heat Transfer Area:

Both HTRI and Aspen EDR produced design that met the required thermal duty, with differences in output values observed primarily in pressure drop and heat transfer area. HTRI reported a shell side pressure drop of 0.3703 bar and tube - side pressure drop of 0.695 bar, while Aspen EDR reported 0.6894 bar and 0.703 bar respectively. These values are reasonable and within expected design limits.

The heat transfer area calculated by HTRI was 62.95 m^2, slightly higher than the 56m2 reported by Aspen EDR. These variations are most likely due to differences in user input, default configurations, and interpretation of process conditions during simulation. Both software platforms are industry - standard tools, and any discrepancies in output here are a result of how the input data was handled during the project.

1) Cost Estimation:

The cost estimation was carried out using Aspen EDR's built - in equipment costing module, based on the finalized design parameters. The estimated cost includes the heat exchanger's material, fabrication, and installation. The output provided a total equipment cost of approximately Rs.3, 02, 100 for the designed shell and tube unit. This figure is based on a default costing assumptions within the software and is intended for preliminary evaluation only.

Cost Component	Estimated Cost (INR)
Material and Fabrication	Rs.2, 65, 000
Installing and Handling	Rs.37, 100
Total Estimated Cost	Rs.3, 02, 100

Figure 2: Approximate cost estimation based on Aspen EDR output

2) Advantages and Limitations:

Both Aspen EDR and HTRI offer reliable thermal design capabilities, but differ in terms of accessibility and depth of control. Aspen EDR is widely used in academic and industrial settings for its user - friendly interface and integration with process simulation tools like Aspen Plus. However it may be limited in advance customization and detailed empirical modeling.

HTRI, on the other hand, is more detailed and widely trusted in industry for its precise calculations and robust empirical database, but it is less accessible due to licensing constraints and may have a steeper learning curve.

For student - level projects, Aspen offers convenience and speed, while HTRI is preferred when advanced accuracy is needed.

4. Conclusion

This paper presented the design and comparative analysis of a shell and tube heat exchanger using HTRI and Aspen EDR software. Both tools successfully produced feasible designs for the given process conditions involving benzene and cooling water. While differences were observed in heat duty, pressure drops, overall heat transfer coefficient, and surface area, these variations were attributed to user inputs and software - specific design approaches.

The study reinforces the practical application of design software in undergraduate projects and highlights the importance of consistent input validation. A preliminary cost estimation was also performed using Aspen EDR to provide an industrial perspective on equipment sizing. Overall both software platforms proved to be reliable for thermal designs and are valuable tools for chemical engineering applications.

References

[1] TEMA Standards, *Standards of the Tubular Exchanger Manufacturers Association*, 10th Edition, TEMA, 2013. [1]
[2] Pravind Thakur, "Design and Optimization of Shell & Tube Heat Exchanger Using Aspen Exchanger Design and Rating (EDR), " *International Journal of Engineering Research & Technology (IJERT),* Vol.9, Issue 4, April 2020. [2]
[3] Faulkner, L. L., *Heat Exchanger Design Handbook*, Hemisphere Publishing Corporation, 1983.
[4] AspenTech, *Aspen Exchanger Design and Rating (EDR) Documentation*, Aspen Technology Inc., 2020.
[5] HTRI, *Xchanger Suite 9.2 – Software Technical Manual*, Heat Transfer Research, Inc., 2021