



HEAT EXCHANGER RATING MODE USING DWSIM: A FREE AND OPEN-SOURCE CHEMICAL PROCESS SIMULATOR



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LEVEL: ADVANCED

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PREFACE

The manual “Heat Exchanger Rating Mode Using DWSIM” present a set of “Heat Exchanger Rating Mode Using DWSIM” exercise using a free and open-source chemical process simulator “DWSIM” and can be utilized to establish process simulation laboratory as part of undergraduate chemical engineering degree or in allied degree curriculum. The problem statements are of intermediate level.

Prerequisite

- Must know about DWSIM UI/UX.
- Flow sheeting in DWSIM
- Selection of Thermodynamic Packages.
- Manipulating variables
- Reading a TEMA Sheet
- Basic Modules

Thanks

Viraj Desai

P.E. O&G

Disclaimer

All the exercises are strictly restricted to learning only and not meant to be used in real world applications.



PROCESS SIMULATION USING DWSIM: A FREE AND OPEN-SOURCE CHEMICAL PROCESS SIMULATOR

PREAMBLE

DWSIM is an open-source CAPE-OPEN compliant chemical process simulator. It features a Graphical User Interface (GUI), advanced thermodynamics calculations, reactions support and petroleum characterization / hypothetical component generation tools. DWSIM can simulate steady-state, vapor–liquid, vapor–liquid-liquid, solid–liquid and aqueous electrolyte equilibrium processes and has built-in thermodynamic models and unit operations (<https://en.wikipedia.org/wiki/DWSIM>). It is available for Windows, Linux and Mac OS.

The objective of the course is to create awareness of the open-source process simulator “DWSIM” among prospective graduates and practicing process engineers. The course will cover Intermediate aspects of create flow sheet in DWSIM and simulation of simple Pressure changing module like pipe segment, Compressor, etc.

Target Audience

- Junior Interns in Process Firms
- III / Final year B. Tech. Chemical Engineering students
- M. Tech. Chemical Engineering students
- Practicing Process Engineers



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1 HEAT EXCHANGER RATING MODE

Objective

Make a process model of Heat Exchanger based on the TEMA Sheet and specs provided:

Data

- TEMA Sheet Specs

Assumption

- Carbon steel thermal conductivity = 45 W/[m.K]

DWSIM Blocks Used

- Material Stream
- Heat Exchanger

Procedure

- Start a new DWSIM Simulation (DWSIM VER 8.6.5 - CLASSIC UI). Click on “New steady state Simulation” as a template for new simulation.
- The simulation configuration window will be opened. It shows a specification page. Add components required to solve the problem statement. In the present case, add benzene & toluene. Ensure the component is added from the same property database. For instance, in this case, both components are added from “ChemSep” database.
- Specify the thermodynamic package as Peng Robinson (PR).
- Customize the system of units for the simulation and click “Next”.
- The flow sheeting section of simulation window will be opened. First, let’s provide four Material Streams **Toluene In**, **Benzene In**, **Toluene Out** & **Benzene Out** for the unit process to be performed.

PERFORMANCE OF ONE UNIT					
8					
9	Fluid allocation	Shell Side		Tube Side	
10	Fluid name	Toluene		Benzene	
11	Fluid quantity, Total	0.5556		0.5556	
12	Vapor (In/Out)	kg/s	0	0	0
13	Liquid	kg/s	0.5556	0.5556	0.5556
14	Noncondensable	kg/s	0	0	0
15					
16	Temperature (In/Out)	°C	25	45.75	70
17	Bubble / Dew point	°C	/	/	93.64 / 93.64
18	Density Vapor/Liquid	kg/m³	/ 864.79	/ 845.49	/ 825.55
19	Viscosity	mPa-s	/ 0.5543	/ 0.444	/ 0.3557
20	Molecular wt, Vap				
21	Molecular wt, NC				
22	Specific heat	kJ/(kg-K)	/ 1.572	/ 1.662	/ 1.724
23	Thermal conductivity	W/(m-K)	/ 0.1308	/ 0.1248	/ 0.1276
24	Latent heat	kJ/kg			
25	Pressure (abs)	bar	2.5	2.48807	1.5
26	Velocity (Mean/Max)	m/s	0.05 / 0.05		0.48 / 0.49
27	Pressure drop, allow./calc.	bar	0.2	0.01193	0.2

Figure 1 Process Conditions from TEMA Sheet

6. On clicking the “Toluene” stream & “Benzene” stream, general information about the stream will be displayed on the left side of screen. Specify the feed compositions, temperature, and pressure for the inlet streams. Once credentials are specified for the streams, the color of stream turns blue.

Toluene In (Material Stream)

Information Connections

General Info

Object: Toluene In

Status: Calculated (11-07-2024 11:32:50)

Linked to

Property Package Settings

Property Package: Peng-Robinson (PR) (1)

Input Data Results Annotations Dynamics Floating Tables

Stream Conditions Compound Amounts

Flash Spec: Temperature and Pressure (TP)

Temperature: 25 C

Pressure: 2.5 bar

Mass Flow: 2000.16 kg/h

Molar Flow: 21.7082 kmol/h

Volumetric Flow: 2.3131 m3/h

Specific Enthalpy: -403.386 kJ/kg

Specific Entropy: -1.06164 kJ/(kg.K)

Vapor Phase Mole Fraction: 0

Figure 2 Toluene Specs

Benzene In (Material Stream)

Information Connections

General Info

Object: Benzene In

Status: Calculated (11-07-2024 11:32:50)

Linked to

Property Package Settings

Property Package: Peng-Robinson (PR) (1)

Input Data Results Annotations Dynamics Floating Tables

Stream Conditions Compound Amounts

Flash Spec: Temperature and Pressure (TP)

Temperature: 70 C

Pressure: 1.5 bar

Mass Flow: 2000.16 kg/h

Molar Flow: 25.6064 kmol/h

Volumetric Flow: 2.42034 m3/h

Specific Enthalpy: -344.053 kJ/kg

Specific Entropy: -0.957795 kJ/(kg.K)

Vapor Phase Mole Fraction: 0

Figure 3 Benzene Specs

7. Below the Unit Operation tab on left, locate the Heat Exchanger. Drag and drop into the flow sheet.

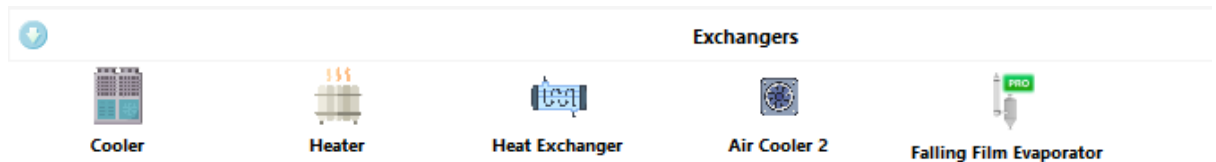


Figure 4 Heat Exchanger

Heat Exchanger Rating Mode

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By Viraj Desai, Process Engineer

8. Under Calculation type search for Shell and Tube Exchanger Rating. And open the Shell and Tube Heat Exchanger Properties.
9. Enter the specs as mentioned in the TEMA Sheet.


31	CONSTRUCTION OF ONE SHELL						Sketch	
32			Shell Side		Tube Side			
33	Design/Vacuum/test pressure	bar	3.44738 / /		3.44738 / /			
34	Design temperature / MDMT	°C	110 /		110 /			
35	Number passes per shell		1		4			
36	Corrosion allowance		mm 3.18		mm 3.18			
37	Connections	In mm	1	25.4 / -	1	19.05 / -		
38	Size/Rating	Out	1	25.4 / -	1	19.05 / -		
39	Nominal	Intermediate	/ -		/ -			
40	Tube #: 34 OD: 19.05 Tks. Average 2.11 mm Length: 1828.8 mm Pitch: 23.81 mm Tube pattern:30							
41	Tube type: Plain		Insert:None		Fin#:		#/m	Material:Carbon Steel
42	Shell Carbon Steel		ID 205	OD 219.08 mm		Shell cover -		
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)	43.02	Hori:Spacing: c/c 171.45 mm	
47	Baffle-long -		Seal Type				Inlet	276.23 mm

Figure 5 Shell and Tube HEX Specs

10. Once necessary specs are filled. Enter Carbon steel thermal conductivity. The Shell and Tube Exchanger Properties shall be as below:

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

Shell Passes

Internal Diameter

mm

Fouling Factor

K.m²/W

Baffle Spacing

mm

Baffle Cut (% diameter)

%

Baffle Type

Single ▾

Baffle Orientation

Vertical ▾

Tubes

Internal Diameter

mm

External Diameter

mm

Length

m

Fouling Factor

K.m²/W

Roughness

mm

Thermal Conductivity

W/[m.K]

Passes per Shell

Tubes per Shell

Tube Spacing

mm

Tube Layout

Triangle ▾

Fluid in Tubes

☒ Hot ☐ Cold

Figure 6 Shell and Tube Exchanger Properties

11. Once done connect the remaining streams in the appropriate port.

HX-1 (Heat Exchanger)

General Info

Object: HX-1

Status: Calculated (11-07-2024 11:32:51)

Linked to:

Connections

Inlet Stream 1: Benzene In

Outlet Stream 1: Benzene Out

Inlet Stream 2: Toluene In

Outlet Stream 2: Toluene Out

Calculation Parameters

Calculation Type: Shell and Tubes Exchanger Rating

Flow Direction: Counter Current

Edit Shell and Tube Heat Exchanger Properties

Cold Fluid Pressure Drop	0.00984941	bar
Hot Fluid Pressure Drop	0.00669335	bar
Cold Fluid Outlet Temperature	46.95	C
Hot Fluid Outlet Temperature	48.768	C
Global Heat Transfer Coefficient	270.525	W/[m2.K]
Heat Exchange Area	3.72627	m2
Heat Exchanged	19.7602	kW
Min Temperature Difference	0	C

Figure 7 Heat Exchanger Properties

12. Run the simulation by pressing "Solve flow sheet" button on the top corner of the screen

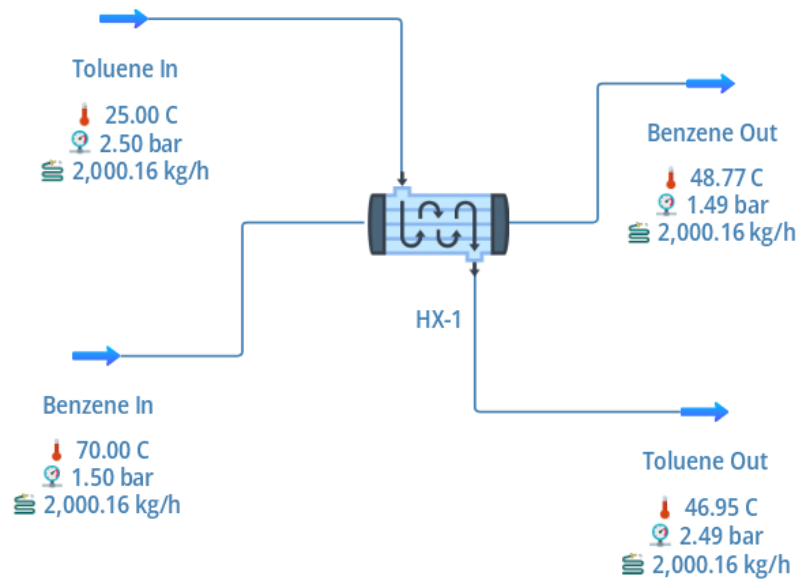


Figure 8 Solved Flow Sheet

13. Once done cross check with the outlet temperature of the streams in the TEMA Sheet which were marked as **green color**.

9	Fluid allocation	Shell Side		Tube Side	
10	Fluid name	Toluene		Benzene	
11	Fluid quantity, Total	kg/s		0.5556	
12	Vapor (In/Out)	kg/s		0	
13	Liquid	kg/s		0.5556	
14	Noncondensable	kg/s		0	
15					
16	Temperature (In/Out)	°C		°C	
17	Bubble / Dew point	°C		°C	
18	Density Vapor/Liquid	kg/m³		kg/m³	
19	Viscosity	mPa-s		mPa-s	
20	Molecular wt, Vap				
21	Molecular wt, NC				
22	Specific heat	kJ/(kg-K)		kJ/(kg-K)	
23	Thermal conductivity	W/(m-K)		W/(m-K)	
24	Latent heat	kJ/kg		kJ/kg	
25	Pressure (abs)	bar		bar	

Figure 9 Cross checking of the properties of the fluid

2 RESULTS OF DWSIM

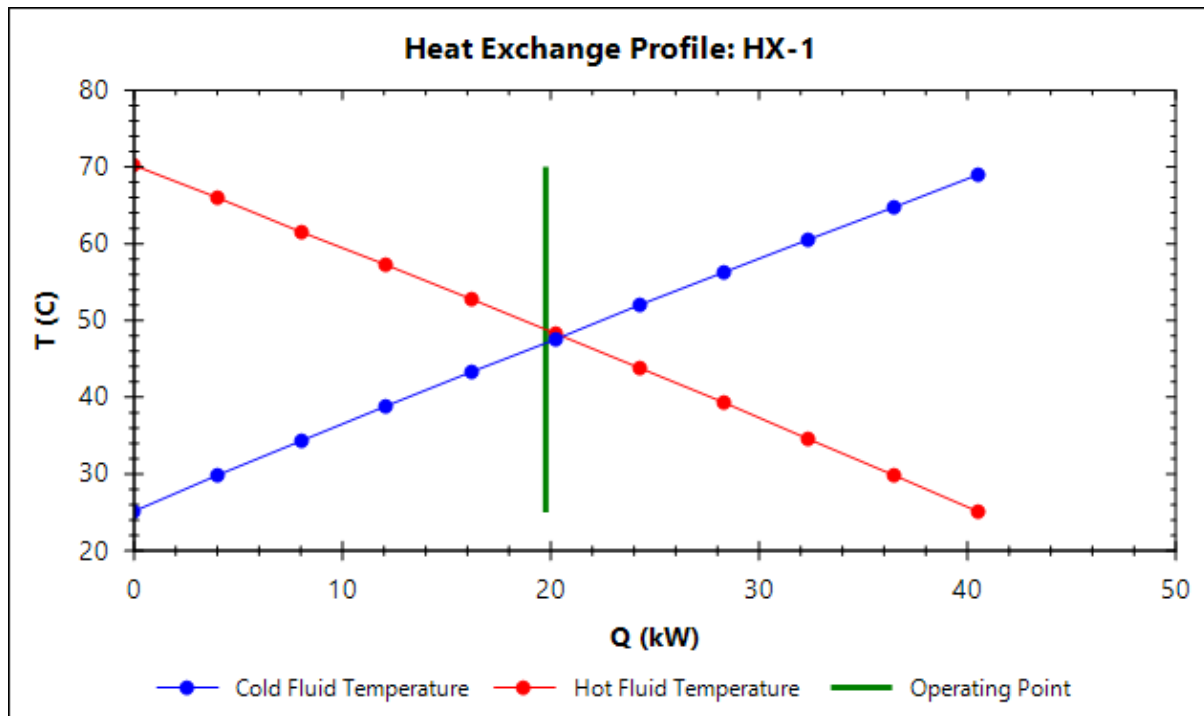


Figure 10 Heat Exchanger Temperature Profile

2.1 HEAT EXCHANGER PROPERTIES

Maximum Heat Exchange	40.5348	kW
Thermal Efficiency	48.7487	%
Log Mean Temperature Difference (LMTD)	23.4129	C.
LMTD Correction Factor (Shell and Tube)	0.83725	
Shell-side Reynolds Number	3111.96	
Tube-side Reynolds Number	12098.9	
Shell-side Resistance	1.946531E-003	K.m2/W
Tube-side Resistance	1.513040E-003	K.m2/W
Pipe Wall Resistance	2.481248E-005	K.m2/W
Fouling Resistance	2.121334E-004	K.m2/W

3 REFERENCES

[TEMA Sheet](#)

[Aspen Model Link](#)