COMPRESSOR SIZING USING DWSIM:

A FREE AND OPEN-SOURCE CHEMICAL PROCESS SIMULATOR

BY

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PREFACE

The manual “Compressor Sizing Using DWSIM” presents a set of Compressor Sizing 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
- Line Hydraulics
- 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 application.

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 BACKGROUND

1.1 POWER REQUIRED IN FAN, BLOWER AND IN ADIABATIC COMPRESSOR

Fans, blowers, and compressors are used to increase the mechanical energy of gases. Discharge pressure of a fan is less than 3.45 kPa g (350 mm WC). If discharge pressure required is higher than 3.45 kPa g then a blower is used. Maximum discharge pressure of blower is 1 atm g. If the discharge pressure required is more than 2 atm a then a compressor is used. Discharge pressure of compressor ranges from 2 atm a to thousands of atmospheres.

Blowers are always operated in an adiabatic manner. Many compressors are also operated in adiabatic manner (Example: air compressors up to 10 bar g). In adiabatic compressor, jacketed cooling is not provided. While in other types; polytropic and isothermal compressors, jacketed cooling is provided around the compressor section. In isothermal compressor, inlet temperature of gas is equal to outlet temperature of gas. If both temperatures are not same even after providing the jacket cooling, it is called polytropic compressor. For adiabatic compression

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^k, \frac{T_1}{T_2} = \left(\frac{V_1}{V_2}\right)^{(k-1)}, \frac{P_2}{P_1} = \left(\frac{T_2}{T_1}\right)^{\left(\frac{k}{k-1}\right)}$$

Where,

$k = \frac{C_p}{C_v} =$ ratio of specific heat at constant pressure to specific heat at constant volume

P_2, P_1 = outlet/inlet pressure of gas, kPa

V_2, V_1 = outlet/inlet volume of gas, m^3/kmol

T_2, T_1 = outlet/inlet temperatures of gas, K

Power required in single stage blowers or in single stage adiabatic compressor,

$$P_0 = \frac{2.78 * 10^{-4}}{\eta} \left(\frac{k}{k-1}\right) q_{v1} P_1 \left[\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right]$$

P_0 = Power required, kW

P_1, P_2 = Absolute inlet pressure & Outlet pressure, kPa

q_{v1} = Volumetric fl ow rate of gas based on inlet condition, m^3/h

η = Efficiency of compressor

Discharge temperature of gas from the blower or single stage adiabatic compressor,

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$$

2 COMPRESSOR SIZING

Objective

Find the Power Requirements, outlet temperature for the given problem statement.

Data

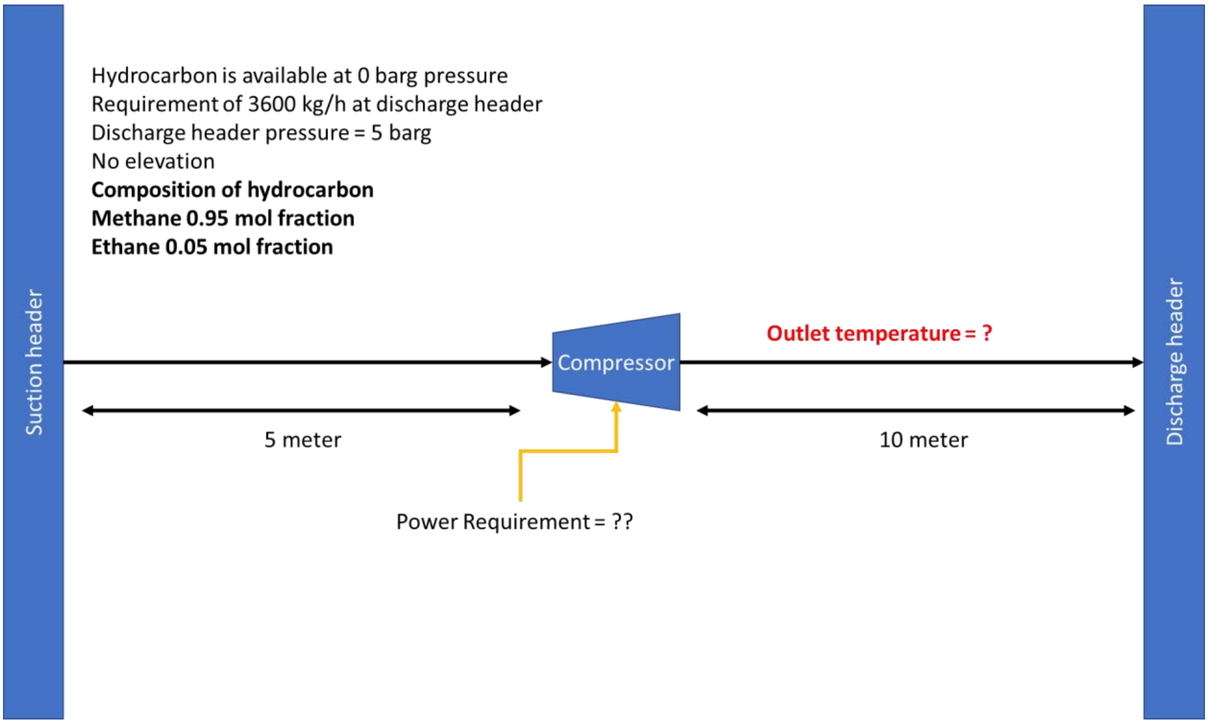


Figure 1 Problem Statement

DWSIM Blocks Used

- Pipe segment
- Material Stream
- Compressor
- Indicators (Digital or Analog)

Procedure

1. Start a new DWSIM Simulation (DWSIM VER 8.2 - CLASSIC UI). Click on "New steady state Simulation" as a template for new simulation
2. 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 methane and ethane. Ensure all components are added from the same property database. For instance, in this case, both components are added from "ChemSep" database.
3. Specify the thermodynamic package as Peng-Robinson (PR) (1).
4. Customize the system of units for the simulation and click "Next".
5. The flow sheeting section of simulation window will be opened. First, let provide suction header, compressor inlet, compressor outlet and discharge header streams for the unit operation to be performed.

6. On clicking the "Suction header" 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 Suction header streams, the color of stream turns blue.

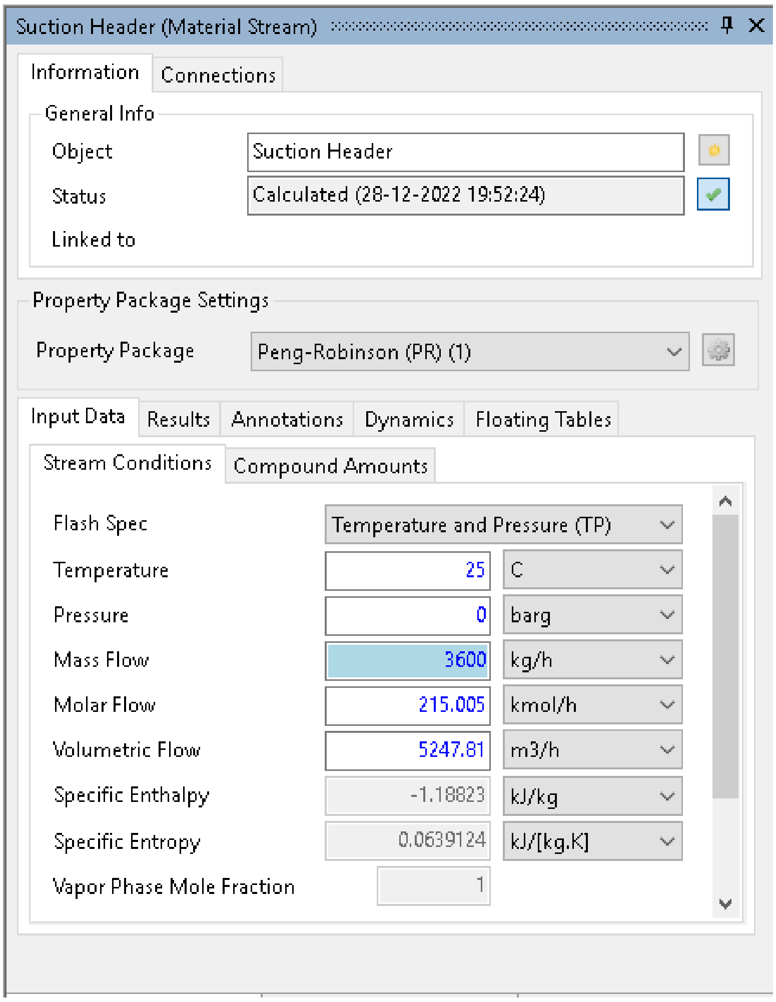


Figure 2 Suction header stream specs

7. Below the Unit Operation tab on left, locate the pipe segment block. Drag and drop into the flow sheet. Rename it as "Compressor inlet".

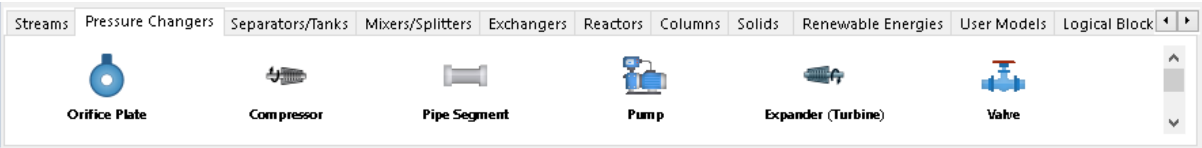


Figure 3 Pipe segment

8. Under specification for pipe segment add the data as follows.

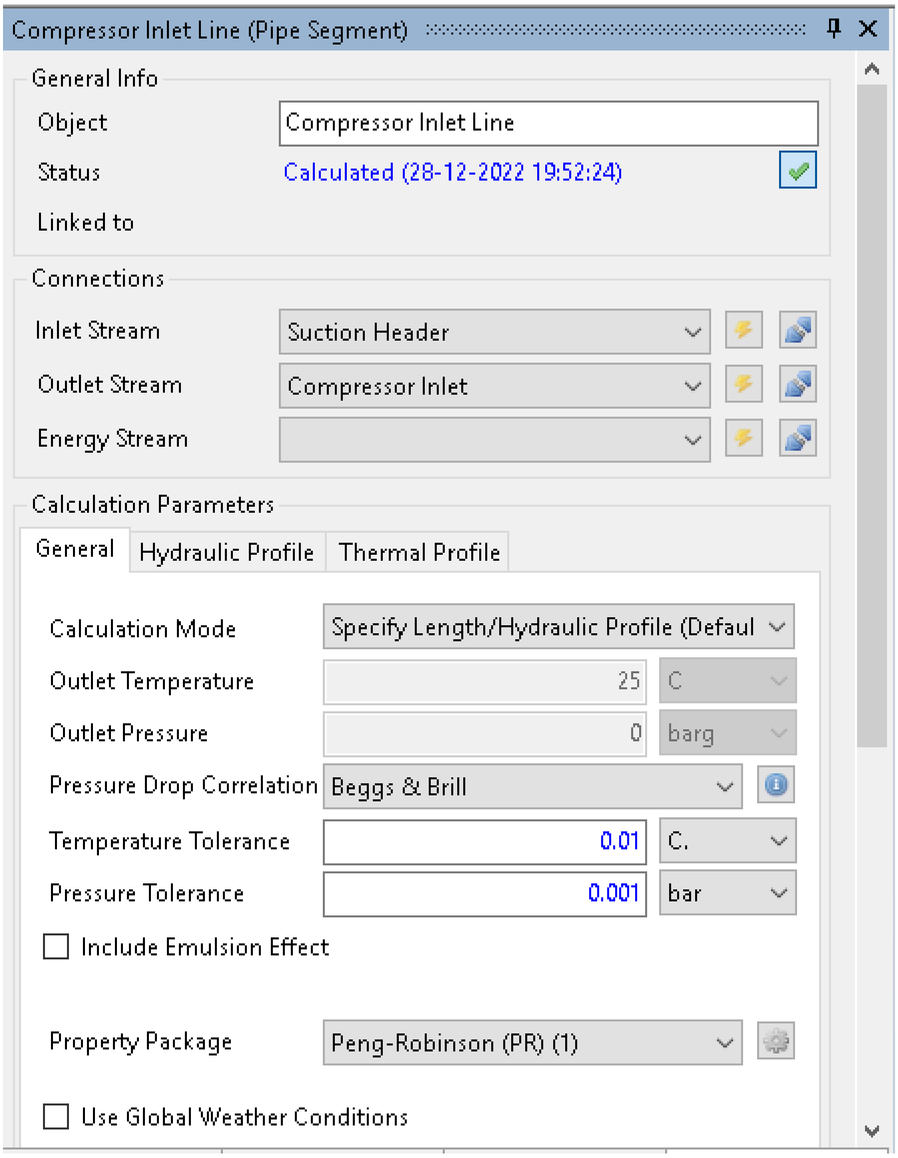


Figure 4 Compressor Inlet Specs

9. Click on the hydraulic profile as shown in the image

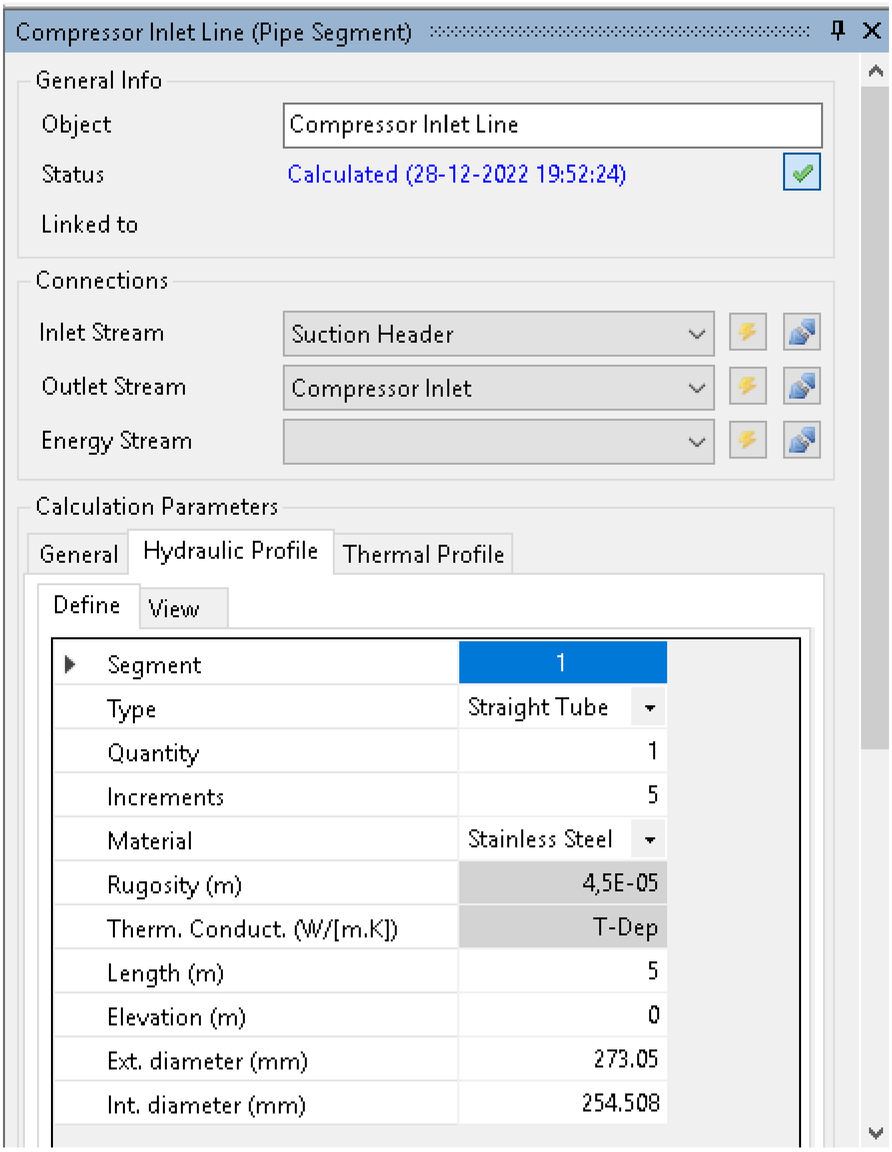


Figure 5 Adding specs for hydraulic profile |Compressor Inlet Pipe |

Segment	1
Type	Straight Tube
Quantity	1
Increments	5
Material	Stainless Steel
Rugosity (m)	4,5E-05
Therm. Conduct. (W/[m.K])	T-Dep
Length (m)	5

Elevation (m)	0
Ext. diameter (mm)	273.05
Int. diameter (mm)	254.508

10. Click on “View” in hydraulic profile tab to see layout of pipe network

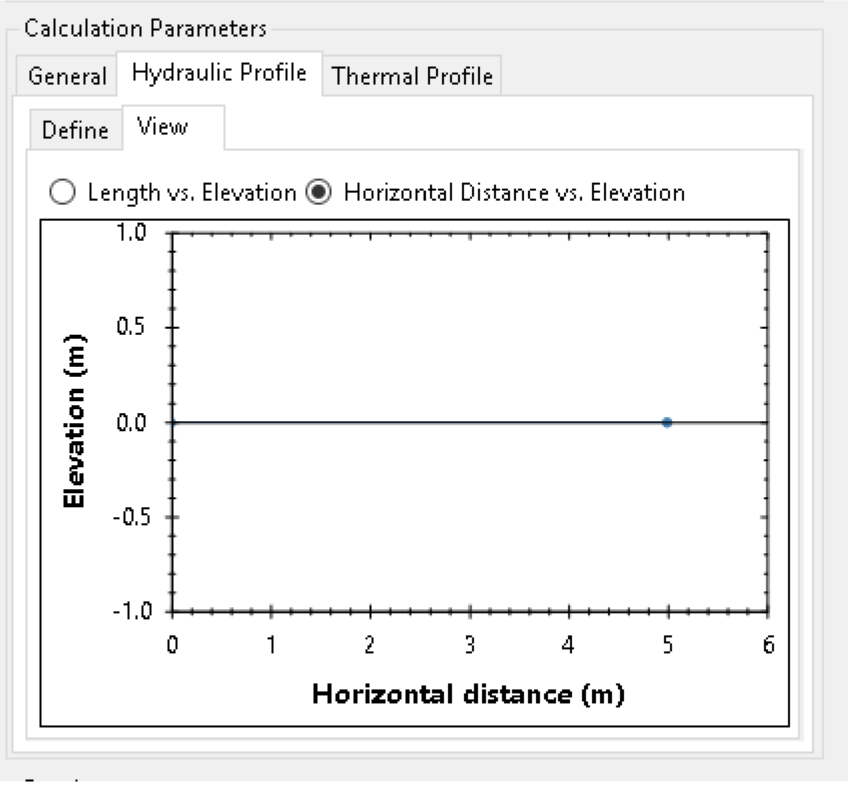


Figure 6 Elevation vs horizontal distance profile for Compressor inlet pipe

11. Once all segments are added with the data provided as reference in the table above click on green tick mark to apply changes 

12. Similarly add a pipe segment name it as “Compressor outlet line” And add the following specs.

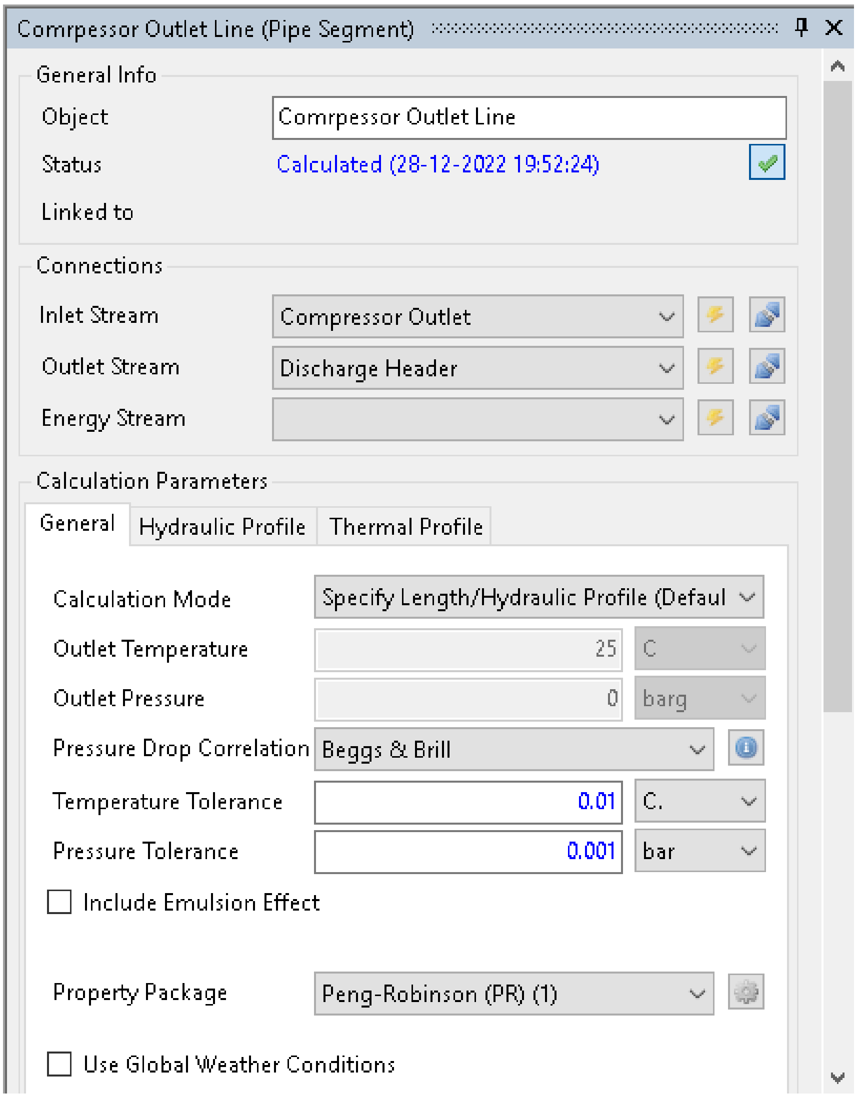


Figure 7 Pipe segment of Compressor Outlet Specs

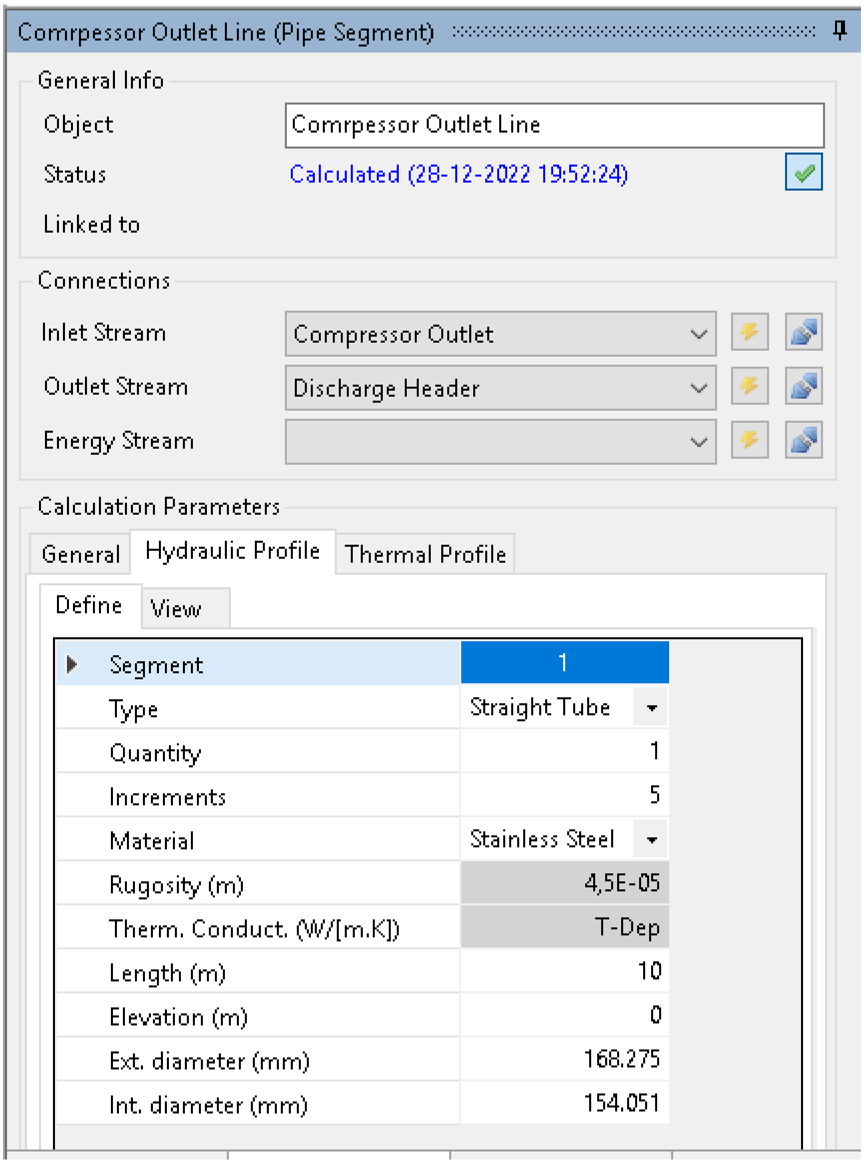


Figure 8 Adding specs for hydraulic profile |Compressor Outlet Pipe |

Segment	1
Type	Straight Tube
Quantity	1
Increments	5
Material	Stainless Steel
Rugosity (m)	4,5E-05
Therm. Conduct. (W/[m.K])	T-Dep
Length (m)	10
Elevation (m)	0

Ext. diameter (mm)	168.275
Int. diameter (mm)	154.051

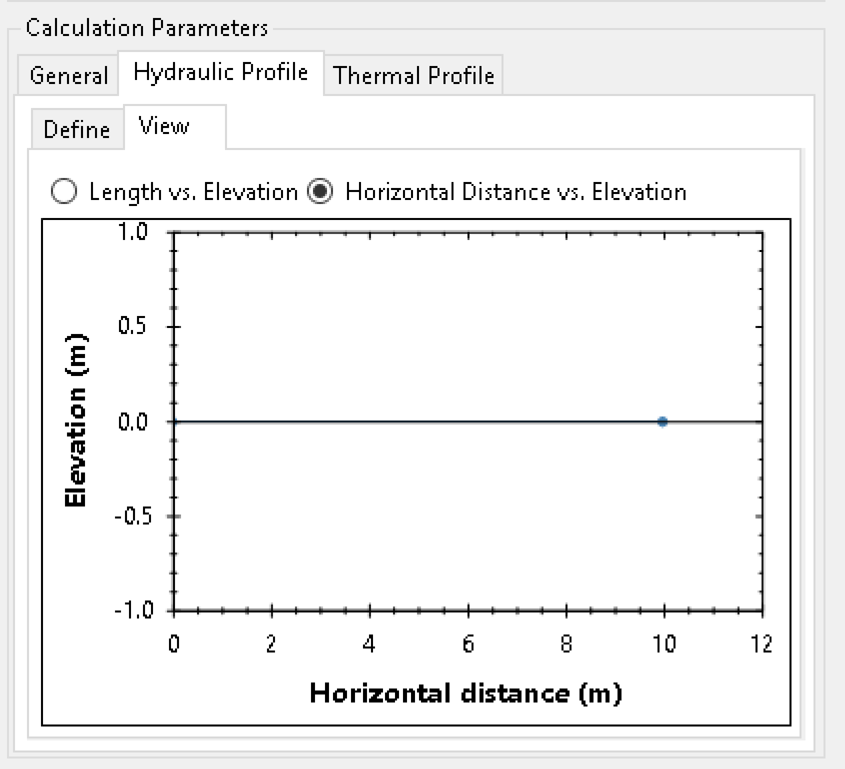
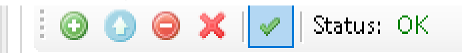


Figure 9 Elevation vs horizontal distance profile for Compressor outlet pipe

13. Once all segments are added with the data provided as reference in the table above click on green tick mark to apply changes 

14. Add a Compressor from the pressure changes ribbon and connect the “Compressor inlet line” and “Compressor outlet line”. And add the following specs

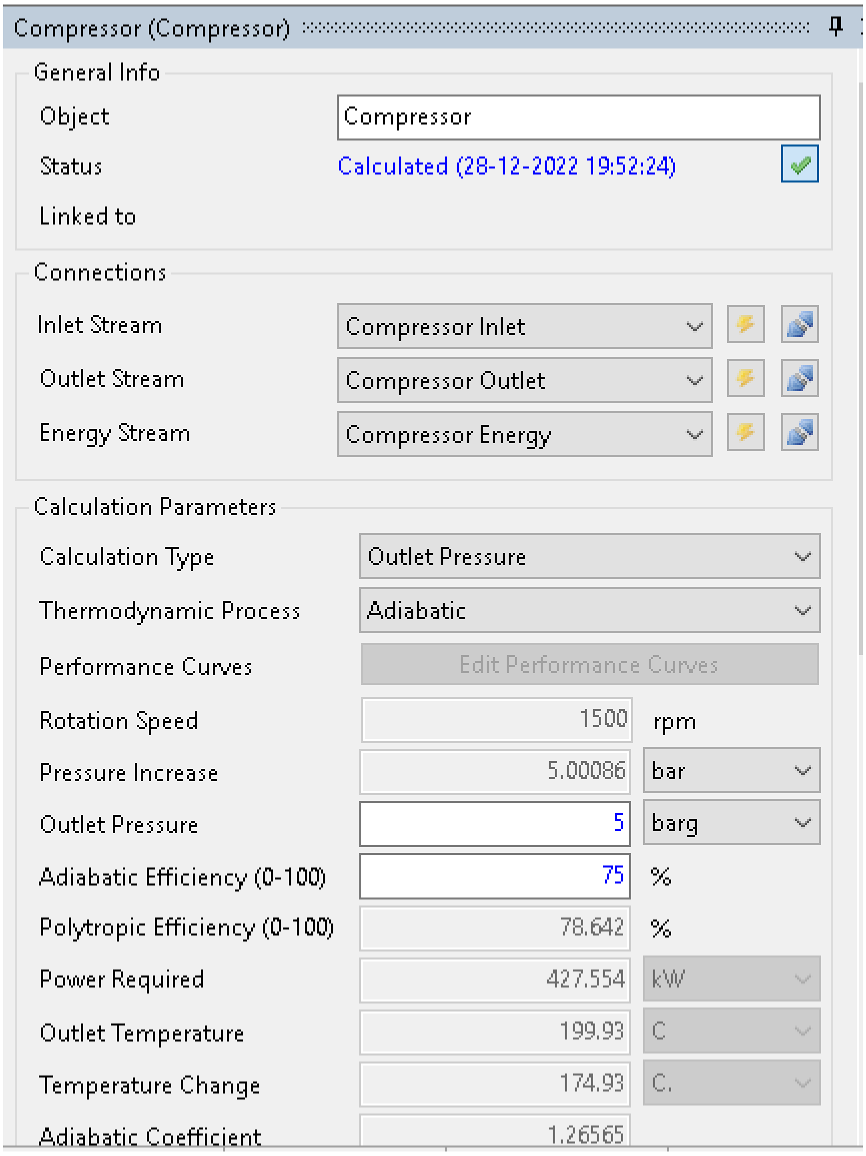


Figure 10 Compressor Specs

15. Run the simulation by pressing “Solve flow sheet” button on the top corner of the screen.

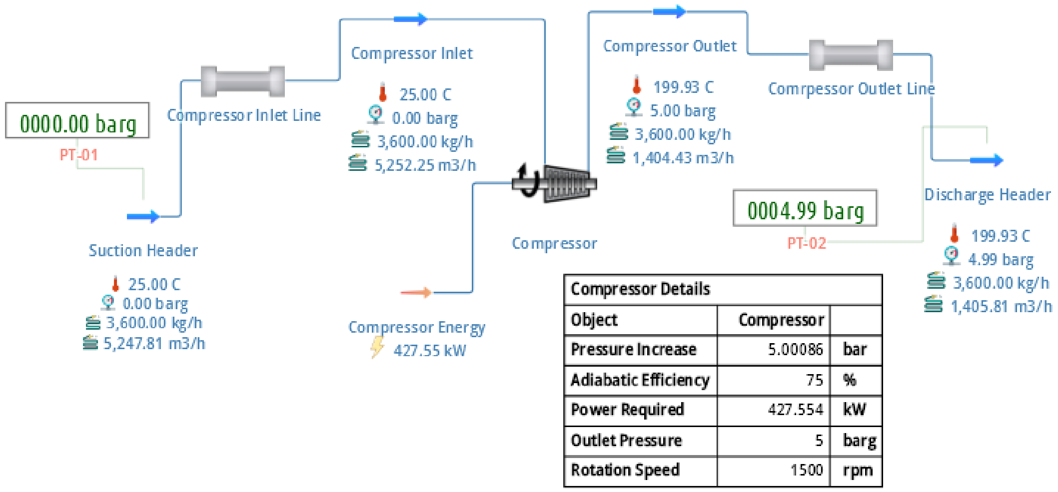
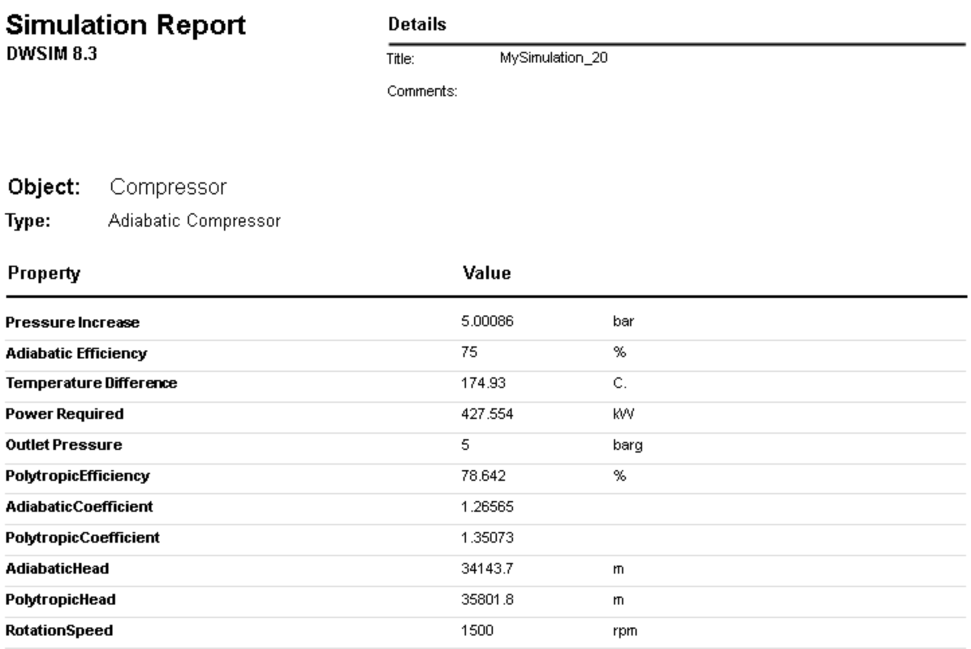


Figure 11 Flow Sheet

16. Click on result tab and generate report for Compressor.



Simulation Report
DWSIM 8.3

Details

Title: MySimulation_20

Comments:

Object: Compressor
Type: Adiabatic Compressor

Property	Value	
Pressure Increase	5.00086	bar
Adiabatic Efficiency	75	%
Temperature Difference	174.93	C.
Power Required	427.554	kW
Outlet Pressure	5	barg
PolytropicEfficiency	78.642	%
AdiabaticCoefficient	1.26565	
PolytropicCoefficient	1.35073	
AdiabaticHead	34143.7	m
PolytropicHead	35801.8	m
RotationSpeed	1500	rpm

Figure 12 Power requirement

	Compressor Outlet	Compressor Inlet	Suction Header	Discharge Header
Temperature (C)	199.93	24.9995	25	199.929
Pressure (barg)	5	-0.000855553	0	4.99407
Mass Flow (kg/h)	3600	3600	3600	3600
Molar Flow (kmol/h)	215.005	215.005	215.005	215.005
Volumetric Flow (m3/h)	1404.43	5252.25	5247.81	1405.81
Density (Mixture) (kg/m3)	2.56332	0.685421	0.686	2.5608
Molecular Weight (Mixture) (kg/kmol)	16.7438	16.7438	16.7438	16.7438
Specific Enthalpy (Mixture) (kJ/kg)	426.366	-1.18823	-1.18823	426.366
Specific Entropy (Mixture) (kJ/[kg.K])	0.300193	0.0643308	0.0639124	0.300681
Molar Enthalpy (Mixture) (kJ/kmol)	7138.97	-19.8955	-19.8956	7138.98
Molar Entropy (Mixture) (kJ/[kmol.K])	5.02636	1.07714	1.07014	5.03454
Thermal Conductivity (Mixture) (W/[m.K])	0.060826	0.0335707	0.0335708	0.0608258
Density (Vapor) (kg/m3)	2.56332	0.685421	0.686	2.5608

3 CROSS-CHECKING IN KORF HYDRAULICS

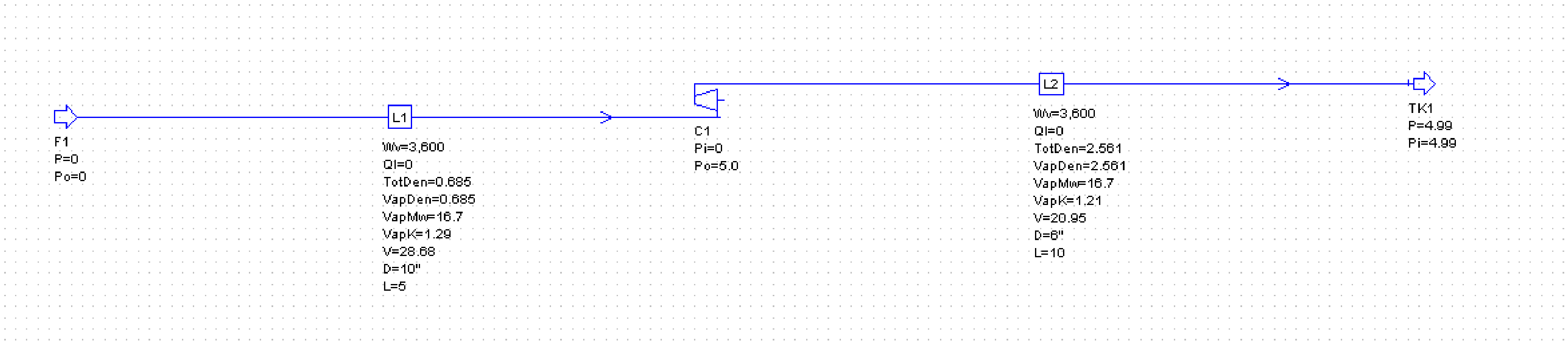


Figure 13 Compressor power calculation in KORF

28 Compressor Sizing Korf Results.p

[Compressor Sizing Using Korf Hydraulics]

COMPRESSOR INLET LINE PROFILE DATA

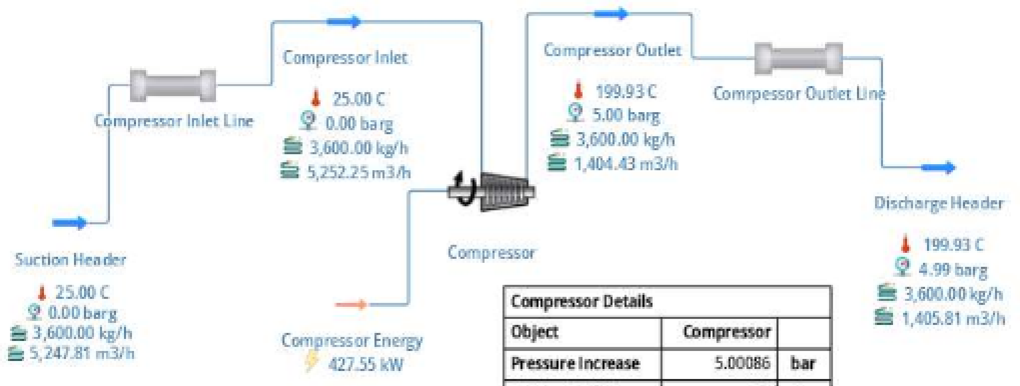
Length (m)	Inclination (degrees)	Pressure (barg)	Temperature (C)	Liquid Velocity (m/s)	Vapor Velocity (m/s)	Heat (kW)	Liquid Holdup	Flow Regime	Overall HTC (W/[m2.K])	h (Internal) (W/[m2.K])	k/L (Wall) (W/[m2.K])	k/L (Insulation) (W/[m2.K])	h (External) (W/[m2.K])	External Temperature (C)
0	0	0	25	0	28.6538	0	0	Vapor Only	0	0	0	0	0	25
1	0	-0.000171053	24.9999	0	28.6587	0	0	Vapor Only	0	0	0	0	0	25
2	0	-0.000342135	24.9998	0	28.6635	0	0	Vapor Only	0	0	0	0	0	25
3	0	-0.000513245	24.9997	0	28.6683	0	0	Vapor Only	0	0	0	0	0	25
4	0	-0.000684385	24.9996	0	28.6732	0	0	Vapor Only	0	0	0	0	0	25
5	0	-0.000855553	24.9995	0	28.678	0	0	-	0	0	0	0	0	25

COMPRESSOR OUTLET LINE PROFILE DATA

Length (m)	Inclination (degrees)	Pressure (barg)	Temperature (C)	Liquid Velocity (m/s)	Vapor Velocity (m/s)	Heat (kW)	Liquid Holdup	Flow Regime	Overall HTC (W/[m2.K])	h (Internal) (W/[m2.K])	k/L (Wall) (W/[m2.K])	k/L (Insulation) (W/[m2.K])	h (External) (W/[m2.K])	External Temperature (C)
0	0	5	199.93	0	20.9304	0	0	Vapor Only	0	0	0	0	0	25
2	0	4.99882	199.93	0	20.9345	0	0	Vapor Only	0	0	0	0	0	25
4	0	4.99763	199.93	0	20.9387	0	0	Vapor Only	0	0	0	0	0	25
6	0	4.99645	199.929	0	20.9428	0	0	Vapor Only	0	0	0	0	0	25
8	0	4.99526	199.929	0	20.9469	0	0	Vapor Only	0	0	0	0	0	25
10	0	4.99407	199.929	0	20.951	0	0	-	0	0	0	0	0	25

4 Manual calculation in SMath Studio

28 Dec 2022 20:14:20 - 28 Compressor Sizing SMath Studio.sm



Compressor Details		
Object	Compressor	
Pressure Increase	5.00086	bar
Adiabatic Efficiency	75	%
Power Required	427.554	kW
Outlet Pressure	5	barg
Rotation Speed	1500	rpm

Inlet pressure from Suction Header (abs)

$$P_1 := 101.32\ \text{kPa} = 1.0132 \cdot 10^{5}\ \text{Pa}$$

Outlet pressure in Discharge Header (abs)

$$P_2 := 600\ \text{kPa} = 6 \cdot 10^{5}\ \text{Pa}$$

Efficiency of Compressor

$$\eta := 75\ \%$$

Volumetric Flow of Gas

$$Q_{v1} := 5247.81\ \frac{\text{m}^3}{\text{hr}} = 1.4577\ \frac{\text{m}^3}{\text{s}}$$

Specific ratio of Heat Capacities

$$k := 1.28$$

Power Required By adiabatic compressor

$$P_0 := \frac{2.78 \cdot 10^{-4}}{\eta} \cdot \left(\frac{k}{k-1}\right) \cdot Q_{v1} \cdot P_1 \cdot \left(\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} - 1\right) \cdot 3600 = 428.5185\ \text{kW}$$

5 REFERENCES

1. Thakore - Introduction To Process Engineering And Design-MC GRAW HILL INDIA (2015) Pg 116-117