PROSIMPLUS APPLICATION EXAMPLE

SIMULATION OF A CROSS-FLOW PLATE-FIN HEAT EXCHANGER (PFHE) WITH PROSEC CAPE-OPEN UNIT OPERATION

INTEREST OF THIS EXAMPLE
This example shows a cross-flow plate-fin heat exchanger used in a gas-gas application. This heat exchanger is modeled using ProSec, ProSim's CAPE-OPEN compliant unit operation dedicated to the simulation of plate-fin heat exchangers. Regarding the thermodynamic and physico-chemical data needed, they are automatically calculated using the thermodynamic calculation server of the process simulation software.

ACCESS	☑ **Free-Internet**	☐ **Restricted to ProSim clients**	☐ **Restricted**	☐ **Confidential**

CORRESPONDING PROSIMPLUS FILE	*COPROSEC_EX_EN-Cross-flow-heat-exchanger.pmp3*

Reader is reminded that this use case is only an example and should not be used for other purposes. Although this example is based on actual case it may not be considered as typical nor are the data used always the most accurate available. ProSim shall have no responsibility or liability for damages arising out of or related to the use of the results of calculations based on this example.

Copyright © 2018 ProSim, Labège, France - All rights reserved

TABLE OF CONTENTS

Copyright © 2018 ProSim, Labège, France - All rights reserved

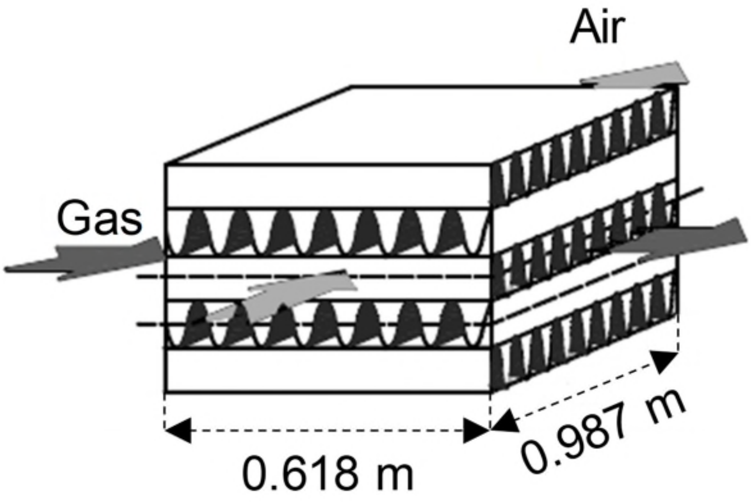
1. PROCESS MODELING

1.1. Process description

This example deals with a gas-gas cross-flow plate-fin heat exchanger (PFHE). Compact heat exchangers are characterized by a large heat transfer surface area per unit volume. Amongst different varieties of compact heat exchangers, crossflow plate-fin heat exchangers are widely used in aerospace, automobile, cryogenic and chemical process plants for their low weight and volume, high efficiency. It will be simulated with ProSec CAPE-OPEN unit operation. In ProSec, cross-flow heat exchangers are modeled as counter-flow heat exchangers and an efficiency coefficient [ROE10] is computed and applied to take into account the cross-flow behavior. The assumptions of the model are:

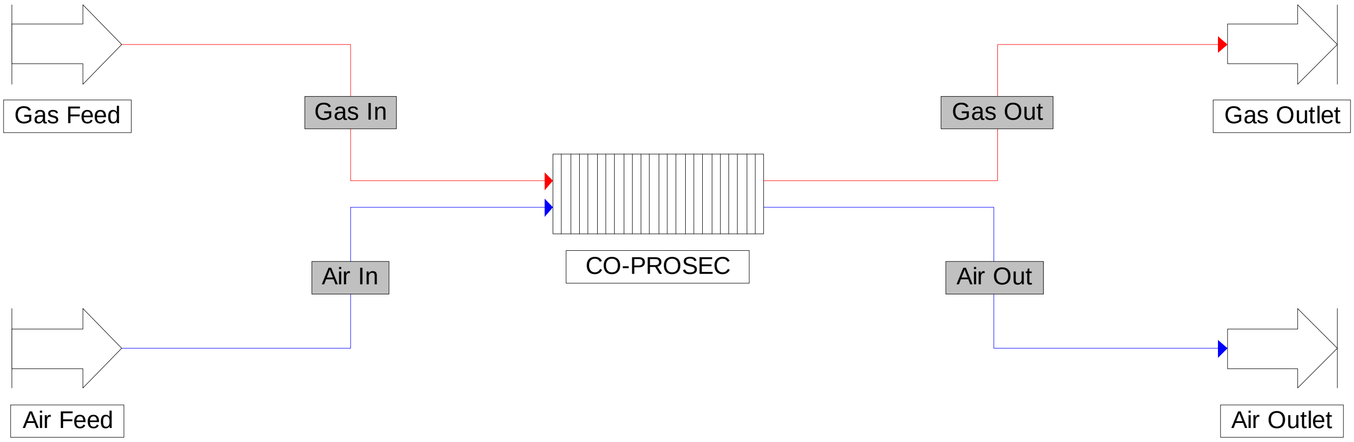
- ✓ Common wall temperature,
- ✓ Longitudinal conduction not taken into account,
- ✓ Two fluids,
- ✓ Continuous thermodynamic option not available.

The example is extracted from [MIS09]. The sketch is shown below. The two fluids are modeled as air. The “Gas” is the main stream and the “Air” is the cross-flow stream.



The thermodynamic and physico-chemical data needed for the simulation are automatically calculated by the unit operation. In this example, as the ProSec CAPE-OPEN unit operation is used in ProSimPlus simulation environment, it uses Simulis Thermodynamics, the calculation server for thermophysical properties and phase equilibria calculations available in ProSimPlus.

1.2. Process flowsheet



Copyright © 2018 ProSim, Labège, France - All rights reserved

1.3. Compounds

The compounds taken into account in the simulation, their chemical formula and CAS numbers are shown in the following table. Their pure component properties are extracted from the standard data base provided with ProSimPlus [ROW17].

Compound	Chemical formula	CAS number
Oxygen	O_2	7782-44-7
Nitrogen	N_2	7727-37-9

1.4. Thermodynamic model

The PSRK profile, which is based on a predictive combined approach model [HOL91], [GME91], [CHE02] is selected.

1.5. Operating parameters

1.5.1. Process feed

	Gas	Air
Temperature (°C)	240	4
Pressure (bar)	1	1
Total flow rate (kg/s)	0.8962	0.8296
Molar fraction		
Oxygen	0.21	
Nitrogen	0.79	

Copyright © 2018 ProSim, Labège, France - All rights reserved

1.5.2. Plate-fin heat exchanger

✓ General parameters

Parameters	Value
Type of exchanger	CO-ProSec
Number of body	1
Orientation	Horizontal
Fin data base	2015 -> Now
Material	
Type	Other
a1	160
a2 = a3 = a4 = a5 = a6 =a7	0
Used width (m)	0.987
Thickness of the side bars (mm)	0.001
Thickness of the end bars (mm)	0.001
Thickness of the separation plates (mm)	0.5

✓ Streams parameters

	Stream	
Parameter	**Gas**	**Air**
Flow direction	From top to bottom	From bottom to top
Cross flow	No	Yes
Heat exchange correlation	HTFS85	

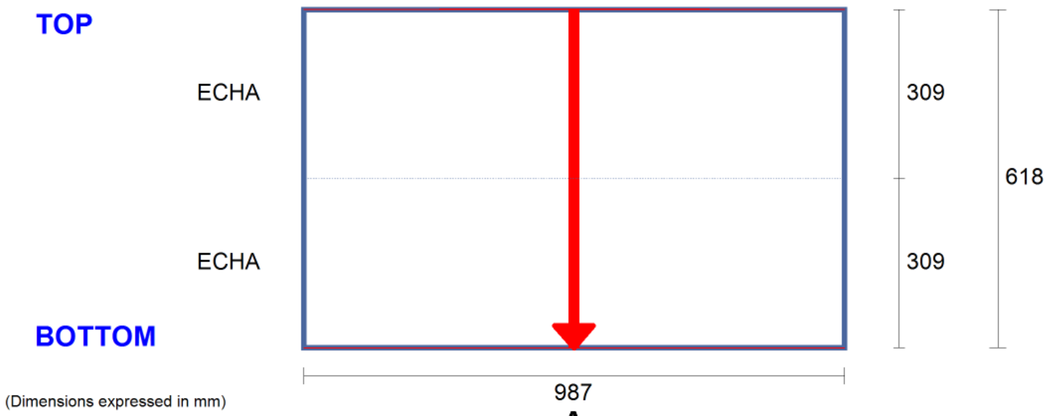
✓ Fin characteristics

Name	Fin #1
Origin	User
Calculation mode	From geometry
Reference	1001
Type	Serrated
Height (mm)	9.799
Thickness (mm)	0.101
Fins number per meter	654.5
Serration length (mm)	7.551

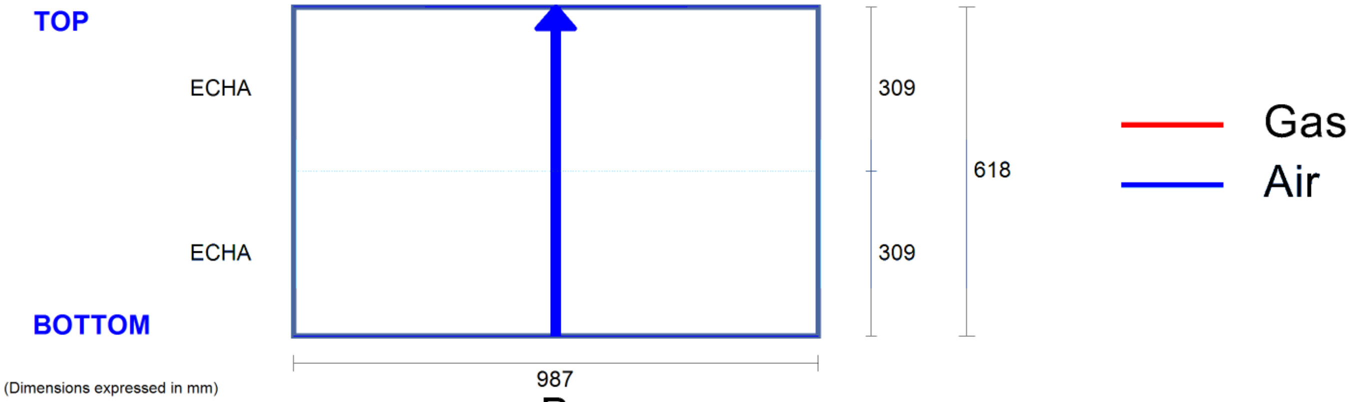
Copyright © 2018 ProSim, Labège, France - All rights reserved

- ✓ Reference passages

Fin #1 is used for each stream. The following figures show the two reference passages of the heat exchanger. The dimensions are expressed in millimeter.



A

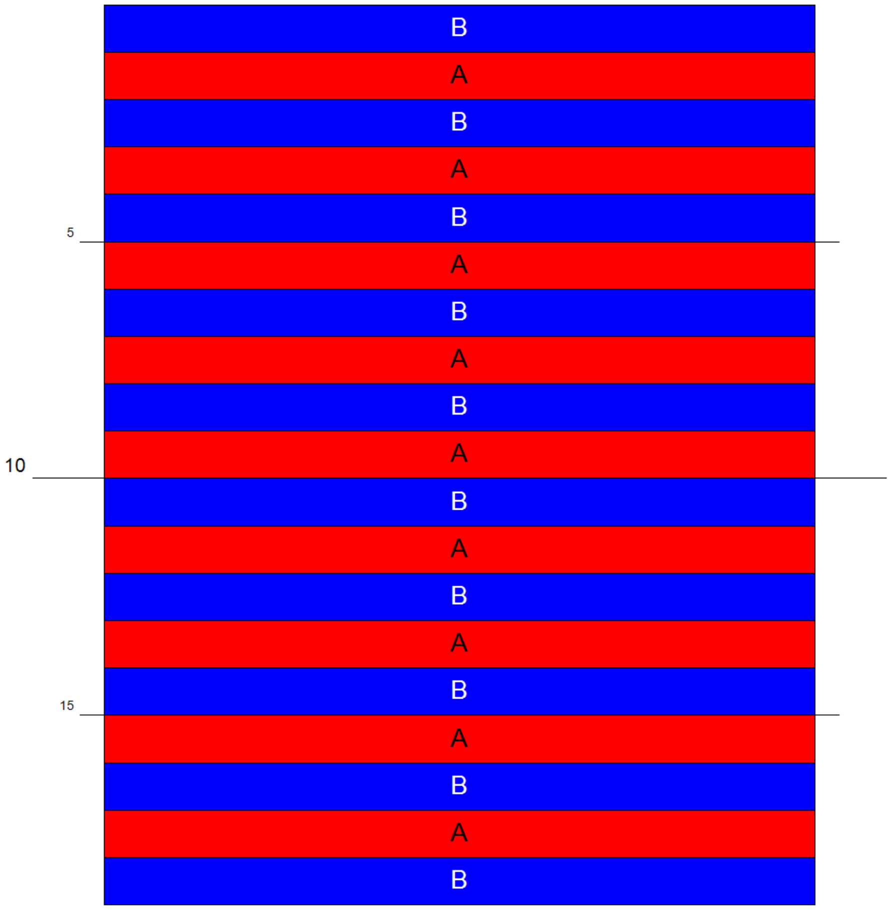


B

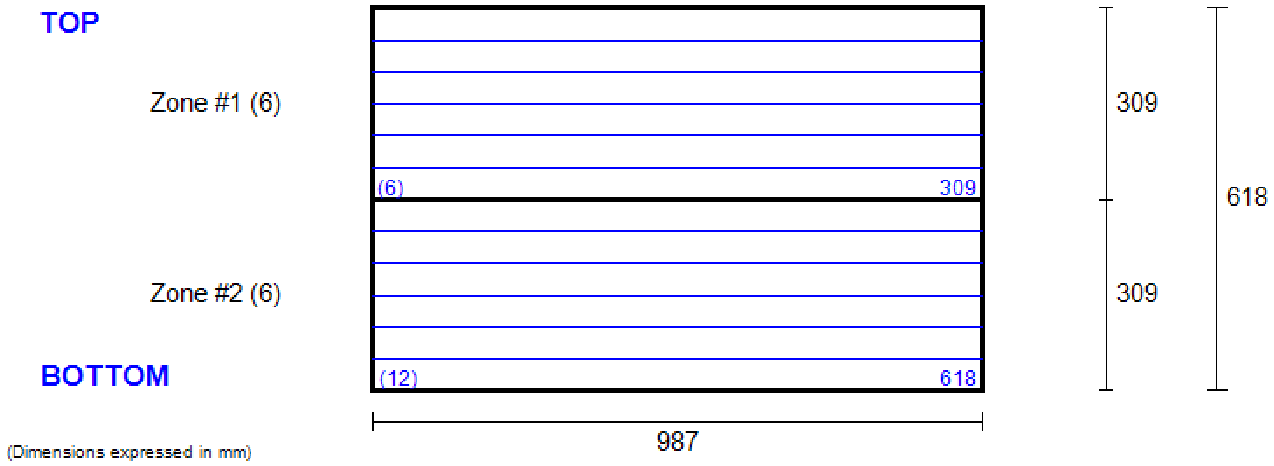
- ✓ Stacking

Parameters	Value
Sequence 1	
Number of repetitions of the sequence	9
Sequence	B A
Sequence 2	
Number of repetitions of the sequence	1
Sequence	B

Copyright © 2018 ProSim, Labège, France - All rights reserved



- ✓ Number of meshs for each elementary zone (dimensions are expressed in millimeter)



2. RESULTS

2.1. Mass and energy balances

Streams		Air In	Air Out	Gas In	Gas Out
Total flow	kg/s	0.8296	0.8296	0.8962	0.8962
Mole fractions					
OXYGEN		0.21	0.21	0.21	0.21
NITROGEN		0.79	0.79	0.79	0.79
Physical state		Vapor	Vapor	Vapor	Vapor
Temperature	°C	4	201.81	240	57.828
Pressure	kPa	100	95.282	100	97.997
Enthalpic flow	kW	-17.831	149.49	196.94	29.624
Vapor molar fraction		1	1	1	1

2.2. Global results

The heat duty computed by ProSec is 167 kW. [MIS09] indicates a value of 160 kW. The deviation is explained by the differences in the assumptions:

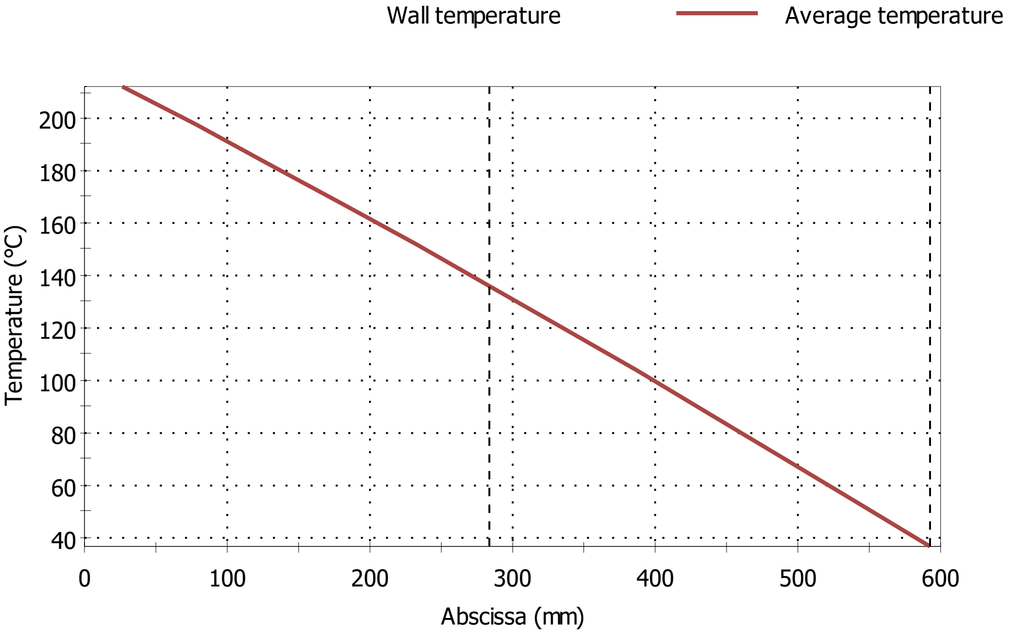
- ✓ Constant physico-chemical properties for [MIS09] vs temperature dependent for ProSec,
- ✓ The correlations used to compute the Colburn and Fanning factors are not the same.

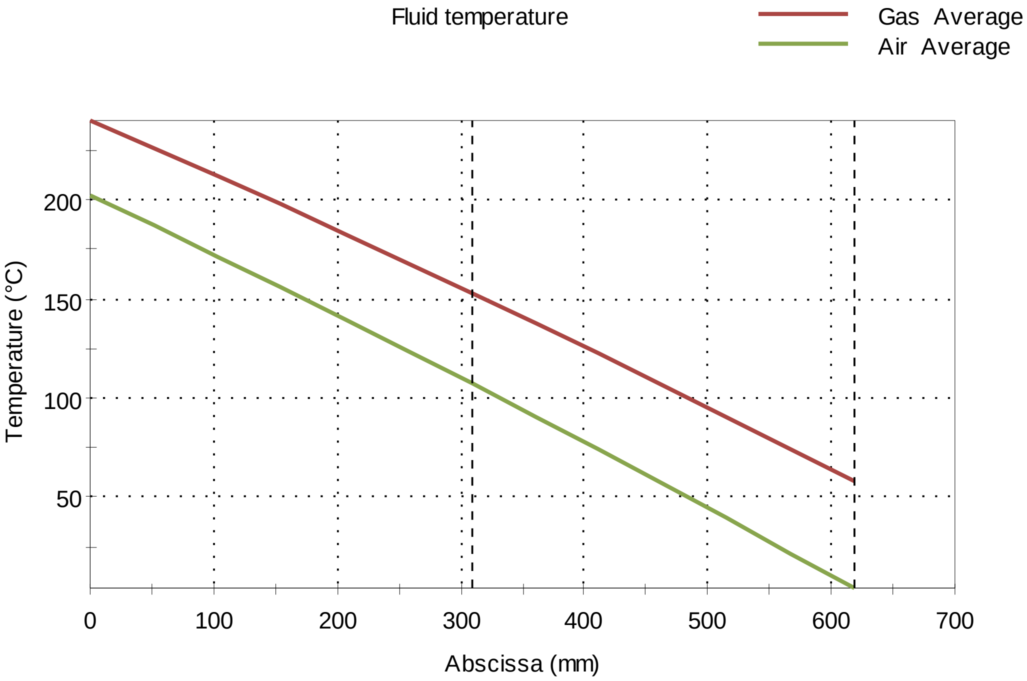
The pressure drops computed by ProSec (2 003 Pa for the gas stream and 4 718 Pa for the air stream) are closed to the ones calculated by [MIS09].

Copyright © 2018 ProSim, Labège, France - All rights reserved

2.3. Plate-fin heat exchanger profiles

Several profiles (wall temperature, fluid temperature, pressure, heat transfer coefficient, vaporization ratio…) in the heat exchanger are available after the simulation from ProSec edition window ("Results" tab). The following figures show the average wall temperature profile and the fluid mean temperature profiles along the length of the heat exchanger.





Copyright © 2018 ProSim, Labège, France - All rights reserved

3. REFERENCES

[CHE02] CHEN J., FISCHER K., GMEHLING J., “Modification of PSRK Mixing Rules and Results for Vapor – Liquid Equilibria, Enthalpy of Mixing and Activity Coefficients at Infinite Dilution”, Fluid Phase Equilib., 200, 411-429 (2002)

[GME95] GMEHLING J., “From UNIFAC to Modified UNIFAC to PSRK with the Help of DDB”, Fluid Phase Equilib., 107, 1-29 (1995)

[HOL91] HOLDERBAUM T., GMEHLING J., “PSRK: A Group Contribution Equation of State based on UNIFAC”, Fluid Phase Equilib., 70, 251-265 (1991)

[MIS09] MISHRA M., DAS P.K., “Thermoeconomic Design-Optimisation of Crossflow Plate-Fin Heat Exchanger Using Genetic Algorithm”, Int. J. Exergy, 6, 837-852 (2009)

[ROE10] ROETZEL W., SPANG B., “VDI Heat Atlas, Chapter C1: Thermal Design of Heat Exchangers”, Springer-Verlag, 2nd Edition (2010)

[ROW17] ROWLEY R.L., WILDING W.V., OSCARSON J.L., GILES N.F., “DIPPR® Data Compilation of Pure Chemical Properties”, Design Institute for Physical Properties, AIChE, New York, NY (2017)