CENTER for ENVIRONMENTAL ENERGY ENGINEERING

Wavy Fin Profile Optimization Using NURBS for Air-To-Refrigerant Tube-Fin Heat Exchangers with Small Diameter Tubes

Paper #2119 - Session R-07

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July 11th, 2016

16th International Refrigeration and Air Conditioning Conference at Purdue, July 11-14, 2016

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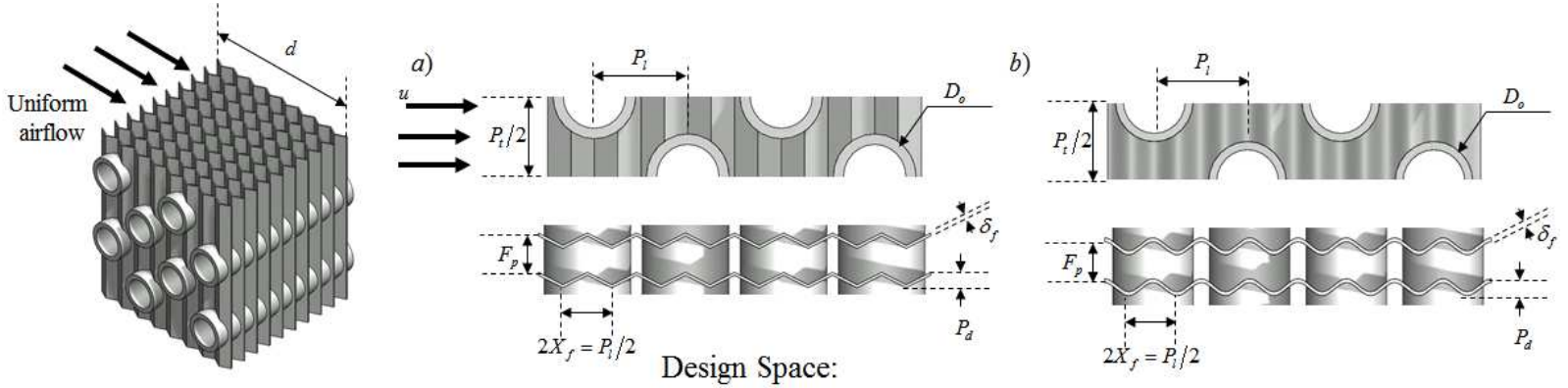
Introduction

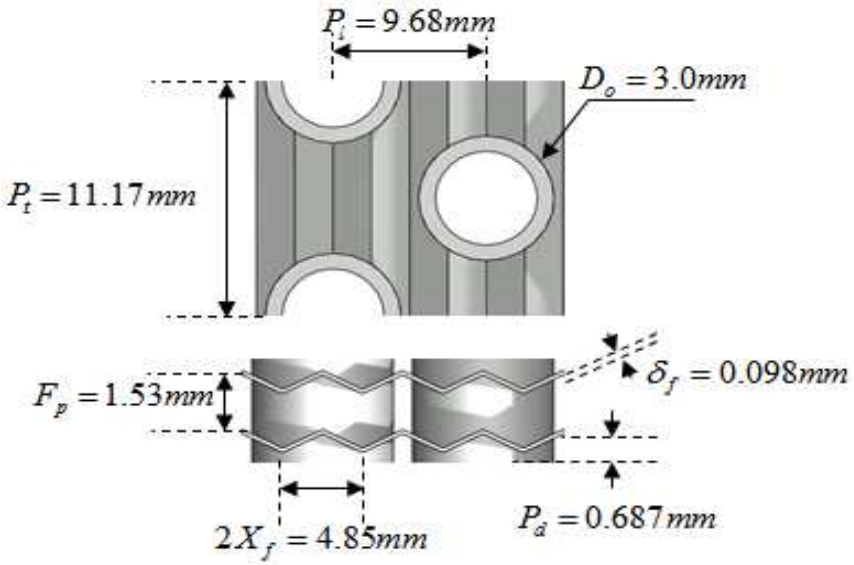
- Wavy fin and round tube heat exchangers are suitable for applications such as heat pumps in cold climates
  - Lower performance degradation compared to louvered and slit fins (Silva et al., 2011; Huang et al., 2014)
- Small tube diameters (below 5.0mm) result in more compact surfaces and better thermal performance (Bacellar et al. 2014, 2015, 2016)
- Objective: Investigate novel wavy profiles for wavy fin and round tube heat exchangers for diameters below 5.0mm

Baseline Surface



Design Space:

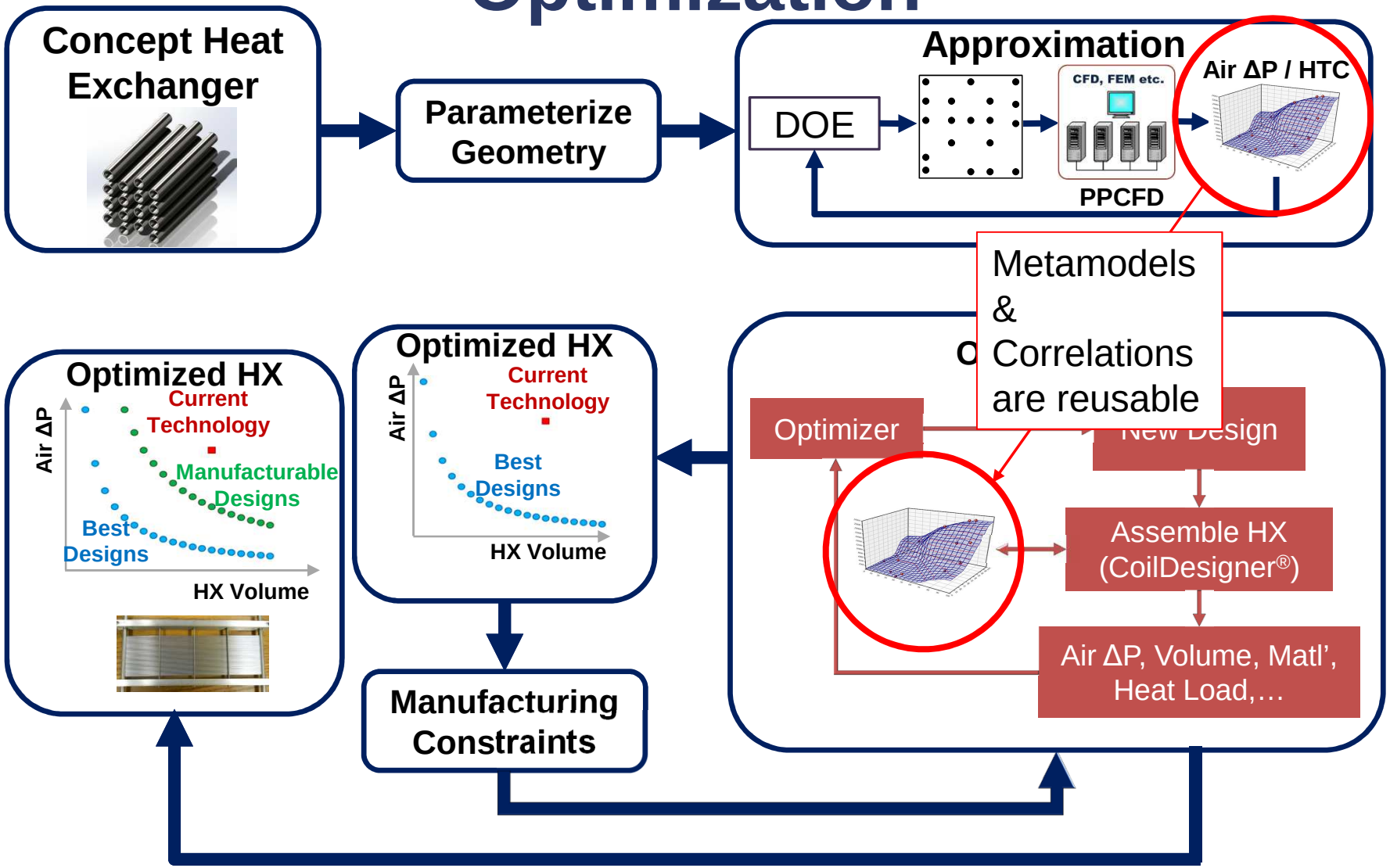
D_o (mm)	P_l/D_o (-)	P_t/D_o (-)	F_p (mm)	P_d/X_f (-)	δ_f (mm)	N (-)	u (m/s)
2.0 - 5.0	1.25 – 4.0	1.25 – 4.0	0.5 – 2.5	0.088 – 0.84	0.05 – 0.1	2 - 20	0.5 – 7.0



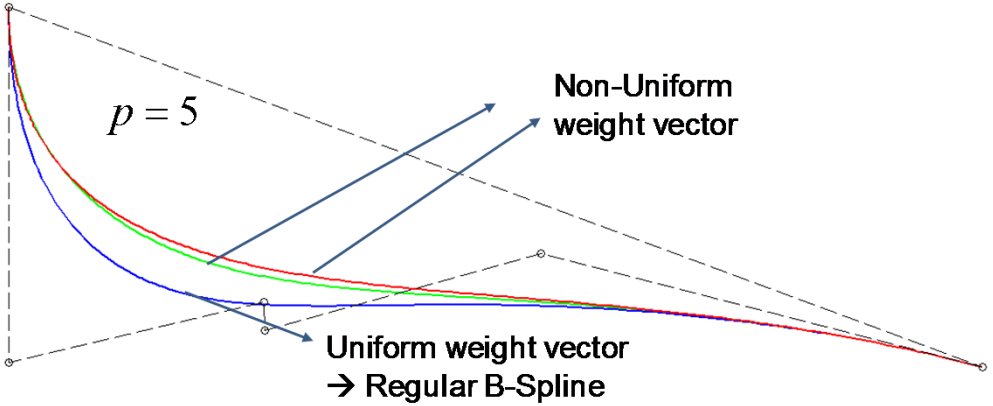
Metric	unit	Value
D_h	mm	2.02
u	m/s	1
NTU	-	1.46
C_f	-	0.129
h	W/m².K	68.9
ΔP	Pa	6.14
η_o	-	0.928

Bacellar, D., Aute, V., Radermacher, R., CFD-Based Correlation Development for Air Side Performance of Wavy Fin Tube Heat Exchangers using 2mm-5mm Tube Diameters, 16th International Refrigeration and Air Conditioning Conference at Purdue, July 11-14, 2016.

Approximation Assisted Optimization

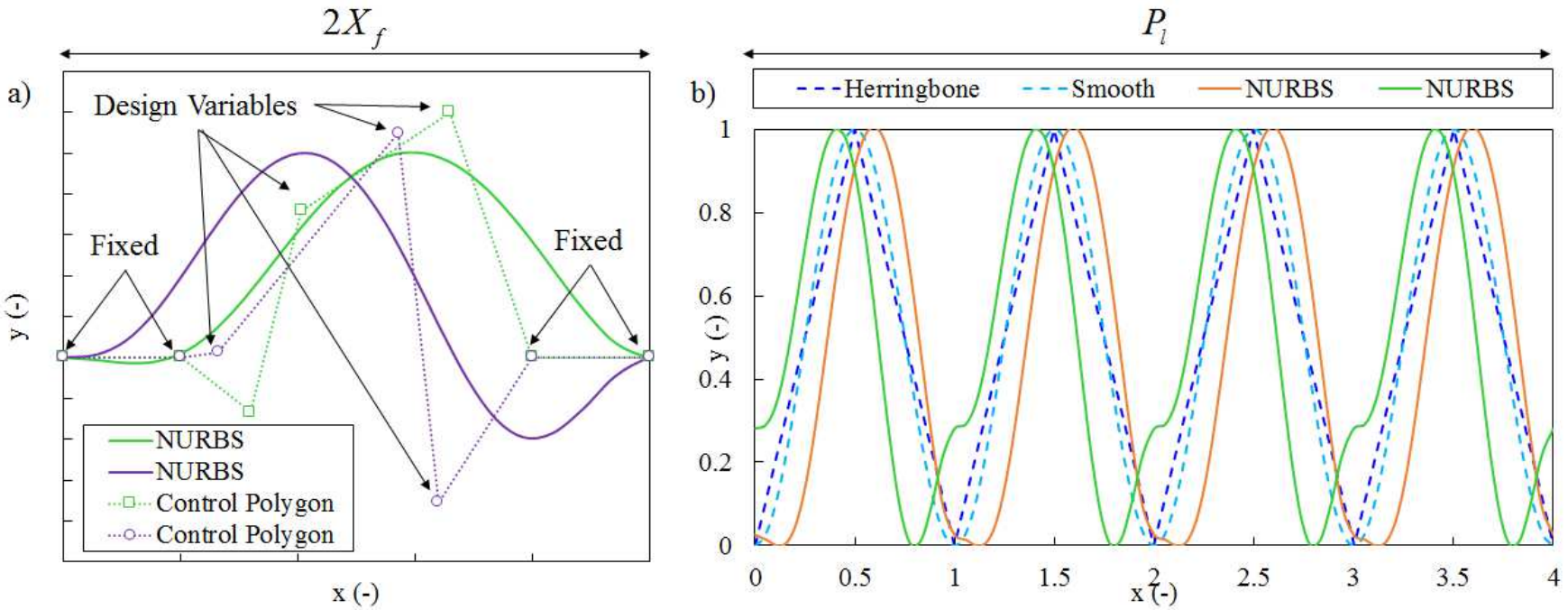


Wave Profile - NURBS

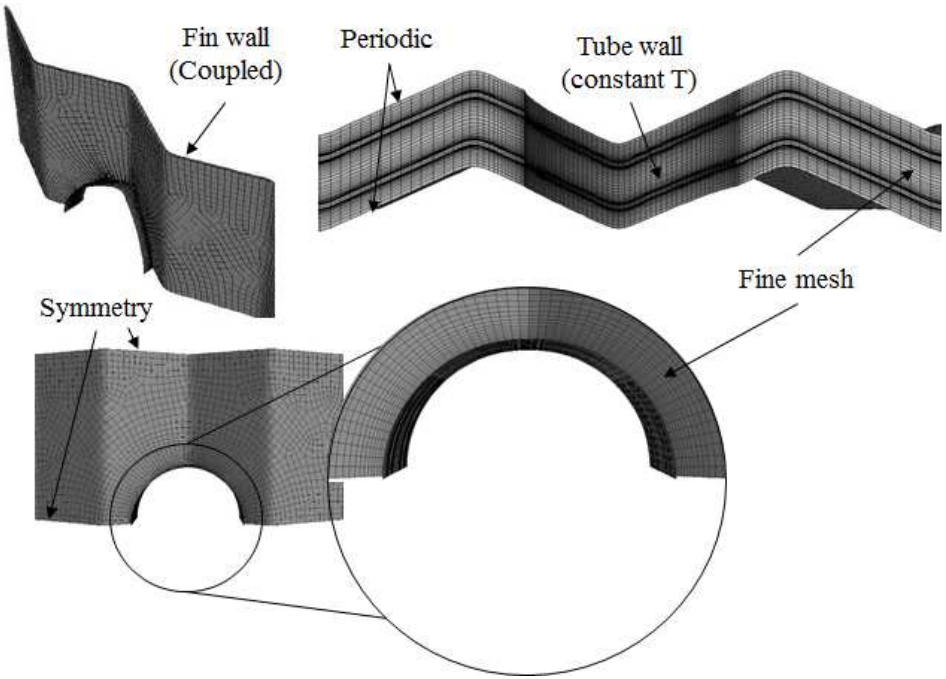


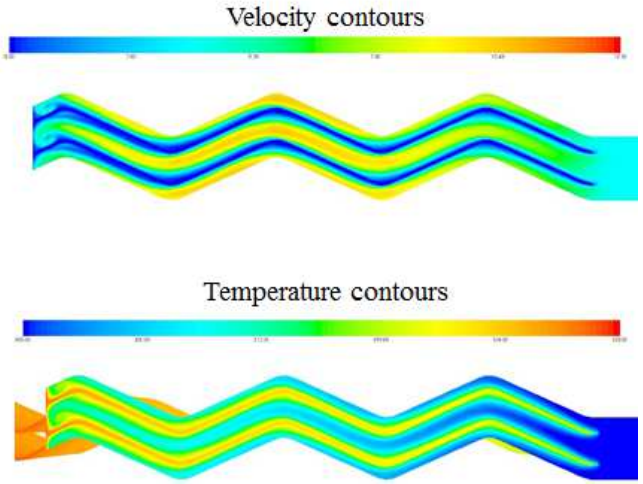
$$C(\mathrm{u}) = \sum F_i(\mathrm{u}) \cdot P_t$$

$$F_i(u) = R_{i,p}(u) \cdot w_i = \frac{N_{i,p}(u) \cdot w_i}{\sum N_{i,p}(u) \cdot w_i}$$



CFD Modeling and Simulation





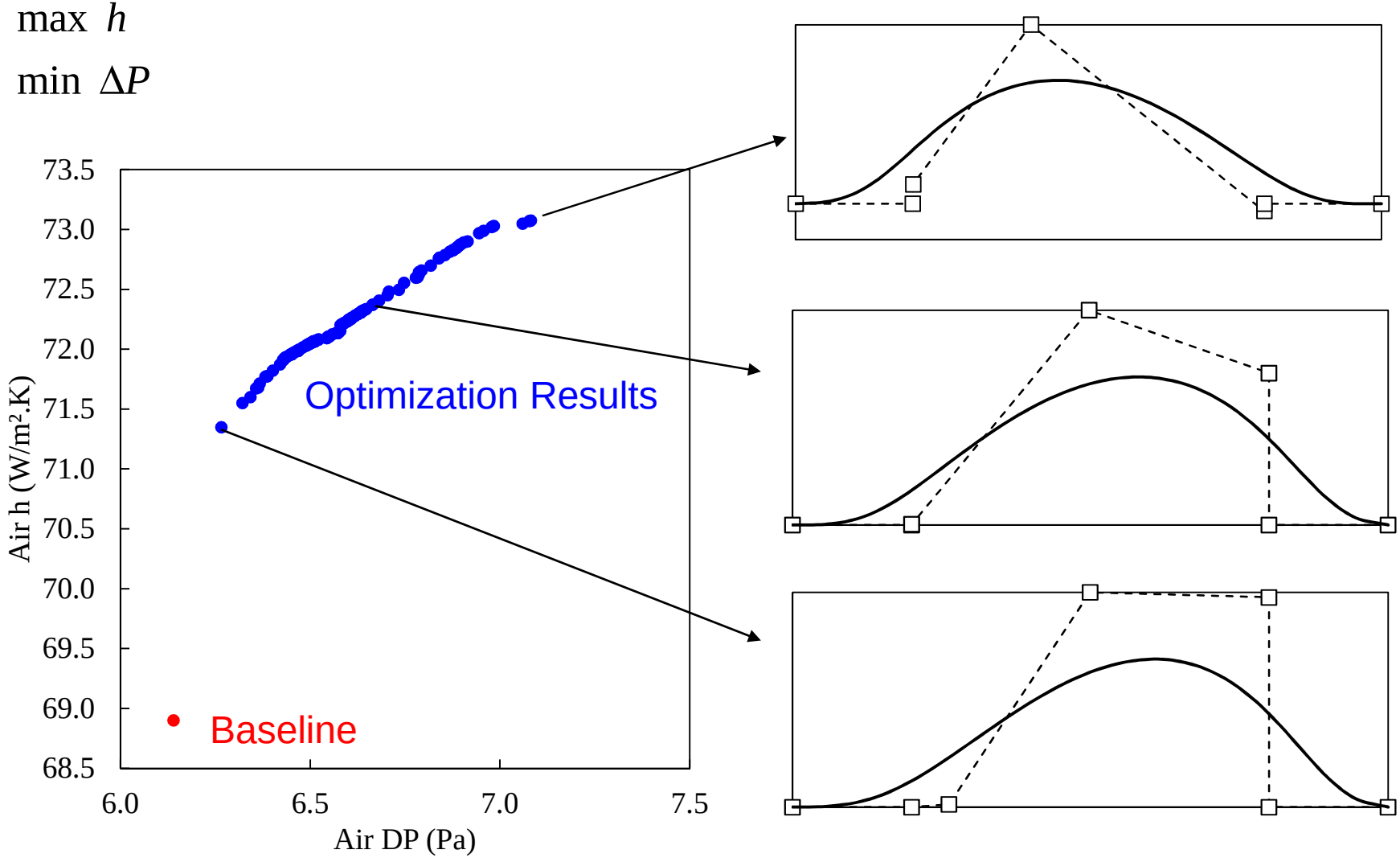
Settings: Ideal gas and k-ε Realizable models

Post Processing: UA-LMTD method, iterative fin efficiency (Schmidt, 1949)

Multi-Objective Optimization 1

max h

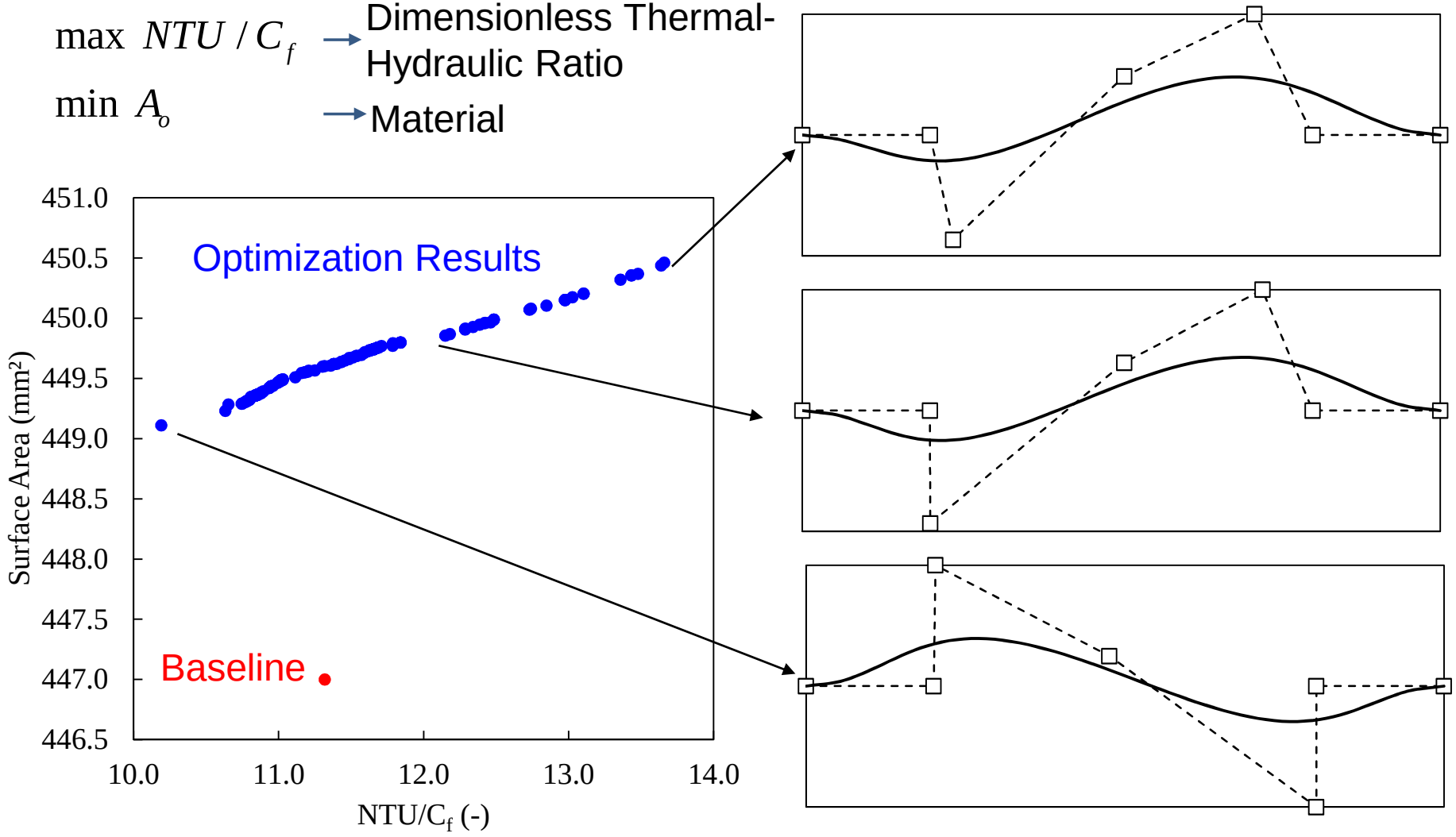
min ΔP



Multi-Objective Optimization 2

$\max\ NTU / C_f$ → Dimensionless Thermal-Hydraulic Ratio

$\min\ A_o$ → Material



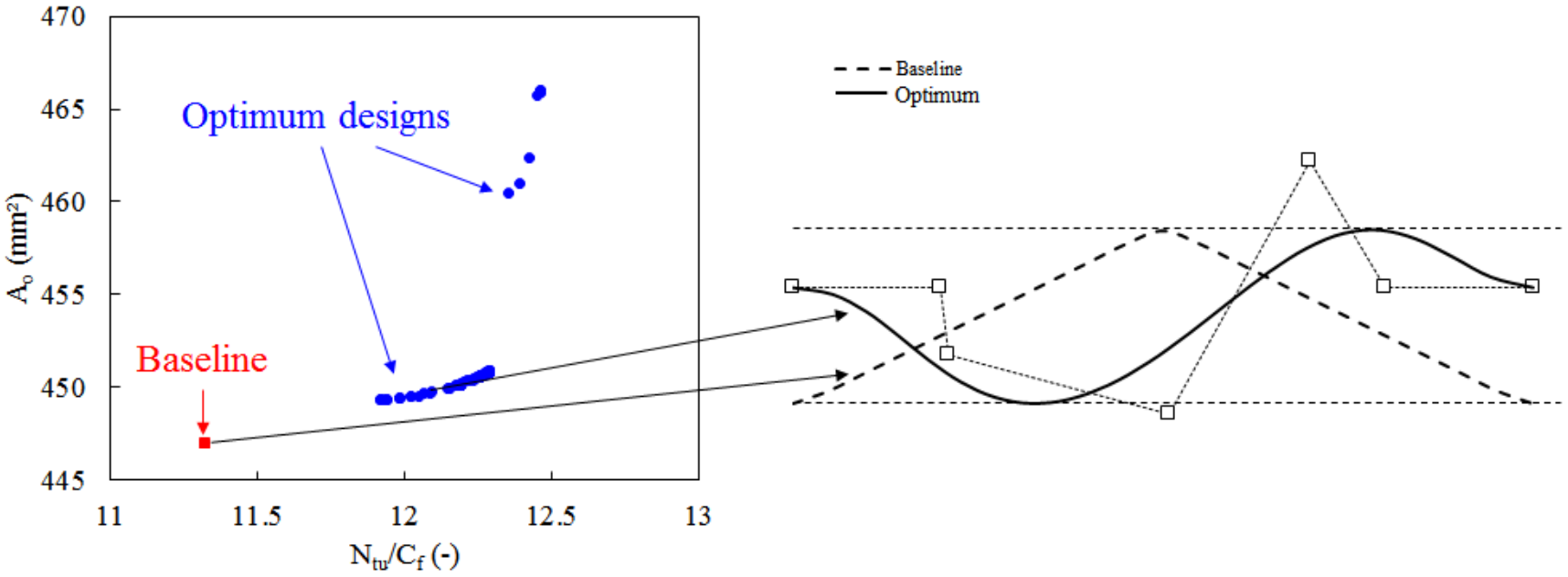
Multi-Objective Optimization 2 (cont'd)

$\max\ NTU / C_f$ ⟶ Thermal-Hydraulic Ratio

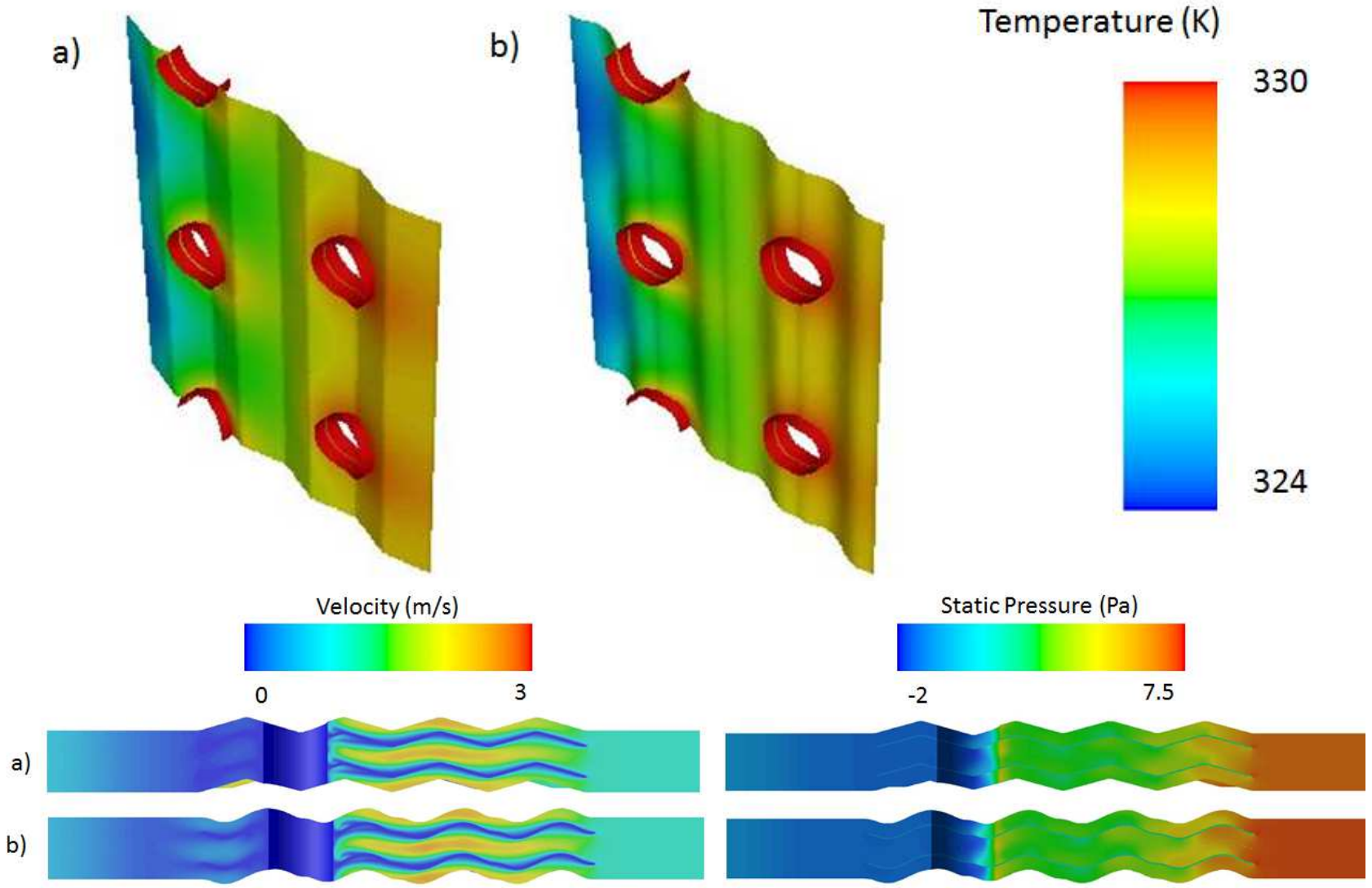
$\min\ A_o$ ⟶ Minimizing material

$s.t.$

$NTU / C_f \geq 1.46 / 0.129$



Post-Processing Analysis



Conclusions

- NURBS profile yield higher heat transfer coefficient and larger surface-to-volume ratio
- Despite the higher thermal-hydraulic ratio, the pressure drop is actually higher than the Herringbone
- The results are yet insufficient to draw broader conclusions
- Future work should include a larger design space, include frosting and/or fouling and perform a full-size heat exchanger optimization
- This work is, however, a starting point for a potentially promising study

Acknowledgements

This work had support from the United States Department of Energy (US DOE) Grant Number DE-EE0006114 and the Modeling and Optimization Consortium (MOC) of the Center for Environmental Energy Engineering (CEEE) at the University of Maryland.

THANK YOU!