Next Generation Liquid-to-Refrigerant Heat Exchangers for Heat Pumps, Water Heaters, & Refrigeration Systems

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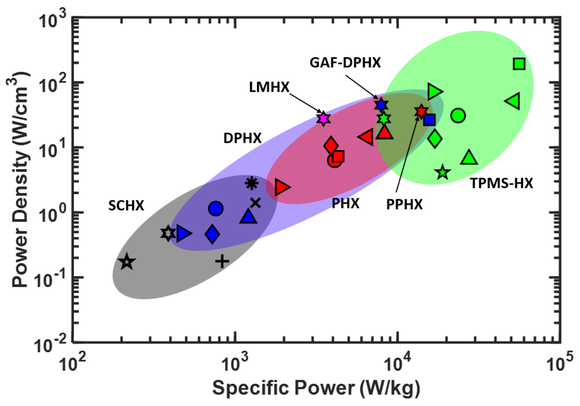
Background

- Liquid-to-Refrigerant Heat Exchangers (LRHXs) are used in many applications, e.g., secondary loop systems, heat pump water heaters, power generation, supermarket refrigeration, etc.
- Main LRHX geometries: Shell & Tube HX, Shell & Coil HX (SCHX), Double Pipe HX (DPHX), Plate HX (PHX)
- Brazed PHXs: Dominate the LRHX space; operational challenges (e.g., flow maldistribution, fouling) can lead to 25% capacity degradation[1]



Potential Next Generation LRHXs:
- PPHX – Pillow Plate HX
- TPMS-HX – Triply Periodic Minimal Surface HX
- LMHX – Layered Microchannel HX
- GAF-DPHX – Genetic Algorithm Fin based DPHX

Objectives

- Develop commercially viable novel LRHXs with at least 20% improved volumetric and gravimetric thermal performance
- Address flow maldistribution and fouling
- Evaluate cost vs. performance tradeoffs

Opportunities / Impact

- *Performance:* 20-50% better heat transfer & pressure drop
- *Packaging:* Reduced HX size & weight
- *Operation:* Improved flow distribution
- *Cost Savings:* Reduced manufacturing costs and energy consumption
- *Environment:* Facilitate industry transition to lower-GWP refrigerants (e.g., R32, R454B, R290)

Timeline

- Year-1: Comprehensive Benchmarking for Current State-of-the-Art LRHXs; Design framework for Pillow PHX (PPHX)
- Year-2: PPHX Fabrication & Testing; HX design framework for advanced LRHXs e.g. Triply Periodic Minimal Surface HX (TPMS-HX)
- Year-3: Independent Validation; TPMS-HX Fabrication & Testing; Tech-to-Market Assessment

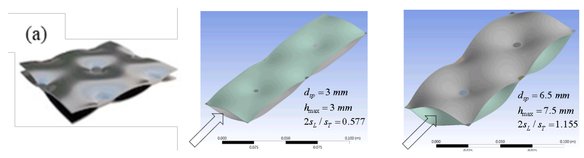
Approach

- Development of novel HX optimization framework for next-generation LRHXs which (i) improve thermal-hydraulic performance, (ii) minimize size, weight, & refrigerant charge, (iii) mitigate operational issues
- Focus on cost-effective manufacturing processes
- Focus on field performance: wetting & fouling
- Active industry involvement
  - Independent testing of new HX prototypes in actual systems at industry partner facilities
  - Timely feedback on commercial viability and other design considerations

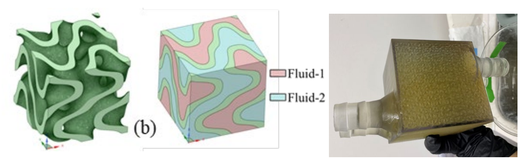
Current Status

- Benchmarking of state-of-the-art LRHX
- Investigating manufacturing options for PPHXs using laser-welding techniques
- Hydroforming simulations for PPHX manufacturing
- Validation of PPHX thermal-hydraulic performance models

LRHX Architectures

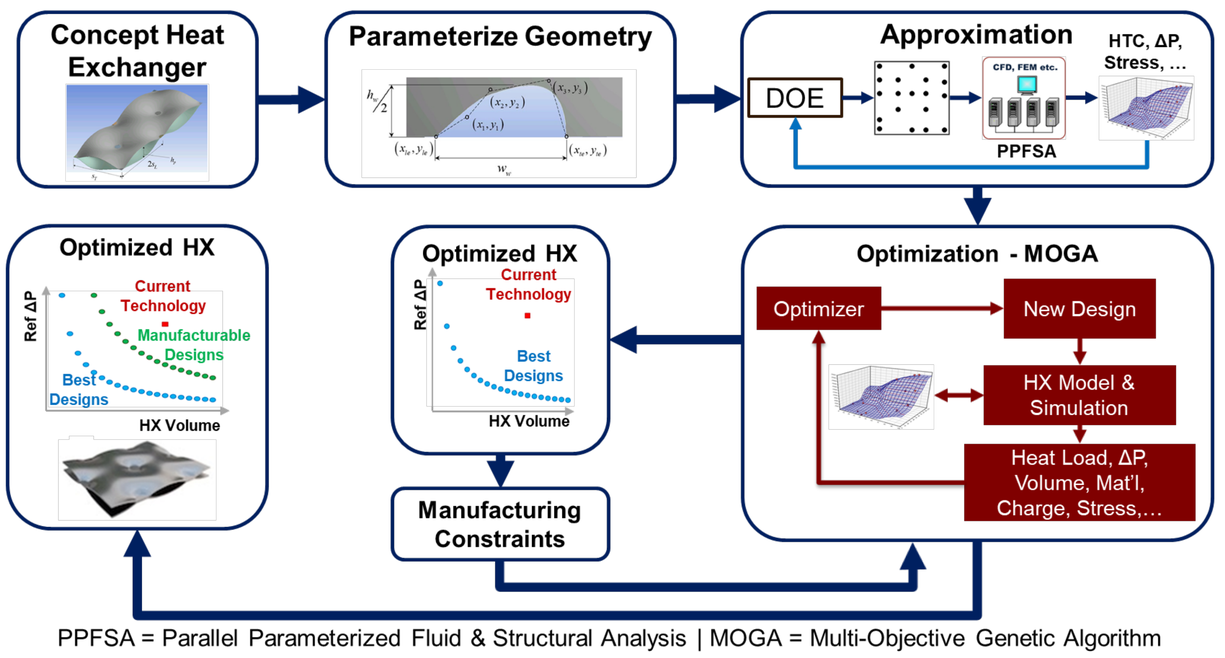


Pillow Plate Heat Exchangers[2]



TPMS Heat Exchangers[3]

Optimization Framework



PPFSA = Parallel Parameterized Fluid & Structural Analysis | MOGA = Multi-Objective Genetic Algorithm

References

[1] Shokouhmand & Hasanpour (2020). *J. En. Stor.*, *32*, 101907.
[2] Eldeeb et al. (2020). *Int. J. Refrig., 110*, 121-131.
[3] Dharmalingam et al. (2022). *19th Int. Ref. Air Cond. Conf.*

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