A Review of the State of the Art in Modeling of Air-to-Refrigerant Heat Exchangers for HVAC&R Applications
Paper 2534

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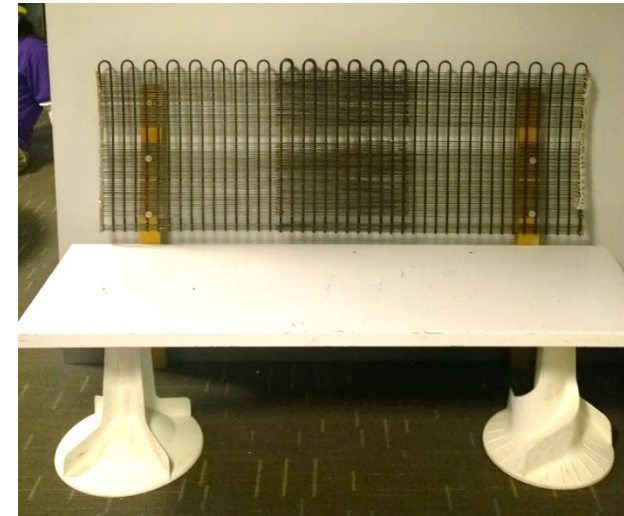# Contents

- Motivation

- Literature Review

- Proposed Approach

- Benchmarks

- Conclusions

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Motivation

- Motivation
- Heat exchangers are everywhere!!!
  - Heat pumps, refrigeration,…
- Key component
- Improved HX
  - Higher efficiency
  - Lower cost
  - Lower charge
  - Lower emissions

Heat Exchanger (HX) Models

- Black-box
  - Polynomials, Neural Networks, Kriging,…
- Physics-based
  - Single-lump models
  - Finite Volume models, aka discretized or distributed parameter models
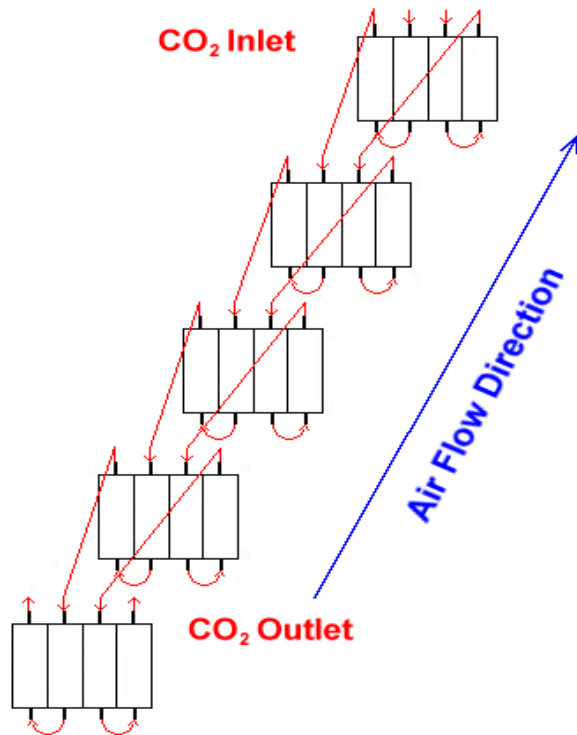   - Focus of this review

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PIRT for HX Model

- Heat transfer
  - Refrigerant (tube-side) phase change
  - Dehumidification (fin-side)
- Pressure drop
  - Core (refrigerant and air-side)
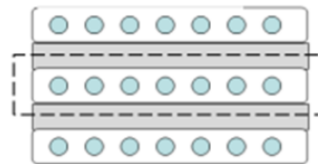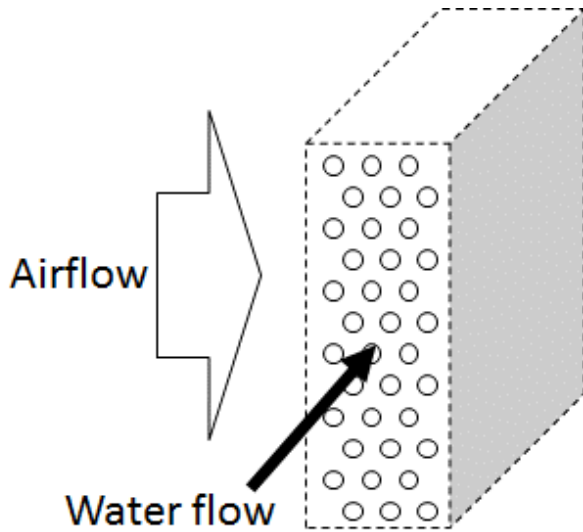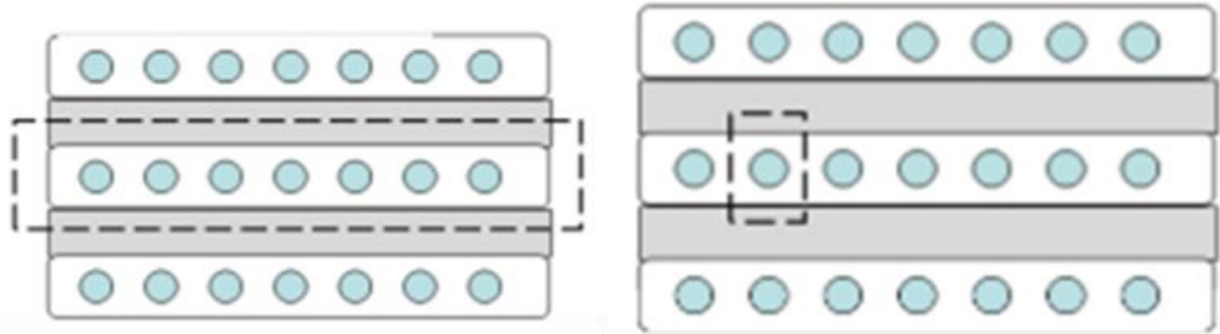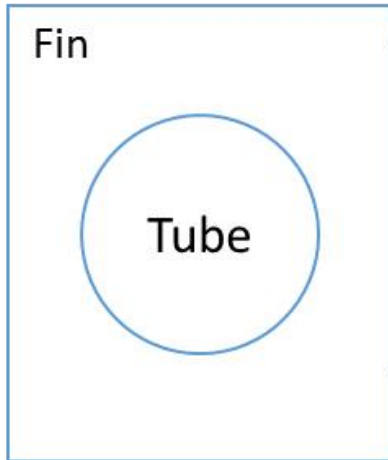 - Headers, connecting pipes etc.
- Flow maldistribution
- Fin conduction

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HX Geometries
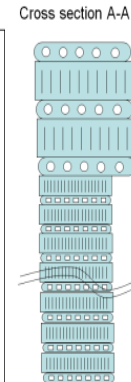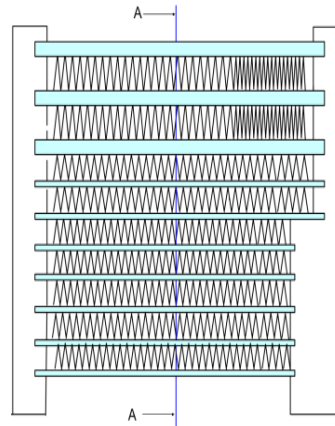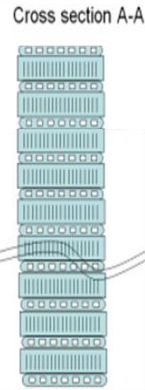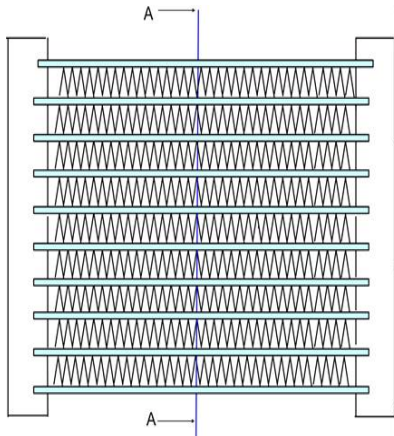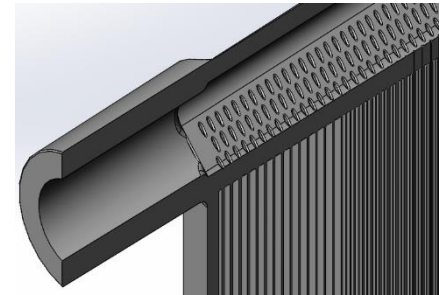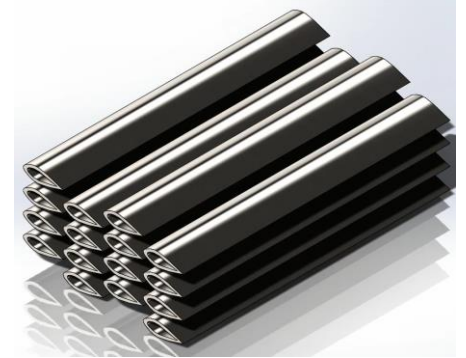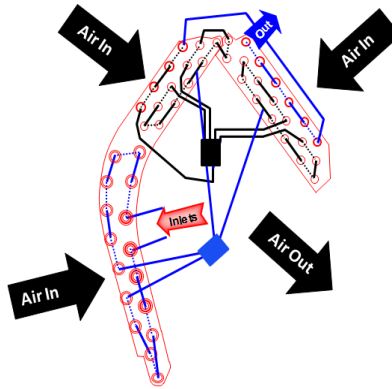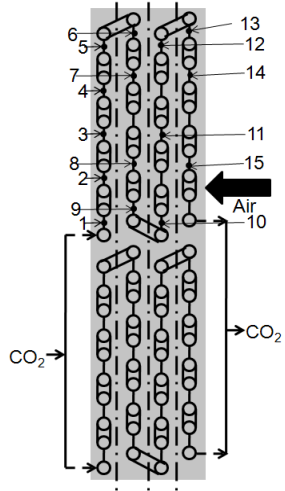
Additional Designs

CO$_2$ Inlet

Air Flow Direction

CO$_2$ Outlet
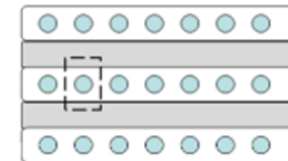
Control Volumes

MCHX, Al Tube 19 ports, Q: non-port vs. port discretization

Air-side Propagation

Air Side

Segment i

Segment j

Segment k
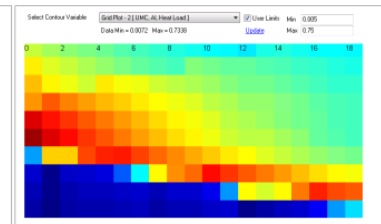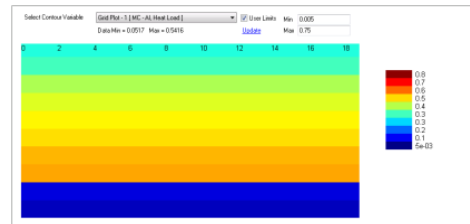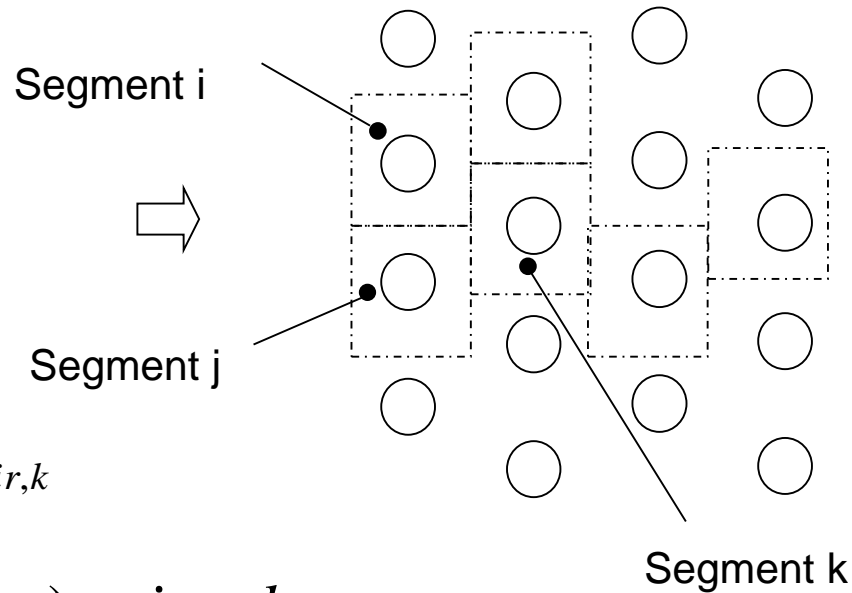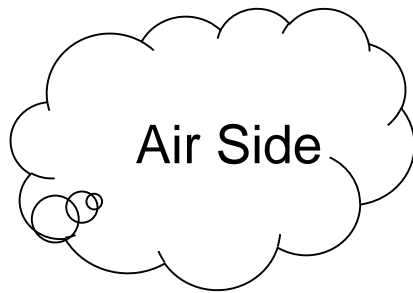
$$0.5(\dot{m}_{air,i} + \dot{m}_{air,j}) = \dot{m}_{air,k}$$

$$0.5(\dot{m}_{air,i} h_{air,i,out} + \dot{m}_{air,j} h_{air,j,out}) = \dot{m}_{air,k} h_{air,k,in}$$

$$0.5(\dot{m}_{air,i} w_{i,out} + \dot{m}_{air,j} w_{j,out}) = \dot{m}_{air,k} w_{k,in}$$

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Flow Path Representation

- Adjacency matrix/lists (based on Graph theory, by Euler, 1736)
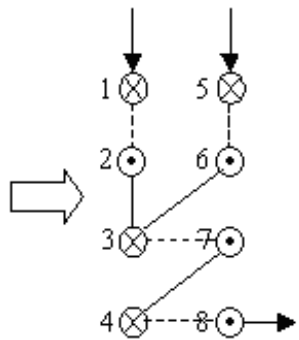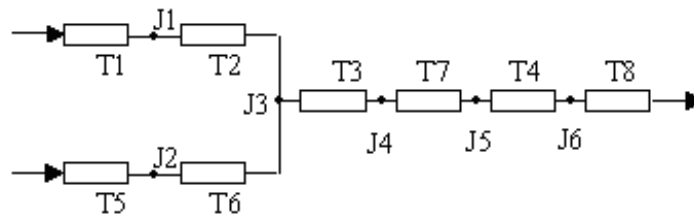
Coil End View   Electric Circuit Analogous Representation

[J1,T1] = -1
[J1,T2] = 1,....
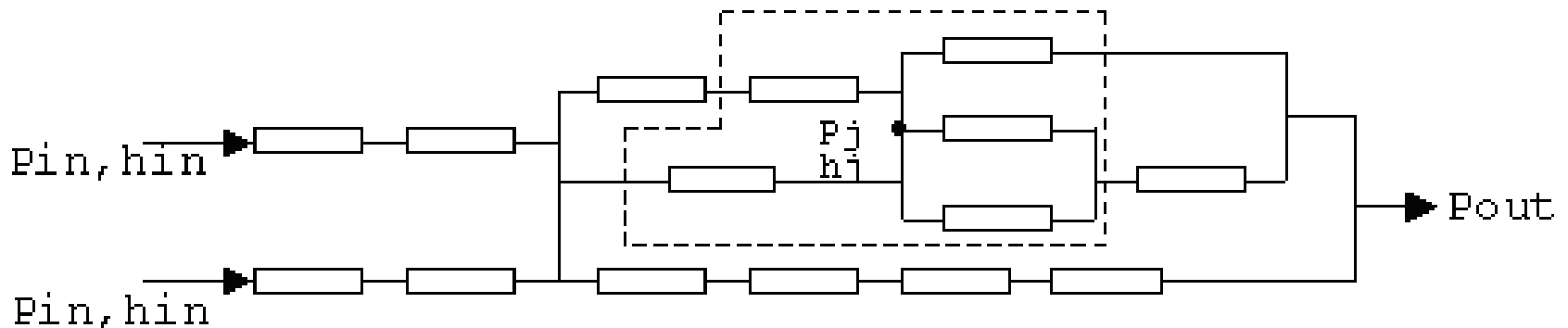
Thermophysical Properties

- Refrigerants
  - NIST REFPROP 9.1
  - Various accelerated versions
- Air-side
  - ASHRAE RP-1485, real gas model
  - ASHRAE Handbook 2013, ideal gas model
  - ASHRAE SPC213P (ideal gas model)

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Control Volumes

- Heat Transfer
  - Eps-NTU
  - UA-LMTD
  - Energy balance
- Pressure drop
  - Evaluate simultaneously
  - After heat transfer
- Thermophysical properties
  - Evaluate at inlet, or average

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Refrigerant-side Correlations

- Flow regime maps based correlations
  - Can have discontinuities

- Continuity between single phase and two-phase correlations, during phase transition

- Recommend to use correlations based on the following fluid classes
  - Ammonia
  - CO2
  - Water/steam
 - Hydrocarbons
  - Pure fluids
  - Blends

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Correlations

- No extrapolation!!!

- Sanity check
  - Check partial derivatives based on known physics
  - Piece-wise equations

- Consistency between forward and backward calculations

Air Flow Maldistribution

- Method-1: Input to model
  - Data obtained from lab or external simulations
- Method-2: Co-simulation
  - Couple HX model with CFD
  - Need to consider mass conservation
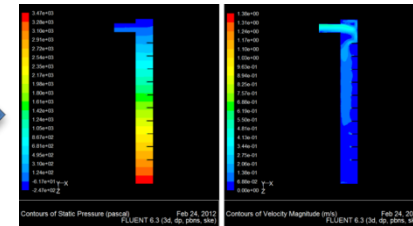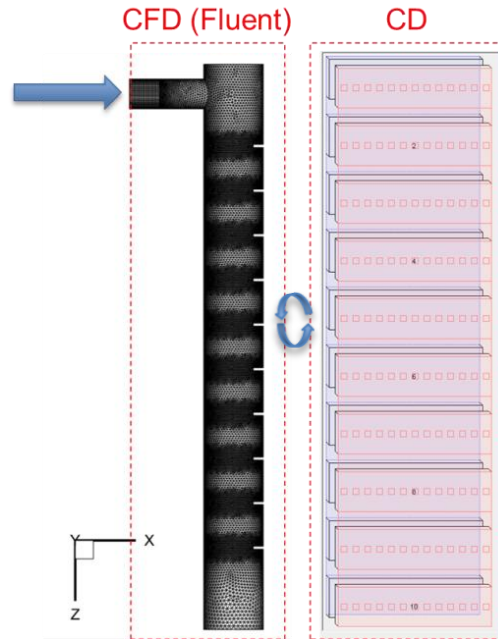
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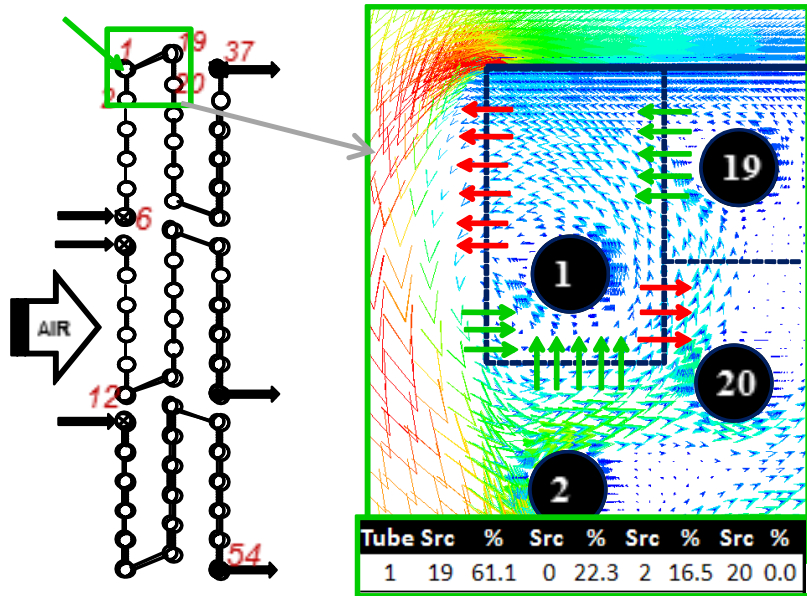# Refrigerant Flow Maldistribution

- Flow distribution in HX core is straightforward (assuming DP correlations work)

- Headers/manifolds are a challenge

Fan   Coil

PPCFD Analyses

Mesh   Temperature   Velocity

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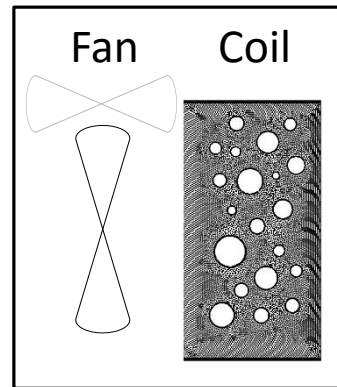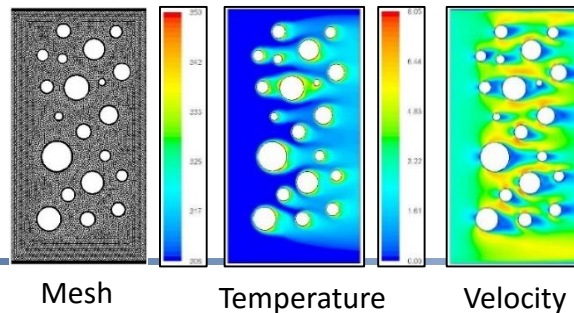
Co-Simulation

Outlook

- Heat Exchanger simulation tools have come a long way
- Leveraged capabilities
  - Co-simulation
  - Optimization
- More to be done
  - How to make HX more compact?
  - How to reduce the overall volume of the (HX + Fan)?
  - How to account for flow maldistribution?

Thank You