Analysis of a Parallel and Counterflow Concentric Heat Exchanger

MECH 257 Presentation

Presented by Andrew Lemus

Goal

Model and simulate a parallel and counterflow concentric heat exchanger.

Additionally:

1. Learn how to analyze a thermal+fluid model in COMSOL
2. Consider mesh sizes along with computation time
3. Compare the results of the two heat exchangers

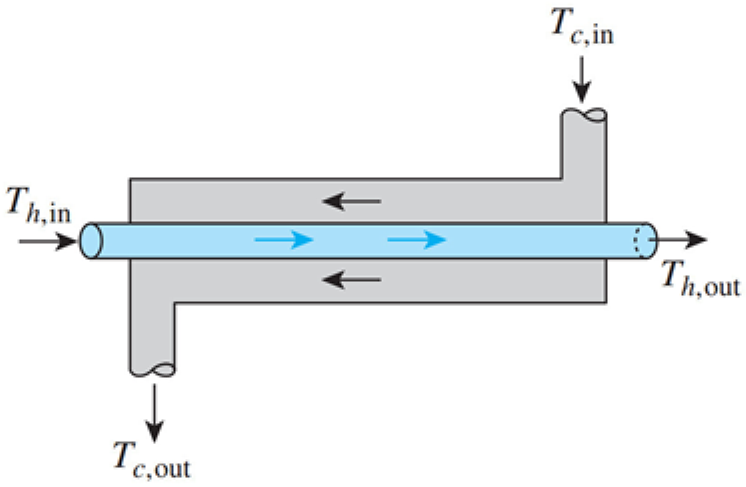
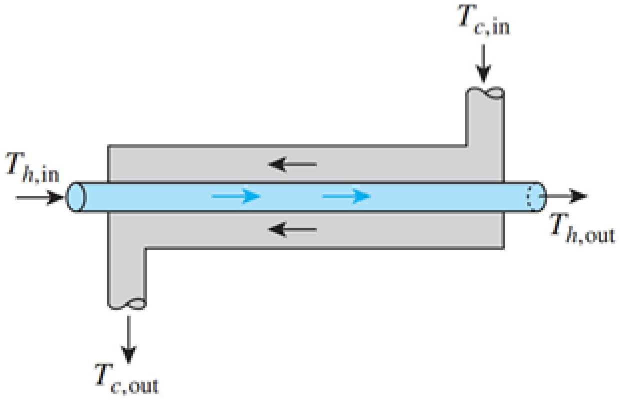


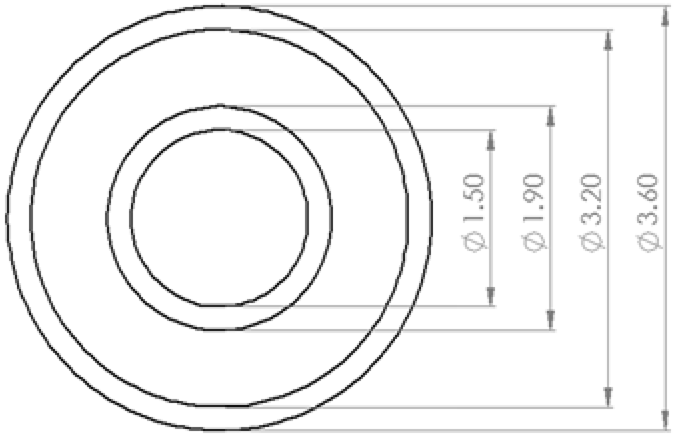
Image from https://www.thomasnet.com/articles/process-equipment/double-pipe-heat-exchangers/

Parameters

- Length, L = 10 meters
- Hot and cold flow, U = 1 m/s
- Hot water input, $T_{h,in}$ = 100C
- Cold water input, $T_{c,in}$ = 20C
- The shell thickness does not matter for this simulation
  - Convection can be applied to outside if desired

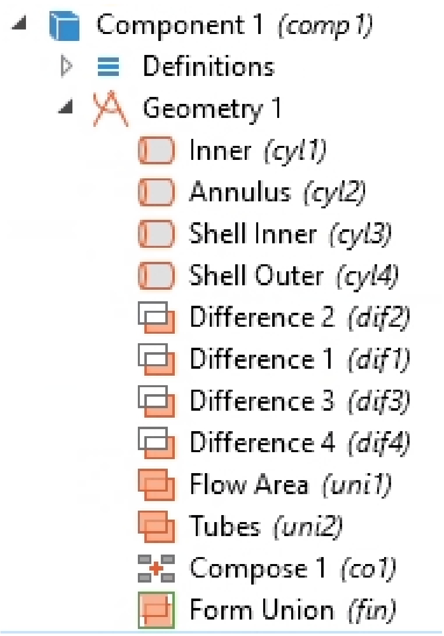
Name	Expression	Value	Description
Di	1.5[cm]	0.015 m	
Da	1.9[cm]	0.019 m	
Dshell_i	3.2[cm]	0.032 m	
Dshell_o	3.6[cm]	0.036 m	
L	10[m]	10 m	
Ucold_in	1[m/s]	1 m/s	
Uhot_in	1[m/s]	1 m/s	
Thot_in	100[degC]	373.15 K	
Tcold_in	20[degC]	293.15 K	

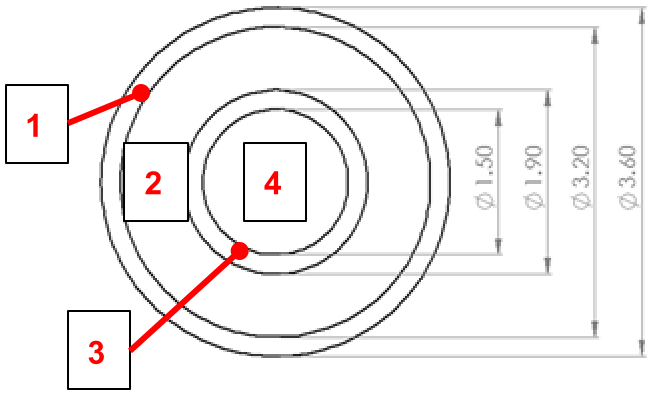


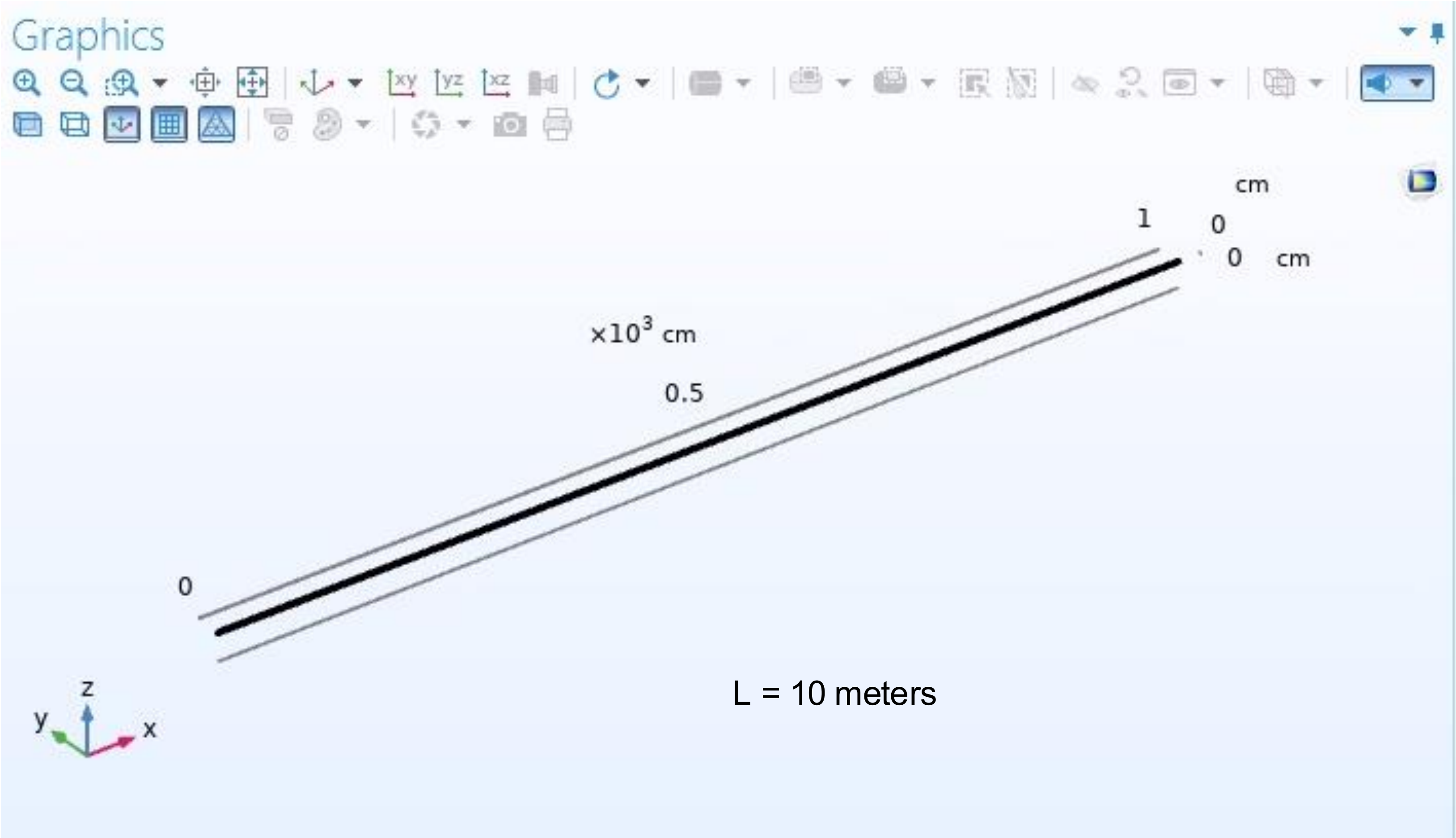


Geometries

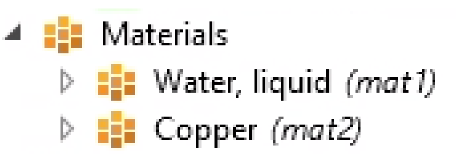
- **Made four cylinders according to diameter parameters**
    - Inner, annulus, shell inner, shell outer
- **Need to separate tube walls and the regions within tubes**
    - Four distinct selections
- **Difference (x4)**
    - Select cylinder you want
    - Select every other cylinder that is not part of that region

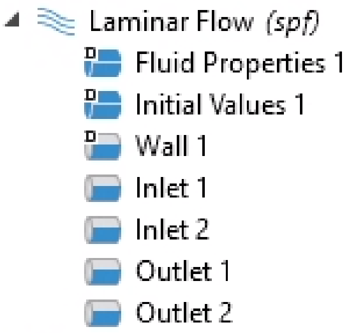





Graphics
cm
1
0
0
cm
×10³ cm
0.5
0
L = 10 meters
z
y
x

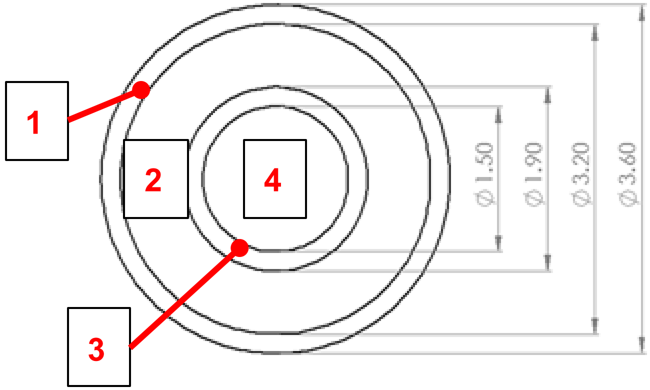
Materials





- **Water**
  - Regions 2 and 4
- **Copper**
  - Regions 1 and 3 (tube walls)

Laminar Flow



- **Set as wall**
  - Region 1 and 3 (tube walls)
- **Inlet and outlet depending on flow configuration**
  - Region 2 and 4 (repeat for both sides!)

Heat Transfer in Fluids

- **Set the temperature at both inlets**
  - Parallel flow and counterflow only change which sides the inputs and outputs are on
- **Inflow and outflow**
  - One on each side
- **Hot water input, $T_{h,in}$ = 100C**
- **Cold water input, $T_{c,in}$ = 20C**

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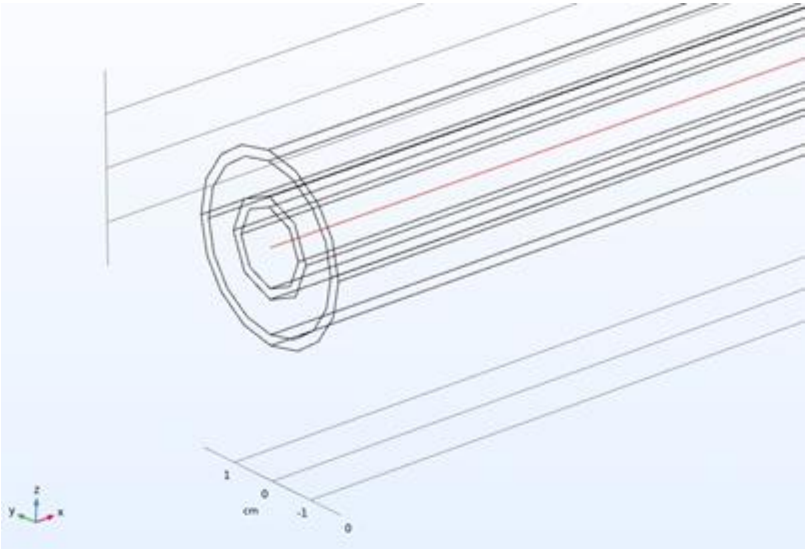
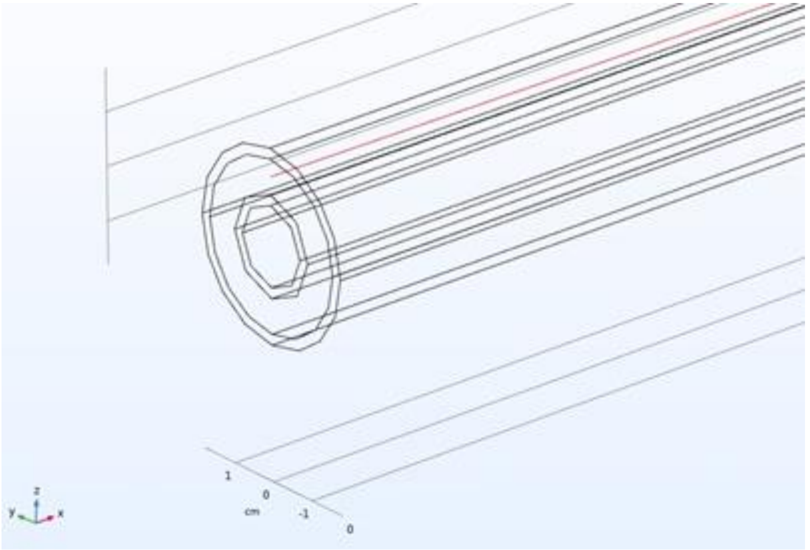
Heat Transfer in Fluids *(ht)*
- Fluid 1
- Initial Values 1
- Thermal Insulation 1
- Solid 1
- Inflow 1
- Inflow 2
- Outflow 1
- Outflow 2

Two Cut Lines



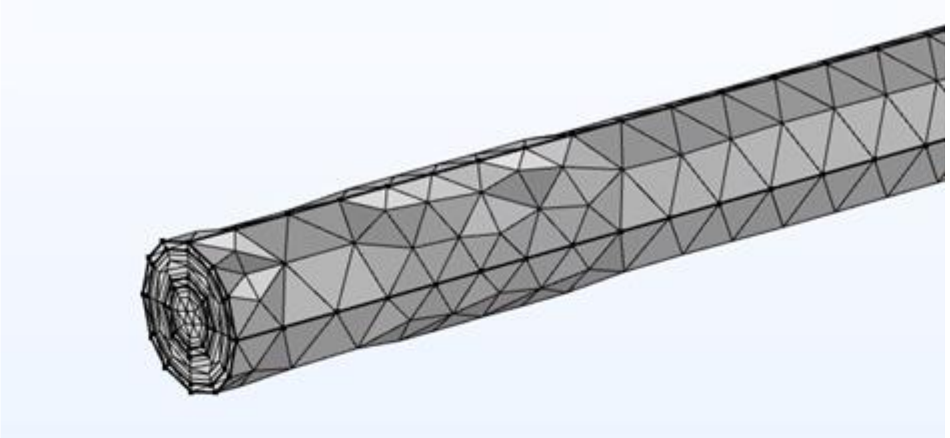
Hot water cut line



Cold water cut line

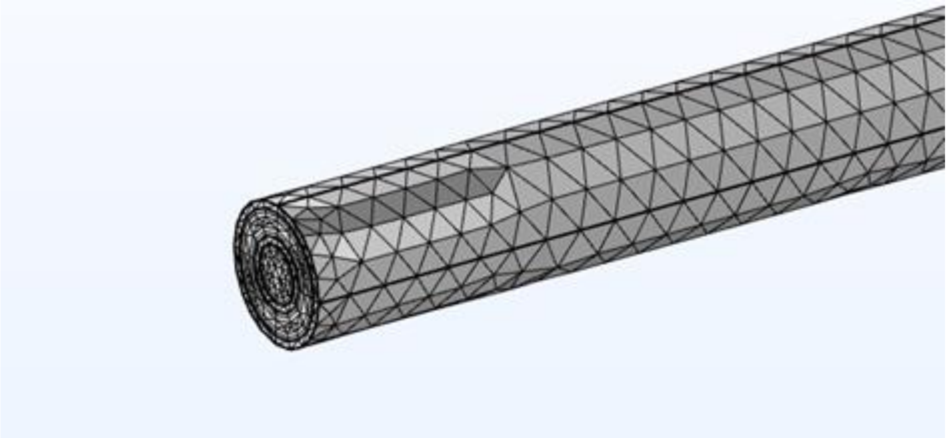
Extra Coarse Mesh

- **754,678 degrees of freedom solved for**
  - Plus 136,936 internal DOFs
- **Computation time**
  - Parallel: 10 minutes, 44 seconds
  - Counterflow: 16 minutes, 15 seconds

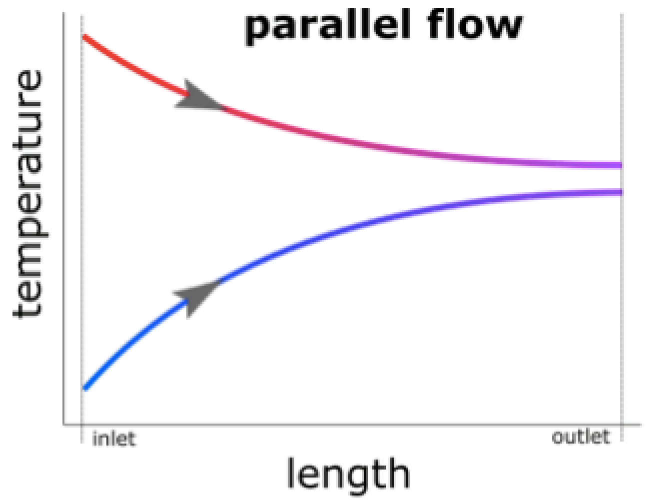


Normal Mesh

- **2,096,525 degrees of freedom solved for**
  - Plus 299,186 internal DOFs
- **Computation time**
  - Parallel: 54% after 1 hour
  - Counterflow: 41% after 1 hour



Expected Results



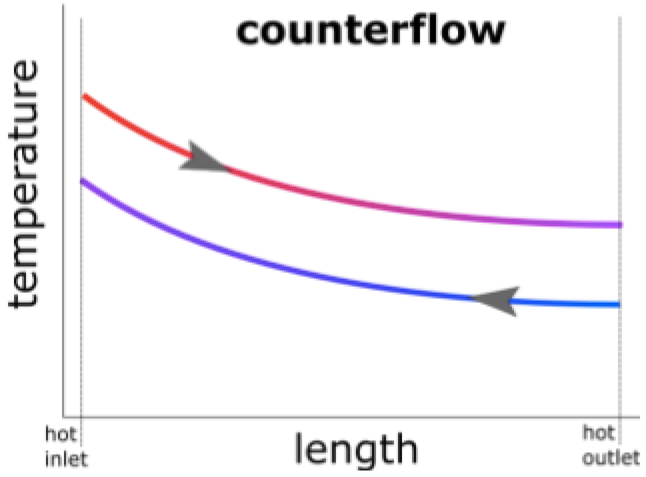
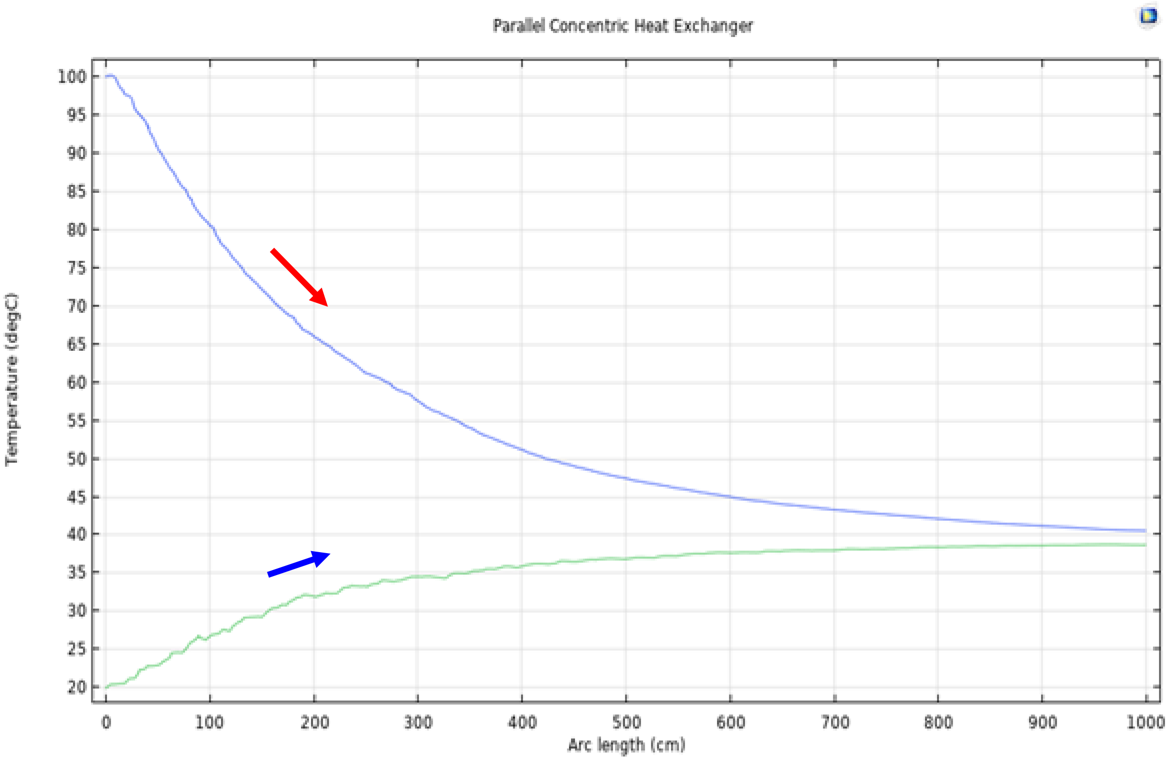


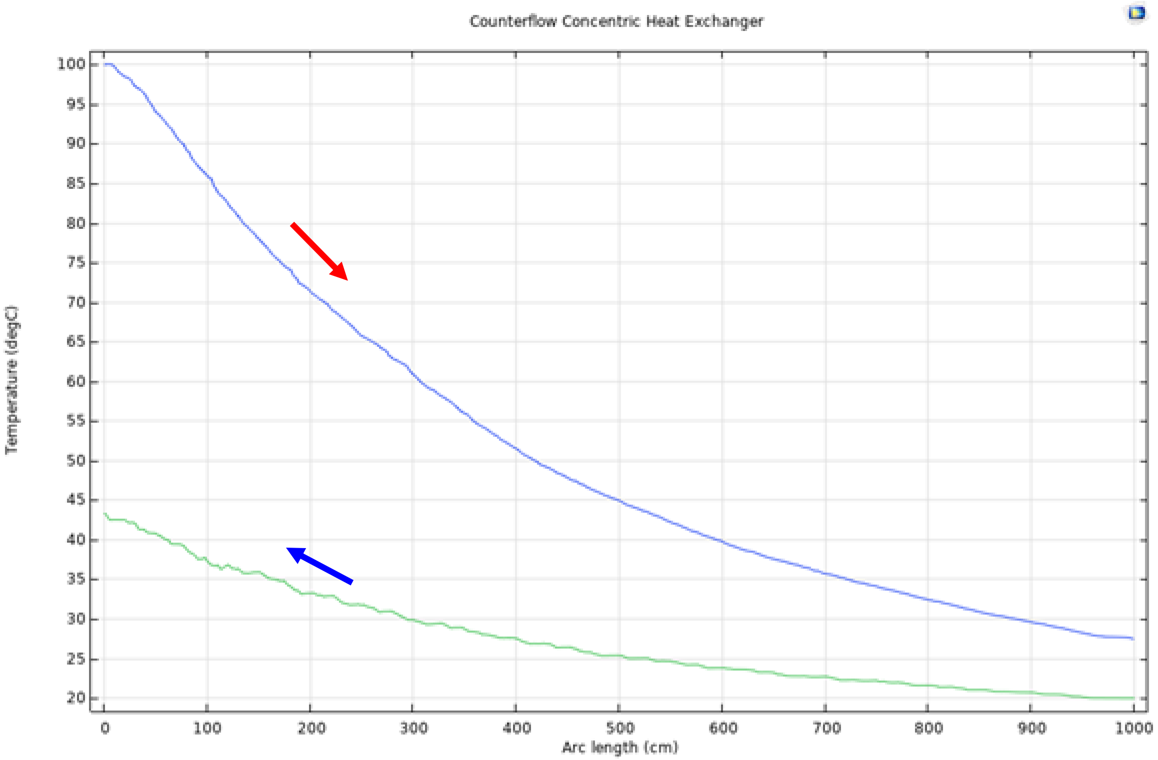
Image from https://www.wattco.com/2021/06/heat-exchanger-configurations/

Extra Coarse Mesh

Parallel



Counterflow



Parallel

- Hot water input, $T_{h,in}$ = 100C
- Hot water output, $T_{h,out}$ = 41C
- Cold water input, $T_{c,in}$ = 20C
- Cold water output, $T_{c,out}$ = 38C

ΔT_h= 59C
ΔT_c= 18C

Counterflow

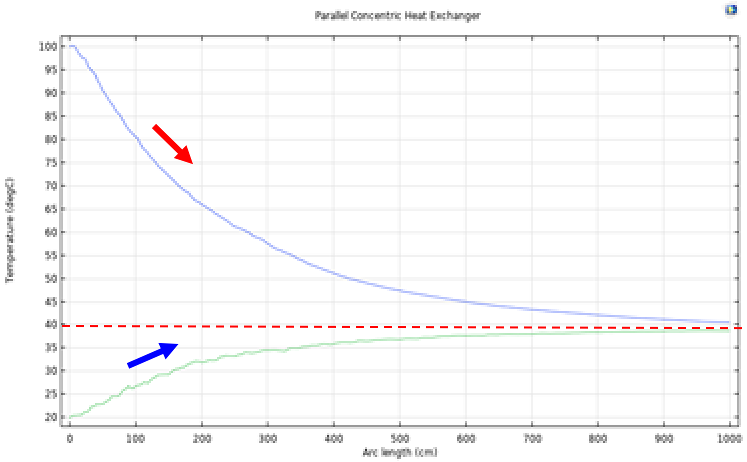
- Hot water input, $T_{h,in}$ = 100C
- Hot water output, $T_{h,out}$ = 27C
- Cold water input, $T_{c,in}$ = 20C
- Cold water output, $T_{c,out}$ = 44C

ΔT_h= 73C
ΔT_c= 24C

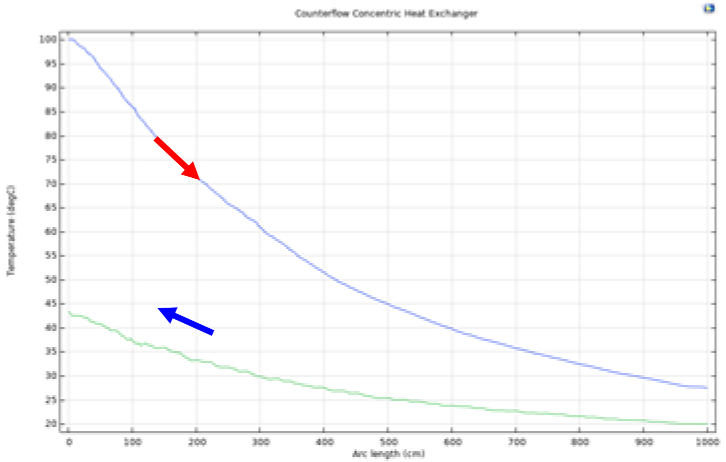
Results

- **The counterflow heat exchanger led to a greater change in temperature**
- **For parallel flow**
  - The exit temperature of the cold water did not exceed the exit temperature of the hot water
- **For counter flow**
  - The hot water got to 27C, close to the cold input
- **Having a finer mesh was not worth the computation time**
  - The extra coarse mesh gives a decent solution

Parallel



Counterflow



One-Way Coupling Approach

- **A way to save computation time and resources**
- **For nonisothermal flow**
  - Compute the flow field first
    - Use it as an input for the heat transfer problem
- **Other possible multiphysics cases**
  - Turbulent regimes and flow in porous media
  - Advected field (if the coupling is weak)
  - Coupling between heat transfer and structural mechanics leading to thermal expansion

Ref: https://www.comsol.com/blogs/how-to-save-computational-time-with-a-one-way-coupling-approach/