WEI HAO WANG
ABB
MECHANICAL INTERNSHIP
WORK EXAMPLES

Self-Introduction

- Case Western Reserve University, Cleveland, Ohio
- Master of Science in Mechanical Engineering
- Research Experience: Loop Heat Pipe, Detonation Modeling

Projects

1. Testing for Liquid Cooling of Motors with Expanded Tube
2. Thermal simulation for E-Drive with ANSYS FLUENT

Testing for Liquid Cooling of Motors

Motivation :

- Improve the power density by utilizing lamination corner vents

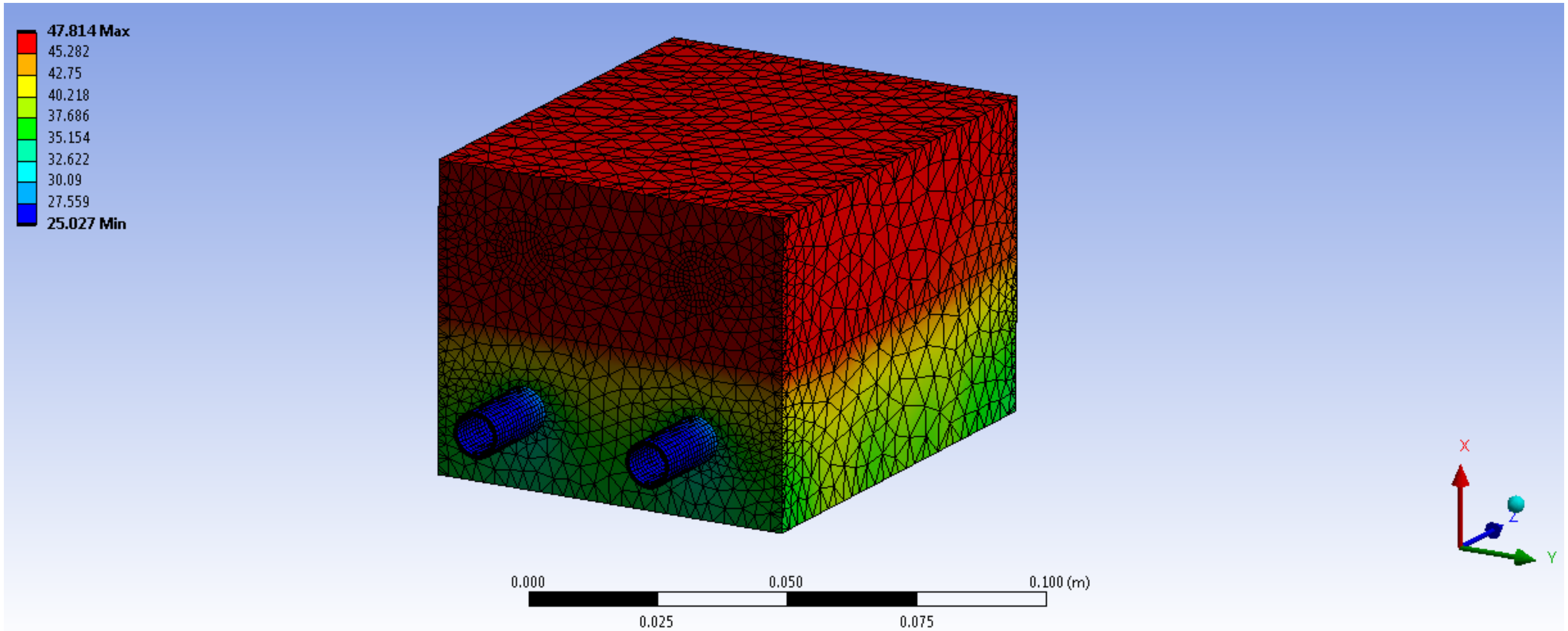
Application :

- To increase cooling capacity for competitive product

Approach :

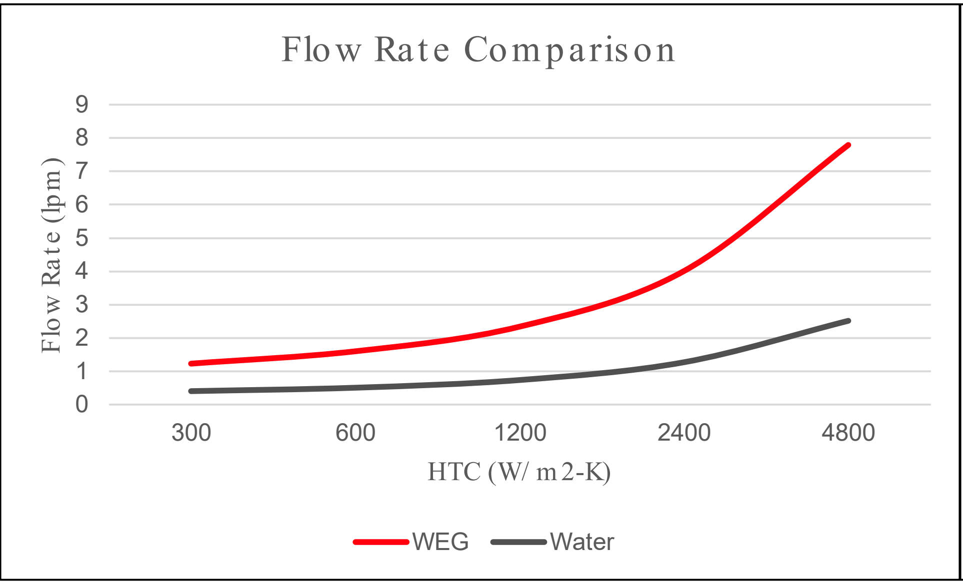
- To study the reduction of thermal contact conductance
- Perform testing of liquid cooling for expanded and unexpanded copper tube
- Test repeatability with another set of expanded copper tube

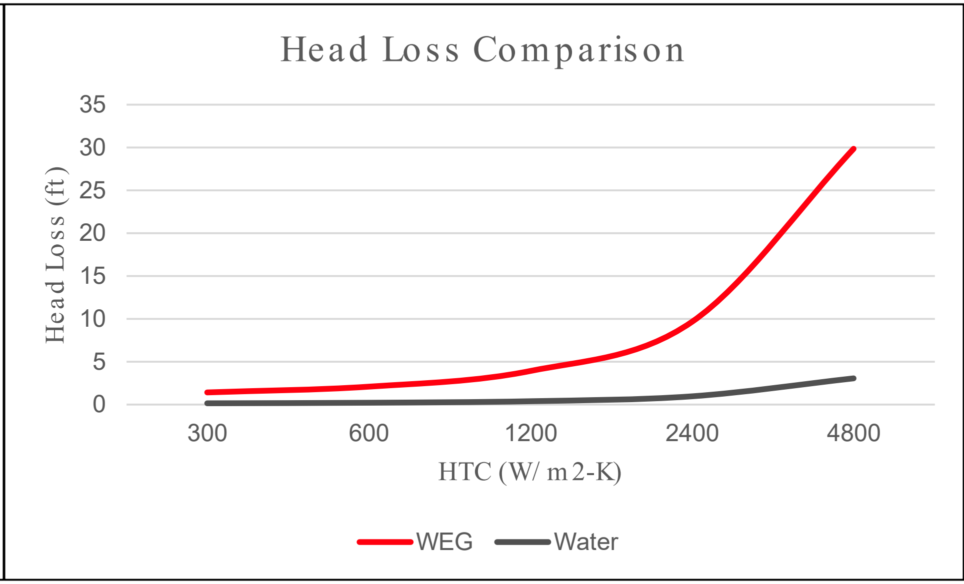
1-D Calculation vs. FEA



	1-D Calculation	FEA
HTC (W/ m^2-K)	4456	4456
Fluid Temperature (C)	25	25
Contact Conductance(W/ m^2-K)	5000	5000
Heating Block Temperature (C)	50	47.814

Working Fluid Selection – Water vs. Water Ethylene Glycol

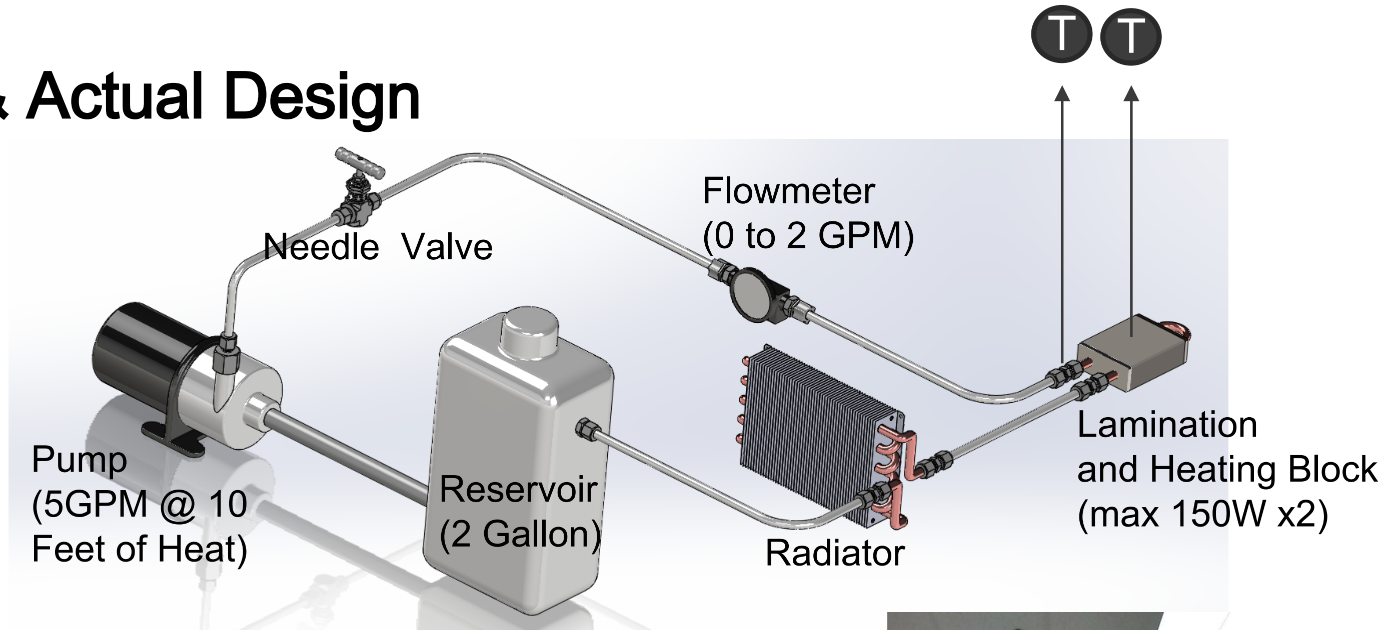


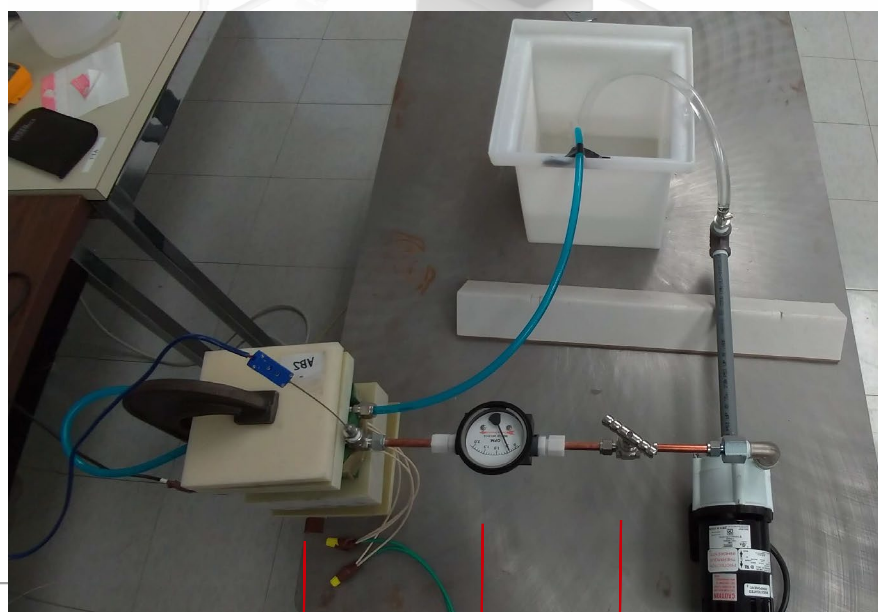


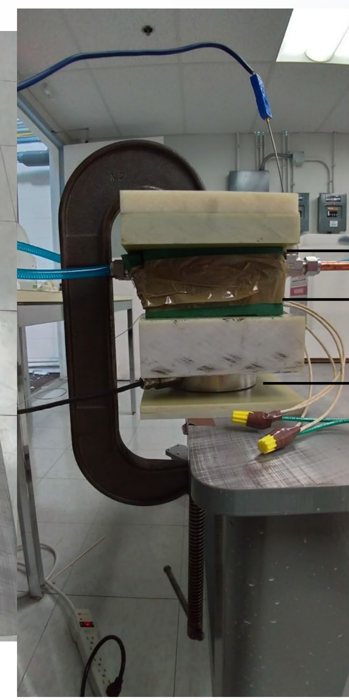
Advantage of choosing water :

- Lower pressure drop and flow rate
- Convenient for testing leakage
- Accessibility

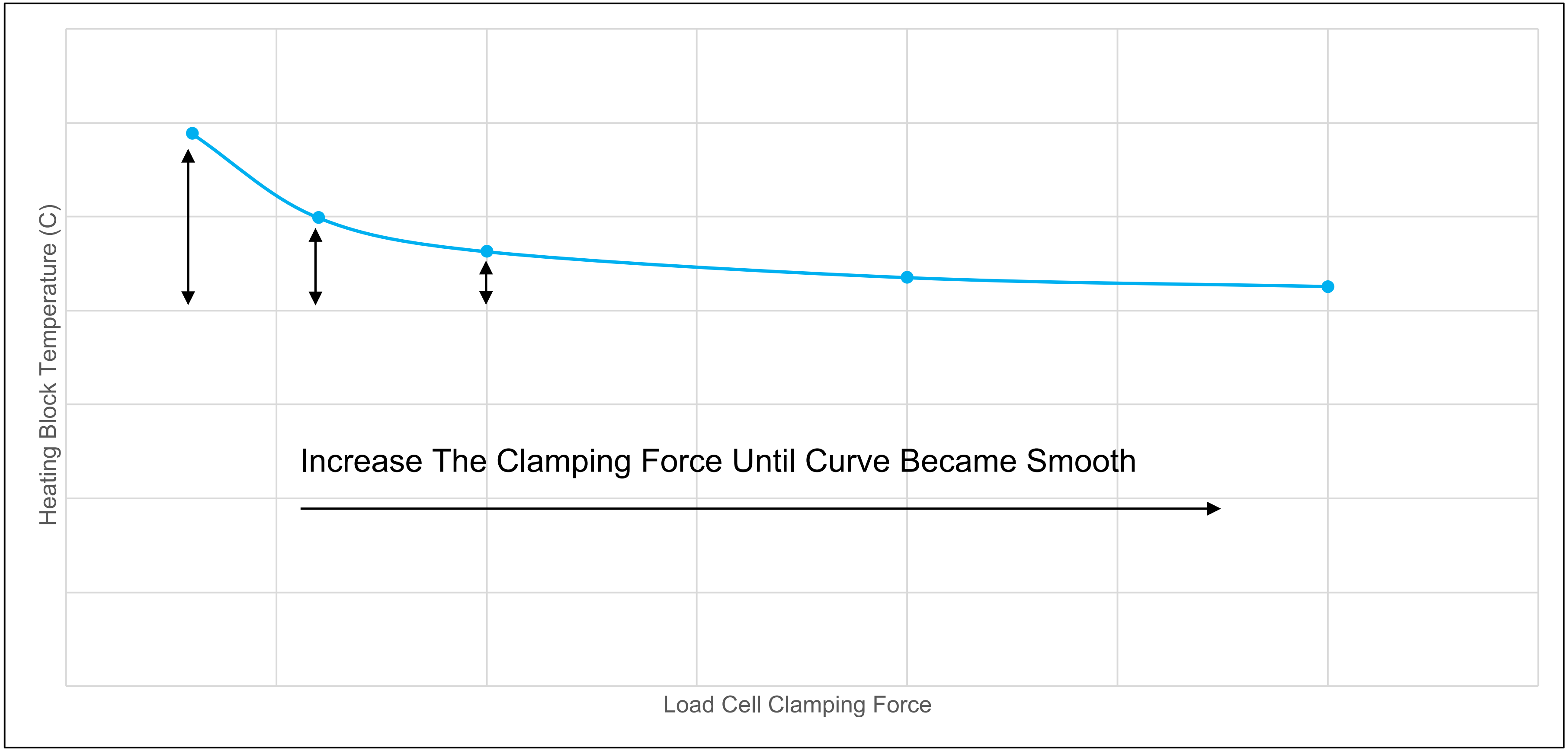
Original & Actual Design







Determine the Clamping Force

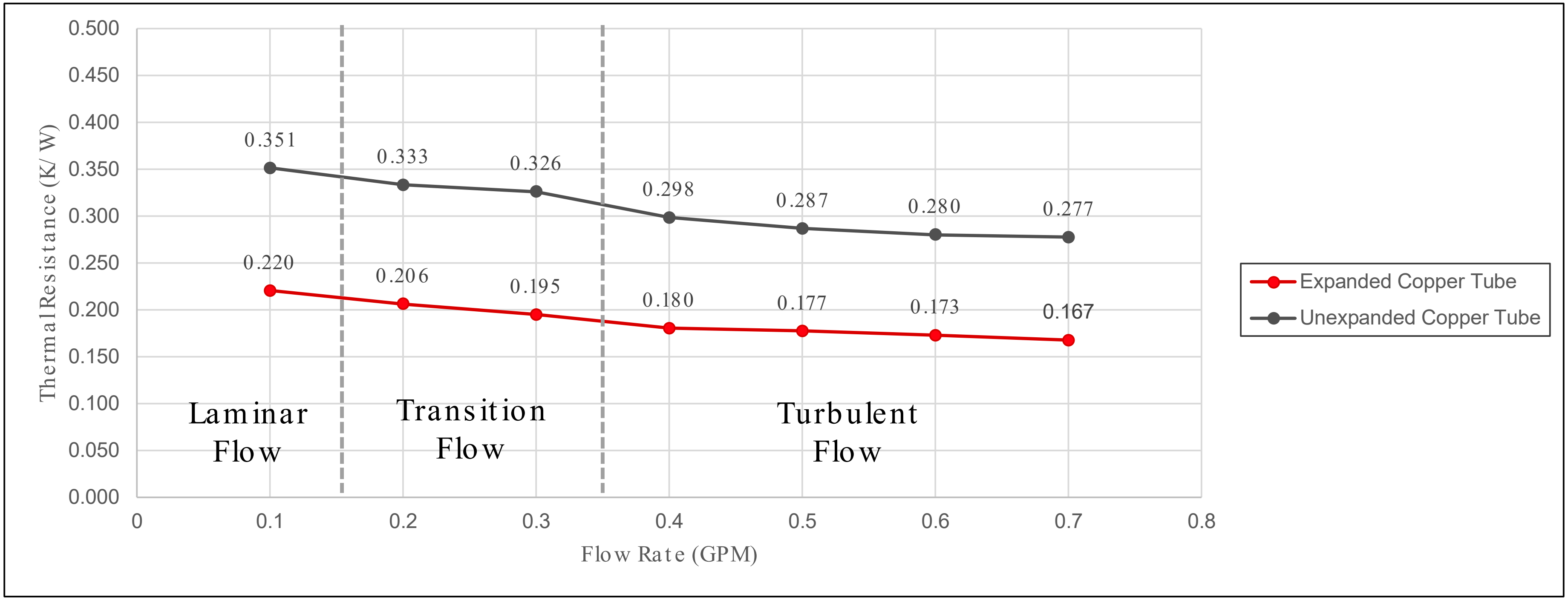


mV	lb f	KN
2.3	2875	12.78863

Testing System Parameters

Testing System Parameters and Settings			
Working Fluid	Water	Power Supply Voltage (V)	60
Total Pipe Length (ft)	10	Power Supply Current (A)	1.3
Ambient Temperature (C)	21	Heat Load (W)	78
Lamination		**Copper Pipe in Lamination**	
Length (in)	4.125	Length (in)	10.7
Width (in)	3	Inner Diameter (in)	0.3125
Height (in)	1.25	Outer Diameter (in)	0.375
Reservoir		**Pump**	
Volume (Gallon)	2	Flow rate (GPM)	0 ~ 0.7
Heating Cylinder			
Heating Cylinder #	2	Parallel/Series	Parallel
Current (A)	1.3	Voltage (V)	120

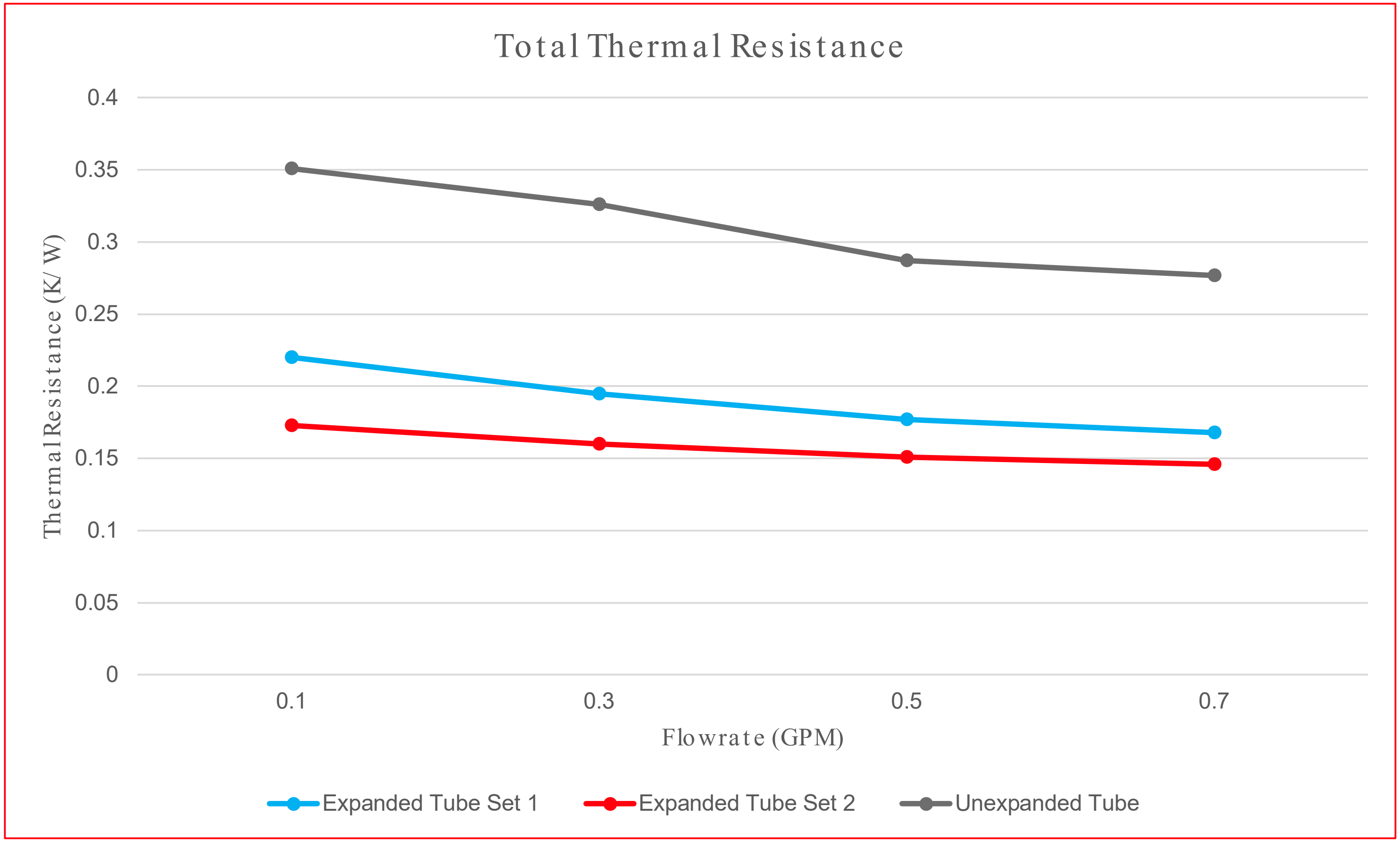
Expanded Copper Tube vs. Unexpanded Copper Tube



Estimate of Contact Conductance (W/ m^2-K) of Unexpanded Copper Tube	
Expanded Copper Tube	Unexpanded Copper Tube
2000 - 8000	750 - 1050

$$\Delta R = \frac{1}{h_1 A} - \frac{1}{h_2 A}$$

Test Repeatability



Air Cooling vs. Water Cooling

Expanded Copper Tube Air Cooling	
Air Speed (m/s)	0.700
Total Thermal Resistance(K/W)	0.793

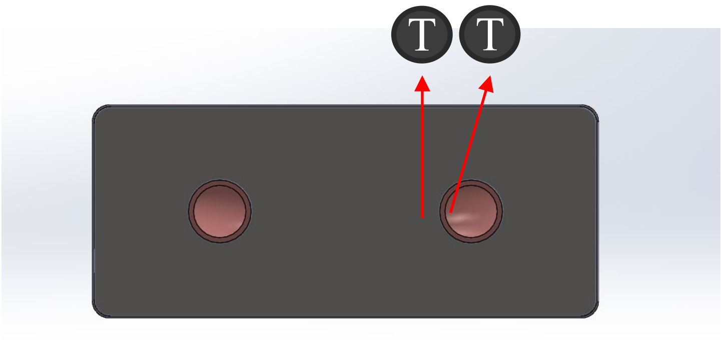
Expanded Copper Tube Water Cooling							
Flow Rate (GPM)	0.700	0.600	0.500	0.400	0.300	0.200	0.100
Total Thermal Resistance(K/W)	0.168	0.173	0.177	0.180	0.195	0.206	0.220

$$R = \frac{\Delta T}{Q} = \frac{1}{hA}$$

Future Work : Verify Thermal Contact Conductance

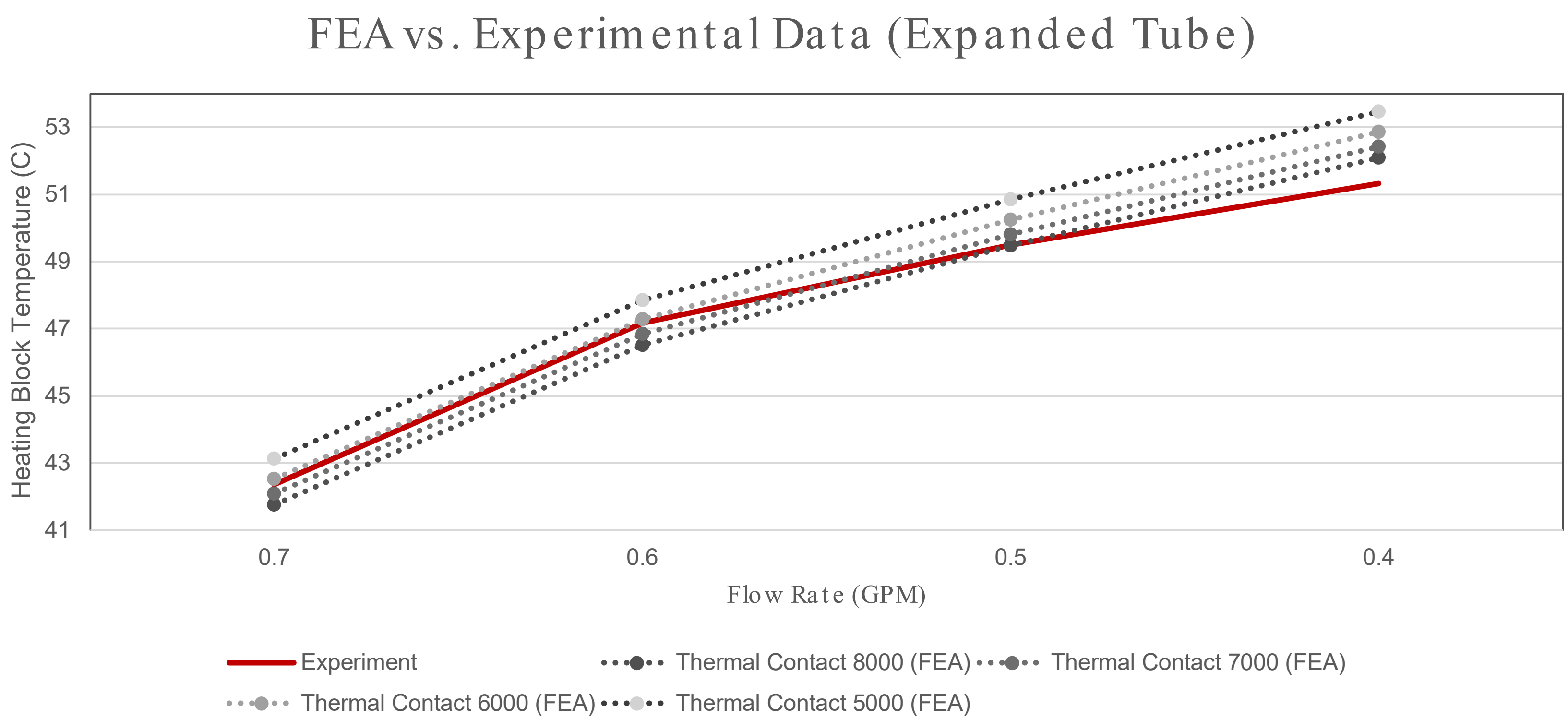
- Apply the heat load and measure the temperature difference between hole and pipe inner surface

$$R = \frac{\Delta T}{Q} = \frac{1}{hA} \qquad h = \frac{Q}{A * \Delta T}$$



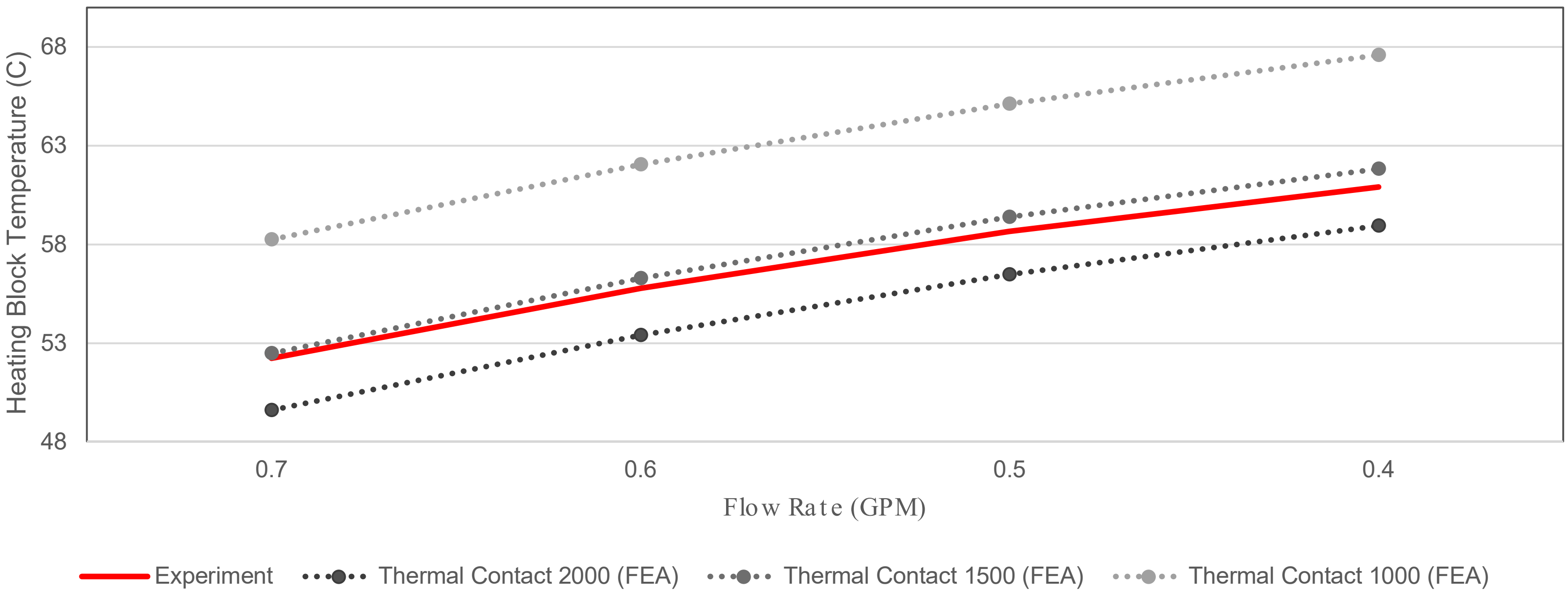
- Check the difference between simulation and experiments
- If they are close to each other, we could

  1. Extrapolate the flow rate where we didn't conduct testing
  2. Extrapolate the simulation to different working fluid
  (i.e. 50/50 Water Ethylene Glycol)



GPM (Expanded Tube Case)	0.7	0.6	0.5	0.4
Theoretic HTC	4711	4062	3391	2689
Fluid Inlet Temperature	29.05	33.3	35.55	37.05

FEA vs. Experimental Data (Unexpanded Tube)



GPM (Unexpanded Tube Case)	0.7	0.6	0.5	0.4
Theoretic HTC	4711	4062	3391	2689
Fluid Inlet Temperature	30.22	33.53	35.9	37.25

Thermal simulation for E -Drive with ANSYS FLUENT

Motivation :

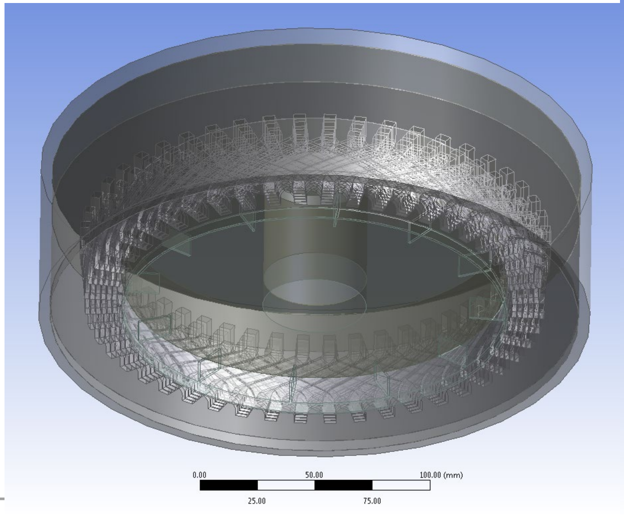
- To understand hairpin winding thermal behavior at end region

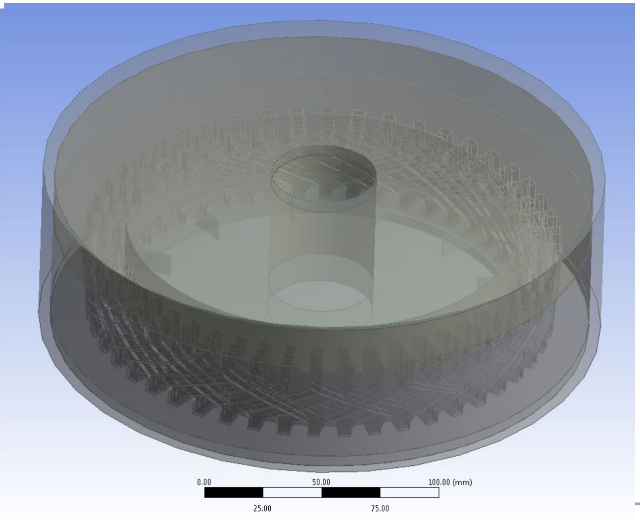
Application :

- To provide the first cut HTC estimation for early design

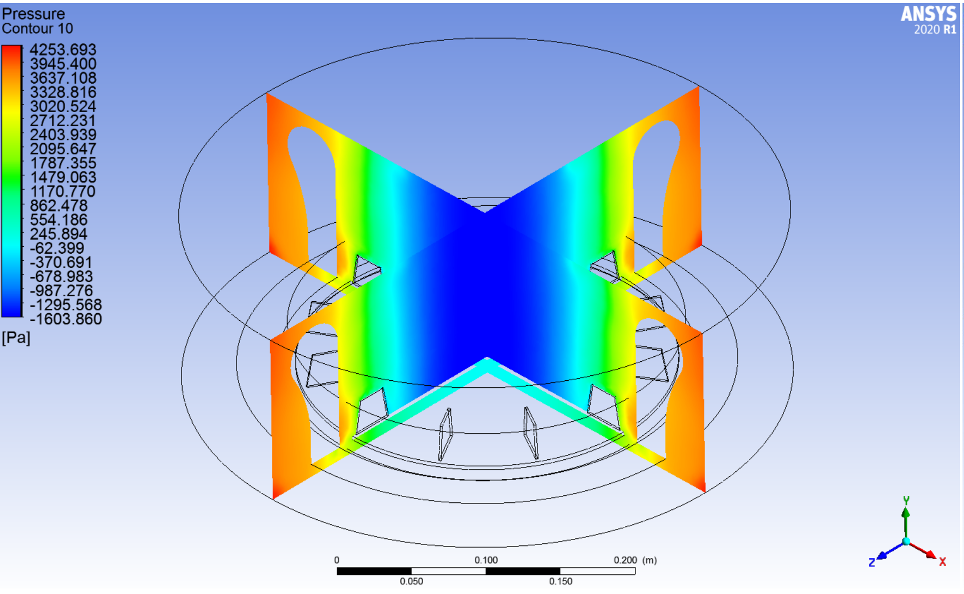
Approach :

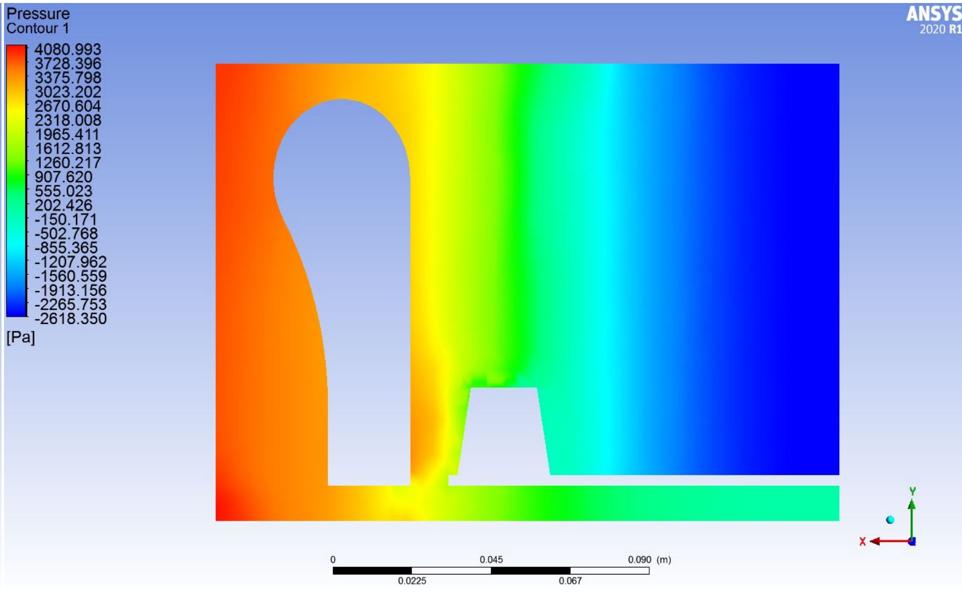
- Investigate winding HTC and frame inner HTC through ANSYS FLUENT
- Save computational effort using Periodic Boundary Condition method

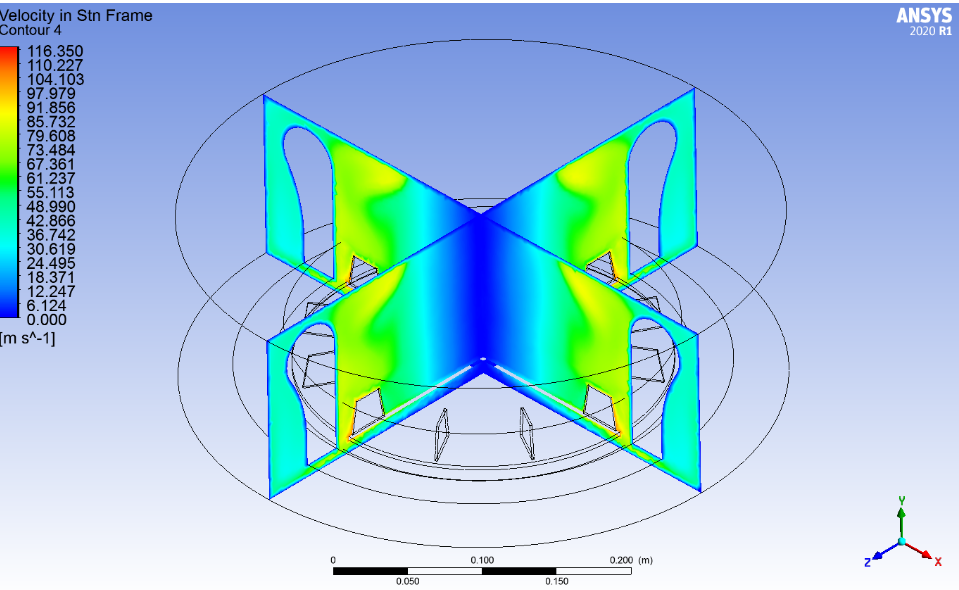


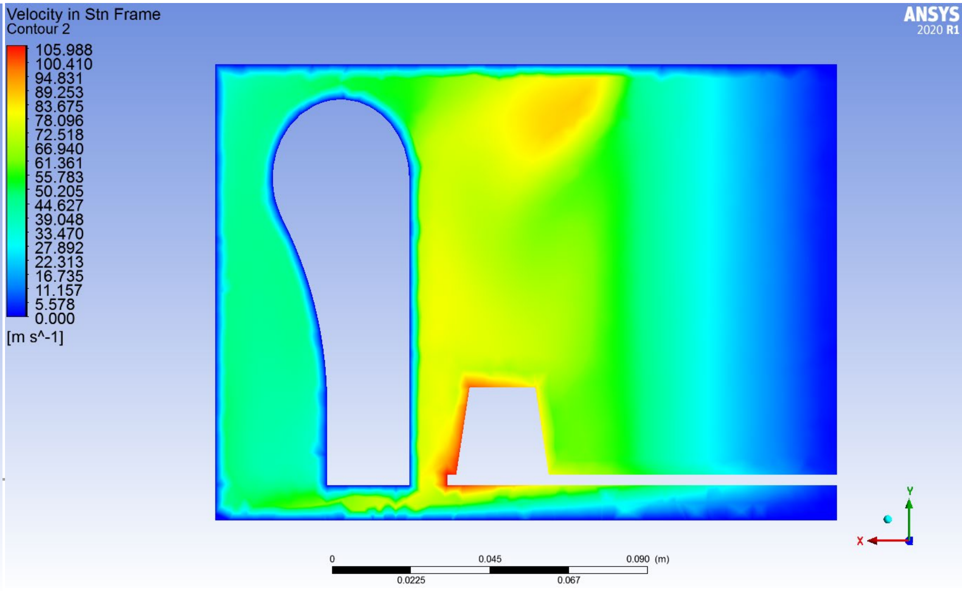


Donut -Like Winding

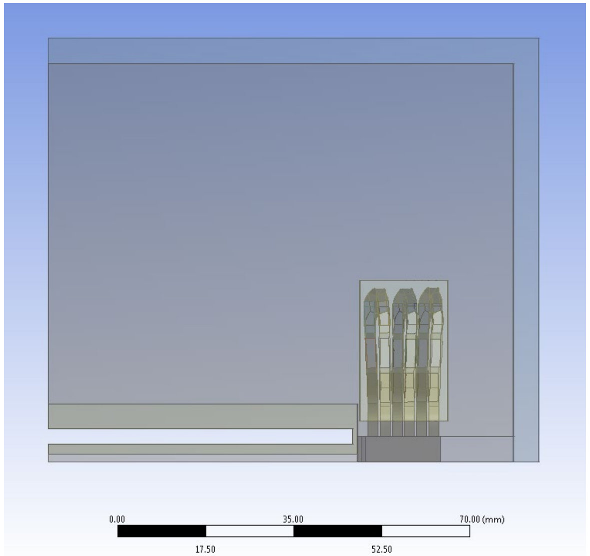


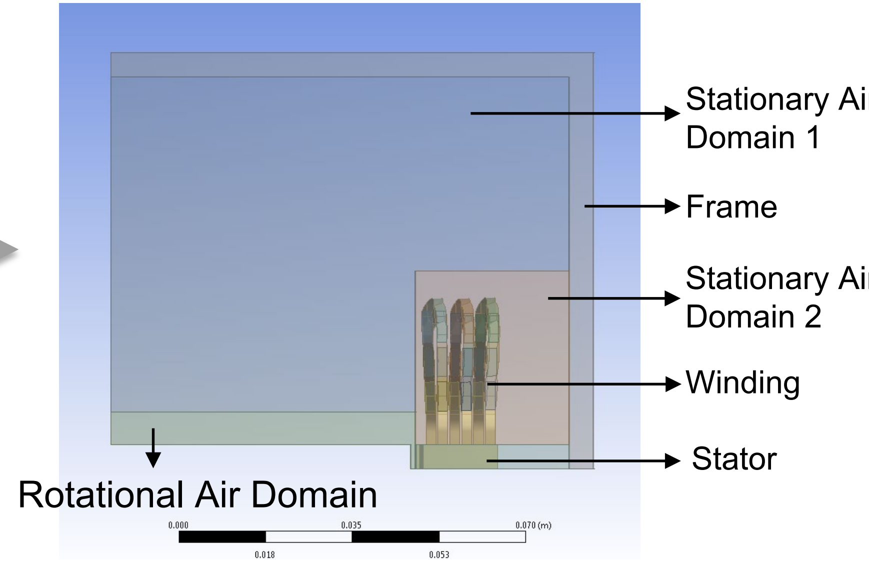


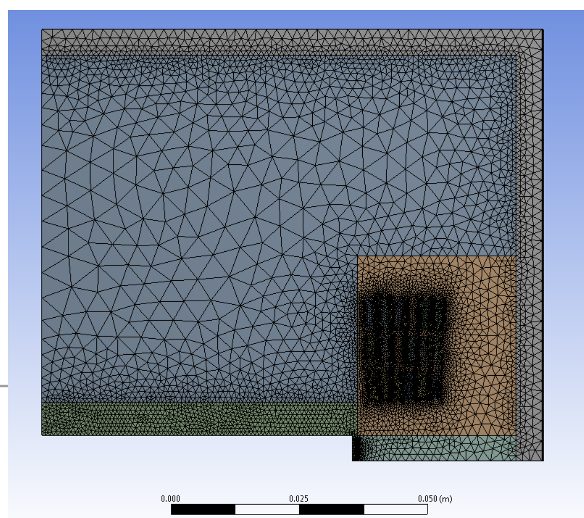


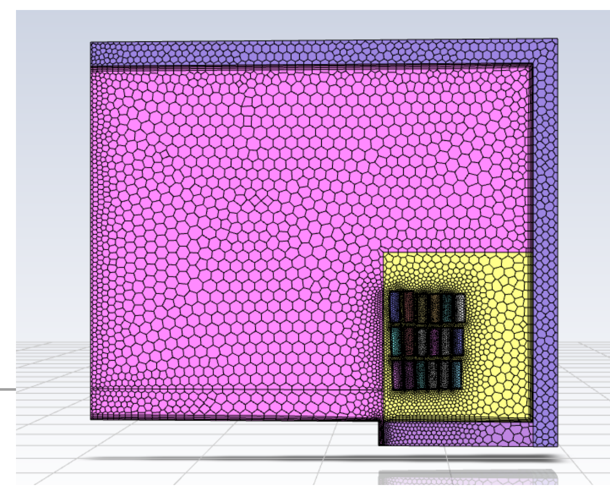


Geometry Improvement and Meshing Improvement

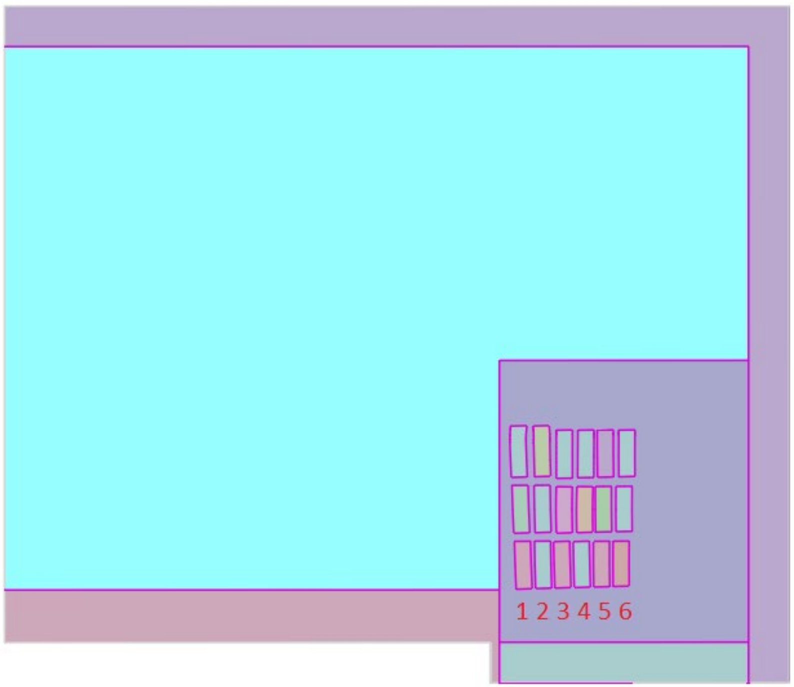








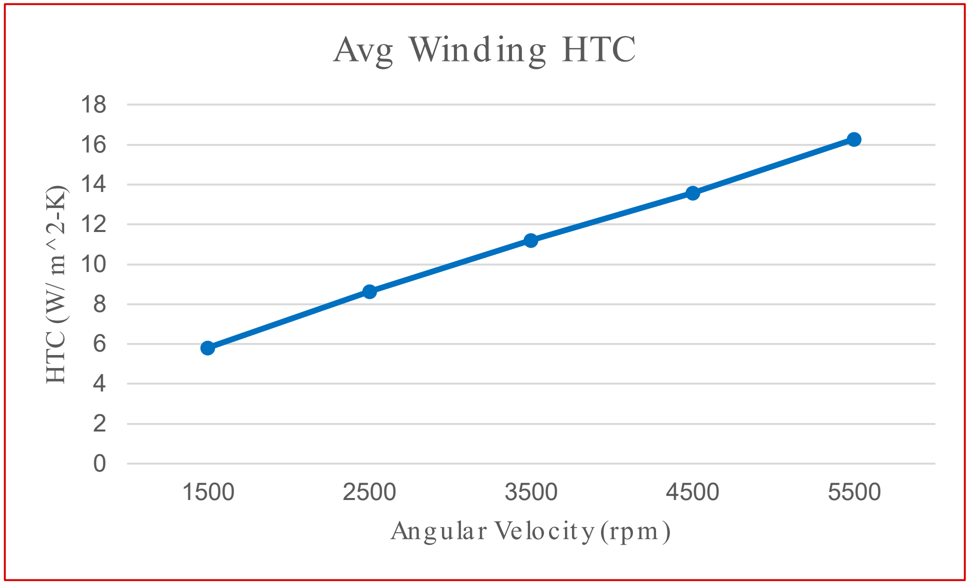
Original Model vs. Meshing & Geometry Improvement



	Original	New
Time (s)	11400	445
Iteration	600	200
1st Layer HTC	44.94	44.87
2nd Layer HTC	11.19	13.41
3rd Layer HTC	6.14	7.9
4th Layer HTC	1.73	2.01
5th Layer HTC	4.4	4.58
6th Layer HTC	6.31	4.98
Avg Winding HTC	**13.06**	**13.58**

HTC at Different Angular Velocity

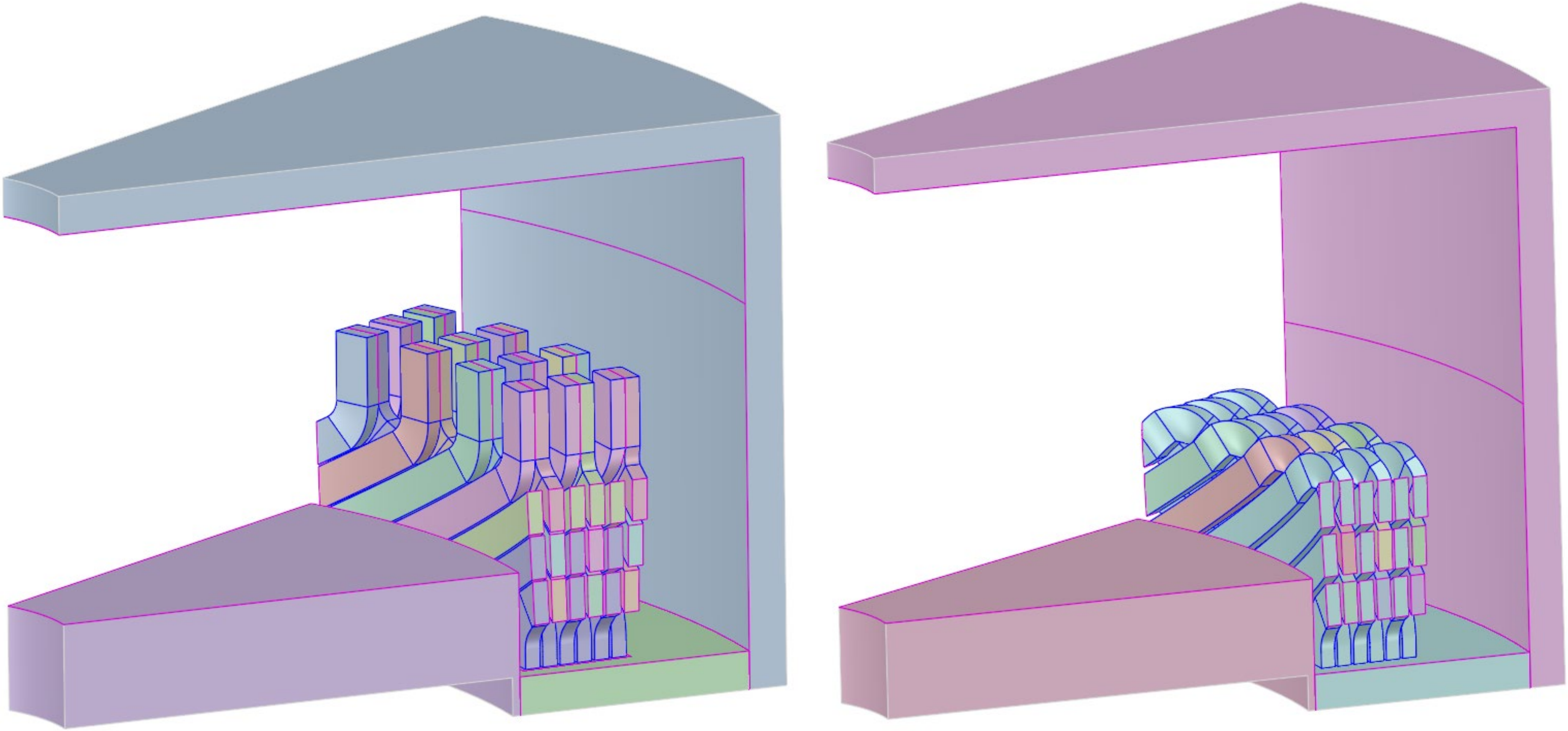
Simulation Results of 1/48 slice PBC without Wafter Blade					
Angular Velocity (rpm)	1500	2500	3500	4500	5500
1st Layer HTC	20.15	28.95	37.25	44.87	53.41
2nd Layer HTC	4.10	7.18	10.38	13.41	18.13
3rd Layer HTC	3.14	4.81	6.46	7.9	10.30
4th Layer HTC	1.27	1.61	1.92	2.01	2.01
5th Layer HTC	2.10	3.20	3.95	4.58	4.87
6th Layer HTC	2.13	3.47	4.24	4.98	4.79
Avg Winding HTC	**5.80**	**8.63**	**11.22**	**13.58**	**16.29**



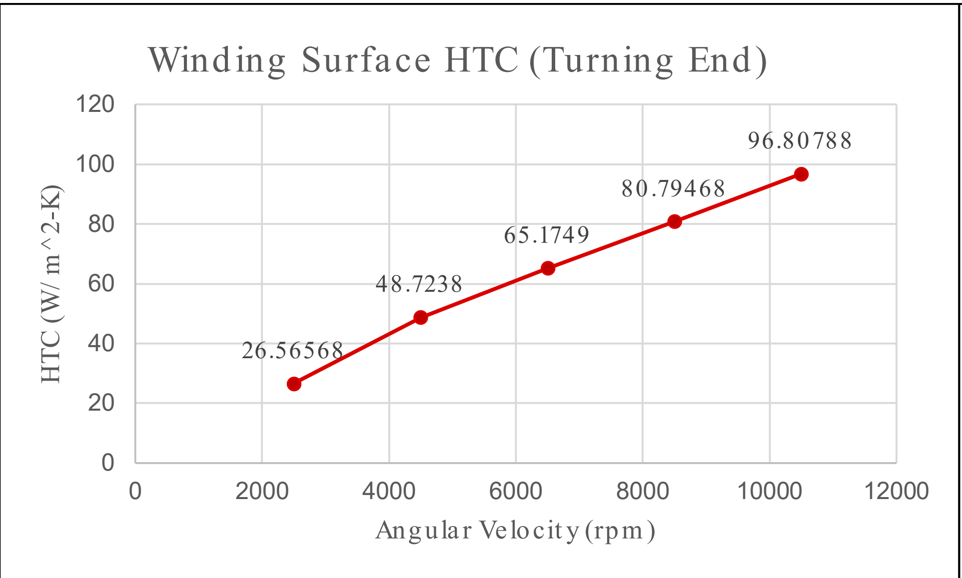
Constant Heat Gen vs. Constant Winding Temperature

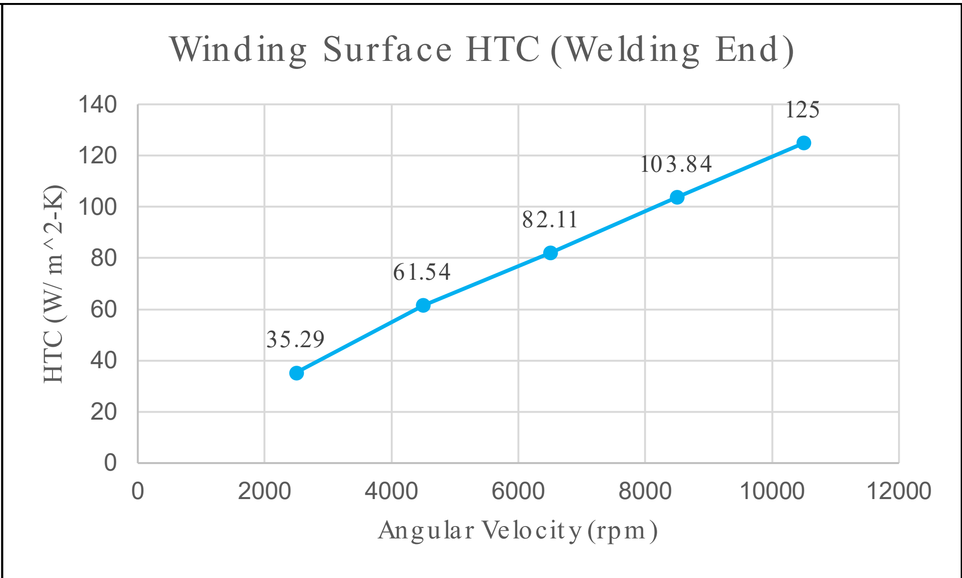
	Constant Heat Generation	Constant Winding Temperature
Angular Velocity (rpm)	4500	4500
Time (s)	600	210
1st Layer HTC	44.87	43.95
2nd Layer HTC	13.41	15.36
3rd Layer HTC	7.9	8.61
4th Layer HTC	2.01	3.42
5th Layer HTC	4.58	6.92
6th Layer HTC	4.98	9.86
Avg Winding HTC	13.58	15.18

Welding End vs. Turning End (Adding   Wafter Blade)

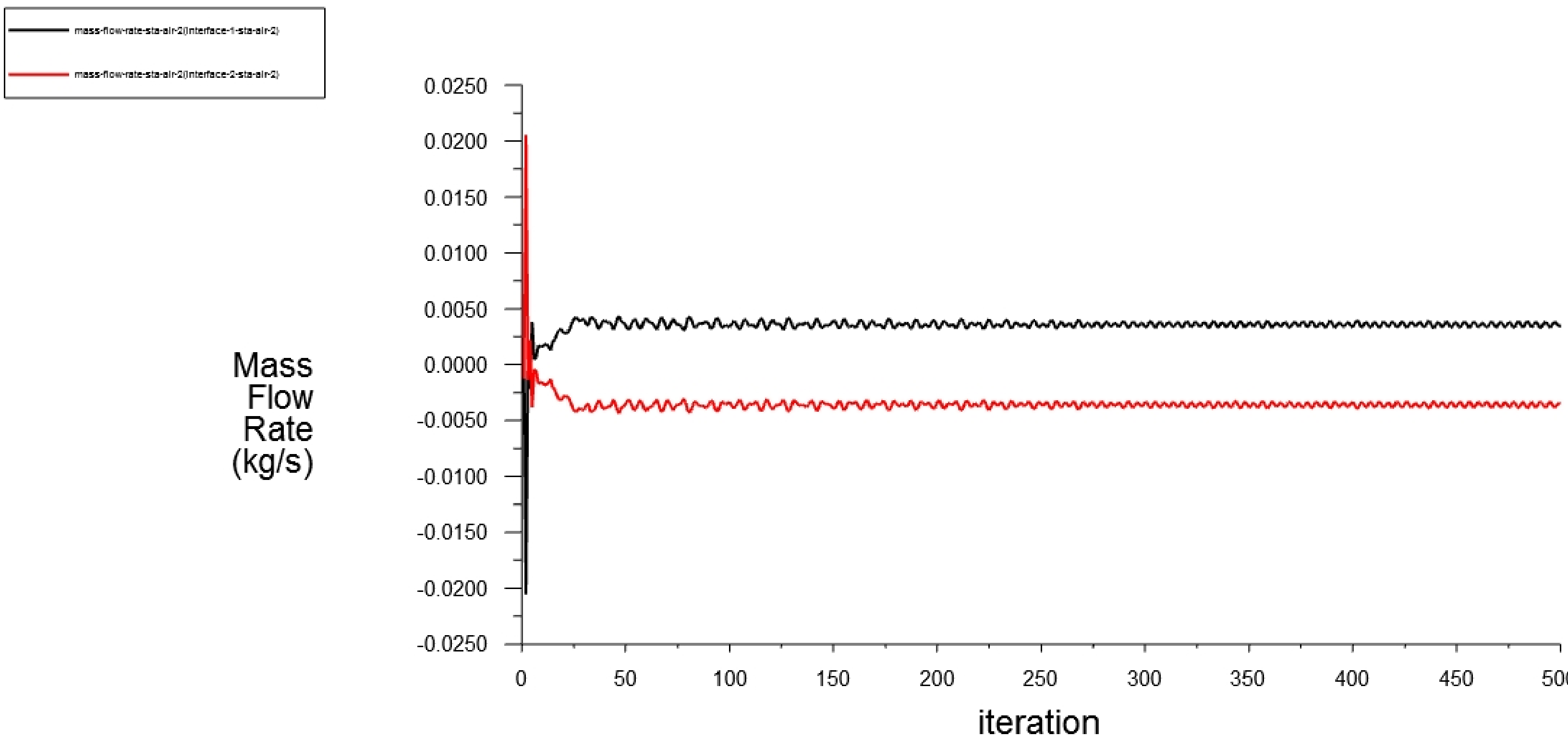


Welding End vs. Turning End

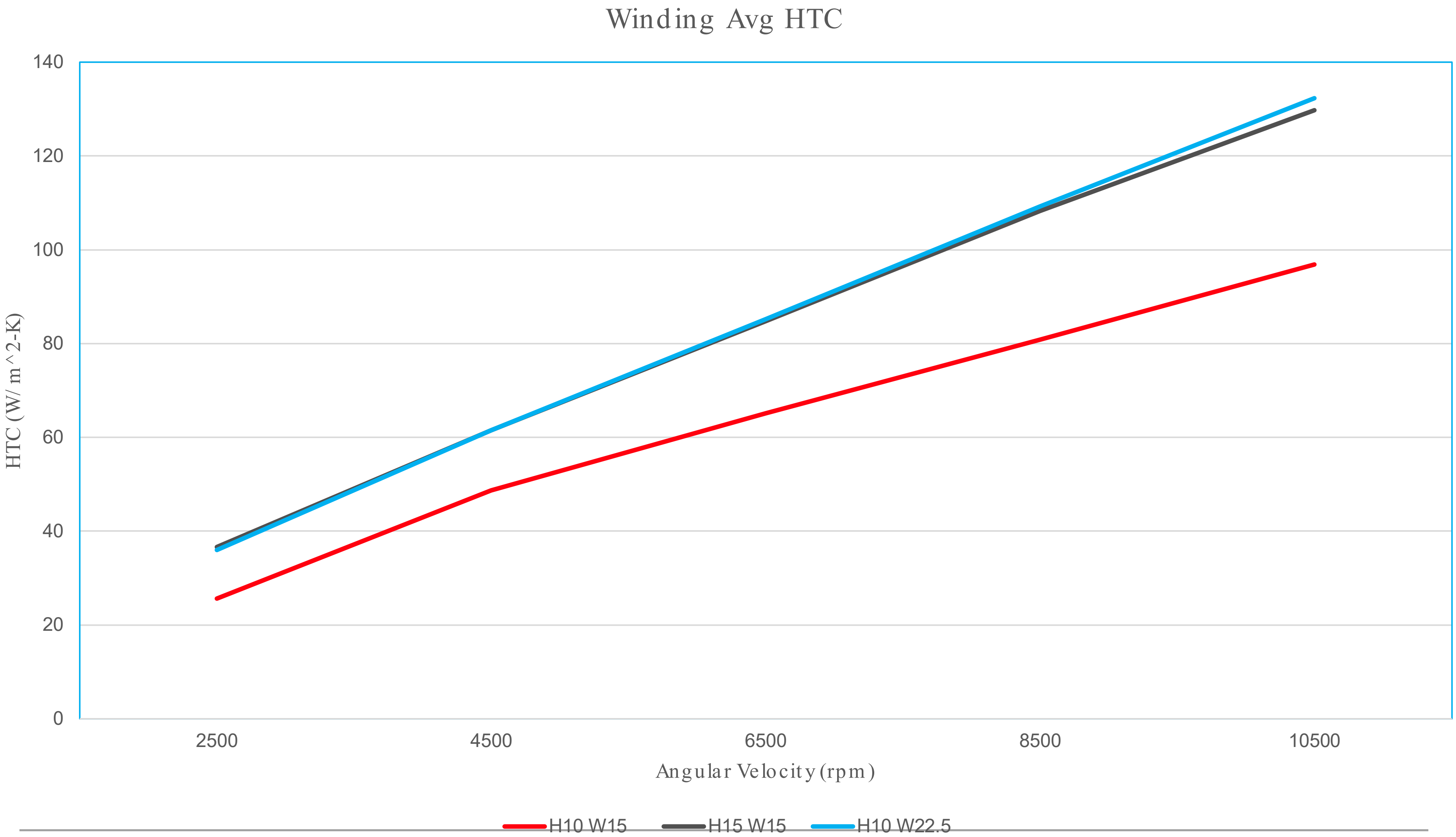




Convergence



Effect of Blade Geometry



Effect of Blade Geometry