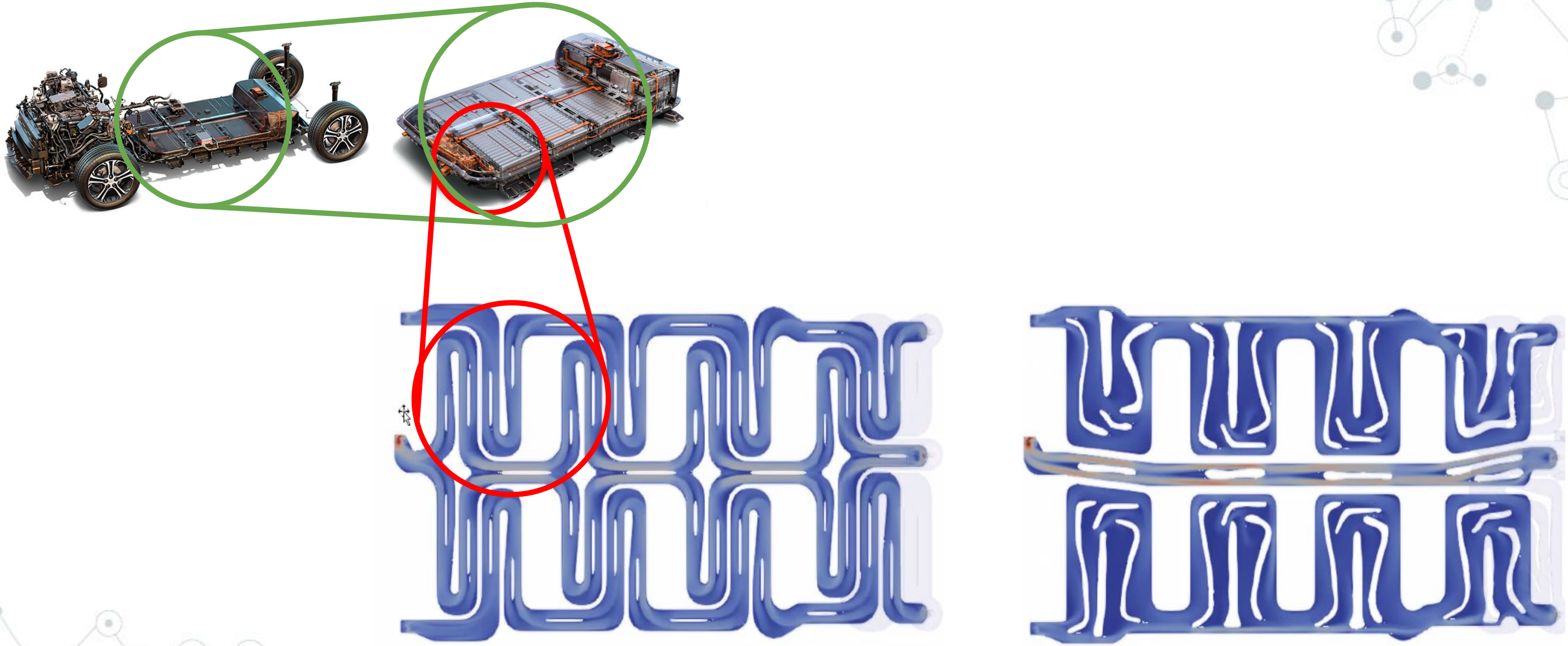
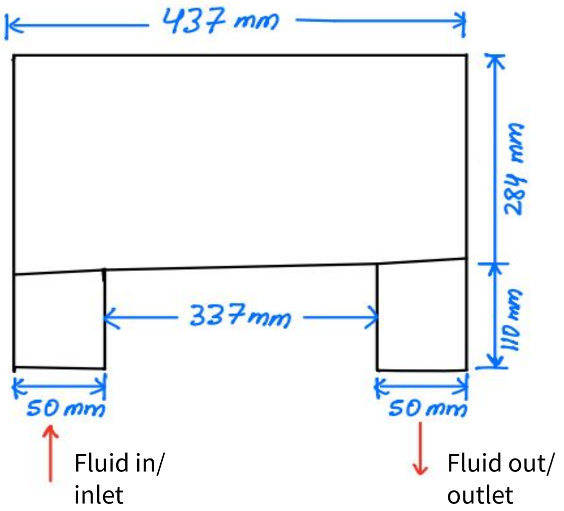
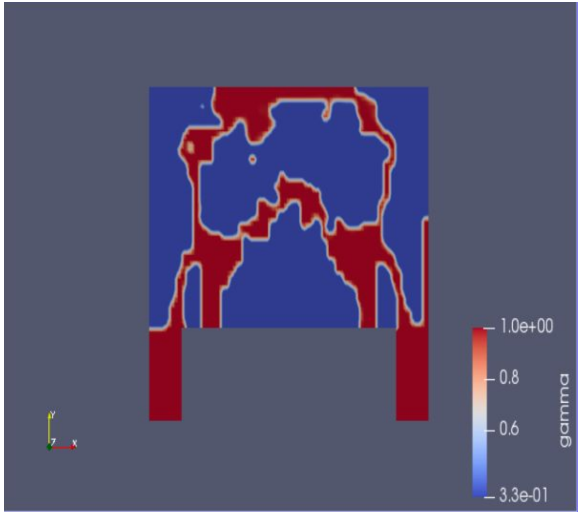
Cooling Plate Geometries



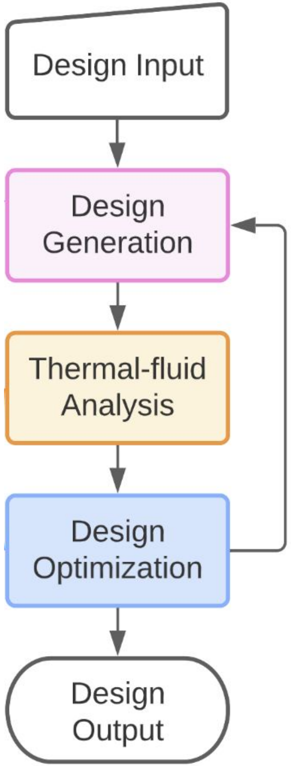
Overview



Design Space Schematic



Produced Design



What does this accomplish?

- Design Generation
  - Extrapolatable to other physics
  - Non-traditional Designs
- Design Exploration
  - Better electric vehicles

Images from GM.com

Q&A

Project Scope

In Scope

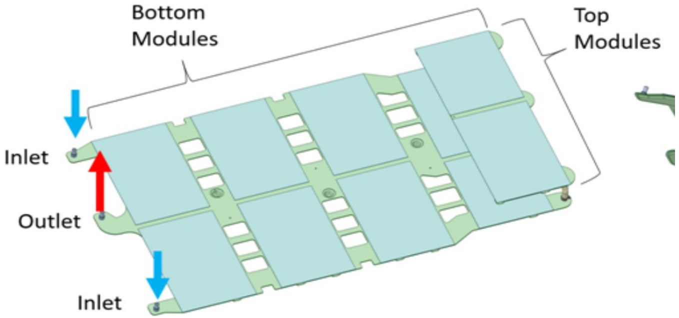
- 2D design
- Single battery module
- CAD file representation of the final design
- Thermal and fluid analysis
  - Temperature uniformity
  - Temperature range
  - Fluid pressure drop
- Integrated generative design software

Out of Scope

- 3D design
- Multiple battery modules
- Physical prototype
- Variable
  - Battery material
  - BTMS size/shape
  - Cooling plate material
  - Coolant substance
- Replacing current supplier (Diabatix)

No significant changes since DR3

Provided Geometry, Conditions



	Given Conditions	
ID	Condition	Value
1.1	Coolant	Dexcool (1:1 ethylene glycol:water solution)
1.2	Volumetric flow rate	1 L/min
1.3	Inlet coolant temperature	25 ˚C
1.4	Ambient temperature	25 ˚C
1.5	Heat dissipation rate	Top: 83.33 W and Bottom:104.17
1.6	Dimensions	CAD representation has been provided by sponsor mentor

Properties of 50/50 Ethylene Glycol/Water Mixture at 25º C:

- Density = 1065 Kg/m^3
- Specific Heat Capacity = 3488.219 J/(Kg.K)
- Thermal Conductivity = 0.42 W/(m.K)
- Viscosity = 6.9 * 10^{-3} kg/(ms)

TABLE 2: Complete List of User Requirements (Top 3 critical requirements are indicated by ***)				
#	Name	Priority (High-1, Low-3)	Target	Origin of Validation Method
1*** Single Battery Module Conditions	0.0 Minimum temperature at any point on battery surface	Sponsor has noted not of concern		
	1.1 Maximum temperature at any point on battery surface (T_{max})	1	$T_{max} \leq 40^{\circ}C$	Student Developed Tests
	1.2 Absolute difference between maximum and minimum battery surface temperatures (ΔT)	1	$\Delta T \leq 2.4^{\circ}C$	Student Developed Tests
	1.3 Pressure difference of coolant between inlet and outlet (ΔP)	2	$\Delta P \leq 1$ kPa	Student Developed Tests

Validation for Requirement #1- Single Battery Module Conditions

1.1. Maximum Battery Surface Temperature ($T_{max} \leq 40^{\circ}C$)
1.2. Absolute Difference Between Maximum and Minimum Battery Surface Temperature ($\Delta T \leq 2.4^{\circ}C$)
1.3. Pressure Difference of Coolant Between Inlet and Outlet ($\triangle P \leq 1$ kPa)

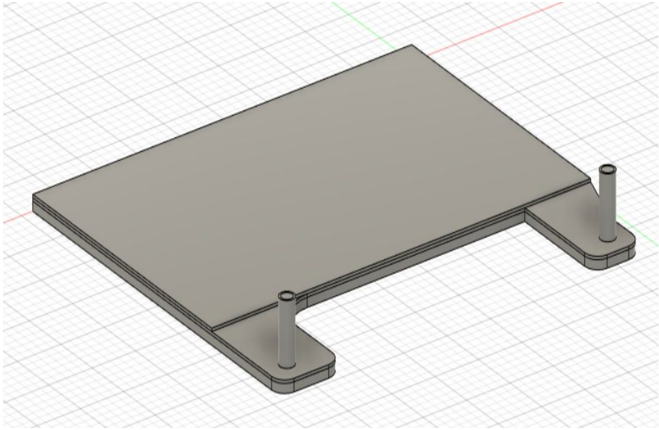


Figure 1. Cooling Plate for One Battery Module

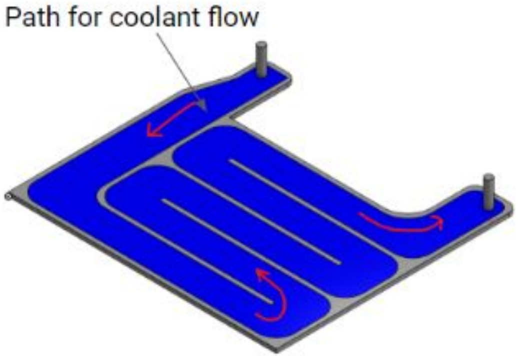


Figure 2. Cooling plate geometry with a sample path for coolant flow

Validation for Requirement #1- Single Battery Module Conditions

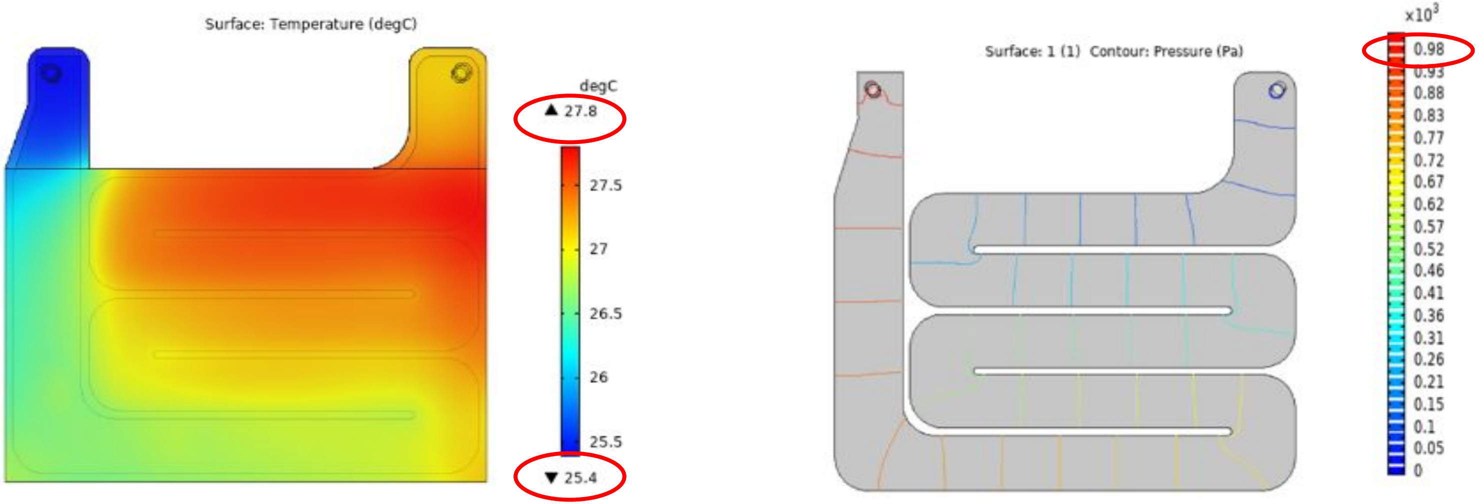


Figure 3. (a) Battery Surface Temperature Distribution; **(b)**Pressure Distribution for Normal mesh

T_{max} **= 27.8˚C ≤ 40˚C**

ΔT **= 27.8 - 25.4 = 2.4˚C ≤ 2.4˚C**

ΔP **= 980 Pa ≤ 1 kPa**

Design Optimization subteam status (cont)

Objective function

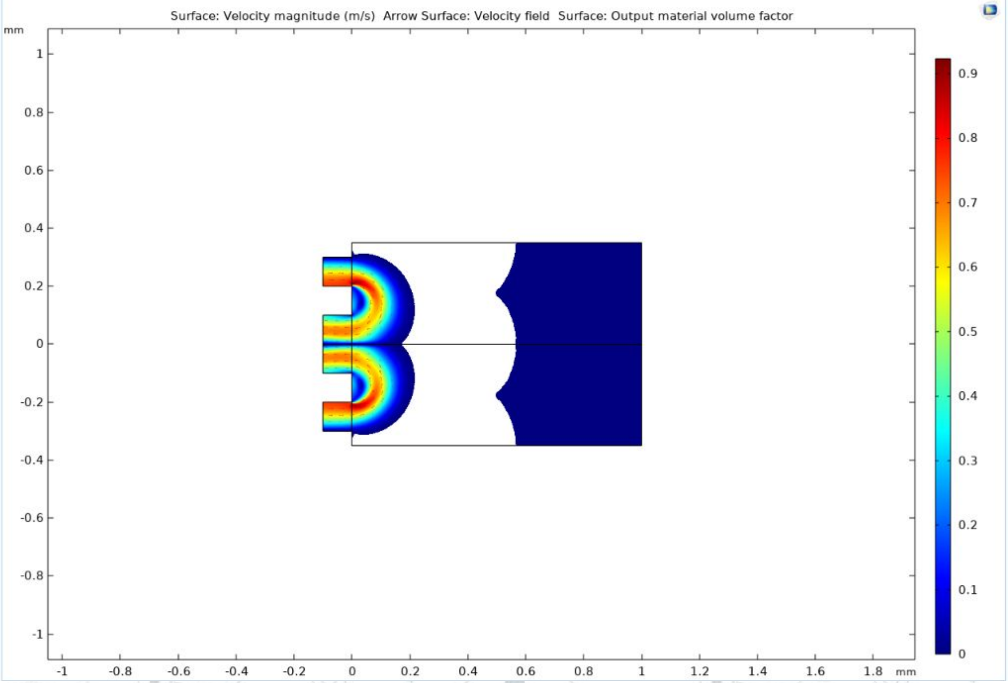
$$min.\ a\Delta T + b\Delta P$$

$$st.\ T_{max} \leq 40^{\circ}$$

$$\Delta P \leq 1kPa$$

$$a + b = 1$$

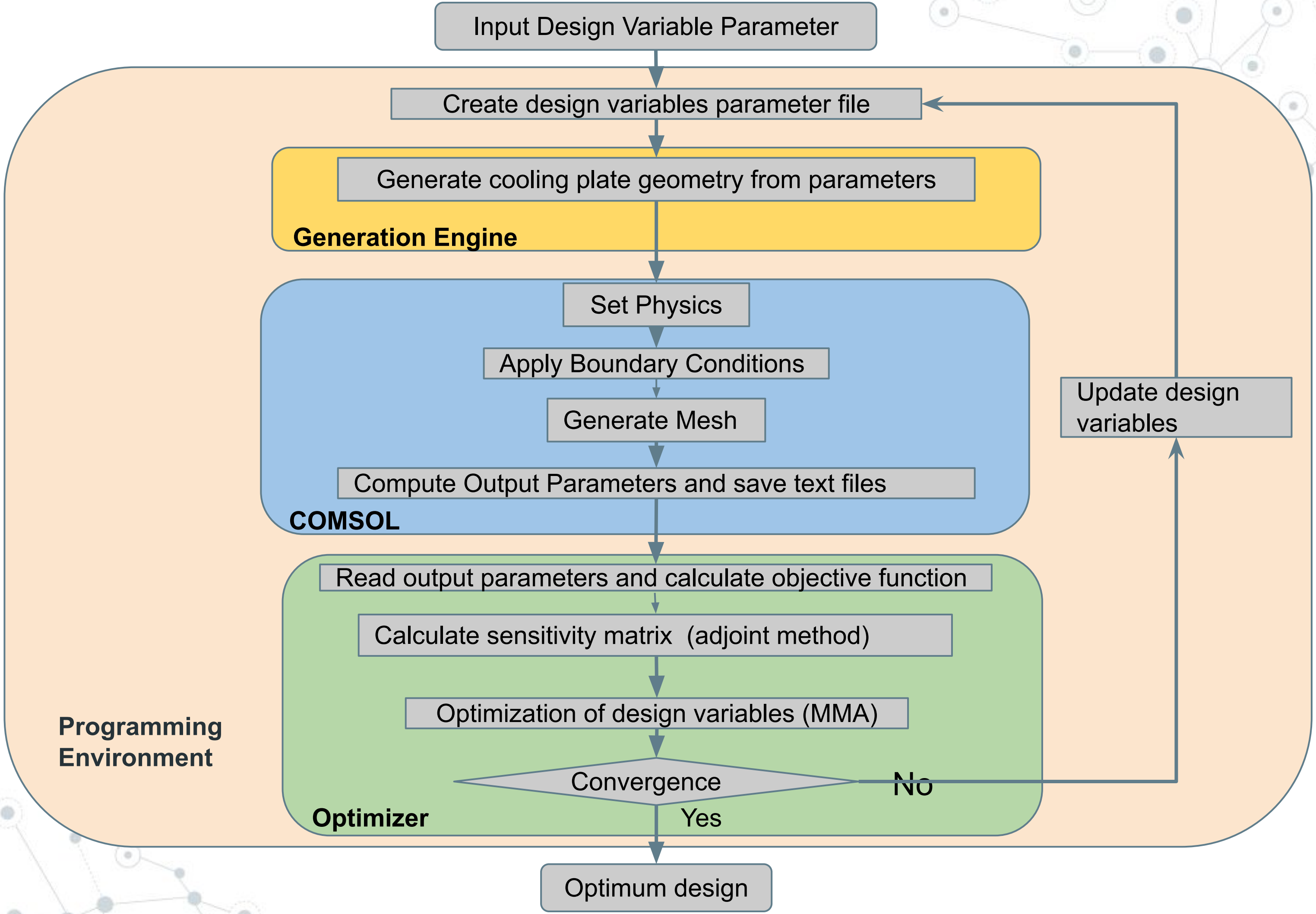
COMSOL topology optimization problem minimizing pressure loss

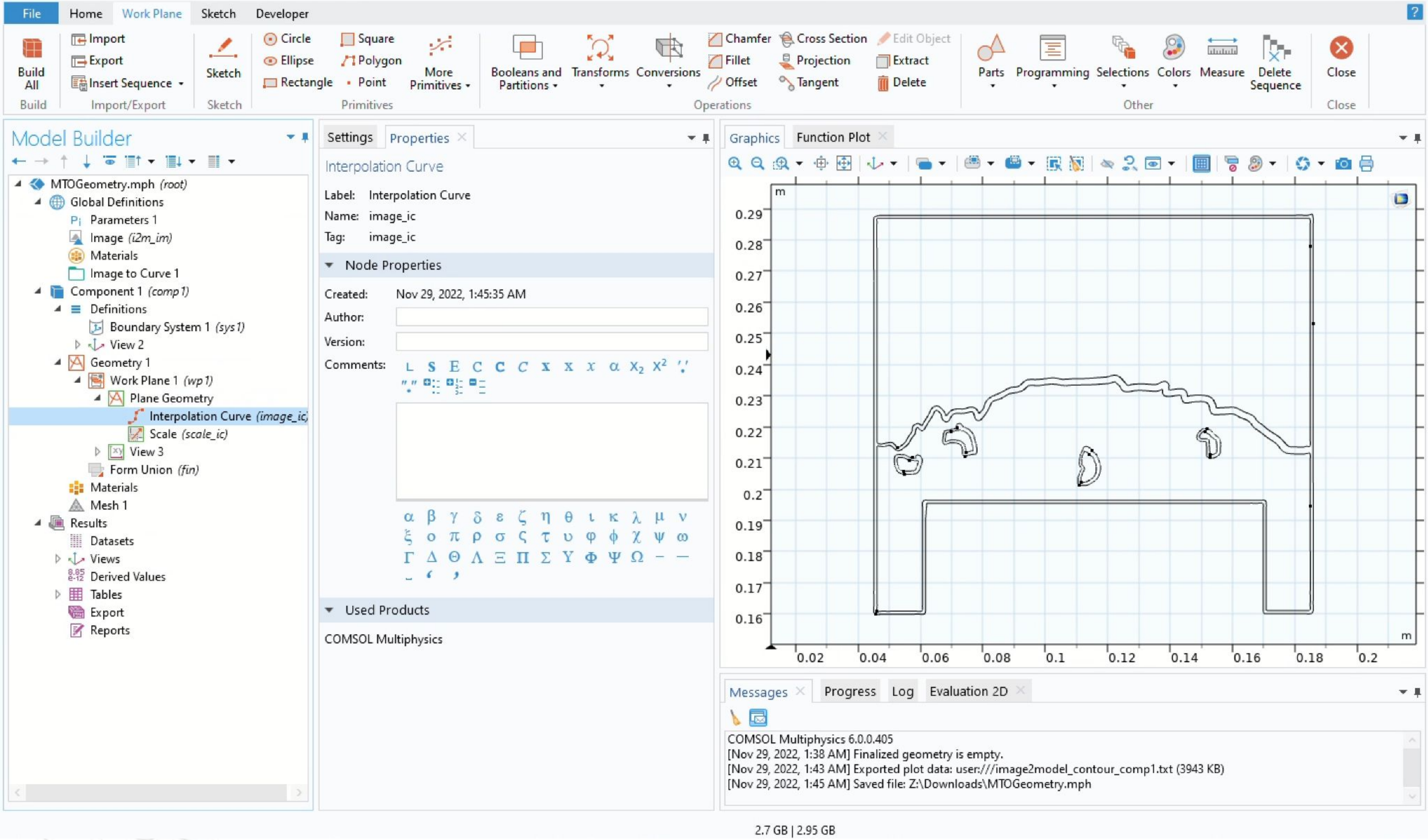


Optimization Function

$$\text{Minimize: } \Delta T(\mathbf{d}),\ \triangle P(\mathbf{d})$$
$$\text{where } T_{max} \leq 40^{\circ}\text{C}$$
$$\Delta T = |T_{max} - T_{min}| \leq 2.4^{\circ}\text{C}$$
$$\triangle P = P_{inlet} - P_{outlet} \leq 1 \text{ kPa}$$
$$f(\mathbf{d}) = a\Delta T(\mathbf{d}) + b\triangle P(\mathbf{d})$$

Optimization function defined by the Design Optimization Subteam: *f*(d) is an objective function where a and b is a penalization factor and a + b = 1 and **d** is a design variable vector.


Input Design Variable Parameter
Create design variables parameter file
Generate cooling plate geometry from parameters
Generation Engine
Set Physics
Apply Boundary Conditions
Generate Mesh
Compute Output Parameters and save text files
COMSOL
Read output parameters and calculate objective function
Calculate sensitivity matrix (adjoint method)
Optimization of design variables (MMA)
Convergence
No
Yes
Optimizer
Programming Environment
Update design variables
Optimum design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Sketch
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Export
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Sketch
Circle
Ellipse
Rectangle
Square
Polygon
Point
More Primitives
Booleans and Partitions
Transforms
Conversions
Chamfer
Fillet
Offset
Cross Section
Projection
Tangent
Edit Object
Extract
Delete
Parts
Programming
Selections
Colors
Measure
Delete Sequence
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Primitives
Operations
Other
Close
Model Builder
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Component 1 (comp1)
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Boundary System 1 (sys1)
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Work Plane 1 (wp1)
Plane Geometry
Interpolation Curve (image_ic)
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View 3
Form Union (fin)
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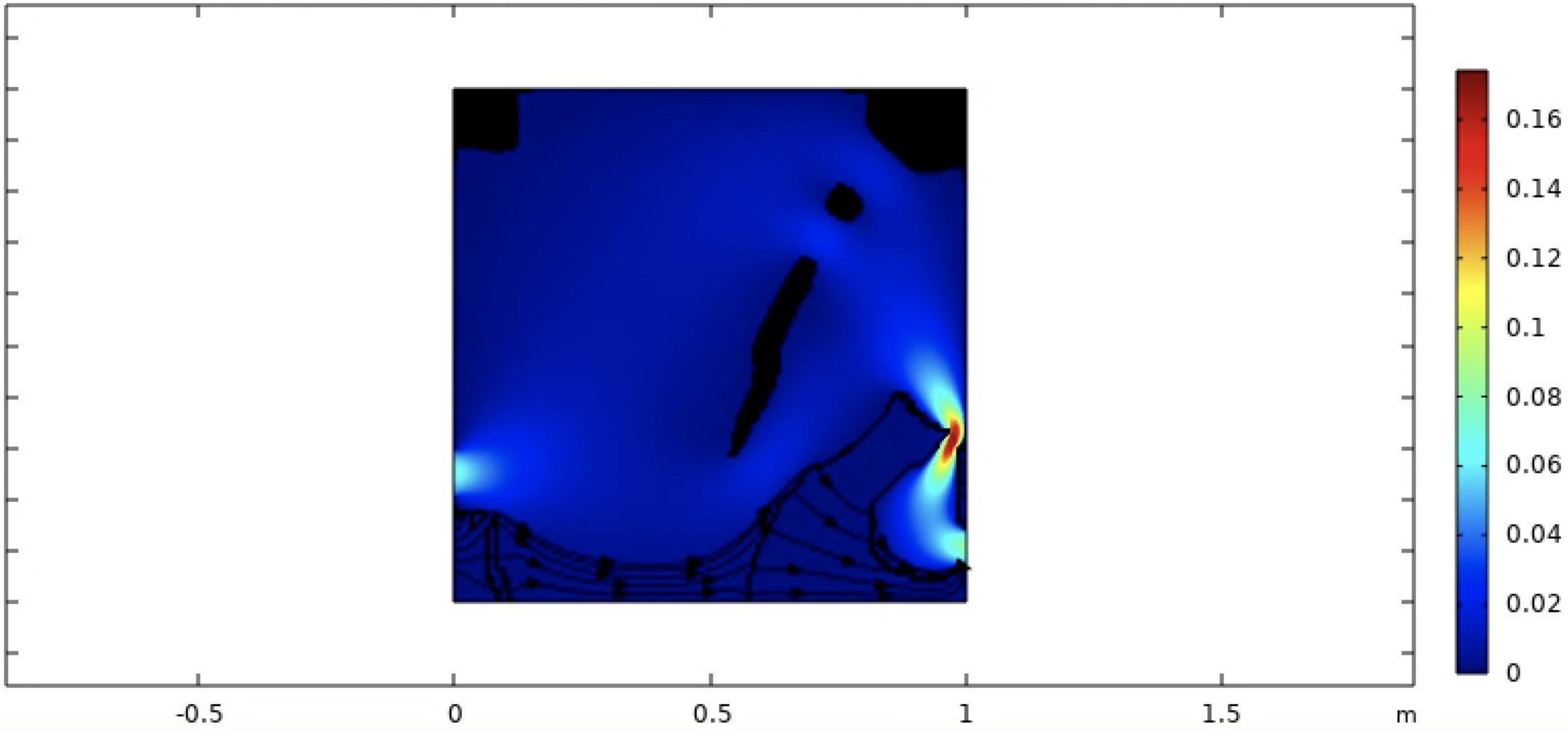
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