

Process Development of Compression Resin Transfer Moulding(CRTM) of a Complex Demonstrator Part

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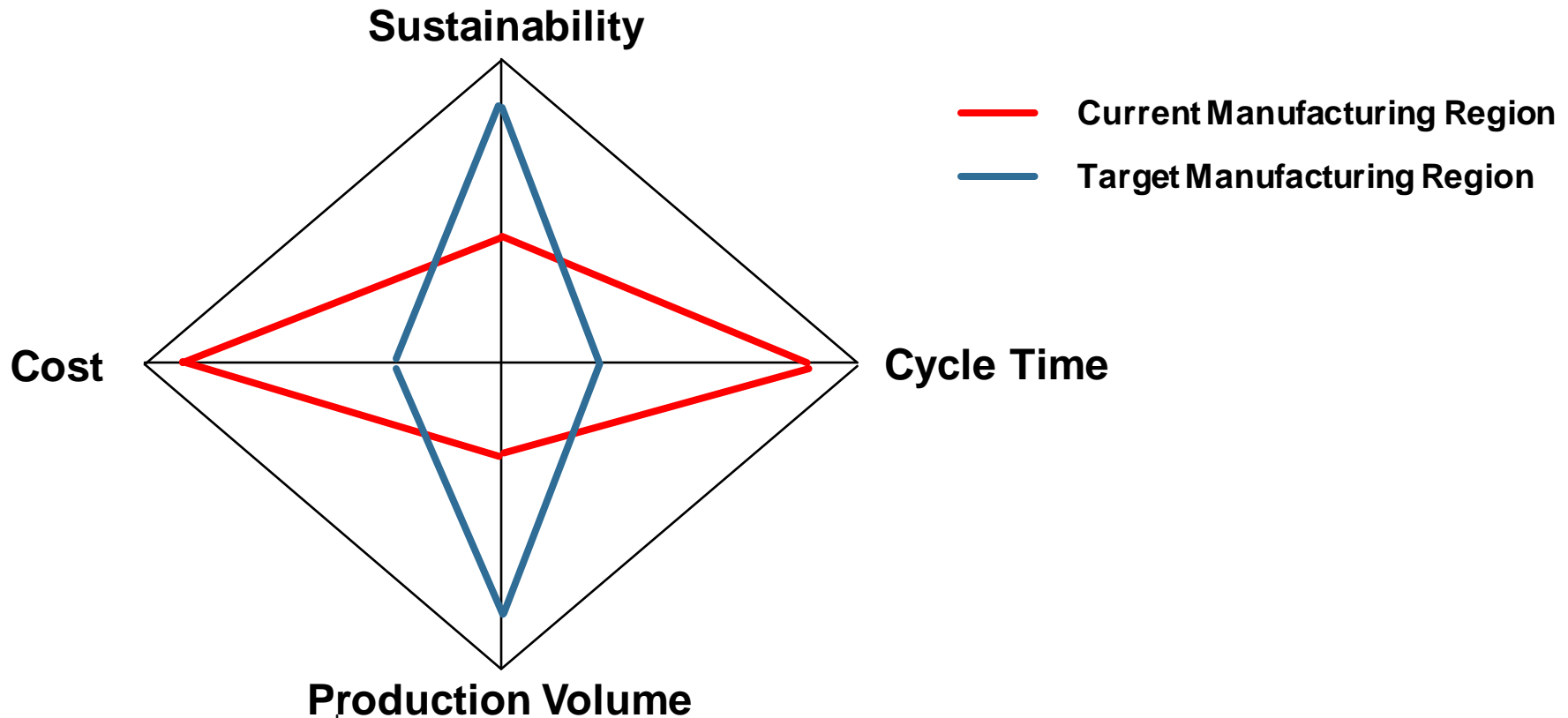
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Overview of Composite Processing and Manufacturing



Background: Composites in Automotive Industry



Ferrari F1 car (2019)



Volvo SuperTruck



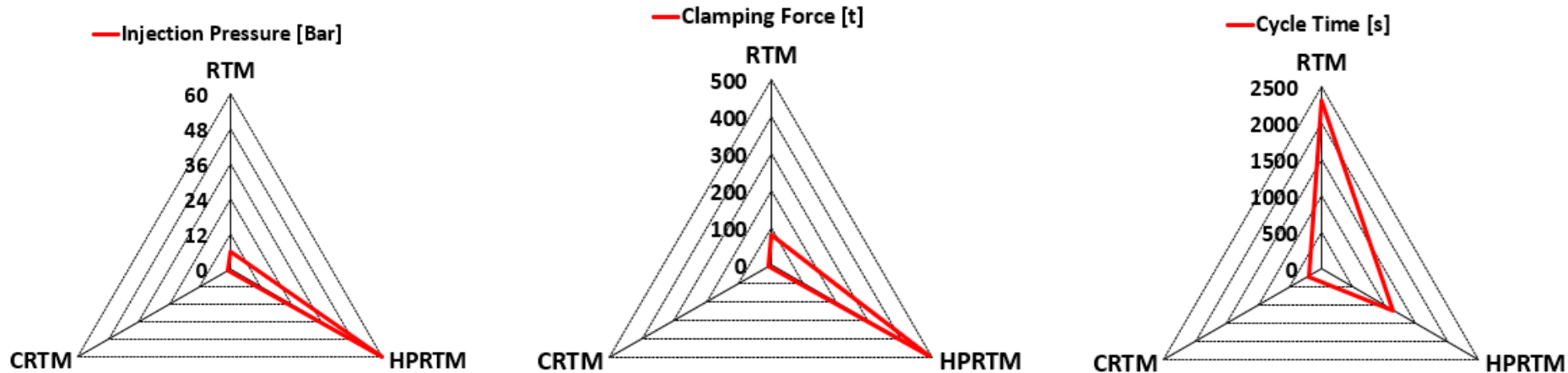
BMW i3



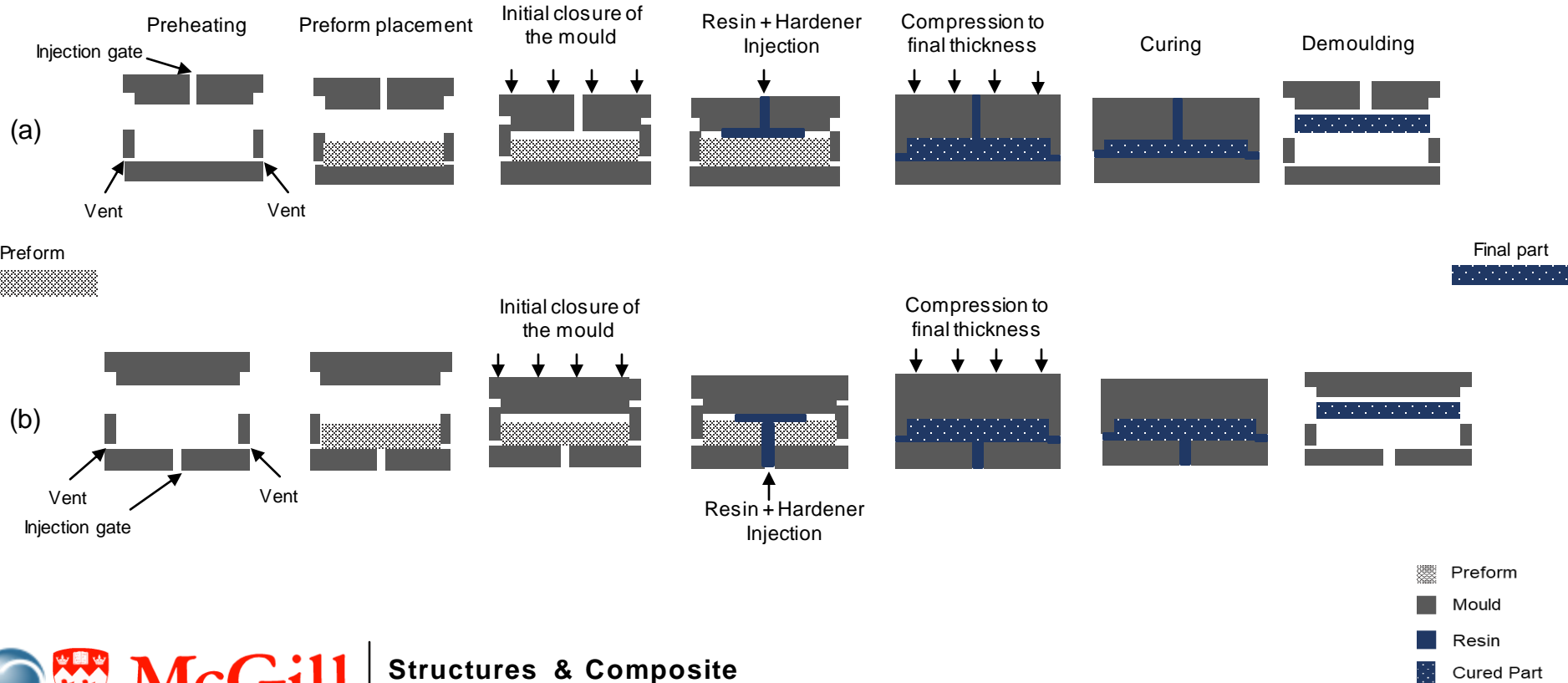
Proterra Catalyst XR

Process Comparison: Liquid Composite Moulding

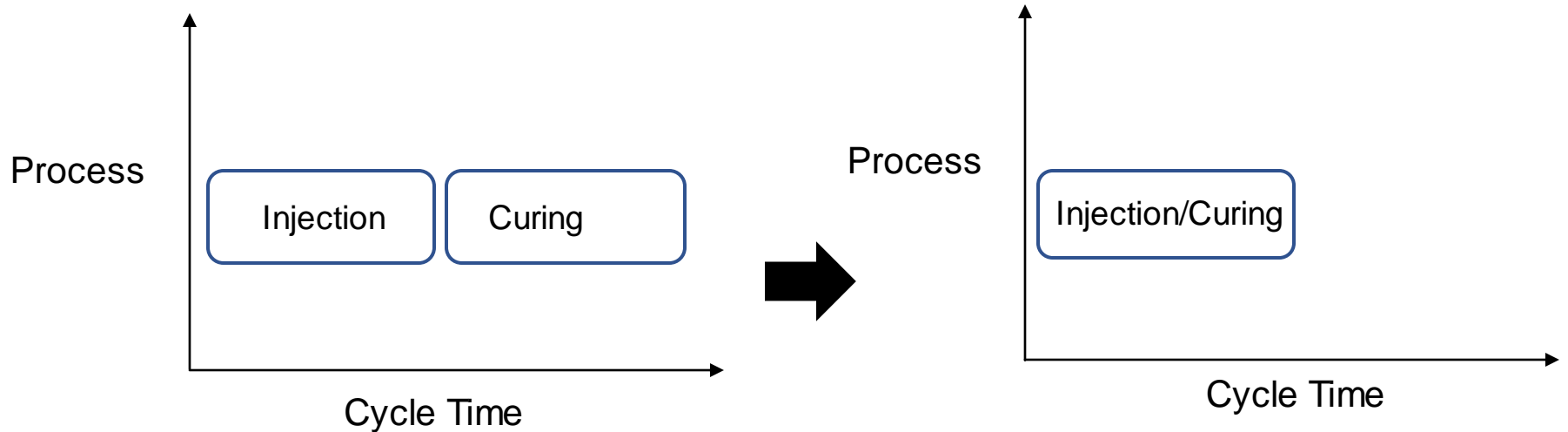
- Resin Transfer Moulding (RTM)
- High Pressure Resin Transfer Moulding (HPRTM)
- Compression Resin Transfer Moulding (CRTM)



CRTM Process



Major Challenges



- ✓ Fully coupled 3D CRTM simulation for the entire process: preheating, injection-compression and curing
- ✓ Difficult to characterize fast curing resins



Objectives

- To simulate and validate CRTM process on a complex 3D part with bottom injection

Material Characterization

- ✓ Resin
- ✓ Fibre

Material models

Process Simulation

- ✓ Preheating
- ✓ Resin injection
- ✓ Mould compression
- ✓ Post compression cure

Process parameters

Gate, Vent locations

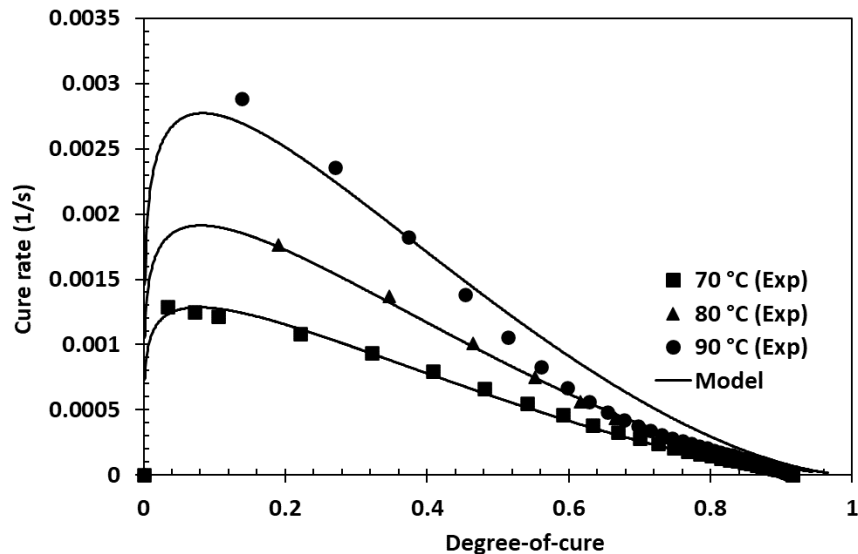
Validation of 3D Demonstrator

- ✓ Flow-front
- ✓ Sensor data(T, P)

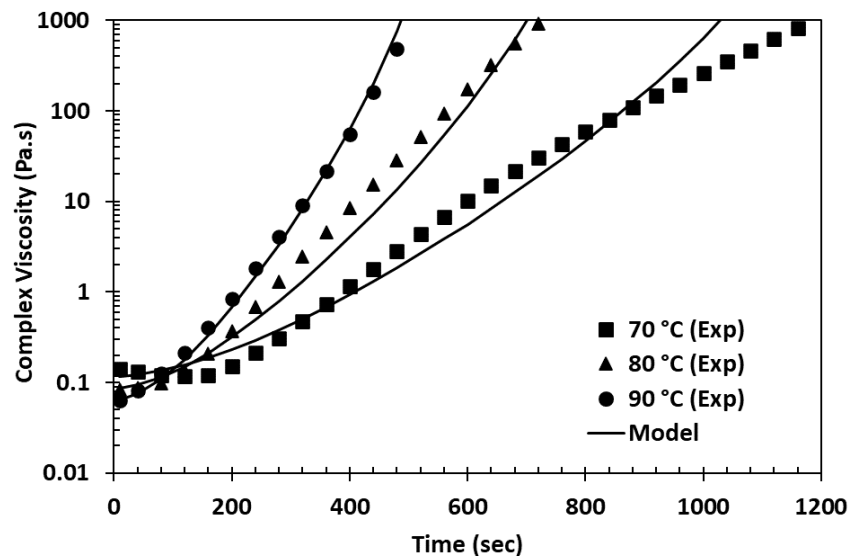
Material Model (1/2)

➤ Resin : Prime 130 SPX26528/26373 fast curing epoxy from Gurit

Cure kinetic model



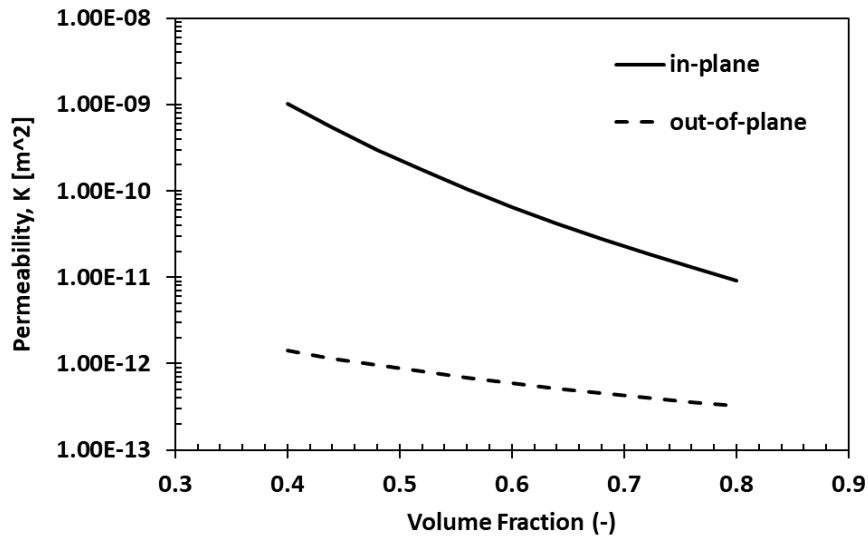
Viscosity model



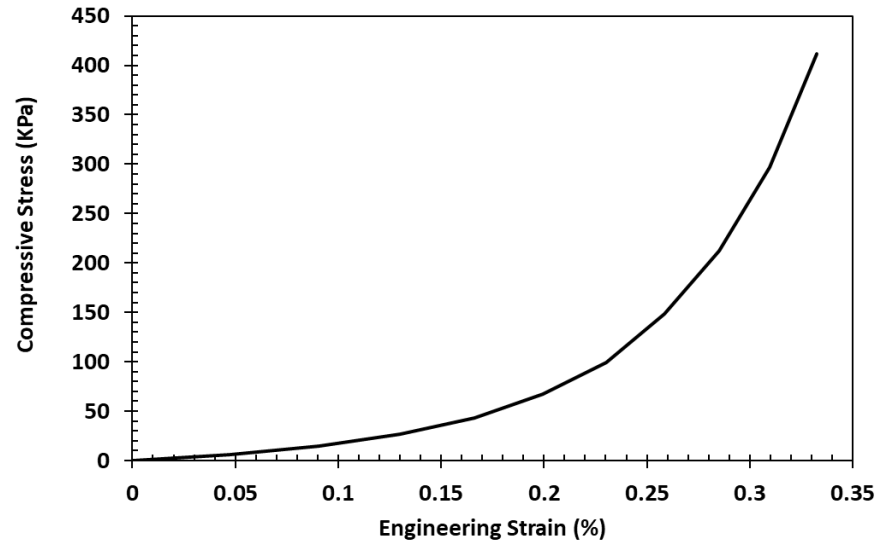
Material Model (2/2)

- Preform: TG15N glass non crimp fibre (NCF) from Texonic Inc.

Permeability model



Compaction model



Case Study

Case 1



3D Flat Plate Structure

- ✓ Flow-front verification using interrupted filling experiments
- ✓ Online pressure and temperature monitoring

Case 2



3D Complex Demonstrator Part

- ✓ Flow-front verification using interrupted filling experiments

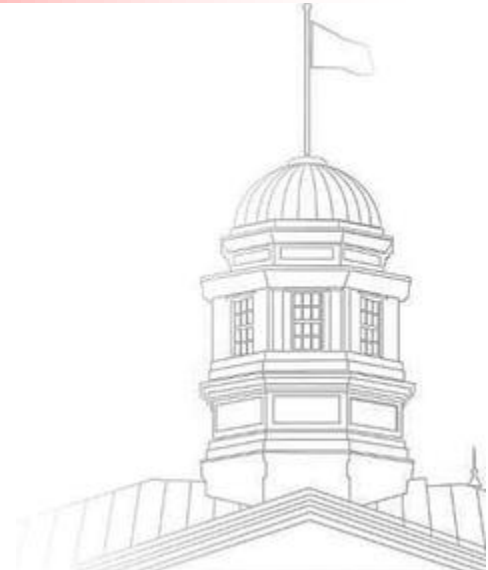
Case 1- Flat Plate



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Experimental Setup Case 1

1250 ton compression press



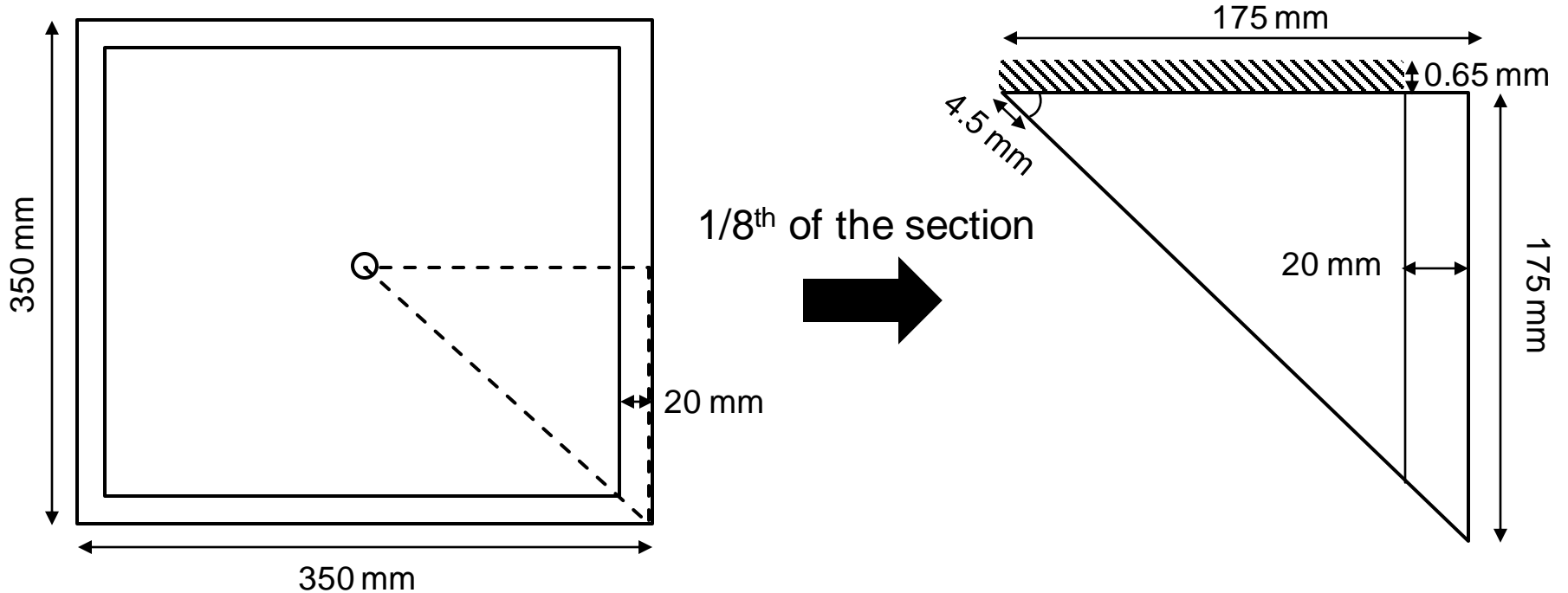
NRC flat plate tool 350x350 mm



Bottom resin injection setup

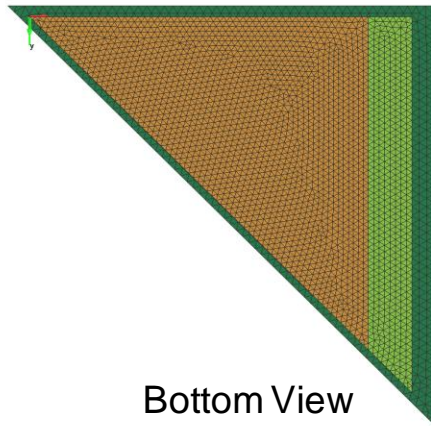
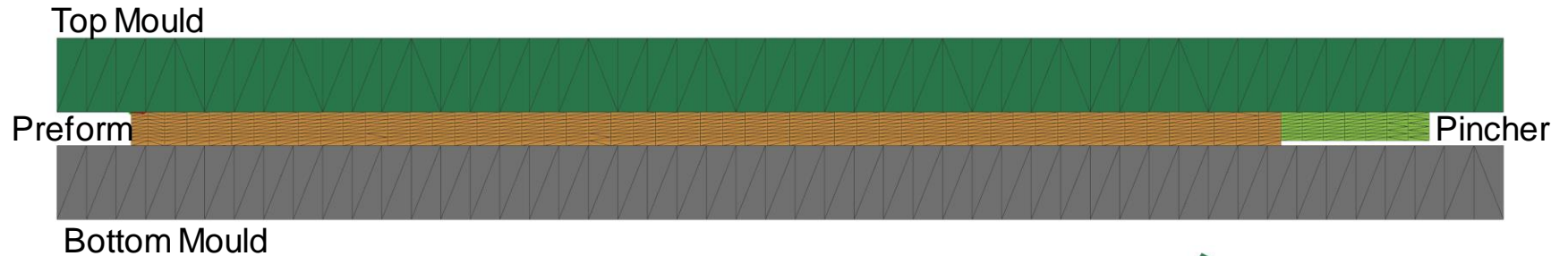


Simulation Setup

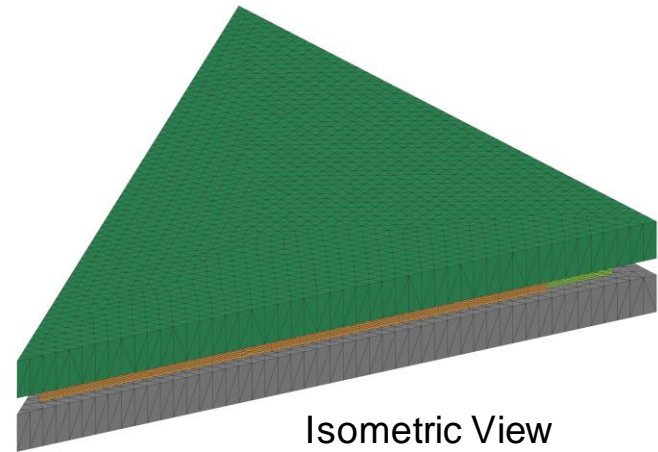


Pincher Region with an elevation of 0.65 mm

Simulation Setup – 3D Geometry



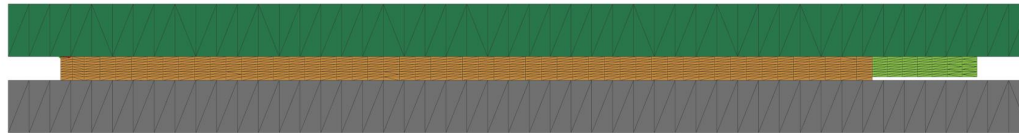
Bottom View



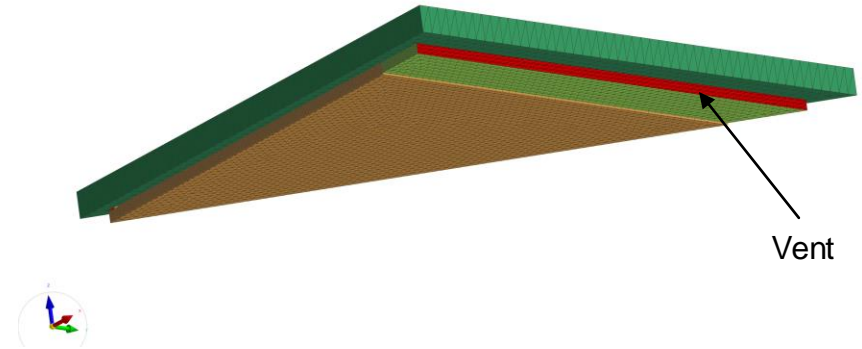
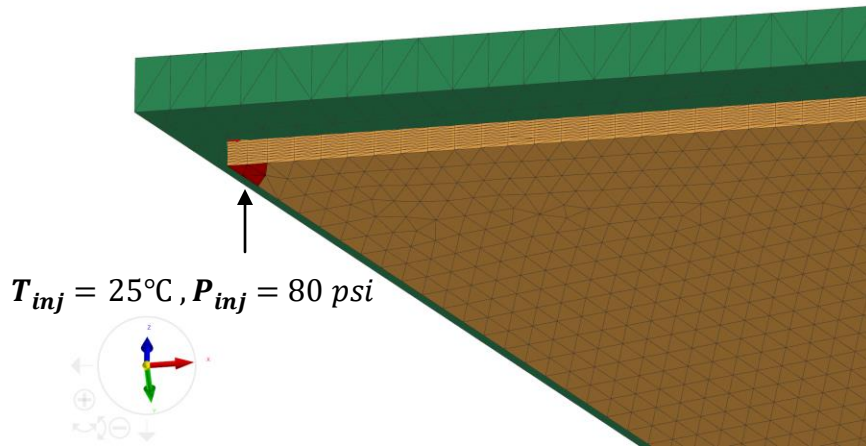
Isometric View

Process Parameters

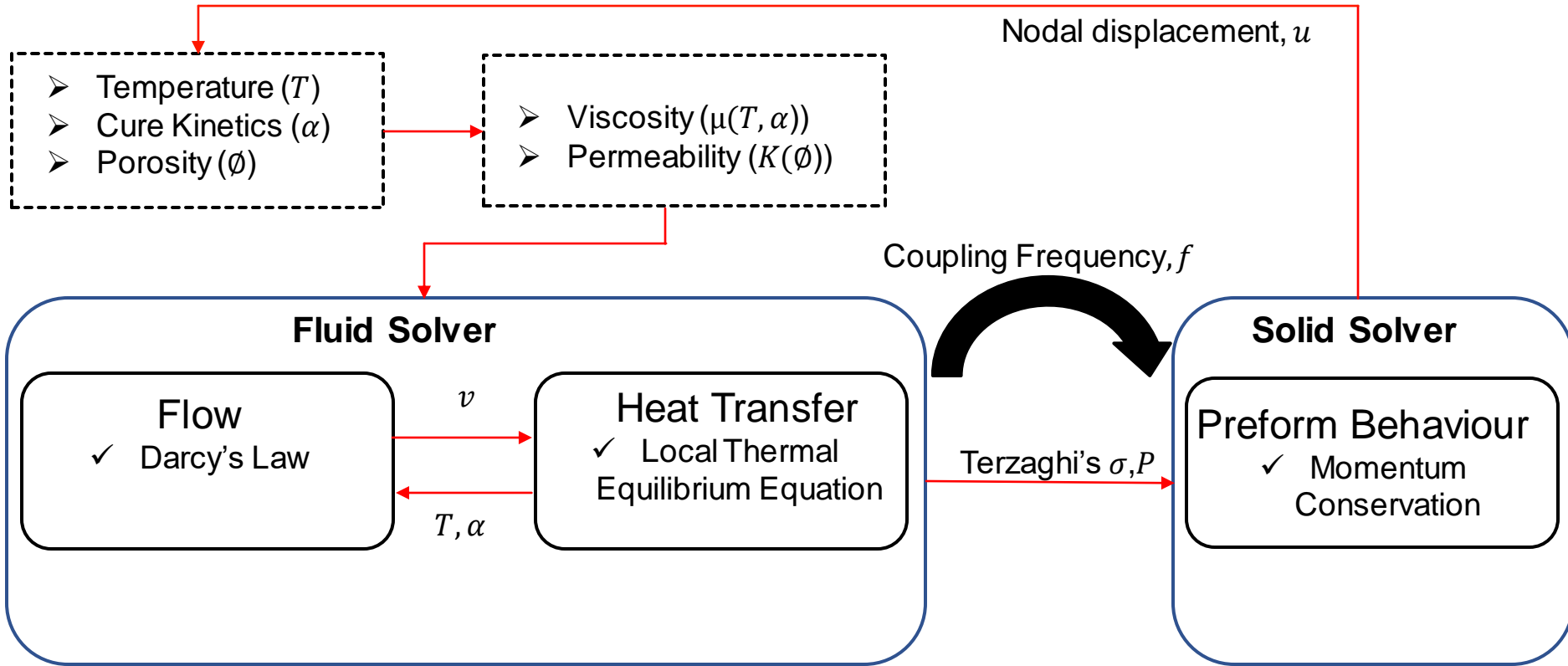
$T = 95\text{ }^{\circ}\text{C}$



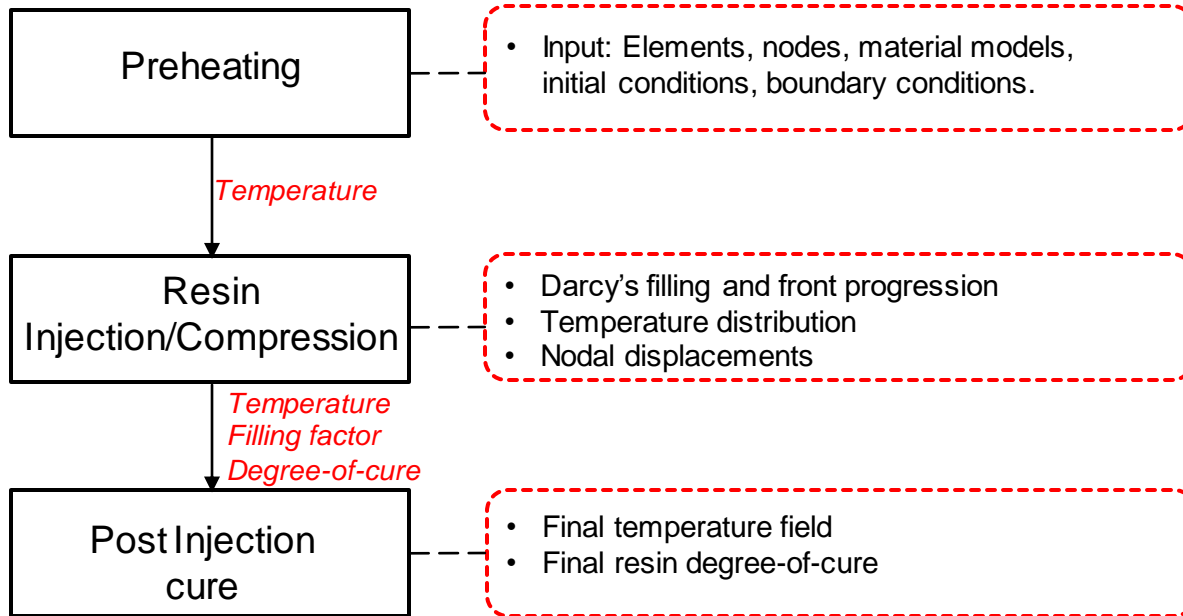
$T = 95\text{ }^{\circ}\text{C}$



Numerical Framework: PAMRTM

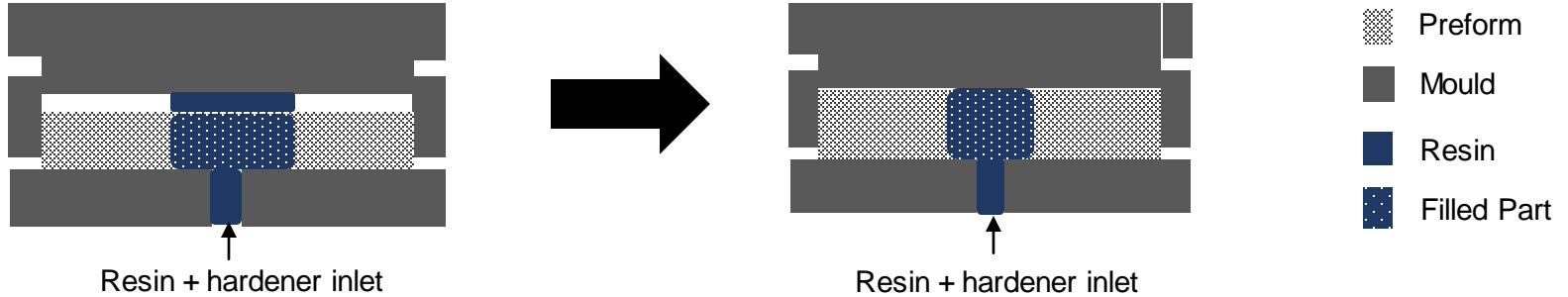


Process Simulation Workflow



Simulation Setup – Gap Assumption Results

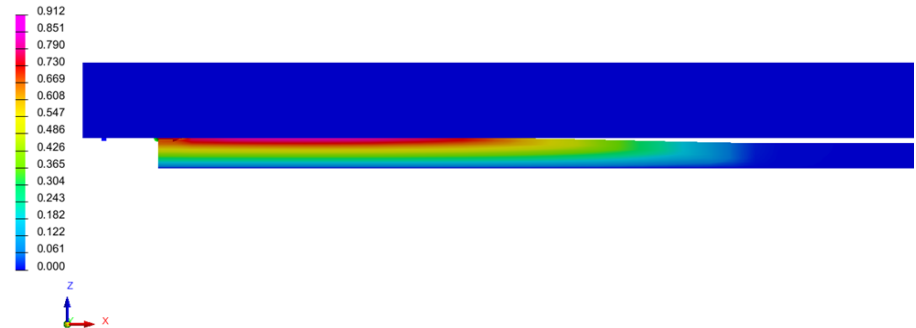
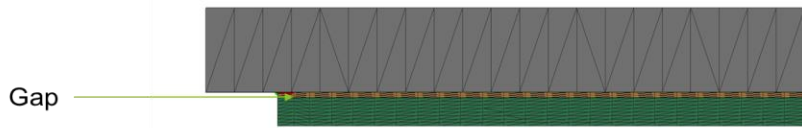
- Preform expands to fill the gap when filling stage begins



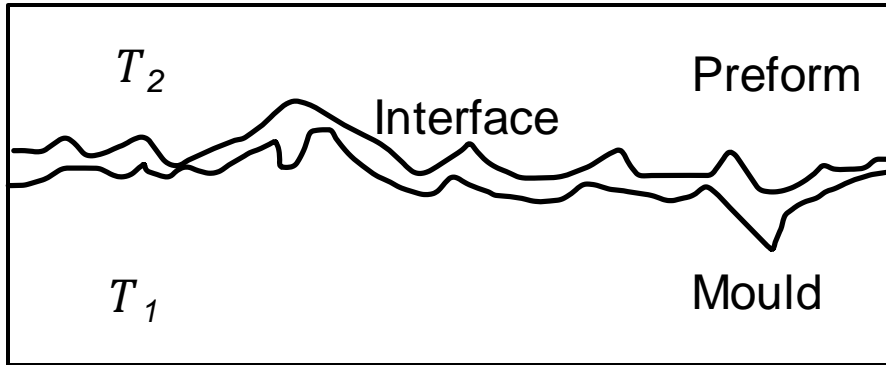
Preform displacement

Length Unit: mm
Simulation Type: Heated Filling

71 / 7.000000



Simulation Setup – Heat Transfer Interface



Heat Transfer Coefficient

$$\phi = HTC (T_1 - T_2)$$

ϕ is the heat transfer

T_1 and T_2 are the contact temperatures

$$HTC = \frac{k}{e} \text{ (W/m}^2 \text{ K)}$$

e is the thickness of the contact region

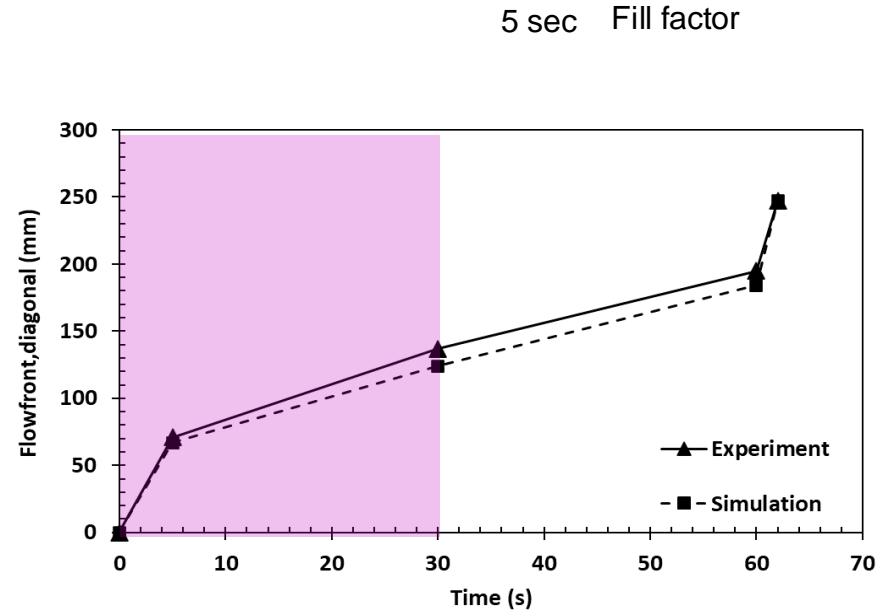
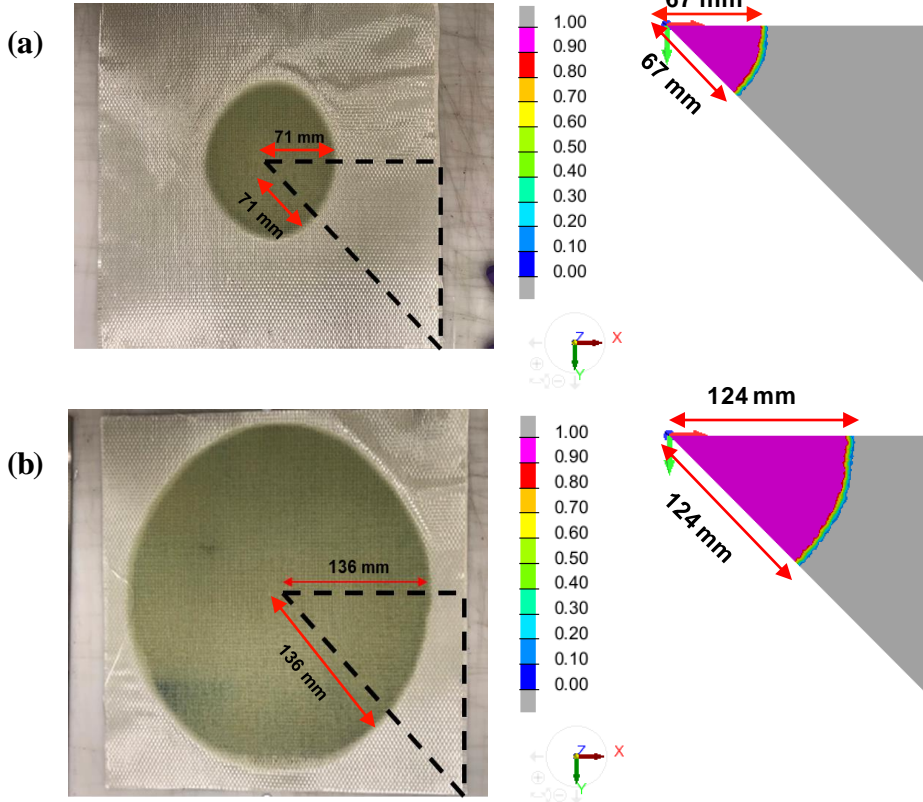
k is the thermal conductivity of air

Experiment Test Matrix

- Interrupted filling test

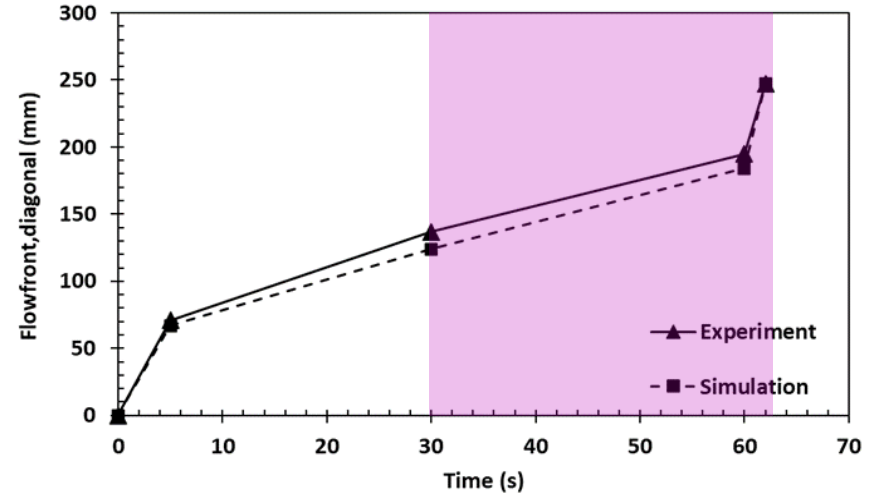
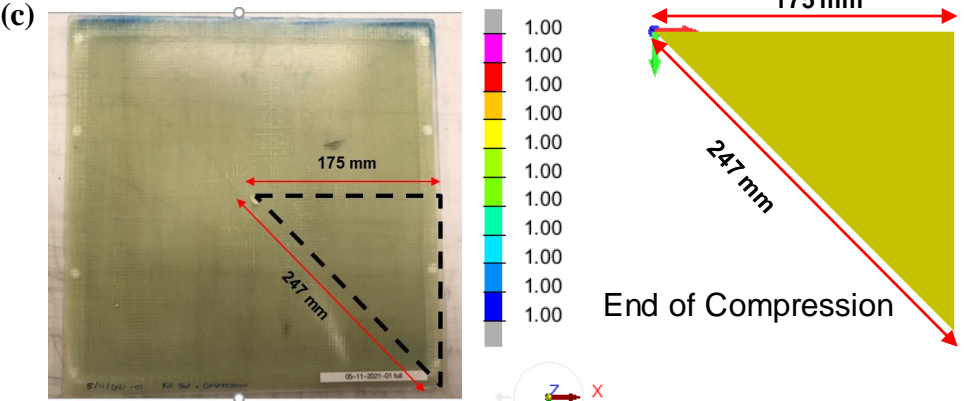
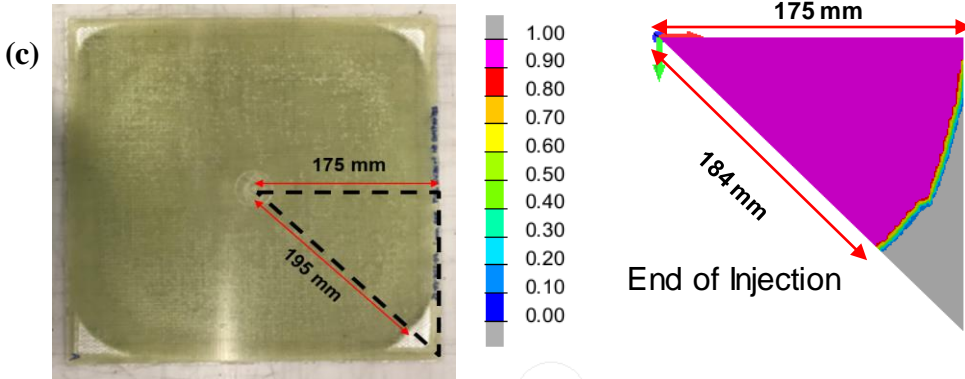
Test No.	Time (sec)
1	5
2	30
3	End of injection
4	End of compression

Model Validation: Experiment vs Simulation – Flow front (1/2)

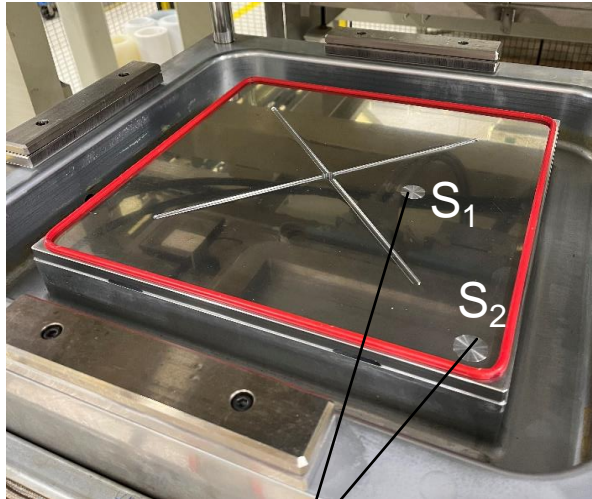


30 sec

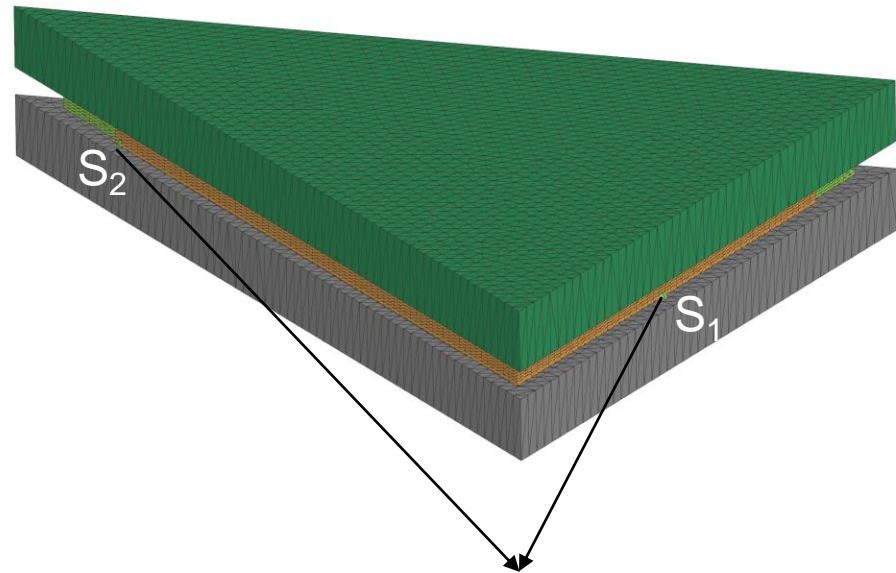
Model Validation: Experiment vs Simulation – Flow front (2/2)



Sensor Setup: Experiment and Simulation

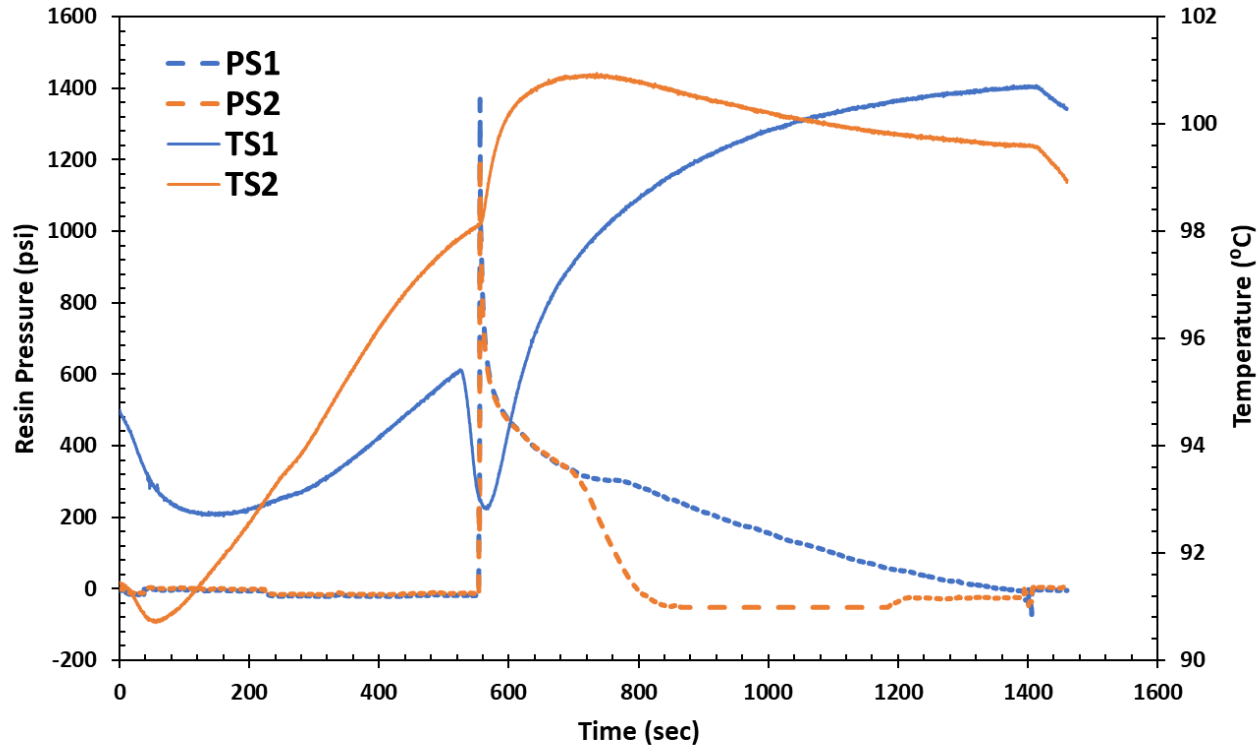


Temperature and Pressure Sensors

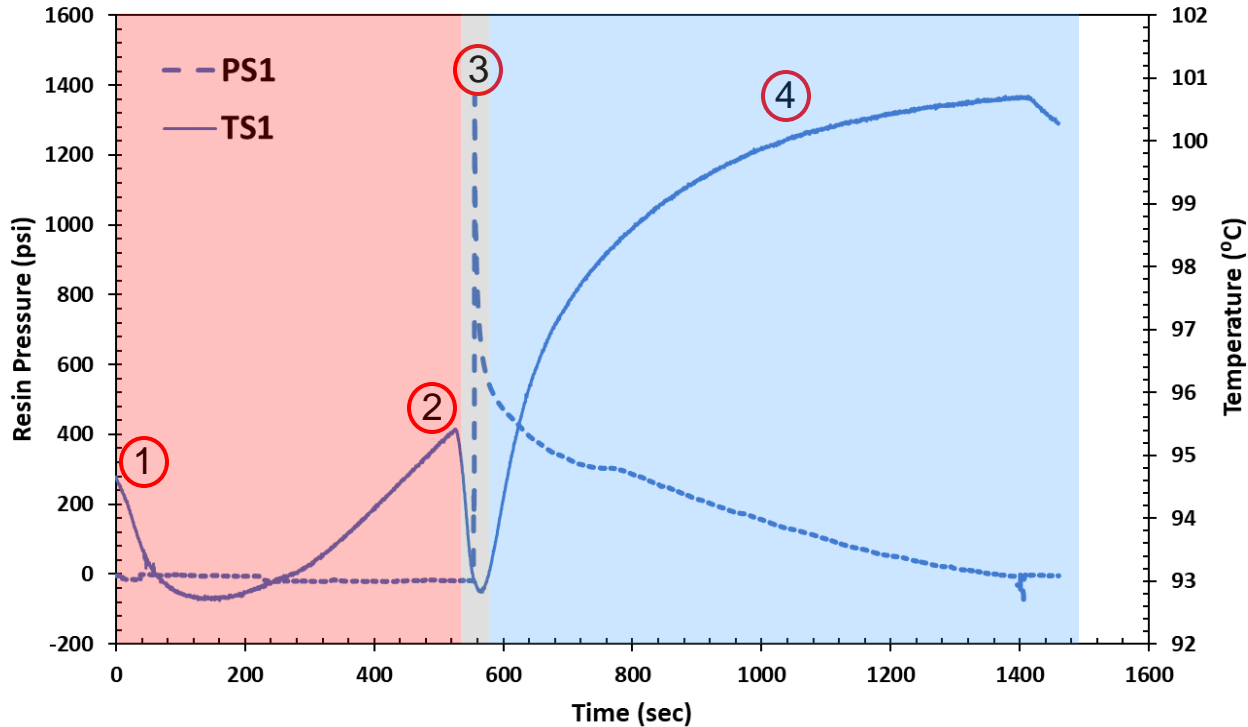


Virtual Temperature and Pressure Sensors

Sensor Data : Entire Process



Sensor Data: Different Stages



① Preform Placement

② Resin Injection

③ Compression

④ Exotherm

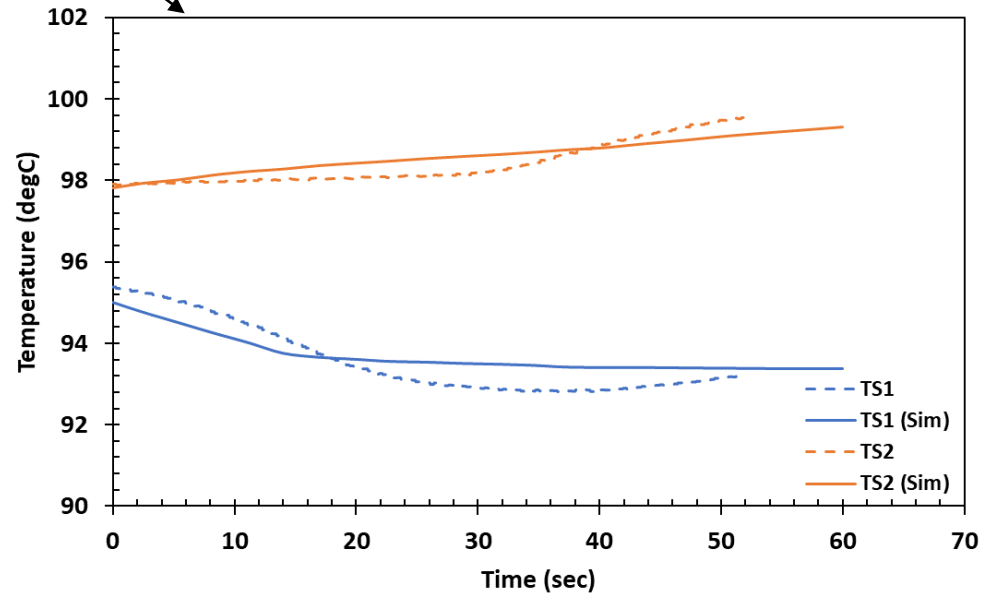
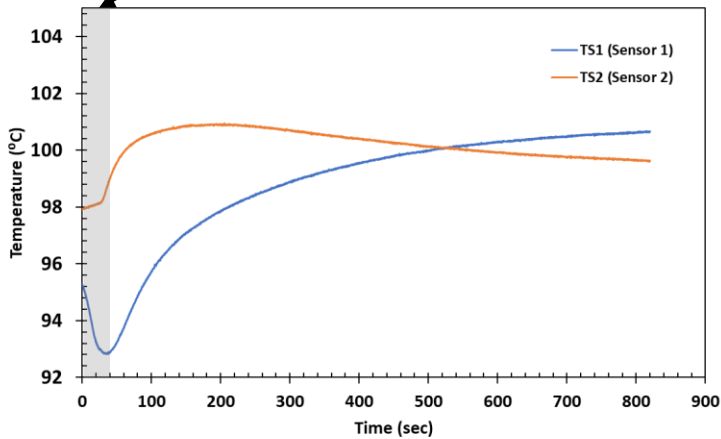
Preheating

Injection/Compression

Curing

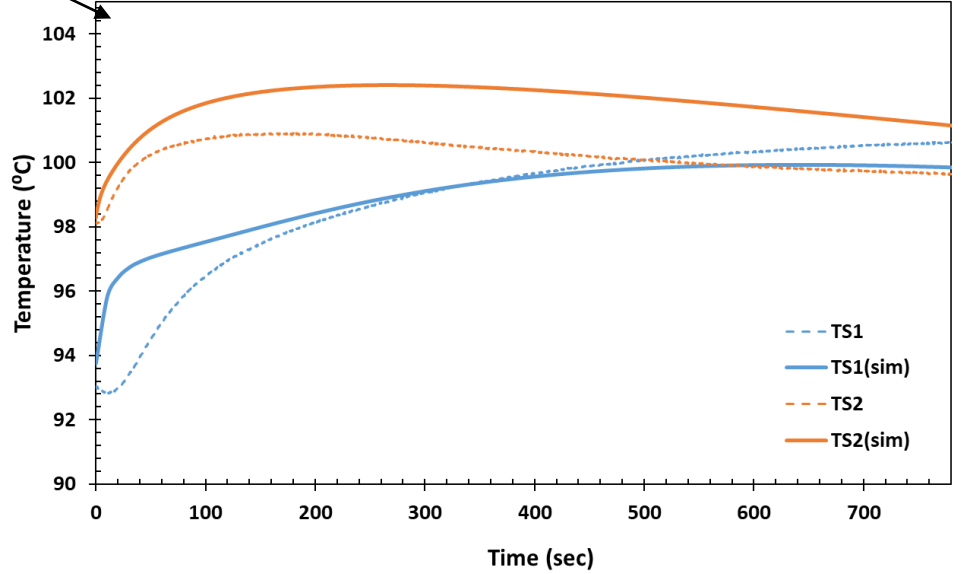
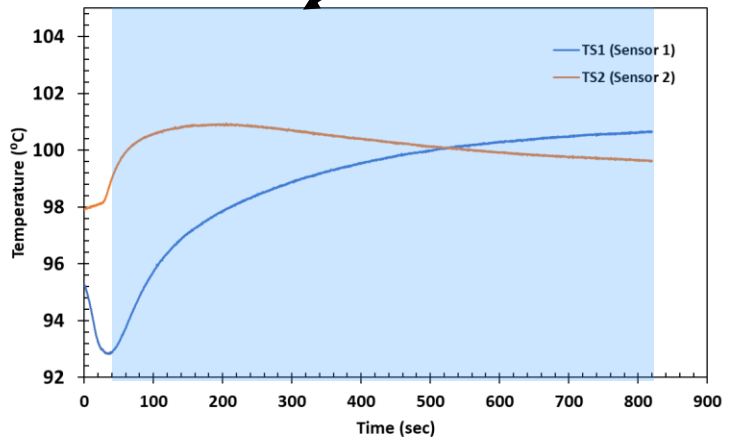
Senor Data: Temperature Validation (1/2)

Injection/Compression



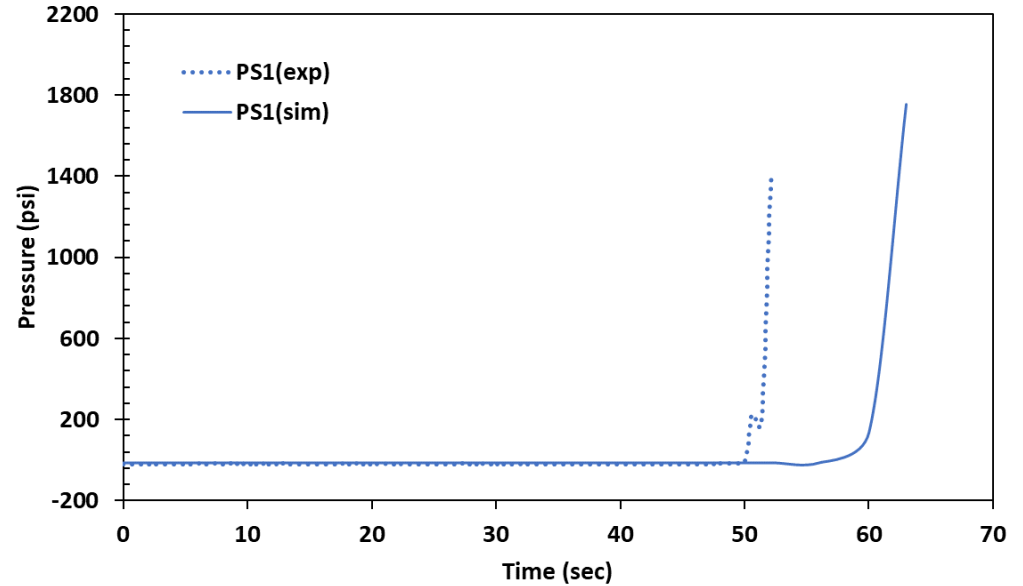
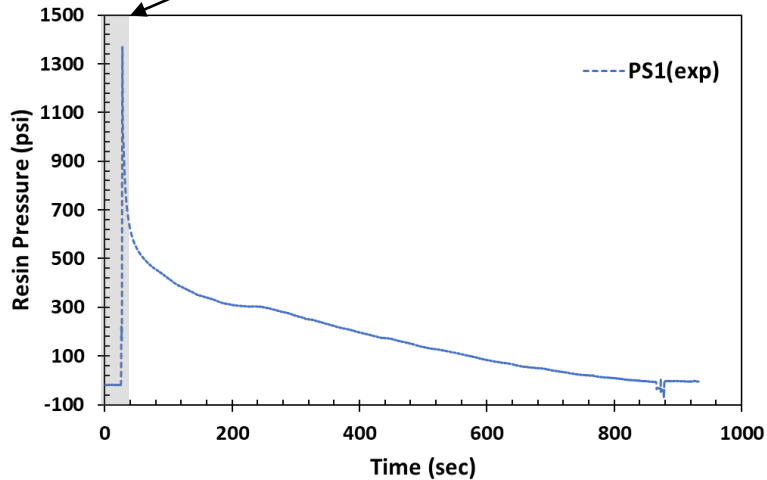
Sensor Data: Temperature Validation (2/2)

Curing



Sensor Data: Pressure Validation

Injection/Compression



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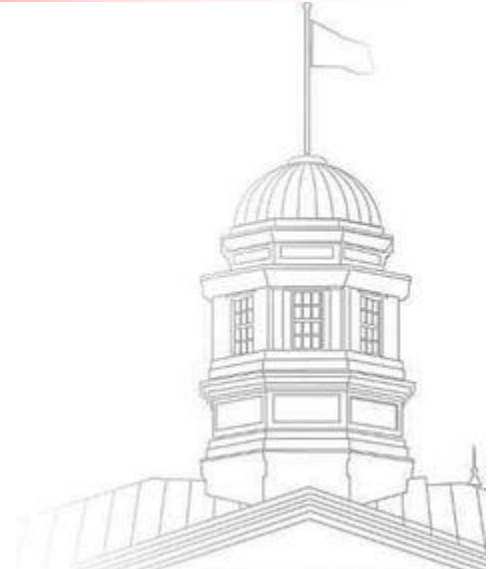
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Case 2- Complex Demonstrator Part for Transportation Industry



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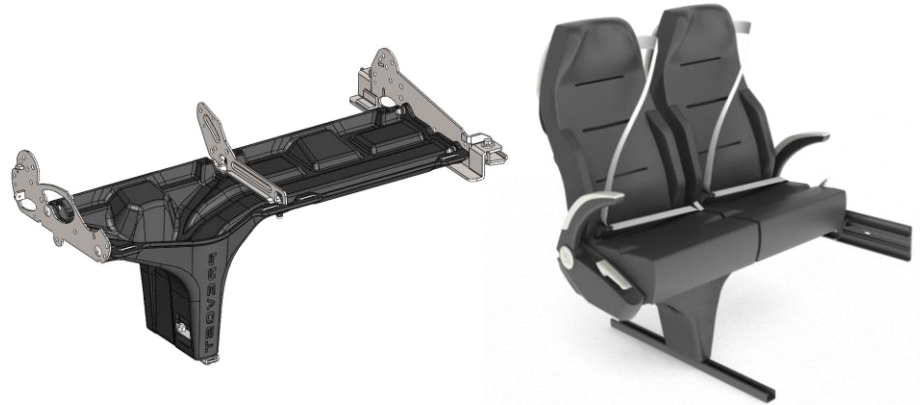
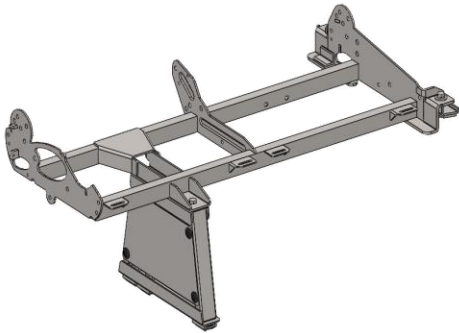
Seat Base Design Change

Original seat base:

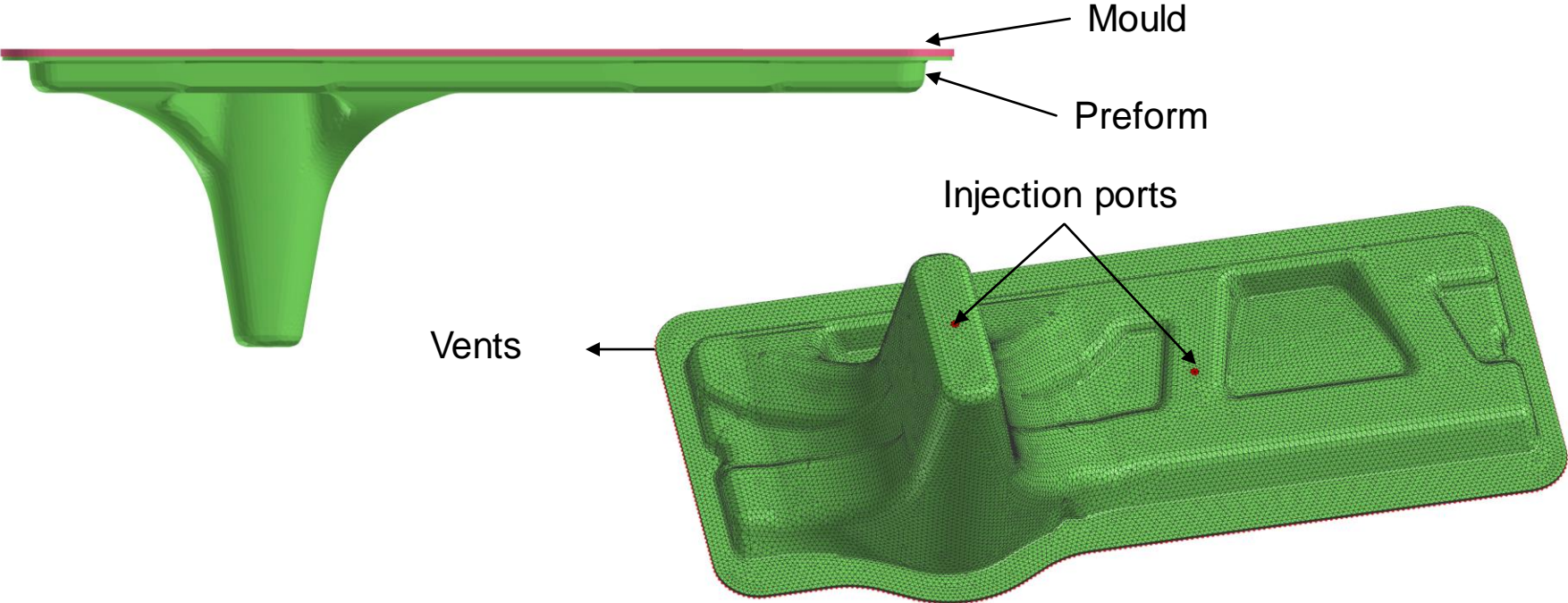
- Welded steel design
- Multiple assembly

Composite seat base concept:

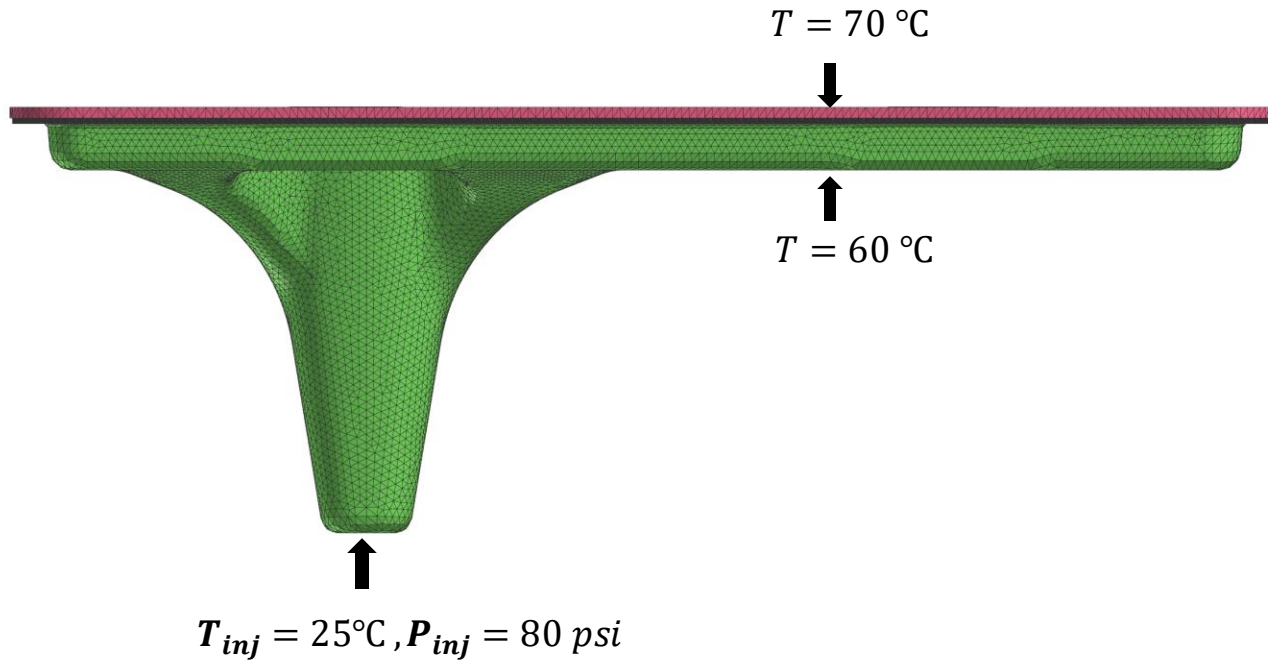
- Continuous reinforced fibre thermoset composite
- Integrated components



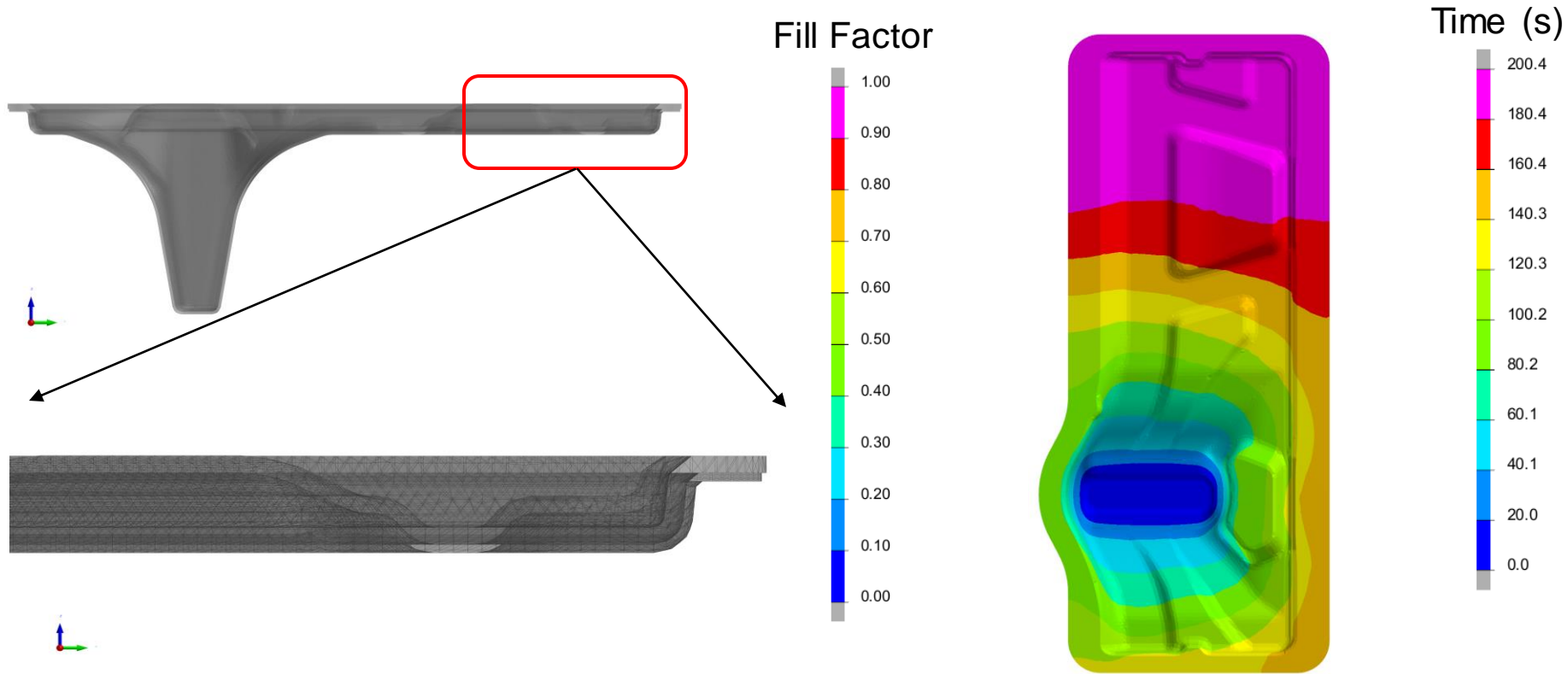
Simulation Setup



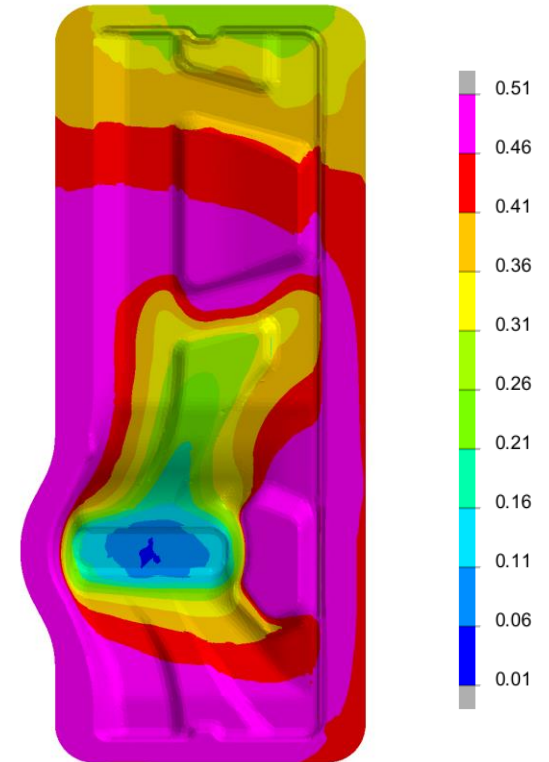
Simulation Parameters



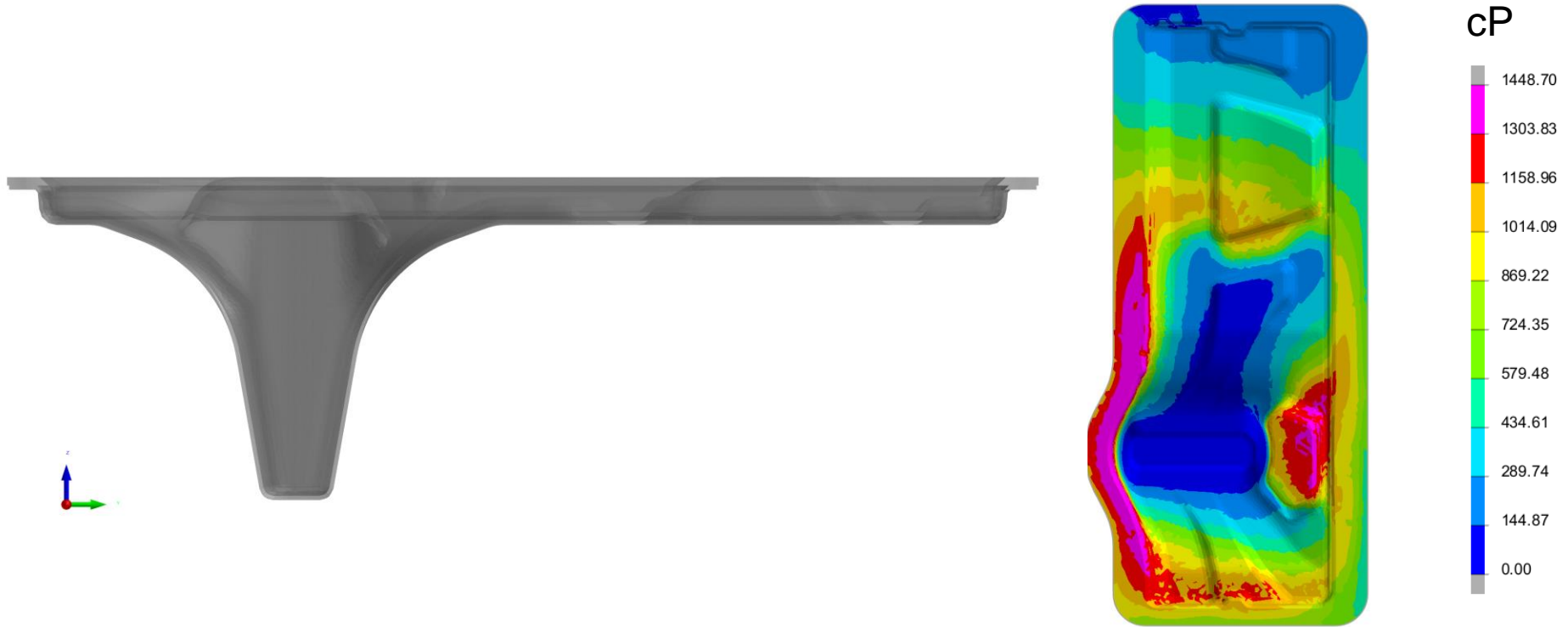
Injection Compression Simulation: Filling Factor



Injection Compression Simulation: Degree-of-cure



Injection Compression Simulation: Viscosity

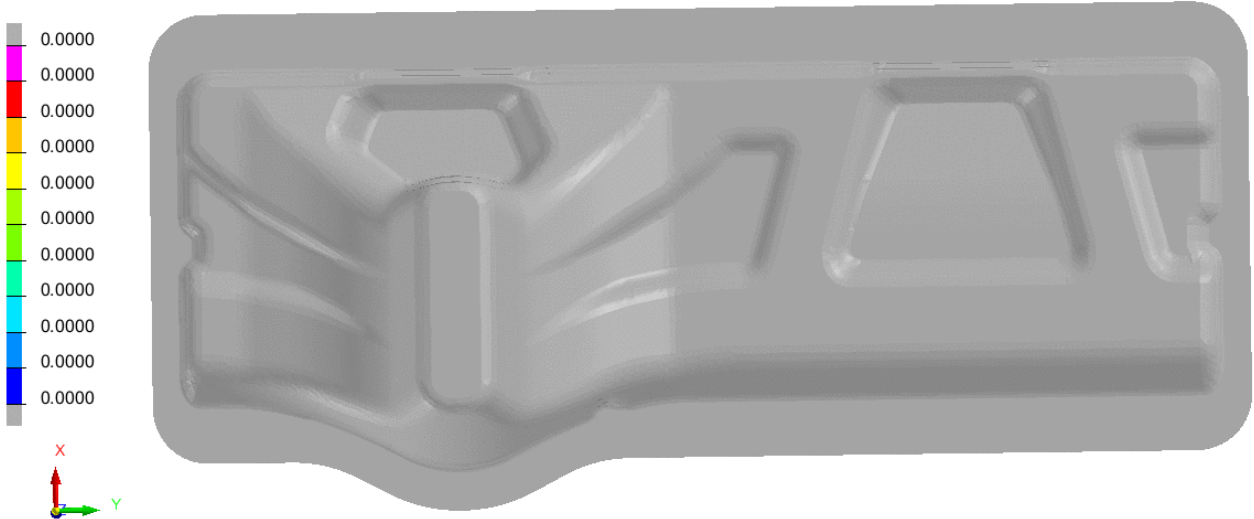


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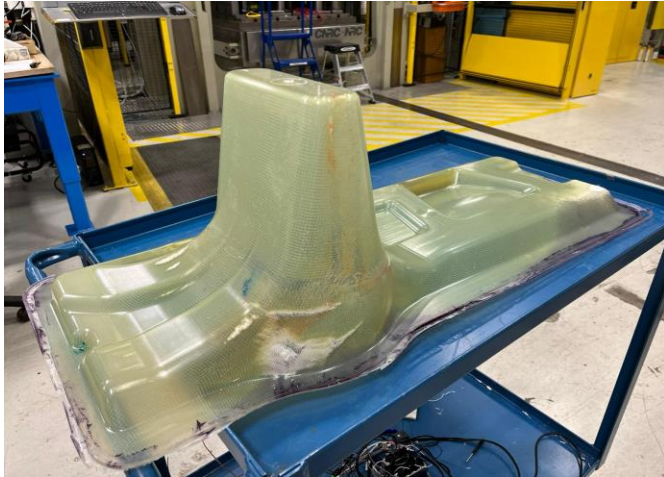
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Injection with Two Ports

1 / 0.000000



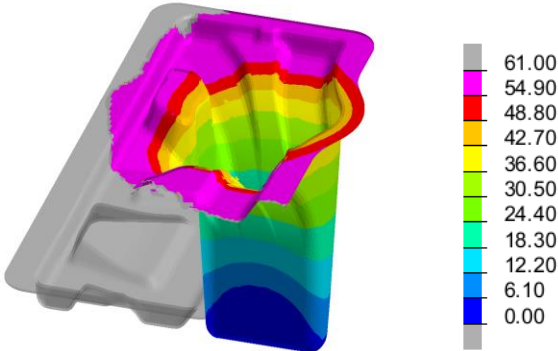
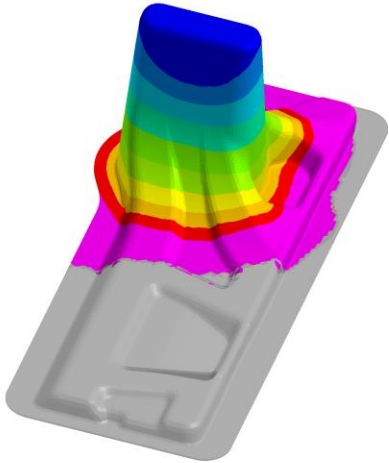
Final Demonstrator Part with Two Injection Ports



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Validation: Interrupted Filling Test (1min)



Conclusion

- Precise material modelling was crucial to accurately simulate the CRTM process with fast curing resin
- Fluid-solid coupled solver gave us good prediction with the experimental results for the CRTM process
- Sensor data was helpful to simulate and manufacture the complex demonstrator part

Future Work:

- Sensitivity analysis of curing to the flow of resin using non dimensional analysis

Acknowledgements

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Dr. Arnaud Dereims (esi group)



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Questions?



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