IN-SITU MIXING AND PRINTING OF CONTINUOUS CARBON FIBRE REINFORCED THERMOSET COMPOSITES

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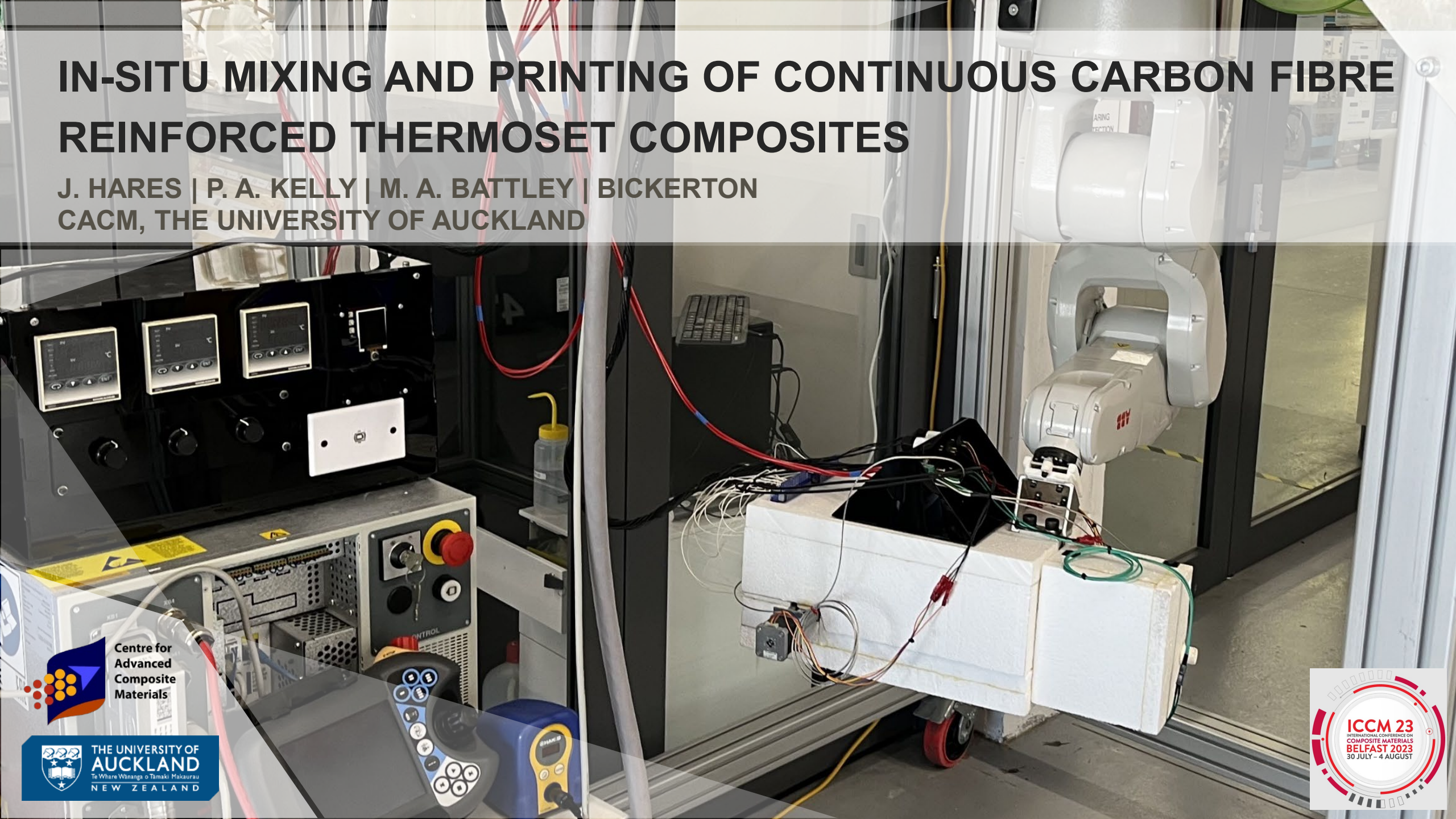
CACM, THE UNIVERSITY OF AUCKLAND



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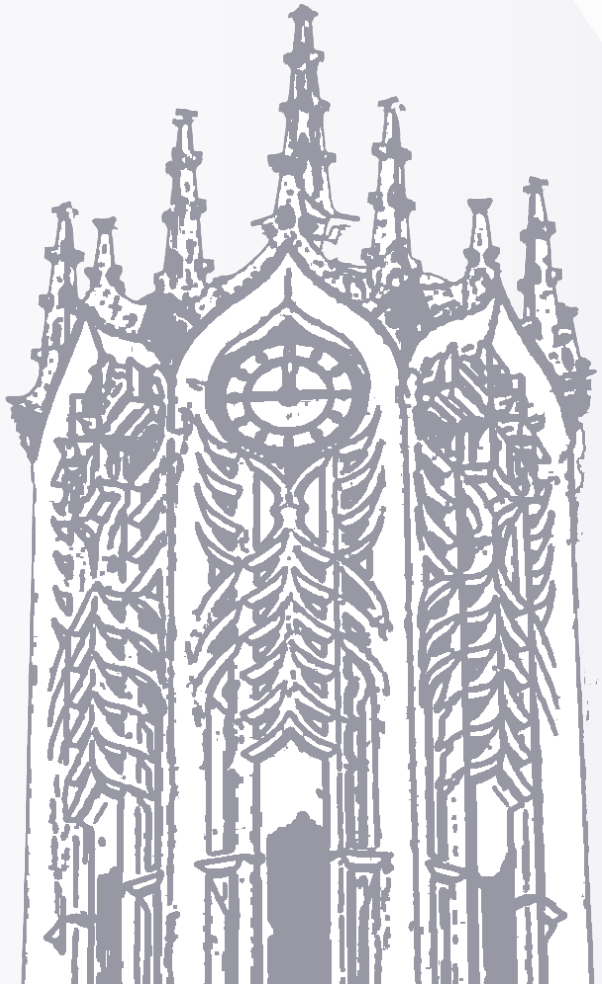
ICCM 23
INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS
BELFAST 2023
30 JULY – 4 AUGUST

CONTENT

- Motivation and Background
- Material Characterisation
- Process Characterisation
- Printer Prototype



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Motivation and Background

IMPETUS, STATE OF THE ART, SCOPE

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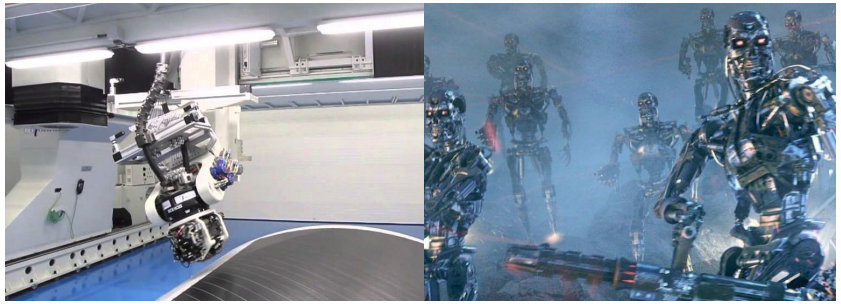
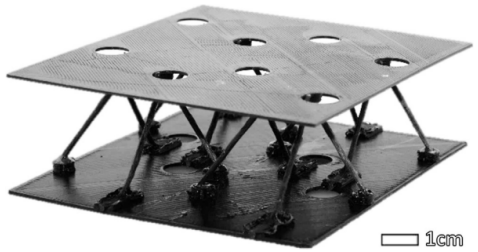
Why Composite Printing?

Automation!



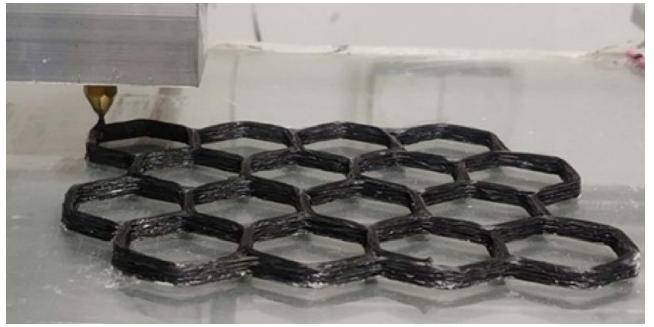
Composites are hard to make

Better parts!



Has anyone else done this?

Of course they have!



But there is a long way to go…

- Low material properties.
- Low volume fraction/no compaction.
- Thermoset printing is underdeveloped.

What will we do?

Gaps in the state of the art

- Thermoset printing is not in commercial use.
- *Very little* investigation into processing behaviour.
- Thermoset printing is underdeveloped.

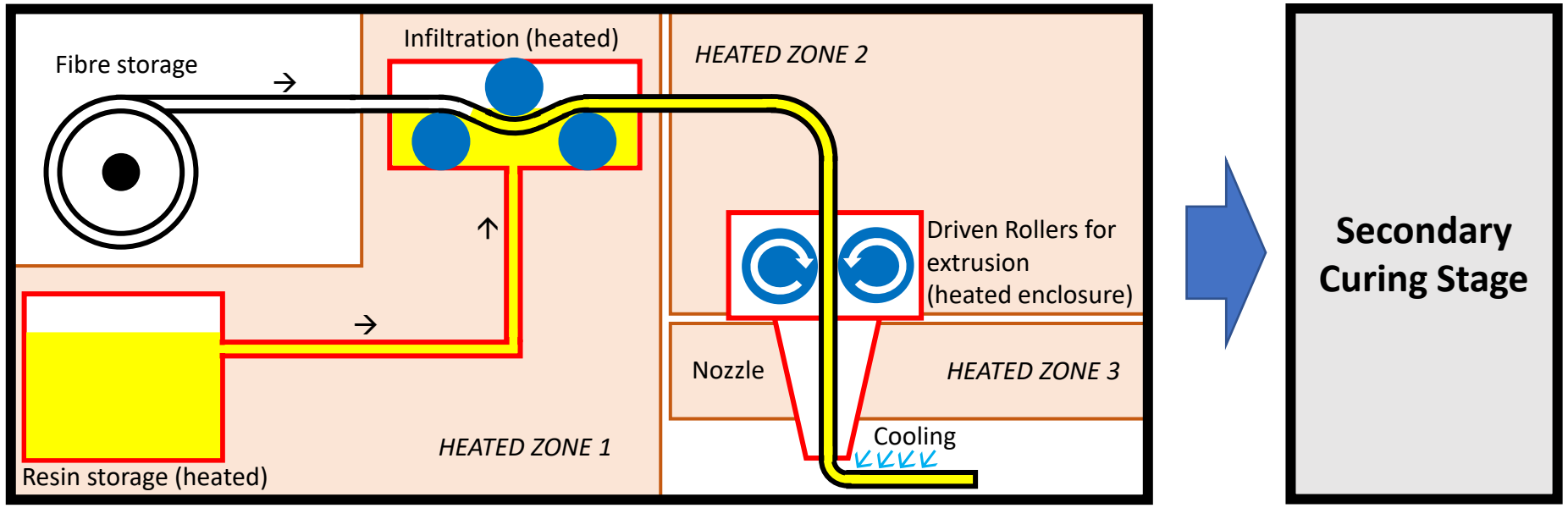
Scope

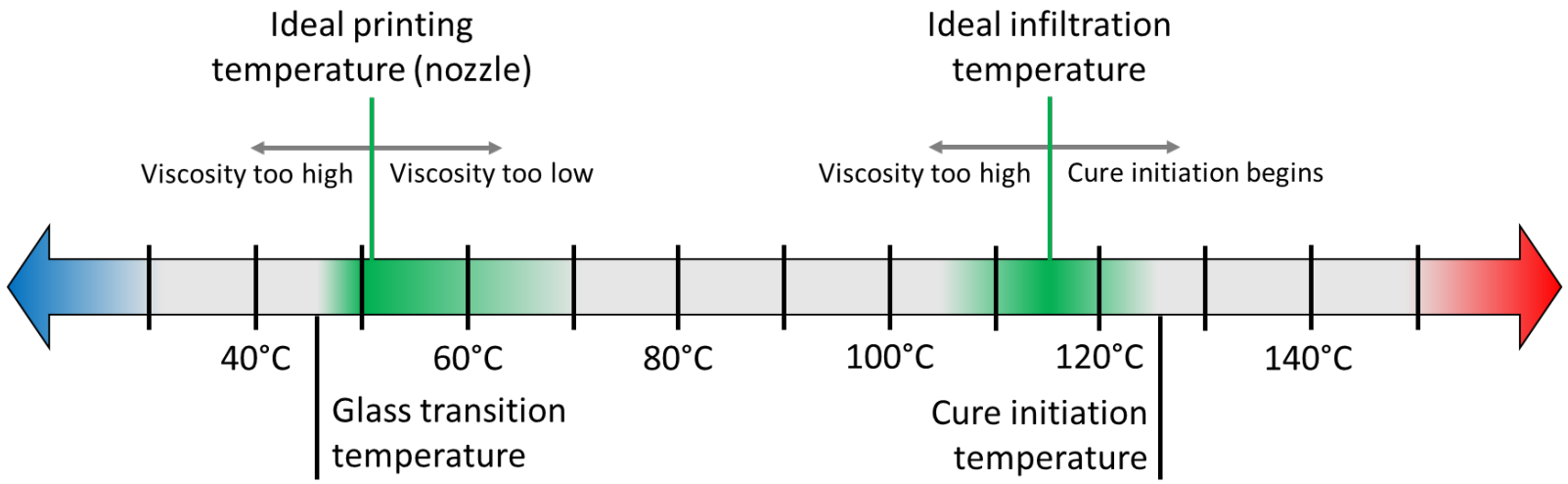
'Processing-science based design'

- Resin characterisation.
- Fibre characterisation.
- Build a prototype

Resin Characterisation

SOLID EPOXY-BASED PRINTING PROCESS CONCEPT





Resin Characterisation

EXPERIMENTS

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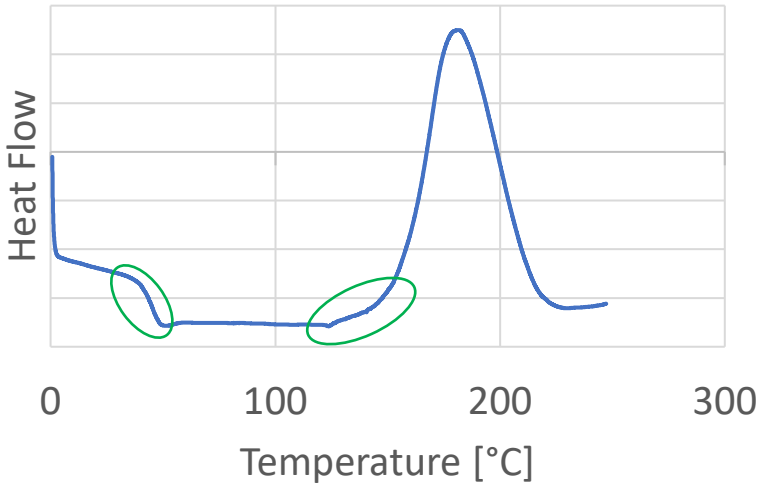
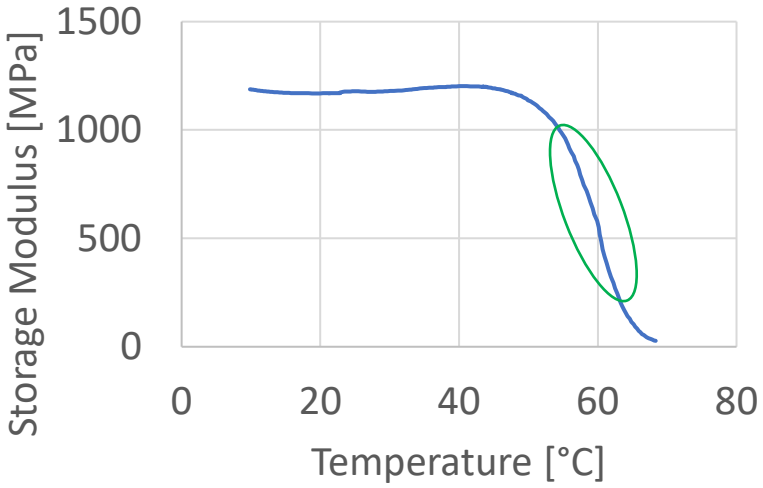
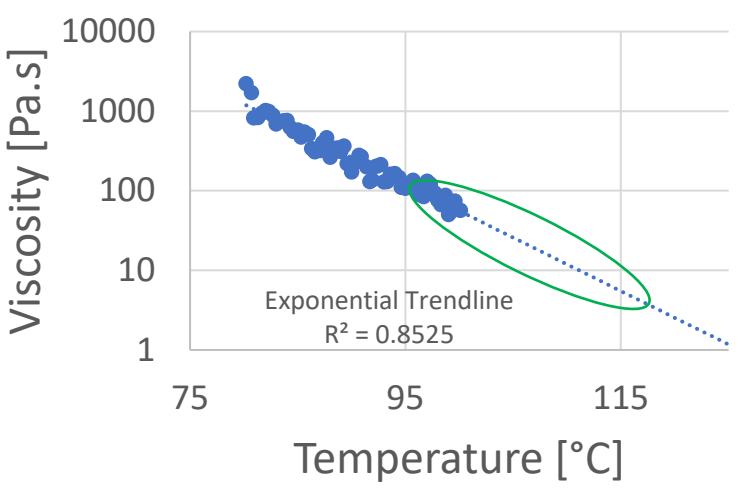
DSC

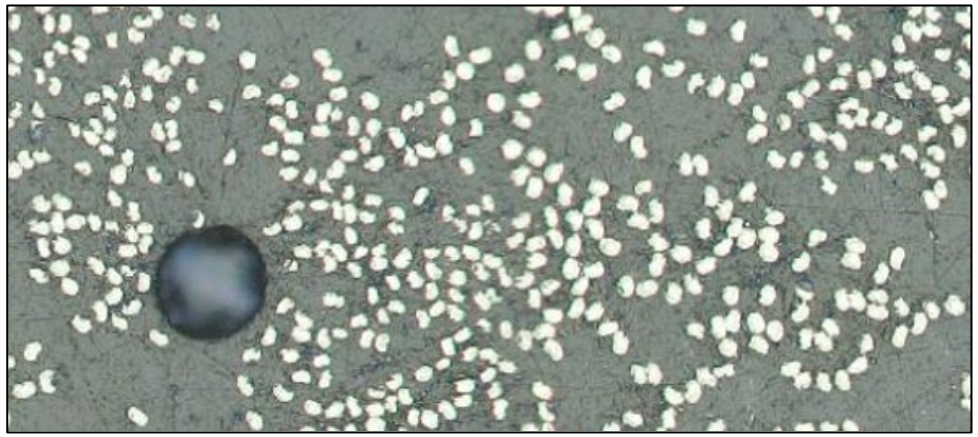


DMA

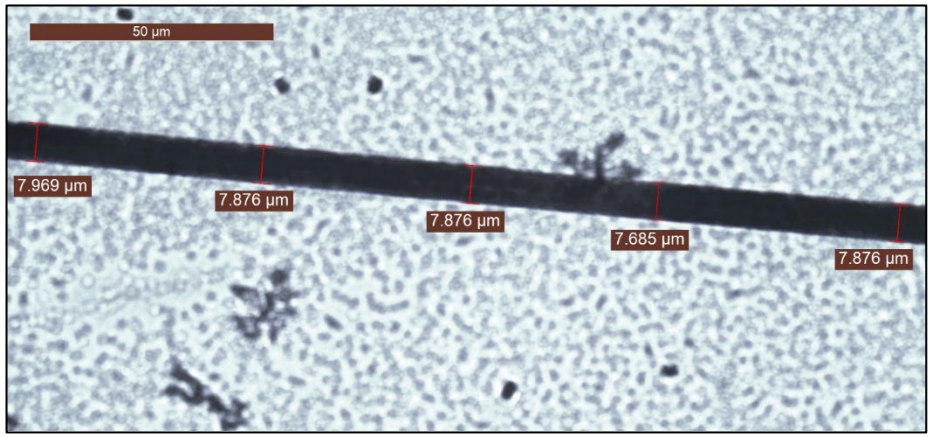


Rheology





Filament Count



Filament Width

Tow Characteristics and Infiltration

EXPERIMENTS

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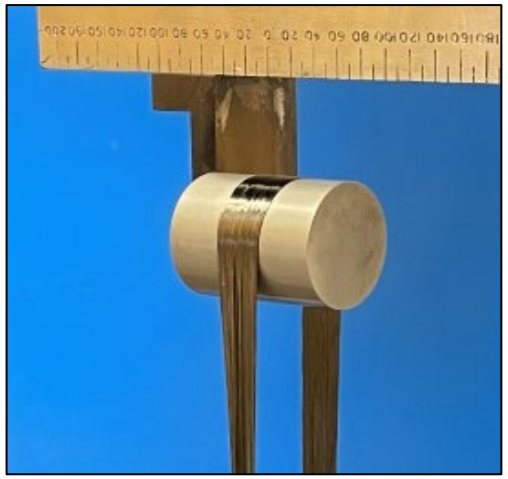
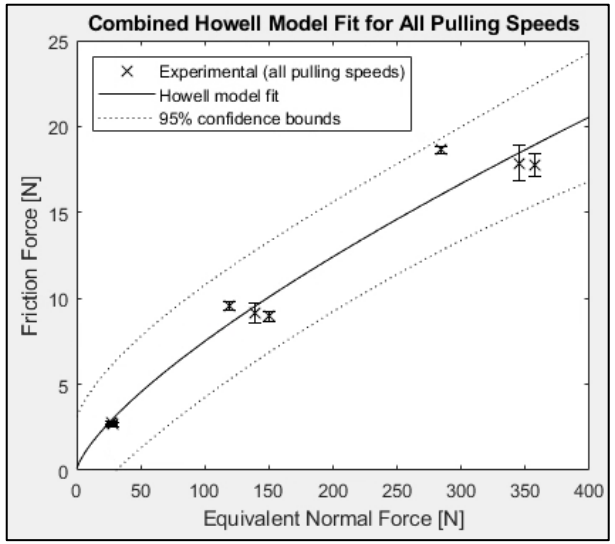
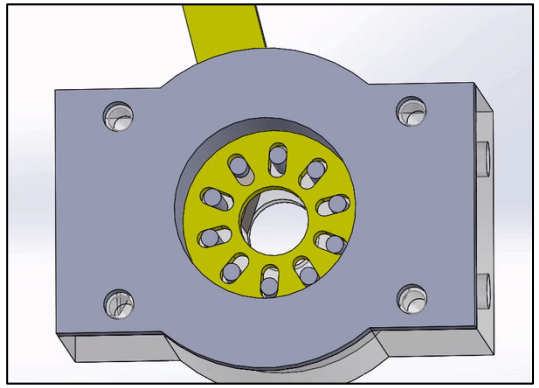
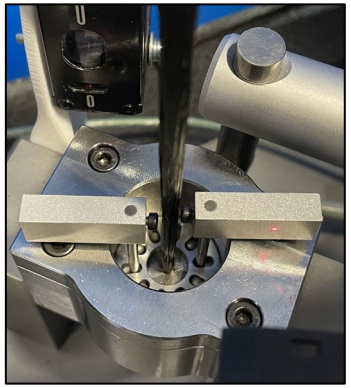
Tow/Metal Friction

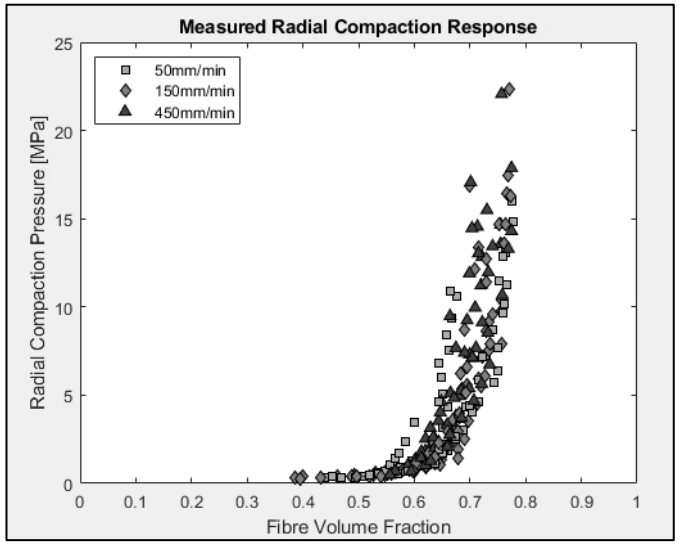




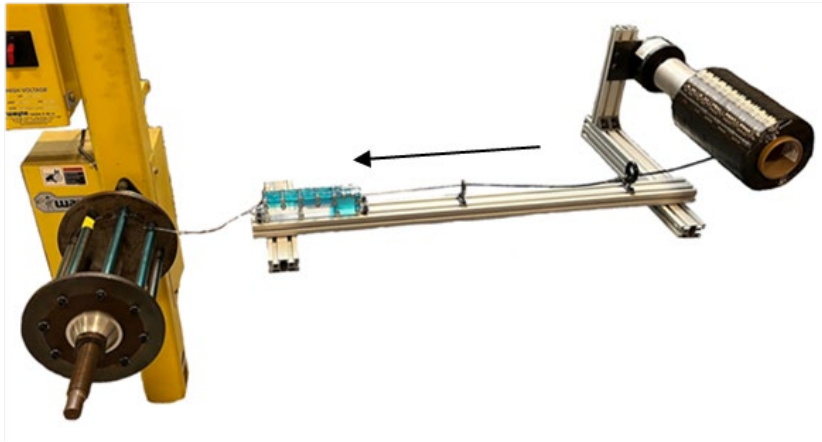
Radial Compaction







In-Line Infiltration



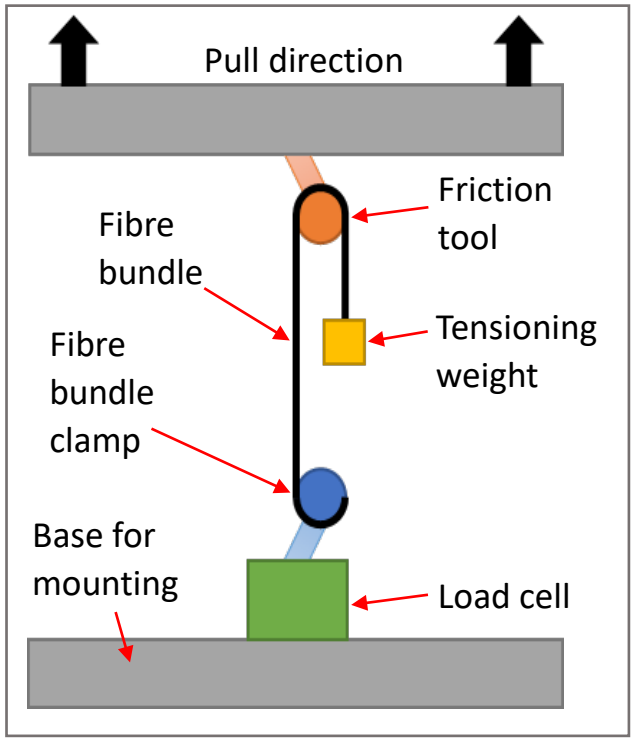
Tow Characteristics and Infiltration

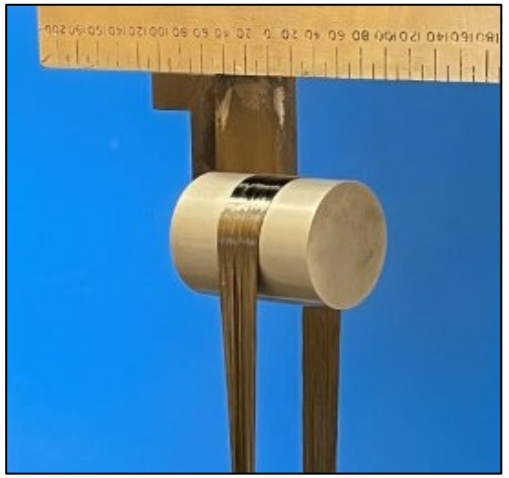
FRICTION MEASUREMENT SETUP

- Need to measure coefficient of friction between iris and fibre material.
- Pull tensioned fibre over drum made from iris material.
  - 4340 steel, 2-4Ra isotropic roughness.
- Capstan Equation used to calculate coefficient of friction.

$$\mu_{app} = \ln\left(\frac{T_2}{T_1}\right)\frac{1}{\theta}$$

  - μ_{app} - Applied friction coefficient.
  - $T_{1,2}$ - Fibre tension on each side of drum.
  - θ – Wrap angle.

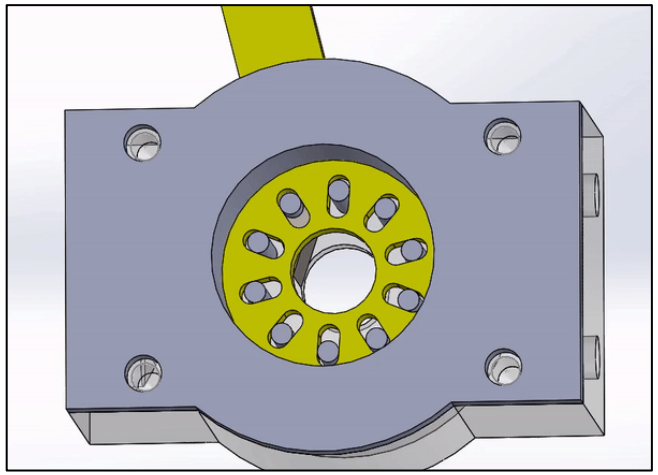


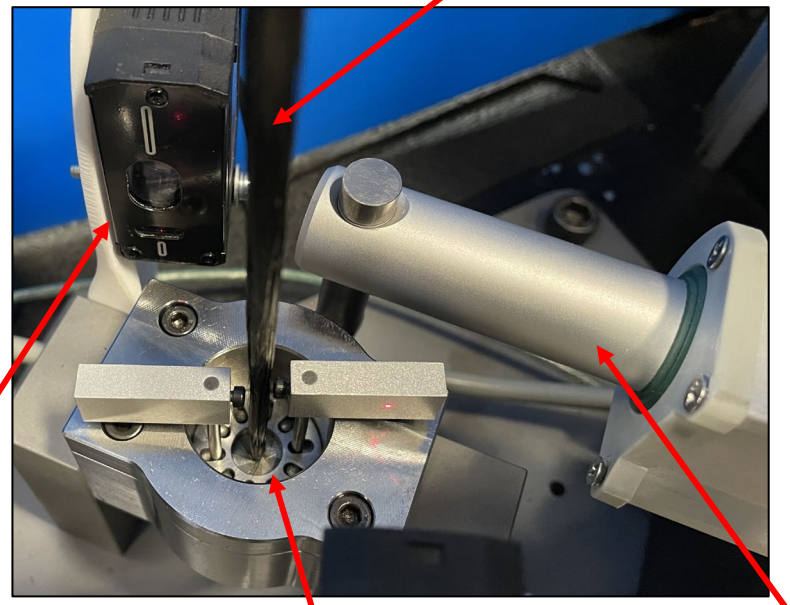


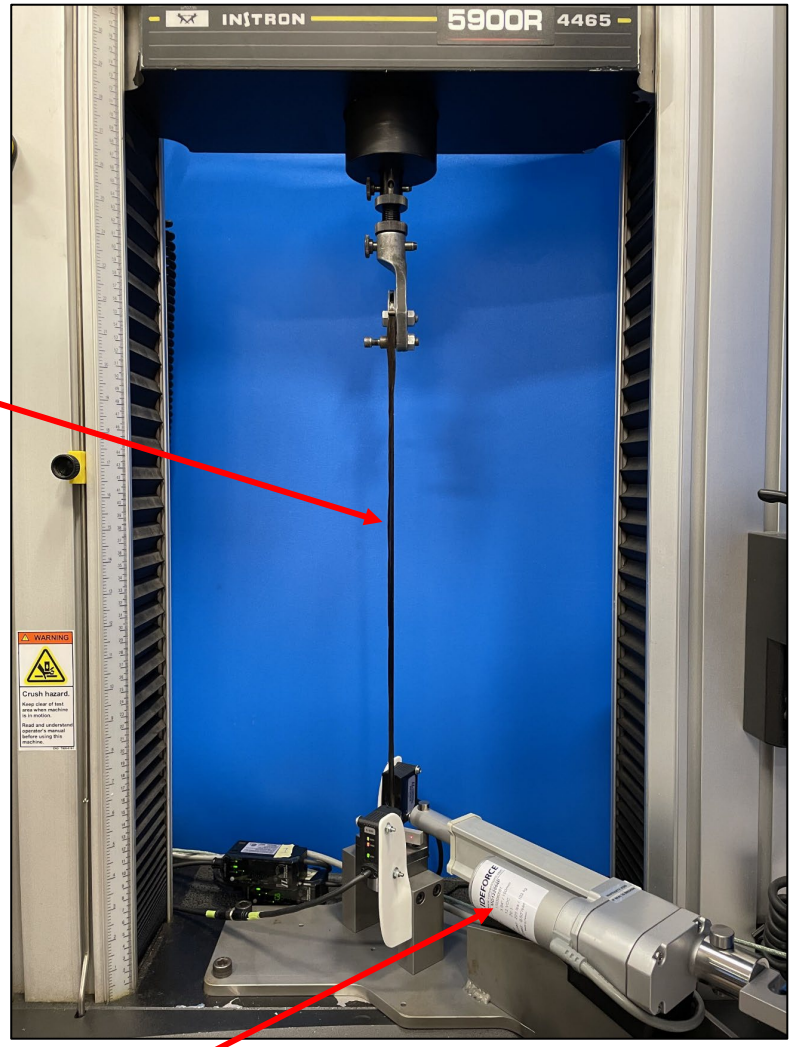
Tow Characteristics and Infiltration

RADIAL COMPACTION, IRIS MECHANISM SETUP

- Need to measure σ_c and V_f relationship for single fibre tows.
  - Must be able to vary opening area.
- Ability to characterise more complex behaviour.
- *Solution: 'Iris' mechanism experiment.*

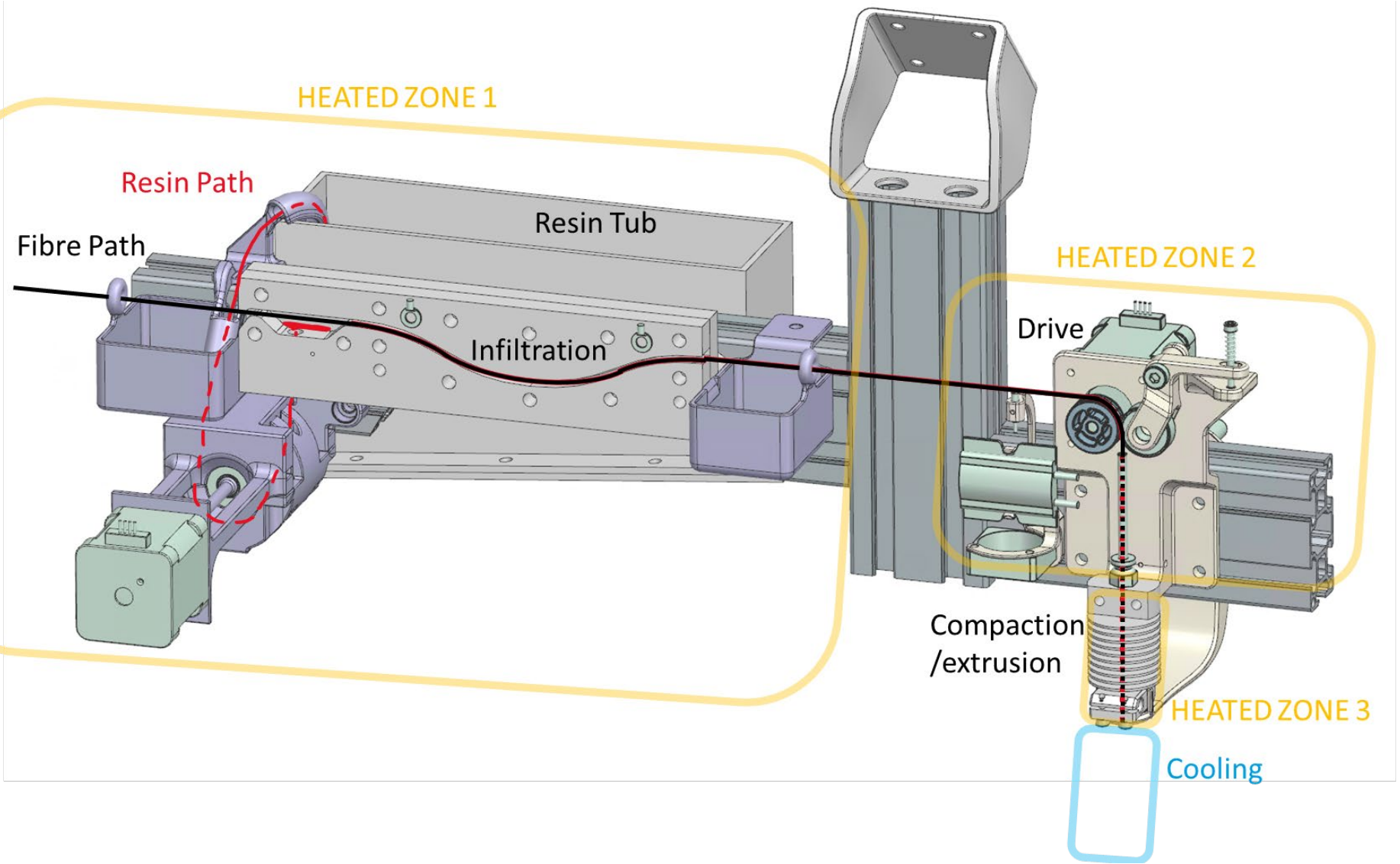






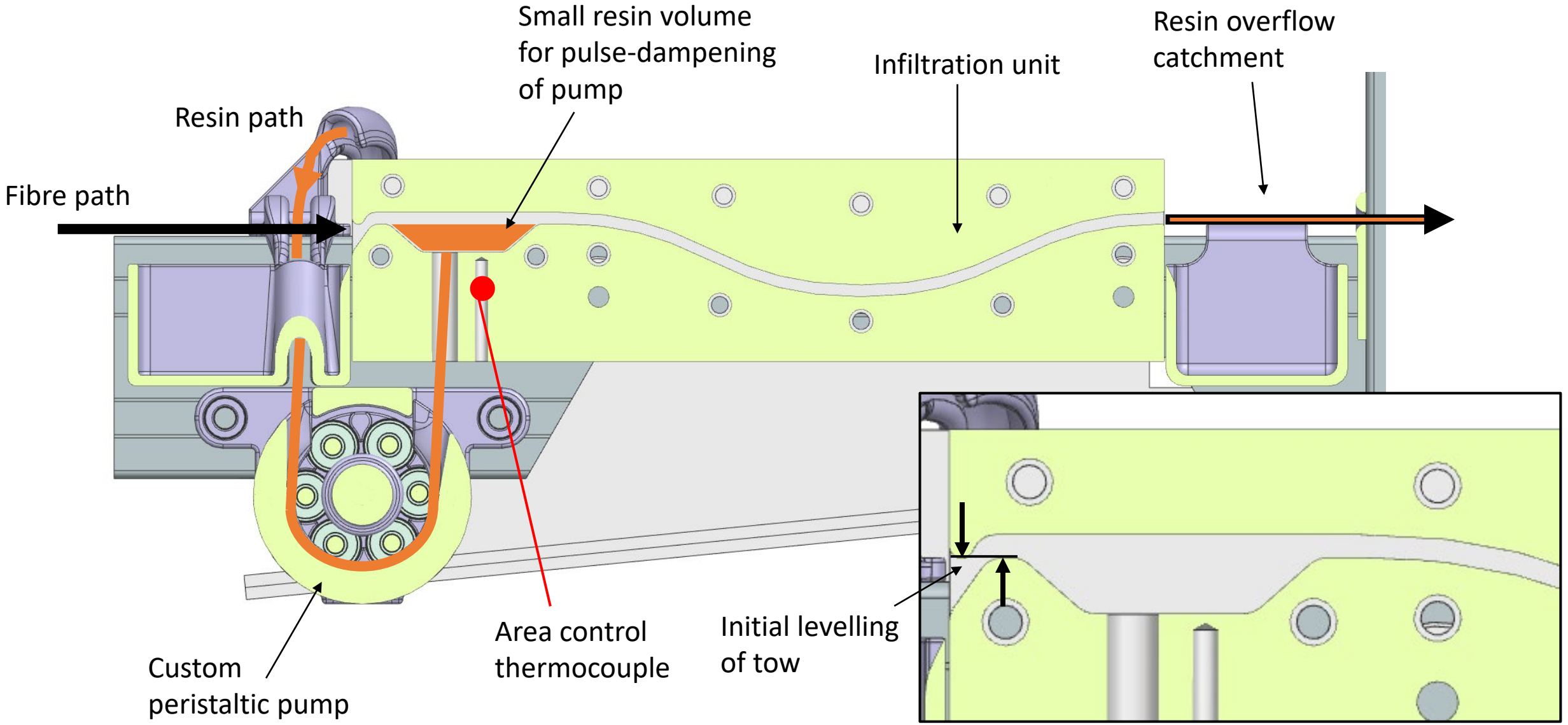
Printer Design

OVERVIEW



Printer Design

ZONE #1 – RESIN STORAGE, PUMPING, & MIXING



Printer Design

ZONE #2 - DRIVE

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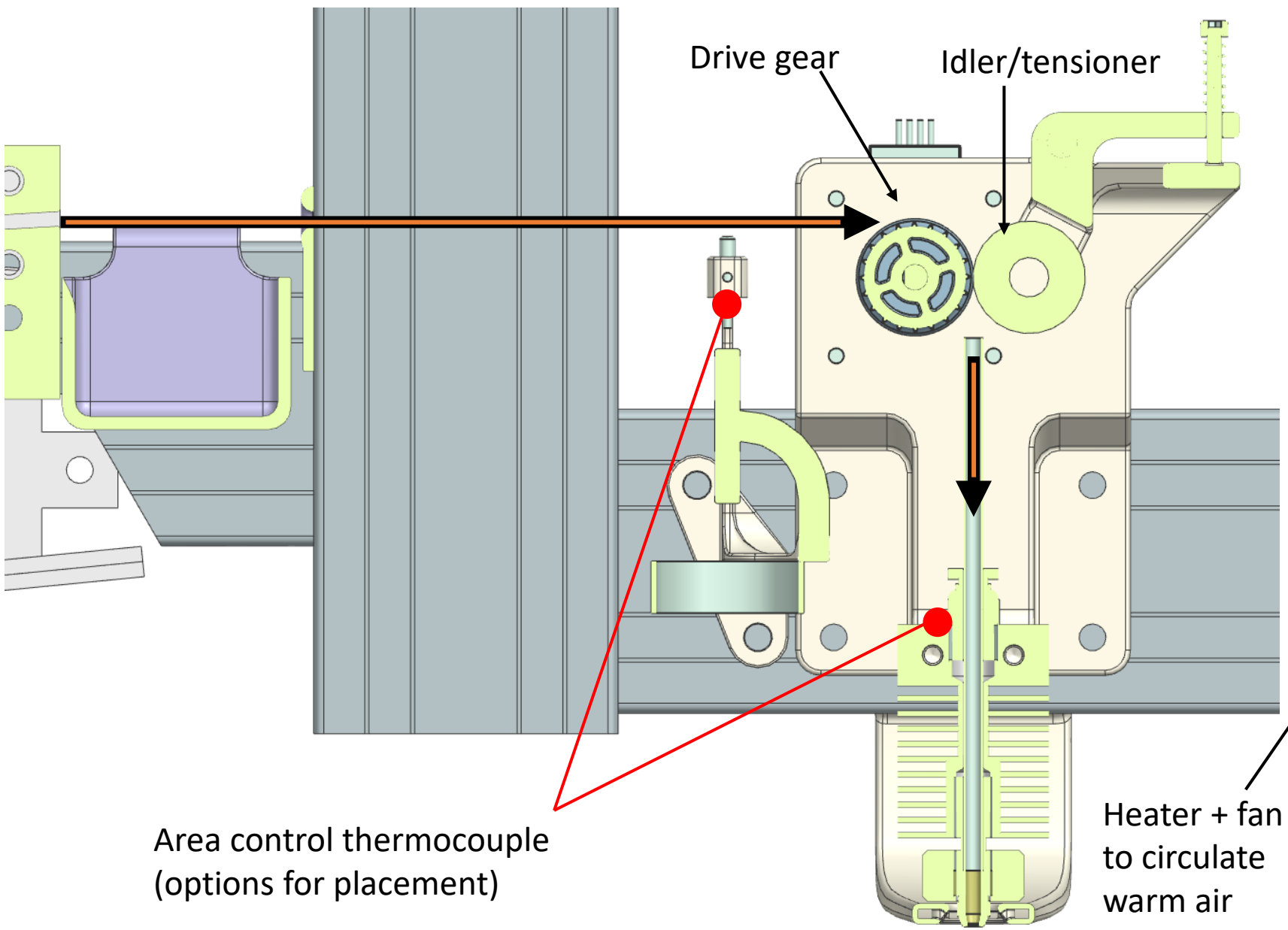
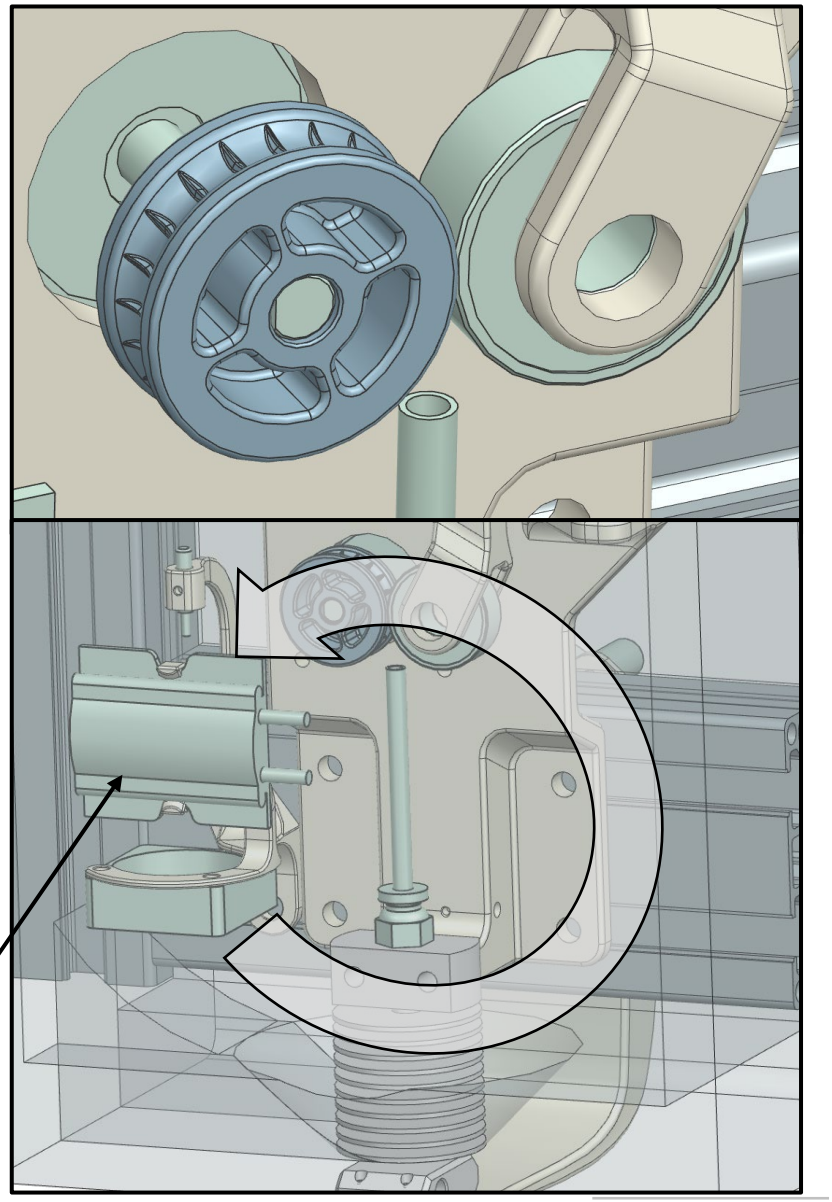
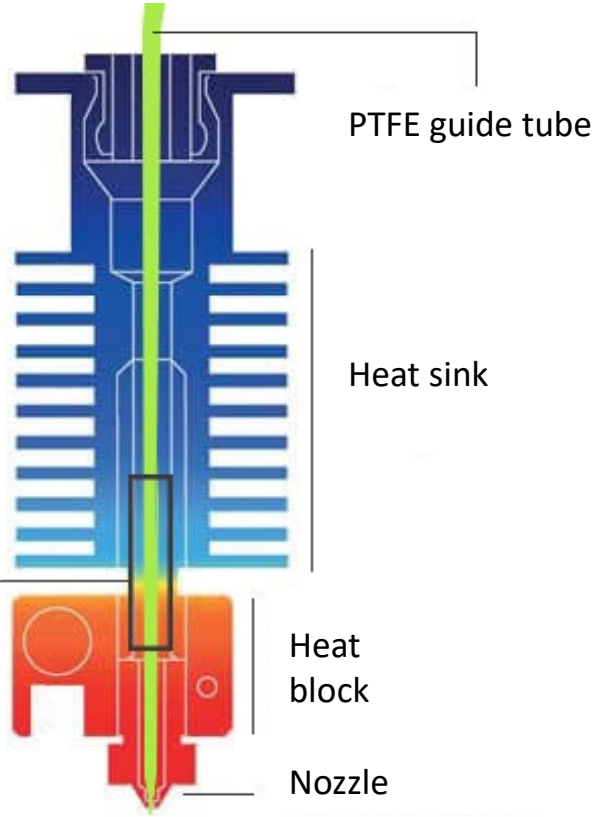
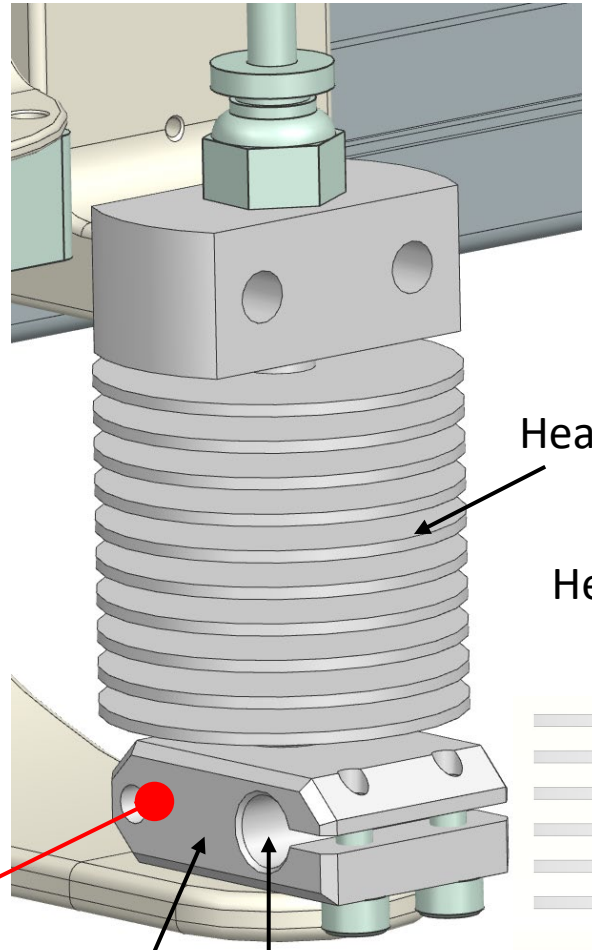


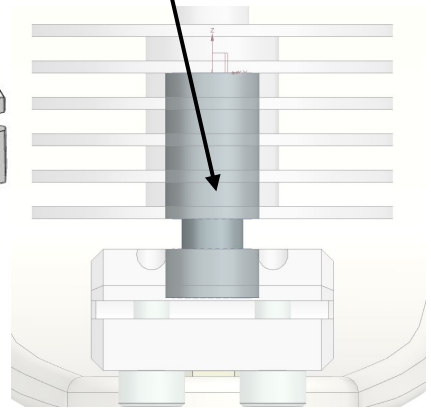


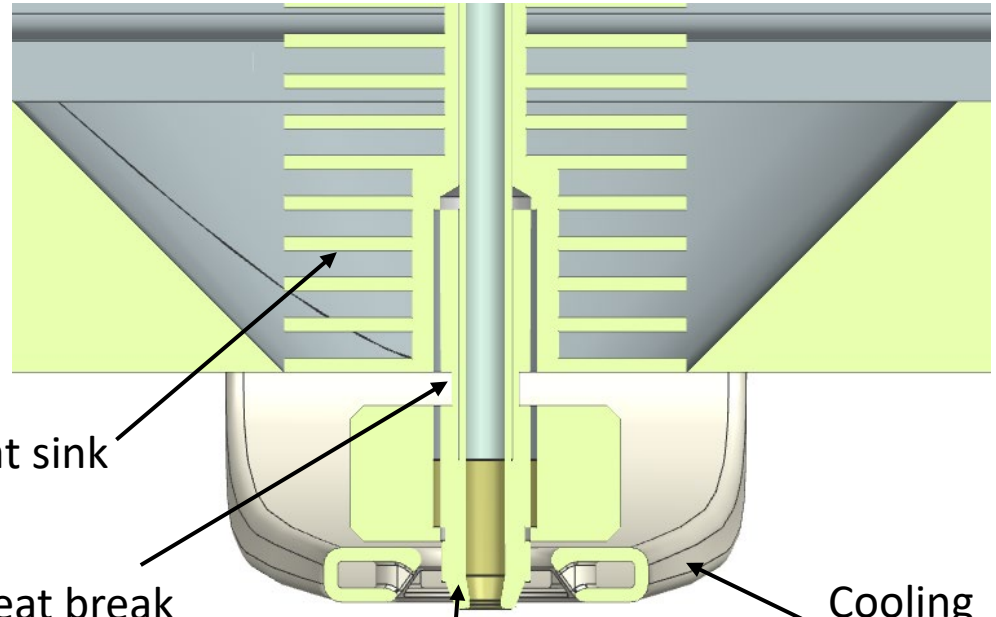
Printer Design

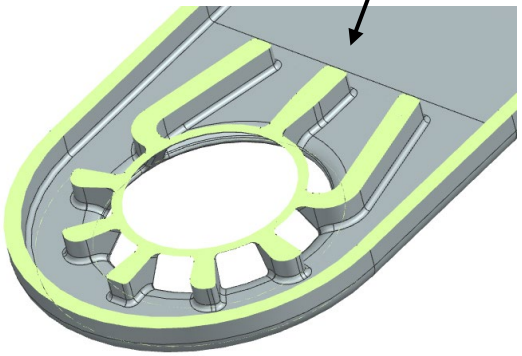
ZONE #3 - NOZZLE





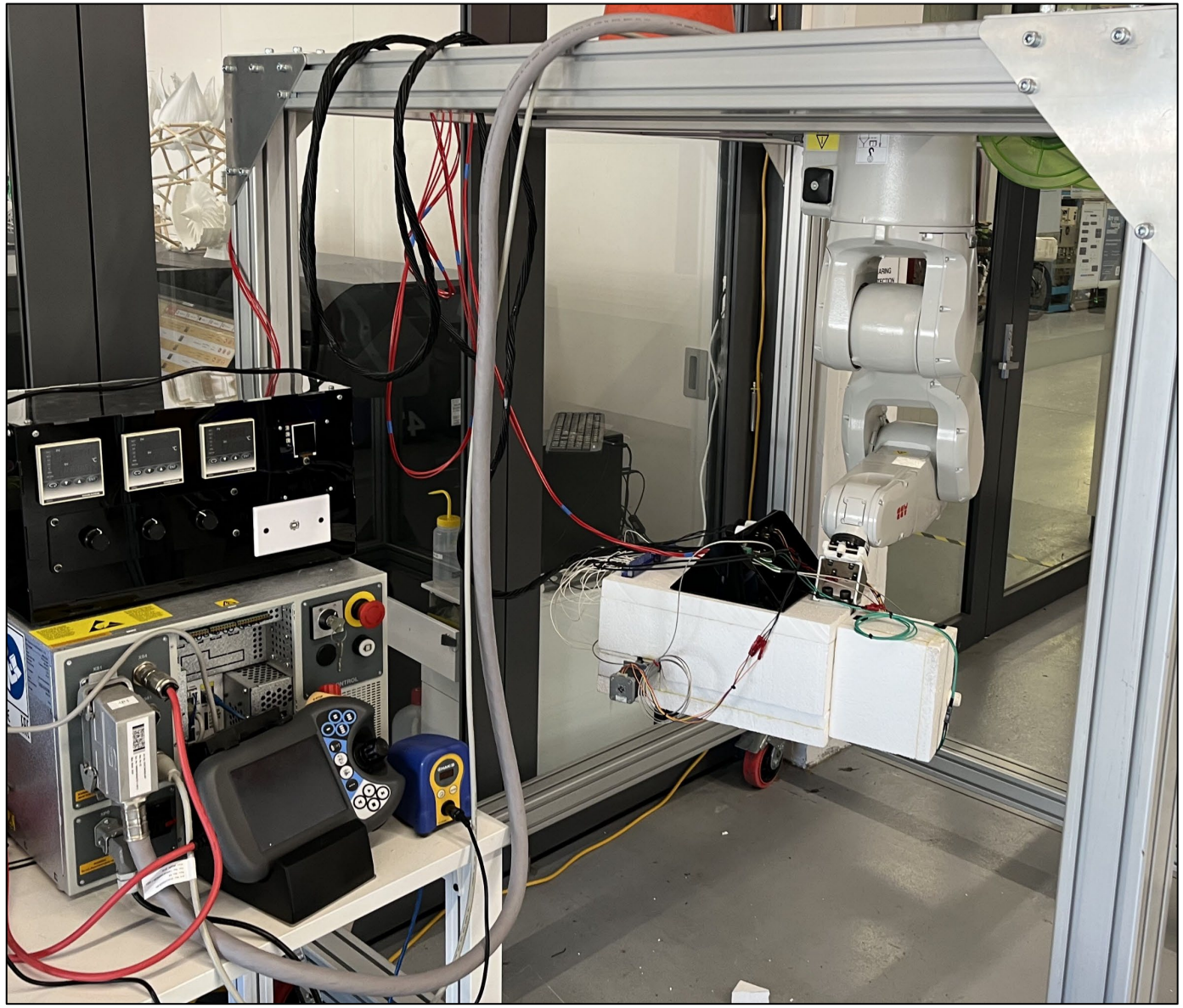


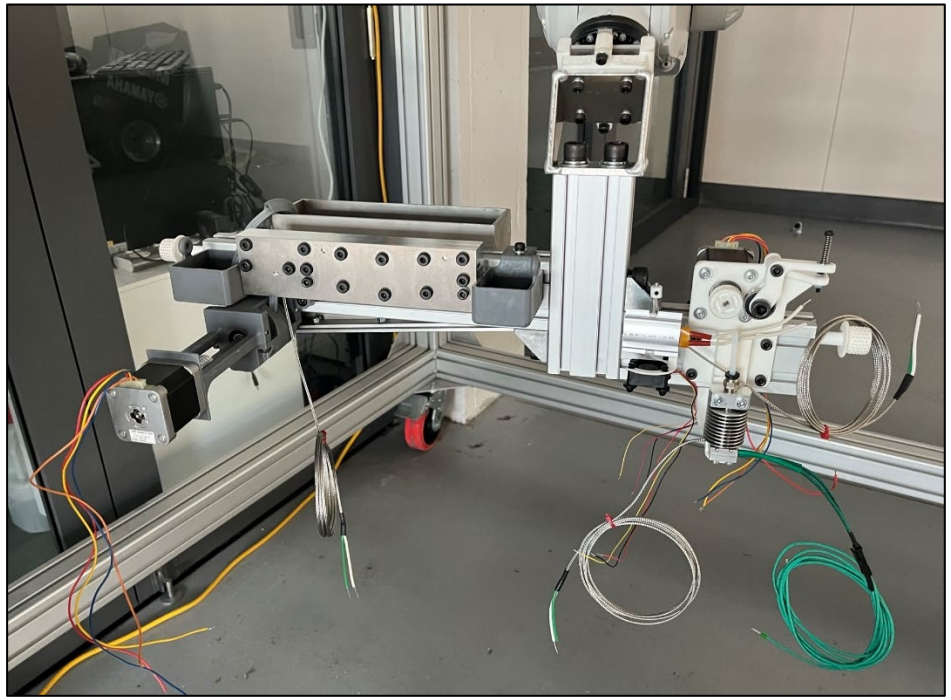




Printer Prototype

CURRENT STATUS





Printer Prototype

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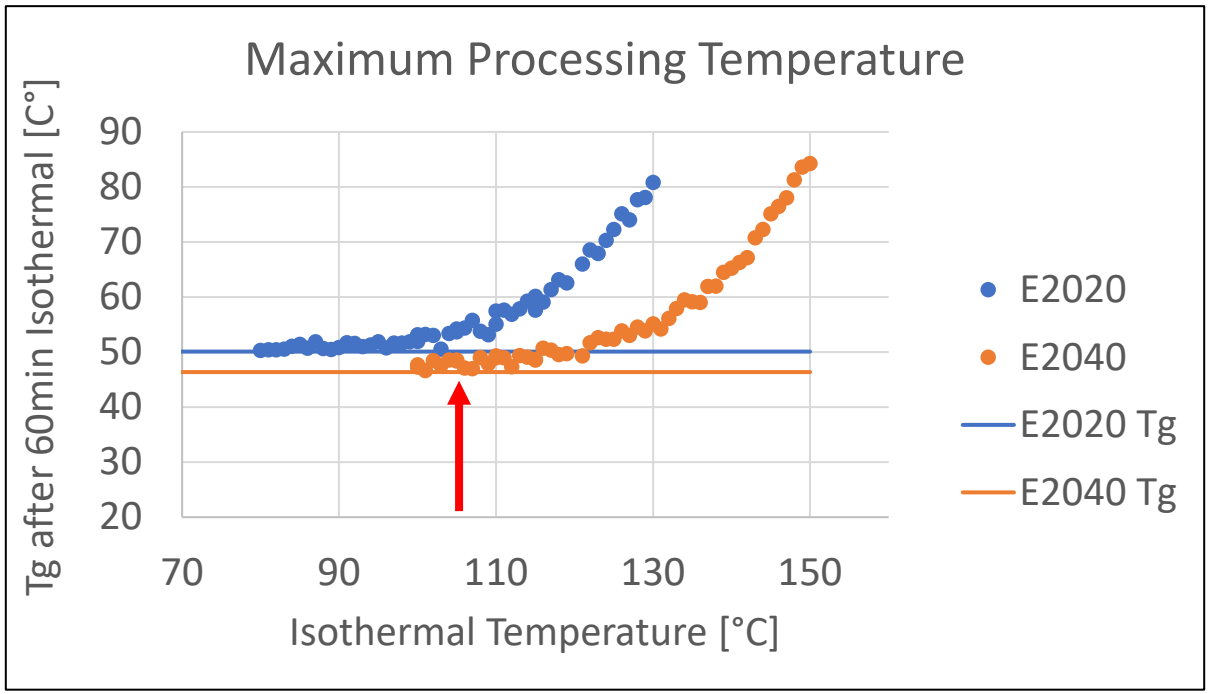

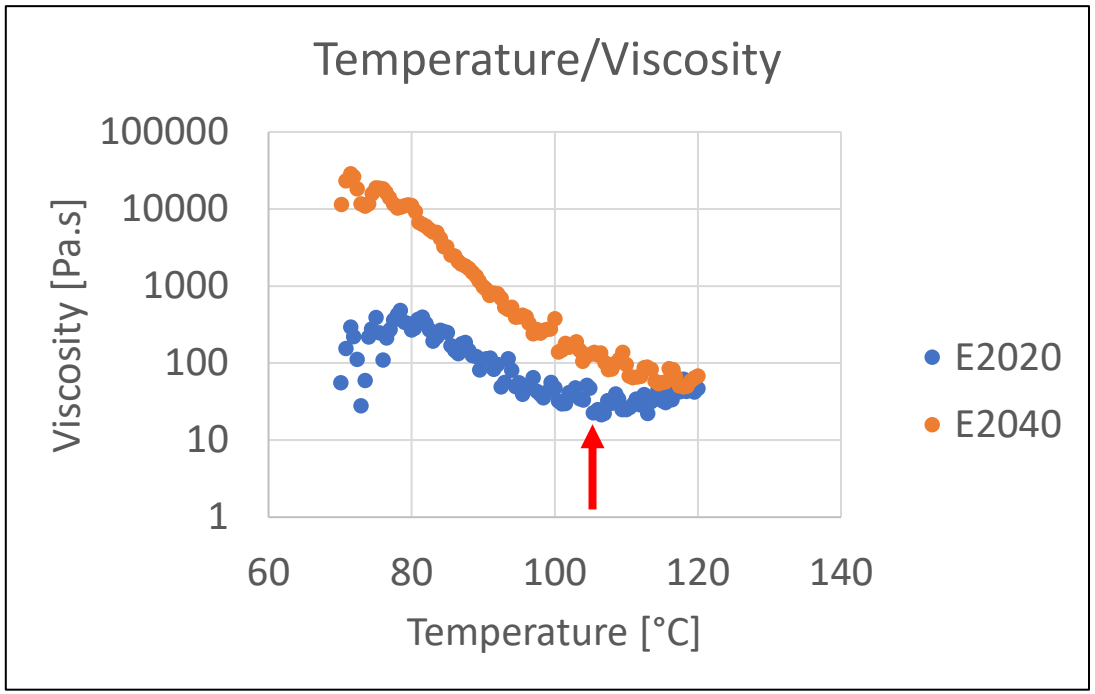

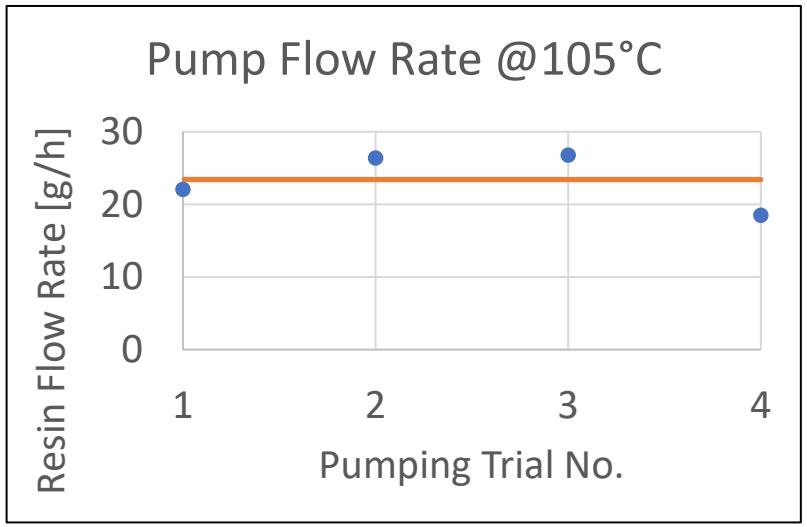

Remaining steps:

1. Flow rate consistency.
2. Resin and fibre together.
3. Microscopy of composite.
4. Tensile test of composite.

Concluding Remarks

A novel concept for a continuous fibre 3D print head has been developed, which infiltrates a carbon fibre tow with a thermoset epoxy in-situ.

The print head has been designed from a series of in-depth material and process chartacterisation experiments, including:

- DSC and Rheometric studies on an epoxy, solid at room temperature.
- Fibre tow frictions, and radial compaction studies.
- Extension and testinng of the Siphon tow infiltration technique developed by the Leibniz-Institut für Verbundwerkstoffe, to small scale.

The prototype print head is currently being commissioned and debugging. The latest progress will be presented at ICCM23.

Acknowledgements

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