

Flow-front measurement and simulation in liquid composite moulding

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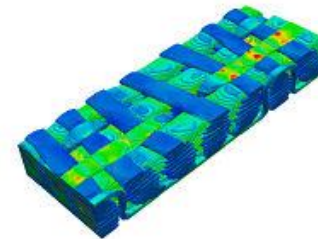
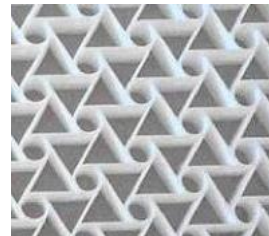
Bristol Composites Institute (ACCIS)

- Established in 2007
- Granted Institute status in 2017
- Core team of 25 academic staff
- Over 30 further affiliated academics in Engineering, Science and Medicine
- Host 2 Centres for Doctoral Training
- Around 200 people overall (Uni)
- Host the National Composites Centre



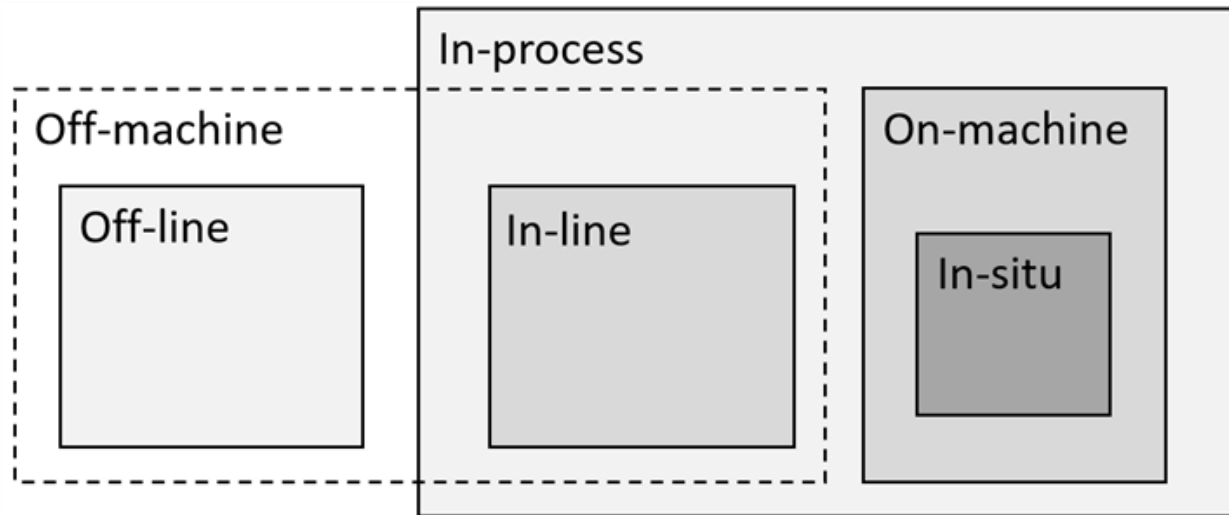
- **ACCIS Groups:**

- Materials
- Structures
- Manufacture and Design



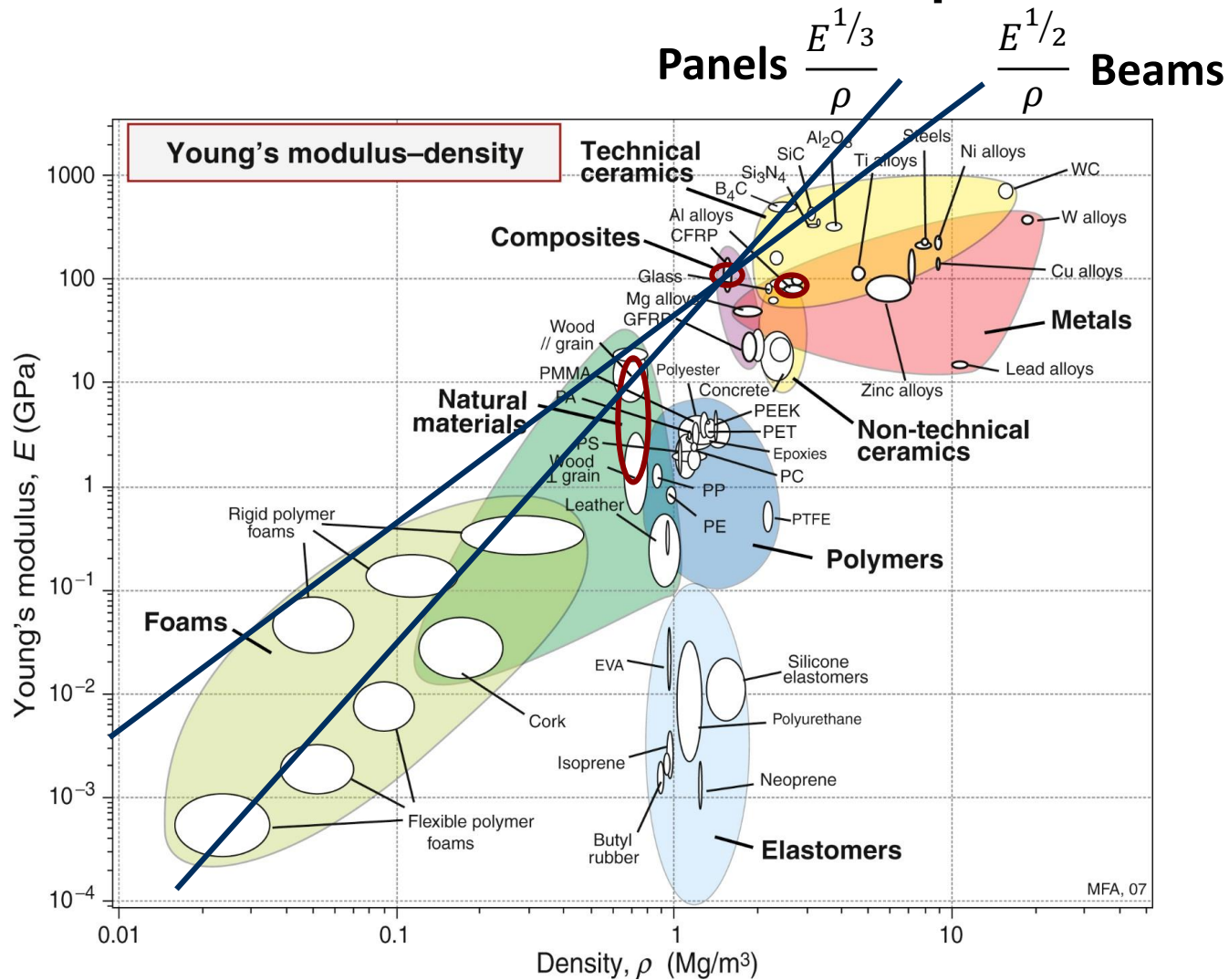
Outline

- Composite materials
- Liquid composite moulding
- In-situ sensing
- Future opportunities

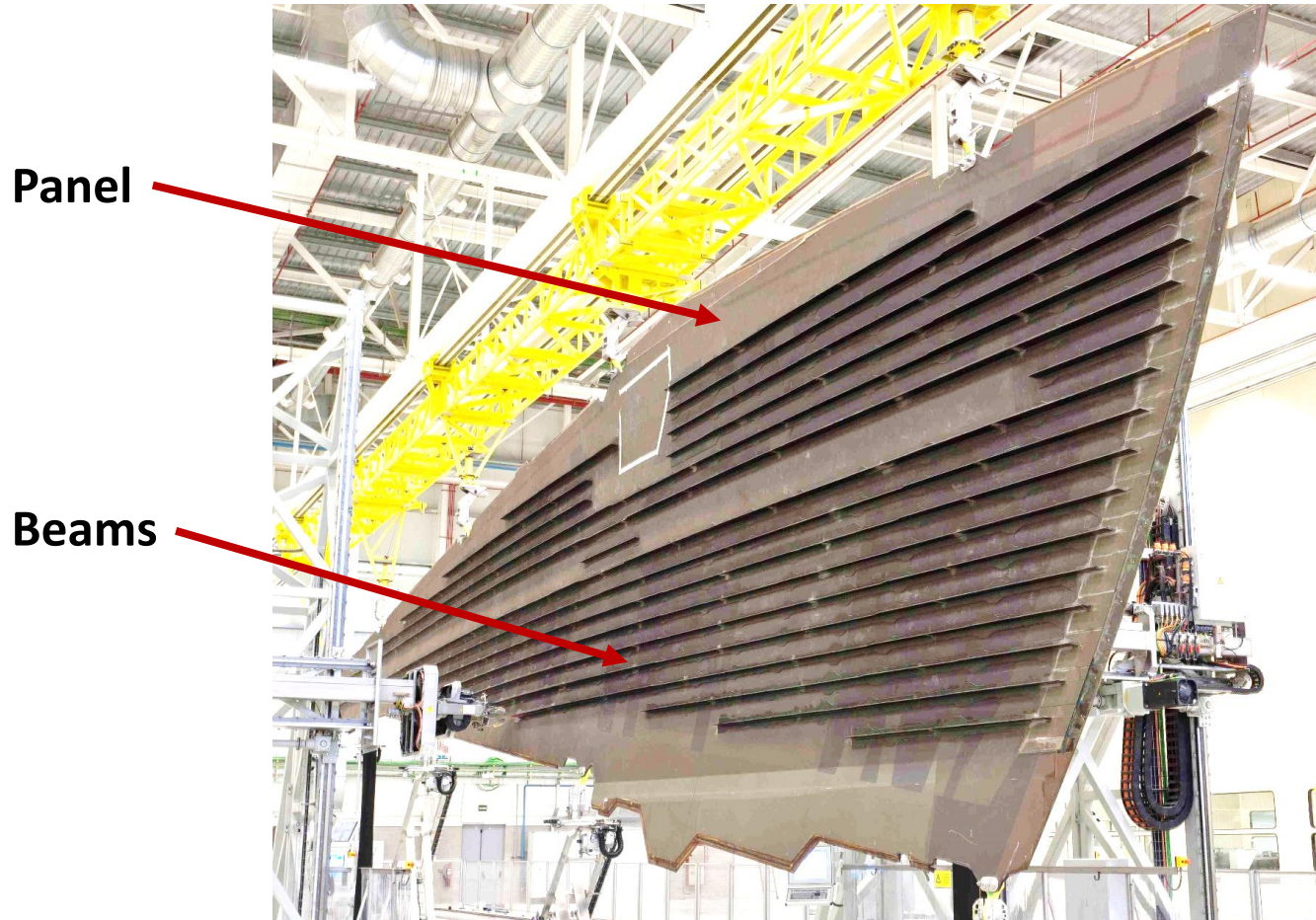


MetMap 2019 manufacturing metrology definitions

Motivation – Advanced Composites



Example – Aerospace Composites

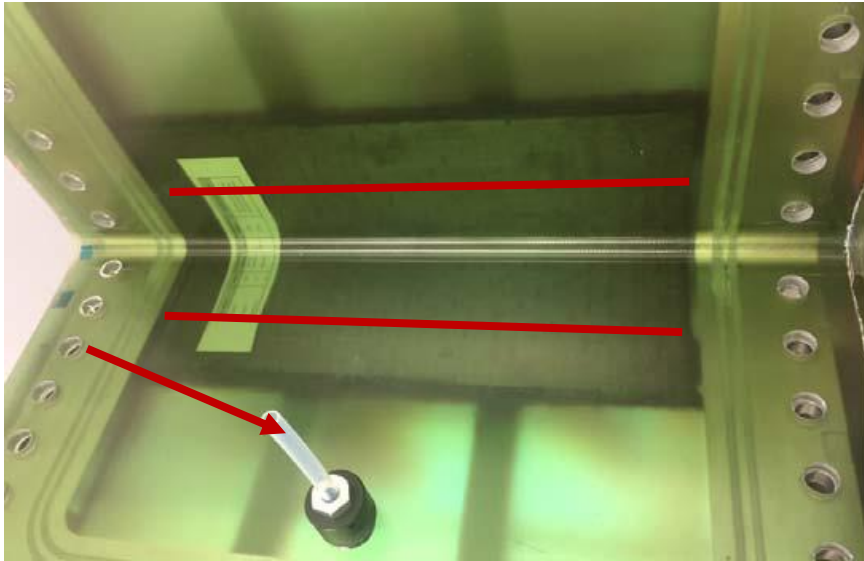


Airbus A350 Wing Cover

Motivation – Liquid Composite Moulding

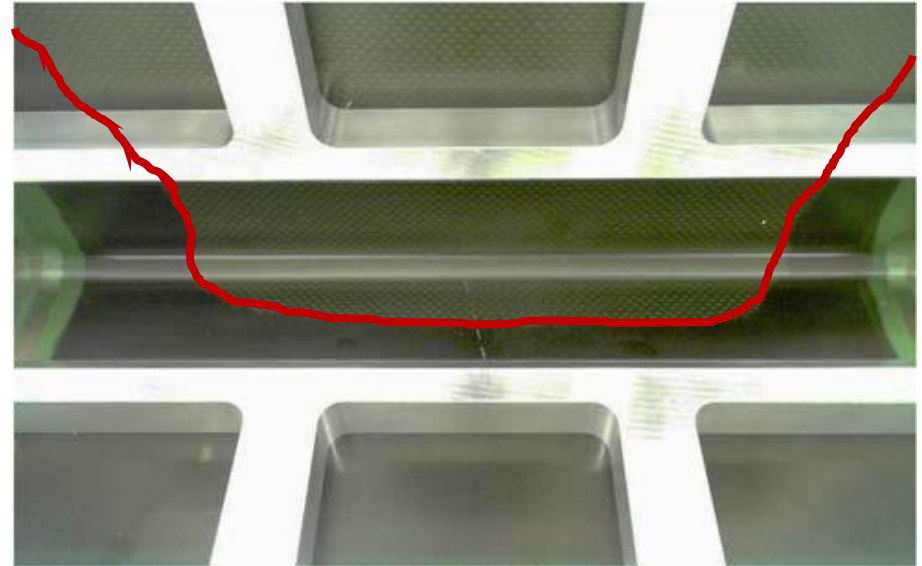
How do we position the fibres according to design?
How do we get the polymer to fill the empty space?

Want rectangular fluid flow



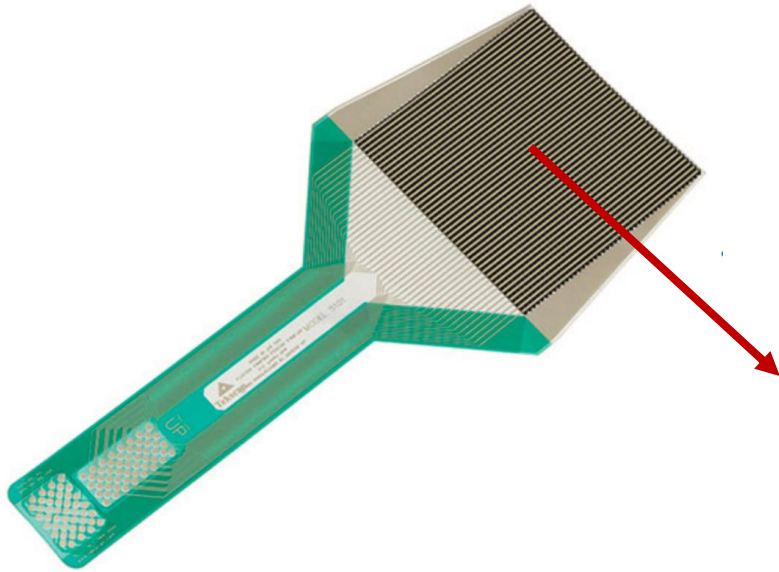
Bracket preform in mould

NOT rectangular fluid flow



Bracket preform infusion

In-situ Monitoring



TekScan Pressure Mapping Sensor

Non intrusive

~2000 sensels in 110mm x 110mm

Quantitative data

Pressure
map

Characterise material
properties

Permeability

Simulate flow front

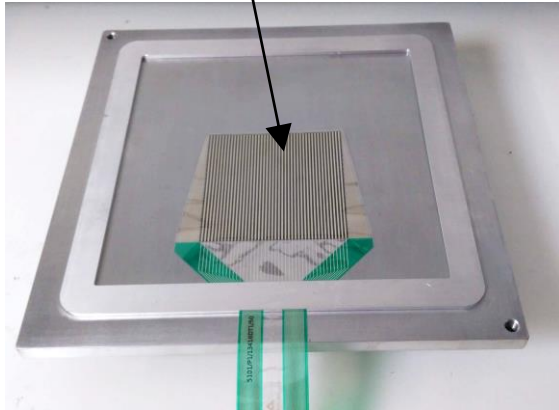
Validation

Measure flow front

Control

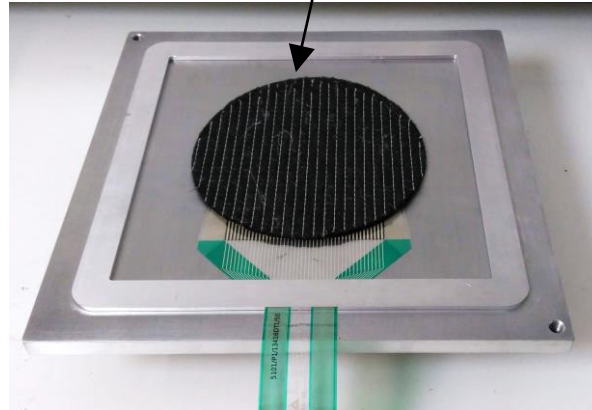
Experimental Set-up

Surface mapping sensor



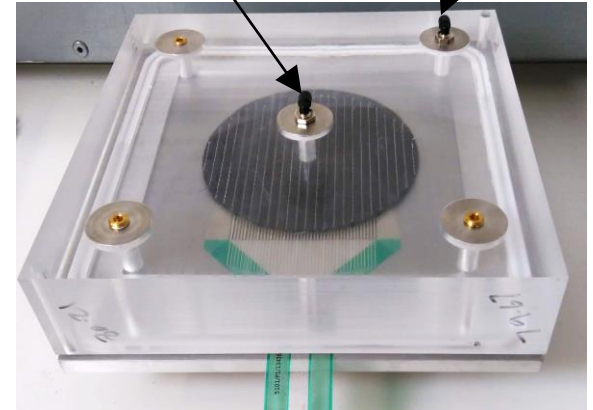
TekScan 5101
110 mm square grid
Measurement every 2.5 mm

Reclaimed fibre preform
(4 mm)



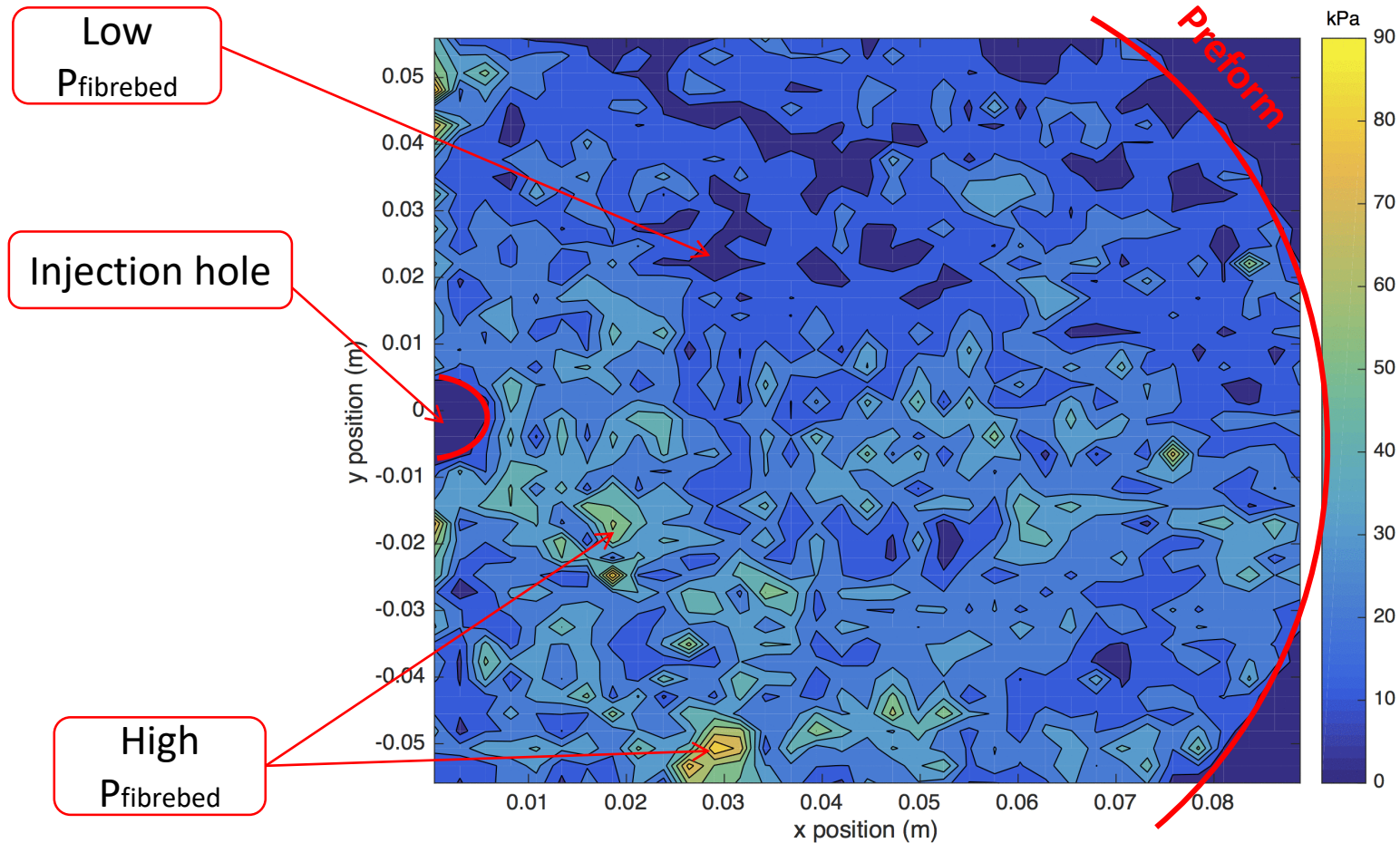
Recatex Type 62 complex
Non-woven 200 g/m²

Central injection
(160 kPa) Perimeter vent
(atmosphere)



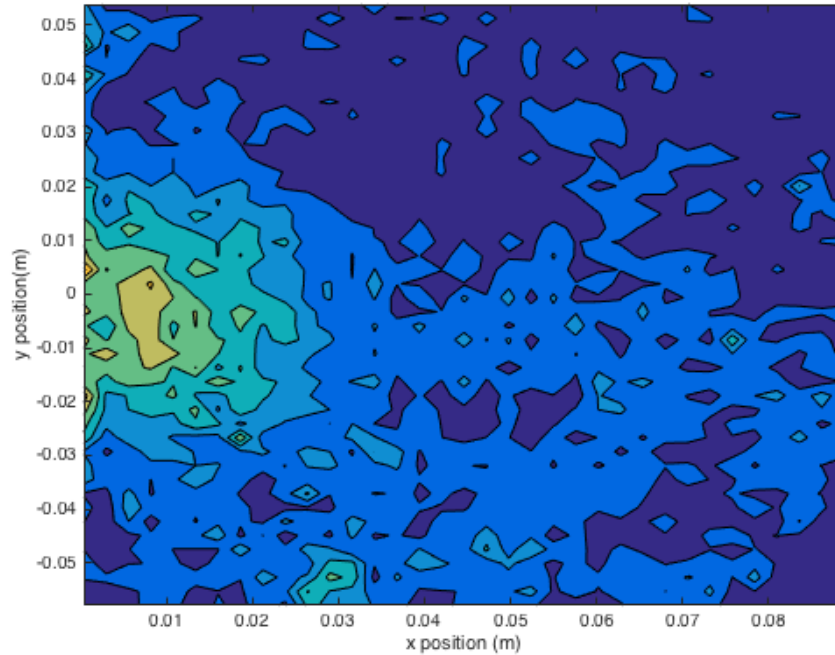
80 mm acrylic upper mould
Camera to record flow
position

Sensor Output after Mould Closed

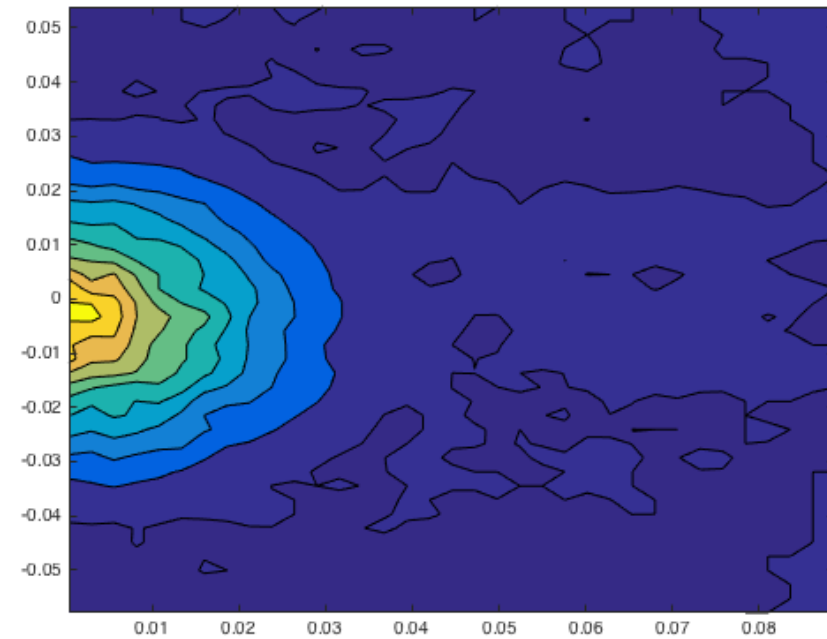


Sensor Response during Injection

Raw pressure signal



After subtracting initial pressure



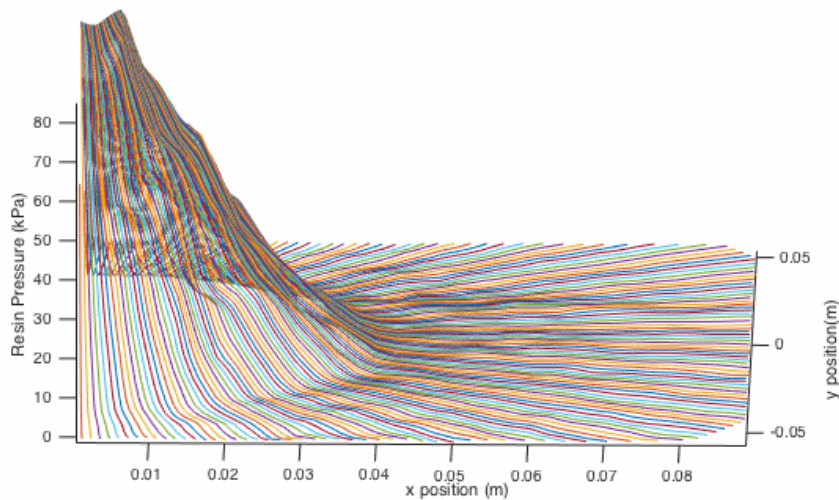
$$P_{Applied} = \sigma_{Fibrebed} + P_{Resin}$$

(Assumed constant)

Characterise Permeability – Sensor

- Using all the pressure data

Polar Description

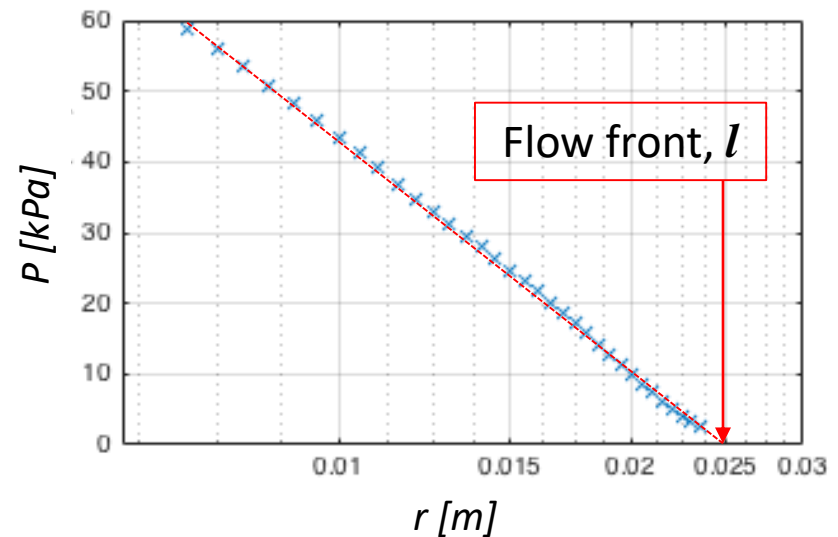


Adapted to central injection

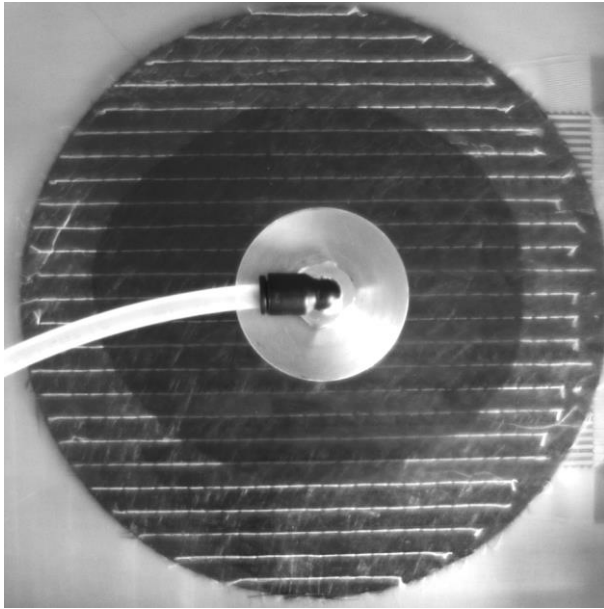
For each angle

Direct model says :

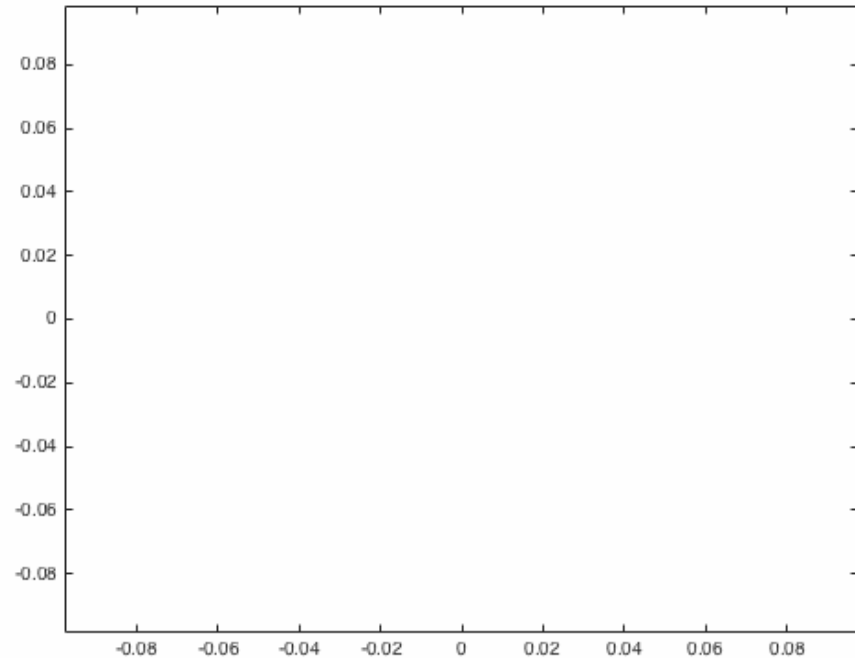
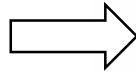
$$P(r) = P_{inj} \times \frac{\ln(r) - \ln(l)}{\ln(r_0) - \ln(l)}$$



Characterise Permeability – Conventional



Video of injection

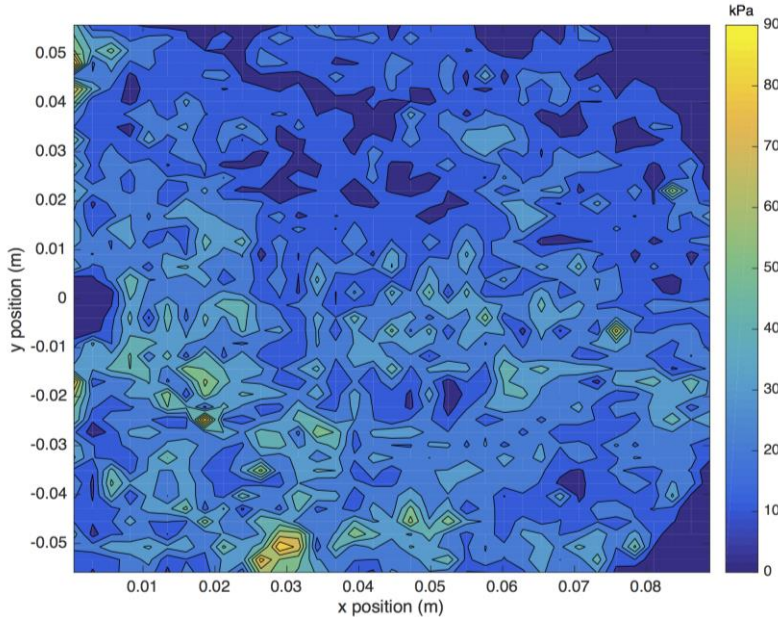


Threshold to fit an Ellipse

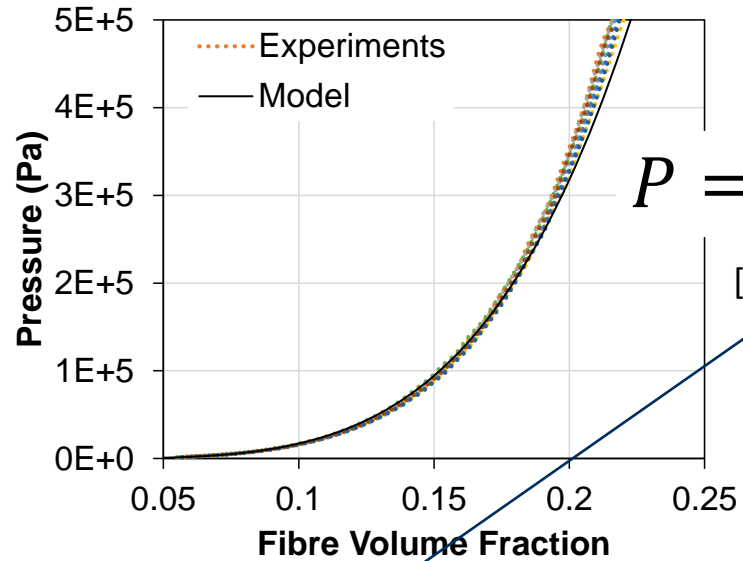
- Conventional: **boundary** to calculate permeability
- Pressure sensor: **pressure data** to calculate permeability

Simulate Flow Front

Dry pressure map



Compaction curve



$$P = E f^4 V_f^A$$

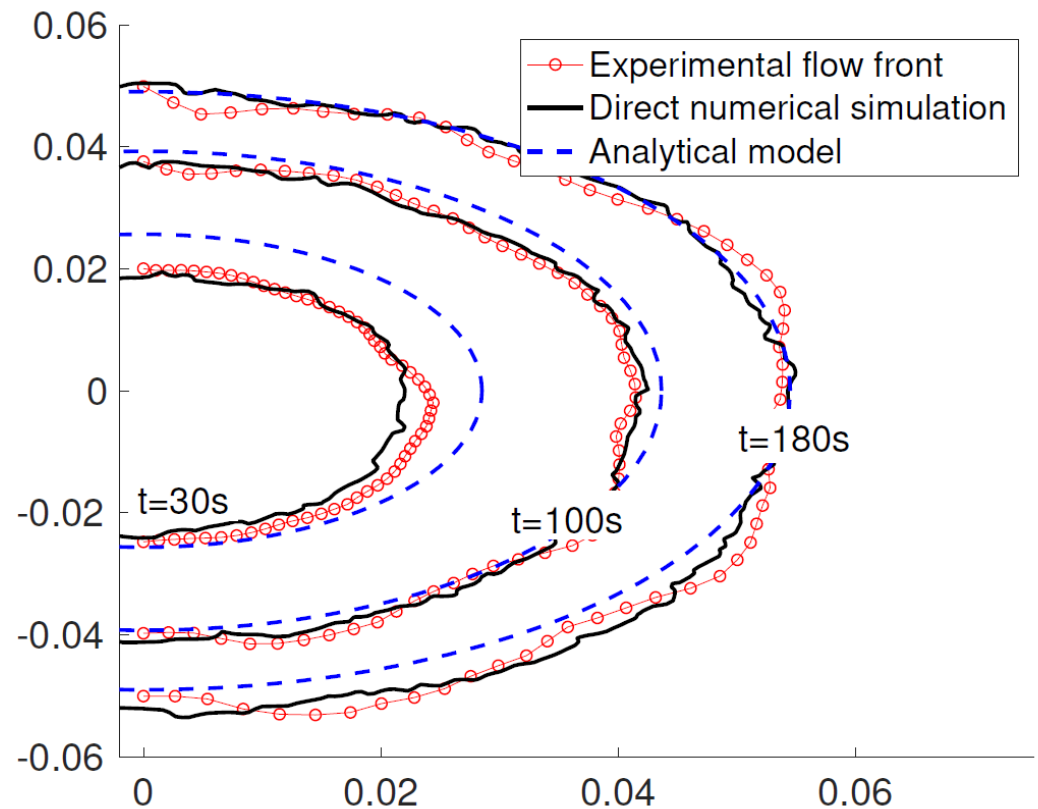
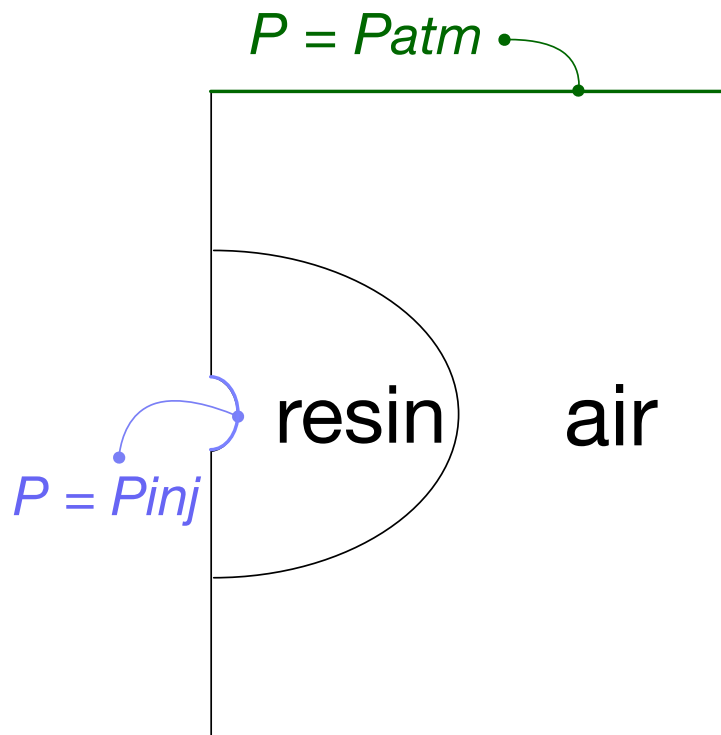
[Toll & Manson 94]

Permeability map

$$K = C \frac{(1 - v_f)^3}{v_f^2}$$

Kozeny-Carman Equation

Direct Numerical Simulation



- Account for permeability variations that will disturb the flow front whereas the analytical model assumes an ellipse

Conclusions

- Surface mapping sensors can provide high density sensor data for liquid composite moulding processes
 - Data available → sensor spacing studies?
- Measure material properties
- Initialise deterministic models
- Measure flow in-process

Future opportunities

- Sensor development
- Real-time process control

Acknowledgements

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