SIMULATION OF LIQUID MOLDING PROCESSES (LCM) FOR CERAMIC MATRIX COMPOSITES (CMC) MANUFACTURING

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PRESENTATION CONTENT

1. Introduction

2. Process description

3. Model description

4. Analytical Verification

5. Application Example

A Complete & Integrated Offer

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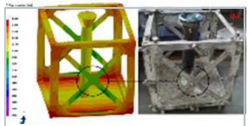
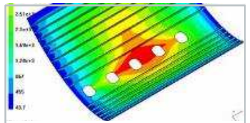
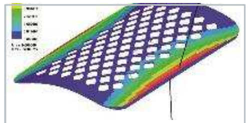
Virtual Manufacturing


Casting


Composites


Sheet Metal Forming

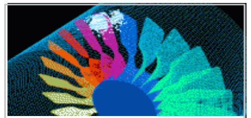

Welding & Assembly

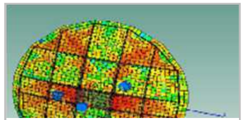
End-to-End Solutions


Virtual Performance Solution


Virtual Seat Solution

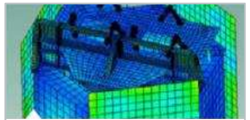
Virtual Performance


Crash & Safety

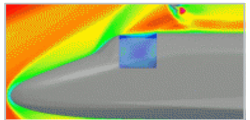

NVH & Dynamics

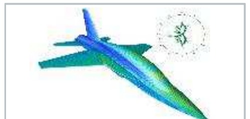

Interior Acoustics


Statics & Strength


Vibro-Acoustics

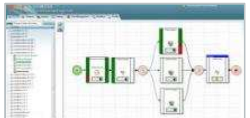
Virtual Environment


CFD & Multiphysics


Electromagnetics

Virtual Integration Platform


Multi-Domain Simulation


Decision Support

Virtual Reality


Collaborative decision-making

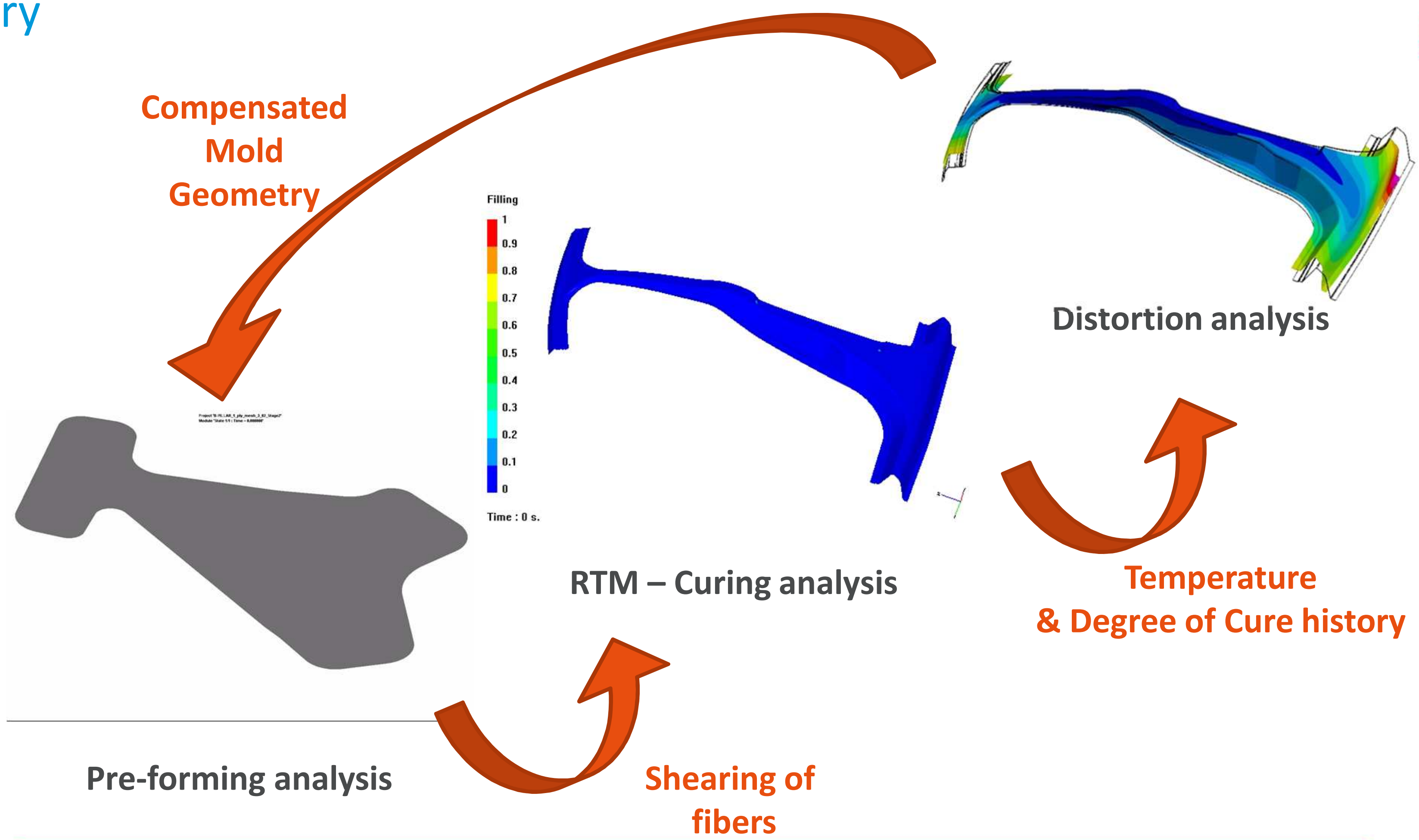
Engineering services


Consulting Services

Images courtesy of EADS Innovation Works, Harbin Aircraft, Expliseat, Boeing, and EADS Casa Espacio.

ESI PAM-COMPOSITES

Summary



SAFRAN CERAMICS AT A GLANCE

SAFRAN

AROUND **100 PEOPLE**

EXPERTS IN **HIGH TEMPERATURE** COMPOSITES

SAFRAN INTELLECTUAL PROPERTY ON CMC :
1000 PATENTS

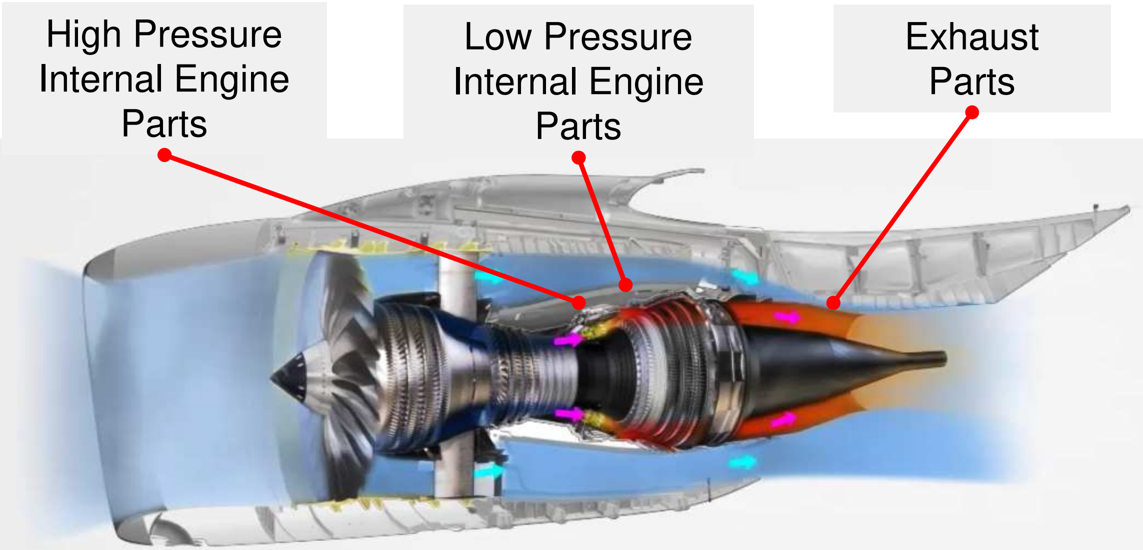
MANY **EXTERNAL PARTNERSHIPS**

A **9800 sqm** BUILDING, CONNECTED TECHNICAL HARDWARE

CMC FOR AERONAUTICS : SAFRAN LEADS DEVELOPMENTS TO TARGET COMMERCIAL AIRCRAFT APPLICATIONS

TARGET

Temperatures : 400 to 1450°C
Life : 30 000 to 100 000 h



Ceramic Matrix Composite
What benefits compared to metallic alloys ?

Low density (between 2 and 3) :

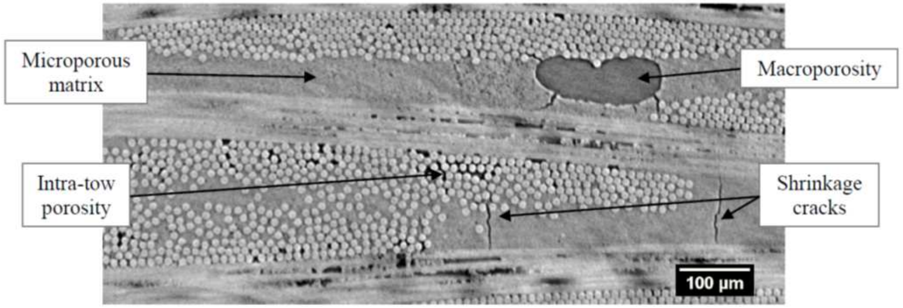
- Mass Saving

Higher temperature capability than the current state-of-the-art metallic alloys :

- Air Cooling Decrease
- Specific Consumption Decrease

CONTEXT

Oxide/Oxide composites (COX) are comprised of alumina matrix and alumina fibers



Oxide are selected for their good compromise between their performance and cost

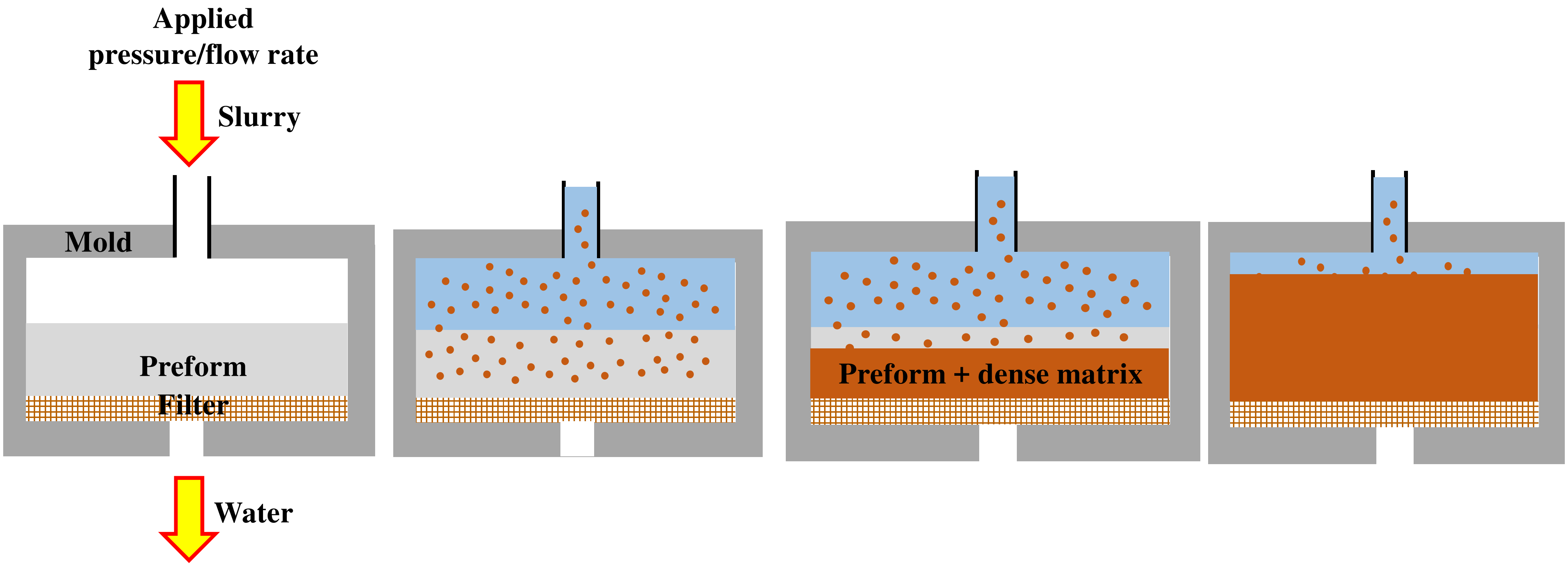
Engine Mixers and Nozzles are typical applications for such materials

These parts are manufactured by the "Slurry Transfer Moulding" process, patented by Safran

This work concerns the modelling of this process

Oxide CMC part

PROCESS DESCRIPTION



At all times the medium is comprised of two phase :

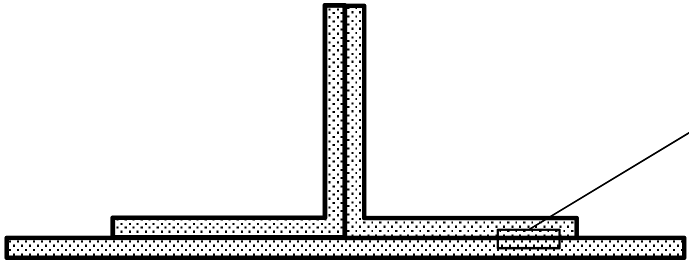
- A non compacted zone where the slurry flows in the inter-tow space
- A compacted phase where a compact granular material (cake) has locally formed

SLURRY MODELLING

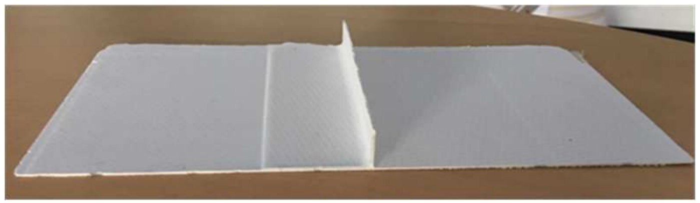
$$\eta = f(C; \dot{\gamma})$$

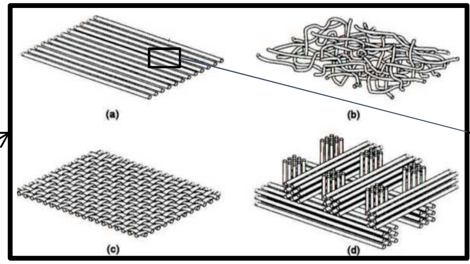
$$\rho = C\phi\rho_{fillers} + (1 - C)\phi\rho_{fluid}$$

PREFORM MODELLING

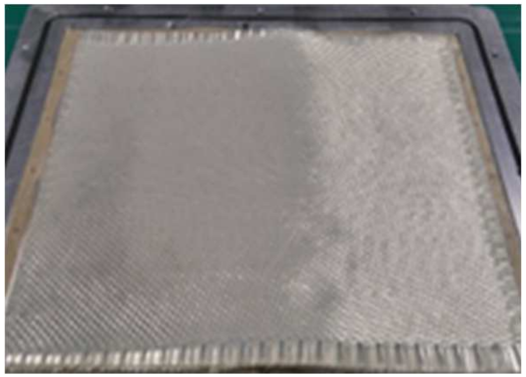


Macroscopic

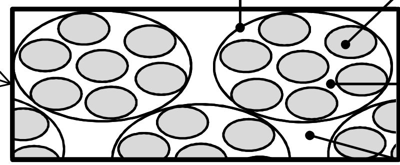




Mesoscopic

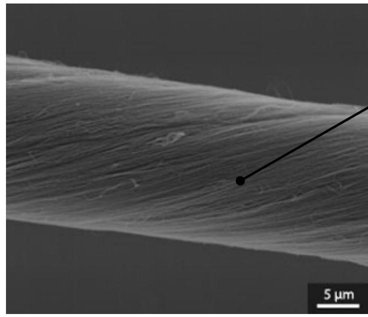


tows
fibers



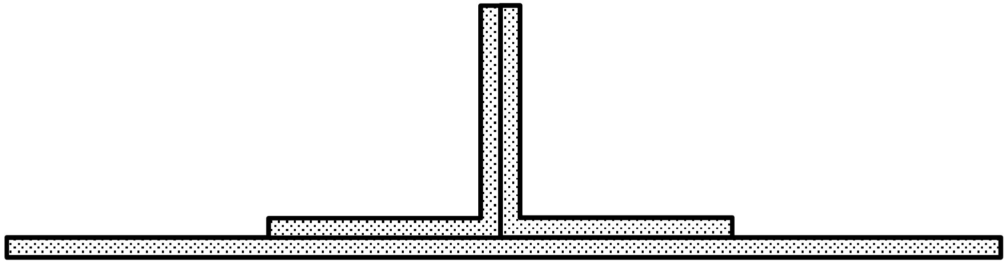
Micro voids
Macro voids

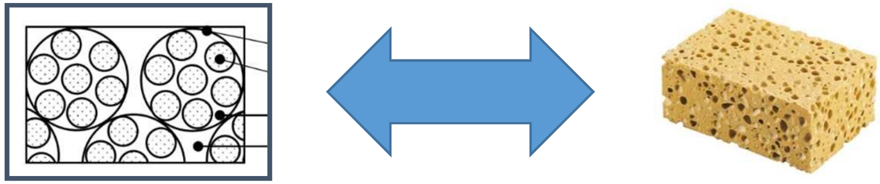
Microscopic



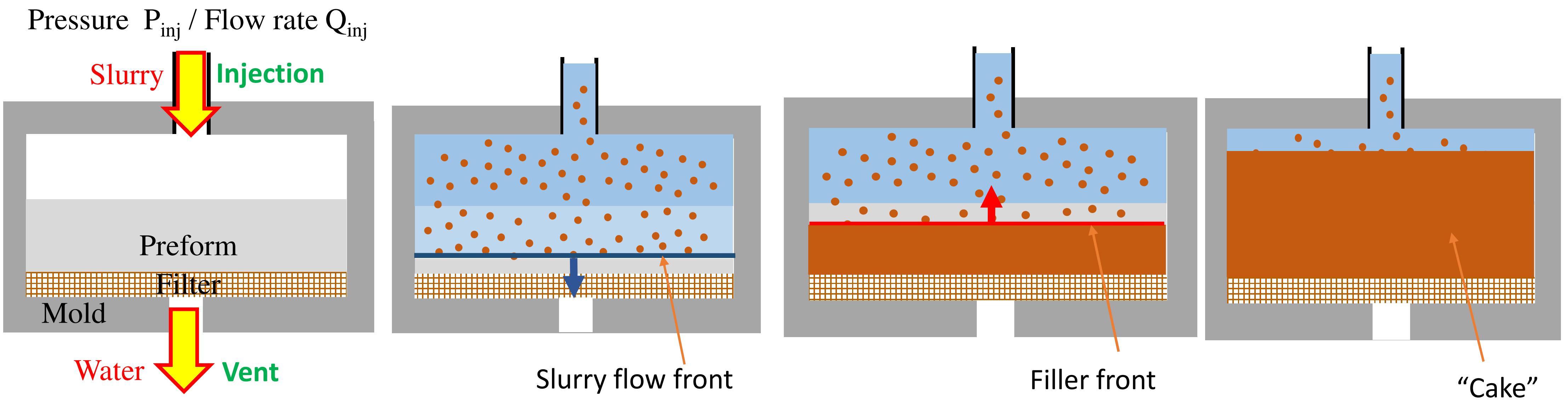
tow

PREFORM MODELLING





PROBLEM DESCRIPTION



Biphasic flow through porous medium

Slurry flow = Particle transport

Porous medium

Filtration

SOME EQUATIONS

Mass conservation

$$\frac{\partial C}{\partial t} + \underline{v} \cdot \underline{\nabla} C = \frac{1}{\phi}(C-1)\frac{\partial \sigma}{\partial t}$$

$$\underline{\nabla} \cdot (\underline{v}\phi) = 0$$

Fluid Velocity

$$\underline{v} = \frac{1}{\phi}\underline{U_d} = -\frac{1}{\phi}\frac{1}{\eta}\underline{\underline{K}}\,\underline{\nabla} P$$

Filtration

$$\frac{\partial \sigma}{\partial t} = \lambda_0 f(\sigma) C - k_r \sigma + S$$

Hypothesis

Dual scale porous medium

$$K^t = \frac{1}{\frac{1}{K_f} + \frac{1}{K_d^t}}$$

$$K_d^t = \frac{1}{h_k a^2}\frac{(1-\sigma)^3}{\sigma^2}$$

Surface filtration only

$$S_e = \frac{Q_{out} C_e}{\Omega_e}$$

$$\lambda_0 = k_r = 0$$

ANALYTICAL VERIFICATION

Belfort law

$$h = \frac{QC}{S(\sigma_{max} - C)} t$$

$$\Delta p = \frac{\mu Q}{SK} h$$

	Permeability (m²)	Compaction ratio
Case 1	$1{,}55.10^{-13}$	0,6
Case 2	$1{,}2.10^{-12}$	0,4
Case 3	$5{,}4.10^{-14}$	0,8

Thickness

Pressure

ANALYTICAL VERIFICATION

	Permeability (m^2)	Compaction ratio
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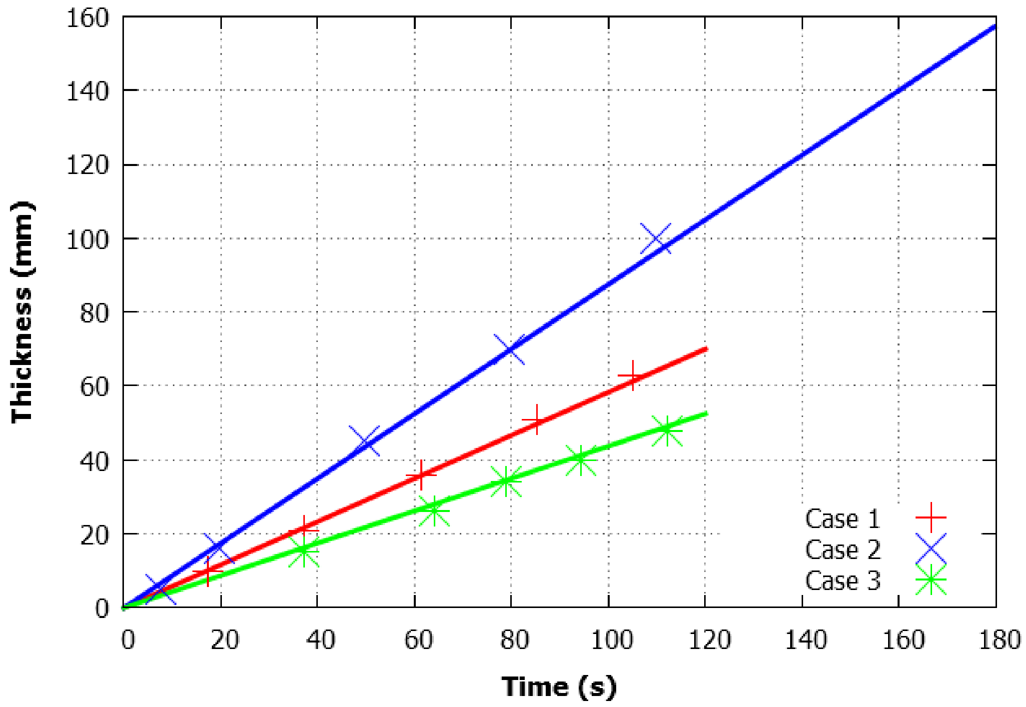
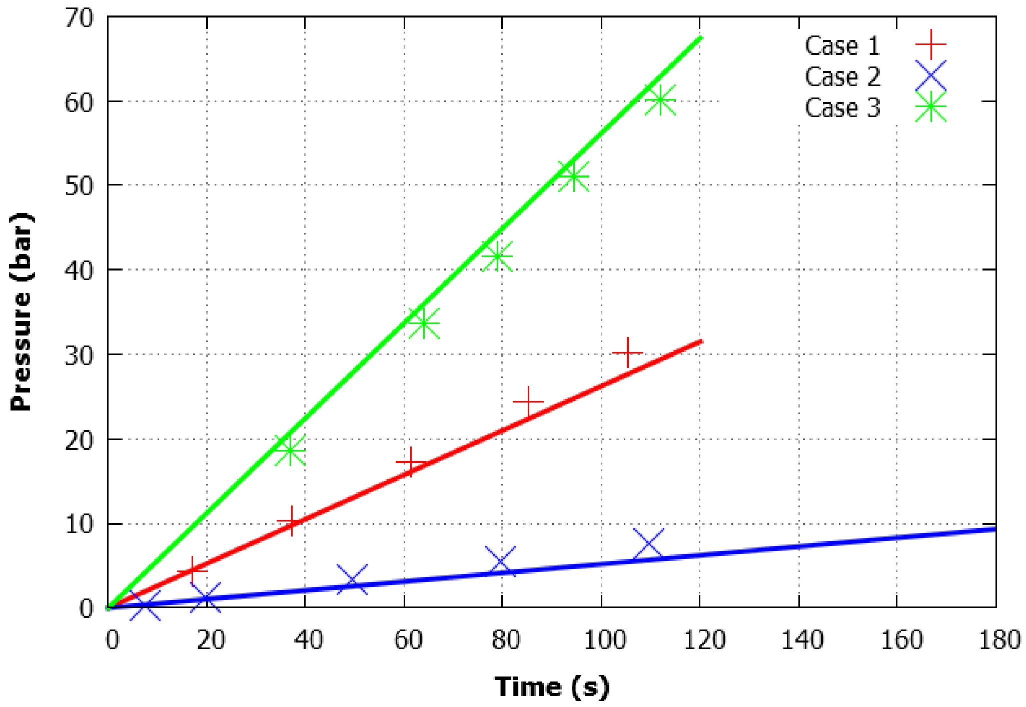
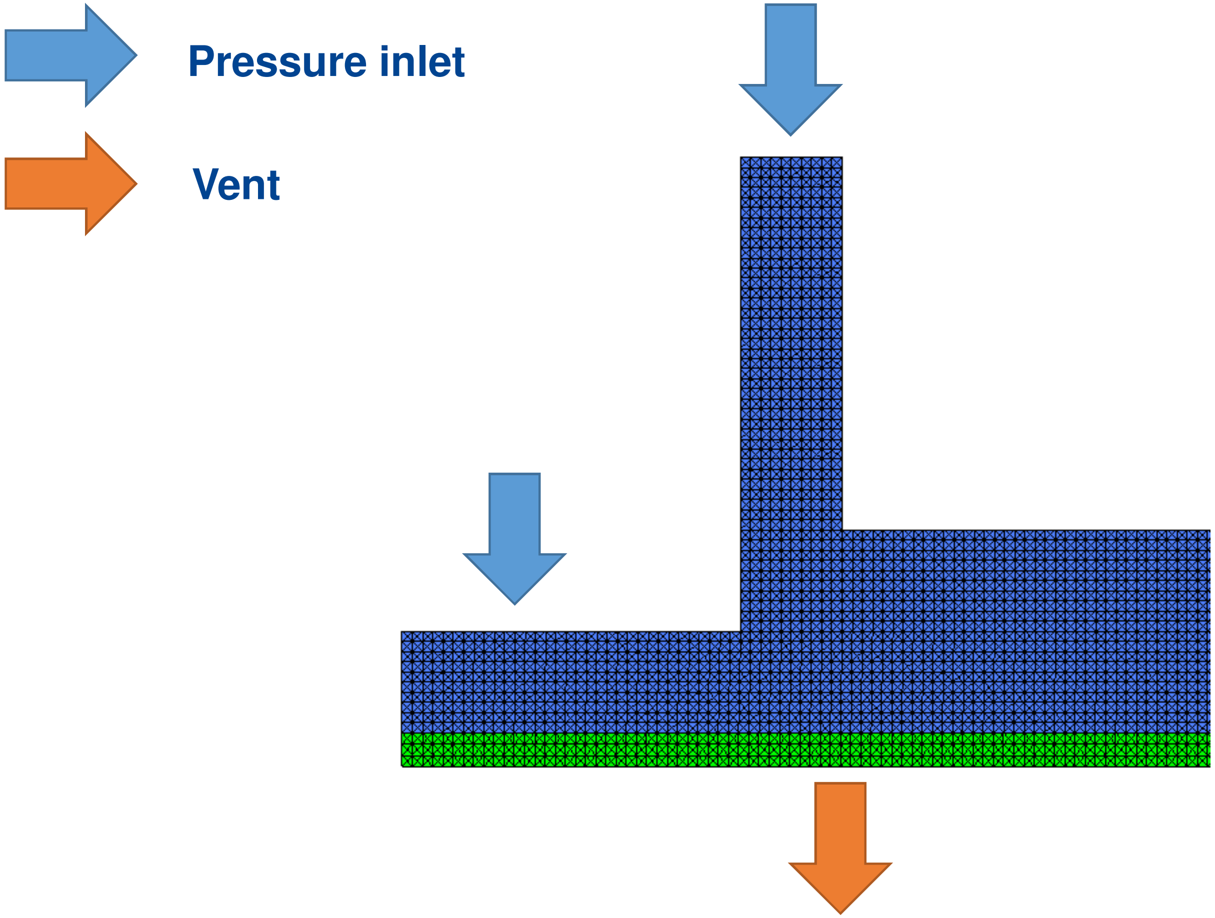




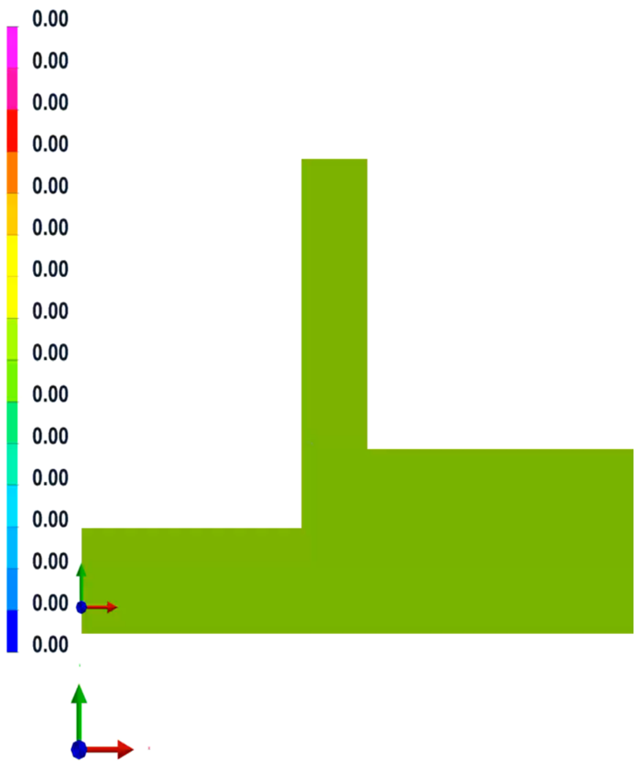
APPLICATION EXAMPLE



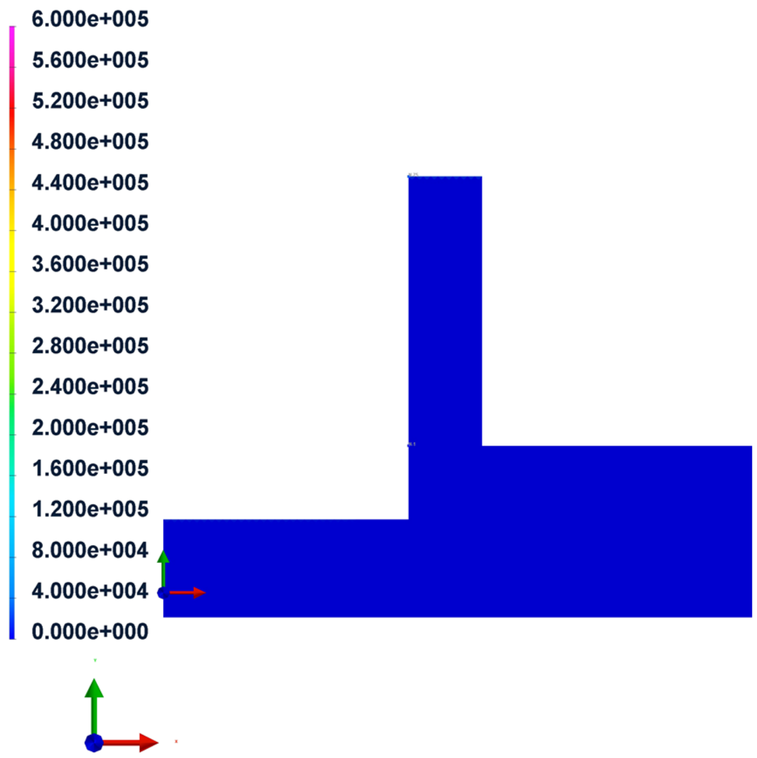
Operating Conditions	
Applied Pressure	6 bars
Vent Pressure	0 bars (relative)
Slurry concentration	30%

APPLICATION EXAMPLE - RESULTS

Cake concentration



Pressure



CONCLUSION

Simulation tool allowing macroscopic simulation on real size part

Implementation verified against analytical laws

On-going works on verification and validation with experimental test comparisons

Use of simulation to define optimized injection strategy

Thank You

QUESTIONS?

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