Research interests and past experience

"VARIABILITY IN LIQUID COMPOSITE MOULDING TECHNIQUES: PROCESS ANALYSIS AND CONTROL"

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FEUP 17 November 2005

INEGI
Composite Materials and Structures Research Unit

OUTLINE

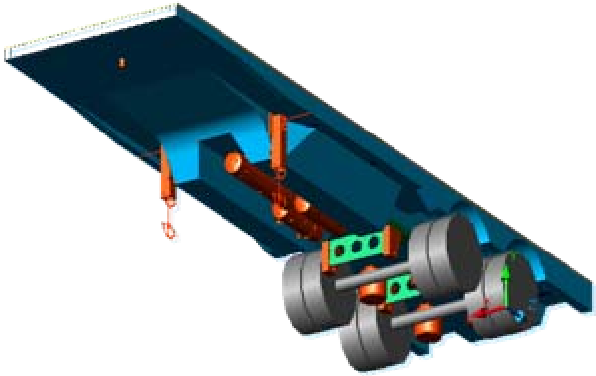
MY PhD.

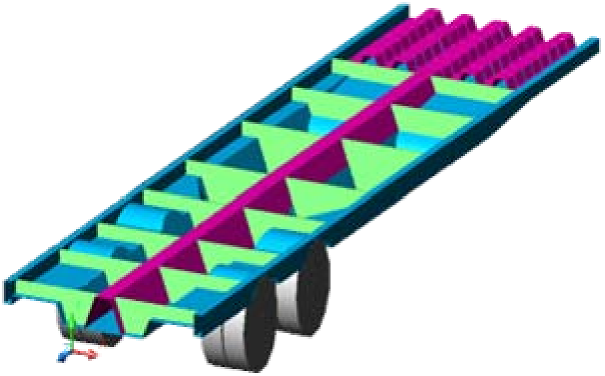
- The RoadLite project
- Liquid composite moulding (LCM)
- Variability in LCM
- Manufacturing repeatability
- Control techniques

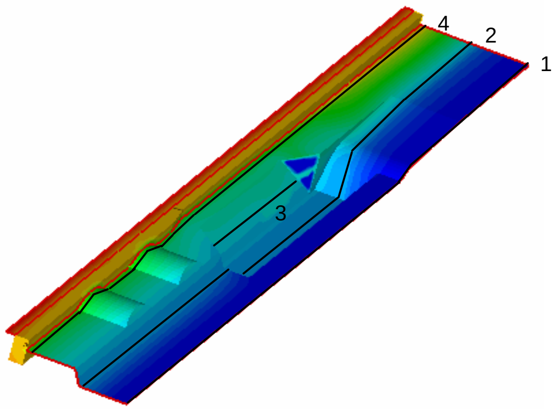
MY Current interests

- Vehicle applications - expertise
- Control of liquid composite moulding (LCM)

ROADLITE
FIRST PROTOTYPE







SECOND PROTOTYPE

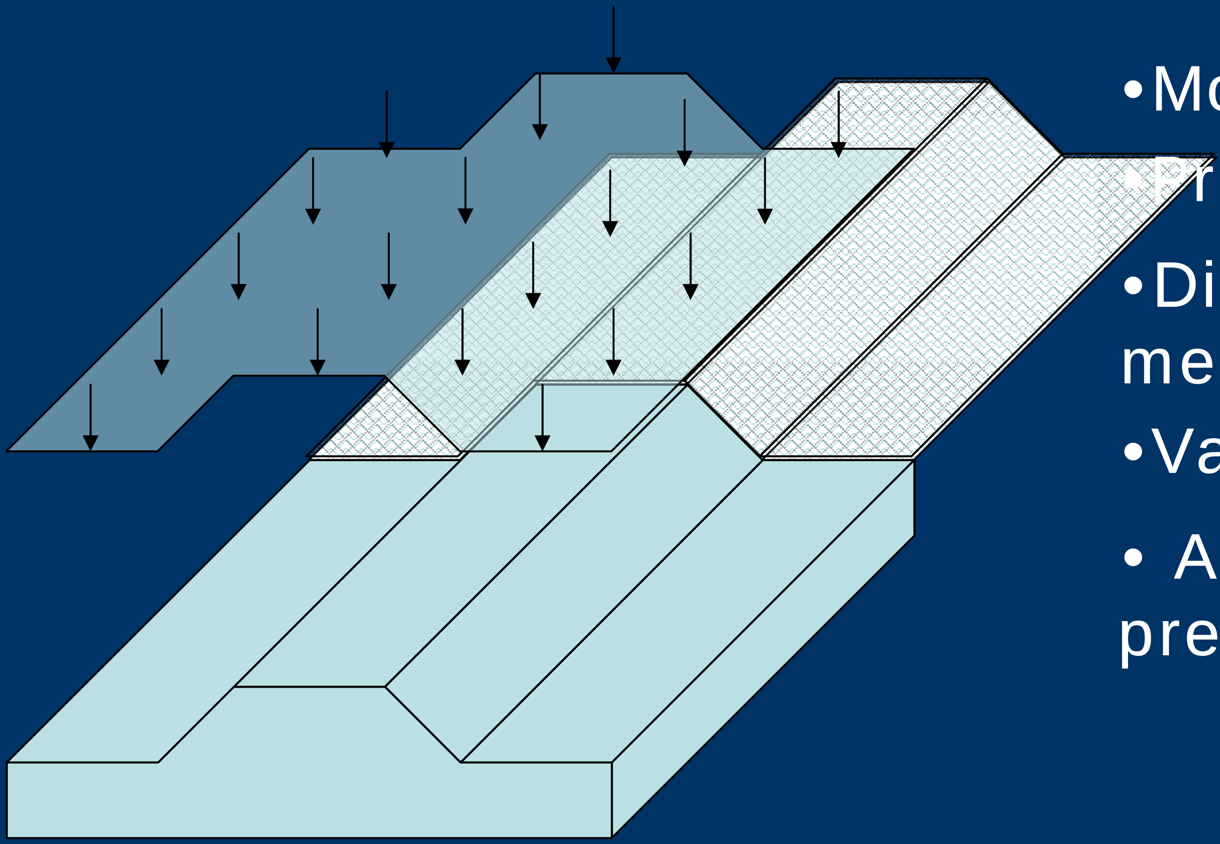
Table 1. Trailer cost analysis

Chassis type	description	value k£
Steel	**Total**	**7 to 12**
Composite	Materials	~ 3
	Labour	~ 5
	Running gear	~ 4
	Total	**~12**

Table 2. Weight savings on composite trailer

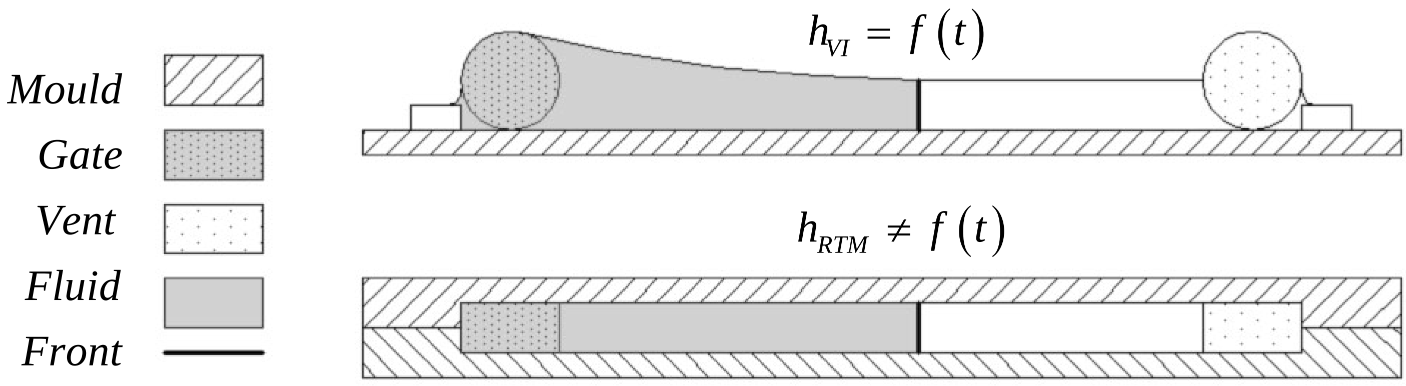
		in total	in chassis
Chassis type	Steel	4130 kg	1930 kg
	Composite	3740 kg	1540 kg
	Weight saving	~ 390 kg	
	Saving ratio	~ 9.5 %	~ 20 %

VACUUM INFUSION - VI

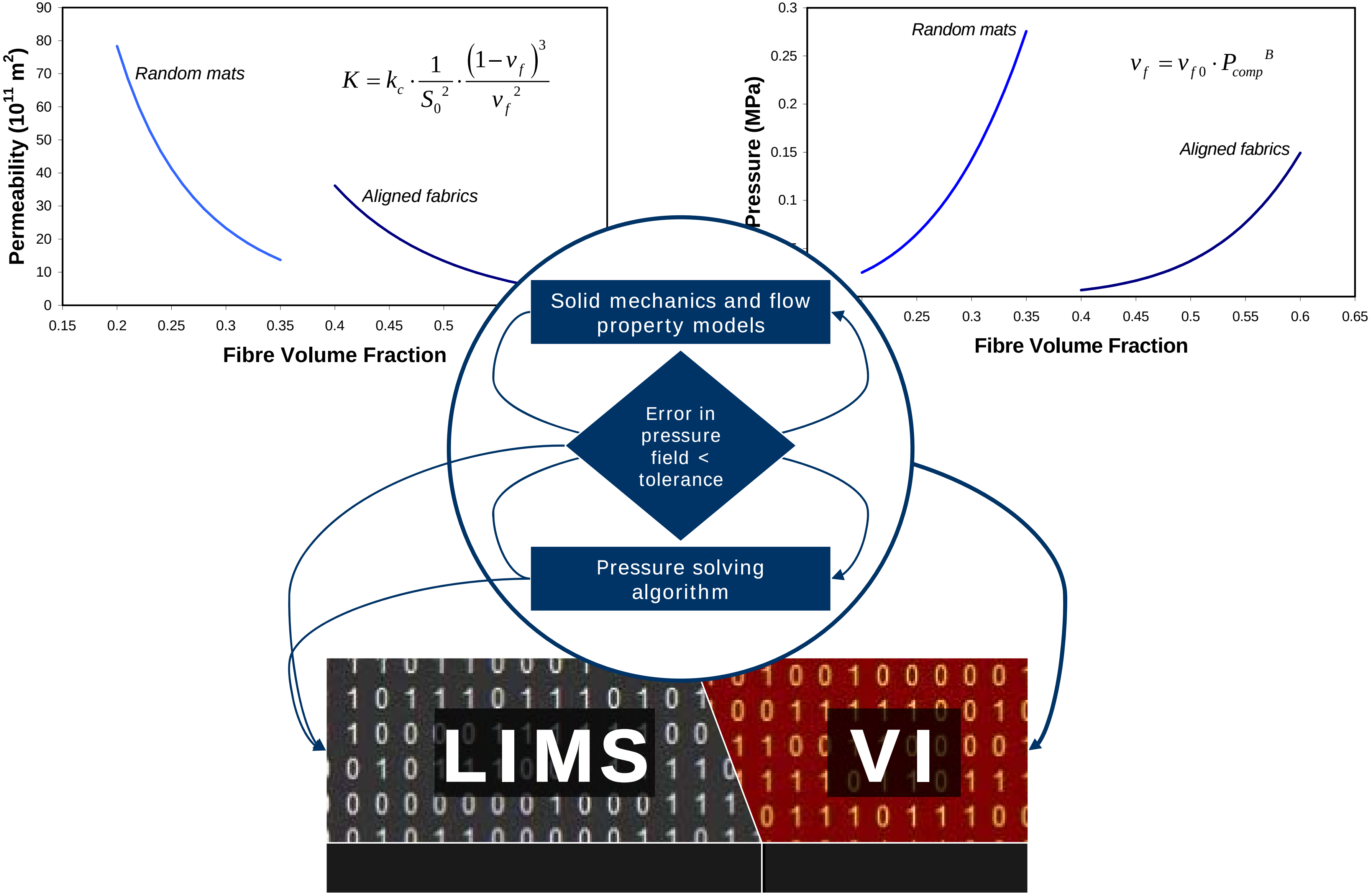


- Mould
- Preform
- Distribution medium
- Vacuum bag
- Atmospheric pressure

COMPACTION IN VI



ADDING VI TO LIMS



VI SIMULATIONS
RoadLite DEMONSTRATOR

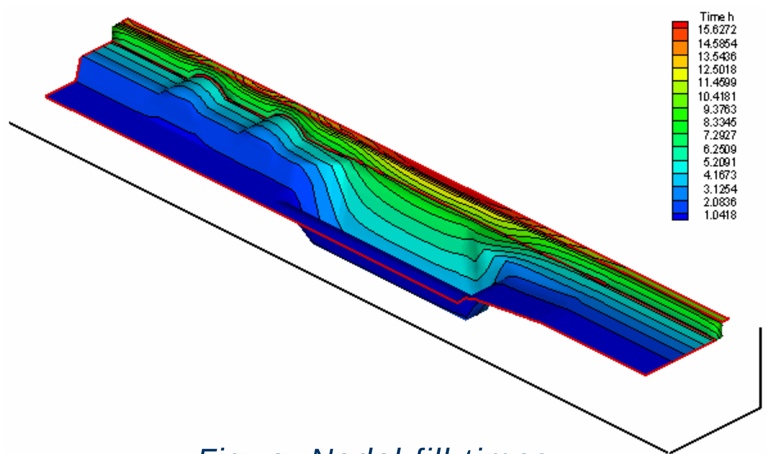


Fig. a. Nodal fill times

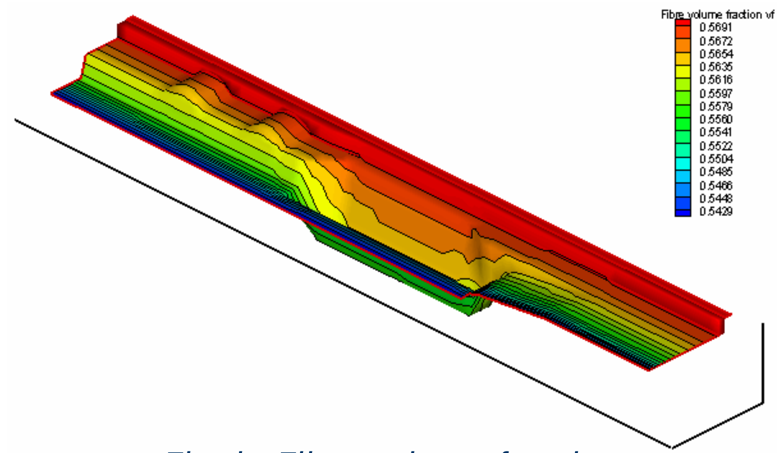


Fig. b. Fibre volume fraction

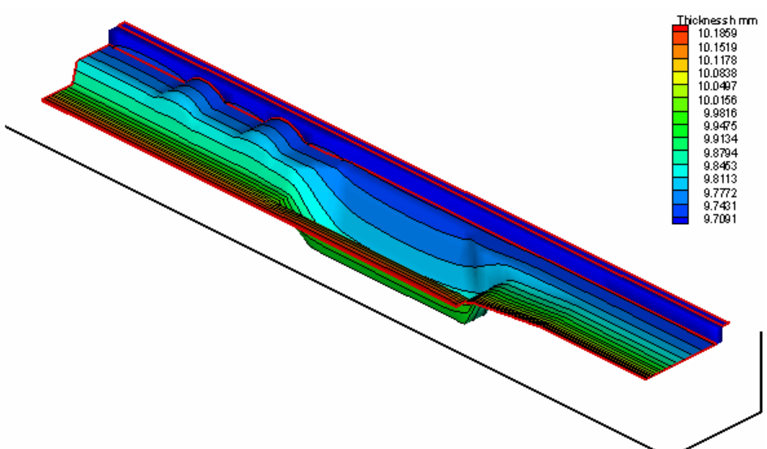


Fig. c. Thickness distribution

- *1124 compliant shell elements*
- *Compliance of 12 layers of Formax FGE 117*
- μ *= 120 mPa.s*

VARIABILITY

- Inlet system
  - –Quantity of resin
  - –Viscosity
  - –Height of container
  - –Piping layout
- Outlet system
  - –Pump pressure
  - –Leaks
- Inside the mould
  - –Reinforcement permeability
  - –Reinforcement density
  - –HPM placement
  - –Flow brake position
  - –Mould geometry
  - –Vac. bag folds
  - –Inlet positioning and cross section

MATERIAL PROPERTIES: VARIABILITY

Examples of variability in fibre angle, permeability and compliance of textiles

HOES, K., DINESCU, D., VANHEULE, M., SOL, H., PARNAS, R., BELOV, E. AND LOMOV, S. (2002) *Statistical distribution of permeability values of different porous materials. Proc.* of the Tenth European Conference on Composite Materials (ECCM10) June 3-7, 2002, Brugges, Belgium.

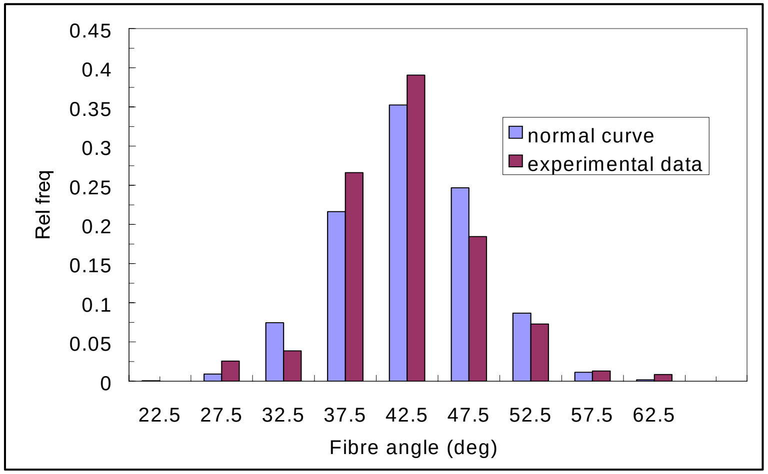


Fig. a. Fibre orientation on a ±45º stitched textile. BTI EBXHD 936

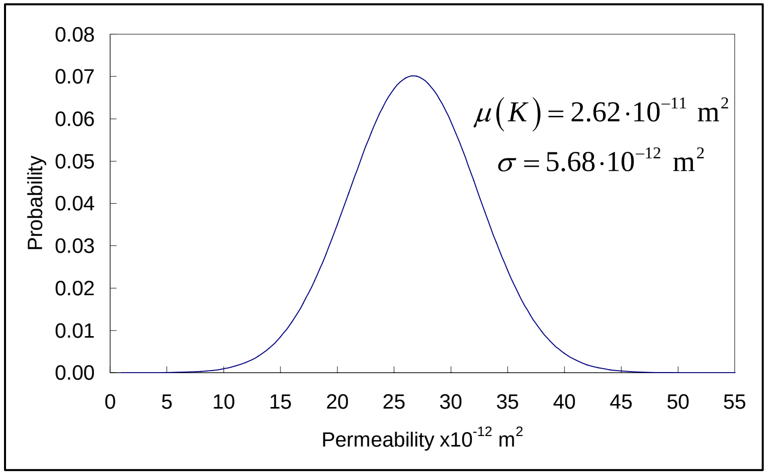


Fig. b. Permeability distribution for Syncoglas twill woven RE 144/255 (Hoes et al.*, 2002)*

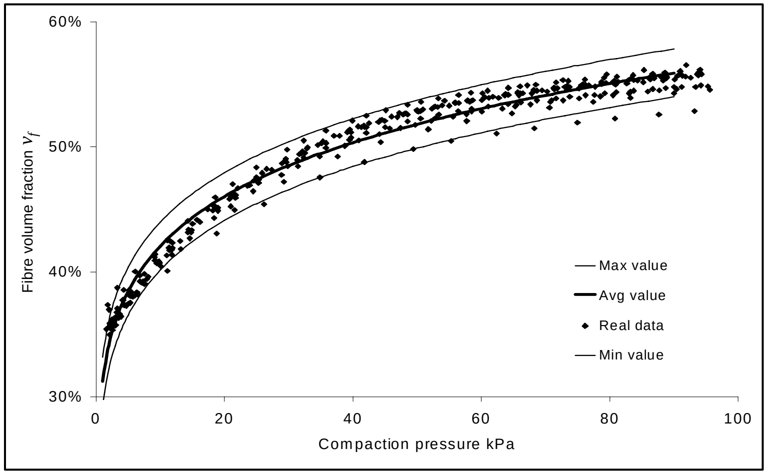
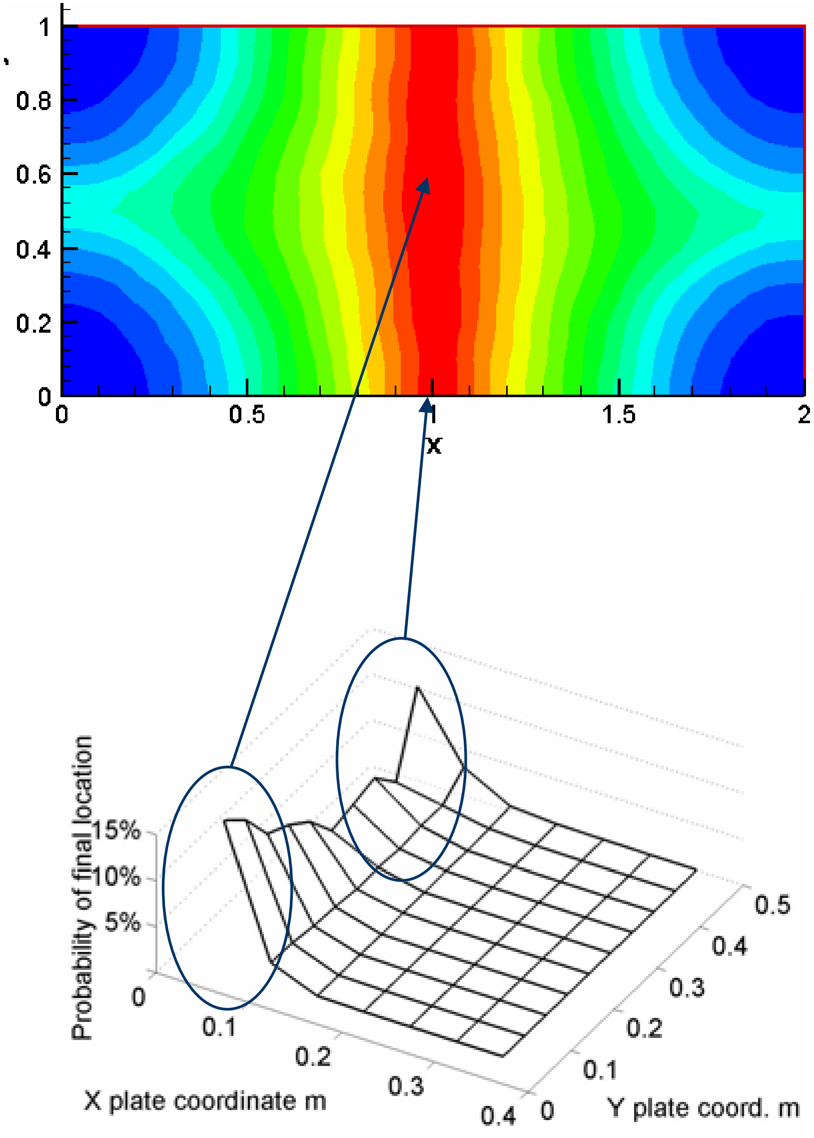


Fig. c. Distribution of observed fibre volume fractions for three layers of FORMAX FGE 117

RELIABILITY RTM

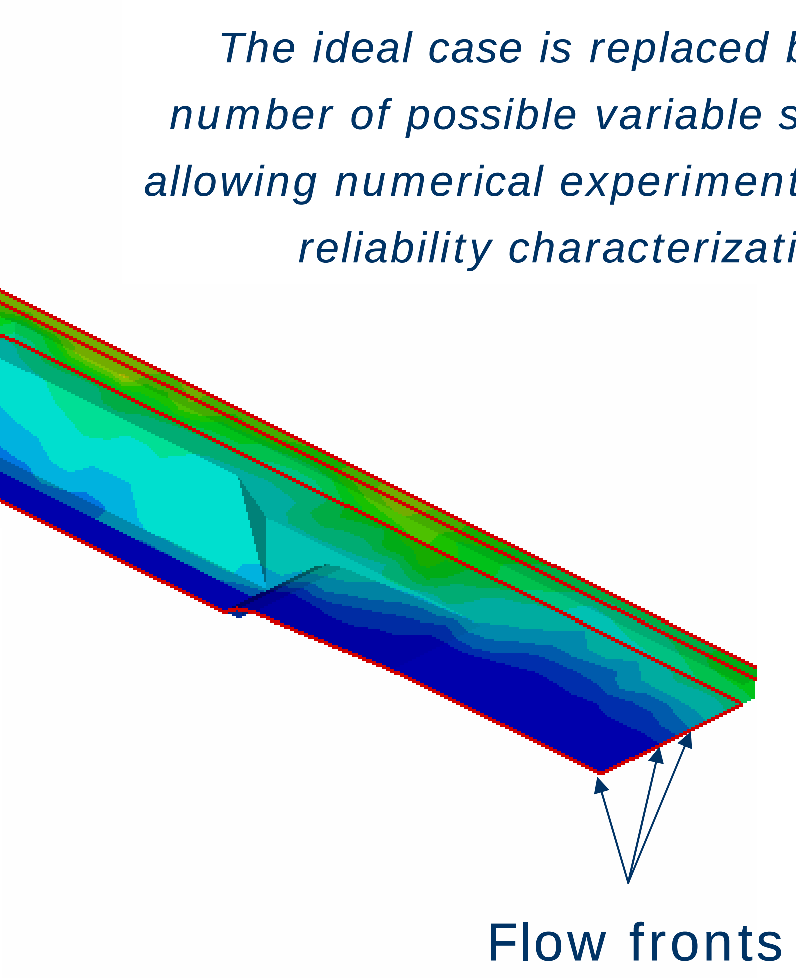
- Monte-Carlo method
- 4 gates
- Syncoglas RE 144/255
- 1xSTD
- 15000 simulations
- 800 elements



However, due to the large number of elements it is not possible to use Monte-Carlo to estimate the number of simulations required for statistical convergence of results

TRAILER SIMULATIONS RTM

σ_K = 0.10 K



The ideal case is replaced by any number of possible variable scenarios allowing numerical experimentation and reliability characterization

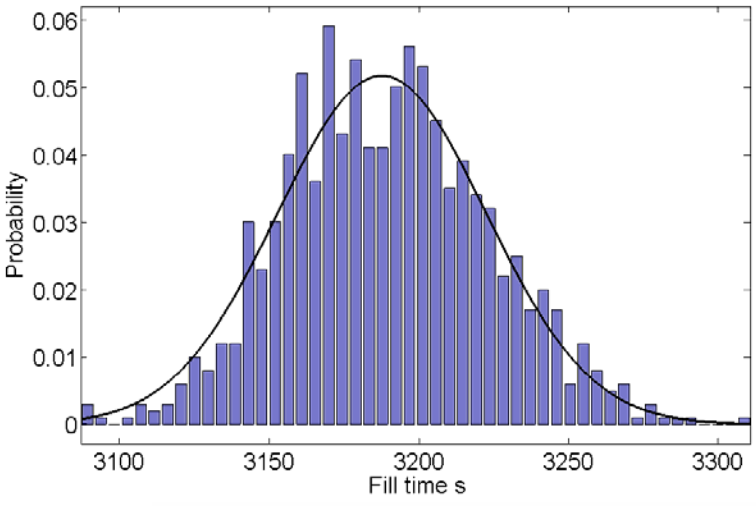


Fig. a. Distribution of mould filling time

VIRTUAL ON-LINE CONTROL
RTM EXAMPLE

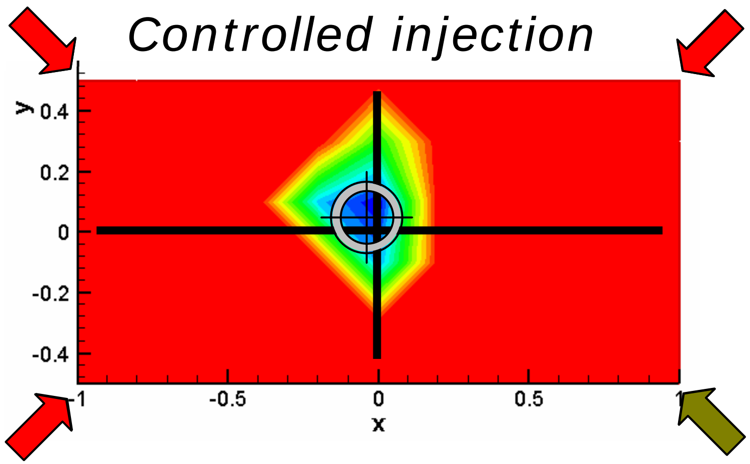
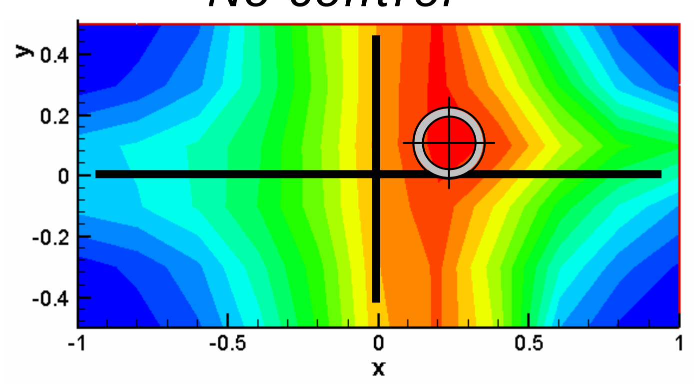


Table 3. Material data used in simulations

	Permeability data		Fibre v. fraction
	K	σ / K	v_f
RE 144/255	$26.2 \cdot 10^{-10}$ m^2	21.70%	50%



Computer selects between two injection pressure levels (0.3 and 1 bar) at each of the four corner gates in five steps.

Results show a high degree of flow front steering when compared with non controlled simulation

Conclusions: Expertise

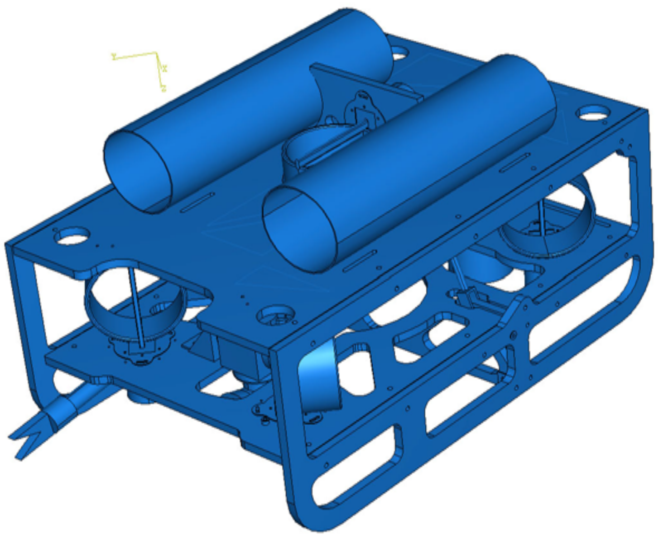
Development of LCM models

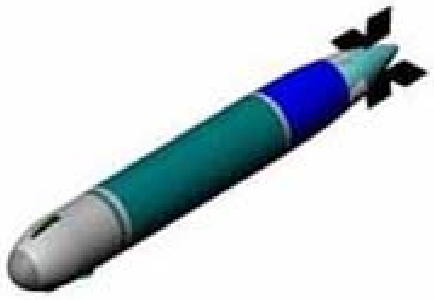
Stochastic modelling: Monte-Carlo

Monte-Carlo based control strategies (online control)

Applied research

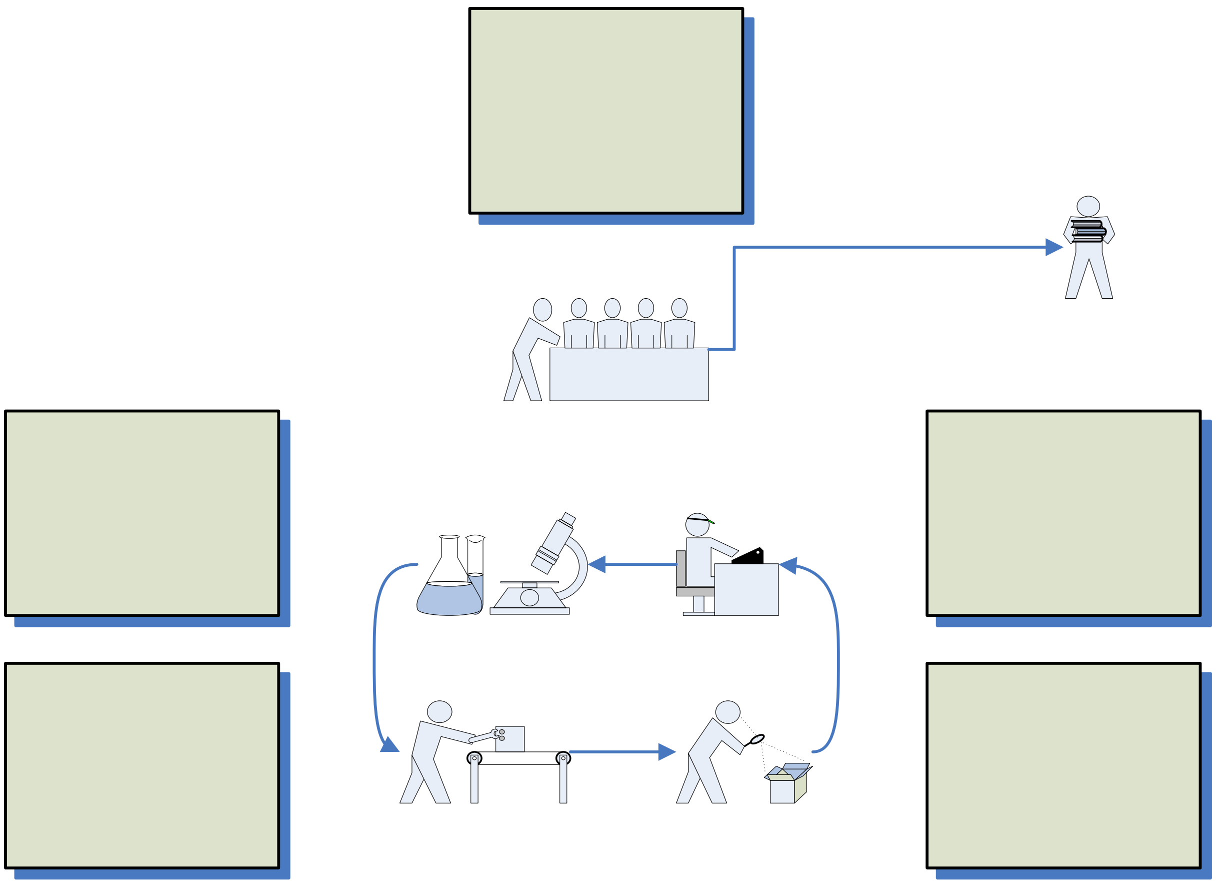
Applied research - Vehicles





Applied research - Smart materials

- ESF S3T: Fibre optic monitored wind turbine blades with PZT actuators



V

Inf

Work in progress

APPLIED	FUNDAMENTAL
Vehicles: UUV, UAV, Bus bodies, chassis, trailers.	Control (stochastic results and neural networks)
Wind energy – smart materials	Models for the compaction of fibre
	Magnetic nano-fluids (viscosity control)

Possible collaboration

INEGI

CCM
U. Delaware

University of
Nottingham

Timisoara - Romania

Europrojects

Southfields

VT Group