Approche pluridisciplinaire dans le domaine des procédés composites : besoins industriels et exemples de réalisation

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(Activités Universitaires en Mécanique)
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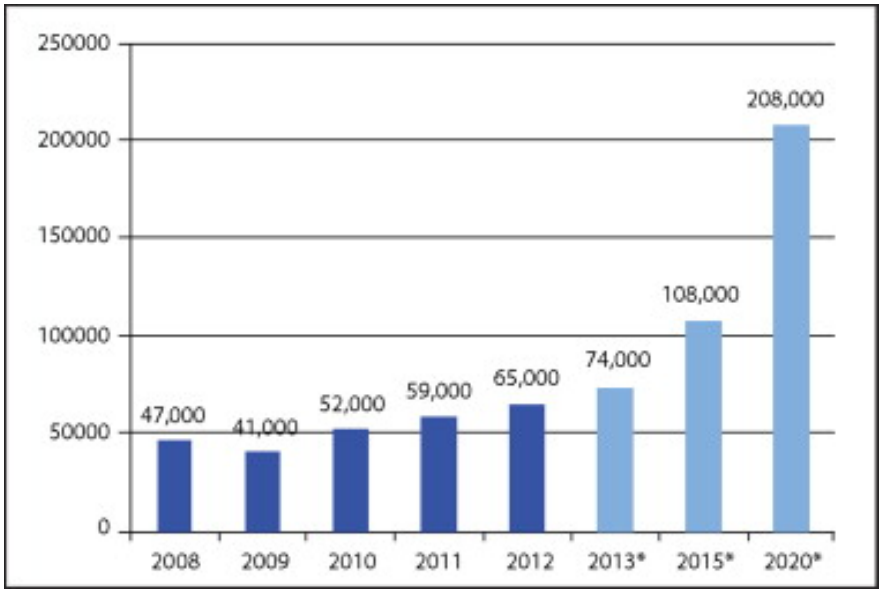
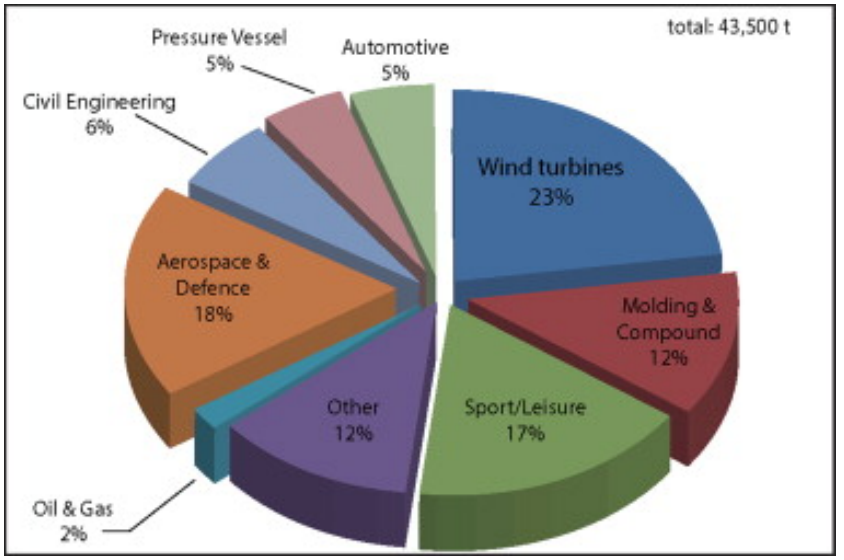
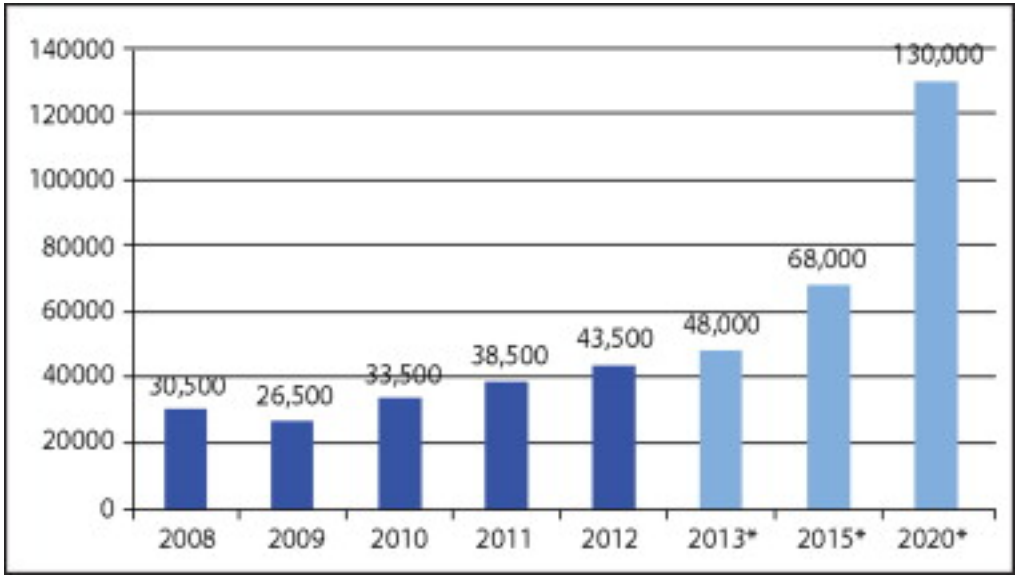


Global demand for CFRP in tonnes 2008-2020 (*estimated)

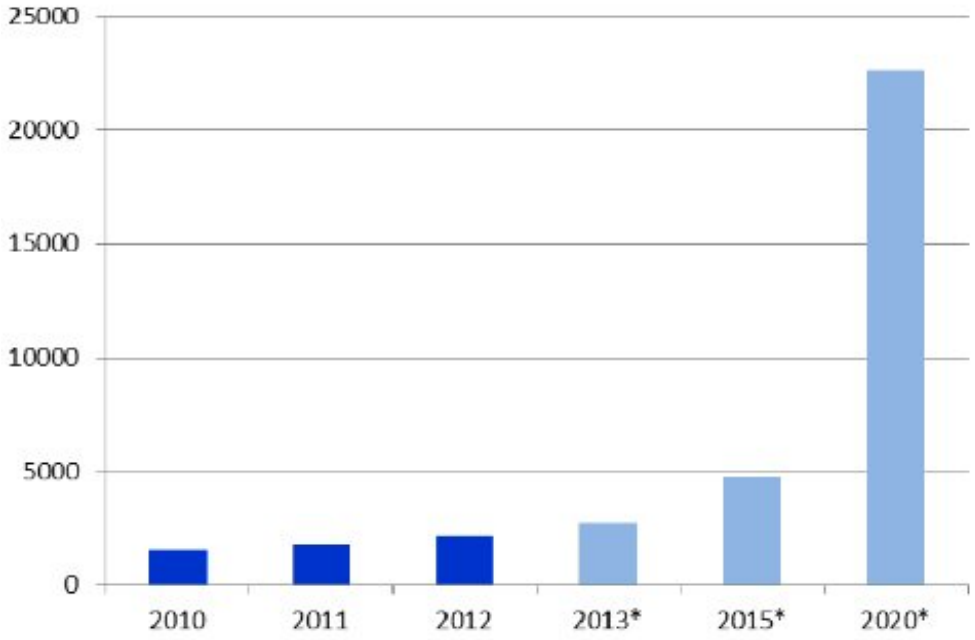


Global carbon fibre consumption (tonnes) by application (2012).



Global demand for carbon fibre in tonnes 2008-2020 *estimated)

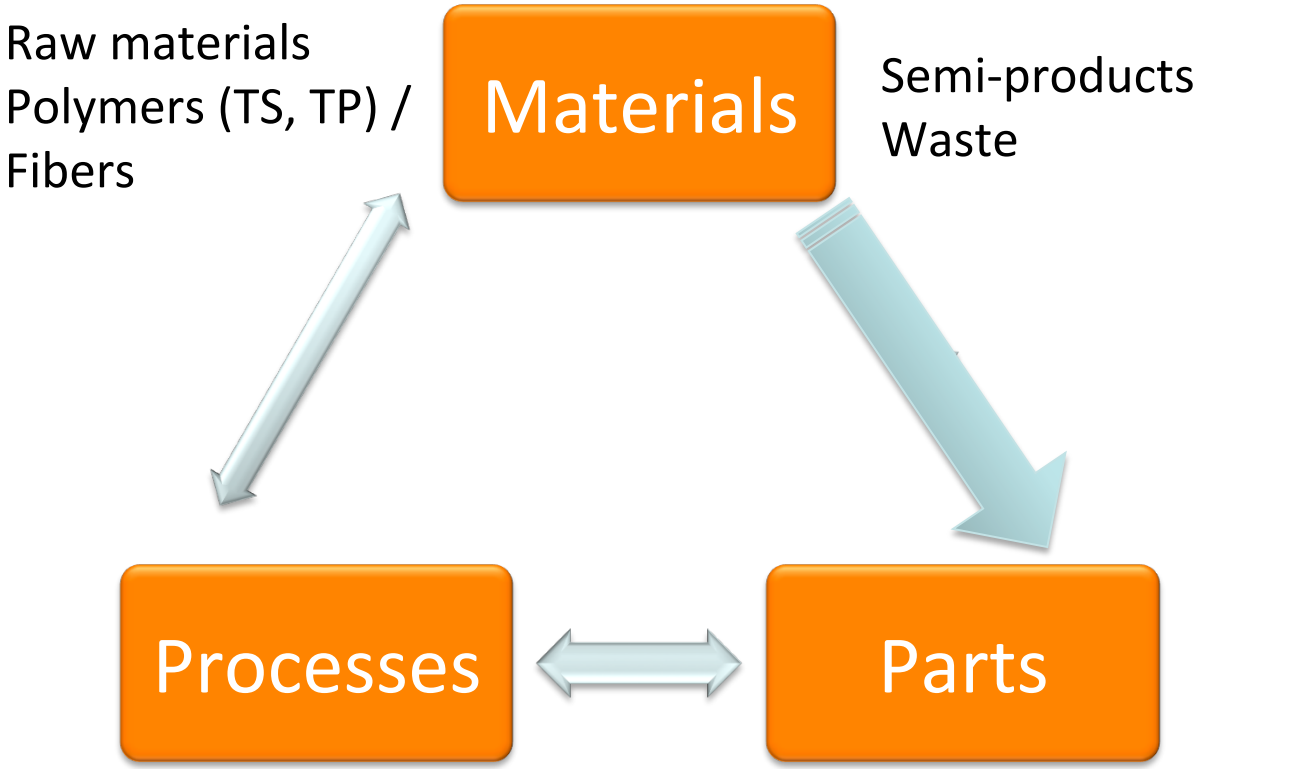
Source : Reinforced Plastics



Forecast growth in carbon fibre use in the automotive market from 2010-2020 (tonnes). *Estimated. (Source: The Global CRP Market 2013: CCeV.)

Source : Reinforced Plastics

OUTLINE

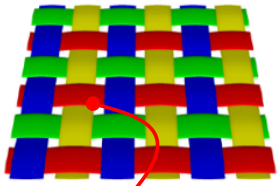

Raw materials
Polymers (TS, TP) /
Fibers
Materials
Semi-products
Waste
Processes
Parts
Direct / one-shot
Multi sequential steps
Tooling
Control, steering
Robustness
Size
Design criteria
Process induced defects
Series

4

Composites Manufacturing

Fibre

Yarn

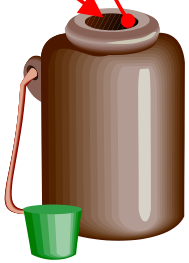


Fabrics

Reactive resin

Multi-physics

Composite part



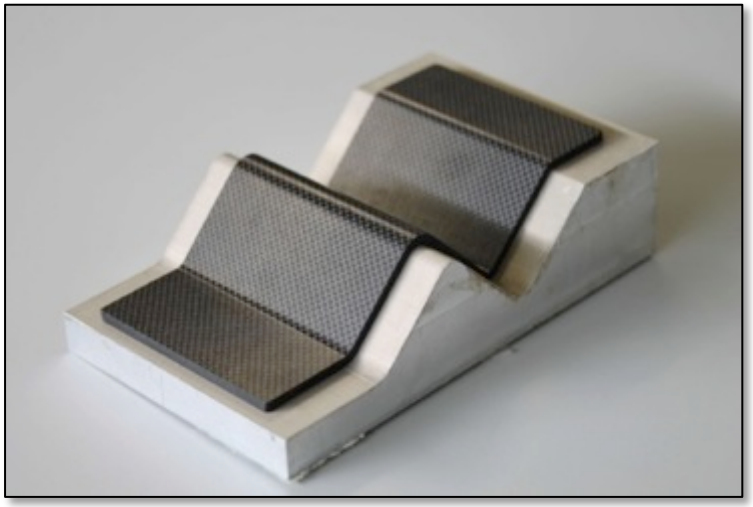
Process

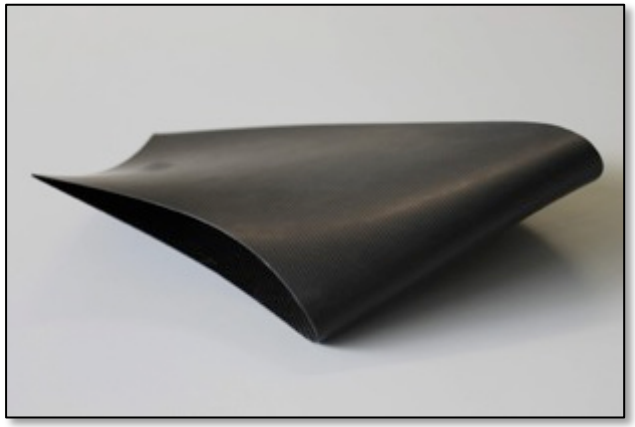
Boundary conditions: P, Q, V, σ, U, T…

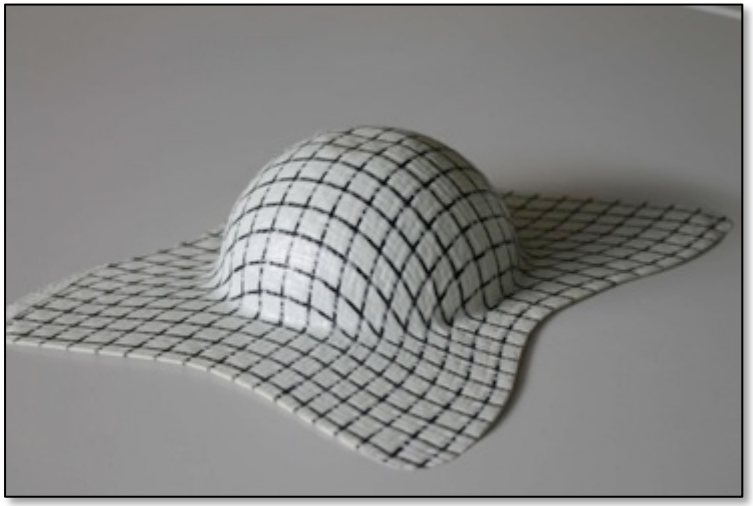
Initial conditions

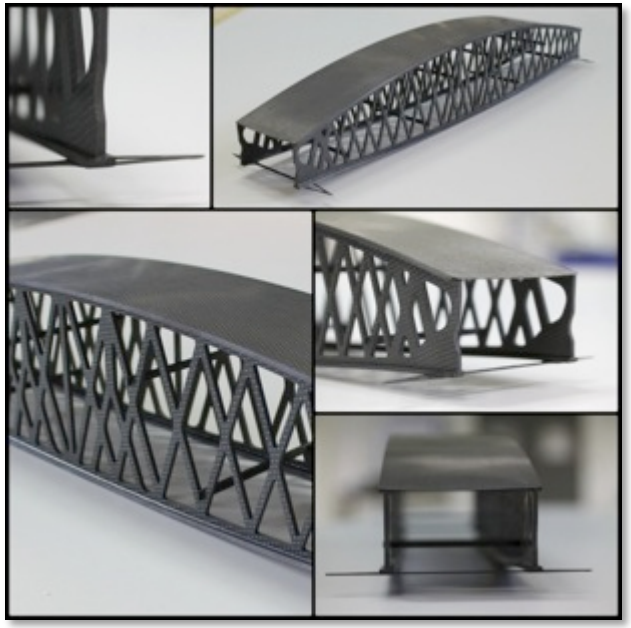
Composite material

Composite parts

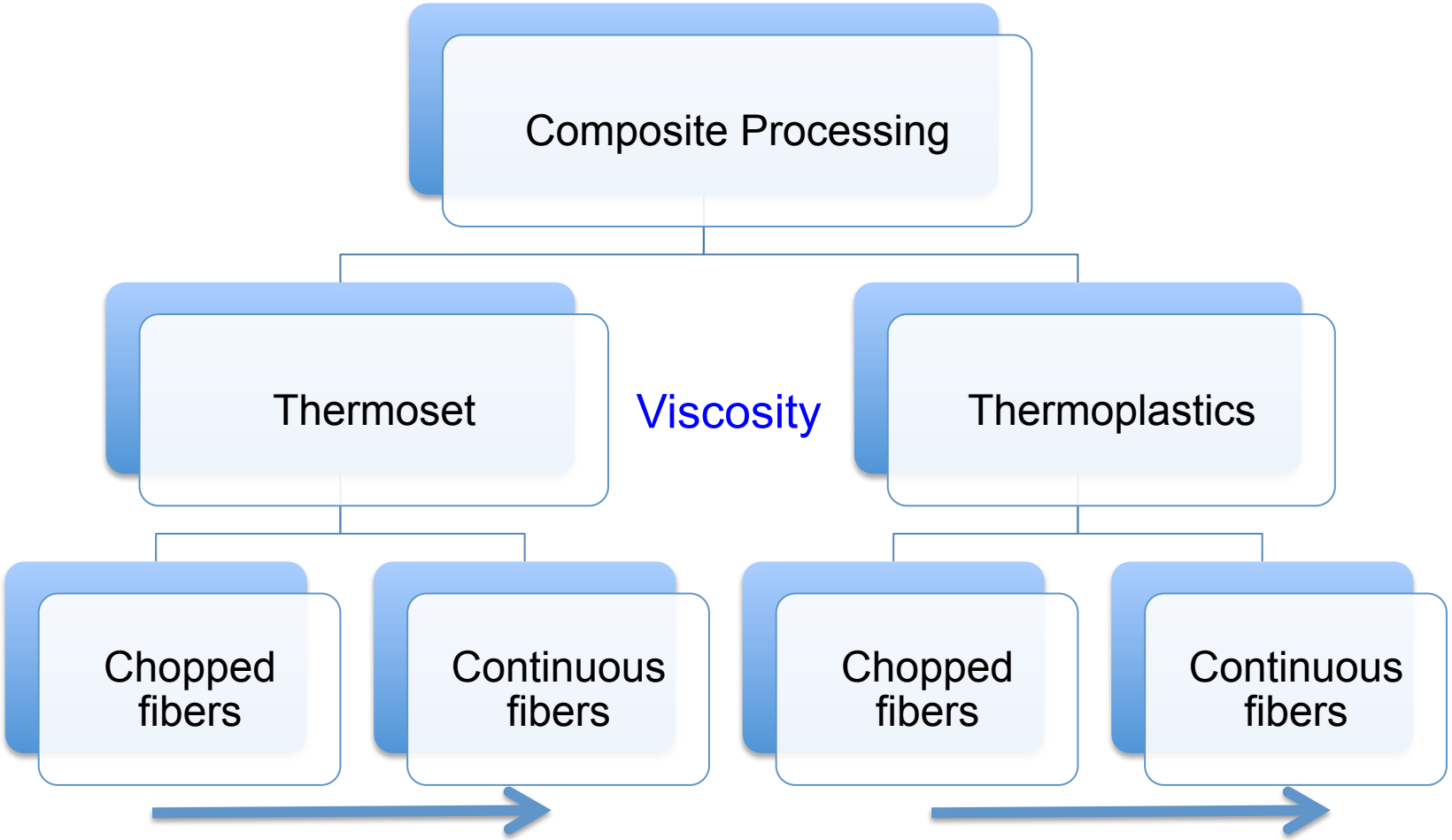








Material based classification



- Flowability of the continuum ↘
- Performance ↗

- Flowability of the continuum ↘
- Performance ↗

Classification based on dominant physical mechanism

- Short fiber suspension manufacturing process : transport of fibers and liquid/melt resin as a suspension over long distance
- Squeeze flow manufacturing process : long discontinuous or continuous fibers preimpregnated with resin deform together to form the part
- Porous media manufacturing method : usually continuous nearly stationary (sometimes process induced out of plane deformation) fiber networks impregnated by liquid resin

Fibers appear at different scales

Porous
Very low cohesion

μm

Fibre

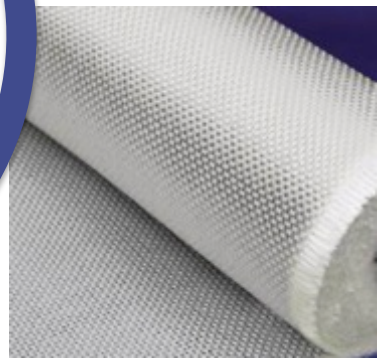
Tow

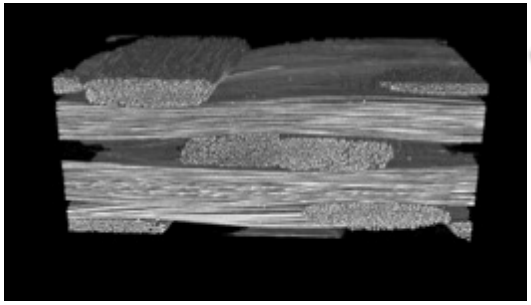
mm

Fibrous reinforcement / Preform

cm-m

Porous
Multi-scale
Low cohesion

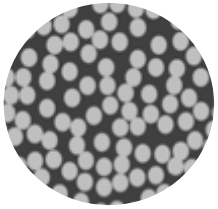




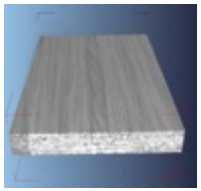
Fibrous constituents

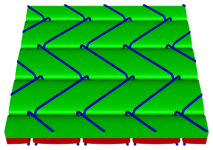
Manufacturing of fiber composites => use of fibers from the micrometer level up to the centimeter level.

Tow

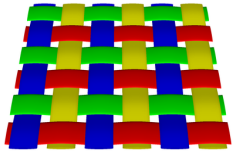


Single fiber

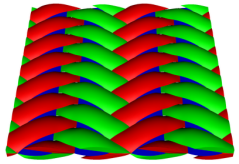




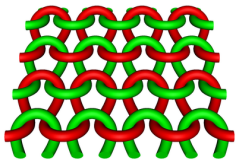
Non-crimp fabric



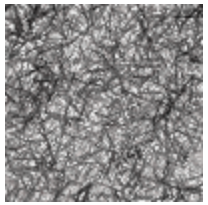
2D Weave

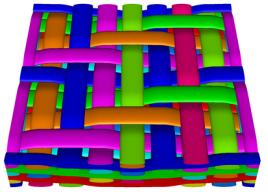


Triaxial braid

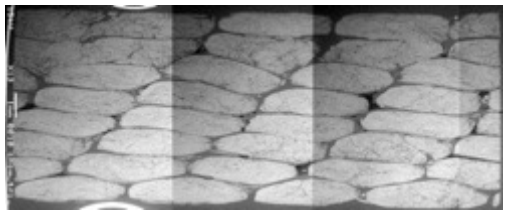


Weft-knit

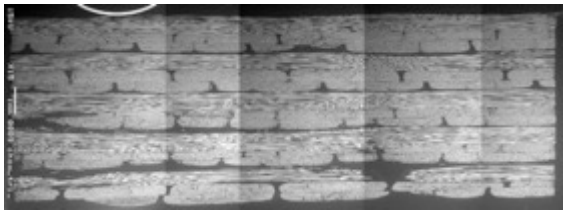


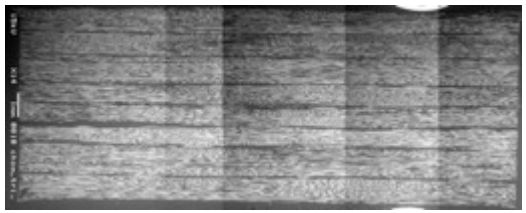


3D Weave



Stack of many layers

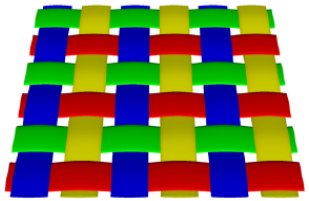




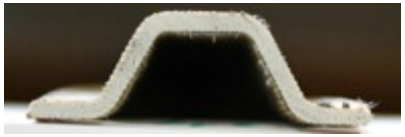
Structural Composites Manufacturing Routes

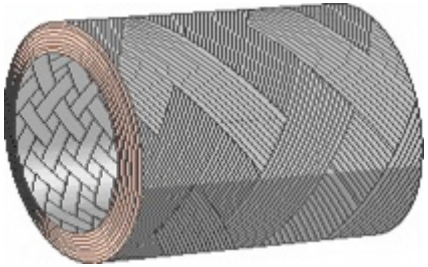
Yarns

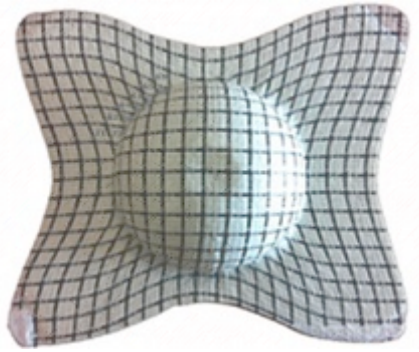
Matrix



Fabrics / UD







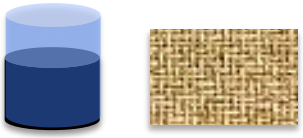
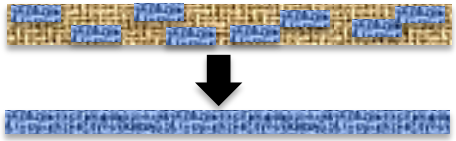
Constituents

Lamina / semipreg

Laminate / dry stack

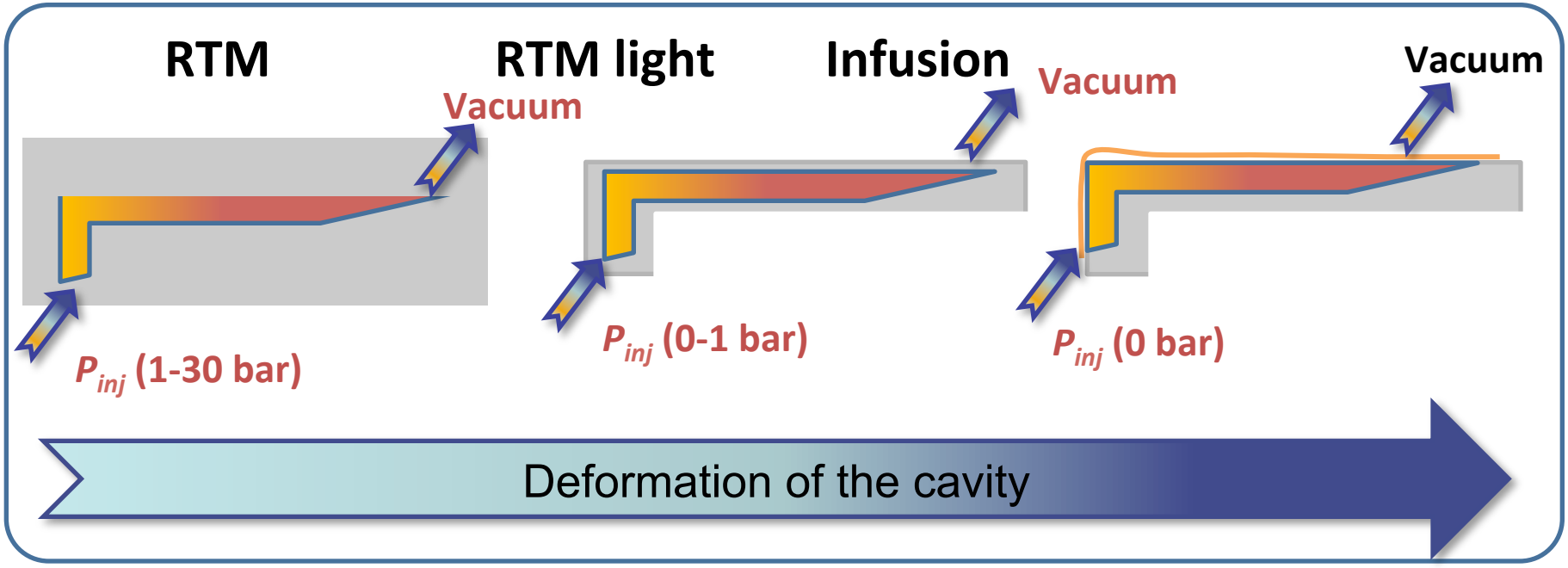
Structures

Composites Processes Classification

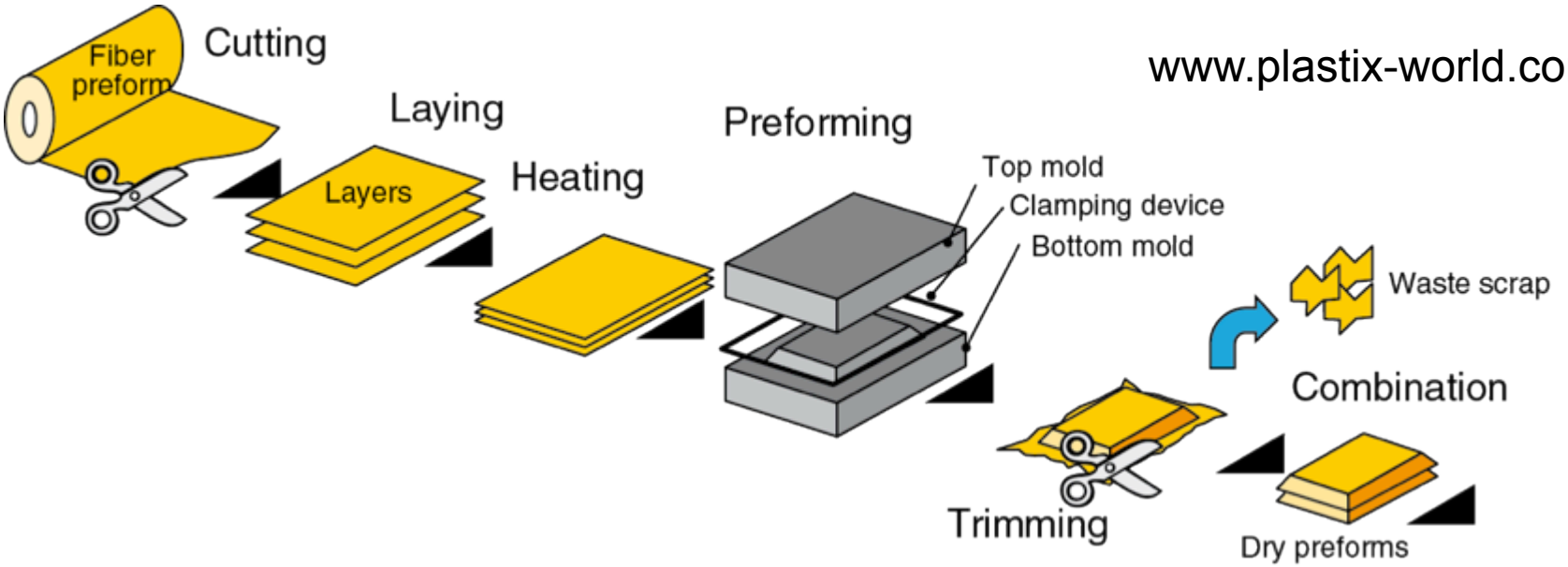
Types	Materials	Main features (Physics)	Processes	Relative Cost
B1	Matrix+ Fibers 	Matrix flow + limited fiber motion 	Injection (RTM, LRI, C-RTM)	Material  Process
B2		Limited matrix flow +fiber motion 	Consolidation Compression, HLU, Spray Up (TS or TP powders, films)	

Liquid Composite Molding

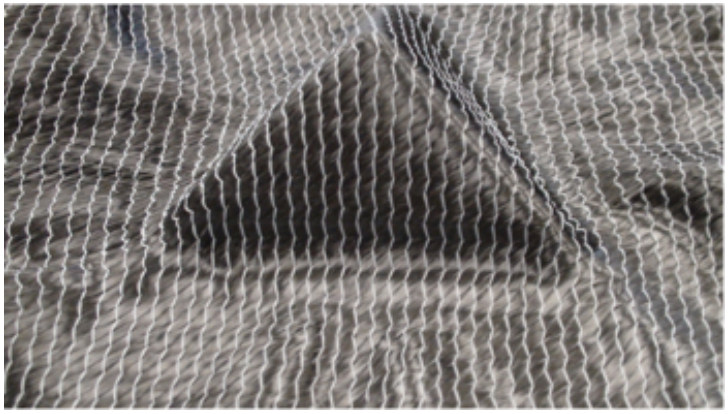
Fibrous preform



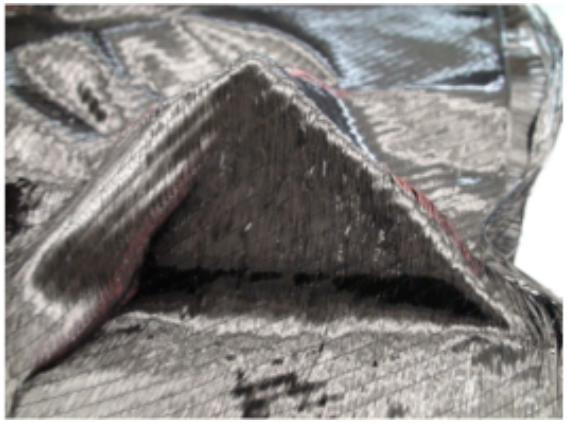
Resin Transfer Molding (RTM)



www.plastix-world.com



Good formability of the NCF1

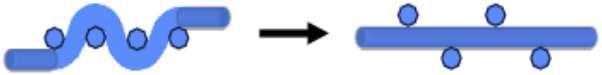


Poor formability of the NCF2

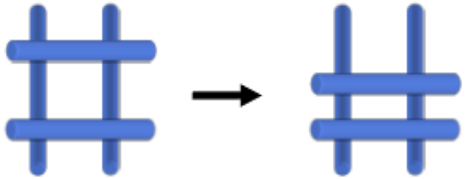
Mechanical loadings

shearing: woven fabric, braid, NCF

elastic fibre elongation (usually very small)

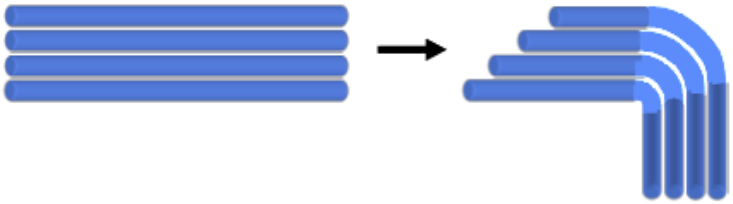


extension

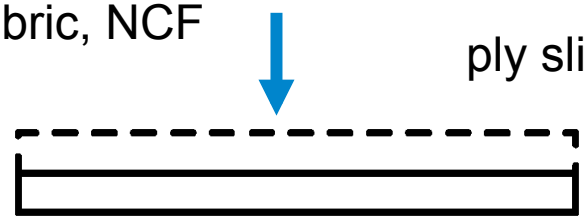


fibre slippage: NCF, woven fabric

wrinkling: woven fabric, NCF

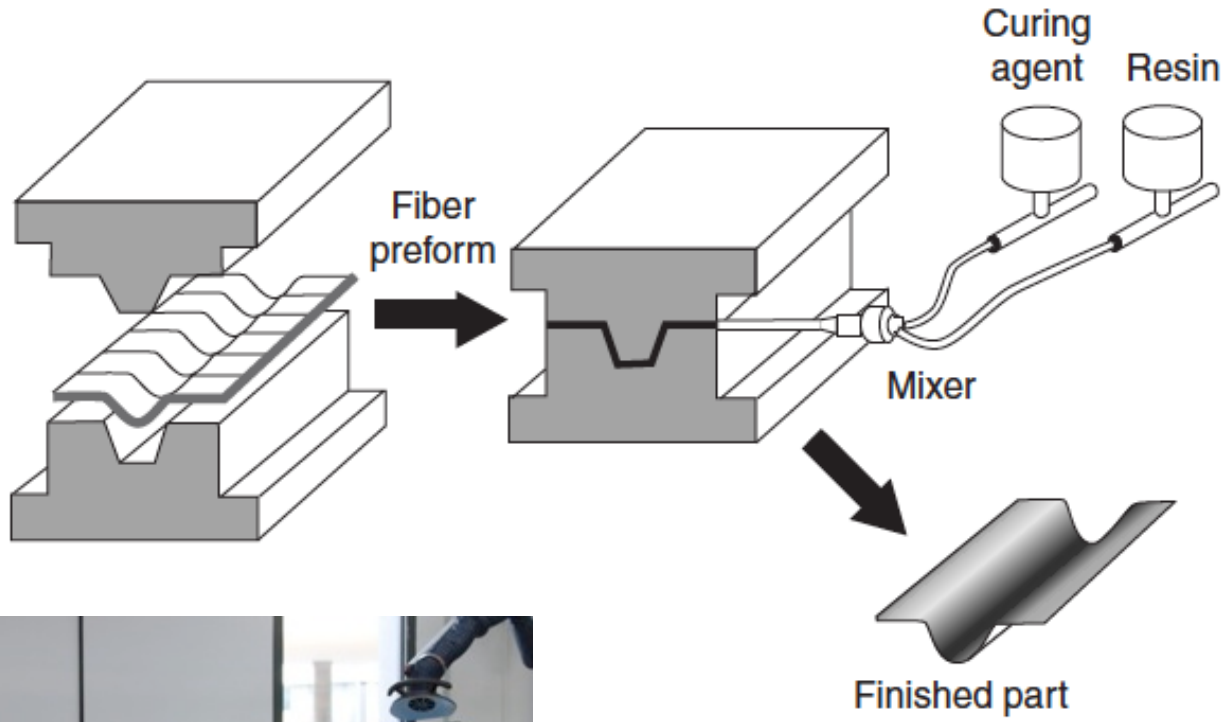


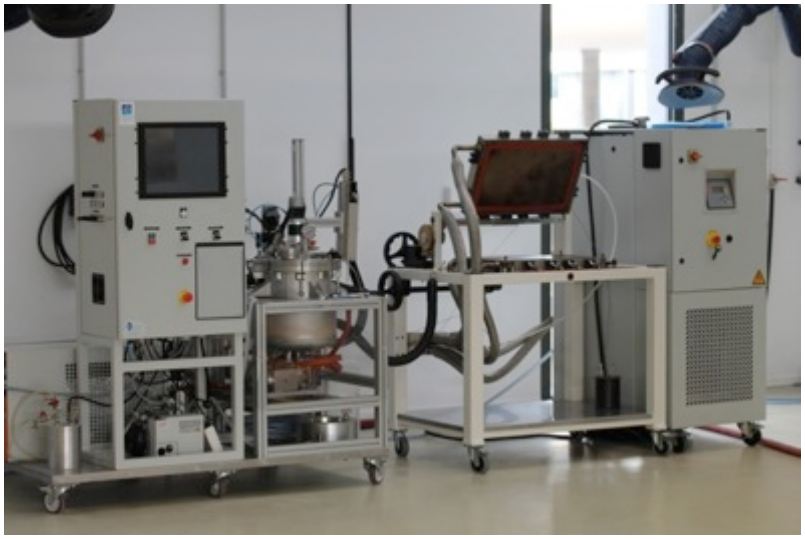
ply slippage: NCF, 3D-structures



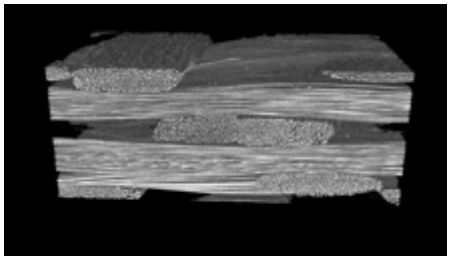
Compression

Resin Transfer Molding (RTM)

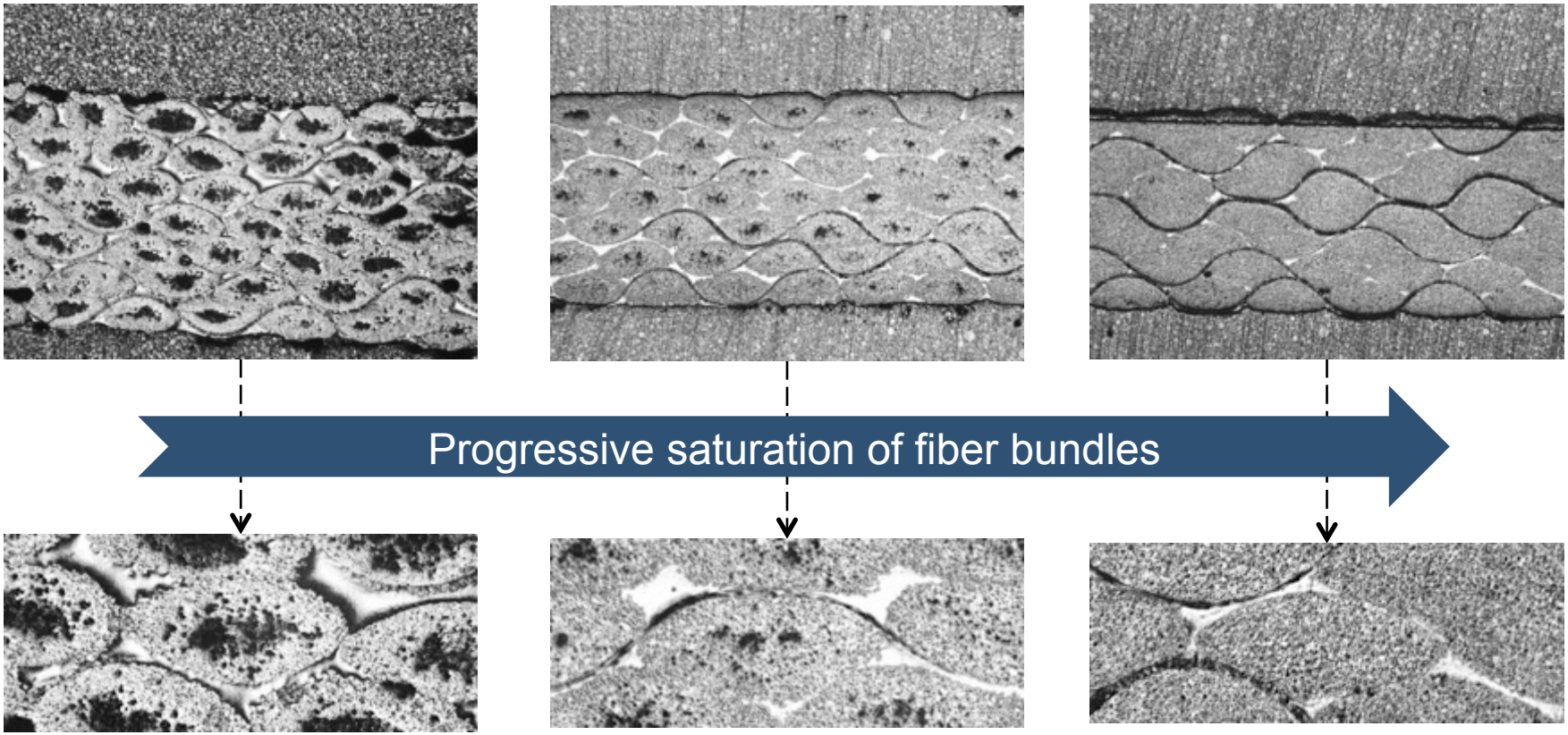




Influence of Fabric

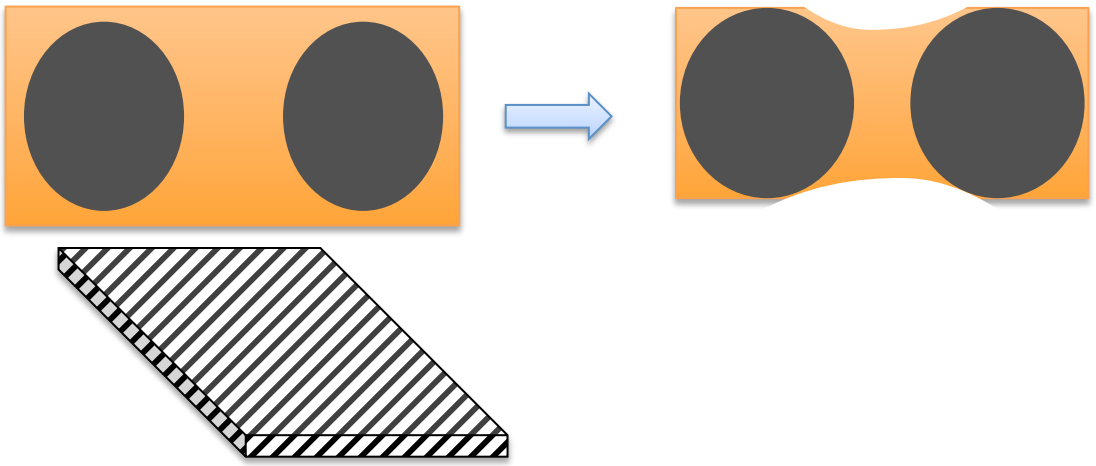


Double-scale porosity => Two-phase flow



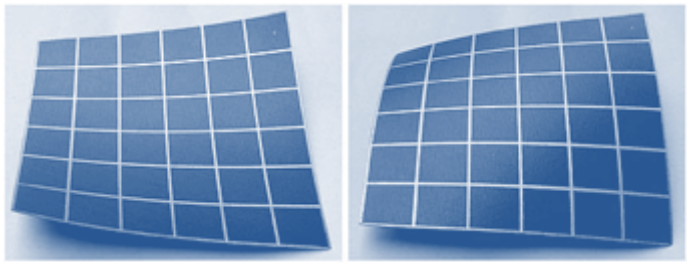
Influence of Polymer

- Fiber scale mechanism (thermal and chemical effects)

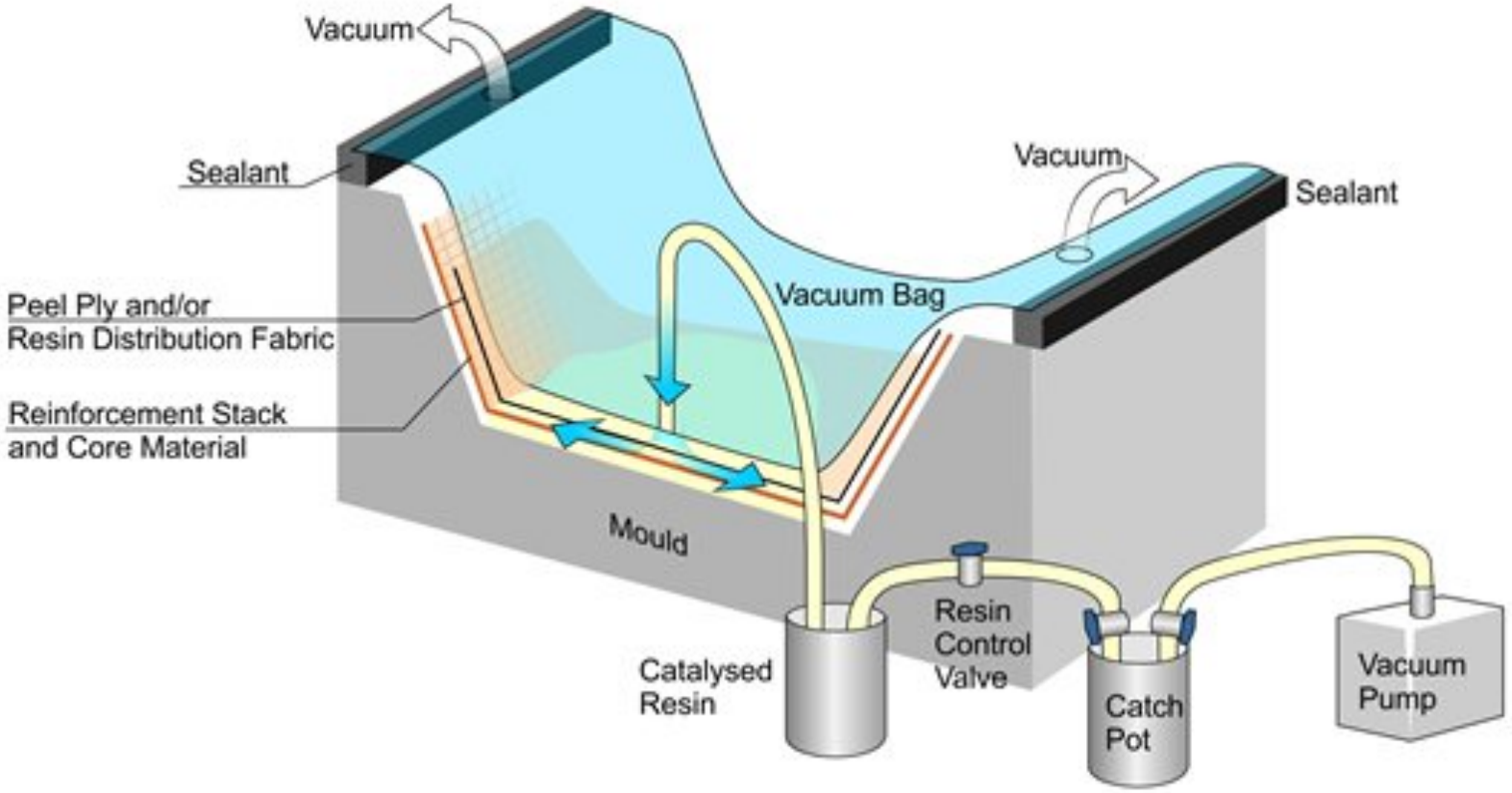


- Shrinkage
  and/or
- Strain mismatch

- Macroscopic scale effects : spring-back effect, warpage

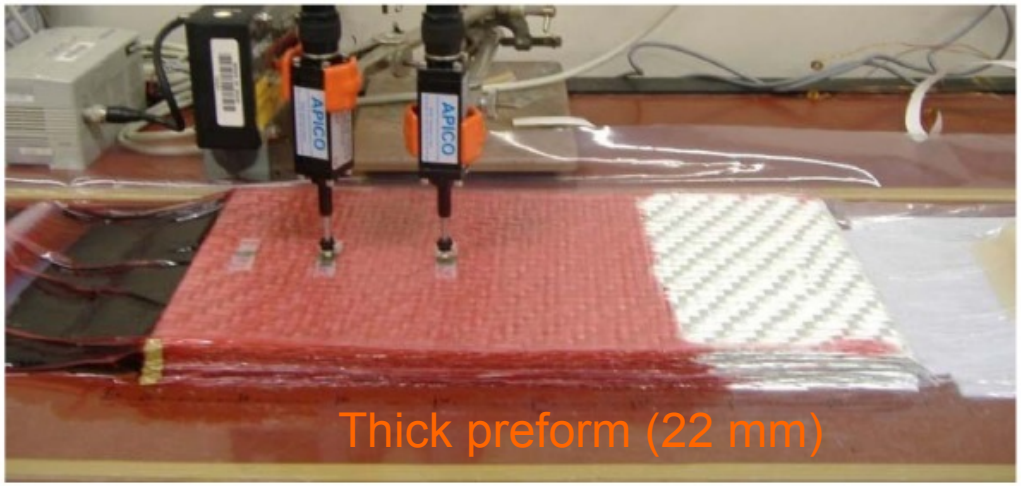


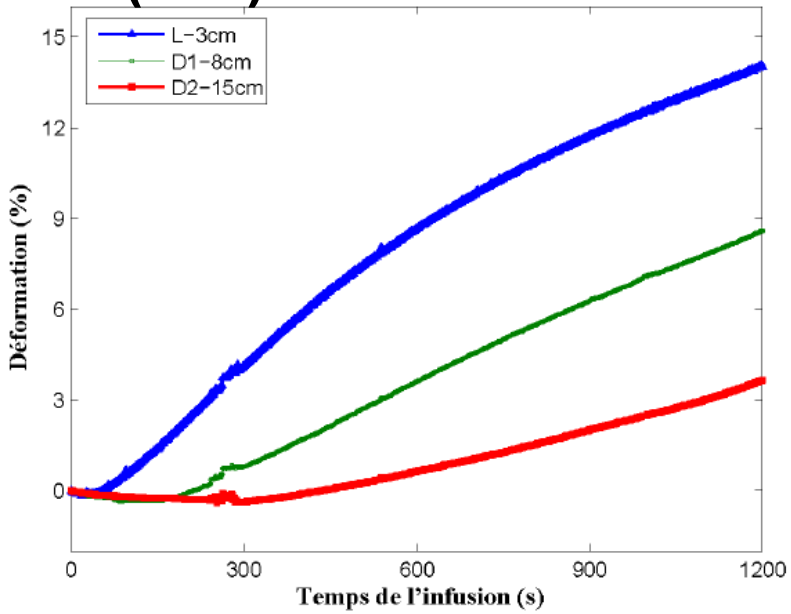
Liquid Resin Infusion (LRI)

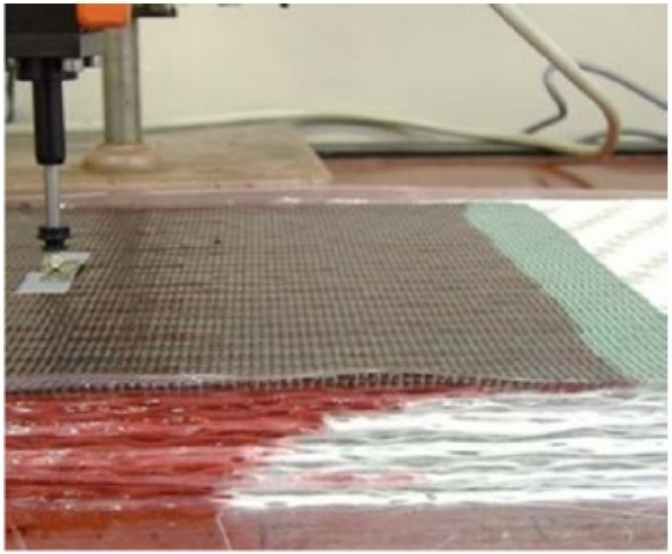


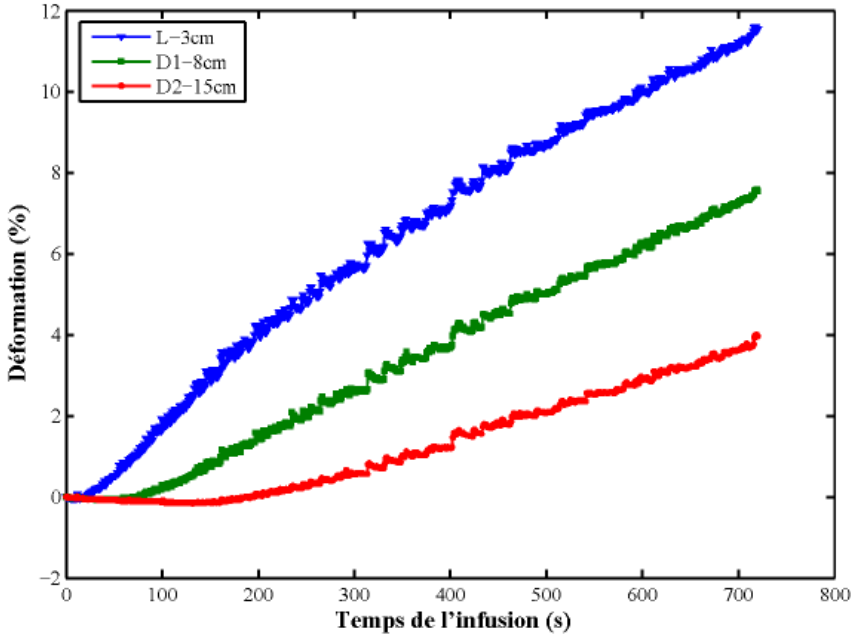
http://nuplex.com

Liquid Resin Infusion (LRI)

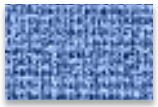
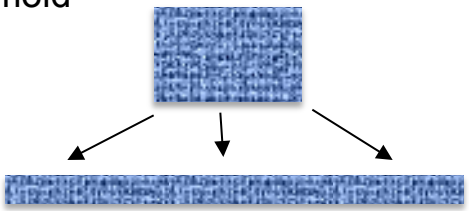
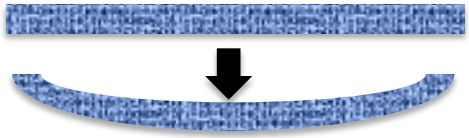




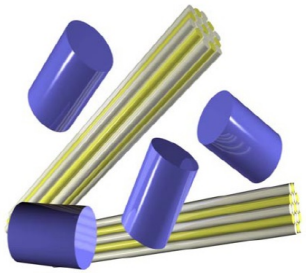




Composites Processes Classification

Types	Materials	Main features (Physics)	Processes	Relative Cost
A1	Semi-products (compounds)  or 	Flow of soft composite in the mold 	Compression (SMC) Injection (BMC, LFT)	Material  Process
A2		Forming of soft composite 	Thermostamping Compression (TS/ TP prepregs)	

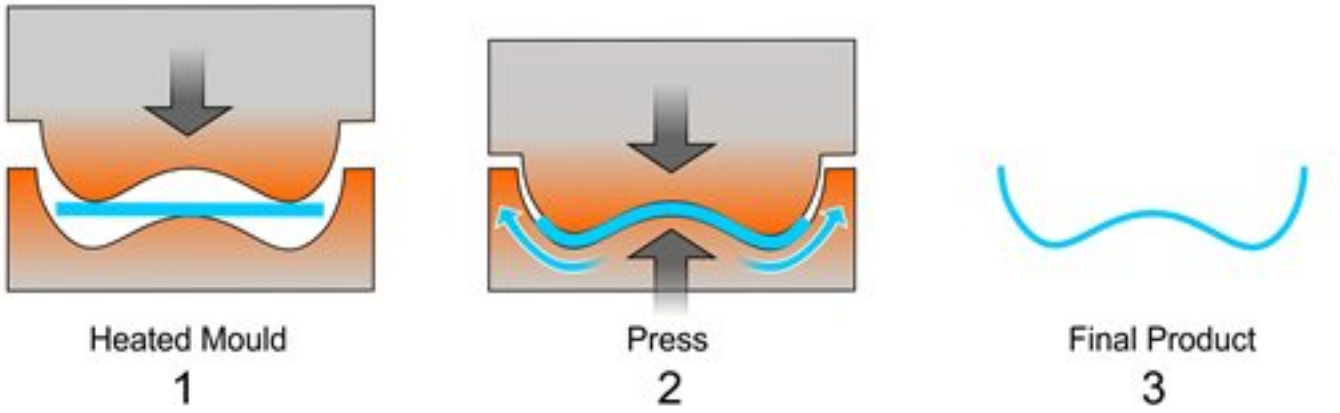
Long Fiber Thermoplastics (LFT)

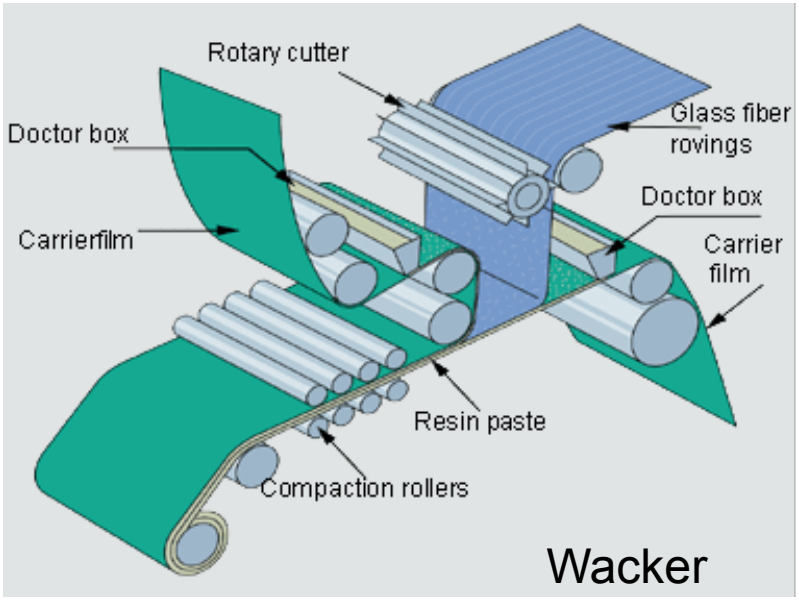


Fibrous microstructures in flows

- Dilute suspensions: no contact between the fibers
- Semi-concentrated suspensions: presences of contacts
- Concentrated suspensions: creation of new microstructures

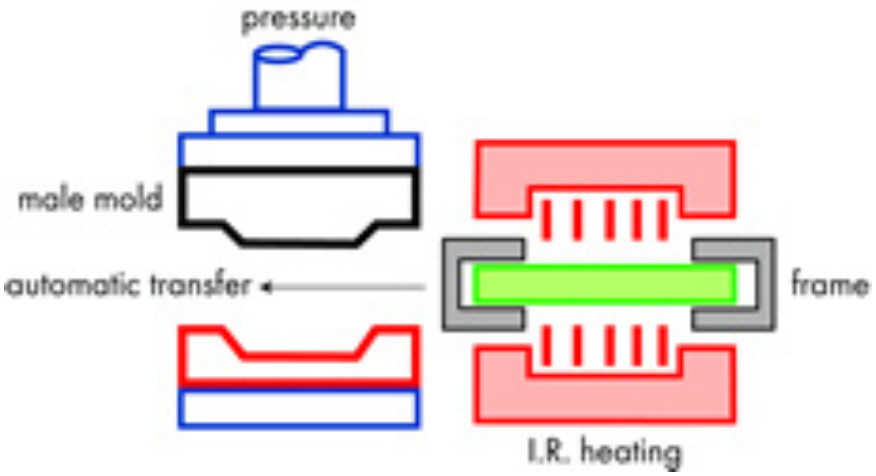
Sheet Molding Compound (SMC)





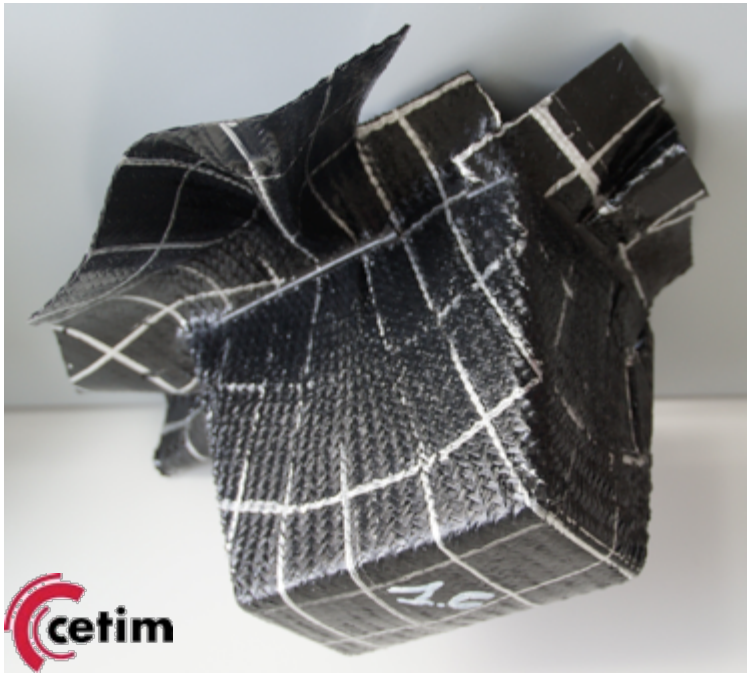
SMC composite automotive floor pan (USCAR)

Stamping/forming



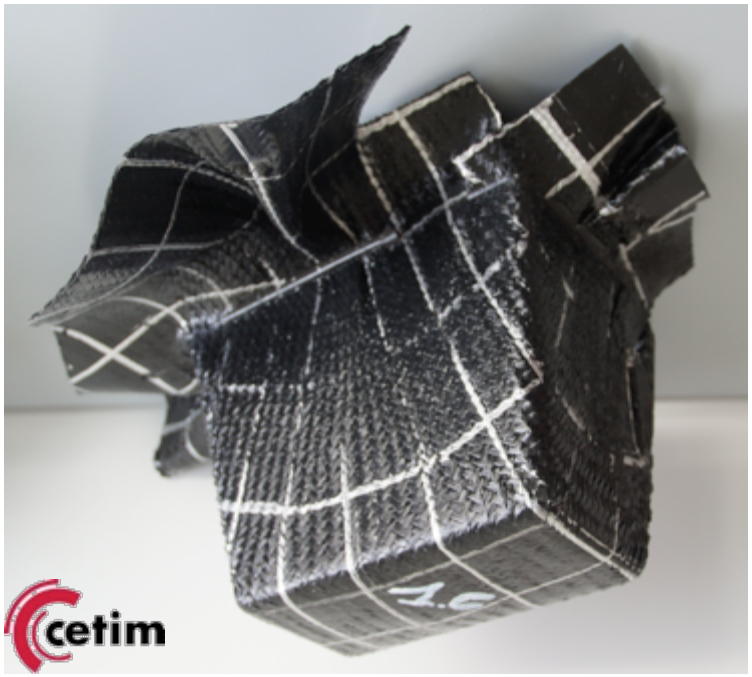
Source : Owenscorning

Thermostamping of prepregs

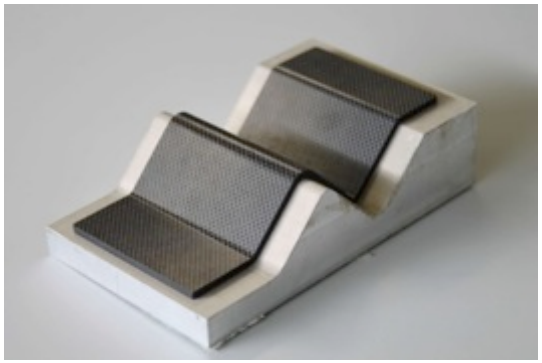


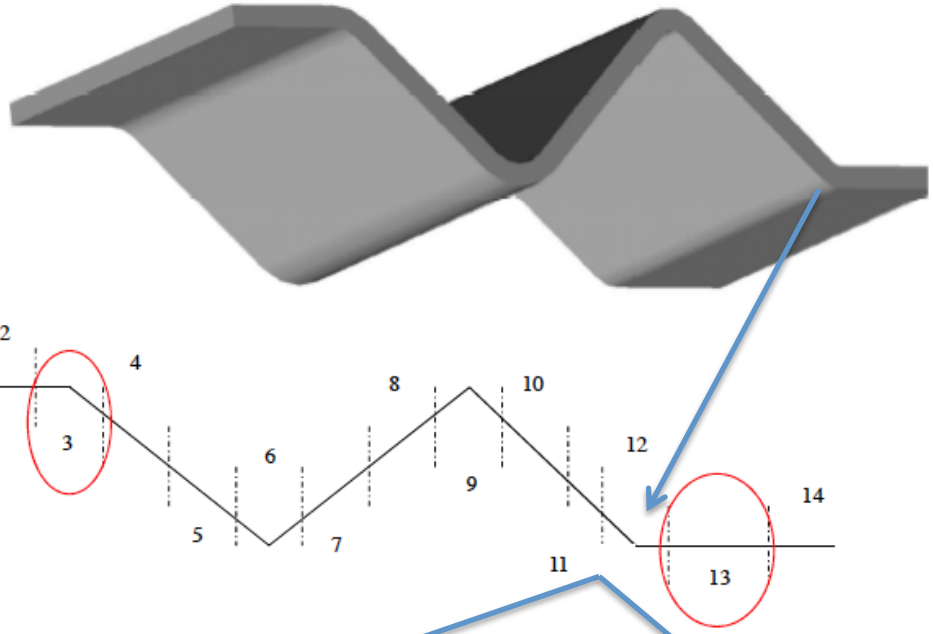
Thermostamping of prepregs

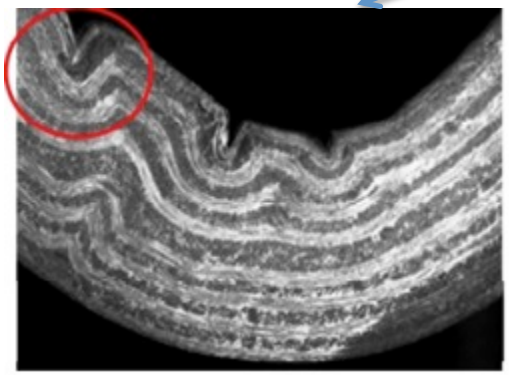
Influence of temperature

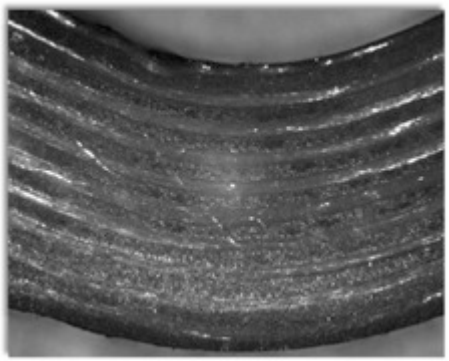


Thermostamping of prepregs





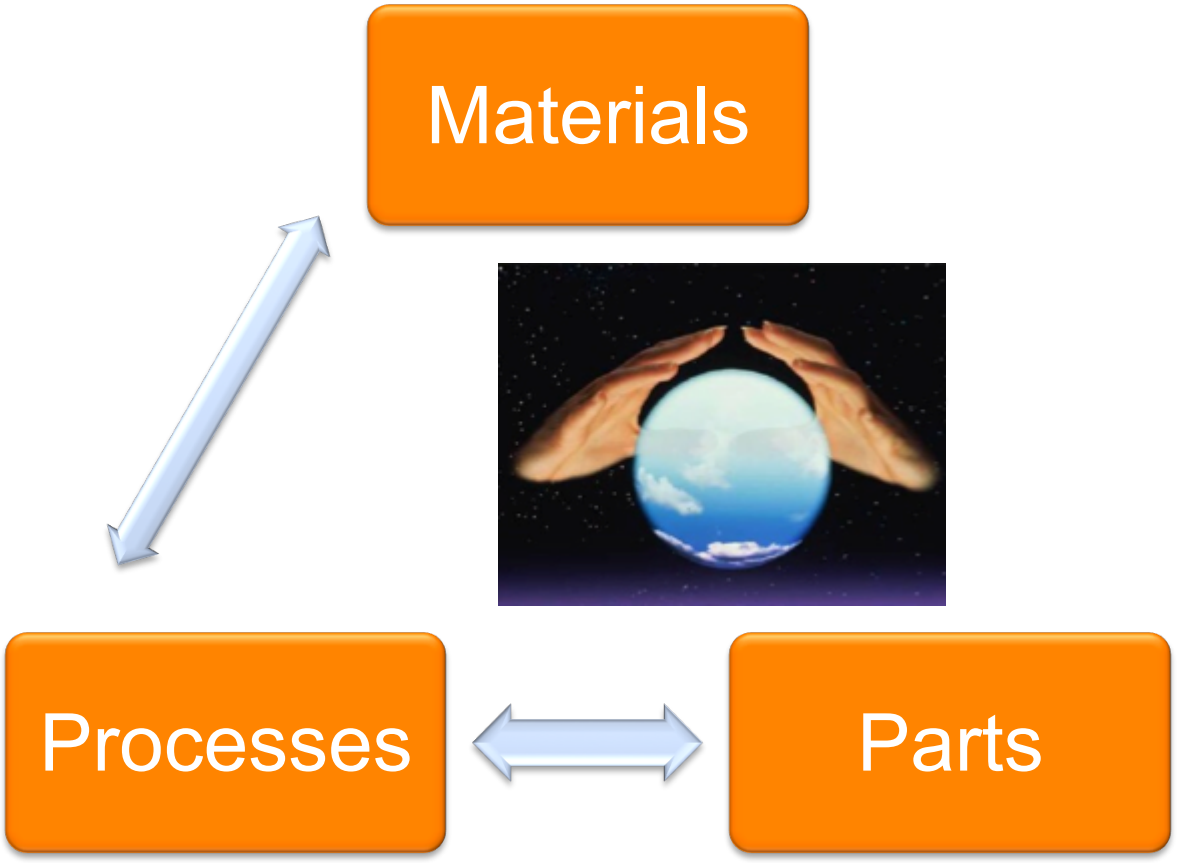




Without blankholder

With blankholder

FUTURE?



Design for manufacturing (DFM)

- Composites manufacturing processes create distinct microstructural properties in the product
- DFM (design for manufacturing) = practice for designing products, keeping manufacturing in mind to obtain maximum benefits and capabilities of the manufacturing method
- Concurrent engineering environment to avoid later changes in the design.

Design for manufacturing (DFM)

Example

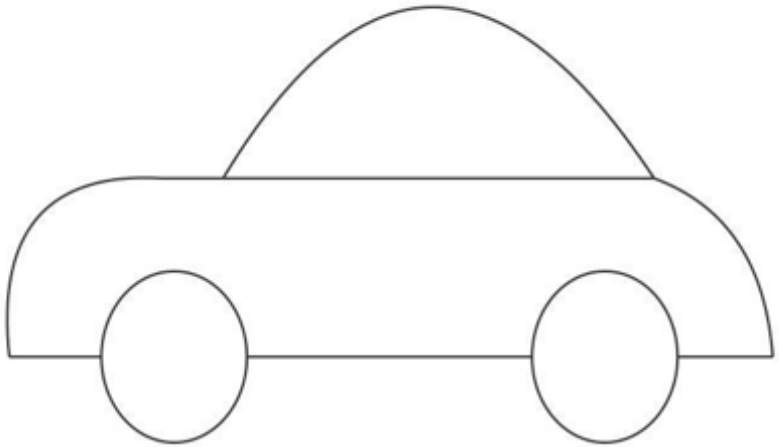
Design and manufacturing engineers work separately to create the design of the outer body panels of a car…

Design for manufacturing (DFM)

Example

Design and manufacturing engineers work separately to create the design of the outer body panels of a car…

Manufacturing engineer

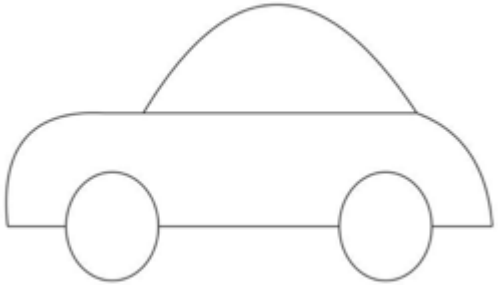


Design for manufacturing (DFM)

Example

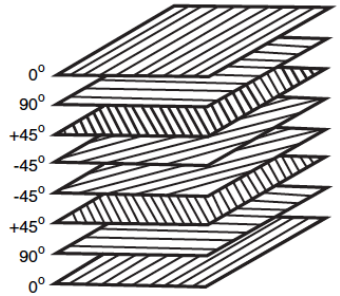
Design and manufacturing engineers work separately to create the design of the outer body panels of a car…

Manufacturing engineer



Design engineer

=> Computational framework for concurrent engineering



The rule of thumb is :

For good quality, the whole process should be broken down into small steps and each step done at a different time.

Weak coupling

Cutting → Forming → Impregnation / consolidation → Curing / cristallization → Demolding and trimming

BUT :

For lowcost manufacturing, many steps may be combined so the process can be done at one time or a lesser number of times!

From aeronautics to automotive applications

Weak coupling

Cutting

Forming

Impregnation / consolidation

Curing / cristallization

Demolding and trimming

Forming

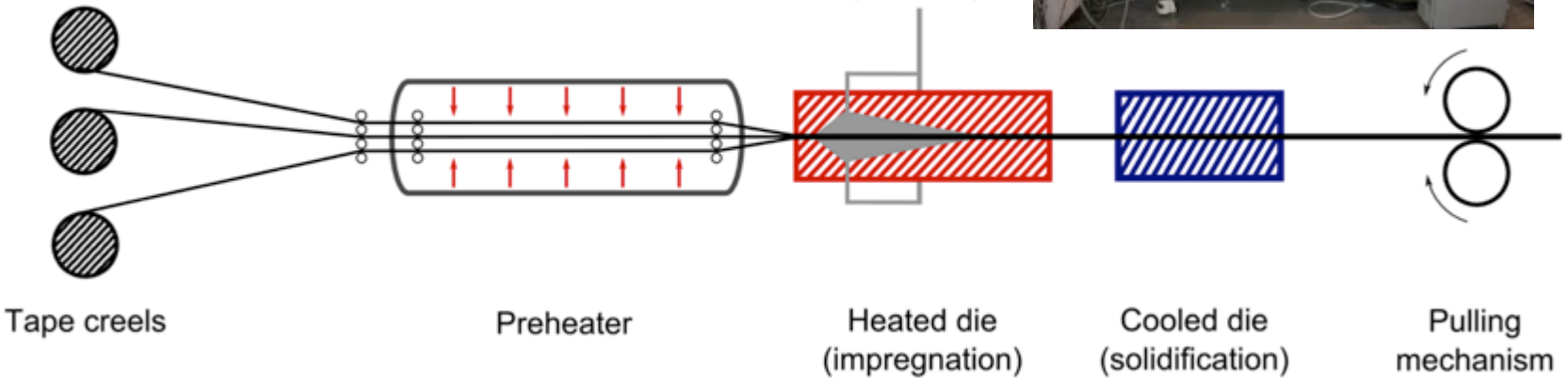
Strong coupling

Impregnation / consolidation

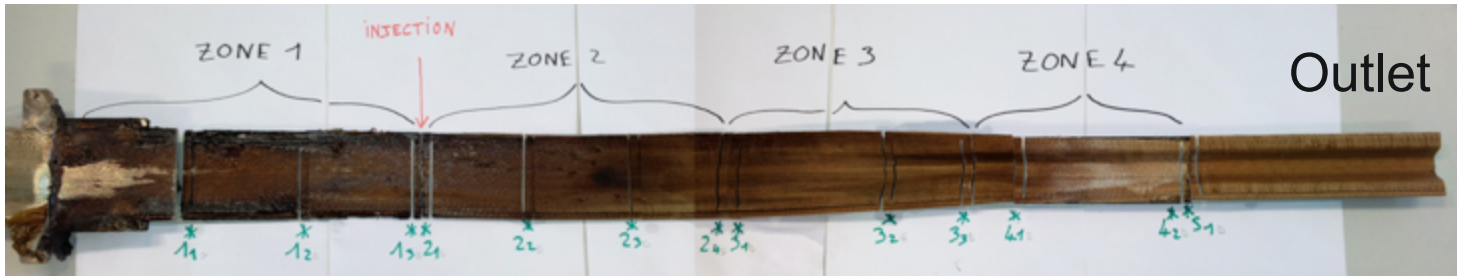
Curing / cristallization

Direct Processing

Injection-pultrusion process



Injection-pultrusion process



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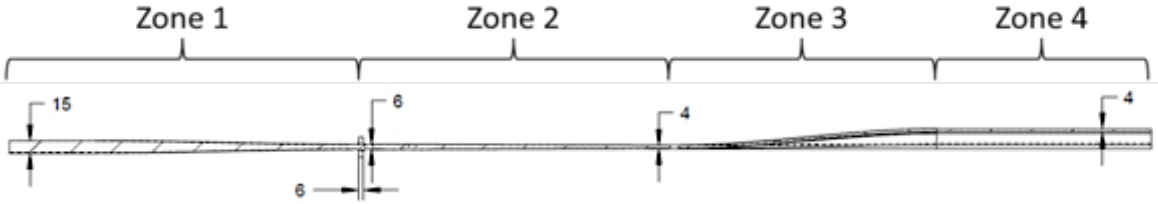
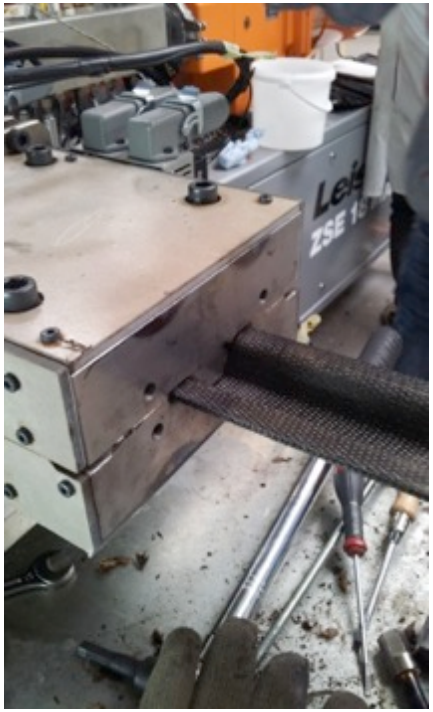
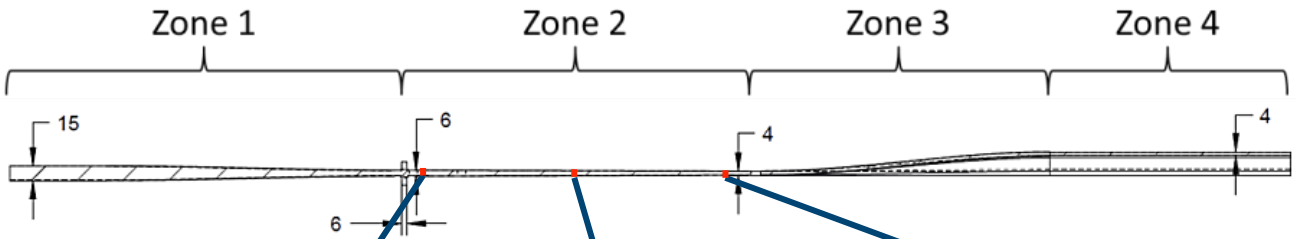
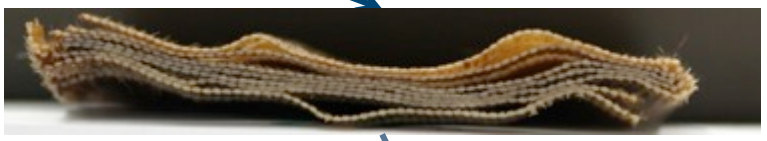
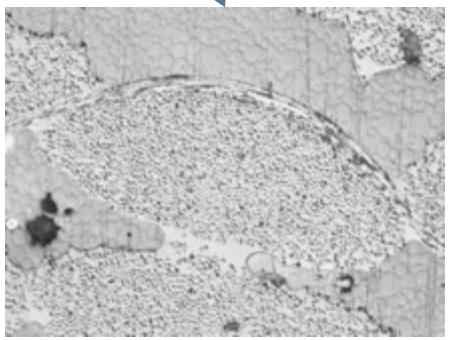




Injection-pultrusion process







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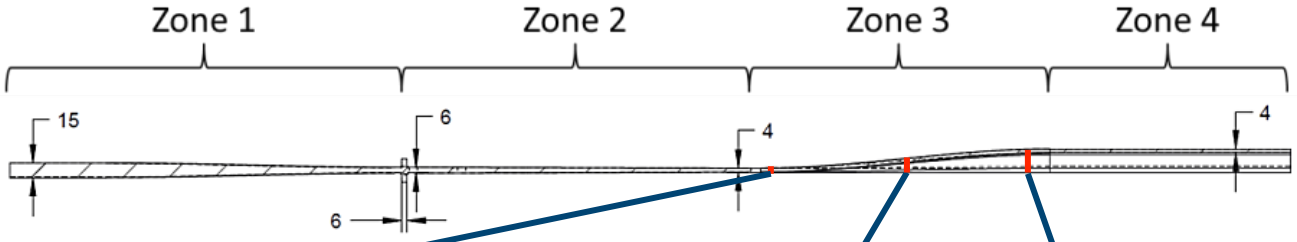
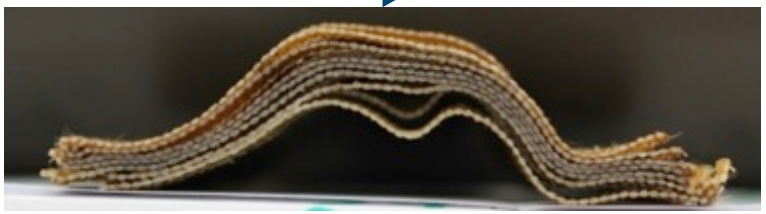
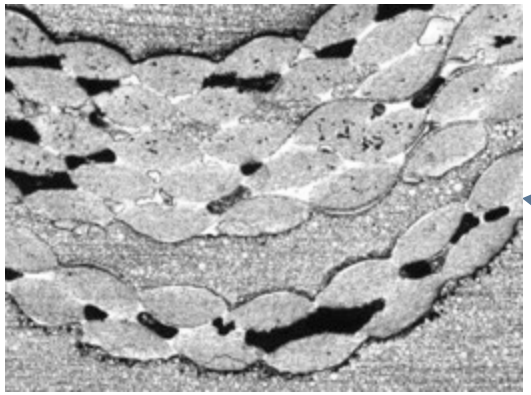
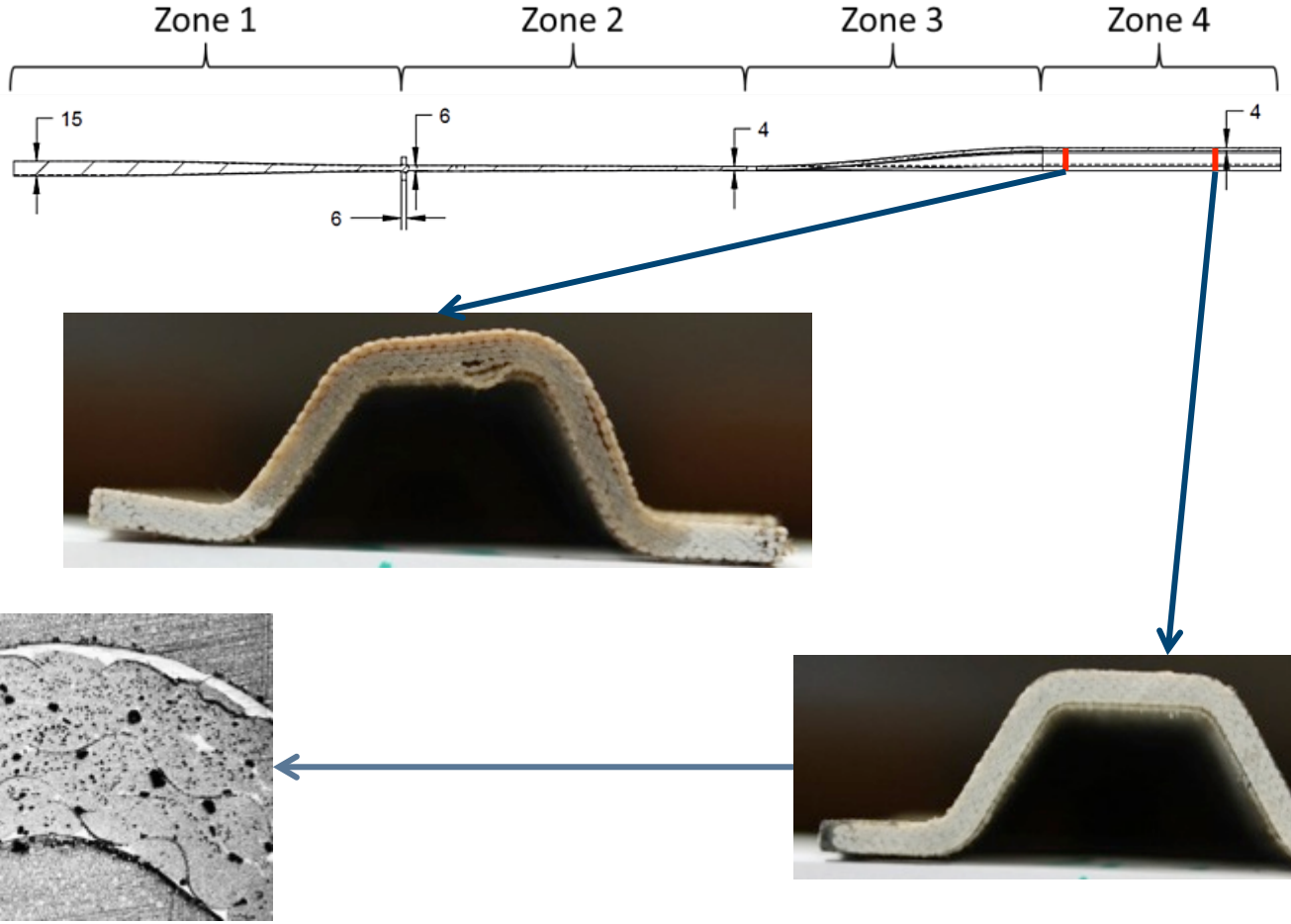
Injection-pultrusion process



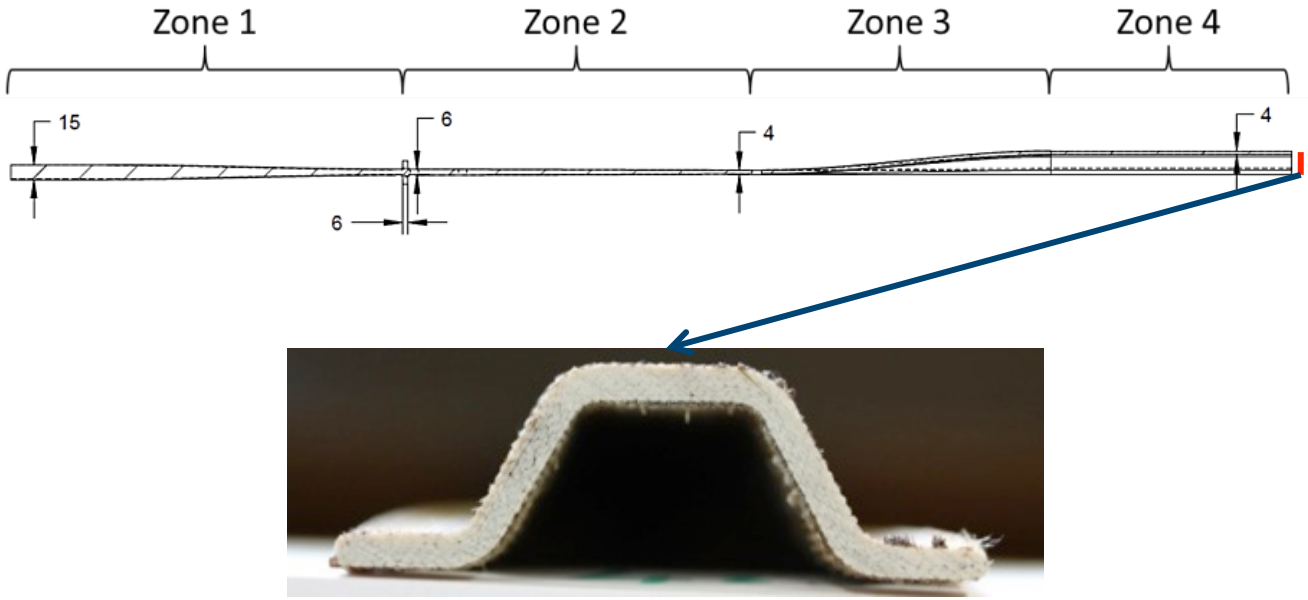




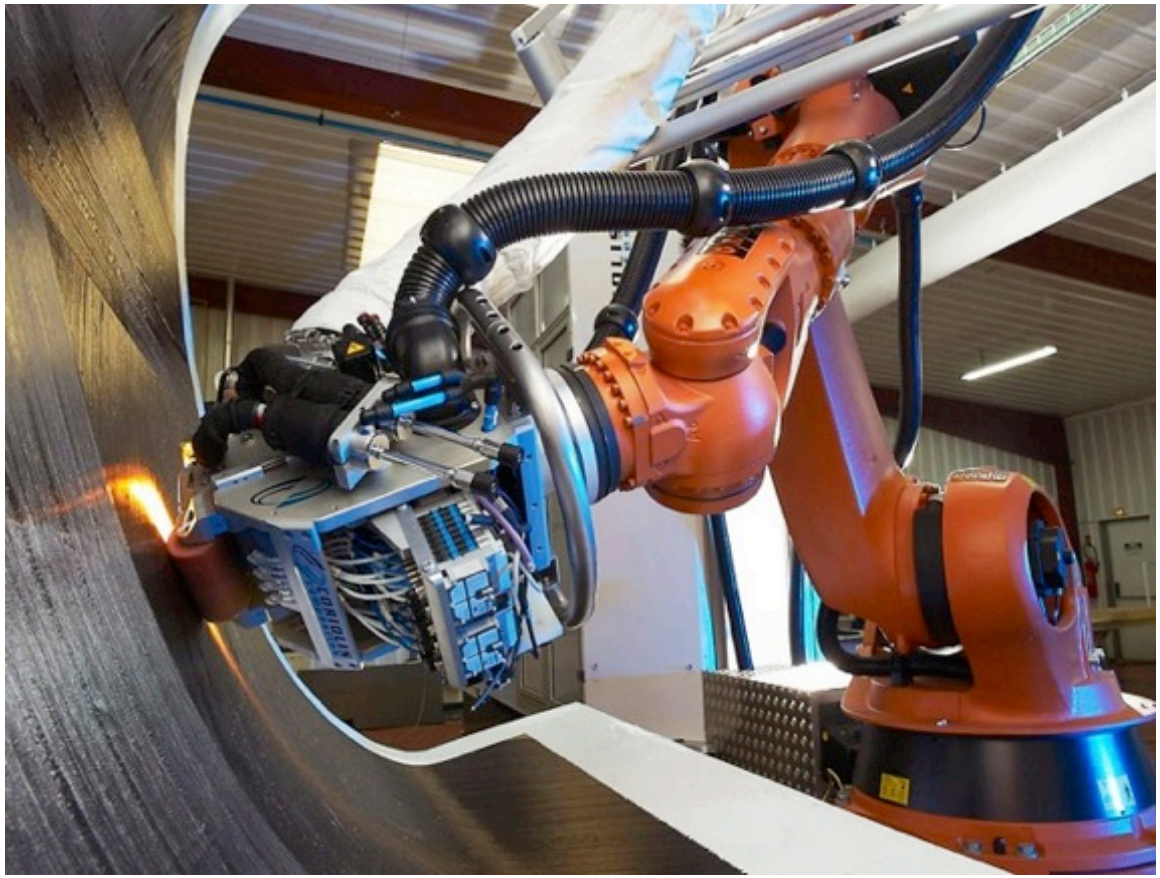
Injection-pultrusion process



Injection-pultrusion process



Automated Fiber Placement (AFP)

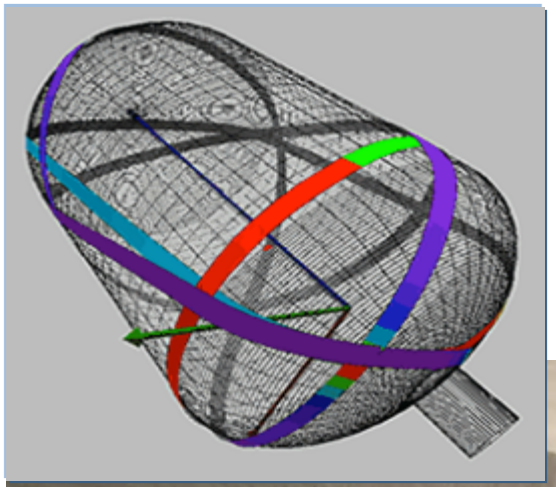


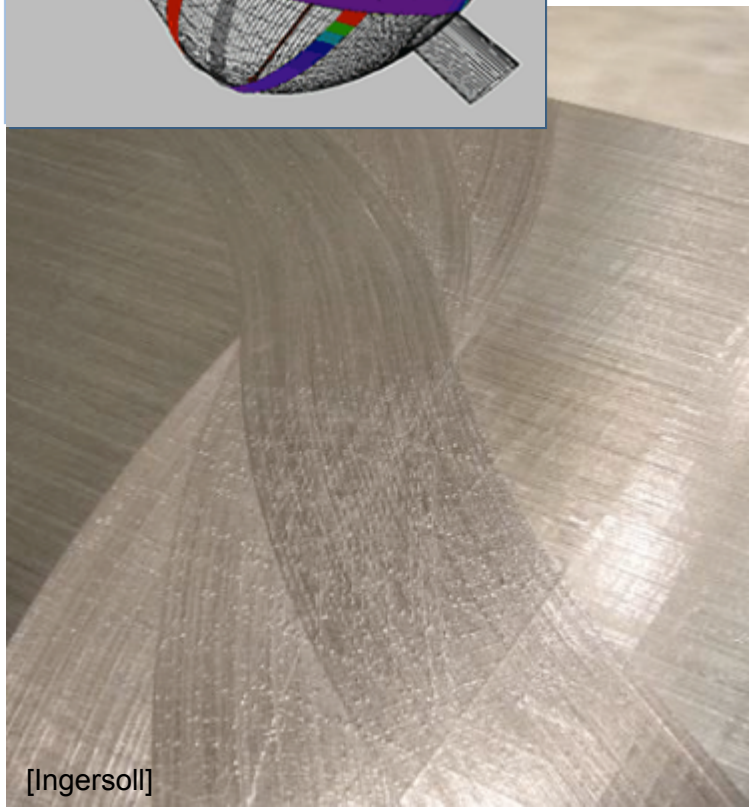
[Coriolis Composites]

Automated Fiber Placement (AFP)

- Fiber orientations can be adapted according to the stress paths and contour of a component
- Net-shape fabrication reduces waste

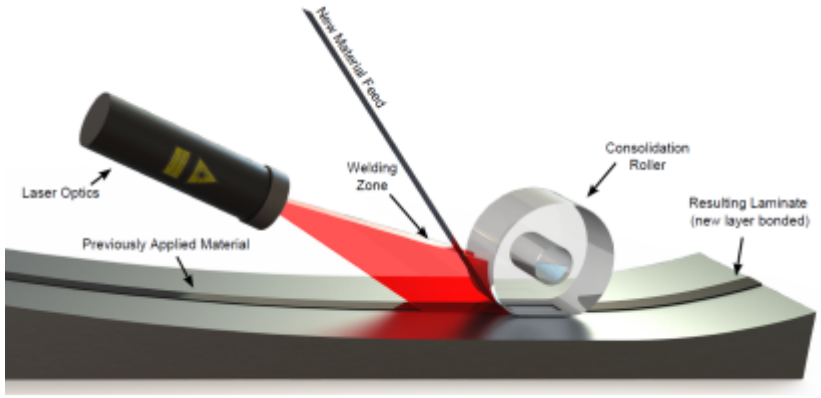
Microstructural and geometrical features are interdependent

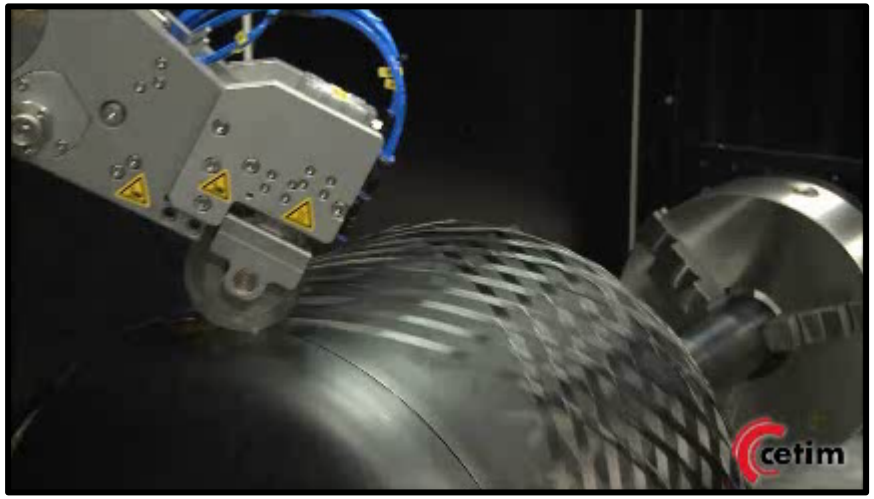


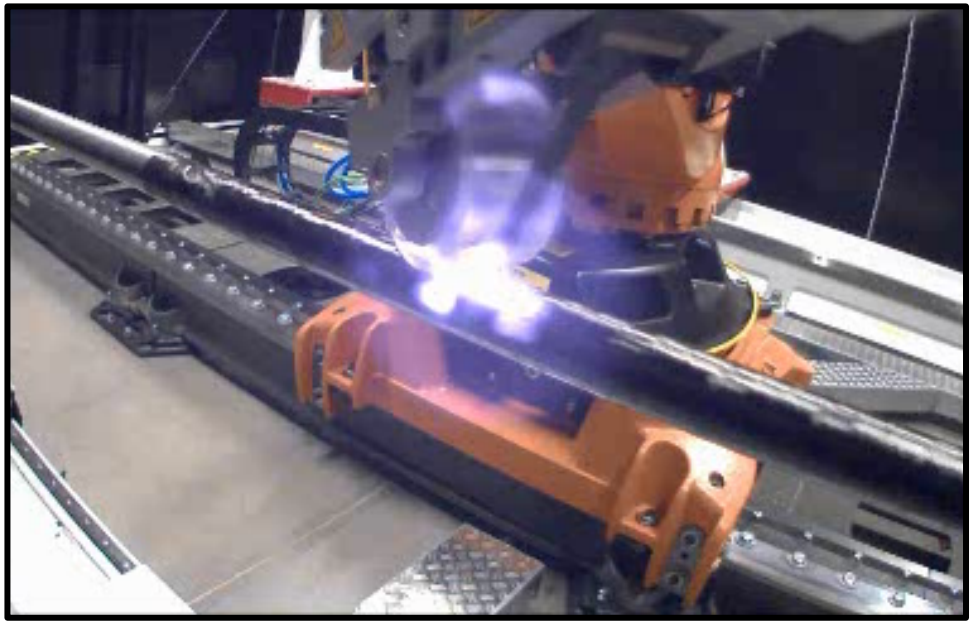


[Ingersoll]

AFP: Exemple







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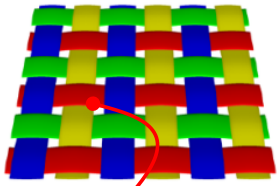
Composites Manufacturing

Fibre

Yarn



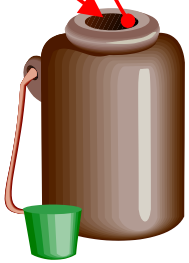
Fabrics

Reactive resin

Multi-physics

Composite part

Composite material



Process

Boundary conditions: P, Q, V, σ, U, T…

Initial conditions

Défis pour la formation

Sensibiliser aux :

- Aspects technologiques des procédés (notamment au travers d'exercices pratiques utilisant des moyens "industriels")
- Aspects multi-physiques et multi-échelles des procédés au travers de la modélisation et de la simulation numérique
- Difficultés liées à l'obtention des données d'entrée des outils de calcul
- Liens entre les constituants, la conception et la fabrication des pièces composites

Centrale Nantes

Institut de Recherche en Génie Civil et Mécanique

Questions?

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