

Composite Technology MSE 440

Processing methods

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Objectives

- Describe the main methods used to process polymer matrix composite materials.
- Justify the choice of a given process based on the materials selection, part complexity and production volume.

Composite processing

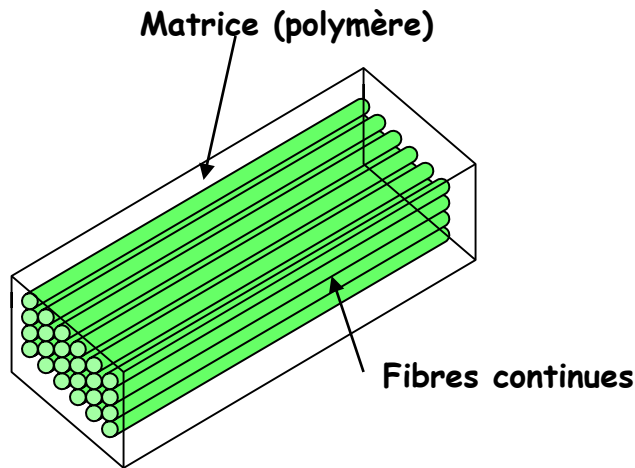
In general, the reinforcement is already under its definite form:
fiber, powder, potentially woven or assembled.

- > the matrix is the one that transforms during processing
- > Interface is also formed during processing.

Processing must ensure:

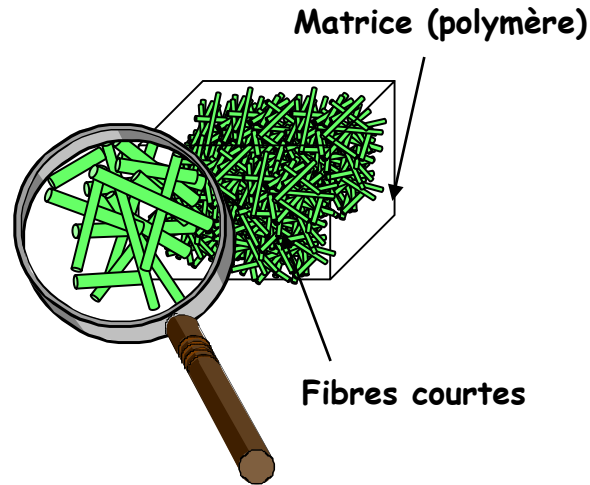
- to preserve the integrity of the reinforcement, its orientation, its architecture if needed.
- to provide a matrix that intimately bonds to the reinforcement, develops desired mechanical properties, and presents few defects.
- to be as cheap as possible, and as fast as possible to process for a given set of requirements.

Form factor



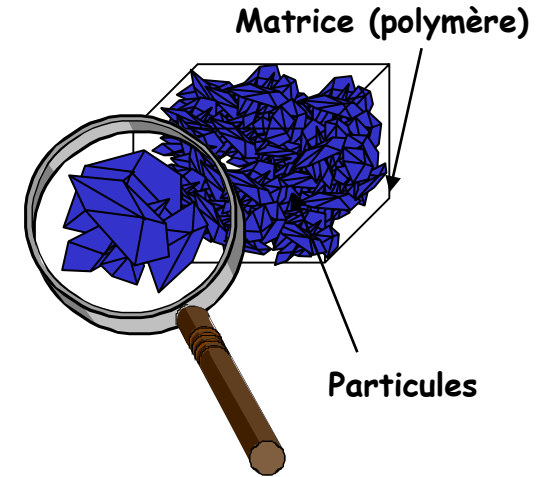
- Fibres orientées
- Composites unidirectionnels (UD)
- Thermodurcis, thermoplastiques

$L/d > 1000$
Methods
adapted to
long fibers,
fixed



- Distribution de fibres courtes (< 3mm)
- Surtout des matrices thermoplastiques

L/d between
100 et 1000

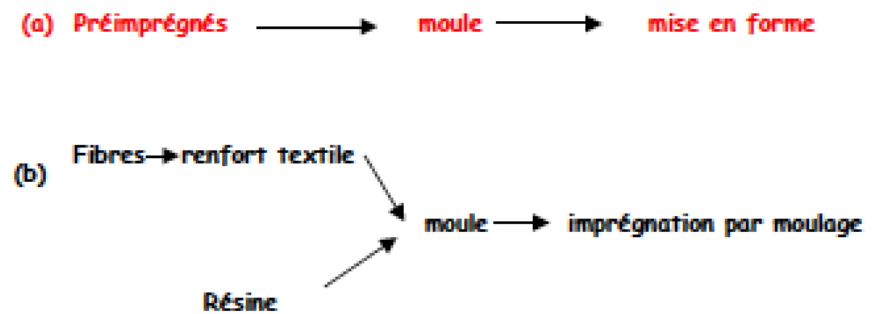
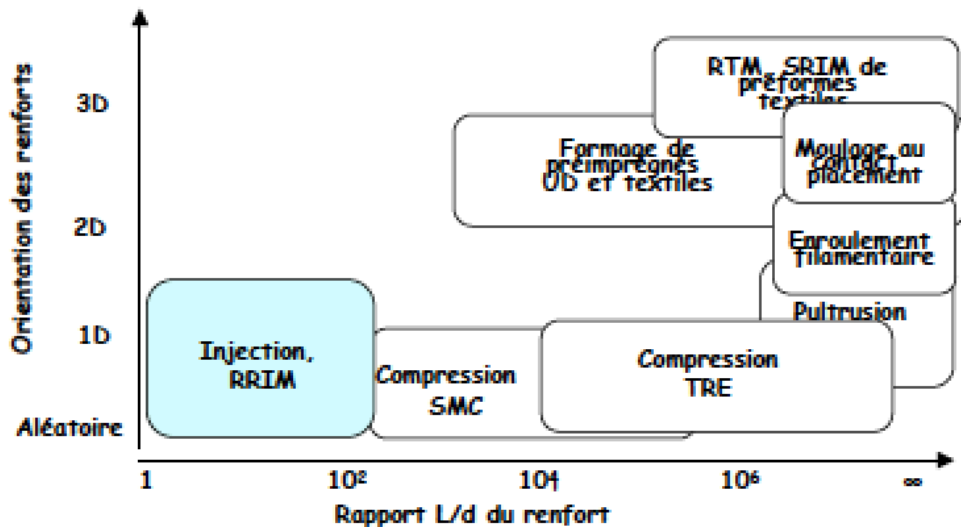
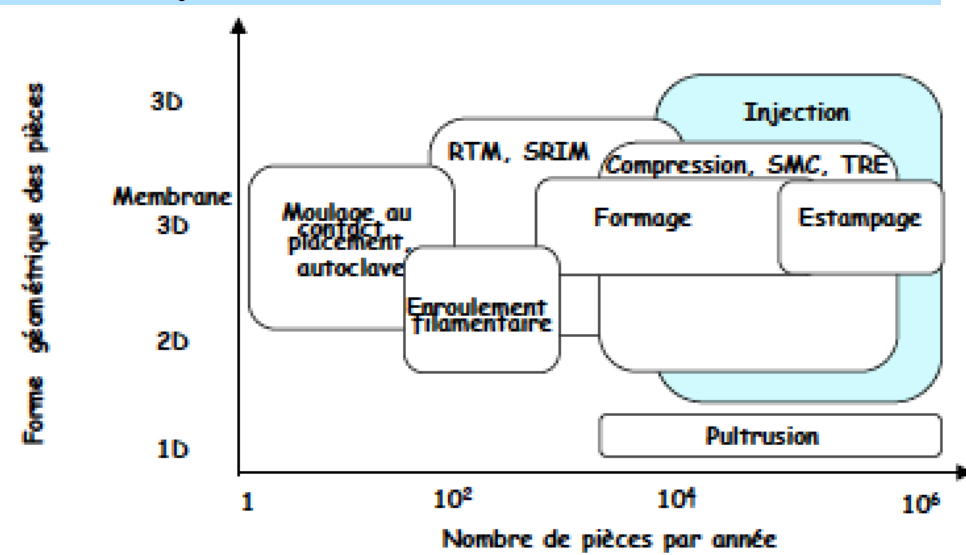
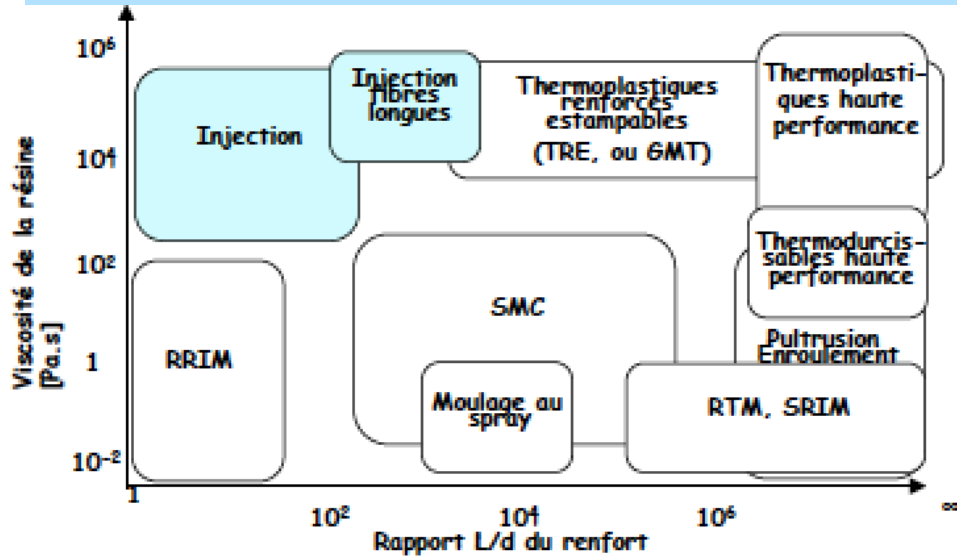


- Particules (1-400 μ m), silice, argile...
- Thermodurcis et thermoplastiques

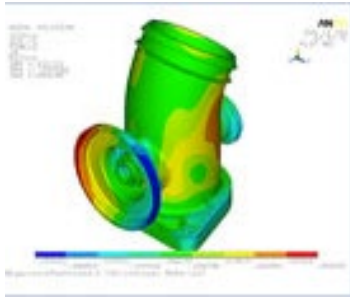
$L/d < 100$ (and nano
materials with large L/d)

Methods inherited from plastics
processing, polymer plus charges

Short fibers /thermoplastic resin



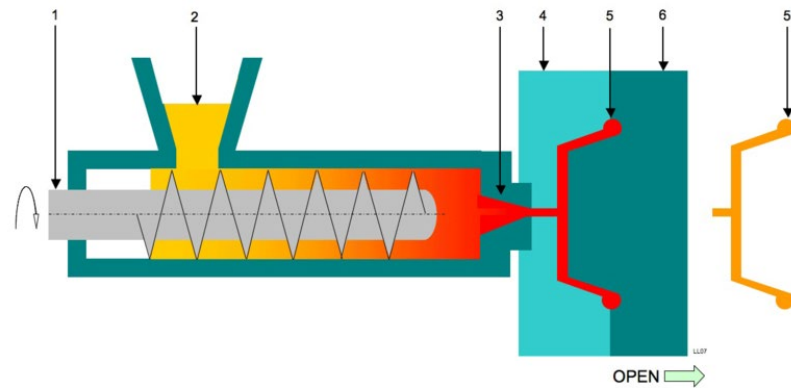
Injection Moulding



<http://www.sino-mould.com.cn/auto-mould.html>

Thermoplastics
Short Fibers

Complex parts



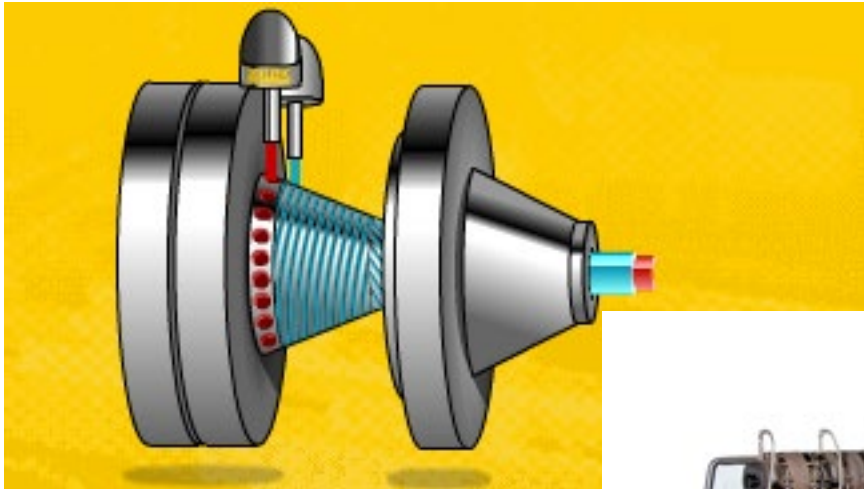
Advantages :

Complex parts
High part quality
Fast production speed

Drawbacks

Tool cost
Limited to short fibers
Fiber orientation difficult to control
Limited to small parts

Extrusion moulding



Thermoplastics
Short fibers

Profiles, several layers possible

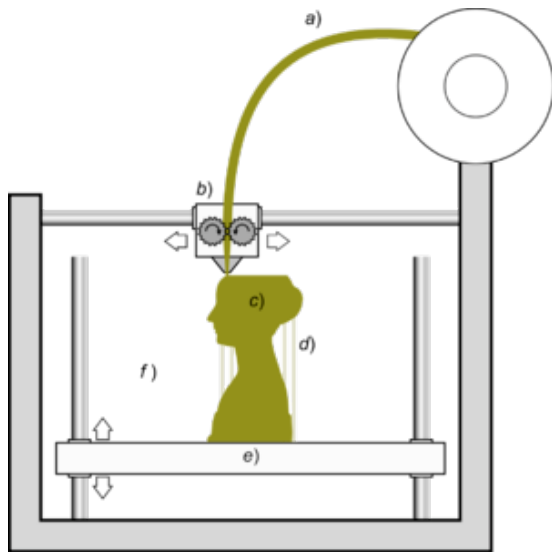


Twin screw extruder



Advantages :	Drawbacks
Cost Part quality High production speed	Tool cost Limited to short fibers Fiber orientation difficult to control Restricted to profiles

3D printing: Fused Deposition Modelling



Wikipedia



Mark Forged

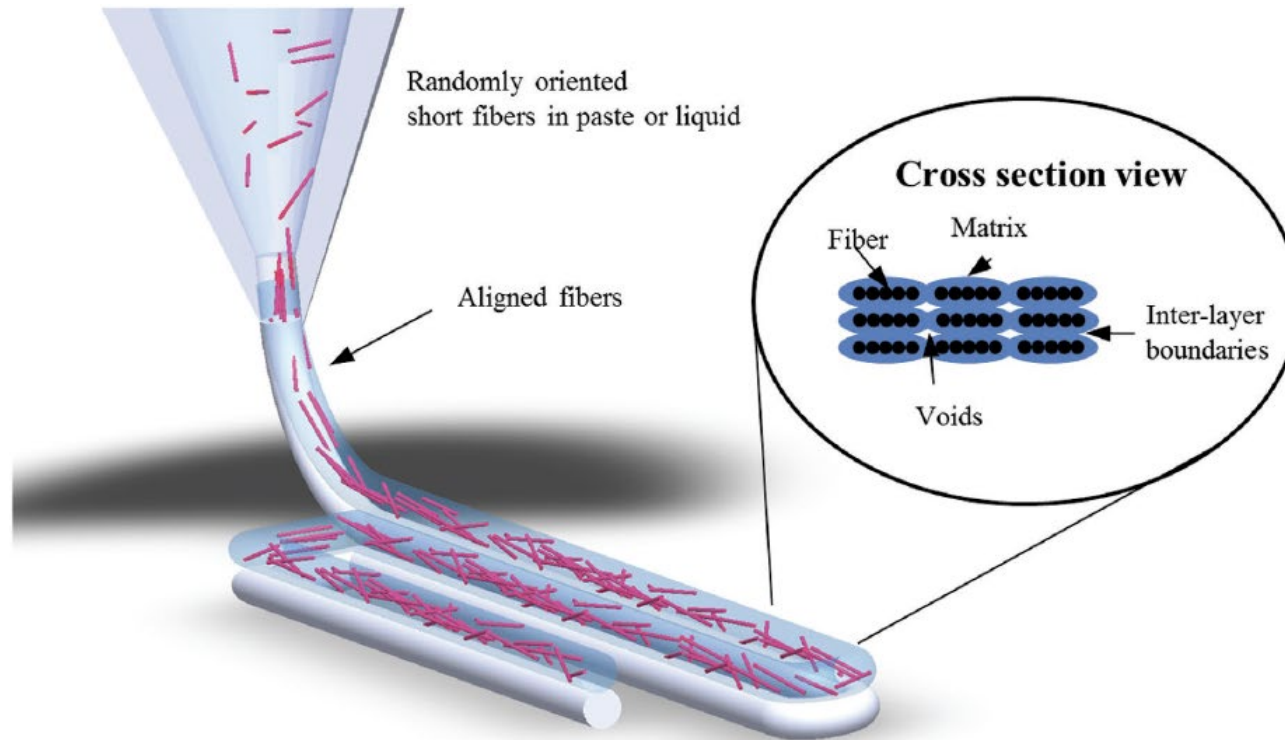
Thermoplastic matrices
Short fibers
Complex shapes



Arevo labs

Avantages :	Drawbacks :
Low cost equipment easy to manufacture prototypes or tailored parts	Limited to short fibers, some attempts with long fibers ongoing. Quality, transverse mechanical properties still limited.

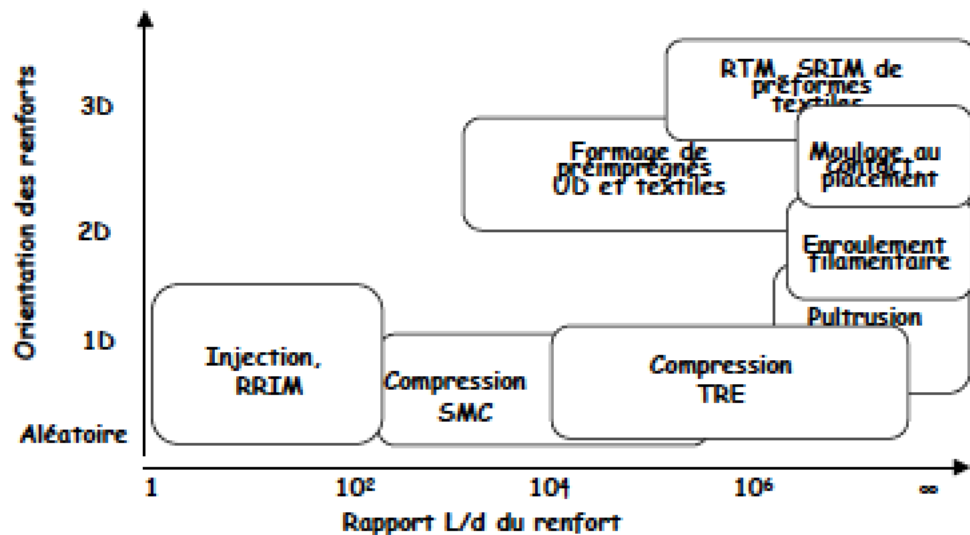
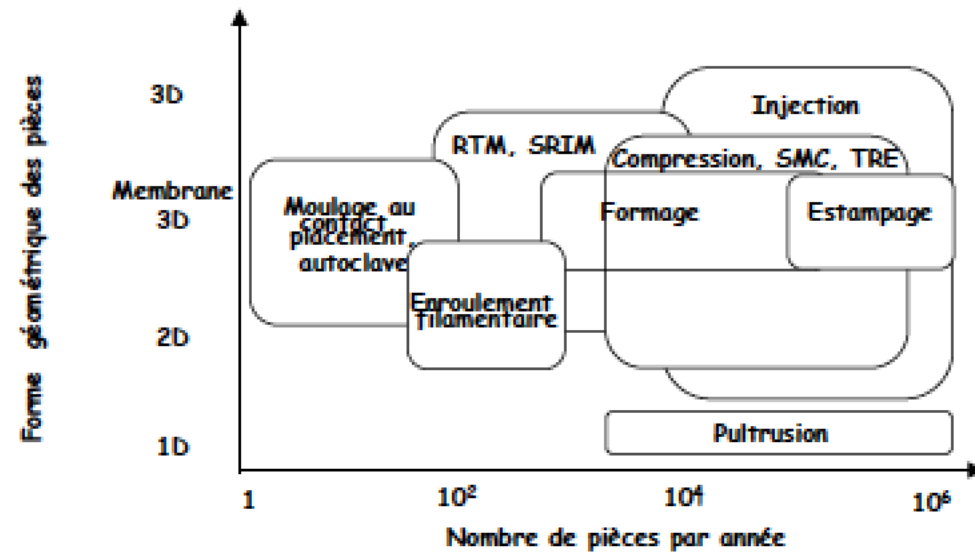
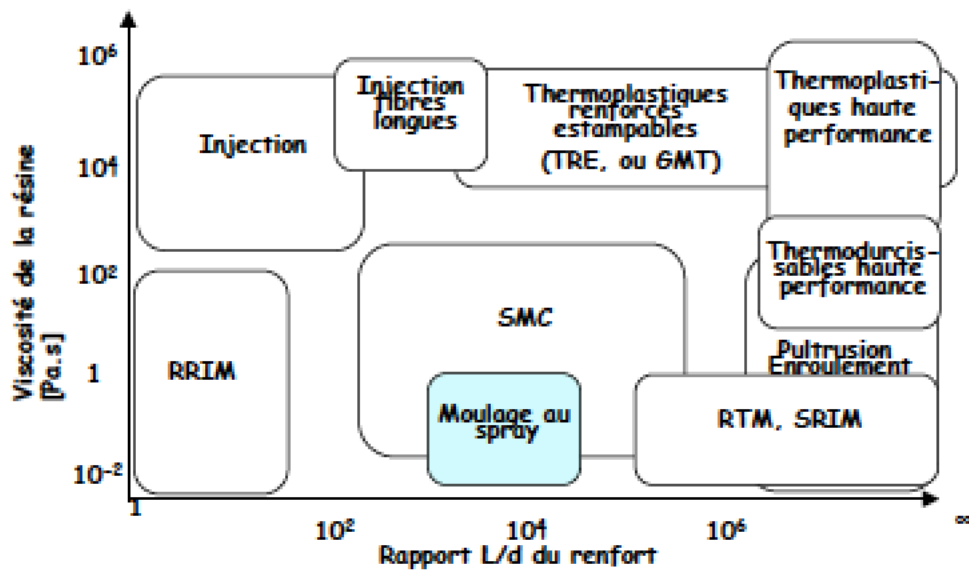
Additive manufacturing: Liquid deposition modeling



Adv. Mater. Technol. 2019, 4, 1800271

Also possible with thermoset resin, flow-induced orientation of fibers.

A bit less short fibers

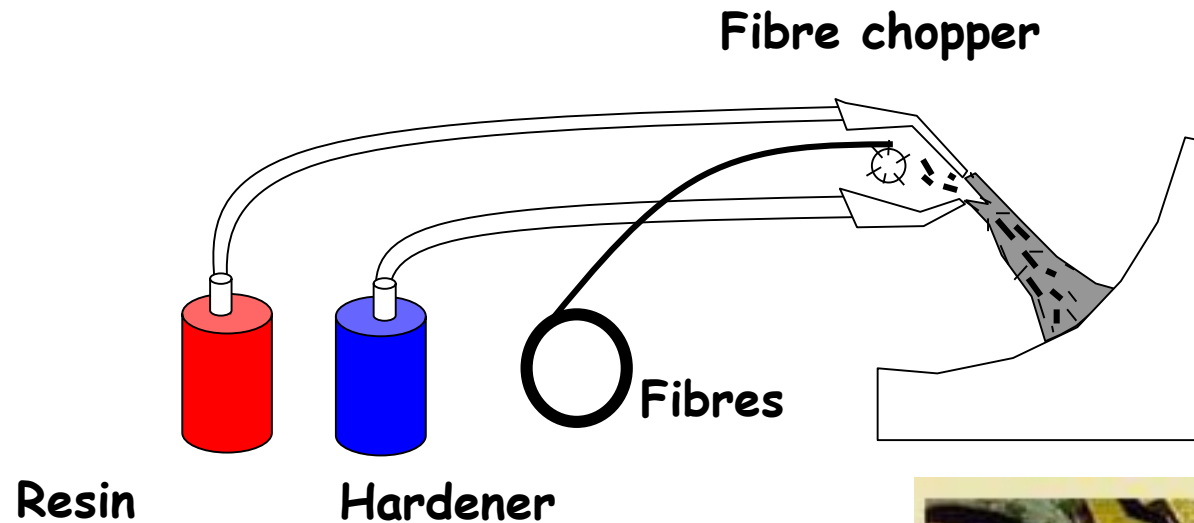


(a) Préimprégnés → moule → mise en forme

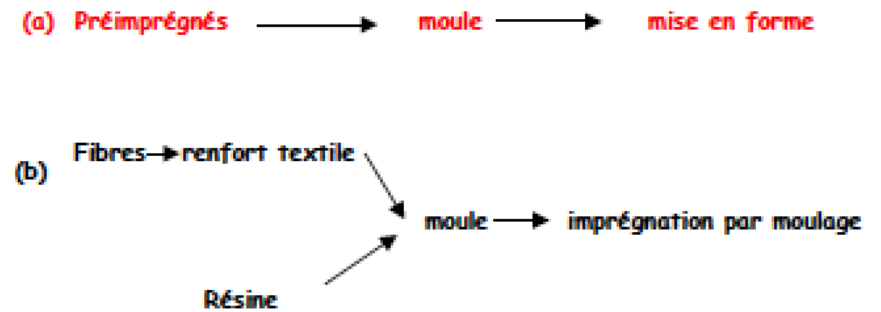
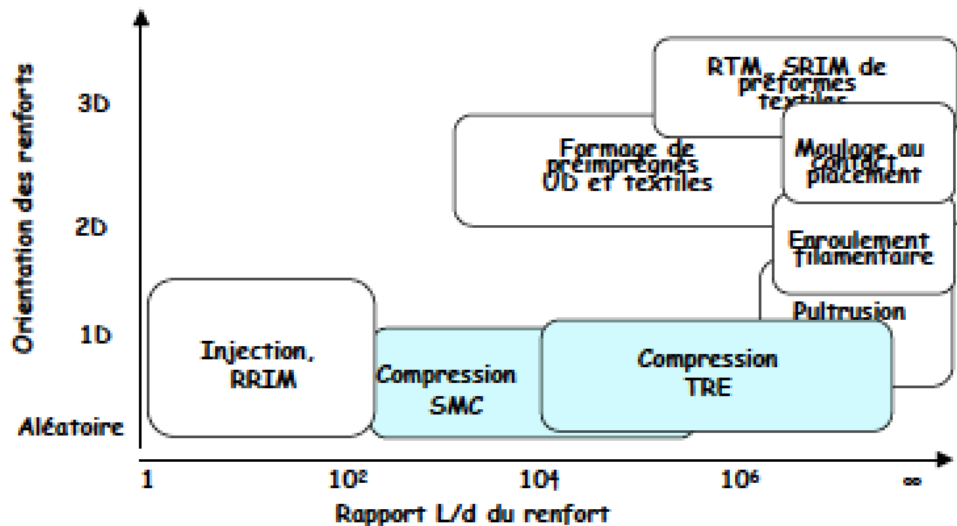
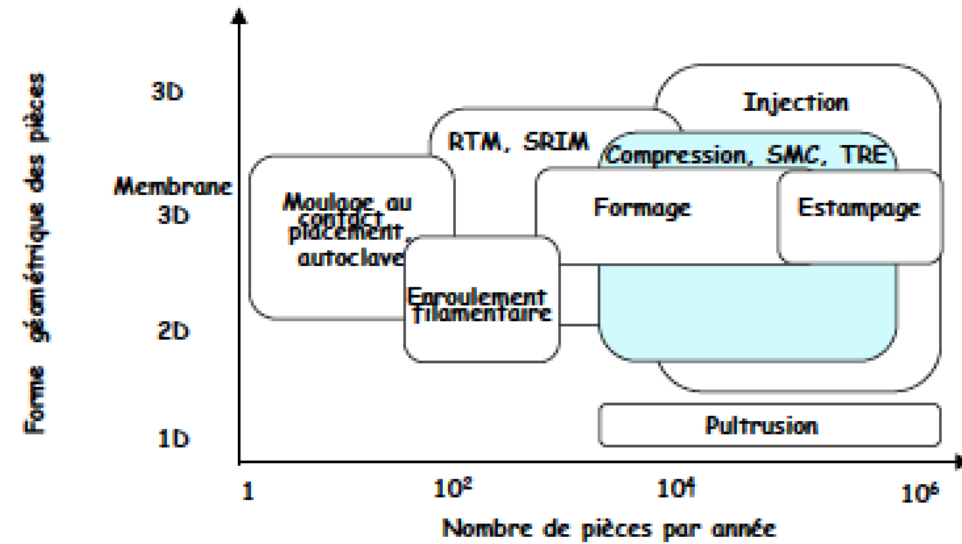
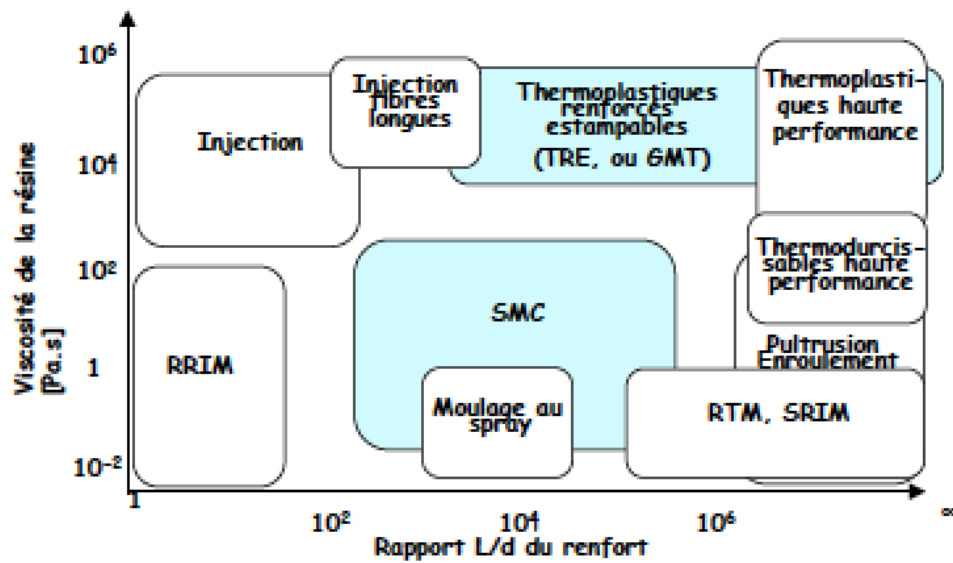
(b) Fibres → renfort textile
 Résine → moule → imprégnation par moulage

Spray moulding

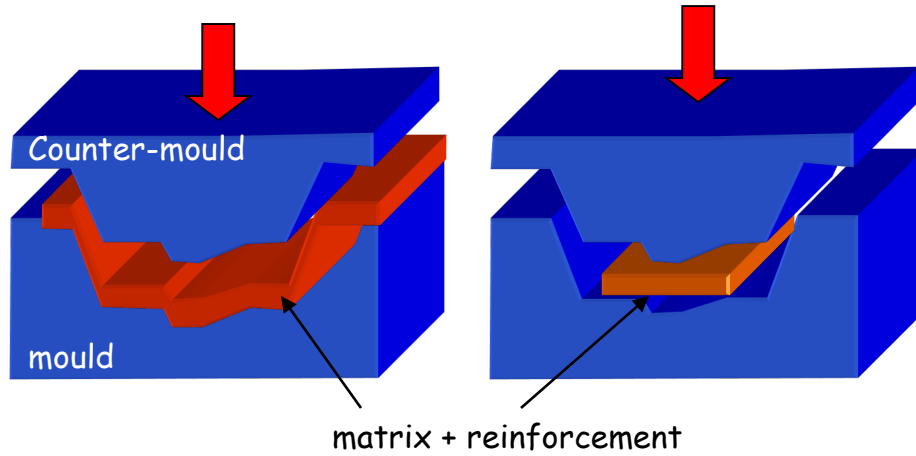
Advantages :	Drawbacks :
Faster rate than wet lay-up No limit in size Light equipment	Numerous and qualified manpower Thickness control Low stiffness



Less short fibers, stamping



Compression moulding



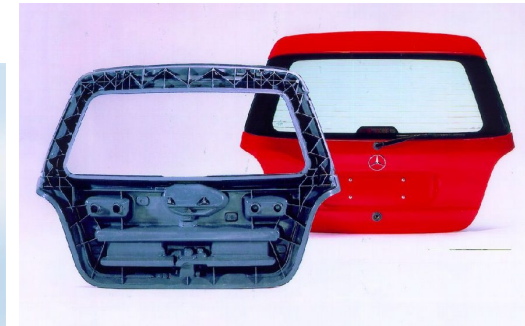
Without flow

With flow

Hoods, car body panels,

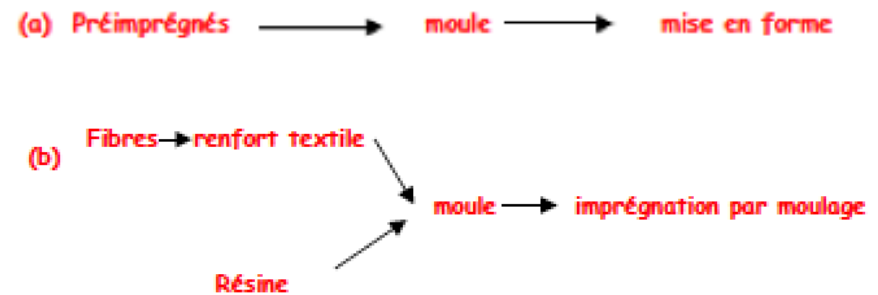
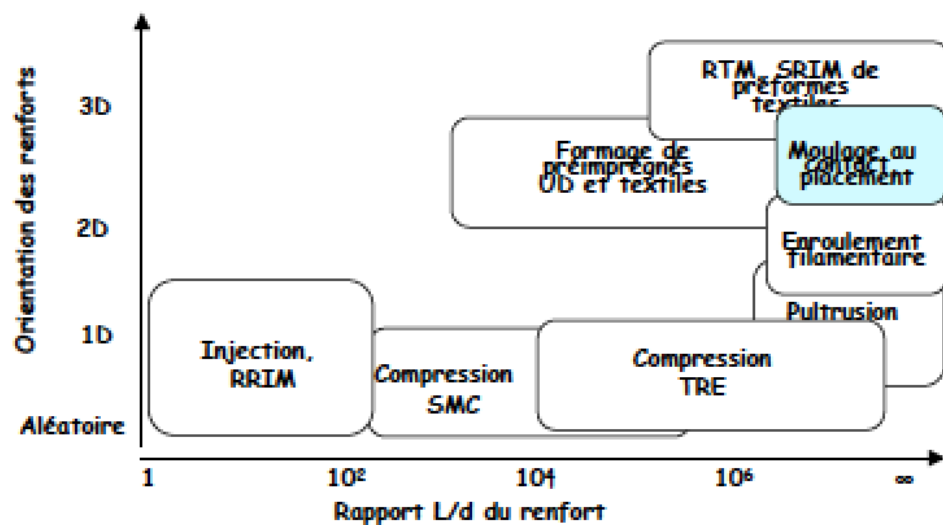
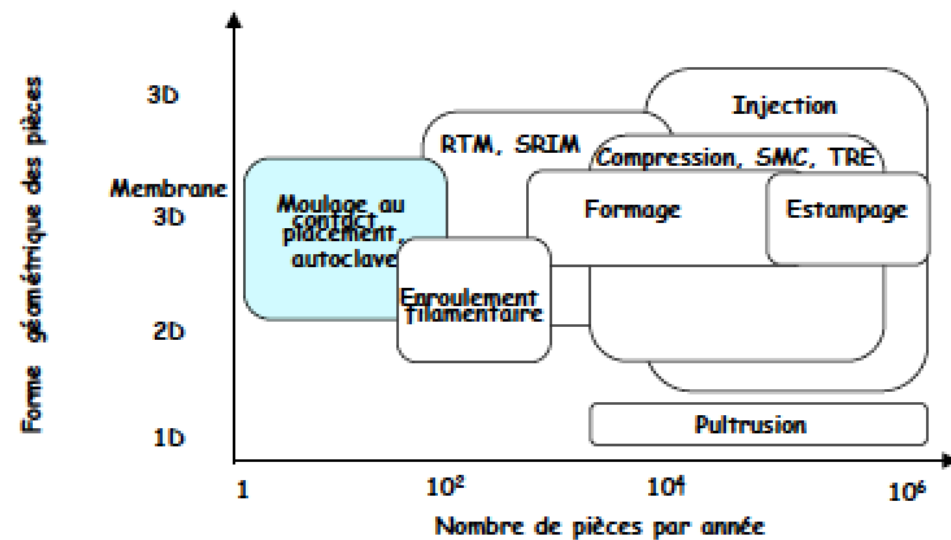
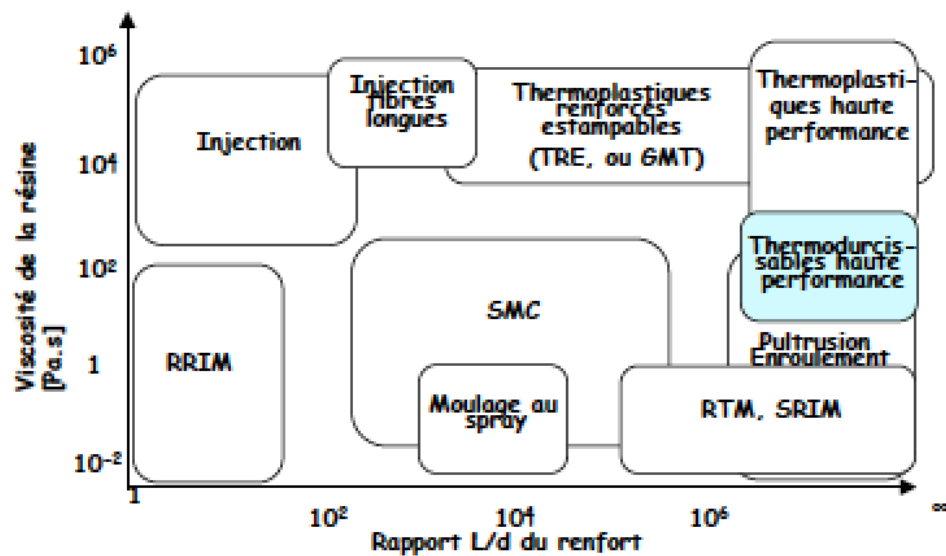
Semi-products processing :

SMC: sheet moulding compound, glass+ polyester
GMT, TRE: glass mat thermoplastics, glass + PP



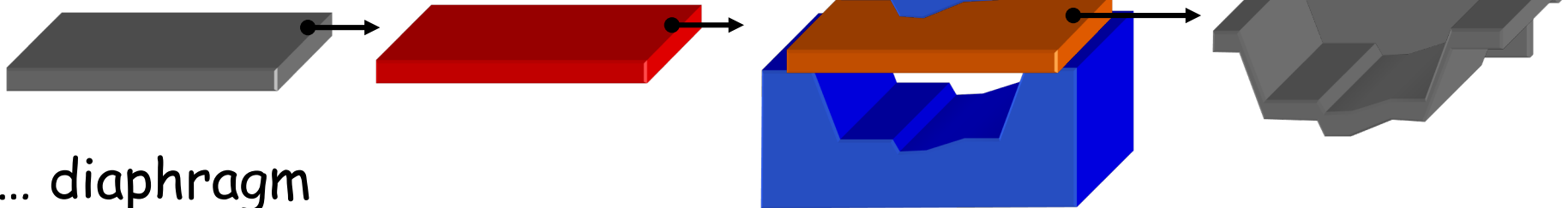
Advantages :	Drawbacks :
Large parts moulding Good quality High production rate	Tools cost Trimming necessary Dosing needed for each mould type, potential segregation, fiber orientation

Long fibers

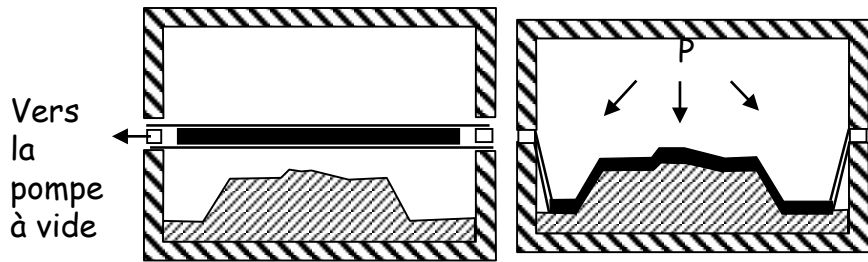


Thermofforming

... press



... diaphragm



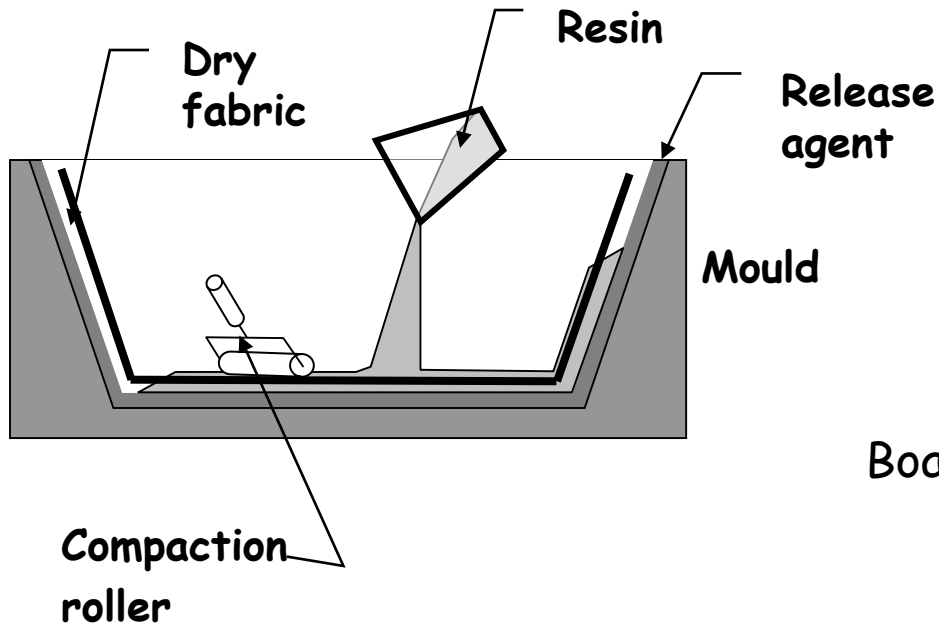
Advantages :

Complex shapes
High production rate
Good quality

Drawbacks :

High investments
Heat transfer control

Wet lay-up

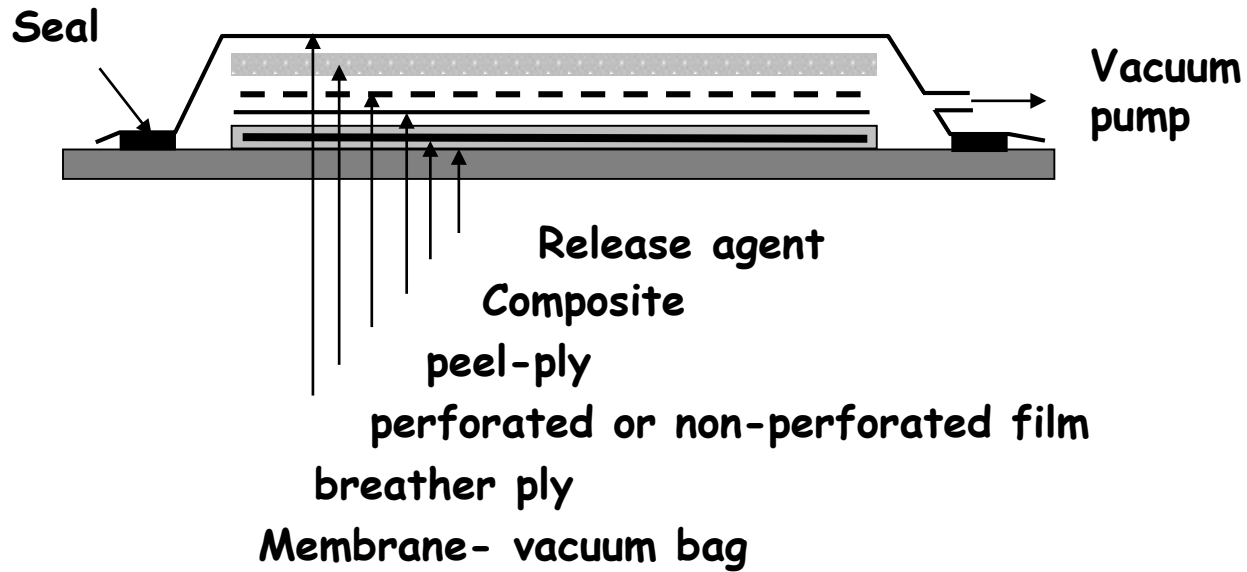


Boats, civil engineering



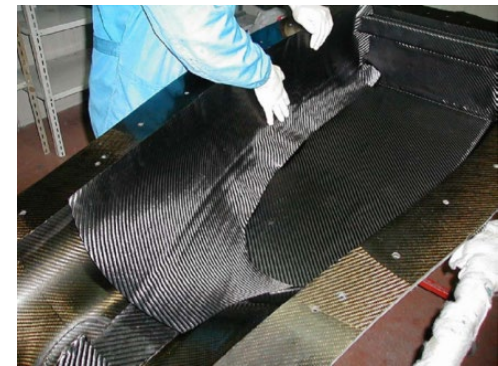
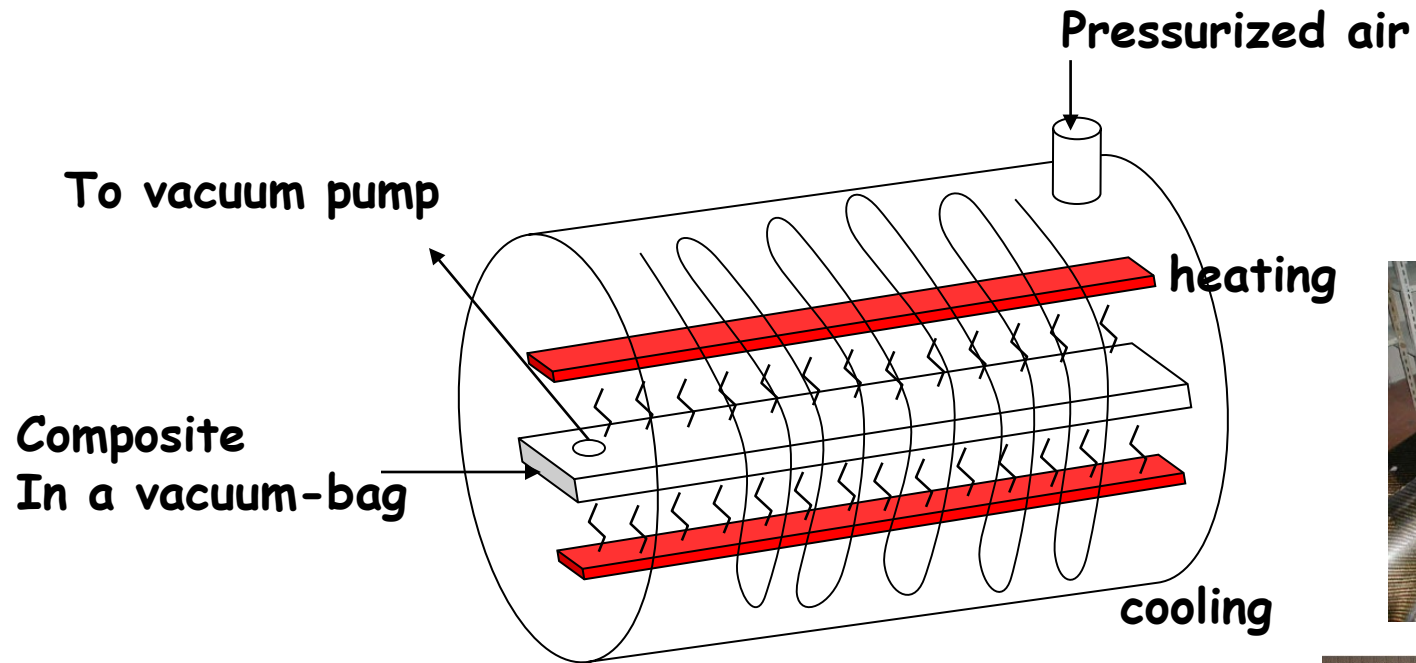
Advantages :	Drawbacks :
Ease of processing	Low production rate
Low investments	Large manpower
No limitation of size	Thickness control
Unqualified manpower	One rough side
	High void content

Vacuum moulding



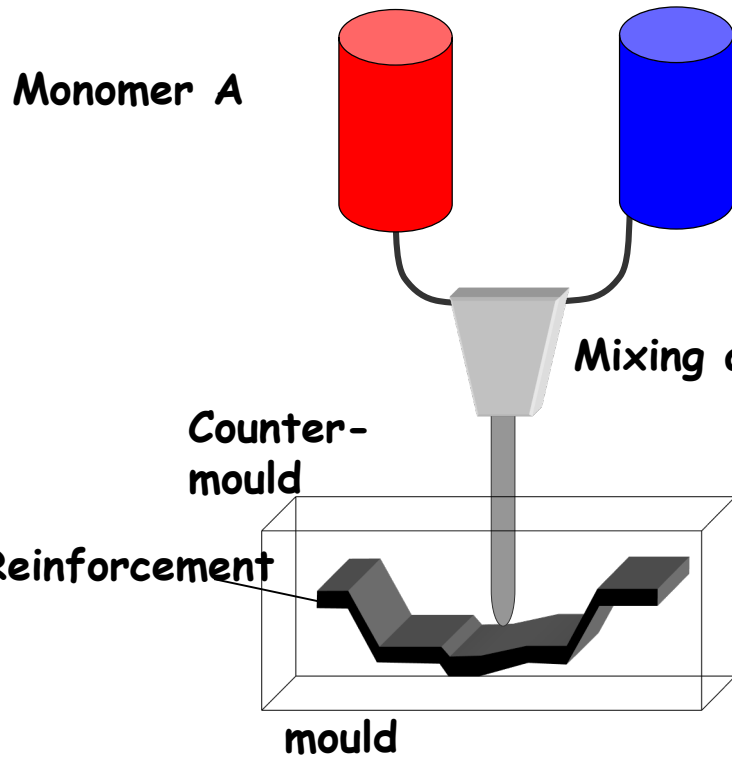
Advantages :	Drawbacks :
Ease of processing Low investments	Low production rate High manpower

Autoclave moulding



Advantages :	Drawbacks :
Good parameter control	High investments
High quality composites	Low production rate

Resin infusion, Liquid composite molding



Reaction injection moulding (RIM, RRIM ou SRIM)
Resin transfer moulding (RTM)

TS and TP (Polyurethane, PA) RTM
Reactive pre-polymers
Short fibres RRIM
or long fibres in the mould SRIM
Vacuum assisted

Advantages :	Drawbacks :
Low moulding pressure, low energy large complex parts possible Short cycle time Automatization	Need preforming step for complex parts Risk of dry spots, race tracking... Process variability

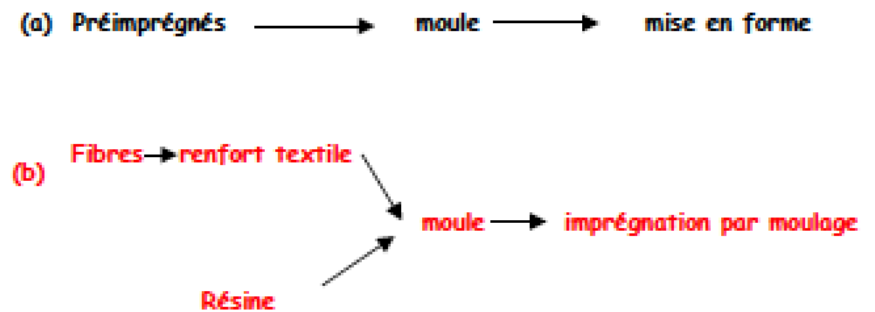
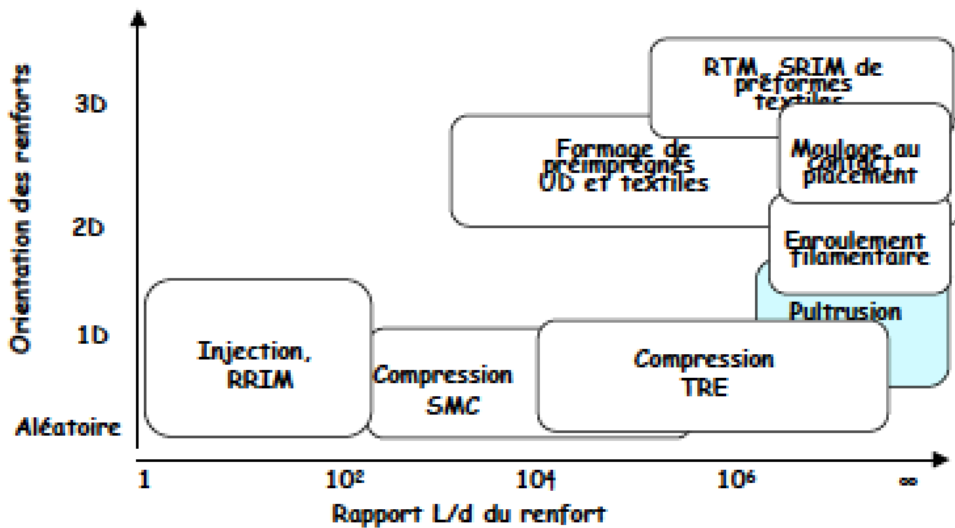
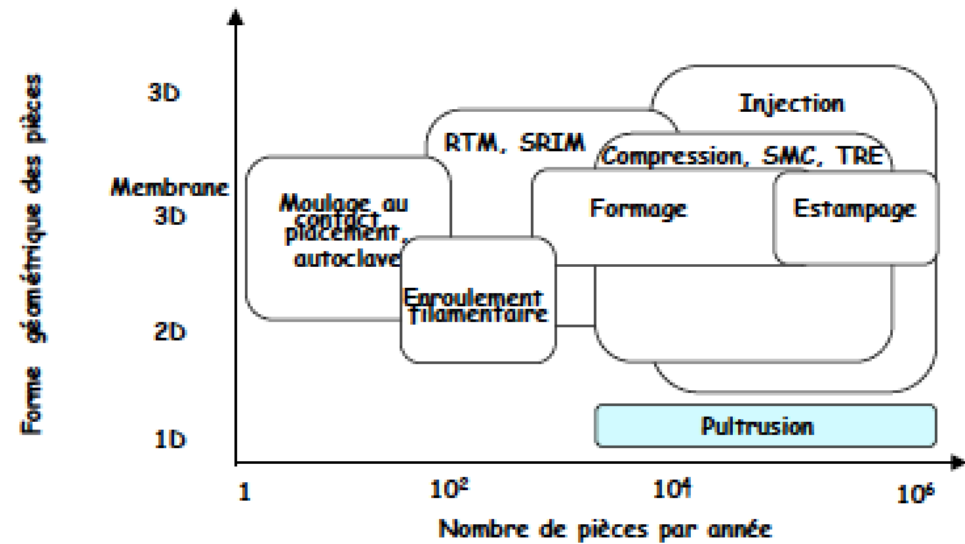
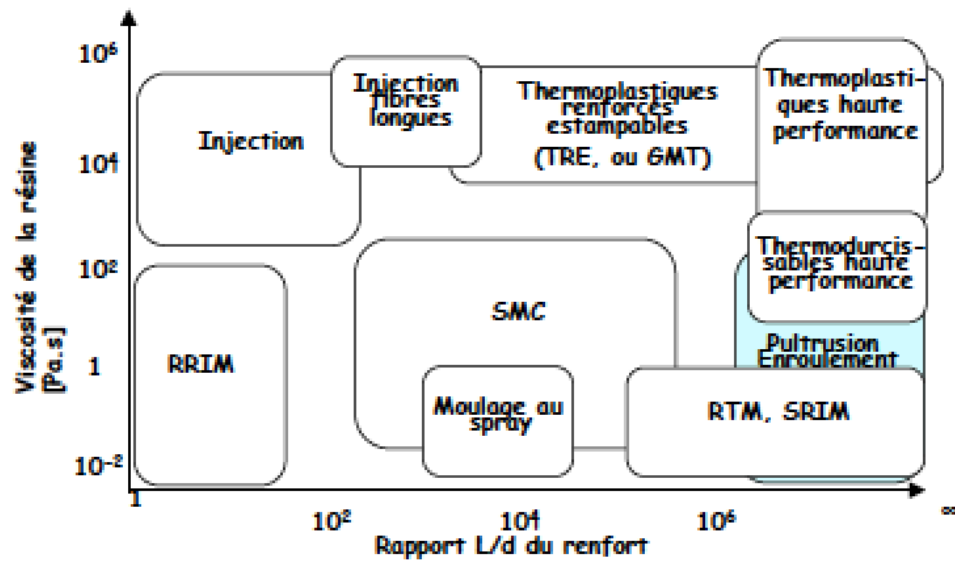


Vacuum infusion

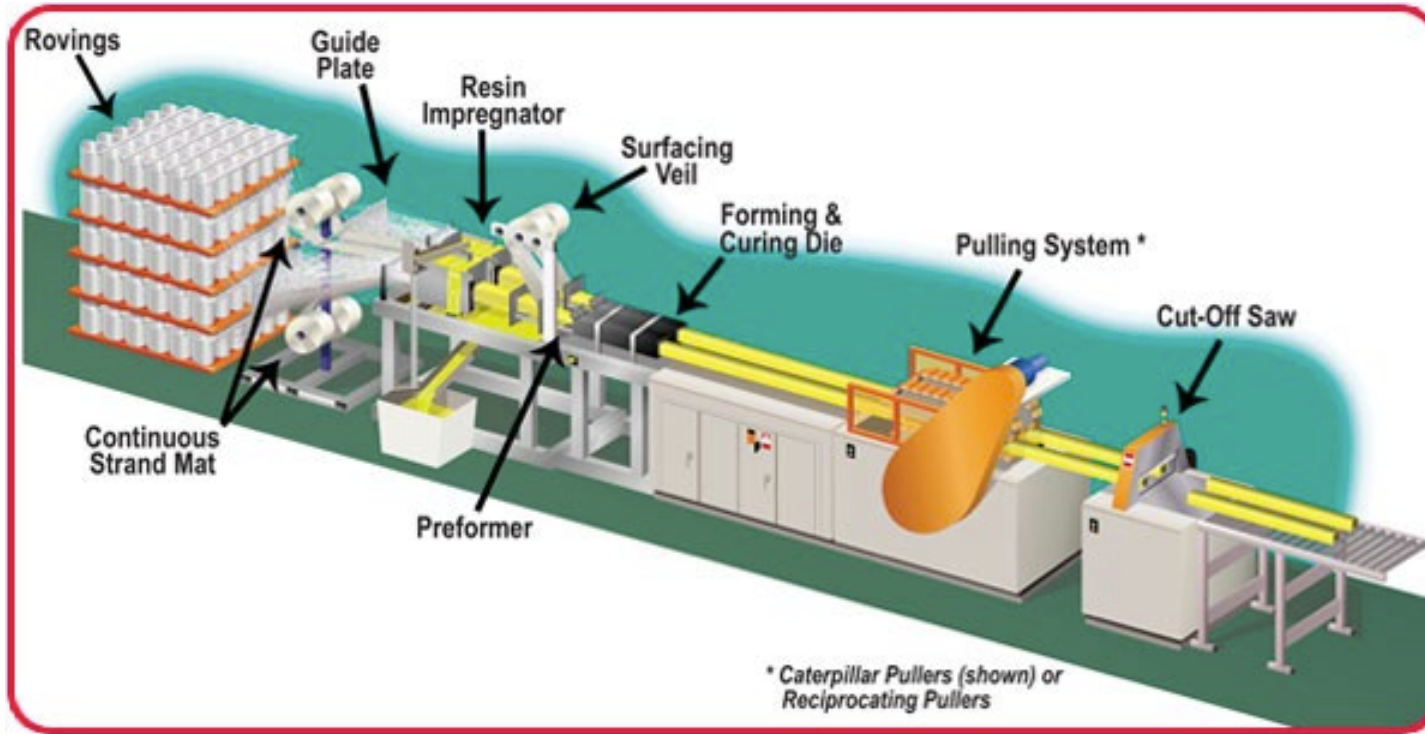
Exemple:
Carène de EPFLoop
(2018)



Selection

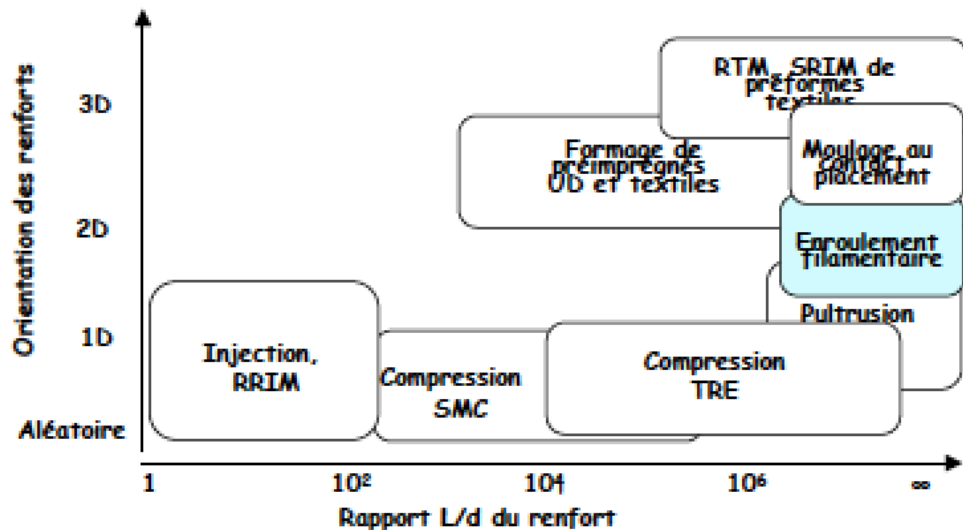
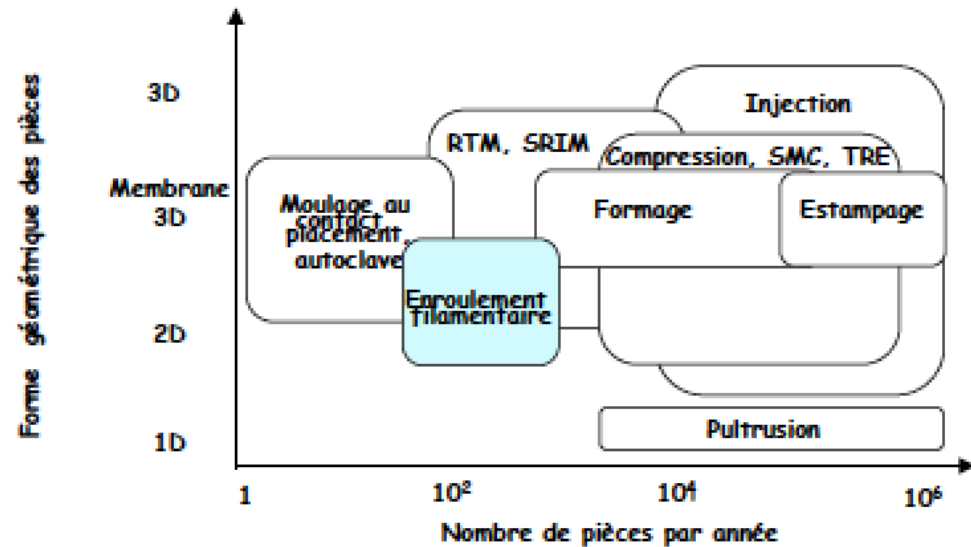
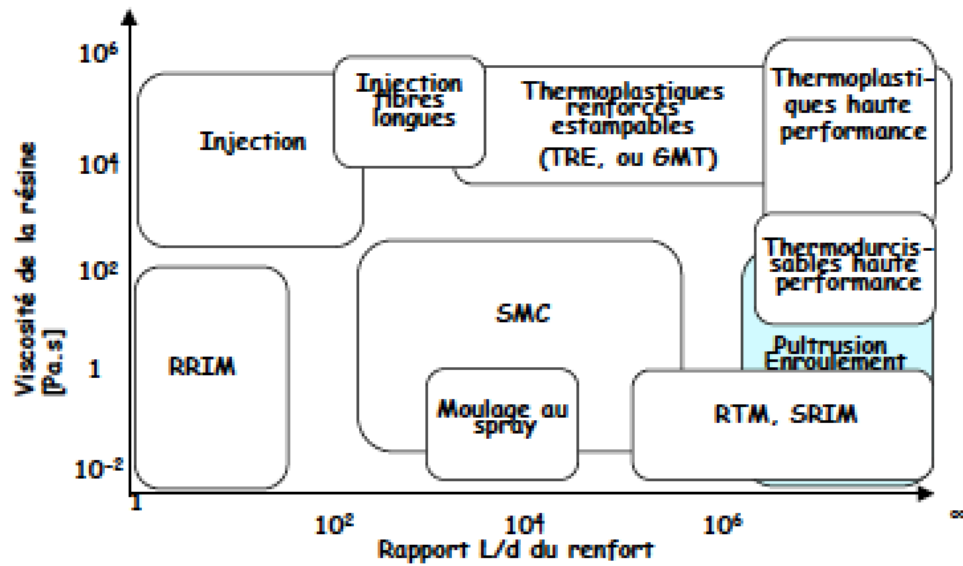


Pultrusion



Advantages :	Drawbacks :
Continuous production method Control of the reinforcement volume fraction Automatization High production rate Profiles	High investments Limitations in thickness variation.

Selection

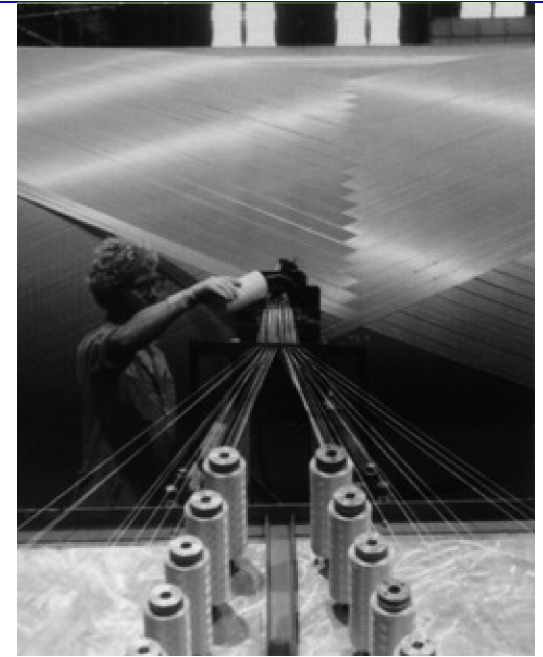
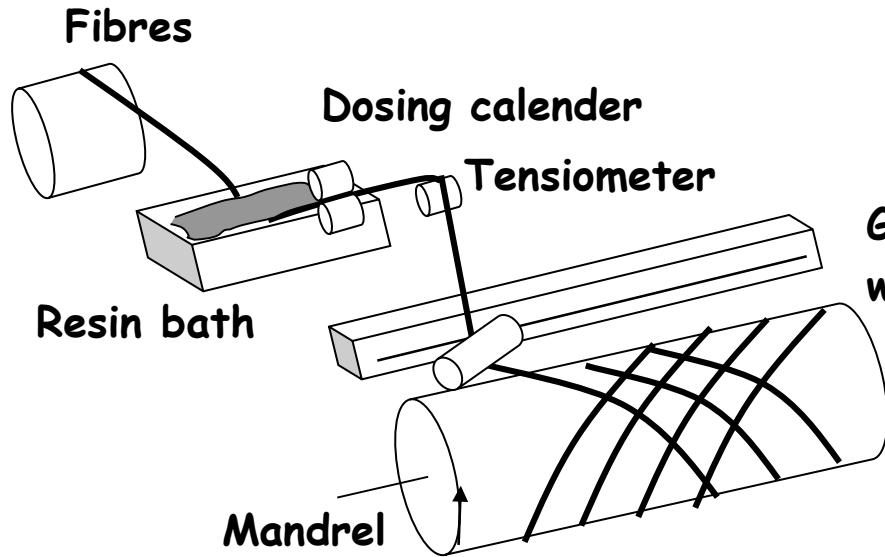


(a) Préimprégnés \rightarrow moule \rightarrow mise en forme

(b) Fibres \rightarrow renfort textile \rightarrow moule \rightarrow imprégnation par moulage
 Résine \rightarrow moule \rightarrow imprégnation par moulage

Filament winding

Pressure vessels, tubes....



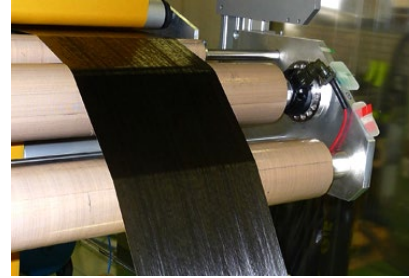
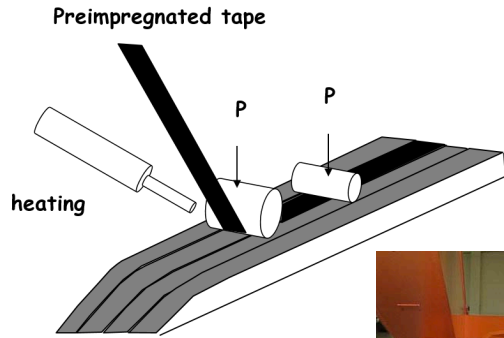
Guides and winding control



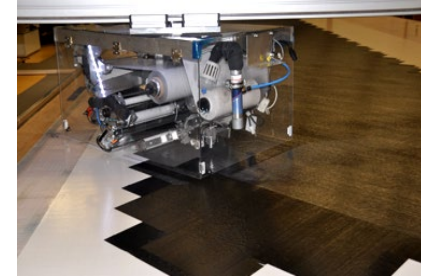
Advantages :	Drawbacks :
Cylindrical parts	High investments
Internal face smooth, liner	Low production rate
Fiber volume up to 80%	External face rough
Preferential fiber orientation	

Tape/ tow /fibre placement

www.thinplytechnology.com



Spread Tow



Tape placement

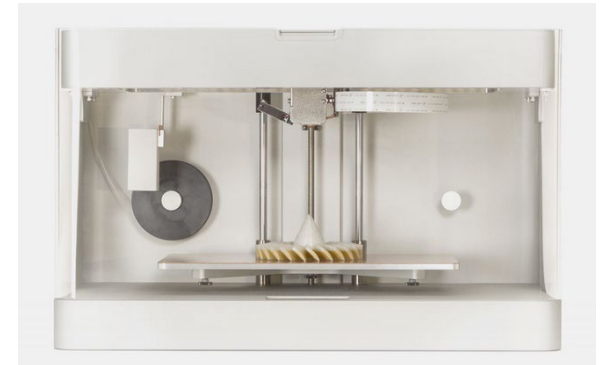


www.eelcee.com

www.inxide.se

Advantages :	Drawbacks :
<ul style="list-style-type: none"> Automatisation Preferential tow or tape placement Convex or concave parts 	<ul style="list-style-type: none"> High investment Bonding control between tapes

markforged.com

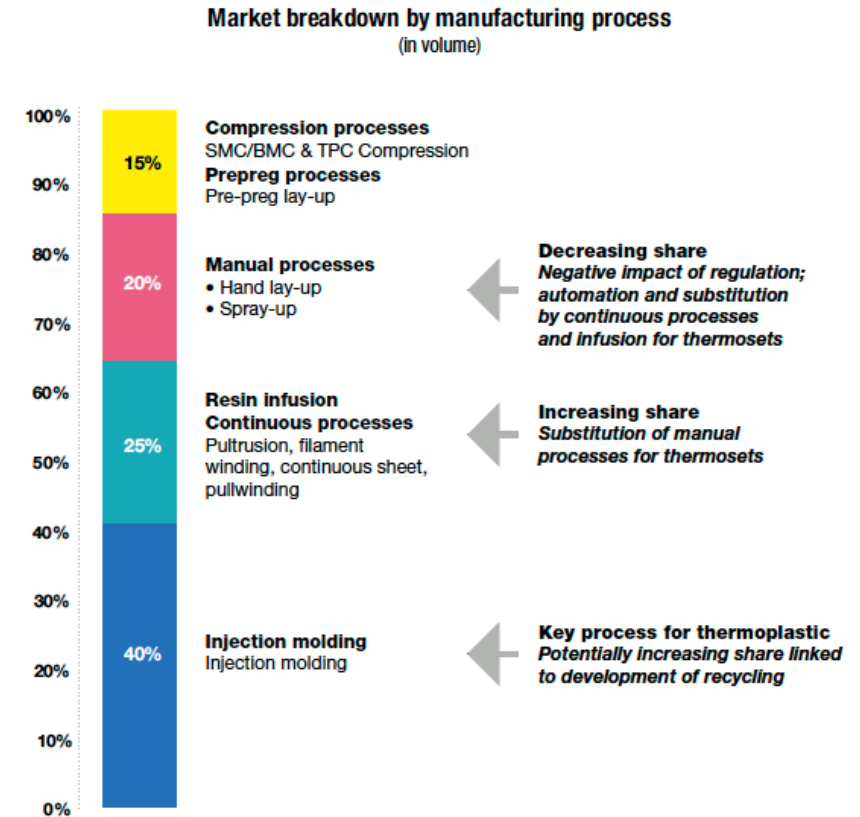


Conclusions

- Many processes exist for making composite materials, depending on the application, volume of production, required mechanical and other properties, etc.

Main processes for composites and key trends

By manufacturing process - 2023 - In volume - (Estimates)



Note: Simplified; others (including TFP, blow molding, bladder molding, diaphragm forming,...) not represented
Sources: Lucintel, interviews, Estin & Co analysis and estimates.