

# Introduction to Composite Materials Design—Second Edition

## Materials and Manufacturing

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## 1 Materials

### Fiber Materials

- Natural fibers

- Reinforcement configuration

- Textiles

### Matrix Materials

## 2 Manufacturing processes

- Hand lay-up

- Prepreg

- Vacuum bagging

- Autoclave

- Compression molding

- RTM

- VARTM

- Pultrusion

- Filament winding

- Advantages/Disadvantages

## Definition

A `composite` is a combination of two or more materials that:

- remain microscopically identifiable
- attain properties that are superior to those of any of the individual components

The simplest `composite` consists of a `matrix` reinforced by a `reinforcement`.

# Materials

## Fiber materials

- 2.2.1. Glass. Inexpensive.
- 2.2.2. Silica and Quartz ( $SiO_2$ ). 900–1050°C
- 2.2.3. Carbon. Inert. Broad variety of modulus  $E$  and strength  $F_f$ . LM, MM, HM, UHM
- 2.2.4. Carbon Nanotubes and Graphene.
- 2.2.5. Organic:
  - Kevlar, Tecnor, Twaron (Aramid based)
  - Zylon (PBO based)
  - Spectra (Polyethylene based)
  - Vectran (Polyester based)
- 2.2.6. Boron. High modulus.
- 2.2.7. Ceramic. High temperature.
- 2.2.8. Basalt. Inexpensive.
- 2.2.9. Metallic.
- Natural Fibers. Moisture. Adhesion to matrix.

# Fiber materials : Natural fibers

## Natural Fibers.

- Bamboo
- Kenaf
- Sisal
- Yute
- etc.

## Research topics:

- Moisture
- Adhesion to matrix
- Natural matrices

# Reinforcement configuration

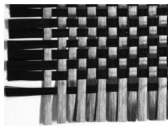
- Long fibers
  - Unidirectional (fibers)
  - Bidirectional (textiles)
  - Random (fibers)
- Discontinuous fibers
  - Random (chopped)
  - Oriented (OSB)
- Particles and Whiskers
  - Random
  - Oriented

# Textiles

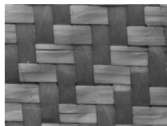
- 2.4.2. One dimensional textiles : Strand, tow, end, roving, yarn (see definitions)
  - Denier : weight in grams of 9000 m of yarn.
  - Yield= $yards/lb$
  - $TEX=g/km$
  - Area of tow :  $A=10^{-5} TEX[g/km]/\rho_f[g/cm^3]$
  - K number : number of fibers in a tow  
 $TEX=A_f \rho_f K$
- 2.4.3. Two dimensional textiles : Fabrics
- Three dimensional textiles. Expensive.



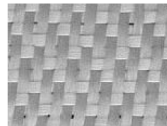
## 2.4.3. 2D textiles : Fabrics



plain



twill



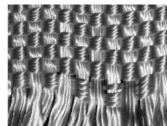
satin



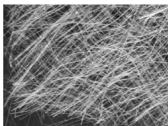
triaxial



stitched



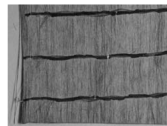
basket



continuous strand mat

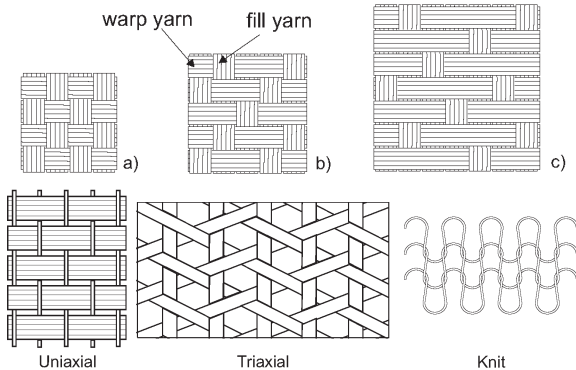


veil



stitched

## 2.4.3. 2D textiles : Fabrics



# Matrices

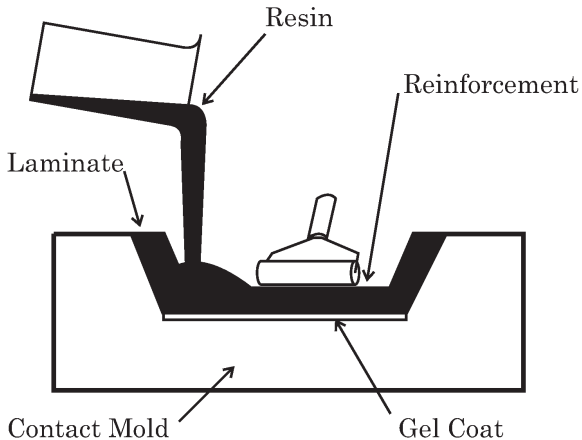
- 2.6.1. Polyester. Inexpensive.
- 2.6.2. Vinyl Ester. Less expensive than Epoxy.
- 2.6.3. Epoxy. High performance.
- 2.6.4. Phenolic. Fire resistance.
- 2.7. Thermoplastics. Repairable. Difficult to mold.
- Biodegradable matrices.

# Manufacturing processes

## Typical unit operations

- 1 Fiber placement, along desired orientation.
- 2 Impregnation, of fiber by resin.
- 3 Consolidation, air removal.
- 4 Curing, by cross linking, into a rigid solid.
- 5 Extraction, from the mold.
- 6 Finishing, trimming, etc.

## 3.1. Hand lay-up



- 1 Fiber placement.
- 2 Impregnation.
- 3 Consolidation.
- 4 Curing.
- 5 Extraction.
- 6 Finishing.

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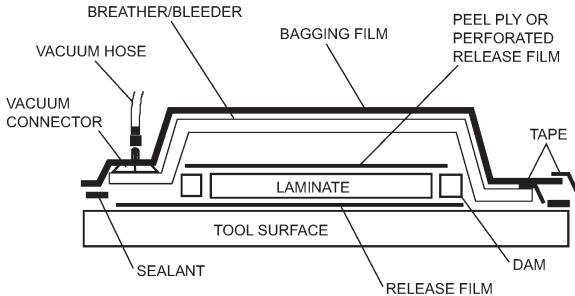
## 3.2. Prepreg



- 1 Fiber placement.
- 2 Impregnation.
- 3 Consolidation.
- 4 Curing.
- 5 Extraction.
- 6 Finishing.

[Watch it on YouTube](#)

## 3.3. Vacuum bagging



- 1 Fiber placement.
- 2 Impregnation.
- 3 Consolidation.
- 4 Curing.
- 5 Extraction.
- 6 Finishing.

[Watch it on YouTube](#)



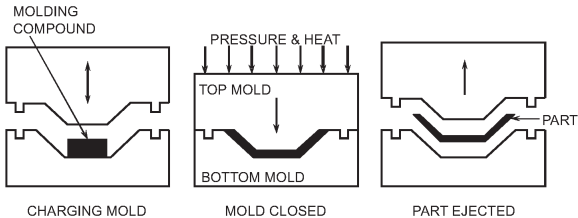
## 3.4. Autoclave



- 1 Fiber placement.
- 2 Impregnation.
- 3 Consolidation.
- 4 Curing.
- 5 Extraction.
- 6 Finishing.

[Watch it on YouTube](#)

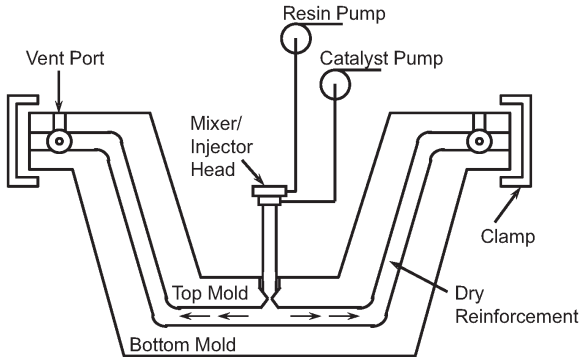
## 3.5. Compression molding



- 1 Fiber placement.
- 2 Impregnation.
- 3 Consolidation.
- 4 Curing.
- 5 Extraction.
- 6 Finishing.

[Watch it on YouTube](#)

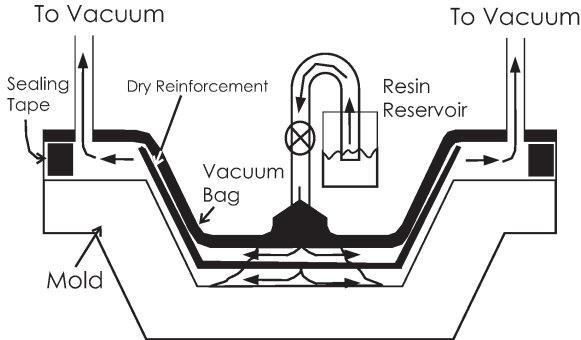
## 3.6. Resin transfer molding (RTM)



- 1 Fiber placement.
- 2 Impregnation.
- 3 Consolidation.
- 4 Curing.
- 5 Extraction.
- 6 Finishing.

[Watch it on YouTube](#)

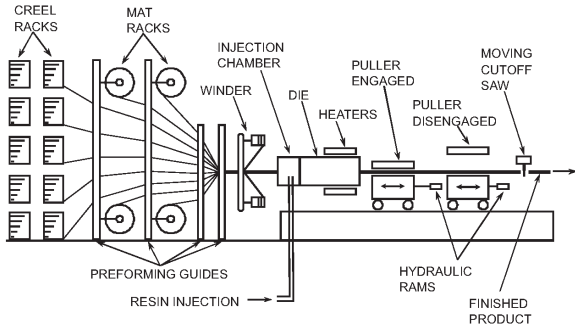
## 3.7. Vacuum assisted RTM (VARTM)



- 1 Fiber placement.
- 2 Impregnation.
- 3 Consolidation.
- 4 Curing.
- 5 Extraction.
- 6 Finishing.

[Watch it on YouTube](#)

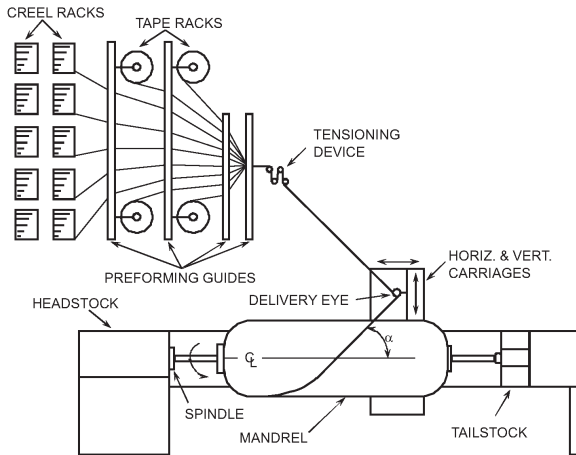
## 3.8. Pultrusion



- 1 Fiber placement.
- 2 Impregnation.
- 3 Consolidation.
- 4 Curing.
- 5 Extraction.
- 6 Finishing.

[Watch it on YouTube](#)

## 3.9. Filament winding



- 1 Fiber placement.
- 2 Impregnation.
- 3 Consolidation.
- 4 Curing.
- 5 Extraction.
- 6 Finishing.

[Watch it on YouTube](#)

# Advantages/Disadvantages

- 1 Cost.
- 2 Quality.
- 3 Production rate.