Polymer Matrix Composite (PMC): Reinforcement and matrix materials used, properties & industrial Application

Note: Fundamentals of PMC i.e. Matrix, reinforce materials used, properties and other application etc. refer material kept in the campus Xerox center
## Differences between Thermosets & thermoplastics

<table>
<thead>
<tr>
<th>Thermosets</th>
<th>Thermoplastics</th>
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<tbody>
<tr>
<td>• Resin cost is low.</td>
<td>• Resin cost is slightly higher.</td>
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<tr>
<td>• Thermosets exhibit moderate shrinkage.</td>
<td>• Shrinkage of thermoplastics is low</td>
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<tr>
<td>• <strong>Interlaminar fracture toughness is low.</strong></td>
<td>• Interlaminar fracture toughness is high.</td>
</tr>
<tr>
<td>• Thermosets exhibit good resistance to fluids and solvents.</td>
<td>• Thermoplastics exhibit poor resistance to fluids and solvents.</td>
</tr>
<tr>
<td>• Composite mechanical properties are good.</td>
<td>• Composite mechanical proper-ties are good.</td>
</tr>
<tr>
<td>• Prepregability characteristics are excellent.</td>
<td>• Prepregability characteristics are poor.</td>
</tr>
<tr>
<td>• Prepreg shelf life and out time are poor.</td>
<td>• Prepreg shelf life and out time are excellent.</td>
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### Differences types Thermosets & Thermoplastics

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<th>Thermoplastics</th>
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<tbody>
<tr>
<td>• Phenolics &amp; Cyanate ester</td>
<td>• Polypropylene</td>
</tr>
<tr>
<td>• Polyesters &amp; Vinyl esters</td>
<td>• Nylon (Polyamide)</td>
</tr>
<tr>
<td>• Polyimides</td>
<td>• Poly-ether-imide (PEI)</td>
</tr>
<tr>
<td>• Epoxies</td>
<td>• Poly-ether-sulphone (PES)</td>
</tr>
<tr>
<td>• Bismaleimide (BMI)</td>
<td>• Poly-ether-ether-ketone (PEEK)</td>
</tr>
</tbody>
</table>
Wet Lay-up

Wet lay-up is the simplest and most widely used process.

Layers of dry fabric are placed on a mold and resin is brushed or sprayed on.

Advantages:
Large parts
Low tooling cost

Disadvantages:
Labor intensive
Uniformity difficult to maintain

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Wet hand lay up
Automated Lay-up machine

Figure 1.9 Automated tape-laying equipment. (Source: From [1.6].)
Hand spray-up
Molds
Autoclave Molding

Autoclave molding is similar to both vacuum–bag and pressure–bag molding. Applications are lighter, faster and more agile fighter aircraft, motor sport vehicles.
Typical Cure Cycle for Carbon/Epoxy Composite
Vacuum Bagging

- Breather/Bleeder
- Vacuum Hose
- Vacuum Connector
- Bagging Film
- Peel Ply or Perforated Release Film
- Laminate
- Tool Surface
- Sealant
- Release Film
- Dam
- Tape
Vacuum bag
Vacuum Bag Molding
Filament Winding

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Filament Winding:

Creel tensioners
Continuous curing oven
Reusable Mandrels

Figure 3: The mandrel is cooled below the transition temperature resulting in a rigid mandrel.

Figure 4: The mandrel is filament-wound and then cured. The cure process for the composite does not affect the mandrel.
Filament Winding

Gas tanks
Composite motors
Glass epoxy filament-wound 9-foot-diameter by 55-foot-long assembled railway tank car
Filament winding machines
Delta IV Rocket faring mandrel
Filament-Wound Products
Filament Winding (Fig. 3.6 in the textbook, p. 57)

Helical winding

Circumferential winding
FIGURE 1.20 Filament Winding of Rocket Motor Case
(Photo courtesy of Alliant Techsystems)
Figure 12. Pressure Vessel Liner Assembly

Figure 13. Automation Dynamics Polar Winding Machine
vessels using a high pressure stream of hot water.

Figure 14. Polar Winding Pressure Vessel

Figure 15. Cured Filament Wound Assembly
Figure 18.22 (a) Schematic illustration of the filament-winding process. (b) Fiberglass being wound over aluminum liners, for slide-raft inflation vessels for the Boeing 767 aircraft. *Source:* Brunswick Corporation, Defense Division.
Figure 18.23: Schematic illustration of the pultrusion process.
Continuous fiber reinforcement in roving, mat and/or fabric forms are drawn through a resin bath to coat each fiber with a specially formulated resin mixture. The coated fibers are assembled by forming guides and then drawn through a heated die.

Cure of thermosetting resin is initiated by heat in the die and catalyst in the resin mix. The rate of reaction is controlled by heating and cooling zones in the die.

The resulting high strength profile is cut to length, ready for use as it leaves the pultrusion machine.
Pultrusion
Pultrusion

Pultruded bridges
Pultrusion

Pultruded I-beam
Pultrusion

FIGURE 1.21 Pultruded Structural Shapes
(Photo courtesy of Strongwell)
Resin Transfer Moulding

Vacuum Assisted Resin Transfer Molding (VARTM)
RTM: typical applications

• marine propeller

• hull of Advanced Composite Armoured Vehicle Platform (ACAVP)
RTM: typical applications

- Lotus car bodies
- British Rail (now First Great Western)
  High Speed Train cabs
- Chelton radomes
- Dowty aircraft propellers
- jet engine blocker doors
Compression Moulding

**Applications:** Computer enclosures, dishwasher inner doors, light truck tailgate, automotive road wheels etc.

[Image of compression moulding process]

Compression molded rubber boots
Sheet Molding Compound (SMC)

SMC manufacture using a configuration that can make chopped-fiber SMC-R; continuous fiber SMC-C; or continuous, random SMC-C/R material.
Figure 18.19. The manufacturing process for producing reinforced-plastic sheets. The sheet is still viscous at this stage; it can later be shaped into various products. Source: T. W. Chou, R. L. McCullough, and R. B. Pipes.
Car parts with Sheet Molding Compound (SMC) - Prowler
Car parts
BM machine
Injection Moulding (IM)

- Image from http://www.rutlandplastics.co.uk/
Injection Moulding (IM)

- Close
- Inject
- Open & Eject
- Hold

Images from http://www.rutlandplastics.co.uk/
Figure 18.7: A 2.2-MN (250-ton) injection-molding machine. The tonnage is the force applied to keep the dies closed during injection of molten plastic into the mold cavities. Source: Courtesy of Cincinnati Milacron, Plastics Machinery Division.
Injection molding

Clamp  Mold  Barrel

Hopper
- Process developed and patented by Seamann’s Composites
- Single-sided tooling
- Injection achieved through high-permeability surface layer to cause through-the-thickness flow
SCRIMP – Boat Hulls

ME 4210: Manufacturing Processes and Engineering  Prof. J.S. Colton © GIT 2009
Extrusion Process

Figure 18.2: Schematic illustration of a typical extruder. Source: Encyclopedia of Polymer Science and Engineering (2nd ed.). Copyright © 1985. Reprinted by permission of John Wiley & Sons, Inc.
Examples of Injection Molding

Figure 18.6 Typical products made by injection molding, including examples of insert molding. 
Source: Plainfield Molding Inc.
Thermoforming Processes

Figure 18.11 Various thermoforming processes for thermoplastic sheet. These processes are commonly used in making advertising signs, cookie and candy trays, panels for shower stalls, and packaging.

1. Straight vacuum forming
2. Drape vacuum forming
3. Force above sheet
4. Ring and ring forming

a. Heater  
b. Clamp  
c. Plastic sheet  
d. Mold  
e. Vacuum line

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Manufacturing Engineering and Technology  
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Prepregs

Figure 3. Schematic of Impregnation and Staging Equipment
Figure 18.9 Schematic illustrations of (a) the blow-molding process for making plastic beverage bottles, and (b) a three-station injection blow-molding machine. Source: Encyclopedia of Polymer Science and Engineering (2d ed.). Copyright ©1985. Reprinted by permission of John Wiley & Sons, Inc.
Thermoforming
Thermoforming

1. Clamping
2. Plastics sheet
3. Heater
4. Vacuum
Thermoforming Patterns
Vacuum holes
Spray lay-up

Automatic tape-laying machine