Composite Materials: Analysis and Design

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Chapter 1:

Introduction to Composite Materials

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❑ Outline

Manufacturing Processes

- **Manual Manufacturing Processes**
  - Wet Lay-Up and Prepreg
  - Contact Molding
- **Semiautomated Manufacturing Processes**
  - Resin Infusion under Flexible Tooling
  - Compression Moldin
- **Automated Manufacturing Processes**
  - Pultrusion Process
  - Filament Winding
  - Resin Transfer Molding

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❑ Manufacturing Processes

Introduction

Along with the type and orientation of the fibers used and the relative proportions of the constituent materials (matrix and fibers), the manufacturing process plays an equally important role in determining the characteristics of the final composite product.

- Hence, it is necessary to:

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❑ Manufacturing Processes

The choice of the manufacturing process will also depend on:

- The user
- Performance
- Size
- Production

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❑ Manufacturing Processes

There are several manufacturing processes, which may be broadly classified into three categories:

I. M

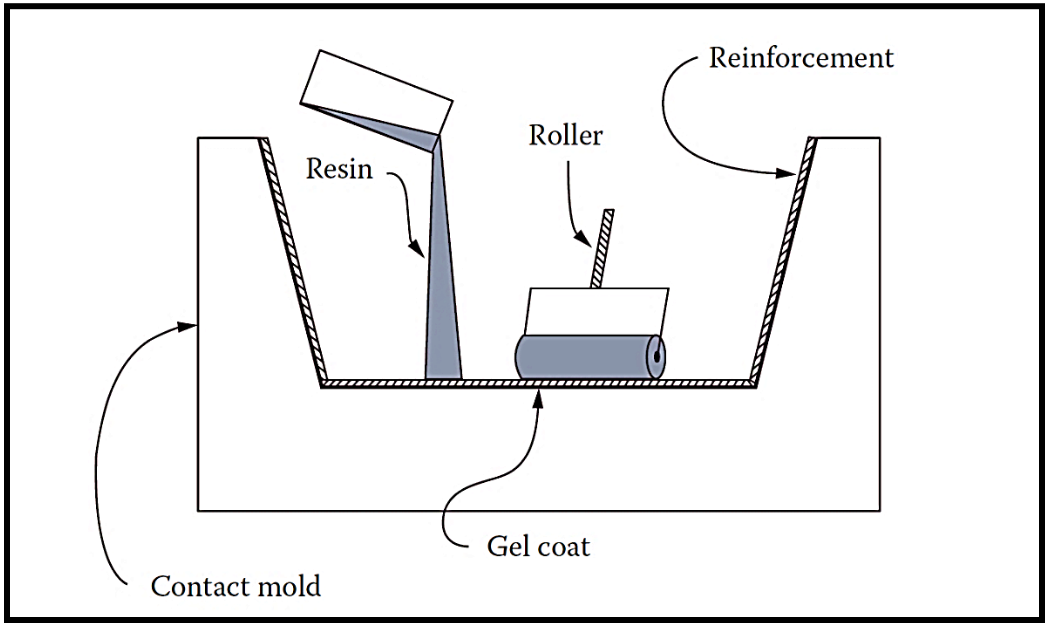
II. S

III. A

❑ Manual Manufacturing Processes

1) Wet Lay-Up:

The wet lay-up process is one of the **oldest** and **simplest** techniques used in the manufacturing of **polymer composites**.



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- **Use of Polymer Composites in Retrofitting and Strengthening:**

❑ Wet Lay-Up:

The main **advantages** of using the wet lay-up are as follows:

- ✓ The processing cost is relatively low since no expensive tooling assembly is required.
- ✓ The parts can be made into any shape or size by choosing the proper mold over which the material is layered.
- ✓ This method gives the designer the flexibility to use any fiber–resin combination and fiber orientation.
- ✓ The start-up lead time and cost are minimal for the manufacturer because there is no requirement for highly skilled technicians or worker training.

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❑ Wet Lay-Up:

The main **shortcomings** of using the wet lay-up are as follows:

- ✓ The method has a low production rate and the quality of the manufactured composite is dependent on the skill of the technician.
- ✓ It can be a labor-intensive process with the cure times being governed by the environment.
- ✓ There can be a considerable waste of materials, particularly the resin, depending on the skill of the technician.
- ✓ It is very difficult to maintain consistent composite properties for multiple parts manufactured using wet lay-up. Quality control becomes a major part of this process to ensure that defects and voids are not left in the composite part.

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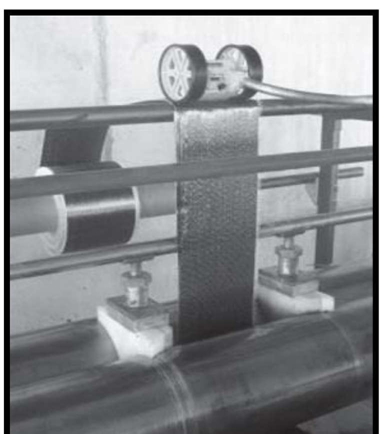
❑ Prepreg:

A variation of the wet lay-up process is the **prepreg method**.

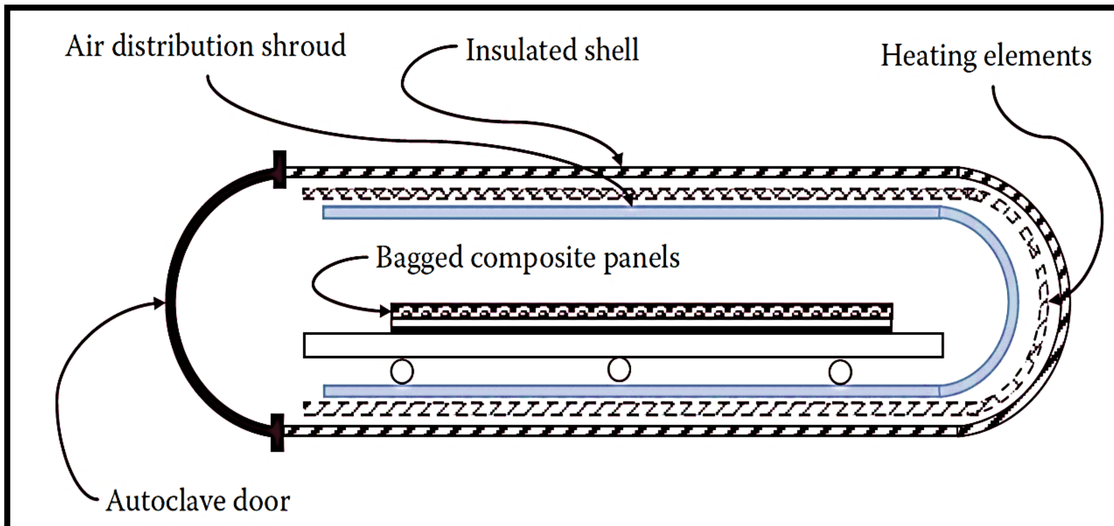
➢ In this method,



❑ Manual Manufacturing Processes

2) Contact Molding:

Encapsulating the molding and the composite part inside a vacuum membrane and applying on the membrane by pulling a vacuum. This extracts the air along with excess resin and produces better compaction of the composite part, resulting in fewer defects and voids.



❑ Semi-Automated Manufacturing Processes

1) Resin Infusion under Flexible Tooling:

The basic principle is to infuse resin material into a dry fiber reinforcement placed inside an evacuated vacuum bagged tool that consists of a rigid male mold tool on one side and a semi-flexible female took on the outer surface. The infusion of the resin under partial vacuum conditions results in good saturation of the dry fibers due to increased flow rate of the resin.

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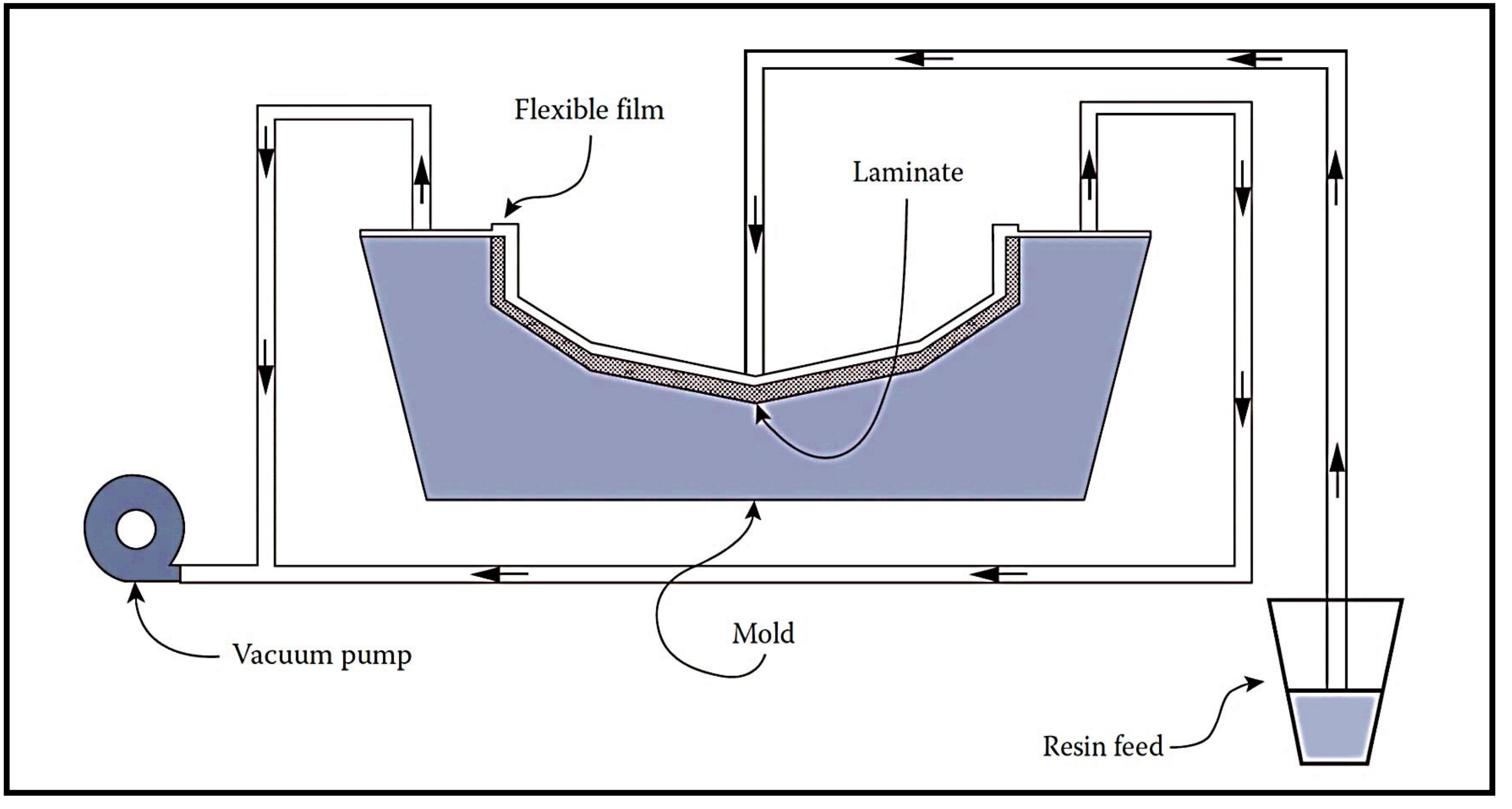
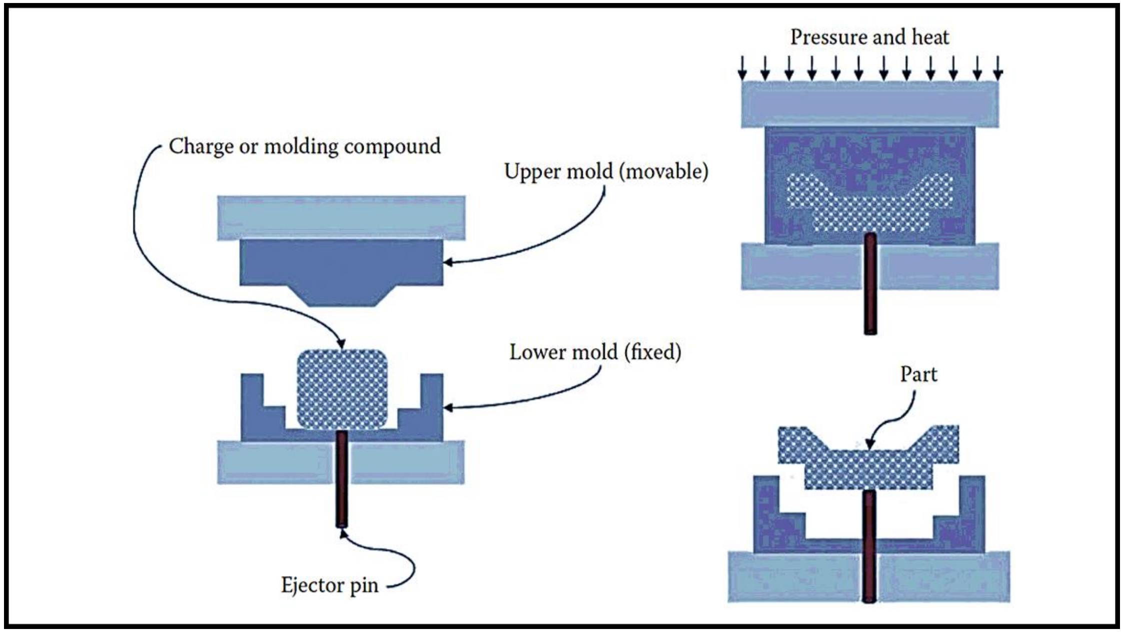
- **Schematic of the SCRIMP manufacturing process:**



❑ Semi-Automated Manufacturing Processes

2) Compression Molding:

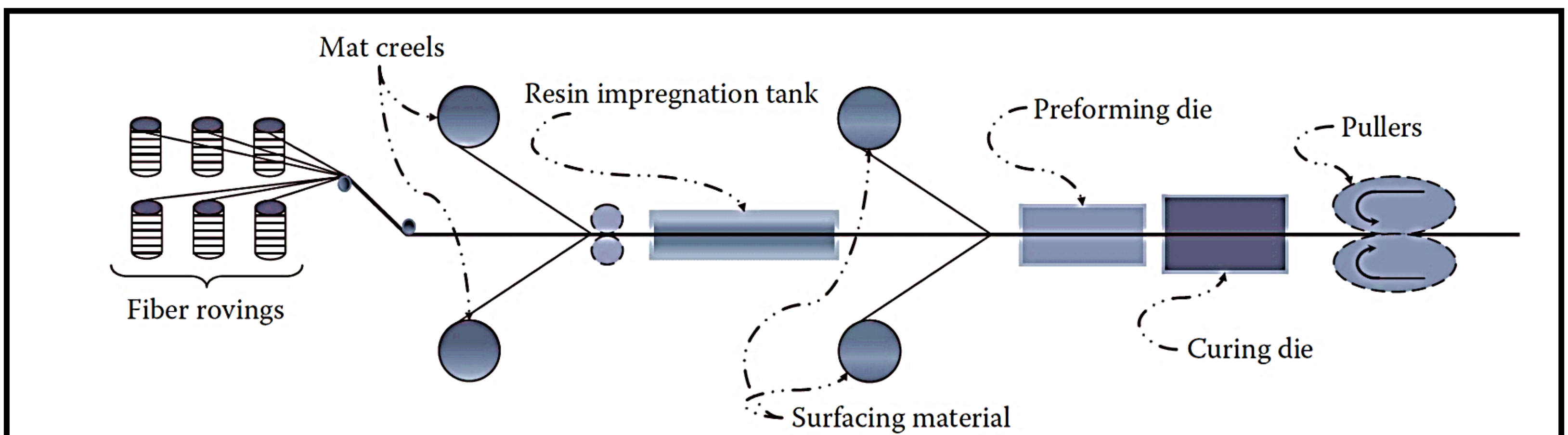
Compression molding is a manufacturing process where the molding material is placed in an open, heated mold cavity along with a thermosetting resin.



❑ Automated Manufacturing Processes

1) Pultrusion Process:

The pultrusion technique is a fully automated closed mold continuous process in which continuous fiber or rovings are passed through a resin bath, drawn through a preforming die to form the composite into a strip, and cured in a heated die.



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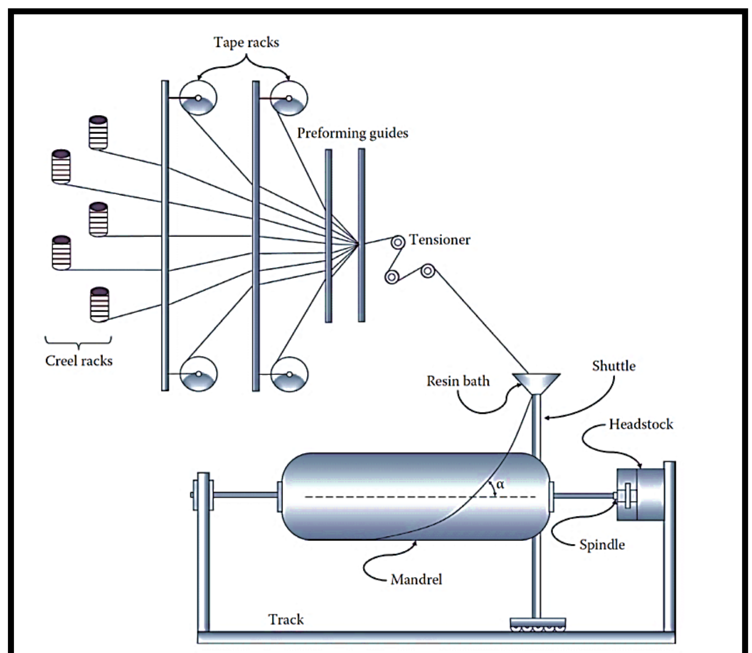
❑ Automated Manufacturing Processes

2) Filament Winding:

Filament winding is an automated process in which continuous spools of dry fiber (tows) are pulled in a predetermined pattern by computer-controlled winding machines.



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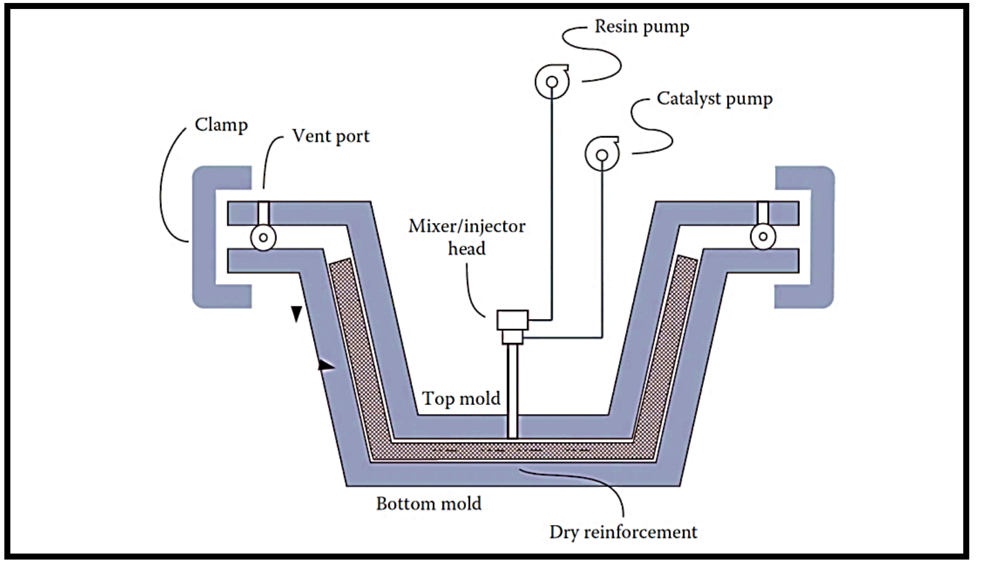
❑ Automated Manufacturing Processes

3) Resin Transfer Molding:

In this process, a preformed dry fiber part is placed on a tool or inside a mold cavity with rigid surfaces on both sides of the composite part, and the whole assembly is encapsulated in a vacuum bag. Thermosetting resin is injected under pressure into the mold. Vacuum is applied, which draws out the air voids and excess resin and compacts the composite part.



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❑ Quality Assurance

Quality assurance (QA) form an integral and significant part of the manufacturing process in order to obtain high-quality composite parts. An effective quality assurance for composite parts depends on:

- Careful and systematic monitoring of the design process
- The manufacturing tools and equipment
- Finished quality of the manufactured part.

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❑ Quality Assurance

The main components included:

- validation and characterization of the properties of the raw materials used to produce the composite part
- monitoring the cure process and post-cure machining, and
- validating the physical and mechanical properties of the cured composite part.

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❑ Visual and Mechanical Inspection

In most cases, the manufacturer of the composite part obtains the raw material components such as fibers, resins, and additives from separate suppliers, who will generally provide the mechanical properties of the components.

- F
- B
- M
- U
- W

❑ Mechanical Testing

Mechanical or destructive testing is often carried out on representative composite samples cut out from larger laminates to determine several mechanical properties of the composite part or that of its constituents, such as:

- T
- C
- F
- S
- T

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❑ Nondestructive Testing

Since it is usually not feasible to carry out any of the mechanical tests on finished composite parts because of size and shape constrains, nondestructive tests are ideally suited for quality control on the factory floor.

- U
- V
- R
- T
- A