Module 1: Introduction to Composites

Lecture 7: Fabrication Processes

The Lecture Contains:

Previous Next

Introduction:

In this lecture we will see some of the important fabrication processes of composites. Further, we will see their advantages, disadvantages and applications.

What are the fabrication processes of composites materials? Describe the processes in brief along with the materials used in the process, their advantages, disadvantages and applications.

The fabrication processes are described in the following along with their advantages, disadvantages and applications in the following.

A. Wet/Hand Lay-Up:

The fibres are first put in place in the mould. The fibres can be in the form of woven, knitted, stitched or bonded fabrics. Then the resin is impregnated. The impregnation of resin is done by using rollers, brushes or a nip-roller type impregnator. The impregnation helps in forcing the resin inside the fabric. The laminates fabricated by this process are then cured under standard atmospheric conditions. The wet/hand lay-up process is depicted in Figure 1.15.

The materials that can be used have, in general, no restrictions. One can use combination of resins like epoxy, polyester, vinylester, phenolic and any fibre material.

Advantages:

- The process results in low cost tooling with the use of room-temperature cure resins.
- The process is simple to use.
- Any combination of fibres and matrix materials are used.
- Higher fibre contents and longer fibres as compared to other processes.

Disadvantages:

- Since the process is worked by hands, there are safety and hazard considerations.
- The resin needs to be less viscous so that it can be easily worked by hands.
- The quality of the final product is highly skill dependent of the labours.
- Uniform distribution of resin inside the fabric is not possible. It leads to voids in the laminates.
- Possibility of diluting the contents.

Applications:

The process is suitable for the fabrication of wind-turbine blades, boats and architectural mouldings.

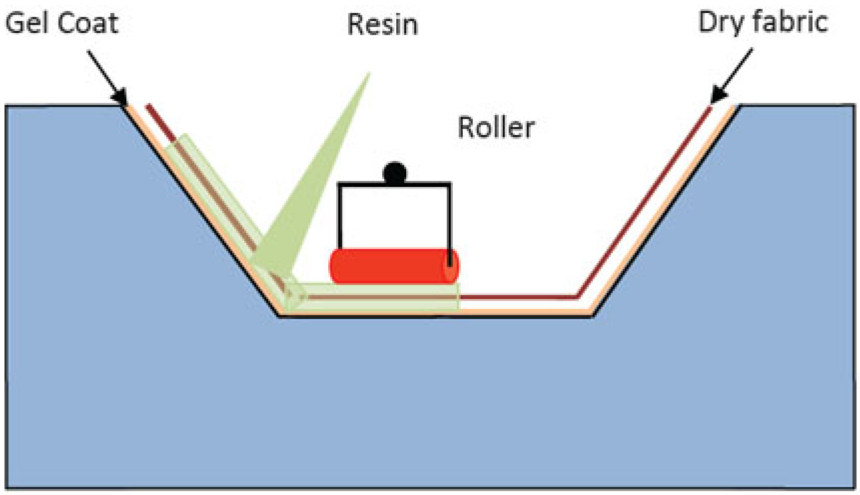

Figure 1.15: Wet or hand lay-up fabrication

Previous Next

B. Spray Lay-Up:

Fibre is chopped in a hand-held gun and fed into a spray of catalyzed resin directed at the mould. The deposited materials are left to cure under standard atmospheric conditions. The fabrication method is depicted in Figure 1.16.

The polyester resins can be used with glass rovings is best suited for this process.

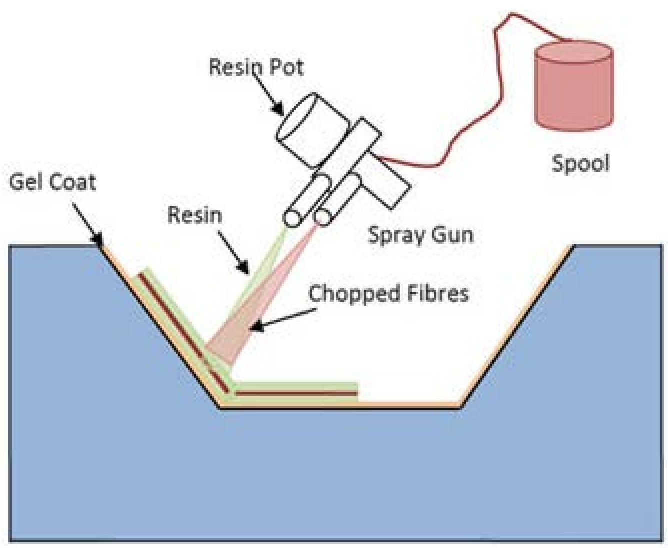

Figure 1.16: Wet or hand lay-up fabrication

Advantages:

The spray-up process offers the following advantages:

- It is suitable for small to medium-volume parts.
- It is a very economical process for making small to large parts.
- It utilizes low-cost tooling as well as low-cost material systems.

Limitations:

The following are some of the limitations of the spray-up process:

- It is not suitable for making parts that have high structural requirements.
- It is difficult to control the fiber volume fraction as well as the thickness. These parameters highly depend on operator skill.
- Because of its open mold nature, styrene emission is a concern.
- The process offers a good surface finish on one side and a rough surface finish on the other side.
- The process is not suitable for parts where dimensional accuracy and process repeatability are prime concerns. The spray-up process does not provide a good surface finish or dimensional control on both or all the sides of the product.
- Cores, when needed, have to be inserted manually.
- Only short fibres can be used in this process.

Since, pressurized resin is used the laminates tend to be very resin-rich.

- Similar to wet/hand lay-up process, the resins need to be of low viscosity so that it can be sprayed.

Applications:

Simple enclosures, lightly loaded structural panels, e.g. caravan bodies, truck fairings, bathtubs, shower trays, some small dinghies.

Previous Next

C. Autoclave Curing:

The key features of this process are as follows:

- An autoclave is a closed vessel for controlling temperature and pressure is used for curing polymeric matrix composites.
- Composites to be cured is prepared either through hand lay up or machine placement of individual laminae in the form of fibers tape which has been impregnated with resin.
- Components is then placed in an autoclave and subjected to a controlled cycle of temperature and pressure.
- After curing, the composite is “solidified”.
- One can use the fibres like carbon, glass, aramid etc. along with any resin.

Advantages:

- Large components can be fabricated.
- Since, the curing of matrix material is carried out under controlled environment, the resin distribution is better as compared to hand or spray lay-up processes.
- Less possibility of dilution with foreign particles.
- Better surface finish.

Disadvantages:

- Initial cost of tooling is high.
- Running and maintenance cost is high.
- Not suitable for small products.

Applications:

The process is suitable for aerospace, automobile parts like wing box, chassis, bumpers, etc.

Previous Next

D. Filament Winding:

This process is an automated process. This process is used in the fabrication of components or structures made with flexible fibers. This process is primarily used for hollow, generally circular or oval sectioned components. Fibre tows are passed through a resin bath before being wound onto a mandrel in a variety of orientations, controlled by the fibre feeding mechanism, and rate of rotation of the mandrel. The wound component is then cured in an oven or autoclave.

One can use resins like epoxy, polyester, vinylester and phenolic along with any fibre. The fibre can be directly from creel, non-woven or stitched into a fabric form.

The filament winding process is shown in Figure 1.17.

Advantages:

- Resin content is controlled by nips or dies.
- The process can be very fast.
- The process is economic.
- Complex fibre patterns can be attained for better load bearing of the structure.

Disadvantages:

- Resins with low viscosity are needed.
- The process is limited to convex shaped components.
- Fibre cannot easily be laid exactly along the length of a component.
- Mandrel costs for large components can be high.
- The external surface of the component is not smoothly finished.

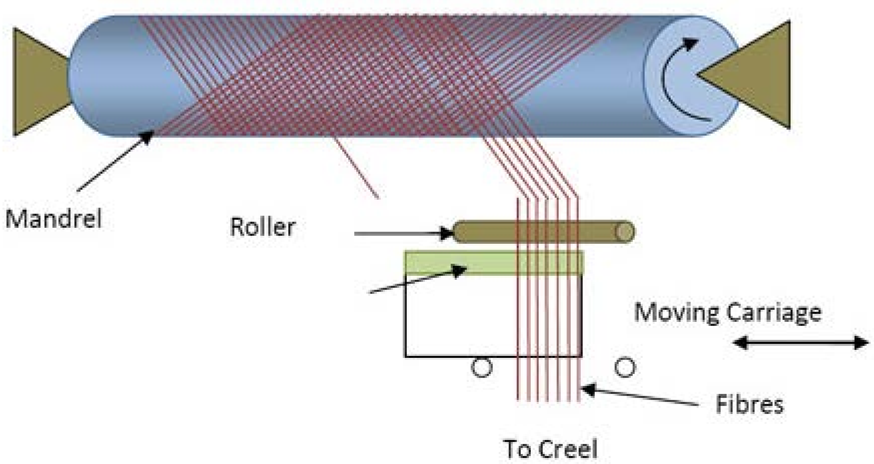

Figure 1.17: Filament winding

Applications:

Pressure bottles, rocket motor casing, chemical storage tanks, pipelines, gas cylinders, fire-fighters, breathing tanks etc.

E. Pultrusion:

It is a continuous process in which composites in the form of fibers and fabrics are pulled through a bath of liquid resin. Then the fibres wetted with resin are pulled through a heated die. The die plays important roles like completing the impregnation and controlling the resin. Further, the material is cured to its final shape. The die shape used in this process is nothing the replica of the final product. Finally, the finished product is cut to length.

In this process, the fabrics may also be introduced into the die. The fabrics provide a fibre direction other 0°. Further, a variant of this method to produce a profile with some variation in the cross-section is available. This is known as ***pulforming***.

The resins like epoxy, polyester, vinylester and phenolic can be used with any fibre.

The pultrusion process is shown in Figure 1.18.

Advantages:

- The process is suitable for mass production.
- The process is fast and economic.
- Resin content can be accurately controlled.
- Fibre cost is minimized as it can be taken directly from a creel.
- The surface finish of the product is good.
- Structural properties of product can be very good as the profiles have very straight fibres.

Disadvantages:

- Limited to constant or near constant cross-section components.
- Heated die costs can be high.
- Products with small cross-sections alone can be fabricated.

Applications:

Beams and girders used in roof structures, bridges, ladders, frameworks

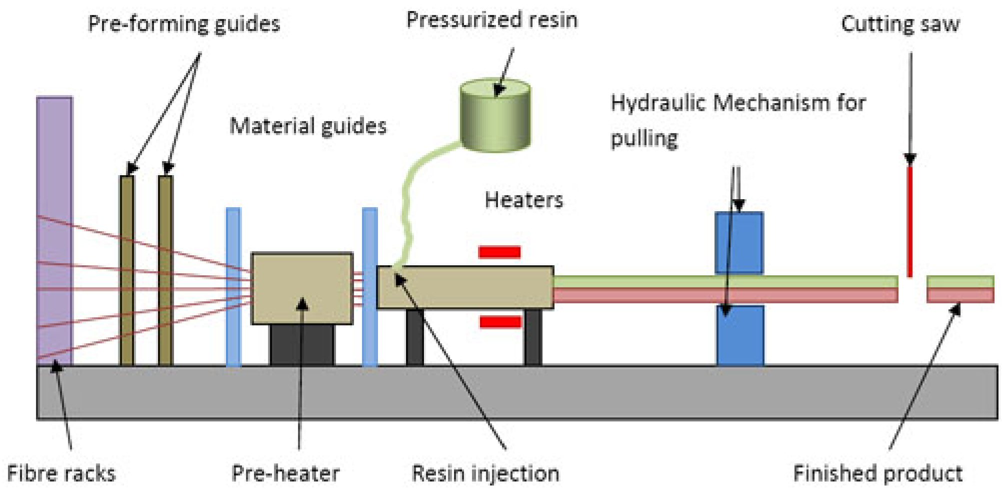

Figure 1.18: Pultrusion

Previous Next

References:

- *MF Ashby. Technology of 1990s: Advanced materials and predictive design. Phil. Trans. R. Soc. Lond. A. 1987; Vol. 322, pp. 393-407.*
- *JY Lund, JP Byrne. Leonardo Da Vinci's tensile strength tests: implications for the discovery of engineering mechanics Civil. Eng. and Env. Syst. 2001; Vol. 18, pp. 243-250.*
- *E de LaMotte, AJ Perry. Diameter and strain-rate dependence of the ultimate tensile strength and Young's modulus of carbon fibres. Fibre Science and Technology, 1970; Vol. 3, pp. 157-166.*
- *CT Herakovich. Mechanics of Fibrous Composites, John Wiley & Sons, Inc. New York, 1998.*
- *BD Agarwal, LJ Broutman, K Chandrashekhara. Analysis and Performance of Fibre Composites, 3rd Edition, John Wiley & Sons, Inc. New York, 2006.*
- *RM Jones. Mechanics of Composite Materials, Material Science and Engineering Series.2nd Edition, Taylor & Francis, 1999.*
- *AK Kaw. Mechanics of Composite Materials. 2nd Edition, CRC Press, New York, 2006.*
- *RM Christensen. Mechanics of Composite Materials. Dover Publications, 2005.*
- *SW Tsai, HT Hahn. Introduction to Composite Materials, Technomic Publishing, Lancaster, PA, 1980.*
- *D Hull, TW Clyne. An Introduction to Composite Materials, 2nd ed., Cambridge University, Press, New York, 1996.*
- *IM Daniel, O Ishai. Engineering Mechanics of Composite Materials, Oxford University Press, 1994.*
- *Composite Handbook.*
- *ASTM Standards.*
- *SS Pendhari, T Kant, YM Desai. Application of polymer composites in civil construction: A general review. Composite Structures, 2008; Vol. 84, pp. 114-124.*
- *CP Talley. J. Appl. Phys. 1959, Vol. 30, pp 1114.*
- *http://composite.about.com/*
- *http://www.netcomposites.com/*
- *http://www.gurit.com/*
- *http://www.hexcel.com/*
- *http://www.toraycfa.com/*
- *http://www.e-composites.com/*
- *http://www.compositesone.com/basics.htm*
- *http://www.wwcomposites.com/ (World Wide Search Engine for Composites)*
- *http://jpsglass.com/*
- *http://www.eirecomposites.com/*
- *http://www.advanced-composites.co.uk/*
- *http://www.efunda.com/formulae/solid_mechanics/composites/comp_intro.cfm*