A215

	Composites manufacturing
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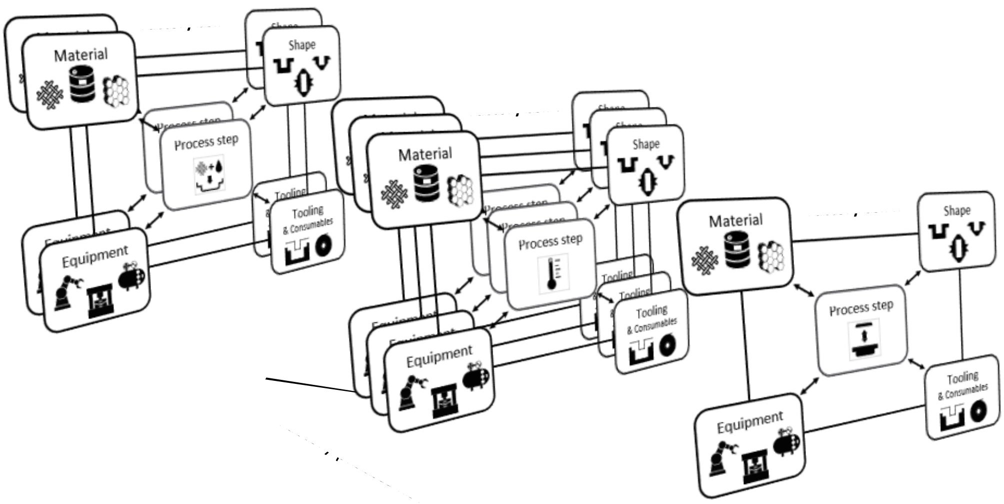
Overview[edit | edit source]

As explained in the Systems Approach to Composites page, a composite manufacturing process is a collection of process steps transforming the raw material reinforcement and resin matrix constituents into a combined composite material of a desired part shape and geometry.



Factory process flow.

Composite manufacturing processes are often named according to a particular process step within the complete part manufacturing process. By convention, the process name is in reference to the material (M), part shape (S), tooling (T), equipment (E), or particular action that is involved in this process step (P) (see KPC's MSTEP approach to manufacturing).

In general, the process naming convention highlights one or several of the following manufacturing processing steps:

1. Placing and aligning the reinforcement
2. Impregnating the reinforcement with the resin matrix
3. Transforming the two material components into a solid material

The complete manufacturing workflow, however, includes other necessary steps; starting with recieving and storage of the raw material, on through to the steps mentioned above, and on through to the final part component inspection and out the factory doors.

For a complete list of the generic process steps involved in the manufacturing process, please see the Factory Process Flow page.

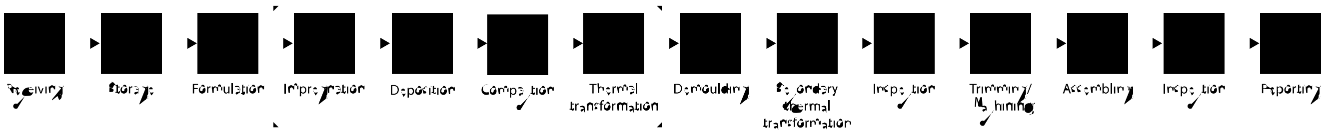
To learn about how to identifying process steps, see Practice for Identifying Process Steps.

Common Process Examples[edit | edit source]

As mentioned, composite manufacturing processes are conventionally named after a prominent process step(s) or action(s), often the material deposition step. Examples of some common industrial manufacturing processes, highlighting these critical defining steps, are listed below.

Wet Lay-Up[edit | edit source]

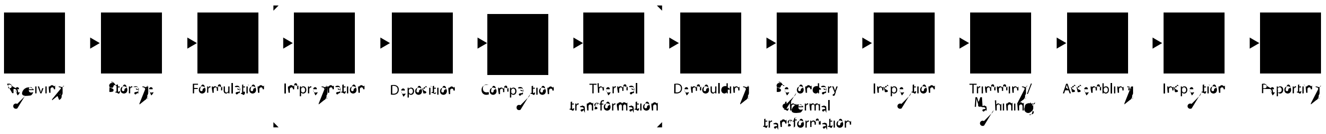
Performed by hand, reinforcement mats, fibre tows or dry fabrics are laid on an open mould. Resin is then spread onto the fibres wetting them. Alternatively, individual fibre plies (layers) are sometimes wetted with resin prior to transfer and laying onto the mould. Compaction of the fibres is usually done by hand with rollers. This wetting and laying process is performed layer by layer until the desired laminate thickness is obtained. Resin curing is carried out at room temperature or in an oven. A limitation to the process is only one smooth surface can be achieved (mould side) and an absence of direct thickness control.



Wet lay-up process steps

Spray-Up[edit | edit source]

Spray-up involves spraying chopped fibres with resin onto a mould surface with a specialized spray gun. Fibre rovings are fed into to a spray gun, chopping the fibres before spraying. Resin may be applied with a brush or mixed with the chopped fibres in the spray process. Similar to wet lay-up, the resin wetted fibre is compacted by hand with handheld rollers. Resin curing is carried out at room temperature or in an oven.

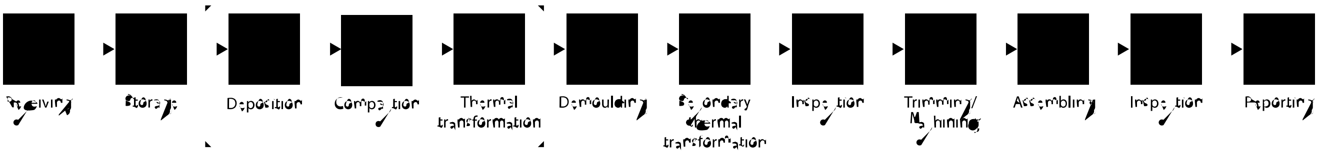


Spray-up process steps

Autoclave / Out-of-Autoclave Prepreg Processing[edit | edit source]

Pre-impregnated (prepreg) layers of fibre/resin (provided in this form by a materials supplier) are laid up on a mould to the desired shape and thickness. The prepreg stack on the mould is then placed into an autoclave in a vacuum bag setup for curing under heat and applied pressure conditions.

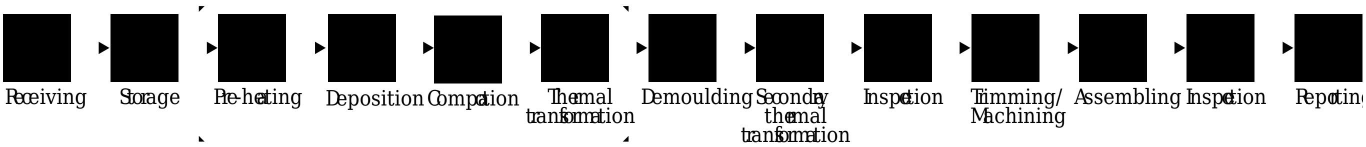
Out-of-Autoclave (OOA) prepreg processing is similar, except curing is carried out with only a vacuum bag setup and oven heating conditions without applied pressure. OOA prepregs are different from autoclave cured prepreg materials in that they are specially designed for curing without the applied pressure provided by the autoclave.



prepreg process steps

Compression Moulding[edit | edit source]

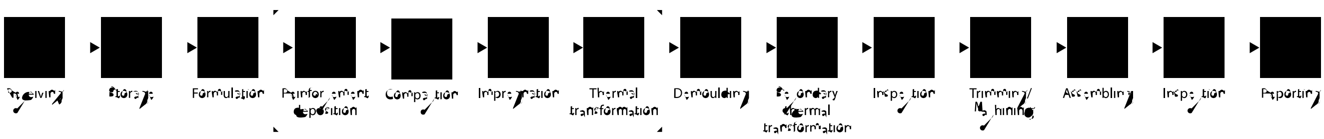
Compression moulding uses a heated mould consisting of matched dies placed in a press where a charge is placed in between that is pressed into shape when the mould is closed. The charge may consist of bulk-moulding compound (BMC), sheet moulding compound (SMC) or preform mat. Both thermoset and thermoplastic polymers can be processed by compression moulding. After curing (thermoset matrix) or solidification is complete (thermoplastic matrix), the mould is opened and the part is removed.



Compression moulding process steps

Resin Transfer Moulding[edit | edit source]

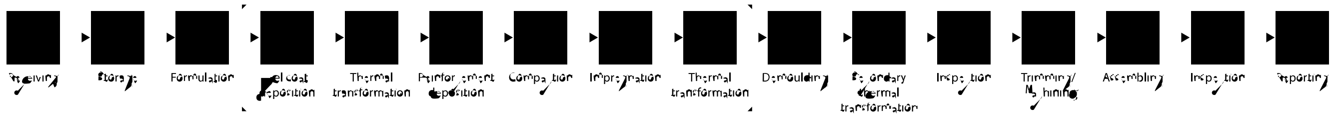
Resin transfer moulding (RTM) is a closed mould resin infusion process carried out in a two or more piece mould. A dry fibre reinforcement stack (preform) is placed into the bottom portion of the mould, after which the top half of the mould is placed to close the setup. Through injection gates, liquid resin is then let into the mould with low to moderate applied pressure up to approximately 7 bar or 100 psi. When mould filling is complete, the resin is let to cure. RTM is generally considered for moderate to high-volume production. It is well suited to small to medium sized parts, limited to large sizes due to injection pressure loads and tool cost.



RTM process steps

Vacuum Assisted Resin Infusion / Vacuum Assisted Resin Transfer Moulding[edit | edit source]

Vacum assisted resin infusion (VARI) or sometimes referred to as vacuum assisted resin transfer moulding (VARTM), involves placing a fibre reinforcement stack (preform) on a one-sided tool, sealed with a vacuum bag on top. Vacuum is drawn to compact the fibre stack and to draw resin through the preform. Once the fibre is fully infused with resin, the resin inlet is clamped and vacuum is held until the resin is cured.



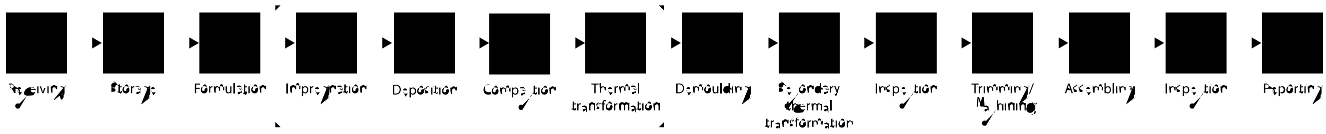
VARI/VARTM process steps

Filament Winding[edit | edit source]

The process is characterized by placing resin wetted fibres onto a rotating mandrel tool. Fibre tows are wetted with resin by running dry fibre tows through a resin bath. The resin wetted fibre tows are then deposited on a rotating mandrel. Layers are stacked through rotation of the mandrel until the desired thickness is obtained. Resin curing is then performed.

Pultrusion[edit | edit source]

Fibre tows are wetted with resin by running dry fibre tows through a resin bath. The wetted fibre tows are then subjected to compaction and heating by being passed through a heated shaping die. The pultrusion process requires the fibre distribution and cross-sectional shape be constant across the produced part length.



Pultrusion process steps

Bladder Moulding[edit | edit source]

Bladder moulding is a process suitable for hollow structures complex in shape. In this process, prepreg plies are wrapped around an inflatable bladder that is then placed inside a closed mould setup. The bladder is then inflated pushing the prepreg plies outwards against the inside of the mould cavity. After curing with heat, the shaped part is removed from the mould. In some cases, the bladder is removed from the interior of the formed part, in other cases, it may be left in place.

Tube Rolling[edit | edit source]

Tube rolling is a process suitable for hollow tube structures or rods with only a minor taper in geometry (e.g. fishing rod). Prepreg plies of either fabric or uni-directional tape are wrapped around a mandrel. Prepreg patterns may be cut to achieve a desired ply lay-up schedule. The mandrel rolling process compacts and debulks the fibre plies layer by applied layer. Often, the prepreg covered mandrel is covered with a specialized release coated shrink tape. Heated in an oven, the shrink tape applies a uniform compaction force consolidating the fibre plies. Upon curing, the shrink tape is removed with only minor surface mark-off.

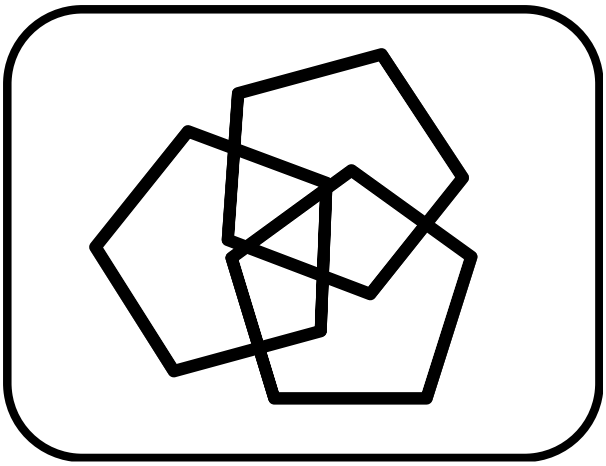
Injection Moulding[edit | edit source]

Injection moulding is a popular plastic forming operation used in the plastics industry suitable for both thermoset and thermoplastic polymers. Liquid polymer is pushed with pressure into a closed mould cavity of the desired part shape upon which it solidifies. This process can be used for short fibre reinforced polymers granted the highly viscous liquid polymer can be injected into and fill the cavity. This short fibre injection process is more difficult than with an unreinforced polymer, as the polymer viscosity rises with the addition of the short fibres. The greater the fibre content, the greater the rise in the mixed polymer/fibre blend viscosity.

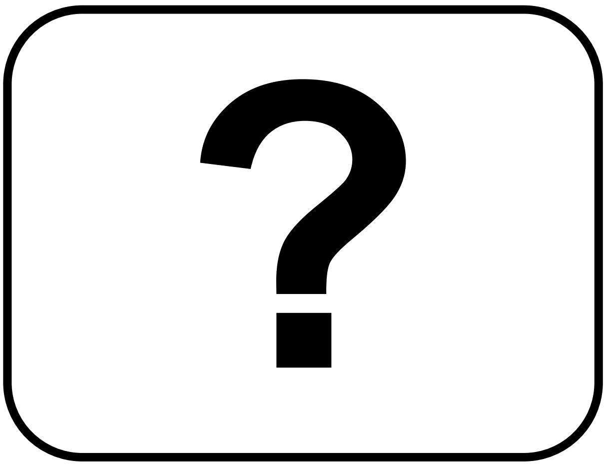
KPC AIM Event Webinars[edit | edit source]

To learn about composite manufacturing processes from one of our past KPC webinar event recordings:

- Click here to view the KPC AIM Event: Composite materials engineering webinar session 5 - Manufacturing processes – Introduction
- Click here to view the KPC AIM Event: Composite materials engineering webinar session 6 - Manufacturing processes - Prepreg processing
- Click here to view the KPC AIM Event: Composite materials engineering webinar session 7 - Manufacturing processes - Liquid composite moulding



About



Help

Engineered materials (designed to have specific properties) made from two or more constituent materials with different physical or chemical properties. The constituents remain separate and distinct on a macroscopic level within the finished structure.

For polymer matrix composites (PMCs), resin refers to the matrix; the continuous material phase that binds the reinforcement together, maintains shape, and transfers load. Resins are divided into two main groups: thermosets and thermoplastics.

The continuous material phase that binds the reinforcement together, maintains shape, transfers load, protects the reinforcement from environment and damage, and provides the composite support in compression.

Desirable characteristics:

- Moisture/chemical resistance
- Low density
- Processability

Pre-impregnated (prepreg) material refers to fibre that is already combined with resin. It is the most common material form used in aerospace.

During prepreg production, (e.g. fibres are run through a resin bath), prepreg is heated and partially cured to B Stage (< 5 % degree of cure). Thermoset prepregs (e.g. epoxy prepreg) have to be kept in a freezer at around -20 °C. At room temperature, the epoxy starts to cure.

‘Preform’ is the term for the fibre reinforcement. This is the stage between the raw material form after it is processed into an architecture (fabric, mat, etc.) and becoming a composite.

Thermosets are a class of polymer that undergo polymerization and crosslinking during curing with the aid of a hardening agent and heating or promoter. Initially they behave like a viscous fluid. During curing, they change from viscous fluid to rubbery gel (viscoelastic material) and finally glassy solid.

If heated after curing, initially they become soft and rubbery at high temperatures. If further heated, they do not melt but decompose (burn)

Comes in two parts: part A (resin) and B (hardener). When mixed, curing reaction starts and is not reversible.

Examples include epoxy or polyester.

A class of polymer, some common examples include polypropylene and polyethylene.

They soften and melt upon heating (i.e. potentially recyclable), high viscosity when melted, therefore difficult to saturate fibres. Usually needs a lot of pressure and heat to process.

Resin transfer moulding (RTM) involves loading a preform into a two (or more) piece, matched tool, closing it, and injecting resin under pressure (~15-100 psi, or ~1-7 bar).

Well suited to small to medium sized parts, limited to large sizes due to injection pressure loads and tool cost.

Vacuum assisted resin infusion (VARI) - also known as vacuum assisted resin transfer moulding (VARTM), vacuum infusion process (VIP) or often just resin infusion. VARI is a liquid composite moulding (LCM) closed mould process with a single side tool and vacuum bag where the resin is drawn through the preform using vacuum.

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In composites processing, viscosity is an indicator of how easily the resin matrix will mix with the reinforcement and how well it will stay in place during processing. The lower the viscosity, the more easily resin flows. Resin viscosity ranges considerably across chemistries and formulations.

By scientific definition, viscosity is a measure of a material’s resistance to deformation. For liquids, it is in response to imposed shear stresses.