

**Lecture 5.10: Resin Transfer Molding and Autoclave Molding**

**Resin transfer molding**

Resin transfer molding is a closed molding process. In this technique, as the name indicates, resin is transferred over the already placed reinforcement. Reinforcement in terms of either woven mat or strand mat form is placed on the surface of lower half mold. A release gel is applied on the mold surface for easy removal of the composite. The mold is properly closed and clamped. The clamping can be done either perimeter clamping or press clamping mechanism. The resin is pumped into the mold through ports and air is displaced through other vents. The uniformity of resin flow can be enhanced by using a catalyst as an accelerator and vacuum application. After curing, the mold is opened and composite product is taken out. The schematic of resin transfer molding process is shown in figure 1. Resin transfer molding can incorporate soft or hard mold depending upon the expected duration of run. For soft mold, thermosetting polymers like epoxy and polyester can be used for molding material. For hard mold, materials like steel and aluminium can be used. The cost of mold varies from very low to high cost mold with short to long life molds. The process can be automated to reduce cycle time. For complex shapes to be produced, preformed fiber reinforcements are used. The viscosity of the resin plays an important role in resin transfer molding process because injection time depends upon viscosity of the resin. If viscosity of resin is high, high pressure is required which may cause displacement of fibers, known as fiber wash. The raw materials used in resin transfer molding are given in table 1.

<table>
<thead>
<tr>
<th>Materials used</th>
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<tbody>
<tr>
<td><strong>Matrix</strong></td>
</tr>
<tr>
<td>Epoxy, Methyl Methacrylate, polyester, polyvinyl ester, phenolic resin</td>
</tr>
<tr>
<td><strong>Reinforcement</strong></td>
</tr>
<tr>
<td>Glass fiber, carbon fiber, aramid fiber, natural plant fibers (sisal, banana, nettle, hemp, flax etc.)</td>
</tr>
<tr>
<td>These fibers are used either individually or in combined form as a woven mat, unidirectional mat or chopped strand mat.</td>
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<tr>
<td>Mineral fillers may also be added to improve surface finish and fire retardancy</td>
</tr>
</tbody>
</table>

Table 1 Raw materials used in resin transfer molding
Important components of resin transfer molding process:

There are mainly five components in the resin transfer molding system which govern the processing of composites. These components are:

1. Resin and catalyst container
2. Pumping unit
3. Mixing chamber
4. Resin injector
5. Molding unit

There are two separate containers for resin and catalyst. Resin container is larger than the catalyst container. Both the containers have separate outlets which pass through pumping unit and opens in mixing chamber. Pumping unit transfers the resin and catalyst to the mixing chamber. Resin and catalyst is mixed thoroughly in the mixing chamber. Resin injector is used to inject the mixture to the mold cavity. Molding unit has two halves namely upper half mold and lower half mold. Heating arrangement is integrated with molding unit. Vents are provided to release the gases in the mold cavity during clamping.

Application:
1. Hollow shapes and complex structure can be produced.
2. Automotive body parts, big containers, bathtubs are commonly processed through resin transfer molding technique.

**Advantages:**

1. Composite part produced with this method has good surface finish on both side surface of the product.
2. Any combination of reinforced materials (including 3D) in any orientation can be achieved.
3. Fast cycle time can be achieved through temperature control tooling device.
4. Process can be manual control, semi-automated or highly automated.
5. Composite part thickness is uniform which is determined by the mold cavity.
6. There is low emission during composite processing.
7. Strict dimensional tolerances are possible to achieve.
8. Ability to incorporate inserts and other attachments into mold.
9. The process does not require high injection pressure.
10. Material wastage is reduced as near net shape parts are produced.
11. Higher production rate is associated with process automation.

**Disadvantages:**

1. Mold cavity limits the size of the composite.
2. High tooling cost.
3. There is limitation on reinforcing materials due to the flow and resin saturation of fibers.

**Vacuum Bag Molding**

In vacuum bag molding, vacuum is created to remove entrapped air, gases and excess resin. As the lay-up of reinforcement (it may be a woven mat or other fabric form) and resin is completed then a non-adhering film of nylon or polyvinyl alcohol (PVA) is placed over the lay-up and sealed. These films forms a bag through which vacuum is created within the mold and at this condition composites are cured either at room temperature or at any specific temperature. In this process, atmospheric pressure is used to suck air under vacuum bag which compacts composite layers down and produces a superior quality laminate.

**Pressure Bag Molding**
Pressure bag molding process which is same as the vacuum bag molding process with the only difference of air pressure. Air pressure is applied to eliminate entrapped gases and excess resin to the film or bag of poly vinyl alcohol or nylon which covers the lay-ups of fiber and resin matrix. Sometimes, pressurized steam is also used instead of air which has dual benefits. Steam removes excess air as well as provides curing to the composite part.

**Autoclave molding**

Autoclave molding technique is similar to vacuum bag and pressure bag molding method with some modifications. This method employs an autoclave to provide heat and pressure to the composite product during curing. In this method, prepregs are stacked in a mold in a definite sequence and then spot welded to avoid any relative movement in between the prepreg sheets. After stacking the prepregs, the whole assembly is vacuum bagged to remove any air entrapped in between the layers. The schematic of autoclave molding process is shown in figure 2. After a definite period of time when it is ensured that all air is removed, the entire assembly is transferred to autoclave. Here, heat and pressure is applied for a definite interval of time. In this process, matrix is uniformly distributed and intimate contact is achieved through proper bonding between fibers and matrix. After the processing, the assembly is cooled to a definite rate and then vacuum bag is removed. The composite part is taken out from the mold. Initially, a release gel is applied onto the mold surface to avoid sticking of polymer to the mold surface. The raw materials used in these techniques are given in the table 1.

![Figure 2 Autoclave molding process.](image-url)
Table 1: Raw materials used in autoclave molding process

<table>
<thead>
<tr>
<th>Materials used</th>
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</thead>
<tbody>
<tr>
<td>Matrix</td>
<td>Epoxy, polyester, polyvinyl ester, phenolic resin, Unsaturated polyester, polyurethane resin and thermoplastic resins,</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>Glass fiber, carbon fiber, aramid fiber (all these fibers may be in the form of unidirectional mat, bidirectional (woven) mat, stitched into a fabric form, mat of randomly oriented fibers)</td>
</tr>
</tbody>
</table>

Application:
The process is mainly used in applications requiring high strength to weight ratio components such as aircraft parts, marine, military, space craft and missiles.

Advantages
1. This composite processing method allows high volume fraction of reinforcement in the composite part.
2. This method is applicable for both thermoplastic and thermosetting polymer composites.
3. High degree of uniformity in part consolidation, better adhesion characteristics between layers and good control over resin and reinforcement is achieved.
4. No void content in the finished part due to removing entrapped air through vacuum.
5. If cores and inserts are used, there is better bonding of these attachments due to vacuum bag processing.
6. Complete wetting of fibers is achieved.

Disadvantages
1. There is limitation on part size which depends upon autoclave size.
2. It is a costly technique for composite processing.
3. Rate of production is low and skilled labour is required in this process.