PREPREGS
Prepregging

The reinforcement (carbon, fiberglass or aramid fiber or cloth) is saturated by dipping through the liquid resin. In an alternate method called a **Hot Melt Process** the resin is impregnated through heat and pressure. The Hot Melt System uses resins with a very low percentage of solvents.

**Figure 2.14**
Making unidirectional prepreg tape. (Courtesy of Cytec Fiberite.)
**Prepreg Lay-Up Process**

- Very common in the aerospace industry. It is also called the **autoclave processing** or **vacuum bagging process**.
- Complicated shapes with very high fiber volume fractions.
- It is an open molding process with low-volume capability.
- The prepreg lay-up or autoclave process is very labor intensive, 50 to 100 times greater than other high-volume processes;

**BASIC PROCESSING STEPS**

The basic steps in making composite components by prepreg lay-up process are summarized as follows.

1. The prepreg is removed from the refrigerator and is kept at room temperature for thawing.
2. The prepreg is laid on the cutting table and cut to the desired size and orientation.
3. Backing paper from the prepreg is removed and the prepreg is laid on the mold surface.
4. Entrapped air between prepreg sheets is removed using a squeezing roller after applying each prepreg sheet.
5. After applying all the prepreg sheets, vacuum bagging arrangements are made by applying release film, bleeder, barrier film, breather, and bagging materials.
6. The entire assembly is then placed into the **autoclave** using a trolley if the structure is large.
7. The cure cycle data are entered into a computer-controlled machine and followed.
8. After cooling, the vacuum bag is removed and the part is taken out.
MANUFACTURING PROCESSES

- Part fabrication is done by laying the prepregs on top of an open mold.
- After applying each prepreg layer, it is necessary to ensure that there is no entrapped air. Squeezing rollers are used to remove entrapped air and to create intimate contact.
- Once all the prepregs are laid in the desired sequence and fiber orientation, vacuum bagging preparations are made.
Apply **release film** on top of all the prepreg. The release film is a perforated film that allows entrapped air, excess resins, and volatiles to escape.

2. Apply **bleeder**, a porous fabric, on top of the release film. The function of the bleeder is to absorb moisture and excess resin coming from the stack of prepregs.

3. Apply **barrier film** on top of the bleeder. The film is similar to release film except that it is not perforated or porous.

4. Apply **breather layer**, a porous fabric similar to the bleeder. The function of the breather is to create even pressure around the part and at the same time allowing air and volatiles to escape.

5. The final layer is a **vacuum bag**. It is an expendable polyamide (PA) film or reusable elastomer. This film is sealed on all sides of the stacked prepreg using seal tape. If the mold is porous, it is possible to enclose the entire mold inside the vacuum bag. A nozzle is inserted into the vacuum bag and connected to a vacuum hose for creating vacuum inside the bag.
Consolidation

The commonly used form of resin matrix prepreg has a resin content beyond 40% and requires a significant amount of resin bleedout during cure to achieve a cured laminate resin content of 28-32%.

Bagging and sealing are crucial to the quality of the composite parts. General requirements for the bag are:

1. The bag must apply curing pressure uniformly;
2. The bag must not leak under molding conditions;
3. A good vacuum path must be provided in bagging.

Silicone rubber vacuum bags are widely used because of their long service life. Nylon is an alternative bag material for up to 193°C (380°F) and is usually discarded after use.

The bleeder, which is usually a nonstructural layer of porous cloth or paper which allows the escape or bleed out of excessive gas and resin during the consolidation process. Sometimes the process is called migration. The bleeder cloth or paper is removed after the curing process and is not part of the final composite.
TYPICAL MANUFACTURING CHALLENGES

Some of the challenges that manufacturing engineers face during the prepreg lay-up process are listed below.

1. **Maintaining accurate fiber orientations** in the part is difficult because prepregs are laid down by hand. Automated tape placement equipment can be used for precise fiber orientation control.

2. **Obtaining void-free parts** is a challenge during this process. Voids are caused by entrapped air between layers.

3. **Achieving warpage- or distortion-free parts** during the prepreg lay-up process is challenging. Warpage is caused by built-in residual stresses during processing.
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Prepreg Lay-Up Process

- Material layed up on mould
- Pressure and heat applied in autoclave

- Advantages:
  - Consistent material properties
  - High fiber volume
  - Flexibility in fiber orientation

- Disadvantages:
  - High labor cost unless automated

Typical composite layup and bagging.
After lamination and bagging, the mold is placed inside an autoclave for curing and consolidation.

An autoclave, similar to a pressure vessel, can maintain the desired pressure and temperature inside the chamber for processing of the composite.
The pressure is created in two ways: using the vacuum bag as well as the external pressure inside the autoclave. The vacuum bag creates a vacuum inside the bagging material and thus helps in proper consolidation.

To create vacuum inside the bag, the nozzle in the bagging system is connected to the vacuum pump using a hose.

The vacuum pump generates the desired vacuum. External pressure inside the autoclave is created by injecting pressurized air or nitrogen.
The heat for curing comes from heated air or nitrogen. The pressurized gas supplied to the chamber comes heated to increase the temperature inside the autoclave.
During the cooling stage after the cure of the composites, residual thermal stress is related to the difference between the cure temperature and ambient temperature, and the thermal expansion behavior of the composite material. A post-cure process is usually applied to the structure to relieve the induced thermal stress.
Specifically, a selected **cure cycle** must ensure that:

1. the temperature inside the material does not exceed a preset value at any time during the cure;
2. at the end of the cure the resin content is uniform and has the desired value;
3. the material is cured uniformly and completely;
4. the cured composite has the lowest possible void content;
5. the cured composite has the desired thermal and mechanical properties;
6. the curing is achieved in the shortest time.