Spray-Up Process

The spray-up process is similar to the wet lay-up process, with the difference being in the method of applying fiber and resin materials onto the mold. The wet lay-up process is labor intensive because reinforcements and resin materials are applied manually. In the spray-up process, a spraygun is used to apply resin and reinforcements with a capacity of 1000 to 1800 lb material delivered per hour. In this process a spraygun is used to deposit chopped fiber glass and resin/catalyst onto the mold. The gun simultaneously chops continuous fiber rovings in a predetermined length (10 to 40 mm) and impels it through a resin/catalyst spray onto the mold. The spray-up process is much faster than the wet lay-up process and is less expensive choice because it utilizes rovings, which is an inexpensive form of glass fiber.

Making of the Part

The processing steps used in the spray-up process are very similar to those in the wet lay-up process. In this process, the release agent is first applied to the mold and then a layer of gel coat is applied. The gel coat is left for 2 hr, until it hardens. Once the gel coat hardens, a spraygun is used to deposit the fiber resin mixture onto the surface of the mold. The spraygun chops the incoming continuous rovings (one or more rovings) to a predetermined length and impels it through the resin/catalyst mixture as shown in Figure 6.27. Figure 6.28 shows the application of chopped fibers and resin by a robot. Resin/catalyst mixing can take place inside the gun (gun mixing) or just in front of the gun. Gun mixing provides thorough mixing of resin and catalyst inside the gun and is preferred to minimize the health hazard concerns of the operator. In the other type, the catalyst is sprayed through two side nozzles into the resin envelope. Airless sprayguns are becoming popular because they provide more controlled spray patterns and reduced emission of volatiles. In an airless system, hydraulic pressure is used to dispense the resin through special nozzles that break up the resin stream into small droplets which then become saturated with the reinforcements. In an air-atomized spraygun system, pressurized air is used to dispense the resin.

In the spray-up process, the thickness built up is proportional to the spraying pattern, and the quality of the laminate depends on operator skill. Once the material is sprayed on the mold, brushes or rollers are used to remove entrapped air as well as to ensure good fiber wetting. Fabric layers or continuous strand mats are added into the laminate, depending on performance requirements. The curing of the resin is done at room temperature. The curing of resin can take 2 to 4 hr, depending on the resin formulation. After curing, the part is demolded and tested for finishing and structural requirements.

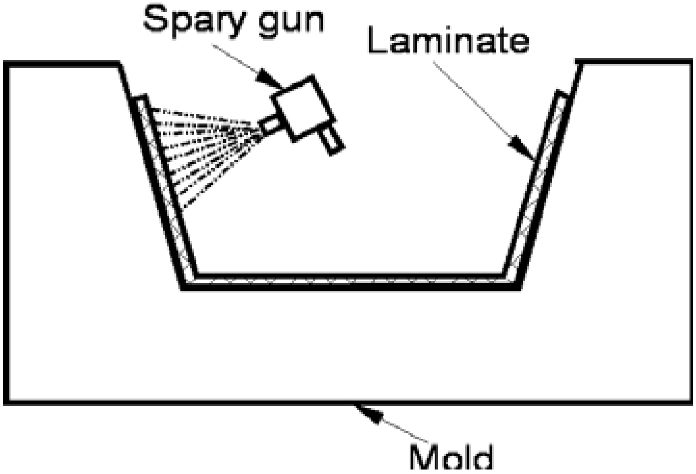


FIGURE 6.27 Schematic of the spray-up process.

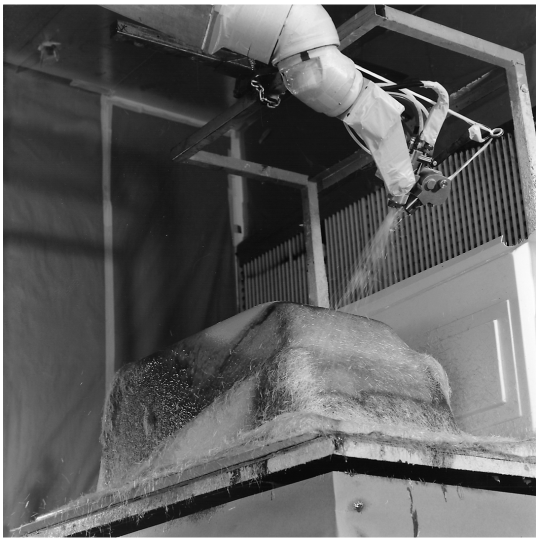


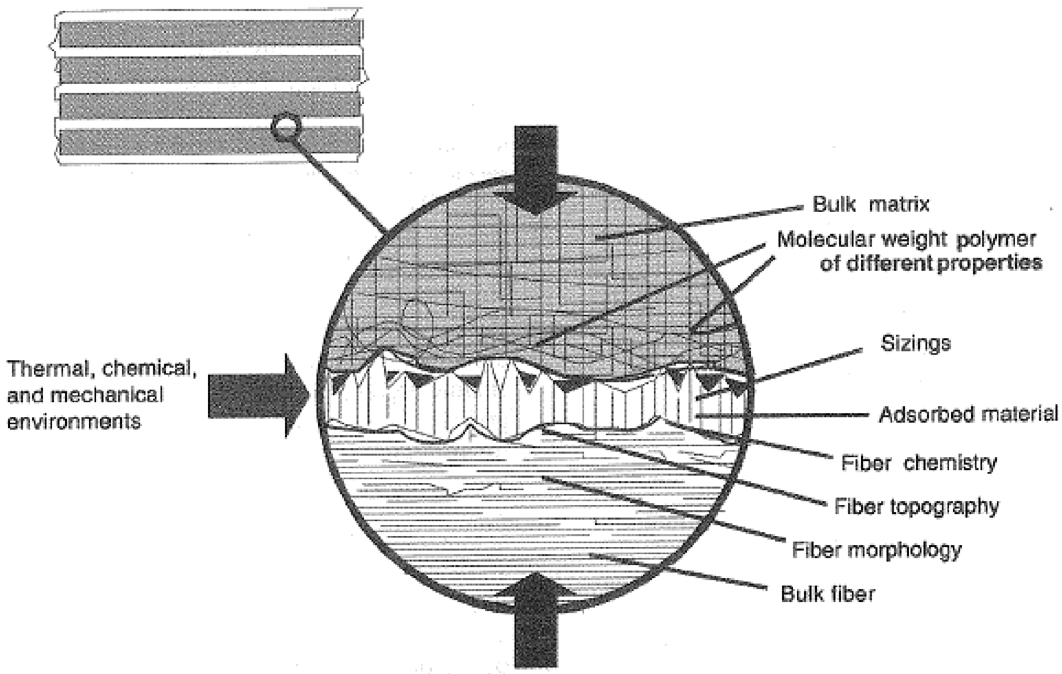
FIGURE 6.28 Robotic spray-up process for making a bathtub. The robot is applying chopped fiberglass with gel. (Courtesy of Fanuc Robotics.)

Methods of Applying Heat and Pressure

The spray-up process is very economical because it does not have a high need for heat or pressure. The part is room-temperature cured or sometimes
oven cured for higher production volume. No pressure is applied during the curing process. After spraying the resin and reinforcement, rollers are used to remove the entrapped air as well as to create an even and smooth laminate surface.

Reinforcement and matrix bonding

The properties of the composites depend both on components properties and the coupling strength between them. The matrix must have the capacity to exchange loading to the reinforcement. The point where the matrix and reinforcement meet is termed the "interface", and a few unique techniques are probable to fulfill bonding and load exchange, including the inter-diffusion of components, chemical reaction between new compounds shaped on the surfaces, electrostatic attraction, molecular entanglement, and mechanical interlocking.



The Mechanism of Adhesion

Adhesion is wonders by which one material is attracted to another by method for surface attraction. The adhesion of polymer to the fiber surface is controlled by the surface structure and the surface chemistry of the fiber. The adhesion between fiber and matrix which can be improved by the following means:

1. By increased the wettability of the fiber surface by the matrix.
2. By evacuating the weak boundary layer, e.g., contaminant species or gas molecules physically adsorbed on the fiber surface. This would give a more private contact between the fiber and the polymer to ensure an important level of van der Waals force.

3. By permitting the matrix molecules physically to entangle with, or diffuse into surface of fibers.
4. By increasing mechanical interlocking between the fiber and the matrix. This can be accomplished by making surface porosity, into which resin particles can infiltrate.
5. By accumulative the quantity of active sites on the fiber surface for following chemical bonding with the unreacted species in the matrix resin.

6. By applying a thin layer of 'coupling agent' that will chemically attach to both; fiber and matrix.

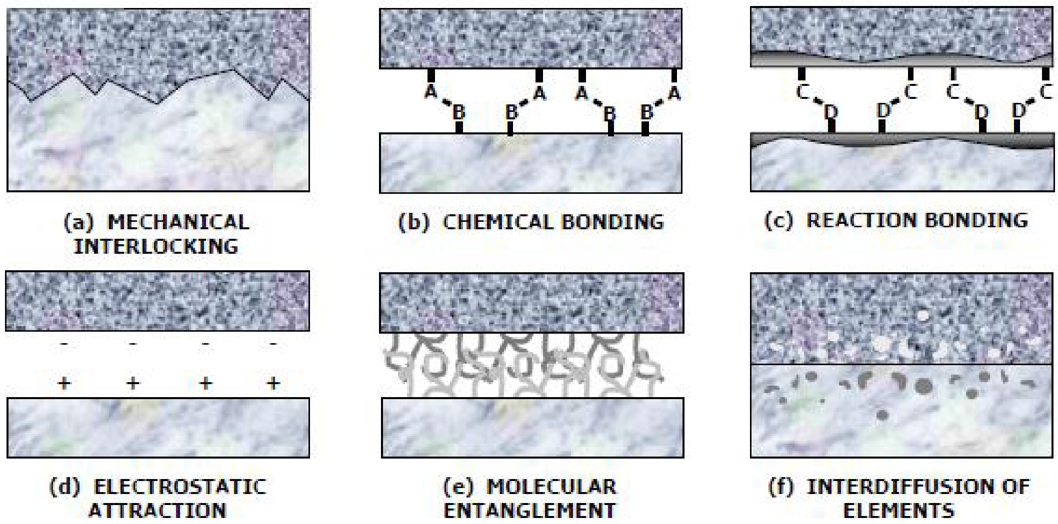


Fig.1-1 mechanism of adhesion

a -Mechanical interlocking. Fig. (1-1) (a) Indicates to two unique aspects, a geometrical one and a residual stress- induced one.Geometrical mechanical interlocking indicates to how the surface irregularities of the support grip the matrix. For geometrical mechanical interlocking to happen, the matrix must have the capacity to infiltrate within the surface irregularities, without bubbles or voids. This procedure is indicated to as "wetting". Geometrical mechanical interlocking is regularly advanced by surface treatments of the support that produce a substantial number of pits, corrugations and more surface area for fiber/matrix bonding**.**

The other aspect of mechanical interlocking, the remaining stress one, includes the shrinkage of the matrix. After manufacturing, when the matrix cools, the thermal constriction of the reinforcement and the matrix are not the identical, often causing the matrix to “clamp” the reinforcement.

b- Chemical Adhesion: Fig. (1-1)(b) Indicates if the adhesive and substrate can shape a compound at their interface or combination, the ionic or covalent bonds that are made result in an excellent bond between the two materials. A weaker bond is shaped when there is hydrogen bonding, that is, H_2 in one molecule is attracted to an electron-donor atom, for example, N_2or O_2in other molecule. As follows, when the surface atoms of an adhesive and substrate structure ionic, covalent, or hydrogen bonds, chemical bonds happen. Still, it can be seen that though the strengths of these chemical bonds can be high.

c- Theory of Weak Boundary Layers: Fig. (1-1)(c) This hypothesis is established principally in light of likelihood considerations demonstrating that the fracture ought to never created just along the adhesive–substrate interface and the cohesive failure within the weaker material close to the interface is a more ideal event .

d-Electronic Theory: Fig. (1-1)(d) Explain adhesion happens because of electrostatic properties developing from interaction potential at the adherent / adhesive interface. Electron exchange is required to happen between the adhesive and the substrate because of a dissimilarity in their electronic band structures. This exchange leads to the creation of an electrostatic twofold layer at the surface.

e- Adsorption (or Thermodynamic) Theory: Fig. (1-1)(e) Show this hypothesis depends on the acceptance that the adhesive will adhere to the substrate as a result of interatomic and intermolecular forces recognized at the interface, gave that a private contact is accomplished. The most widely recognized interfacial strengths result from van der Waals and Lewis acid–base interaction,

f- Diffusion adhesion theory: Fig. (1-1)(f) Indicate the dispersion hypothesis of bond suggests that adhesion can be ascribed to the interdiffusion of polymer molecules at the interface. Subsequently this requires the adhesive and substrate are commonly soluble and have significant mobility, the mechanism does not specifically apply in the case of metal to polymer adhesion. Interdiffusion may, however, be operational in the adhesion of the polymer to primer and coupling agents, if a high level of crosslinking or crystallinity is incomplete.