Joining of Composite Materials
The purpose of the joint is to transfer loads from one member to another, or to create relative motion between two members. In any structure, a joint is the weaker area and most failures emanate from joints.
There are two types of joints used in the fabrication of composite products:
• Adhesive bonding
• Mechanical joints
Adhesive bonding is the more common type of joint used in composites manufacturing.

Basic Science of Adhesive Bonding
There is no single theory that explains the complete phenomena of adhesion. Some theories are more applicable for one type of application than others.

Adsorption Theory
According to this theory, adhesion results from molecular contact between two materials and the surface forces that develop between these materials. The surface forces are usually designated as secondary or Van der Waals forces. To develop forces of molecular attraction, there should be intimate contact between the adhesive and the substrate surfaces.

The process of developing intimate contact between the adhesive and substrate material is known as wetting. Figure 1, illustrates good and poor wetting. For an adhesive to wet a solid surface, the adhesive should have a lower surface tension than the solid’s critical surface tension. Metals usually have high critical surface tension and organic surfaces usually have a lower critical surface tension. For example, epoxy has a critical surface tension of 47 dyn/cm and aluminum has a critical surface tension of about 500 dyn/cm. For this reason, epoxy wets a clean aluminum surface very well. Epoxy has poor wetting with polycarbonate, polystyrene, polyimide, polyethylene, and
silicone surfaces because these substrates have critical surface tensions of 46, 33, 40, 31, and 24 dyn/cm, respectively, which are lower than epoxy’s critical surface tension.

**FIGURE 1**, Demonstration of (a) poor wetting and (b) good wetting.

**Mechanical Theory**
According to this theory, bond formation is primarily due to the interlocking of adhesive and substrate surfaces. The true surface of the substrate material is never a flat, smooth surface; instead, it contains a maze of peaks and valleys.

During the wetting process, adhesive flows into microcavities of substrate surfaces and fills them. Application of pressure during the bonding process
aids in penetrating the cavities and displacing the entrapped air from the interfaces.

During the bonding of composites or metals, sandblasting or surface roughening is performed on joining surfaces to increase joint strength. Surface roughening provides benefits such as removal of oily surface, formation of a more reactive surface, increased mechanical locking, and formation of larger surface area. The larger surface area increases the bond strength by increasing intermolecular forces (adsorption theory).

**Electrostatic and Diffusion Theories**

This theory is not as well regarded as the above two theories (adsorption and mechanical) on adhesion. According to this theory, electrostatic forces in the form of an electrical double layer are formed at the adhesive/substrate interface. These forces create resistance against separation. According to the diffusion theory, adhesion occurs due to the inter-diffusion of molecules on the adhesive and substrate surfaces. This theory is more applicable for the cases in which both the substrate and the adhesive material are polymer based. The key to diffusion processes is that the substrate and adhesive materials should be chemically compatible.