**Joining Composites**

Mechanical fasteners, adhesives, or both are used to join composites. The joining technique used on a particular composite depends on the application and the material composition. For instance, composites used in aircraft are usually joined by a combination of mechanical fasteners and adhesives, whereas those used in automobiles are often joined only with adhesives.

Theoretically, all composites could be adhesively bonded. However, many manufacturers avoid adhesive bonds where joints undergo large amounts of stress; thus, fasteners are still specified for many joints. Also, some structures and components are so large that they preclude the use of the special lay-up tooling and curing equipment needed for most adhesive applications, making fasteners cost-effective for such cases.

***Mechanical fasteners:*** Rivets, pins, two-piece bolts, and blind fasteners made of titanium, stainless steel, and aluminum are all used for composites. Several factors should be considered when specifying fasteners for composite materials:

* Differential expansion of the fastener in the composite.
* The effect of drilling on the structural integrity of the material, as well as delamination caused by fasteners under load.
* Water intrusion between the fastener and composite.
* Electrical continuity of the composite and arcing between fasteners.
* Possible galvanic corrosion at the composite joint.
* Weight of the fastening system.
* Fuel tightness of the fastening system, where applicable.

Aluminum and stainless-steel fasteners expand and contract when exposed to temperature extremes, as in aircraft applications. In carbon-fiber composites, contraction and expansion of such fasteners can cause changes in clamping load. Potential clamping changes should be determined before the fastening system is chosen so joint design can be modified accordingly.

Drilling and machining can damage composites. The number of defects, such as delamination, resin erosion, and fiber breakout allowed in any structure depends on the application. For instance, because joint failure in carbon-fiber composites is caused primarily by localized bearing stress rather than overall stress, delamination is a much more serious defect than fiber breakout in a carbon-fiber composite application.

Drilling techniques and the tools selected are determined by the resin, the fiber or fiber combinations in the resin, the way the fibers are configured, and the composite/metal composition of the structure.

Fasteners for composites should have large heads to distribute loads over a larger surface area. In this way, crushing of the composite is reduced. Fasteners should also fit closely to reduce the chances of fretting in the clearance hole. Interference fits may cause delamination of the composite. Special sleeved fasteners can limit the chances of damage in the clearance hole and still provide an interference fit. Fasteners can also be bonded in place with adhesives to reduce fretting.

When carbon-fiber composites are cut, fibers are exposed. These fibers can absorb water, which both weakens the material and adds weight to the structure. Sealants can prevent moisture absorption, but this both complicates the process and adds cost. It also defeats any effort made to maintain electrical continuity between the composite fibers and the fasteners. Sleeved fasteners can provide fits that reduce water absorption, as well as provide fuel tightness.

Additionally, carbon-fiber composites may corrode galvanically if aluminum fasteners are used, due to the chemical reaction of the aluminum with the carbon fibers. Coating the fasteners guards against corrosion but adds cost and time to assembly. Aluminum fasteners are often replaced by more expensive titanium and stainless steel when carbon-fiber composites are used.

***Adhesive bonding:*** Composite bonds with adhesives generally are not weakened by drilling or other machining. Adhesives have been used to assemble composite components, such as rotor blades and airplane wings, and are sometimes used to join structural components. Bond reliability of adhesive joints is sometimes questioned, however, and fasteners may be specified as reinforcements for many composite applications.

Three adhesives are often used to bond composites: epoxies, acrylics, and urethanes. Epoxies are especially reliable when used with epoxy-based composites because they have similar flow characteristics.

Careful preparation of adherend surfaces is essential to making a quality adhesive bond, but it varies depending on the adherend and adhesive used. Recommended preparation of many composite adherends consists of a solvent wipe, to remove loose surface dirt and oil, and an abrading operation. Abrasion should be done carefully to avoid damaging composite surface fibers.

In some cases, primer is required to coat the composite before applying the adhesive. When bonding composites to metals, the metal substrate can be prepared by blasting with sand, grit, or metal oxides; abrading with a wire brush; and machining or scoring with cutting tools. Metal surfaces can also be prepared chemically. To protect freshly prepared metal surfaces from corrosion and contamination, adhesive should be applied as soon as possible.