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TRANSFER OF WOOD/FABRIC STRUCTURES CONCEPTS TO COMPOSITE STRUCTURES PROCESSES

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Instructors in the Federal Aviation Administration aircraft maintenance technology field have routinely taught some form of non-metallic structures, comprising wood and dope-covered fabric technologies for many years. Recently, a definite shift of emphasis has occurred in this curriculum from the use of traditional materials to the use of modern composite materials. The purpose of this article is to provide basic crossover information from the familiar concepts and techniques used with wood/fabric structures to the similar techniques used with composites and to introduce its unique vocabulary.

EASY TRANSFER

Because the composites industry is relatively young, materials and practices are in a continual state of change. Engineers, limited only by their imaginations, are free to design custom combinations that appropriate specific desired properties of individual materials. Despite constant changes, techniques for fabrication and repair of composite structures still transfer easily from wood/fabric fabrication and repair processes.

GENERAL DEFINITIONS

A composite consists of two or more substances joined on a macroscopic, as opposed to a microscopic, level; that is, it is visible to the naked eye. These combined substances perform a function that none of the single elements perform alone. A peanut butter and jelly sandwich is a simple example of a composite that everyone can understand. The peanut butter provides a salty flavor, the jelly provides a sweet, fruity flavor, and the bread provides its own flavor while stabilizing the combination. The blended flavors are presented in a convenient form and perform a function not performed by any individual ingredient. The whole tastes better, and is easier to eat, than the sum of its parts.

The basic categories of composites are particulate, laminate, and fibrous. Particulate composites consist of particles of one material suspended in another material; for example, crushed rocks and sand suspended in portland cement to make concrete. Laminate composites consist of layers of various materials, such as the layers of glass and film in safety glass. Most modern composites used in aircraft are fibrous and use extremely strong fibers, such as boron or carbon. Fibrous composites are produced by embedding such fibers in a fluid matrix material. The hardened matrix serves to stabilize the reinforcing fibers and to transfer stresses to them. This is the same function dope performs on aircraft fabric. The dope saturates and encases the cloth fibers and transfers flight stresses to the fabric while maintaining the basic shape.

Terminology from aircraft plastics technology also transfers directly to composite matrices. Thermoplastics are formed by long molecular chains that can be reheated and remolded. In contrast, thermoset plastics cannot be remolded because they consist of cross-linked molecular chains that form a superior but unalterable bond. Epoxy is one such cross-linked polymer. Techniques used to drill and secure plastics apply directly to composites; for example, wide bearing surfaces and special drilling practices to eliminate shattering.

DIRECTIONAL STRENGTH

Homogenous composites, such as concrete, exhibit strength in all directions, similar to metals, and are considered to be isotropic. Most composites, though, are anisotropic and are designed to have strength in only one direction. Wood, a natural composite material, is also considered anisotropic because it has greater strength perpendicular to the grain boundaries. Wood aircraft structures are oriented in such a way as to take advantage of this strength and to avoid grain-boundary weaknesses.

Composite structures use the attributes of unidirectional strength to save weight and material. This characteristic allows designers to develop custom applications that use the least possible material to produce the most efficient strength-to-weight ratio. There is no need to waste material and add extra weight in unnecessary directions.

REPAIR TECHNIQUES

Unidirectional strength does present unique problems. Improper loading, rough ground handling, and poor landings, for example, put unplanned loads on structures and result in damage. Even the manufacturing process can produce defects that require repairs. Techniques analogous to those used in wood/fabric repairs are applicable. Most repairs in composite materials will be either bolt-on, scarfed, steplayered, or injection.

BOLT-ON REPAIRS

Bolt-on repairs are used extensively by the airline industry because they are simple and allow fast turn-around time. After the extent of the damage is ascertained, a patch is bolted over the damaged area using a pattern prescribed by the manufacturer. This method is usually considered temporary.

SCARFED AND STEPLAYERED REPAIRS

Scarfed and steplayered repairs depend on the use of long glue lines, just as do wood splices. Instead of using the 10-to-1 ratio slopes used in wood repairs, composite splices use slopes ranging from 30-to-1 to 100-to-1. The orientation of fibers so that they are perpendicular to the direction of the shear load is a requirement in composite fabrication and repairs and relates directly to similar orientation of the grain boundaries in wood repairs. It is critical that every layer of fibers in composite repairs be oriented exactly as the fiber it is replacing. The steplayered repair is similar to the scarfed repair, but it consists of distinct layers with perpendicular edges rather than beveled layers in a smooth slope. Scarfed and steplayered repairs are preferred and are the most frequently used permanent repairs.

INJECTION REPAIRS

Injection repairs have less parallel to wood/fabric repair processes. Small holes on the surface of wood structures can be repaired by filling with putty but this is as far as the parallel extends. A familiar test method can be borrowed, though, from honeycomb practices. Because of the way laminate composites are manufactured, voids may develop that cause delaminations (also called disbonds). The tap-test, either manual or ultrasonic, is used to locate these voids.

Voids can be repaired by two injection methods. Both begin by drilling holes at each end of the damage. The first uses a syringe to exert pressure on the filler material, forcing resin into the void until full. The second uses a vacuum to draw resin from a reservoir into the affected area. The aircraft manufacturer determines the limitations on the location and size of the damage on which such repairs can be used.

JOINING AND CURING

Bonding of composite materials involves the same considerations as bonding of wood joints. Wood bonds are performed by a series of steps -- open assembly, closed assembly, and pressure -- because glues do not dry, they cure, producing gases and possible voids. To prevent the trapping of gases, wood surfaces are first coated with the bonding agent, and allowed to begin to cure. Next, the surfaces are mated. In this condition the gases can still escape through the edges of the assembly. Finally, pressure is applied to expel almost all remaining gases, ensuring the strongest possible bond.

Composites cure in a corresponding manner, producing unwanted gases during the chemical processes that form the new molecular bonds. These gases will produce porosity or voids in the finished product. To remedy this situation, excess resin is applied during the lay-up assembly. During curing, as off-gassing occurs, bubbles rise through the excess resin and into an absorbent bleeder cloth that draws them away from the assembly. Most room-temperature cures assist this process by pulling a vacuum.

RAMPING

Many industrial composites must be taken to elevated temperatures to cure properly. In a method called ramping, temperatures are slowly and gradually raised and periods of vacuum and/or pressure are applied to expel gases. The unit is then gradually cooled.

CONCLUSION

Many of the basic concepts and practices used in the fabrication and repair of wood/fabric/doped aircraft structures can be adapted to that of composite aircraft structures. The most noticeable difference is in the terminology used to describe them. The study of composites can be combined fortuitously with the study of wood/fabric practices to form a curriculum in which the principles of each division build on and reinforce those of the other.□

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