



AEROSPACE INFORMATION REPORT

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Machining of Composite Materials, Components and Structures

RATIONALE

Currently there is no standard document for machining composite materials. This document provides guidance for these operations.

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides information related to machining of composite materials, components and structures. This document is intended to supplement the machining processes and guidelines provided in OEM repair manuals and structural repair manuals. It is not intended to supersede the approved data provided in OEM repair documents.

1.1 Purpose

This AIR provides background information intended to promote a basic understanding of standard machining methods that may be referenced in repair documents produced by airlines, airframe manufacturers and engine manufacturers. This AIR is one of a number of AIRs and Aerospace Recommended Practices (ARPs) that cover various aspects of composite repair techniques.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.2 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AIR4844	Composites and Metal Bonding Glossary
ARP4916	Masking and Cleaning of Epoxy and Polyester Matrix Thermosetting Composite Materials
ARP4977	Drying of Thermosetting Composite Materials
ARP4991	Core Restoration of Thermosetting Composite Components
ARP5256	Mixing Resins, Adhesives and Potting Compounds
ARP5319	Impregnation of Dry Fabric and Ply Lay-Up
AIR5431	Repair Tooling

2.3 Other References

Original Equipment Manufacturers (OEM) structural repair manuals, standard practices manuals, overhaul manuals, component maintenance manuals, airplane maintenance manuals and other approved repair documents.

3. GENERAL

This document provides information for machining of fiber reinforced epoxy airplane structural components during repair. Techniques and required equipment are covered.

The basic repair-related machining steps include:

- a. Paint finish removal
- b. Sanding

- c. Drilling and countersinking
- d. Trimming
- e. Damage removal
- f. Machining of honeycomb core
- g. Post-machining sealing

Use of proper machining techniques and equipment during repair of composite structures is critical for ensuring that the completed repair has the required structural capability and durability. If these operations are not performed correctly, the repair may not be structurally acceptable.

Typical composite panel fiber reinforcements are: carbon, aramid (e.g., Kevlar®), and glass (commonly referred to as fiberglass). The machining techniques for these typical composite materials are similar, but minor differences exist, such as the style of cutting tool or drill bit.

Machining of composites differs from machining of typical metals. High-speed steel drill bits and other cutting tools are normally used to machine aluminum and mild steel alloys. However, composite materials are abrasive and can cause higher drill and cutter wear than is experienced in machining of metals. Therefore, the required bits and cutting tools for machining of composites are different than those typically used for machining of metals. Further, it is important to change drill bits and cutters before they become dull. Using worn drill bits and cutters is a common cause of damage when drilling and machining composites. The cost of changing a drill bit or cutter is small compared to the cost of re-work that may be required due to a damaged hole or other machined surface.

Components containing carbon fibers are machined similar to those containing glass fibers except that carbide or diamond abrasive coated cutting tools are preferred for components containing carbon. Carbide tipped and diamond abrasive coated tools stay sharp through many cutting operations.

Components containing aramid fibers (including hybrid panels contain aramid and carbon fibers) are difficult to machine using conventional drill bits and cutting tools. Use of conventional tools can produce a fuzzy appearance on the machined surface. This results from what is essentially a tearing of the fiber as it is machined. Specialized cutting tools will reduce or eliminate fiber fuzzing, fiber breakout and interply delamination. These special tools are designed to grab the fibers and stretch them prior to cutting. When drilling or machining hybrid panels that contain aramid and carbon fiber, an aramid fiber cutter is to be used. However, the tool life should be monitored closely because the carbon fibers will dull the cutter quickly. The typical cutters that are preferred for machining carbon fiber materials are not effective for preventing fuzzing in aramid components.

Additional factors that affect a composite laminate at the edge of the cut are feed rate and tool rotation speed, especially during final drilling and cutting operations. Maximizing cutting tool life is also dependent upon choosing the appropriate feed rate and tool rotation for the material being machined.

Since the quality of the cut degrades as the tool wears the finish characteristics of each hole or cut should be continuously monitored during machining. Cutting tools should be changed before an unacceptable cut surface is produced. For hand held operations the number of cuts or holes that can be made before changing the tool can vary significantly. Using carbide and diamond abrasive tools to machine carbon and glass fiber materials significantly improves the number of cuts or holes that can be produced before the cutter needs to be changed. The epoxy resin component of the composite laminate has a low thermal conductivity and using worn cutters or too high of a feed rate can result in localized overheating or burning that can damage the laminate. Worn cutters can also result in backside fiber breakout and delamination.

The OEM repair manuals contain guidelines for tool type, material feed rates, lubricant use and tool rotation speeds that are known to produce satisfactory results for specific applications.

To prevent damage, it is recommended to practice unfamiliar machining procedures on scrap pieces of composite material before using them on the component being repaired. This can prevent having to perform unnecessary repairs caused by improper machining techniques.

WARNING: During machining operations personal protective equipment including eye protection should be worn by all personnel in the immediate area to prevent breathing dust created during the machining process. Health and safety procedures should be followed at all times.

CAUTION: Carbon dust can become electrically conductive. All electrical equipment and connectors in the local area should be covered to prevent carbon dust from settling in those areas. Both carbon and fiberglass dust are highly abrasive. Care should be taken to keep dust from settling on mechanisms, actuators or other moving parts.

CAUTION: Many paint materials are epoxy based and are similar in composition to the epoxy resins that make up the component surface or laminate. During paint removal operations, use extreme care to remove only the paint, and not damage the underlying laminate. In some instances, high performance finishing materials may be tougher to sand than the underlying surface of the component. Use extreme care to avoid exposing the fibers in the component surface. If the fibers are damaged, it may be necessary to expand the size of the repair as a result of fiber damage created during paint removal.

CAUTION: Chemical paint strippers can damage the resin matrix of the composite material. Exposure to chemical strippers that soften epoxy paints can cause similar damage to the epoxy resin in the composite component. Chemical stripping materials should NOT be applied to composite components except where OEM approval and processes are provided.

4. PAINT FINISH REMOVAL

Sanding procedures used to remove paint and prepare the surfaces of composite materials for bonding are common between the different fiber reinforcements. Paint removal consists of removing any exterior paint or other materials from the surface where a bonded composite repair will be installed.

Clean the area where the paint will be removed in accordance with the repair document or ARP4916, Composite Cleaning Method 4 or 5.

Apply masking or protective tape around the area to protect the existing paint that will not be removed. Refer to the repair document to determine the size of the area to be sanded, which will be based on damage size, required number of repair plies, ply overlap width, etc. Also refer to the repair document or ARP4916, Masking Method 5 for masking procedures using a protective tape. Place the tape around the perimeter of the area where the paint will be removed to protect the surrounding finish. It is important to remove enough paint to ensure all repair materials are placed directly on the abraded composite material. Overlapping the repair materials onto incompletely removed exterior finishes and paints will produce a structurally unsatisfactory repair.

An example of protective masking detailing the areas requiring paint removal and taper sanding is provided in Figure 1.

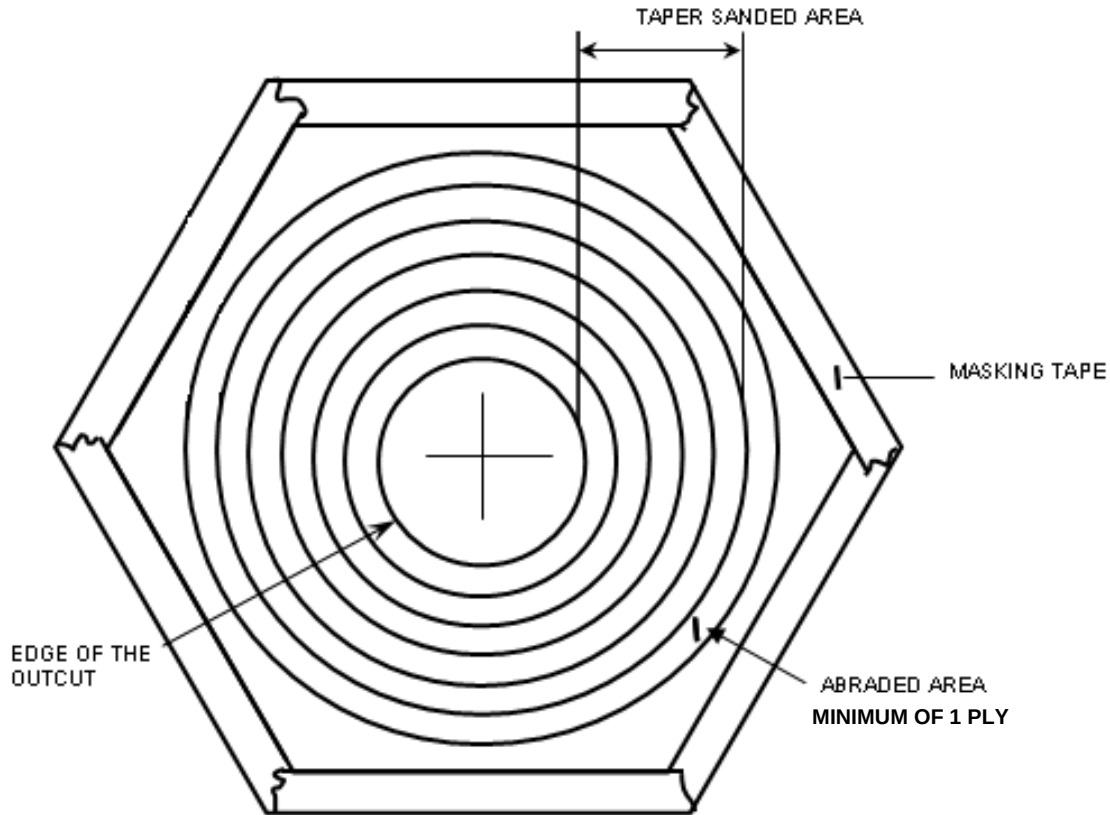


FIGURE 1 - MASKING FOR SANDING OPERATIONS

Using an air powered sander, or equivalent, remove the paint in the masked off area using the OEM specified procedure. If no procedure is specified by the OEM, a medium or fine abrasive pad or paper is typically used. An abrasive pad is preferred when removing exterior finishes as there is less risk for fiber damage using an abrasive pad.

Paint removal operations are intended to remove all topcoat paint, primer and surfacing materials from areas where adhesive bonds will be located.

Ease of finish removal is affected by the overall smoothness of the component surface. A composite component normally has two different types of surfaces that are referred to as the tool side and bag side surfaces. The tool side surface is generally smoother than the bag side because it was cured against a smooth tool surface during initial fabrication. The bag side surface typically follows the contour of the weave pattern of the ply materials since the flexible bag and bagging materials conform to the contours of the ply surface during curing. When using abrasive pads, it is recommended to NOT remove all the finish from the low areas of the bag side surface to keep from damaging the fibers in the high spots of the laminate. Therefore, removal of paint on tool side surfaces is generally easier than on bag side surfaces.

Abrasive media stripping is effective at removing finishes from both tool side and bag side surfaces and can quickly strip large areas. Wheat starch particles and carbon dioxide pellets are examples of media that are approved for use in some OEM abrasive blasting procedures. Care is required when using abrasive stripping materials to prevent fiber or resin damage.

MA4872 can be used as a resource for evaluating abrasive stripping media and other processes. Consult the OEM for guidance when evaluating and selecting alternate paint stripping processes and materials.

5. SANDING

5.1 Ply Sanding

The surface of composite materials must be sanded in preparation for installation of the repair patch. Depending on the style of the repair patch, the surface will either be taper sanded, step sanded, or simply abraded to accept a "overlay" style patch. Generally, repairs in thicker laminates, repairs on aerodynamic surfaces, and repairs that are intended to restore structural load carrying capability are taper sanded or step sanded. Non-scarf patch, or overlay repairs, that do not require step or taper sanding are typically used for thinner laminates, repairs on bag side surfaces, and for smaller repairs that are not intended to restore the original strength of the panel.

In taper and step sanded repairs, the purpose of the taper or step is to allow each individual repair ply to overlap the original skin ply it replaces. The majority of taper and step sanded repairs use hand-held sanding equipment. These operations require high skill and craftsmanship on the part of the repair technician to produce a structurally satisfactory repair. Figure 2 depicts the typical configuration used for taper sanding. Figure 3 depicts the typical configuration used for step sanding.

Some repair documents may contain information for automatic and/or semi-automatic equipment used to machine stepped or tapered contours. Consult the OEM repair manual for procedures and associated component surface contour restrictions related to automated machining equipment. Some OEMs may recommend the use of automated machining depending on the type structure and the type of repair performed.

Use the OEM specified procedure if available for taper or step sanding. If a procedure is not specified, machine the required step or taper contour into the surface of the component using 80 grit or finer abrasive paper. Final surface preparation should use 150 grit or finer abrasive paper. Mark and mask the outline of the area to be sanded on the component first. Use tape, colored pencils, felt tip markers that are approved for contact to the component surface. Using non-approved materials may damage or contaminate the component surface and result in a below strength repair.

When sanding through the thickness in a solid laminate area, a backside backup plate is recommended. The backup plate prevents damage or fraying at the thin edge. The plate can be made of any material with enough stiffness to support the edge of the material. Use double sided tape to attach the plate.

5.2 Taper Sanding

The procedure for creating a machined taper is to generally start at the center of the location of the damage and remove the damage through the thickness first. The sanding operation is then extended outward ply by ply until the final repair size is obtained.

Sanding through the thickness is required only if the damage extends through the entire thickness of the skin or laminate. Sand the edge of the damage cleanup hole to an edge that is approximately 0.2 mm (0.010 inch) thick or the approximate thickness of the bottom ply. For sandwich components the taper should be a knife edge at the top of the core.

Continue to sand the taper area, working from the edge of the damage hole (or the center of the repair area) to the outline of the taper that was marked on the component. When completed, the tapered area should be free of delaminations and have a smooth contour with the slope required by the repair document. See Figure 2 for details of a typical taper sanding configuration.

After sanding is completed, remove all remaining dust with a vacuum or equivalent method.

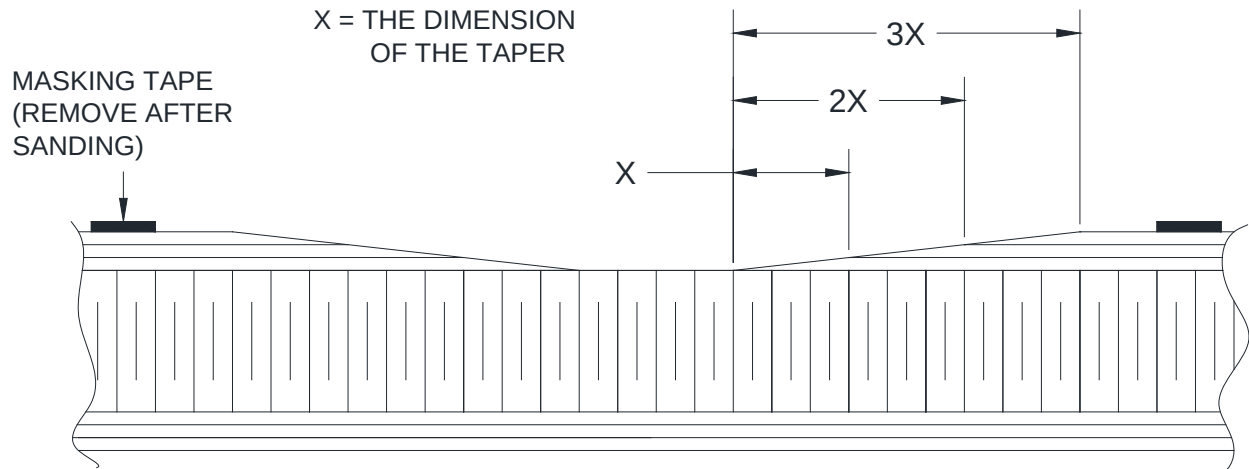


FIGURE 2 - TYPICAL TAPER SANDING - TAPER WILL DIFFER DEPENDING ON PLY LAYUP

5.3 Step Sanding

The procedure for creating a machined step is to generally start at the outer edge of the final repair size and remove the damage ply-by-ply. The sanding operation is then extended inward for each step until all the damage is removed.

Determine the number and width of steps to be machined into the component. This is normally the number of plies to be replaced minus one. The location of each step may also be marked on the component surface.

The damage may be removed by machining a clean-up hole perpendicular to the surface of the component. Machining through the thickness is only required if the damage extends through the entire thickness of the skin or laminate.

Sand the steps into the skin. Begin the steps at the outer perimeter of the repair area and continue down into the center of the outline that was marked on the component. When completed, the stepped area should be free of delaminations and have a series of level, evenly spaced steps. When making steps, it is important to remove only the material in the ply being removed. Removing material from the underlying ply will affect strength properties of the repair. See Figure 3 for details of a typical step sanding configuration.

After sanding is completed, remove the remaining dust with a vacuum or equivalent method.