TCO(Terminal Course Objective) B

Understand the basics of composite materials maintenance and repair

Introduction

Some critical elements of good maintenance

1. A very critical element of good maintenance is good inspection. If a problem is not found it is certain that it will not be dealt with. Careful inspection is essential.

2. Good lighting and comfortable working conditions are needed. This means good lighting and a temperature of 20-25^{o}C (68-77^{o}F) and less than 50% relative humidity.

1. Good access to any component is essential to good inspection. This is really a design issue.

4. Training is very important. We learn, but we also forget if an action is not performed frequently. Refresher courses are useful to preserve and update knowledge.

B1: List the basic steps in maintenance procedures from damage detection through repair completion.

1. **Damage Assessment:** Inspect the damage that has been reported. This must be done carefully and may require careful cleaning of the part before a detailed inspection can be made. If the damage has been found at an outstation and is within the limits of "allowable damage" then the part should be cleaned and dried before being covered with Speedtape. If a small puncture exists in a honeycomb panel it should first be dried to SRM requirements and then filled with potting compound and taped over. In this case the objective is to prevent the damage getting any worse and it must be scheduled for permanent repair within the time limits given in the source documentation (i.e.SRM). In any case it should be repaired as soon as possible. If the damage requires repair before the next flight then the part must either be replaced, while the original part is removed for repair, or the original part must be repaired per the instructions in the SRM before next flight. Please note that "allowable damage" means only that the aircraft may return to service before a permanent repair is required. It does not mean that no repair is eventually required. If the damage is outside all the SRM limits then the OEM should be consulted to see if they can offer a specific repair to the part concerned. If not the part must be removed and dispositioned for re-build by the OEM or a qualified MRO, or be scrapped. In the event that the damaged part is not removable (e.g. a wing skin) , the aircraft is grounded and an AOG team is sent out to effect a permanent repair. Typically the AOG team is sent out from the OEM.

2. If a repair before next flight must be made then the part must be first be inspected visually and then inspected using an NDI technique. If the damaged part is a honeycomb panel a coin tap test may be used to map the damage. If the damage is to a solid laminate area of a sandwich panel (e.g. the edge band) or a stiffened laminate part the coin tap test will only detect disbond in the first few layers and an ultrasonic method will be required. If any doubt exists then the NDI (Non-Destructive Inspection) team must be called in to establish the boundary of the damage.

Repair Options:

The SRM must be consulted for permitted sizes of repairable damage. The size of repair that is allowed depends on the type of repair to be done (i.e. repairs using room temperature curing adhesives or resins are usually small in size). If a warm 65-93^{o}C (150-200^{o}F) curing adhesive or resin is used the permitted repair size becomes larger.If repairs are made at the original cure temperature then large repairs and sometimes unlimited size repairs are allowed. See the SRM for each part. A problem is that hot-cured repairs may require tooling to maintain the shape of the part. This tooling may not be available. Repairs at the original cure temperature also require pressures higher than a vacuum bag can give and so an autoclave or press may be needed. If a large repair is necessary, the part may be sent away to an approved repair station that has the equipment required. If the damage is to a stiffened laminate part, careful trimming of the skin will be needed to avoid damaging substructure (e.g. a stringer or rib). Special fasteners and drilling equipment may also be needed. Damage to Principal and Primary structure will usually involve consultation with the OEM.

The SRM or the part drawing, available on microfilm in some larger airlines, is needed to give the exact lay-up details, the type of fiber used and the weight of the fabric and the orientation of each fabric layer. They will also give the type of honeycomb, if used, and the SRM will list the resins and adhesives that may be used for the part in question. Repair is, in this sense, more difficult than manufacture because we first have to find the materials from which the part was made in order to use the right ones for repair. The correct part and revision number must be ascertained to make sure of the required repair materials and layups. It is essential to select the correct fiber type and weight of fabric or tape with the right surface finish in order to make a strong, durable repair. It is very easy to use a fabric of the wrong weight and great care must be taken to ensure that this does not happen. When fabric, pre-preg or film adhesive is cut from a roll a label with full identification details must be attached, or included in the plastic bag used to keep the material clean. This information must give, for dry cloths, surface finish details and fabric type and weight. For pre-pregs the type and weight is needed and for film adhesive the type and weight as various weights are available. A further point that should be noted is that some composite layups may use fabrics of different weights and types in the layup, e.g. aramid is sometimes used with carbon or glass layups to add toughness. This means that all the plies in a layup may not be of the same materials or the same weights so careful identification is necessary and correct location and orientation of each ply within the layup is important. The transverse strength of a composite is low compared to the fiber direction so every effort must be made to ensure a good bond. When preparing the repair surface it is important to ensure that it is clean, that it has been dried to SRM requirements and that the repair fabric has the finish required. This is why clean, dry composite surfaces , which have been carefully abraded with aluminium oxide or silicon carbide abrasive paper need to be used. Only the surface resin layer should be abraded without damaging the first layer of fiber. Use the grit size recommended in the SRM Note that for repair work the first ply should be oriented in the same direction as the ply to which it is to be bonded.

Repair Materials:

The next, and often difficult question is, "Are the required materials in stock?" If not the manufacturer may have to be contacted for alternatives.
If the materials are in stock it is then necessary to check that they are within their permitted shelf life and not already "time-expired".
If all the materials are within their shelf life limits the materials can be ordered and the work can be planned.

Damage removal:

The damage must be cut away completely and if more damage is found then the repair must be re-assessed for permitted size and repair method.

Paint and surface protection systems removal:

The original paint and primer, and any other surface protection system such as lightning protection aluminium flame spray must be removed very carefully so as to avoid damaging the first layer of fiber. For repairs, careful sanding is probably the best method.

Core damage removal:

Assuming that a honeycomb panel is being repaired then the damaged honeycomb core must be removed and the bottom skin sanded lightly.

Core replacement:

Depending on the type of repair a two-part paste adhesive may be applied to the bottom skin or a layer of film adhesive put in place. It is wise to use a fairly heavy layer of film adhesive to bond honeycomb core. The new piece of honeycomb must then be cut to size so that the ribbon direction of the honeycomb matches that of the original and adhesive must be spread on the bottom cells, if a paste is used. The edges of the core must either be joined with an approved potting compound or a layer of foaming film adhesive must be placed around the edge if a hot cure is to be performed.

3. A problem here is that heat and pressure will need to be applied to both the bottom skin and the top skin if the honeycomb on the bottom skin is to be cured at the right temperature and at the same time as the top skin. It also requires that the honeycomb is exactly flush with the top skin. For this reason it is often better to cure the honeycomb to bottom skin joint and the edge potting compound in one operation and then to sand the core flush with the top skin and bond the new top skin as a second operation. It can be seen that room temperature repairs are much easier than hot-cured repairs because the honeycomb can be potted in place without any pressure and left to cure while the top skin plies are cut to shape. Often RT (Room Temperature) repairs can be made without any tooling, which is a further advantage. However, the SRM usually permits only small repairs of this type. Always check the SRM for limits.

Preparation for final cure:

Before final room temperature or hot-curing starts the repair area for the skin patch and the honeycomb core and the new honeycomb insert must be dried to SRM requirements. If the skins are carbon fiber, or in the case of glass or aramid skins a moisture meter can be used to check if drying is required. Next, and ideally within one hour of drying, the top skin layers must be put in place, after the honeycomb has been sanded down flush with the skin. An extra layer of film adhesive over the honeycomb area is helpful to a good bond if a hot cure is used. The top skin layers must be of the correct fabric with each ply laid in the correct sequence and aligned in the SRM specified directions. The overlaps at the edges of the damaged area must be those given in the SRM. When bonding composites or metal repairs at the original cure temperature additional pressure above vacuum must be provided or the skins around the repair area will be blown apart due to steam pressure in the cells if any moisture is present. See Chapter 10 of Ref: 1. The limitations of vacuum pressure need to be understood, although it is a very useful and convenient method of pressure application. Tooling must be used if needed to maintain the part profile. See Figs 10.19 to 10.28B from Ref: 1.

Repair processing:

Apply a vacuum bag to the repair whether it is to use vacuum only or autoclave pressure. A vacuum bag is also used with an autoclave to ensure that the autoclave pressure will be used to hold the plies together. If the higher autoclave pressure can leak into the vacuum bag then it will be between the plies as well as around them and the actual pressure to clamp the parts together will be zero. The lay-up of the vacuum bag and all the release films, both perforated and non-perforated in their correct positions is given in the SRM and in Chapter 10 of Reference 1. If hot curing is used then thermocouples must also be located as required by the SRM. The specified temperature and vacuum or autoclave pressure must be maintained throughout the cure cycle and the pressure must be maintained until the temperature has fallen below 50^{o}C (122^{o}F).

Post-repair vacuum bag removal:

Care must be taken when removing the vacuum bag and release films to ensure that no damage is done to the repair area or the rest of the part.

Post-repair inspection:

Visual and non-destructive inspections should be carried out at this stage to confirm that there are no disbonded areas in the repair. The in-process quality control records (e.g. strip charts printed from the hot-bonder or autoclave) must be inspected to make sure that the correct vacuum, autoclave pressure (if used) and temperature were used for the specified period of time.

Restoration of protection coatings:

If the repair is considered satisfactory, any protective coatings need to be restored i.e. erosion resistant coatings, or lightning protection systems, this must be done before painting. Lightning protection systems must be tested and must meet the SRM electrical conductivity requirements.

Paint restoration:

Finally the part should be painted in accordance with the company logo using materials approved in the SRM. Some paints, e.g polyurethanes, require special masks and safety precautions when being sprayed.

B2 List key composite and expendable materials needed for simple laminate structure repair including appropriate storage requirements.

Composite materials

1. **Dry (Unimpregnated Fabric):** Carbon, glass and aramid fibers need to be stored in clean, dry conditions at room temperature and aramids need to be stored in black plastic bags out of contact with sunlight to avoid degradation by Ultra violet radiation . Aramids absorb moisture into the fibers therefore, dry storage is important. Fabrics and tapes made from these materials need to be those specified in the SRM.

2. **Pre-preg materials and film adhesives** need to be kept in a freezer at -18^{o}C. Shelf life and open time must be recorded.

3. **Foaming adhesives:** must also be kept in a freezer at -18^{o}C and their shelf lives and open times must be recorded.

4. Pre-pregs, film adhesives and foaming adhesives must be re-tested at the expiration of their shelf lives and open times or be scrapped. This is because

time-expired materials may be partially cured and may not melt and flow well enough during the repair cure cycle to achieve good bonds.

5. **Honeycomb materials:** must be kept in their plastic bags and boxes to avoid damage and must be returned to them after their required amounts have been cut. Aramid honeycombs should be dried before use as these materials absorb moisture from the atmosphere. Drying should be conducted per the SRM and 8110 documentation. They should then be used within one hour of drying to ensure strong, durable bonds.

6. Warming of pre-pregs, film adhesives and cans before use:

It is very important to note that all pre-pregs and adhesives stored in a freezer MUST be warmed to room temperature before removal from their bags or cans. All these containers must be allowed to warm at room temperature until no condensation can be seen on the bags or cans. This is to prevent moisture absorption into the resin which often affects the curing process and lowers the resin mechanical properties .

7. **Two-part paste adhesives, resins and potting compounds:** must be stored in accordance with their data sheets and their shelf lives must also be recorded. When the tins of these materials are opened their lids must be replaced as soon as the required amount has been taken. This is essential to avoid moisture absorption from the atmosphere which degrades these materials.

Expendable materials

There is quite a range of expendable materials that may be used. All the plastic film materials need to be kept clean and dry. The following is a list of these expendable materials

1. **Vacuum bagging films**.
2. **Vacuum bag sealant tapes.** The price of these depends on the maximum usage temperature so cheaper types can be used at lower temperatures.
3. **Release films.** These may be perforated or non-perforated. The perforated types are used when surplus resin needs to be bled from a lay-up. The size and number of perforations is important as too much resin may be lost and the composite surface can become resin-starved if the perforations are too large or too numerous. The choice of perforation size and density can only be found by experience for a given resin system.
4. **Peel plies.** These are fabrics made from non-stick plastic materials that have no chemical release agents on them. This is vital because their purpose is to provide a rough and uncontaminated surface when two composite parts need to be joined by adhesive bonding. The use of peel ply, usually for large areas, is to avoid the need to abrade large areas of composite prior to bonding.
5. **Release fabrics** are very similar in appearance to peel plies and MUST NOT be confused with them. Release fabrics do have a chemical release agent on the

surface to ensure that a part will release from the mold. If this surface later needs to be painted then the chemical release agent must be removed before painting is attempted.

6. **Breather cloths** are used over the lay-up and inside the vacuum bag to allow easy air extraction when the vacuum pump is switched on. They provide an essential pathway for the air to escape and so allow atmospheric pressure to be applied to hold the parts together. Coarse weave breather cloths of glass fabric coated with PTFE may be used and can often be re-used. These cannot be used as bleeder cloths.
7. **Bleeder cloths** are made from the same material as breather cloth and are used on top of the perforated release film to absorb the surplus resin that flows through the perforations.
8. **Liquid mold release agents** may be used when the affected surface does not need to be bonded afterwards. Mold release materials must be applied outside the workshop so that parts cannot be contaminated and only returned to the workshop when they have dried on the mold surface.
9. **Sealant materials** i.e. thiokol sealants, polythioether sealants and silicone sealants must also be stored at the temperatures specified on their data sheets. They also have limited storage lives. Silicones should be stored separately from other sealants.

B3 List the necessary tooling and equipment to accomplish a simple laminate structural repair.

Tooling or profile jigs

The repair of composite or bonded metal parts may require tooling, varying from no more than a flat bench for vacuum bonding flat panels, to extremely expensive tools approaching manufacturing standard, for very large repairs and or autoclave bonding for components having complex shapes. If both skins of a sandwich panel have to be repaired then some form of tooling will be needed to maintain the shape even when room temperature curing is used. If a repair has to be made at the original cure temperature, and the part is of any shape other than flat, then tooling capable of withstanding the cure temperature without distortion will need to be used. It can be said, from painful experience, that the design of tooling is not a simple matter.
See SAE AIR 5431 –Repair Tooling.

Several factors are important.

1. The temperature of cure must not cause distortion of the tool and ideally the tool should be made from a material having the same thermal expansion coefficient as the part. This is particularly important for profiled parts that need to be made to an accurate shape.
2. The tool should not be too heavy so as to make movement and general handling difficult.

3. The tool should have high thermal conductivity so that the tool and the part both warm up at the heating rate specified for the film adhesive or pre-preg if these are used. From experience I have known a case where a tool, or profile jig, made by an expert tooling firm, would not heat up at the required rate and had to be modified to do so.
4. The tool must be designed for surface bagging and not for envelope bagging (see Ref:1 Chapter 14) so that the tool itself is not under great stress during cure. In one case this was not done. A lower grade of aluminum alloy was used by the tooling firm than we expected. After a number of hot curing cycles the skin of the tool had begun to creep between the supports in an "egg crate" design and many extra supports had to be added. A company that can make the shape may not be experienced in the end use of the tooling they are making. Beware of this and supply drawings and a tight specification for materials to try to avoid this problem.

Some types of tools that can be made for small repairs

1. **Splash moldings** can be made from another part of the same part number by making a gypsum intermediate splash tool on the part. This tool can then be used to make a profile from low temperature curing pre-preg from Advanced Composites Group, Toolmaster or equivalent, This can then be used to make a patch that can be bonded to the part for repair. Alternatively, the original part can be used to make this if a layer of release film is laid over it, provided that the spare part can be made available for the length of time required to make the patch. This can sometimes be a problem and cause the splash method to be used.

2. Simple solid laminate tools can be made from a suitable number of fabric layers and epoxy resins to achieve the stiffness required.

3. **2-Part Fiberglass Tool**: Another simple tooling technique, if a stiff tool is required of light weight, is to make a sandwich panel of fiberglass or other fiber and a two-part room temperature curing epoxy resin and honeycomb core. A layer of release film must be taped to another part of the right shape and then a few fiberglass skins can be laid up, a honeycomb core added and few more layers of fiberglass. The assembly can then be vacuum bagged to the part and allowed to cure. This will provide a cheap tool for use with room temperature curing resin systems.

4. **Simple aluminum alloy tools** can sometimes be made by rolling a plate to the radius required for some parts. In this case envelope bagging works well.

5. Several companies make room temperature and low temperature curing pre-pregs from most fabrics and after the initial cure these can be step cured at intervals of about 20^{o}C up to 200^{o}C and they make very good and durable mold tools for repairs or manufacture.
6. The latest issue of the SAMPE Journal Vol: 41, July/August 2005 contains two new systems that may be worth investigating. SAMPE is the Society for the

Advancement of Material and Process Engineering and membership is helpful to keeping up-to-date in Composites and repair work. One new method is Carbon Foam Tooling. CFOAM has an open cell structure so this material requires a vacuum –tight tool face formed with a surface coating of CFOAM. The other is Water Soluble tooling Materials for Filament Winding and VARTM (Vacuum Assisted Resin transfer Molding). This method could easily make tooling using another part of the same shape as a temporary mold.

7. High Performance Composites Magazine, September 2004, pp24-29, describes a number of tooling options that could be used for repair. The problem is always "horses for courses" and it is up to each repairer to decide which tooling method is the quickest and cheapest for each repair that arises.

Another company has introduced a combination of fabrics and resins called "Toolfusion", for vacuum-assisted resin transfer molded (VARTM) tools. Toolfusion has been demonstrated as suitable for aerospace –grade parts, with service temperatures in the range >150^{o}C (300^{o}F). They do not require autoclave cure. Toolfusion 1A/1B is cured at room temperature, with a post-cure at 191^{o}C(375^{o}F).

A similar system is SP Resin Infusion Technology (SPRINT). SP interleaves pre-catalyzed resin film and dry carbon or glass fiber fabrics to create tooling SPRINT or T-SPRINT material. T-SPRINT allows entrapped air to escape more easily during compaction and cure, for exceptionally low void content. This technique was tried many years ago to repair cracks in wing leading edges and was very successful using a 180^{o}C curing film adhesive. T_SPRINT, however, can be cured at room temperature under a vacuum bag and has a relatively high service temperature of 160^{o}C(320^{o}F).

Another method is RENSHAPE high-temperature epoxy-based tooling paste.

A method that may be useful for the repair of small parts is a new low-cost, tooling system that employs ceramic microspheres in a proprietary binder that can be reversibly cycled again and again from a liquid-like state to a solid state at room temperature, with no change in volume. A tool can be created in minutes from a master model or an actual part. The system consists of a portable, vacuum tight, rectangular tool bed filled with a mixture of solid ceramic microspheres, inorganic binder and a small amount of water, all covered with a robust elastomeric membrane. A master model or a part can be placed against the membrane and covered with a vacuum bag or temporary vacuum cap, so that atmospheric pressure brings the liquid-like material, which has the consistency of wet sand, up against and around the master model. The excess water is drained out by pulling a vacuum on the tool bed, which allows the material to assume its solid state characteristics. To stabilise the tool shape the master model is removed and moderate heat applied, causing the inorganic binder to lock the microspheres together to form a ceramic-like tool. This material can function at temperatures up to 204^{o}C(400^{o}F). The hardening process can take from 30 minutes to several hours depending on the size of the model or part. The tool bed would have to be large to be used for anything other than relatively small aircraft parts but could have some applications.

These are a few mold tooling types that have been found to work well. There may be many others and more new methods can be expected as companies seek to meet repair needs.

Equipment

1. A flat workbench of comfortably adequate size is essential.
2. If the part is profiled and not flat then a mold or suitable tooling may be needed to maintain the part shape.
3. Hand tools will be needed such as pneumatic drills and diamond cutting discs.
4. Tank cutters are needed to cut corner radii.
5. Grinding burrs are required to smooth corners and blend them into straight cuts.
6. Stanley knives or large old hacksaw blades, ground to a sharp edge, are useful for cutting honeycomb down the cells.
7. A high speed bandsaw will be needed if sheets of expanded honeycomb need to be cut to thickness. The bandsaw requires special blades with a 0.05mm (0.002 inch) offset on the teeth to avoid tearing the honeycomb. These blades need to be sharp.
8. Sheets of abrasive paper of the required type and grit size must be readily available.
9. A can of acetone is required to be used with suitable tissue or rags to wipe off any surplus resin from the part and for cleaning tools.
10. Medium files are also useful for trimming edges.
11. A vacuum pump and gauge are needed with associated piping.
12. A moisture meter is useful to check when fiberglass and aramid parts are dry enough to be bonded. Carbon fiber parts have no economical moisture meter at present so must be dried to the SRM as a precaution.
13. Thermocouples may be required if a hot cure is needed. See Section A2, composite processing , para 8.
14. Heater blankets will be required for hot-curing. It should be noted that these need to be at least two inches (50mm) larger all round than the repair area to avoid cool spots at the edge of a repair that are below the required curing temperature.
15. A hot bonding console is required to control the heater blankets via the thermocouples that are laid around the part.
16. Heater lamps may be needed to add heat to any local cold spots in order to maintain an even temperature across the whole part. If honeycomb panels are located over ribs or any other heavy structure they may require additional local heating in these areas as heavy parts act as heat sinks.
17. If liquid resins are used, suitable paint brushes will be needed to apply the resin to the fabric layers.
18. Electronic scales accurate to one tenth of a gram will be needed to weigh out resins and two-part adhesives if they are of the room temperature curing type.
19. Shallow aluminum trays will be needed for resin and adhesive mixing.
20. Packs of medical "tongue depressors" are useful to provide sticks for stirring liquid resins.
21. Sharp scissors will be required to cut the cloth plies to shape.

22. A supply of clean rags is needed to clean up any spilled resin.
23. A roll of clean tissue is needed when cleaning paint brushes and other items.
24. If a solid laminate has to be repaired, and this involves fasteners, then suitable drills and reamers will be required to produce accurate holes. These may require support jigs to ensure precise hole alignment.

B4 Adhere to personal and equipment safety requirements.

It is worth stating at this point that a number of people working with composites and adhesives have, after some time in the job, become so sensitised to epoxy resins that they cannot stay in the same room as a film adhesive without breaking out in a skin rash. This is hard to believe even when you have seen it happen.

It has happened, more than once, and usually to the keenest people, who try to get the job done, but forget to use their rubber gloves and masks. Such people have been taken off their jobs on medical grounds because of this. This loses the operator their job and the company the services of a skilled person. Dermatitis, or skin rash, can occur if you don't wear your gloves at all times. Resins must not be allowed to contact the skin. If it happens wash it off with soap and water immediately.

Wear rubber or latex gloves and overalls and lap the gloves over the sleeves. The use of solvents to remove resin from the skin dissolves the natural skin oils and causes skin cracking which can pick up infection. Ensure that the gloves you wear are compatible with the solvent cleaner you are using. For example acetone will dissolve cheap latex gloves very quickly. Note that gloves need to be worn when handling pre-pregs and film adhesives not just wet layup resins. Allergic skin reactions to resins, adhesives and pre-pregs are also consequences of not wearing personal protective equipment e.g. overalls.

Use sealed containers of cleaning solvent such as acetone. Do not leave it evaporating into the workshop air. Most solvents are flammable and have vapors that are health hazards. Electrical equipment in a bonding shop needs to be spark proof and only specially designed and made equipment will meet this standard.

Compressed air must not be used to blow dust away from the part. It contaminates the atmosphere and the bonding surfaces. Vacuums with composite dust collection systems should be used instead.

Lubricants and water repellent compounds act as release agents and must not be located in any bond shop.

All tools must be handled with care and any safety guards supplied must be used.

Masks must be worn if the material being sprayed requires them

Safety glasses or goggles should always be worn. This is especially important if low viscosity resins are being mixed to avoid splashing them into the eyes. Approved face shields can also be used.

Helmets covering the ears should be worn when performing some paint spraying processes.

Approved hearing protection should be worn if noisy processes such as riveting or grinding are required.

Ventilation booths with extractor fans should be used when mixing resins that give off hazardous or unpleasant vapors.

B5 Describe the differences between repairing composite and metal structures, including discussions about metal bonding,

There are several important differences between composite and metal bonding and many similarities.

The main differences are:

Metal bond repairs

1. **Special treatments**. Metal surfaces need special treatments to raise their surface energy to ensure good adhesion. Aluminum alloys need phosphoric or chromic acid anodizing to produce a high energy oxide layer with a porous structure that aids good adhesion. Other methods are available, see Ref:1, but no other known method is better than these. Titanium and Stainless steel can be bonded but always check the SRM recommendation for treatment. It can be said, without the slightest doubt, that good surface preparation is more important than anything else if good durable bonds are to be achieved to repair metal parts.

2. **Primers**. Primers are often used when bonding metals. These must be compatible with the adhesive used. Primers do not improve bond strength very much but they do improve corrosion resistance and hence durability by a useful amount.

3. **Metals are non-porous**. Metal surfaces are not porous and therefore when honeycomb cored panels are being repaired there is no escape path for volatiles from the resin or air that is in the core. To allow vacuum pressure to work, a thin positioning cloth from 3M, called AF 3306-2, can be used between the honeycomb and the film adhesive that is laid up against the skin. This allows air and volatiles to be extracted from the core to produce a good bonding pressure, See Chapter 10 of Ref: 1, and Figs 10.19-10.28B. Once a good vacuum has been drawn the heat can be applied and this melts the adhesive, which absorbs the positioning cloth and a good bond with good fillets to the honeycomb is achieved.

A fairly heavy layer of film adhesive is needed to absorb the fabric and ensure good filleting to the honeycomb cell ends. Film adhesive of 425g/m^2 (085lb/ft^2) weight is recommended or two layers of 300g/m2 (0.06lb/ft^2) if the heavier grade is not available.

4. **Metals have the same properties in all directions**. The metal repair patch should be the same thickness as the original skin or one gauge thicker but no more or too much load will be attracted to the patch. The patch should be chamfered half its thickness and tapered over about half an inch (12.7 mm) at the edges to reduce edge stresses and improve airflow. All shaping and trimming must be done before anodizing to avoid contamination of the bonding surfaces. The overlap all round the skin cut-out should be in accordance with the SRM and is usually 50 times the skin thickness.

Composite bonded repairs

The main differences between repairing metal and composite structures are:

1. **In-plane properties of composites depend on ply orientation and transverse properties are low**. The composite skin plies must be oriented correctly to the SRM or drawing and laid up in the correct sequence in order to locate the strength in the right directions. **A sheet of metal has similar properties in all directions.**

2. **Surface preparation of composites is easier.** The existing skin must be cleaned, dried and lightly abraded but for small repairs this is easier than the chemical treatment of metal skins. Always use the SRM recommended drying time as a minimum. The reason for this is that composite resins, and in the case of aramids also the fibers, will absorb moisture. The parts will not feel wet or show any visible signs of moisture but drying is needed to obtain stronger and more durable bonds to composite surfaces. The longer a part has been in service the more important drying becomes. Moisture meters can be used on fiberglass and aramids but not on carbon fibers because they are electrically conductive. See Ref: 1**.** **Metals require complex chemical surface treatments for high bond strength and long-term durability.**

3. **Composite skins are fairly porous.** If a wet lay-up repair is done at room temperature, or up to about 95^{o}C, or if a pre-preg is used, some gas and air can be drawn out through the resin to give a bonding pressure to hold the skin to the honeycomb and the repair area of the skin. The problem remains that the area surrounding the repair may be blown apart if there is water in the honeycomb and a cure at the original temperature is attempted. Ideally all repairs to honeycomb panels should be made at a temperature significantly lower than the original manufacturing temperature to avoid this problem. See Chapter 10 of Ref:1. If this is not permitted then a higher pressure must be provided by a press or autoclave**.** **Metal skins are non-porous.**

4. Primers are seldom used on composites for adhesive bonding but may be required. They are almost always used on metal parts. Check the SRM. Modern paint systems, such as Desothane HS (CA 8000) from PRC De Soto, use a strong primer that remains on the aircraft for its whole life. An intercoat is then applied and followed by a topcoat. The use of a solvent stripper, based on benzyl alcohol, allows the topcoat and intercoat to be removed for repainting several times without damaging the primer. Great care must be taken with this process as many aircraft are repainted ten or more times during a thirty year service life. Repair areas will need to use the strong primer that was used in manufacture to restore this capability. **Metals almost always use primers to minimise corrosion and increase durability of the bond. In this case composites use a primer to protect the first layer of fiber. This paint system is also used for metals when a brightly colored primer, of high strength and durability, is used to protect the anodized aluminum surface.**

Similarities are

1. Adequate pressure is needed for bonding.
2. Correct cure temperatures and times must be used.
3. Composite repair patches cured at high temperature often use a film adhesive to assist good bonding of the repair patch to the honeycomb and to the skin. This is similar to a metal patch.
4. Only anodized aluminum alloy honeycomb should be used for repair or manufacture. This applies to composite and metal panels if aluminium honeycomb is used in the original panel. Note that most composite –skinned honeycomb panels use aramid honeycomb or foam cores
5. The original primer must be restored in repaired areas.

B6 Describe the process of metal bonding

1. Although stated earlier, it is worth repeating, that good surface preparation of metals and most other surfaces is the single most important factor in achieving good, durable adhesive bonds.
2. Sheet metal for adhesively bonded construction or repair should be kept clean and free of scratches until ready for the anodizing or other treatment process. All cutting, trimming and edge chamfering should be completed before the part is anodized or given any other surface treatment. Holes and countersinks should also be drilled before anodizing if this is possible. If Phosphoric acid anodizing is used and carried out to Boeing Process Specification BAC 5555 then the procedure is as follows. See the latest issue of this Specification for any new developments.
3. Step 1 is vapor degreasing.
4. Step 2 is alkaline cleaning in a tank.
5. Step 3. The alkaline solution must then be rinsed away in clean water.
6. Step 4, Deoxidise to BAC 5765, Method 1, Amchem No 2 solution

7. Step 5. Rinse again.
8. Step 6. Anodize in phosphoric acid solution at the specified voltage for the required period of time.
9. Step 7. Remove details from the anodizing solution and start rinsing within 2 minutes after the current is switched off. Cold water rinse for 10-15 minutes.
10. Step 8. Dry thoroughly at 60^{o}C maximum.
11. Step 9. Examine for the presence of an anodic coating.
12. After thorough drying the part should be sprayed with a primer within four hours and allowed to dry. It is then ready for the bonding process and if this does not take place immediately the part should be placed in a clean plastic bag. Priming within two hours of drying is essential as the highly reactive surface produced will attract dust and dirt that progressively reduce the high surface energy required for good bonding.
13. The phosphoric acid anodizing process is covered by Boeing Spec BAC 5555 and the latest issue should be studied for precise details.
14. A new Boeing Sol/Gel process is useful for field repairs but like all surface treatment procedures it must be carried out strictly in accordance with the instructions provided if the full benefit is to be realised.
15. Other surface treatments are given in the SRM and should be used when and where permitted.

References

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