TCO J Module Understand Other Critical Elements of Composite Maintenance and Repair.

J1. Discuss issues affecting the selection of bonded or bolted repairs.

There are two very different types of bolted repairs.

1. **Permanent bolted repairs:** Where a section of stiffened laminate structure has to be repaired it is generally accepted that bolted joints are more weight efficient when the composite material is thicker than two or three millimetres. This is because the extra weight of composite, due to the length of overlap required, exceeds the weight of the bolts in a bolted joint.

A further important consideration is that if scarfed or stepped joints are used for thick materials they need to use very long overlaps or scarfed areas in order to meet the recommended overlap or scarf length of 50 to 80 times the thickness of the material being repaired. To achieve the full benefit of scarf joints the scarf on the structure and on the repair section must be accurately matched. Stepped lap joints also need to be cut very carefully to avoid cutting part way through any ply. This may require the use of special tooling. Scarfed and stepped lap joints in thick laminates mean extra weight (often more than the weight of the bolts in a bolted joint) and the cutting away of large amounts of good material, which in the event of a failure of the repair will leave much less original material to carry the load. Most commonly, bonded repairs are made to skins of up to two millimetres in thickness.

2. **Temporary bolted repairs:** If a quick temporary repair has to be made to, say a sandwich panel or fairing, then bolted repairs using a thin sheet of metal on the outside and large washers on the inside can allow the aircraft to return to base. This may be economic if it allows the aircraft to be in position for the next day's operations. Such a temporary repair may require a large permanent repair and may result in the part being scrapped.

If damage occurs to heavily loaded stiffened laminate structure then bolted repairs are almost certain to be used, possibly in conjunction with adhesive bonding. For example wing skins, which are stiffened by stringers are most likely to be repaired using bolts or blind fasteners.

When these scenarios are considered the number of occasions when there is a choice of bonding or bolting is likely to be small. In general if the panels are of sandwich construction then bonded repairs are usually chosen. If the parts are heavily loaded stiffened laminate structures then bolted repairs are almost certain to be used, possibly using adhesive bonding as well. In every case check the SRM for the repairs that are permitted to each part. If in doubt contact the OEM for advice. Tooling may be required to ensure accurate drilling of holes.

J2. Describe various electrical requirements and effects, including prevention of corrosion, hazards of electromagnetic interference and electrostatic discharge (lightning protection systems) and how they need to be considered during the repair processes.

All these factors need to be considered and all existing protection systems replaced during repair and tested for effectiveness, where possible, after repair.

Corrosion prevention

Where aluminum parts are in contact with composite parts the possibility of corrosion to the aluminium needs to be considered.
All bolts and fasteners used in carbon fiber composites must be made from bare titanium alloy, titanium alloy coated with aluminum or corrosion resistant steel (CRES). Aluminum or alloy steel fasteners may not be used in carbon fiber (graphite) structures. Glass fiber and aramid fiber composites are not a problem as they are not electrically conductive. Metal parts used as reinforcements in composites must be properly surface treated and primed. If aluminum alloys are used adjacent to carbon reinforced composite parts, then a layer of glass fiber must first be applied to the composite parts to minimise electrical contact and prevent corrosion to the aluminium parts. The adhesive used should also be of a non-conductive type and of low moisture uptake. Trials using carbon fiber as a reinforcement for cracked aluminum alloy parts have shown very consistently that if moisture enters the crack then severe aluminium corrosion takes place.

Hazards of electromagnetic interference: For many years aircraft made from aluminum alloys have had very few problems with electromagnetic interference because the aircraft structure could conduct the signals away and prevent any unwanted effects. With the increasing use of composites this problem has become more significant. See Chapter 5, Ref: 1. Where RF/EMI (Radio Frequency/ElectroMagnetic Interference shielding is included in any part of the design, repair work must ensure that this protection is replaced and tested to ensure that the level of protection originally provided is replaced and meets the specification requirements. Design should be to the latest ARINC (Aeronautical Radio Incorporated) standards.

Lightning protection systems

These protection systems are vital to safe aircraft operation and must be maintained to SRM and 8110 documentation. If parts that are coated with lightning protection systems have to be repaired, then the repair must include full restoration of the lightning protection system. These protection systems are applied to radomes, wing tips, rudder and elevator tips and any aircraft extremities including the leading edges of engine nacelles. Lightning strikes are powerful and can reach up to two million volts and a current up to 300 amps. In one case of a lightning damaged elevator the inductive forces had fractured the earth lead between the horizontal stabiliser and the elevator, although it was about 3 centimetres wide and about 3 millimetres thick. The electrical current also ran along the carbon fiber front spar and up through a bolt and out at the elevator tip.
The bolt was undercut at the head and the bolt hole enlarged. The temperature had been so high at the bolt position that the resin had completely vanished from the fibers. The temperature reached was probably around 1,000^{o}C . In addition to this the current had travelled from the fuselage and through the elevator operating ball race bearing. The bearing itself felt "gritty" where each ball in the race had been almost welded to the race itself. One elevator hinge bearing felt much the same. On

one recorded occasion a.light aircraft was lost because the elevator control bearing had been welded in similar circumstances. Restoration of lightning protection systems must be taken seriously and they must be restored per the instructions in the SRM.

Electrostatic discharge:

The friction of high velocity air passing over a large-surface electrical insulator such as a radome or cockpit window results in the build-up of static electricity, which periodically discharges by arcing to a metallic part of the aircraft.

These discharges can punch very small holes in a radome's protective coating and through the outer skin, which can lead to moisture penetration and a loss of radar signal strength. The use of an anti-static coating that allows the charge to slowly bleed away can solve this problem.
Boeing specify two types of anti-static coating, one for radomes and antennae (Type II) and the other for all other fiberglass parts (Type I). Type II is considerably less conductive.

Precipitation Static

Static charge and precipitation static have a common origin but differ in degree. Normal air produces a static charge by the friction of air molecules, but precipitation static comes from larger masses such as raindrops, hailstones, dry ice and snow. This is often known as p-static. See Ref: 1. It can lead to radio communication problems often at low altitude when communications for landing are most important. For these reasons conductive coatings are applied to windows and radomes. They must be restored when radomes are repaired. It should be noted that composite structures are very susceptible to P-static effects. Care must be taken to maintain configurations that bleed off P-static charge when designing and implementing composite repairs. Windows are usually serviceable or scrapped although sometimes repairs are possible.

Radar signals and radomes

Most airliner radomes are made from fiberglass or aramid skins with honeycomb cores. Some types use quartz fiber fabrics. SRM pages do not always mention that the thickness of the sandwich is critical. It must be one quarter of the radar signal wavelength for maximum signal transmission. The correct thickness must be maintained or a "wave test", to check signal transmission, will result in a failure to pass the test. For an "X" Band radar the correct thickness is 0.31 inch or (8mm).

A further point is that resins used to repair radomes must not contain any conductive fillers. These too can drain away some of the signal and reduce transmission strength.

Use only the correct type and number of skin plies, correctly spaced, and the correct core material. Work strictly to the SRM and 8110 documentation. Always carry out a wave test and ensure that this meets the standard required. Restore any lightning protection scheme fitted to the radome and check that it meets the electrical resistance requirement.

J3: Understand the need for protective coatings and surface finishing steps used for composite aircraft structure.

Protective coatings may be used for static bleed-off, as mentioned above, or they may be needed for lightning protection or for erosion protection. See Ref: 1.

Anti-Static Coatings

These are covered by BMS10-Type I (Boeing material designation) for all fiberglass areas other than radomes and antennae.

BMS10-Type II is used for radomes and antennae and is less conductive.

Other manufacturers use similar materials. Wherever they are used they must be replaced after repair. The SRM must always be consulted for the appropriate type of coating.

Lightning protection systems (LSP)

These are not always in the form of coatings and may consist of aluminum strips, usually on the outside of radomes but sometimes on the inside. Picture type frames of aluminium are usually used at rudder, aileron and elevator tips. Check the SRM or part drawing for the specific type of lightning protection system that needs to be restored after a repair. Copper mesh and foil are also used for LSP when applied to graphite structures to eliminate galvanic corrosion effects.

The conductive coating forms of lightning protection are,

1. Flame-sprayed aluminum.
2. Metal-coated fabric such as Thorstrand, Alumesh and Alutiss. These fibers are coated with aluminum and embedded in the outer layer of composite components. Nickel -coated carbon fibers and aramids have been tried.
3. Wire mesh has been used i.e woven aluminum wire fabric.
4. Expanded foil mesh is a relatively recent development and has good conductivity. Copper or aluminum foil can be used to make the mesh.
5. In some cases an aluminum foil has been laid into a mold and the composite pre-preg then laid up onto it. On some occasions, a layer of Speedtape may be used as a temporary replacement for an area of flame-sprayed aluminum on the surface of a composite part after a repair had removed the original layer.

Erosion resistant coatings

These have a number of applications from polyurethane paint coatings or polyurethane or neoprene boots, or overshoes, on radomes to metal erosion shields on the leading edges of helicopter blades and also on gas turbine engine bypass fan blades. See Ref:1. If overshoes are used they should be 0.5mm (0.02 inch) thick ,or thicker, to give a good service life. Check the SRM or part drawing.

They are employed to reduce erosion due to rain, hail, dust or sand. The higher the speed of an aircraft or the airspeed of a helicopter blade or engine fan blade the more erosion is likely to take place. Clearly if helicopters are operated in desert areas or airliners fly to dusty airfields then more erosion will take place.

Metal erosion shields are often made from titanium alloy, stainless steel or aluminum sheet, formed to the profile required. The main problem with these is to ensure good quality adhesive bonding to the leading edge concerned. It cannot be overemphasised that good surface preparation is essential whether the adhesion is required for paint, sealants or adhesives and resins. They all need good adhesion.

Repairs to, or replacements of, any of these systems require careful study of the SRM and close adherence to the procedures laid down.

J4: Describe typical paint and surface layer removal techniques for finished composite parts.

Paint removal for repair

The paint system must be removed in order to perform any bonded repair. For small to medium sized repairs the use of aluminium oxide or silicon carbide abrasive papers, or "Scotchbrite" pads of suitable grit size is a common method. Care must be taken not to go through the primer coat or to damage the first layer of fibers. At the first indication of the primer coat a finer abrasive paper should be used to avoid damage to the first layer of fiber. One consolation with abrasive papers is that they always get finer as the grit breaks up but this usually generates more heat. Hand abrasion is preferred. It is much safer to take a little longer and do it by hand than to have to replace a layer of fabric because it has been damaged in the rush to get the job done! Additional repairs mean that the job takes longer in the end.

Large area paint removal

If a large part or the complete aircraft needs to be re-painted then alternative systems need to be considered. Many have been tried with varying degrees of success. Paint removal is also a serious issue because airlines like to keep their aircraft looking smart to keep the passengers happy. They also change the company logo periodically in order to appear up-to-date. These requirements mean that the paint scheme on an aircraft can be changed ten or more times during the life of an aircraft even if it remains with one airline for the whole of that time. Airliners made today are expected to be in service for about 30 years. Paint is quite heavy so it must be removed before the new paint scheme is applied. If an aircraft is rented by a leasing company to a number of airlines over the years then the number of paint scheme changes could be even larger.

This is a tricky area to deal with because new methods are being tried at frequent intervals. The best advice is to consult the SRM or aircraft paint manufacturers. This has also been studied by an SAE committee which produced SAE MA 4872, Paint Stripping of Commercial Aircraft-Evaluation of Materials and Processes, IATA Guidelines for Evaluation of Aircraft Paint Stripping Materials and Processes, latest Issue. SAE MA 4872 was last amended in March 1998 and copies can be obtained from SAE. This document gives methods for evaluation of paint stripping systems, it does not give recommendations or procedures for using them during maintenance. If you are considering a paint stripping system for your company then this document will tell you how to do it and the tests needed to confirm suitability.

Some paint stripping methods that have been tried

The problem, with all methods, is how to remove existing paint quickly, easily and cheaply without damaging the first ply of composite, or in the case of aluminium alloy skins, the anodized oxide layer. See the end of this section for Desothane CA 8000 polyurethane paint. If this system is used the topcoat and intercoat can be removed with a solvent to avoid mechanical damage . Only the primer will need to be removed with an abrasive paper. See also at the end of this section the Sponge Jet paint removal system which looks a good possibility for safe paint removal from large areas.

I suggest leaving the rest of this in as background to the efforts that have been made.

Plastic media blasting was tried but found to be
very sensitive at certain angles and fairly ineffective at others. The type of media, the pressure and hence speed of blasting and the proximity of the jet to the part and the angle of the jet are all important. Unfortunately, it is a slow and boring job and it is hard to maintain the concentration required to avoid damaging the part. It is all too easy to cut into the first layer of composite or if used on aluminum alloy to remove the anodized oxide layer. This also removes the corrosion protection and the oxide layer required to make a good, strong bond. Other materials have been tried as alternatives to plastic media. The list given in SAE MA 4872 is as follows:

1. High pressure water blasting, with/without the use of chemical paint softeners.
2. Dry media blasting (e.g. wheat starch, plastic media blast (PMB) etc.
3. Wet media blasting (e.g. sodium bicarbonate)
4. Ice–pellet blasting (e.g. CO_2 or water, with/without use of chemical paint softeners.
5. Chemical paint stripping (e.g.with/without a dedicated strippable layer in the paint system).
6. Thermal paint stripping (with/without the use of ice pellet stripping).
7. Other processes, may require different or additional requirements as determined necessary by the user or OEM.

It can be seen that a considerable amount of attention has been given to paint stripping but in view of no amendments for eight years it would be advisable to check with the OEM and the SRM before using any of these methods. These techniques must be used with care and in accordance with any procedures that have been developed. It is essential that no damage is done either to an anodized metallic surface or to the outer ply of a composite component.

In general it should be said that the use of paint stripping chemicals should be avoided as they damage the resin matrix. One case, which occurred many years ago, was when a methylene chloride paint stripper was used on a fibreglass-skinned honeycomb panel with a composite skin. The operators said they thought it was

aluminum. The result was that two layers of fiberglass skin were found partly peeled away from the honeycomb like old wallpaper in a steamy bathroom. If paint stripper is used it should be timed with a stopwatch, not applied on a Friday afternoon and left for the weekend!
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One technique considered was to coat the composite with a good, relatively thick layer of primer having a bright color, such as orange, so that it would be obvious to the person preparing the surface that it was time to stop before damage was done. Even this was not much help if the operator lost concentration for more than second or two.

Another, much better, technique is to use a good strong primer coat, brightly colored as mentioned above, and then to apply an intercoat followed by a top coat of polyurethane paint. These two layers can then be removed using a benzyl alcohol-based solvent, which does not damage the primer coat. This paint scheme Desothane HS (CA 8000), from PPG Aerospace /PRC De Soto, now has five years of successful operation and has demonstrated good durability. This system is approved by Airbus, Boeing, Bombardier, De Havilland, Embraer, Federal Express, Gulfstream, Lufthansa Technik, Raytheon, Rolls-Royce and SAAB. The topcoat and intercoat can be removed, using a solvent based on benzyl alcohol, without damage to the primer and this can be done many times if care is taken with this process. The neutral version of benzyl alcohol should be used as this does not damage aluminium structures. Acidic versions must not be used on aluminium. Contact PRC De Soto division of PPG Aerospace, www.prc-desoto.com or www.ppgaerospace.com for details.

Another method mentioned to me is from Sponge Jet Inc. (www.spongejet.com). They embed abrasive grit, of various grit sizes and material types, in a softer material, a polyurethane foam, and this reduces the rate of surface removal to a more controllable level and also absorbs some of the dust produced. The media can be re-cycled a few times, which reduces cost. This system is more controllable than dry plastic media blasting and can remove paint layer by layer and without damaging the primer, if care is taken and the correct grade of grit is used at the correct pressure and jet angle settings. This system has been successfully used by BAE Systems. The grit system Aero-Alox™ 320 has been used on metallic and composite aircraft, aerospace components and radomes. The Sponge Jet method looks promising. This is a relatively new process not listed in SAE MA4872 but seems to be an improvement on those listed.

J5 Discuss proper disposal of wastes from the composite repair process, including EPA/OSHA requirements.

This is becoming an increasingly important issue as the health effects of materials are more fully appreciated and legislation is made to deal with the problems discovered. Legislation varies across the world and all known hazards should be removed as far as possible whether legislation exists or not. Local regulations must be observed as a minimum. On the wider scene we all must live with the results of what is being done so it makes sense to work to a higher standard than the minimum required, where that is possible. See Ref: 1, Chapter 6.

There are several aspects that need to be dealt with. Almost all the materials involved need to be disposed of as hazardous waste.

1. All resins, film and paste adhesives and pre-pregs are much safer in landfill sites if they are fully cured before disposal. These materials are less toxic in the cured state as the base resin and curing agent have reacted together to produce a solid resin. This applies not only to off-cuts of pre-preg when cloths are trimmed to shape, but also to time-expired materials that need to be cured even if they are about to be scrapped. A little forethought and planning can arrange for them to be cured in an oven or autoclave along with production items. However, exothermic heat can be a problem and is certain to occur if large amounts are cured at the same time. For example, it is not sensible to cure a complete roll of film adhesive or pre-preg at one time, even when it is time-expired. Similar problems are likely to arise if paste adhesives or liquid resins that are time-expired are cured in amounts exceeding the data sheet limits. Shallow aluminum trays should be used for mixing so that heat can escape and maximum mixing quantities should not be exceeded. Check the data sheet. Disposal must be in hazardous waste containers.

2. Dusts from cutting composites or abrading their surfaces should be removed with a vacuum cleaner that uses a disposable bag that can be sealed. Disposal must be in hazardous waste containers.

3. Waste solvents also need to disposed of in accordance with local regulations and to be re-cycled where such facilities exist.

4. Other waste, such as paint brushes solidified by resin and tissues and rags that have wiped resin from parts or benches, also needs to be treated as hazardous waste. Off-cuts of dry fabric too small for use at another time and mixing sticks coated with resin also need to be included. Disposal must be in hazardous waste containers.

5. All adhesives, resins, sealants, solvents and other chemicals must be labelled and when small amounts are taken and placed in other containers they must be labelled so that users know what they are dealing with.

6. Workshop benches and floors should be vacuum cleaned at least once a day and preferably twice a day. Waste is produced in significant quantities in composite workshops. Use a vacuum cleaner with a disposable bag that can be sealed. Disposal must be in hazardous waste containers.

7. Technical Data Sheets and Material Safety Data Sheets (MSDS) must be made available to those using composite materials, resins, adhesives, sealants, solvents, paints etc so that personal safety precautions can be taken and waste disposal instructions observed. The company must set up collection points for hazardous materials with suitable instructions for their use. See ISO 14000, ISO 14001, ISO 14010 and ISO 14011/1 in the UK and EPA/OSHA regulations in the USA. Use local regulations in other countries.

8. Company Safety Officers should be able to advise on all matters of safe waste disposal.

J6 Discuss emerging advances in repair process technologies that may appear for bonded and bolted repair and quality control.

Bonded repair: Work is always going on to improve adhesives and resins. A major advance would be if resins could be cured at lower temperatures while retaining the same upper usage temperature. Generally the upper service temperature is related to the glass transition temperature Tg, which itself is usually related to the cure temperature. Some film adhesives and paste adhesives can be cured for longer times at lower temperatures, while still achieving a full cure. Others have to be cured in a narrow band of temperature. More work in this area could be helpful.
One useful example is Cytec FM 300-2 film adhesive. This is a 120°C (250°F) curing version of FM 300, which is itself well known as a useful repair material. This does achieve the ideal expressed above. It can be cured at 120°C but has a service temperature of 150°C (300°F).
Huntsman Epocast 52 is now CACRC approved and can be cured at 65°C (150°F) but has a service temperature of 177°C (350°F).
Hysol EA 9390 has been very successful for many years and can be cured at 93°C (200°F) to give a service temperature of 177°C (350°F).
Hysol EA 9394 is a paste adhesive that can be cured at 25°C (77°F) for 5-7 days or at 66°C (150°F) for one hour to give a service temperature of 177°C (350°F).
Hysol EA9396, a low viscosity laminating resin, can be cured at 25°C (77°F) for 5-7 days or at 66°C (150°F) for one hour to give a service temperature of 177°C (350°F).
Hysol EA 9396/C-2 can be cured at 93°C (200°F) for one hour to give a service temperature of 204°C(400°F). These also meet the ideal suggested above i.e. a low cure temperature with a high Tg is very desirable together with good low temperature and hot/wet performance.
Waiting info from 3M who have some new materials about to be released, hopefully in September 2005.

GMI Aerospace now offer a second blanket and control on their hot-bonders so that extra heat can be supplied to a cold spot and separately controlled. This should greatly assist the achievement of uniform temperature over a repair area.

J7 Discuss emerging damage and repair inspection technologies, such as bond testing, moisture meters and interferometer (3D characterisation).

Introduction

Ref: 2, IATA Doc: Gen: 3043, Chapter 4 –Design for Inspectability, requires that inspectability shall be considered at the design stage and that every practical effort shall be made to simplify and standardise inspection procedures. Chapter 3 covers design for maintainability. Ref:3, published in 1988 says, “Air Force leadership is totally committed to increasing aircraft availability and capability through enhanced reliability and maintainability. Inspectability is a vital part of maintainability. This depends on the designer to provide adequate access but also on the inspector having the best equipment to do a good job, together with the training and the time to do it.

Bond testing methods

A study of NDI/NDT companies on the internet and help from friends and contacts has revealed that many companies have been bought by others, some are still trading under their own names and others have been absorbed by their new owners. Some older equipment may no longer be made so a check with the following companies should be a good start if you wish to find modern testing equipment.

One company currently producing bond testers is Staveley NDT, itself recently purchased by Olympus NDT. Olympus have also absorbed Panametrics who continue to trade under their own name. Staveley make a bondtester called Bondmaster 1000, which can use probes for pitch/catch, resonance and MIA (mechanical impedance analysis) techniques. This portable instrument weighs only 3-6 pounds depending on the batteries used. It will detect flaws in metal/metal bonds, graphite/Nomex, graphite/graphite and metal /honeycomb bonds. They say that this is the most commonly used instrument in the US Armed Forces. With three different probes it appears to include all the methods previously used in one instrument.

The Fokker Bond Tester Model 90 is still in use and can be found on the website of Stork-Fokker Aerospace and The Technical University of Delft. It says that the Fokker Bond Tester uses the principle of ultrasonic resonance testing to determine the through-thickness acoustic resonance frequency and amplitude of a ply or laminate with just one transducer. The technique is especially suitable for thin laminates where it can detect air bubbles, delamination and porosity. It can be used on relatively thick laminates but can give no depth information. Small defects down to about 6 mm can be detected.
This item of equipment may not be in production. No site advertising the product for sale could be found.

Panametrics are offering a portable ultrasonic system. Their Epoch LT is a truly hand-held and affordable flaw detector. They also offer their Epoch 4 with extensive data storage or a cheaper version Epoch 4B, which has less data storage.

R.D Tech, now part of Olympus NDT, offer their Portable Phased Array Ultrasonic system known as Omniscan and NDT Solutions offer a similar system called Rapidscan.

It is useful to have both ultrasonic and x-ray methods available as they complement each other very well. X-rays are better at finding cracks normal to the plane of the sheet and water in honeycomb structures and ultrasonics are better at finding disbonds and delamination between the plies of composites and between the skin and core in sandwich panels. See Chapter 7 of Ref:1.

Of considerable current interest, for the Airbus A.380, is the endoscope method that can be used with GLARE, which is a lamination of plies of aluminum alloy and glass fiber.
This endoscope method is a small instrument that uses visible light to create an optically magnified image on a monitor. It is used to detect small surface defects that are invisible to the naked eye. Endoscopes can access places that are difficult to reach and inspect. A limitation is that this method can only be used for surface breaking cracks Contrast is important and black materials are far more difficult to inspect for cracks, which is unfortunate for carbon fiber composites.

In general it would seem that existing methods have been improved rather than that totally new methods have been developed.

NDI Equipment Suppliers

The following list gives most of the leading NDI Equipment Manufacturers at the time of writing. Many of these are UK branches of US companies.

Advanced NDT Instruments
Diagnostic Sonar Ltd
GE Inspection Technologies
Holroyd Instruments Ltd
Laser Technology Inc
LOT Oriel Ltd
NDT Solutions Ltd
Olympus NDT
Panametrics
Pancom

Physical Acoustics Ltd
Qados
RD Tech UK Ltd
Staveley NDT Technologies Ltd

Tap Test

This test was originally performed, and often still is, with a medium sized coin, a steel washer of about 25 mm diameter, a small tap hammer or the Mitsui Woodpecker WP-632DS. This, the latest version at the time of this writing, now has a display system that can be connected to a computer. The Woodpecker is a great improvement in that it can record the sound of a good section of panel and then compare this record with subsequent readings in other areas that may contain disbonds. The latest version can give a C-scan type of computer print-out of the damaged area as indicated by the results of tapping. A further development of the Woodpecker is under development and this has been designed to work with thick laminates. It is to be named "Lapin". For details contact J.R. Technology on www.jrtech.co.uk or by e-mail at enquiries @jrtech.co.uk. The older methods relied on the human memory of one sound and a comparison with another. They actually work remarkably well but cannot give numerical values to the results.
The Woodpecker is light in weight and easy to use. Three similar methods are the Boeing Tap hammer, the Wichitech RD3, developed by Boeing and licensed to Wichitech and The CATT (Computer Aided Tap Test) developed by Iowa State University and licensed to Advanced Structural Imaging Inc. This has an automatic tapping carriage to eliminate any effects due to a human operator. All the automated methods have the advantage that they can produce a print of the damaged area, which is both useful and a permanent record of the damage found. All the tapping methods work well for thin laminates and honeycomb and other sandwich panels but are not so effective on thicker parts.

A problem is that the coin, the washer and the small tap hammer are very cheap and simple to use. NDI only gets more expensive and more complex after that. Unfortunately, a disadvantage of these simple methods is that they cannot provide a permanent record as a print-out. However at least one of them is always available and they are a lot better than nothing.

All the more sophisticated methods vary from fairly expensive to very expensive.

Moisture meters.

The most common type relies on radio frequency di-electric power loss attributed to an increase in the conductivity of the composite due to moisture absorption. These have been around for a long time and are useful. However, carbon fiber, now the most commonly used fiber in aircraft structures, is electrically conductive itself. This makes the use of contact meters applicable to only certain structural components.
Note that these moisture detectors emit electrical energy and cannot be used in the presence of metals or other conductive materials, including anti-static coatings containing carbon. Panels having such coatings must be tested from the back side, which typically is not coated with anti-static paint. Caution must be exercised in the case of some panels that contain buried metallic doublers. These doublers will give a false indication of moisture and may cause a panel to be removed needlessly. Conversely, if moisture is genuinely present in the area of the metal insert, this type of meter cannot positively identify it. If in doubt about the reliability of the measurement use the drying procedure for carbon fiber. Typical moisture meters are the A8-AF from Moisture Register Products Division of The Aqua Measure Instrument Company, 1712, Earhart Court, PO Box 369, La Verne, California, 91750-0369, and the M.49/P from J.R. Technology. Both of these have served the aircraft and airline industries very well for many years. J.R. Technology also supply the MW 105 moisture meter, which is the only digital, microwave, moisture meter in the world. It corrects the readings for the density of the material. This is the most accurate system known as the measurement enables the density to be calculated and allowed for in the readings. For details contact J.R. Technology on www.jrtech.co.uk or by e-mail on enquiries@jrtech.co.uk.

Methods for use on carbon fiber composites have been tried, that work on different principles, but they proved to be very expensive and seem to have disappeared from the market. It is often easier to give the surface a drying process that has been proven to be effective. This is usually a specified drying temperature for a specified period of time and is given in the SRM. Repair work usually requires something cheap, portable and easy to use that is available on the spot. One problem is that expensive equipment cannot be afforded at a large number of locations. It is easier to justify an item of expensive equipment if it is in daily use on a production line.

Interferometric/ Shearographic methods.

Holographic interferometry techniques have been extensively investigated in recent years. They can detect loose rivets, cracks under rivet heads and weak adhesive bonds in metal structures. In composites they can detect heat damage, impact damage, weak bonds and delamination in sandwich structures. Another type of interferometry is called Shearography. For more detail see below.

Future bondline characterisation may be conducted by the advent of a Laser Bond Inspection system that is currently under development. This system uses a laser pulse to excite the composite, while a scanner measures the composite's response to the pulse. Current methods can only measure void content of bondlines without being able to determine how strong the bond is between the patch and the panel. Laser Bond Inspection systems are meant to verify that the bondline meets the strength requirements rather than just measuring bondline regularity. When applied to hot-bonded repairs, weak hot-bonded patches yield a distinct response to the laser pulse which can be used to detect unacceptable repair processing.

Although bond strength cannot yet be measured other very useful information can be obtained from these methods. See Ref: 1, Chapter 7. For further information on these techniques contact Laser Technology Inc, USA.

Holography.

This method provides an object image from the properties of reflected light using their intensity, wavelength and phase. Phase provides the 3-D effect. The light source must be coherent, in that it is monochromatic and has simultaneous emission; thus lasers are used. Interference occurs when an object changes its relative position and, after double exposure to laser light, the light's phase has changed. The double exposure occurs before and after object movement. This can be produced by lightly loading the component mechanically or by the application of localised heating. The method works well on both metal and composite structures. The method can detect loose rivets, cracks under rivet heads and weak adhesive bonds in metal structures. In composites it can detect impact damage, heat damage, weak bonds and delamination in sandwich structure.

Shearography

Holographic interferometry measures purely out-of-plane displacement. Another type of interferometry is called "shearography". This measures the first derivative of the out-of-plane displacement or the slope of the deformation. See Ref: 1 Chapter 7. The difference between holographic interferometry ansd shearography is explained in Fig: 7.8 from Heslehurst. Fig: 7.9 from Laser Testing Instruments Ltd illustrates the principle of shearography. These can be found in Ref: 1.

J8: Discuss the importance of knowing your skill limits and who to go to for help in completing maintenance tasks.

Whatever the maintenance or repair activity it is always wise to know your limits and to work within them comfortably and not right at the edge of your performance. If in doubt ask another member of the maintenance or repair team or consult the SRM for the correct repair instructions. It is much less embarrassing to ask or to take a little extra time to get the right information than it is to have to scrap the job and start again. Performing a repair action beyond your capability can be a flight safety issue.

The repair of aircraft composite structure is an important task on which the lives or, at the very least the convenience of others depends. There is a lot to learn and as you go along you will find more to learn. Eventually you will realise that no one knows it all and that there is always more to learn. Don't be too keen to rely on memory. Always check the data sheet, SRM and 8110 documentation for details. For example, there are many different two-part resin systems and their mix ratios vary by quite large amounts. To obtain the required strength and the right maximum service temperature, adhesives and resins must be weighed correctly and then mixed thoroughly for at least three minutes. Always mix for this length of time and check it with your watch. Always check the mix ratio for the two-part system you are using. Almost certainly it will not be the same as another resin mixed previously.

Sometimes a foreman or supervisor can help but in some companies these posts are administrative functions. Try to find someone with real experience of composite repairs.
If you have any doubt, consult with a qualified maintenance engineer, the SRM, the 8110 documentation , a data sheet or other source documentation for details. If necessary telephone or e-mail the material supplier. Always read the Data Sheet for product details and the Material Safety Data Sheet (MSDS) for the safety precautions required such as gloves, masks and goggles before starting work.
Follow the instructions carefully, the results are always better when you do.

One area where it is essential to use the skills, and equipment, of others is in Non- Destructive Inspection. Ultrasonic methods, in particular, need experienced personnel to make correct interpretations NDI device readouts. X-ray film needs experienced eyes to know what is a crack and what is not. Only trained personnel, wearing radiation film badges, are allowed to do X-ray work. Other personnel must leave the aircraft while this work is done. Thermography and Holography also require trained personnel with expensive equipment.

Always remember that any NDI methods may only inform you if you have performed a good repair or a bad one. Understanding and performing the correct procedures in manufacture and repair will ensure a good result.

J9: Discuss the importance of documenting/ sharing information about damage scenarios discovered in service between OEM and Maintenance Organisations and Regulators.

It has been found to be important and very helpful over many years for airlines to share details of their problems with the OEM concerned and with their Regulatory body.
For a long time Incident Reports have been required for any defect that occurs in flight, e.g. an engine failure, a cracked window ply or any similar defect. Defects found on the ground during maintenance have to be notified as Maintenance Occurrence Reports (MOR's). It is important that these reports are sent to the OEM and the Regulatory body without delay. As an example, if a specific composite part is consistently or easily damaged, these reports can provide the impetus for the OEM to modify the part so as to be more durable. It is useful if this information is then passed, by the OEM, to other operators of the same aircraft type. Although these reports are submitted to the OEM, and the Regulator, they are not always passed to other airlines as quickly as they could be and sometimes not at all. Serious problems can at one extreme cause the grounding of a type, although this is rare. Less serious problems and their corrective procedures can result in Mandatory Service Bulletins with time limits within which inspection or repair must be carried out. Minor faults can be corrected by Service Bulletins where the adoption is optional. If you find a fault during inspection then an MOR must be raised.

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