



ENGINEERING & MAINTENANCE

Composite repairs — the future

In September 2011, the US Government Accountability Office (GAO) released a report on the “status of the FAA’s actions to oversee the safety of composite airplanes” (GAO-11-849 Aviation Safety). The study was necessary, it said, because “although composites are lighter and stronger than most metals, their increasing use in commercial airplane structures such as the fuselage and wings has raised safety concerns”.

GAO, an independent agency that works for the US Congress and is mandated to investigate how the US federal government spends its money, released the composites report shortly after the certification of the Boeing 787 Dreamliner by the FAA and EASA in August 2011. With regard to the FAA, GAO found that the organisation had “followed its certification process in assessing the airplane’s composite fuselage and wings against applicable FAA airworthiness standards” and had “applied five special conditions when it found that its airworthiness standards were not adequate to ensure that the composite structures would comply with existing safety levels”.

Shortly after the heavily composite 787 was certified, a US government report looked into the safety concerns surrounding the use of composite materials. Four focus issues, concerned with future maintenance and repair, were identified. *Mario Pierobon* reports on what is being done to address these issues, and how the future of composite repairs is shaping up.

For its part, Boeing declared itself “pleased that the GAO report demonstrated confidence in the FAA and in the process through which the FAA certifies the safety of commercial airplanes”. A company spokesperson comments: “Regardless of the materials we use, Boeing employs the same rigorous methods to deliver products that are safe for the flying public and efficient for airlines. We test, we analyse and we demonstrate to ourselves and to the regulatory agencies that even in extreme conditions — which may never be experienced in a full life of service — the airplane is safe and durable.”

Such safety approval provides full reassurance in a world in which composite materials are be-

coming increasingly important in aircraft manufacturing. Phillip Reichen, an aerospace and aviation consultant and contractor specialising in engineering and maintenance, notes that “whilst earlier Boeing and Airbus aircraft are approximately 10 to 15 per cent built of composite materials in terms of their total structural weights, the A380 is approximately 20 to 25 per cent composite materials”. He says both the 787 and A350 are approximately 50 per cent constructed of composite materials, including aircraft surfaces like fuselage barrels.

The GAO report also identified four central safety-related concerns with the repair and maintenance of composites. These were: limited infor-



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The A350 will feature new all-composite wings. The final assembly line in Toulouse, France, recently took delivery of the no. 1 wing.

mation on the behaviour of aircraft composite structures; standardisation of repair materials and techniques; training and awareness; and technical issues related to the unique properties of composite materials. These issues provide an interesting insight into the future of composite repairs — in particular the proficiency that needs to be built in the medium- to long-term to fully address them.

It should be noted that these safety issues were not recognised by GAO as posing extraordinary safety risks or as being insurmountable. Boeing points out that because composite materials have been used in commercial aircraft for decades, albeit less intensely, there is already much repair expertise in the industry. “These issues are already being addressed through an industry-wide effort involving regulators, manufacturers, operators and maintenance and repair organisations,” the Boeing spokesperson adds. “This is a great example of how all stakeholders work together to ensure safety continues at today’s high levels.”

Limited information

The GAO report admits that its concerns over the limited information on the behaviour of composite structures as they age or when they are damaged “are partly attributable to the limited in-service experience with composite materials used in the airframe structures of commercial airplanes” and therefore, “less information is available on the behaviour of these materials

than on the behaviour of metal”. The report suggested that “more empirical data would help better predict the behaviour of damaged composite structures through more robust models or analytical methods”. Reliable damage behaviour predictions are considered vital as they help form the basis for a new aircraft’s design or maintenance programme.

The FAA has already issued an aircraft fatigue damage rule intended to help address “concerns related to limited information on how composite structures age and fatigue”. The regulation, “Aging Airplane Program: Widespread Fatigue Damage, 75 Fed. Reg. 69746 (2010)”, requires that “all manufacturers take a proactive approach to managing risk related to widespread fatigue damage by requiring the demonstration of the validity of the structural maintenance programme by test or service experience, in an effort to reduce the FAA’s current practice of issuing airworthiness directives after an incident,” according to GAO.

As a result of attempts to increase the predictability of composite structures’ behaviour Reichen believes that additional regulatory requirements are on the horizon. “I imagine that the FAA is going to mandate more and longer testing on the static fatigue testing aircraft used for certification similar to the already performed fatigue testing requirements, but under more stringent rules, including expanding non-destructive testing (NDT) on the fleet leader aircraft,” he says.

Another method for achieving greater industry-wide availability of data on the behaviour of ageing and damaged composite structures might be the implementation of a composite behaviour data sharing and database development initiative, as part of an industry collaborative decision-making effort. But this option faces considerable limitations. “The two main players are only going to share data when it is mandated by local authorities. Advanced know-how in composites manufacturing and behaviour represents a competitive advantage in the market and therefore sharing would not be very much appreciated by the manufacturers,” explains Reichen. “The operators will accumulate most of the information anyway as usual; the question will be how this information is captured, funnelled back, validated, standardised and analysed for the most accurate results, in order to extrapolate the most accurate potential future results for the damage and fatigue behaviour of the surveyed aircraft structures.”

Limited standardisation

GAO also reported that “composite materials and repair techniques are less standardised than metal materials and repairs”. This is due, in part, to business proprietary practices and the relative immaturity of the application of composite materials in airframe structures. As well as a repair technician potentially confusing materials or processes, which may result in improper repairs, the GAO report cautioned that “less standardis-



Composite materials make up 50 per cent of the primary structure of the 787 including the fuselage and wing.

ation can have a negative economic impact for airlines and repair stations because a repair facility might have to keep a large stock of repair materials and parts in house, which creates an inventory and storage challenge. Composite materials generally need to be stored at a specific temperature, and the materials also have shelf lives (i.e. expiration dates)."

These issues are being addressed by the Commercial Aircraft Composite Repair Committee (CACRC), whose stated mission is "to reduce the cost of maintaining composite structures through standardisation of materials technique and training". Boeing, an active member of the committee, reports that a standardisation effort such as that supported by CACRC can provide significant benefits to the MRO industry. "An industry standard guideline would decrease the amount of time necessary to obtain regulatory approval for repairs," says a spokesperson. "This would then reduce cost to an airline or MRO."

CACRC's 'Repair Technique Task Group' is currently active in the development of standard repair process documents from current best practices, and a number have thus far been produced.

Another CACRC task group is the 'Analytical Design Group', which is active in the development of a standard repair design and analysis document, "a guide of generally accepted stress analysis methods used for the design and evaluation of composite repairs for approval submission". "The intent of the document is to provide best practices for the development of a repair to be submitted to an airworthiness authority," says

"Composite repair skills will be demanded, with all the necessary background education like gluing, carbon and composite cloth handling. Know-how in vacuum and heat treatment techniques for curing of repairs and more NDT skills to verify repairs will be needed as well."

—Phillip Reichen, aerospace and aviation consultant

the Boeing spokesperson. "This will be beneficial to aircraft maintenance and repair because it will provide a better understanding of repairs design requirements to composite structure."

The problem of limited standardisation has also been, in part, proactively addressed at the aircraft manufacturing level. In the case of the 787, the aircraft was "designed from the start with the capability to be repaired in exactly the same manner that airlines would repair an airplane today — with bolted repairs". Boeing states: "The ability to perform bolted repairs in composite structure is service-proven on the 777 and offers comparable repair times and skills as employed on metallic airplanes. In addition, airlines have the option to perform bonded composite repairs, which offer improved aerodynamic and aesthetic finish. These repairs are permanent, damage tolerant, and do not require an autoclave. While a typical bonded repair may require 24 or more hours of airplane downtime, Boeing has taken advantage of the properties of composites to develop a new line of maintenance repair capability that requires less than an hour to apply. This rapid composite repair technique offers tempo-

rary repair capability to get an airplane flying again quickly, despite minor damage that might ground an aluminium airplane."

Level of training and awareness

The GAO study's training concerns centre on whether repair technicians receive sufficient training and whether all those who come into contact with composites "are aware of and can appreciate the differences between metal and composite materials".

This issue is being addressed by the CACRC's 'Training Task Group', whose purpose is to develop standard curricula for non-NDT inspectors, technicians, and engineers. "The curricula were first developed in the mid 1990s," according to Boeing. "The training task groups' goal is to modularise the current curriculum into manageable training blocks. The first is a basic repair training curriculum that is non-equipment specific and then can be used as a method to meet initial training requirements. This curriculum will be referred to as the basic composite repair training programme. We have drafted a qualifi-



The A380 also makes heavy use of composite materials, at approximately 20 to 25 per cent.

cation/certification standard that would give training providers a method to issue an industry accepted certification of basic repair skills, knowledge, and abilities. The new document would refer to the curriculum document.” The items to be developed are an advanced course curriculum that adds to the basic skill set, a metal bond repair curriculum, and, finally, a curriculum development guideline for the hardware specific repair that will be in an OEM’s structure repair manual (SRM) or other repair documents.

The CACRC’s curricula appear likely to receive the endorsement of a relevant and influential regulator, since “the task group has worked closely with the FAA”. With regard to the availability of personnel competent enough to actually deliver the training on the contents proposed in these curricula, the Boeing’ spokesperson says that “there are several training providers who would be able to provide the basic composite repair certificate training. However, an industry accepted basic repair certification would reduce the time required to train new employees.”

On the differences between traditional metals and composites, Reto Inderbitzin, claims manager at Global Aerospace Underwriting Managers in Zurich, says that “in many cases mechanics and engineers still lack the necessary skills”, with “proficiency in this discipline not yet that well developed”. Inderbitzin draws attention to a specific example. “Composite aircraft encountering a lightning strike quite often record small dark holes on the skin and these need to be repaired as soon as possible, otherwise there is an in-

creased risk of moisture infiltration,” he says. “The problem is that even pilots conducting ramp checks may not have the competence to detect such damages as threatening. There is a need for an increased know-how as to the behaviour of composites in the maintenance side of the business as well as in the piloting side.”

Technical concerns

Another category of concern raised in the GAO report relates to the “challenges in detecting and characterising damage in composite structures, as well as making adequate composite repairs”. The study noted that impact damage to composite structures is unique in that it may not be visible or may be barely visible, making it more difficult for a repair technician to detect than damage to metallic structures.

A long term solution could involve applying evolved protective skins. The US National Aeronautics and Space Administration (NASA) is funding a research programme whose goal is “the development of potential concepts for protective skins which enable natural laminar flow and a significant weight reduction in the aircraft’s primary structure”. Vicki Johnson, a principal investigator at Cessna Aircraft who is overseeing the project, says a protective skin is needed to absorb impact damage and to provide environmental protection.

The NASA contract led to the development of the ‘STAR-C’ concept, which Johnson says “should be responsible for smoothing out bumps or gaps, providing thermal insulation, absorbing

impact and acoustic energy, reflecting ultraviolet and infrared radiation, conducting large amounts of electrical current (for lightning strike), and providing a cosmetic or appealing surface”.

She explains that composite structures are currently “overdesigned” to be able to handle impact and hot, humid conditions in addition to carrying the loads. “On the inside of the fuselage, acoustic (and sometimes thermal) insulation is present,” she says. “The outside uses filler and fairing to provide a smooth and cosmetically pleasing surface along with a layer of lightning strike protection material and paint which provides a smooth, cosmetically appealing surface which reflects sunlight to help minimise the temperature in the cabin.” Ideally, the STAR-C² concept is intended to lead to “a composite primary structure which only has to carry loads and can be designed without the weight penalties to handle impact and hot, humid conditions”. In ideal conditions, “the core handles impact along with thermal and acoustic treatment, eliminating the need for treatment inside the fuselage”. A film takes care of all the other functions.

But the skin concept under study is not applicable to currently manufactured passenger airliners. “Results from the first half of the research have led to a conclusion that current materials don’t support achieving STAR-C² protective skins with weights less than or equal to current composite structures with only two layers,” reports Johnson. “The goal is to prove the feasibility for an airplane three generations from

now (about 2035). We're doing it with today's materials. The outcome from our research will be an assessment of feasibility — after a complete cycle of testing on 173 panels, we think it is feasible with four layers today — and guidance for material developers on the properties their materials need to have to ensure that the concept is feasible in 2035.”

The NASA funded research project has also tested materials which could be used in the shorter term for paint replacement and would allow easier composite surface damage detection. ‘Fluorogrip’ is one of the films tested to provide the smoothing, cosmetic and reflection functions. “The film is capable of being coloured and even printed with a “paint” scheme. The adhesive is critical to ensuring proper adherence throughout the required temperature range for flight,” says Johnson. Integument Technologies is working on a version of this film which has encapsulated dye which would rupture if the skin is impacted, causing a “bruise” on the skin. Meanwhile, Cessna is looking at impact absorbing and spreading layers which would show the damage without resorting to a dye, according to Johnson.

Another potential method of simplifying the detection of damage on composite aircraft structures comes from the Massachusetts Institute of Technology (MIT). In an effort to make composite aircraft skins stronger, the MIT has developed a technique called “nanostitching”, which reinforces carbon fibres’ plies with nanotubes aligned perpendicular to the plies. “Because the nanotubes are 1,000 times smaller than the carbon fibres, they don’t detrimentally affect the much larger carbon fibres, but instead fill the spaces around them, stitching the layers together” reports the MIT. The advantages of this technique are that it can be used in currently manufactured advanced composites and that it allows for composites to be one million times more electrically conductive than their counterparts without nanotubes, thus granting greater protection against damage from lightning, according to the MIT.

An additional advantage is in the area of damage detection: composites reinforced with nanotubes “can be subjected to infrared thermography without the need for an outside heat source”. When a small electric current is applied to the surface, the nanotubes heat up. This means that abnormal flow of heat is then clearly visible to an inspector equipped with a thermographic camera or goggles and a simple handheld device to supply the electric current, the MIT states.

The future of the MRO industry

The increased presence of OEMs in the aircraft aftermarket business could lead to more

consolidation of the MRO industry, which in turn will impact on the future of composite repairs.

“In twenty years, a further concentration of the MRO industry can be expected similar to the current concentration being witnessed with airline operators,” says Reichen. “New skills will be demanded from the maintenance personnel, whereas before sheet metal repairs where common trades. Composite repair skills will be demanded, with all the necessary background education like gluing, carbon and composite cloth handling. Know-how in vacuum and heat treatment techniques for curing of repairs and more NDT skills to verify repairs will be needed as well.”

He continues: “This change will demand that basic maintenance personnel’s education will need to address this. The aircraft manufacturers will have to help in developing field repairs for minor repairs. When it comes to major repairs, this could be very difficult and either only possible for the aircraft manufacturers or very large organisations that can afford to build up the skills and invest in the tooling. Aircraft repairs will become more expensive, as they always do, and the cost of labour will be under even more pressure — but the special skills will be more expensive.”



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