

The Composite Evolution

New uses of composite materials in airliners will result in new ways of thinking for maintenance personnel.

BY LINDA WERFELMAN



Composite materials have been used in aircraft for decades, but the next generation of airliner airframes will be the first in which many major structural components are constructed from composites instead of metals.

Does this represent a change as dramatic as the switch early in the 20th century from wood and fabric airframes to metal?

Maybe, says Fred Mirgle, chairman of the Department of Aviation Maintenance Science at Embry-Riddle Aeronautical University in Daytona Beach, Florida, U.S., because, even though Airbus and Boeing have used composites for decades in control surfaces and secondary structures, their coming models use composites for primary structures and are “a different breed of airplane ... totally different than one that’s made from aluminum and steel.”

Maybe not, says Gary Oakes, an associate technical fellow at The Boeing Co.

“It’s an evolutionary change, not a revolutionary change,” Oakes said, referring to the gradual increase in the use of composite materials over the years.

While commercial jetliner manufacturers typically have used composites somewhat sparingly, the manufacturers of helicopters and military and experimental airplanes have for decades produced aircraft with composite airframes. Boeing began using composites more than 30 years ago, in the spoilers of 737s; in the new 787, they will be used much more extensively — the 787 will be the first commercial jetliner made primarily of composites. Airbus used composites on primary airplane structures in the early 1980s and, in the late 1990s, constructed the first carbon-fiber keel beam for a large commercial airplane — the A340; composites are used throughout the new A380.

Years of experience with composites — which typically combine layers of long, strong fibers (usually carbon or glass) with a matrix (a tough plastic glue) to produce strong, lightweight materials — mean that, to a great extent, their advantages and disadvantages, when compared with those of metals, are well understood by aircraft designers and maintenance specialists.

“Composites are different materials and have their own unique requirements. ... They don’t present any really surprising challenges to work with — just differences.”

Among the advantages of composites are their greater strength and stiffness, their lighter weight and their resistance to fatigue.

“The weight savings, combined with improved structural efficiency, ... directly translated into increased payload, reduced acquisition and operating costs, and increased performance,” said a report by the Advanced Materials Research Program at the U.S. Federal Aviation Administration (FAA) Hughes Technical Center. “A pound of weight saved on a commercial aircraft is estimated to be worth \$100 to \$300 over the service life of the aircraft.”¹

The disadvantages, however, include material degradation, which can be associated with heat damage, and the complications associated with the use of many different types of composites, which do not necessarily share the same characteristics.

No Surprises

“Composites are different materials and have their own unique requirements,” Oakes said. “They’re not as simple to engineer with, and their behaviors are more complex. ... They don’t present any really surprising challenges to work with — just differences.”

Among those differences are composites’ resistance to the fatigue and corrosion that plague metal components; however, composites are more sensitive to damage caused by impact and have stiffness and strength properties that vary with temperature, moisture content and the manner in which the composite materials are assembled.

As a result, nondestructive testing (NDT) of composite materials is critical, both to check for flaws during the manufacturing process and, later, to check for problems that may develop during the service life of an aircraft.

These checks typically begin with thorough visual inspections. If maintenance technicians see a flaw in an aircraft’s skin — such as a surface bulge, a common indicator of a subsurface anomaly — they can determine what types of NDT might be required to further identify the problem, Mirgle said. For example, the many

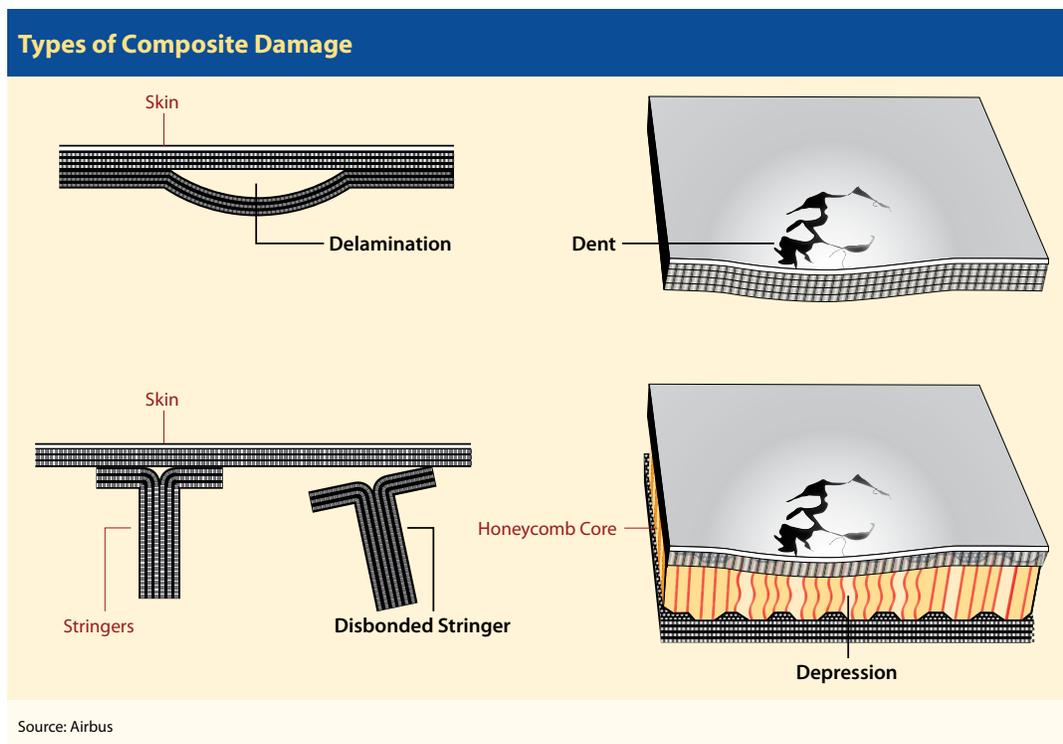


Figure 1

varieties of ultrasound tests can “penetrate the material with sound” to help technicians determine if layers of composite material beneath the surface have separated, and “tap tests” — tapping with a coin or other, more sophisticated equipment — on honeycomb structures can provide an indication of their condition, he said. Other testing methods involving X-rays, laser technology and infrared imaging also can be useful.

Roland Thévenin, composites certification specialist for Airbus, said in a July 2006 presentation before an FAA workshop on composites, that comprehensive testing is required throughout the manufacturing process to guard against unacceptable internal defects.²

“The aim is to detect any manufacturing anomaly which may not be detected with a detailed visual inspection,” Thévenin said. “This is part of the production quality process.”

Some minor defects may be permitted during manufacturing, he said, adding that the only allowable defects are those that “do not grow and do not adversely affect strength.”

Inspection Issues

After a composite airplane is placed in service, the most common inspection issues involve impact damage or the degradation of composite materials, Gary Georgeson, a specialist in NDT and nondestructive inspection at Boeing, said in a presentation to an NDT conference in 2001. Impact damage — such as interply delamination (the separation of a composite material along the plane of its layers) and skin-to-core disbonding (a flaw that occurs when a layer of composite material fails to adhere to another layer) — most often is a result of an aircraft encounter with hail, dropped tools or runway debris. Degradation of composite materials can result in part from heat damage, which can occur because of repeated exposure to jet engine exhaust or to the heat generated by a lightning strike (Figure 1).³

Manufacturer specialists in composite maintenance say that airworthiness standards have been developed so that, if damage cannot be seen, the aircraft can be safely flown with

that damage for the remainder of its time in service.

“Barely visible impact damage is something that, by design, an airplane must be able to tolerate for the life of the airplane,” Oakes said.

If damage is visible, however, further inspection is required to determine the extent of the problem and the type of repairs that will be made, if necessary.

Repairs to composite materials typically involve either the use of composite “patches,” applied to a damaged area with epoxy and then “cured” under a heat lamp for several hours, or bolted repairs similar to those performed on metallic airplanes (see “Working Safely With Composites”).

Justin Hale of Boeing, the 787 deputy chief mechanic, said that scheduled maintenance on the 787 will differ very little from scheduled maintenance on metal aircraft, and composite structures will be managed in much the same way as metal structures — “to accommodate bolted repairs, ... to withstand dropped tools and the daily bumps and bruises every aircraft is subjected to during normal handling.”

Some materials that might be encountered during normal aircraft operations should be avoided, however, because exposure could lead to degradation of composite material.

Hale noted, for example, one insecticide — sometimes sprayed inside aircraft — that must be avoided within the cabin and in cargo areas. A list of all such materials still is being developed for the 787, he said. Items not on the lists will be considered safe for contact with aircraft.

Similar lists exist for metal aircraft, which, for example, can be damaged by exposure to mercury, Hale said.

Accident Risks

Although maintenance specialists say that knowledge of composites has advanced to a stage that the materials’ behavior no longer presents surprises, two specialists in aviation accident analysis say that the substantial increase in the role of composites in the next generation of airliners, and in very light jets, presents an increased risk of aircraft accidents involving composite failures (see “Composites in Accidents”).⁴

“Why would ... composite structures fail?” Joseph F. Rakow, Ph.D., and Alfred M. Pettinger, Ph.D., of Exponent Failure Analysis Associates asked in a September 2006 presentation to the International Society of Air Safety Investigators.

“First, we are building composite structures on a scale never before achieved. ... Second,

Working Safely With Composites

As composite materials have become more common, so have recommendations to limit the exposure of maintenance personnel to associated fumes, dusts and chemicals.

Adequate ventilation is essential, as is use of personal protective equipment, such as respiratory equipment and safety goggles, maintenance specialists say. Maintenance personnel should always use the protective equipment that is appropriate for the composites that they are working with — and be sure that the equipment is fitted properly.

They also should protect themselves against absorption of harmful chemicals through the skin, using gloves, face shields and other protective clothing when necessary.

Maintenance personnel should review the material safety data sheet (MSDS) that accompanies hazardous substances to determine acceptable exposure levels.

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Note

1. Feeler, Robert A. “How to Work Safely With Composite Materials.” *Aviation Mechanics Bulletin* Volume 39 (January–February 1991).

we are building composite structures through relatively new, automated techniques rather than relying on traditional methods of constructing composites by hand. And third, our inspection and maintenance requirements will no longer be driven by fatigue and corrosion performance, as they are for metallic structures, because composites are not as susceptible to these failure mechanisms. Instead, accidental subsurface damage and subsequent failure progression will be more important.

“Past experience with metallic structures will be relevant, but new methods and techniques particular to composite structures will be required.”

They characterized these changes as “a collective departure from applications, techniques and methods of the past” and cautioned that they might “lead to landmark lapses in safety with subsequent ‘lessons learned’ for composites” in much the same way that investigations of the series of de Havilland Comet accidents in the 1950s and ’60s led to new information about stress concentrations and metal fatigue.

They said that aviation accident investigators, generally accustomed to analyzing failed metallic structures to help determine what caused a crash, must look at composite failures differently. For example, composite structures respond differently to loads, depending on such factors as the orientation of fibers in the structure, the thickness of layers in the structure and other design factors, and the direction in which the load is applied. Each of these factors influences the appearance of a failed composite; the difficulty for investigators is that composite structures that fail for similar reasons can look very different. ●

Notes

1. U.S. Federal Aviation Administration (FAA) William J. Hughes Technical Center Advanced Materials Research Program. *FAA William J. Hughes Technical Center*. <www.tc.faa.gov/its/cmd/visitors/data/AAR-430/advanced.pdf>.



U.S. National Transportation Safety Board

Composite parts have figured in some airliner accidents, including the Nov. 12, 2001, crash of an American Airlines Airbus A300 after take-off from Kennedy International Airport in New York. The airplane, bound for the Dominican Republic, was destroyed; all 260 occupants of the airplane and five people on the ground were killed. The U.S. National Transportation Safety Board said, in its final report, that the probable cause of the accident was “the in-flight separation of the vertical stabilizer [which was made with composite materials] as a result of the loads beyond ultimate design that were created by the first officer’s unnecessary and excessive rudder pedal inputs.”

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2. Thévenin, Roland. *Composites at Airbus: Damage Tolerance Methodology — Maintenance and Repairs Validations*. Paper presented at the National Institute for Aviation Research, FAA Workshop for Composite Damage Tolerance and Maintenance, July 19–21, 2006. Chicago.

3. Georgeson, Gary. *NDT: A Continuing Responsibility in the Future of Aerospace*. Presented to the 10th Asia-Pacific Conference on Non-Destructive Testing. Brisbane, Australia. September 2001.

4. Rakow, Joseph F.; Pettinger, Alfred M. *Failure Analysis of Composite Structures in Aircraft Accidents*. International Society of Air Safety Investigators. 2006 Annual Air Safety Seminar, Cancun, Mexico, Sept. 11–14, 2006.