Downwind Debris

The full implications of shattered or burning fiber composite materials sometimes are not considered adequately in the protective measures, strategies and tactics of civilian aircraft rescue and fire fighting (ARFF) services and accident investigators, says a report by the Australian Transport Safety Bureau (ATSB). Tapping readily available information, however, airports and airlines can raise awareness of composite-specific risks before conducting evacuations/rescues from damaged large commercial jets, aircraft fire fighting, accident investigations and site cleanup operations. The report also discusses fiber composites in light general aviation aircraft and military aircraft, and accident investigation techniques for all types of composite aircraft.

Since the earliest industry experience with fiber composites 50 years ago, standards have evolved in aircraft design, manufacturing and maintenance that enable the aerospace industry to safely capitalize on composite materials' greater strength and stiffness, lighter weight, durability and resistance to fatigue relative to aluminum and other metals (*ASW*, 3/07, p. 17). *Fiber composite* refers to laminates made of alternating layers of long, strong reinforcing fibers — usually glass or carbon — woven into a ply with a binder, a tough plastic glue that shapes the fibers into a carbon/epoxy or glass/phenolic matrix, for example. The binder also bonds the plies of matrix together into stiff structures of the desired thickness. In many applications, two sheets of laminate are bound to a core of plastic foam, aluminum or Nomex honeycomb to create structures of the required shape and strength.

Material safety data sheets list the precautions for normal handling, fabricating and repair for each type of fiber composite, and those relevant to other possible activities involving human proximity to fiber composites in fires, crashes and other emergencies.

"There is a lot of conflicting or incorrect information in the aviation community about the safety and capability of fiber composite

Australian Government Department of Defence

Fire damage to an F/A-18 Hornet fighter illustrates fiber composite debris.

U.S. Air Force

Australian study summarizes post-crash health risks from fiber composites in transport aircraft.

BY WAYNE ROSENKRANS

materials," the report said. "First responders involved in post-crash cleanup operations [in the late 1990s] expressed concerns about the long-term effects from exposure to carbon fibers released from burning composites. Fiber dust can pose an inhalation risk similar to asbestos. Released fibers or splinters are needle-sharp and can cause skin and eye irritation. In the event of a post-crash fire, smoke and toxic gases are also released from decomposing composites, presenting further health risks."

From the standpoint of firefighter/investigator response to transport aircraft crashes, a rule-of-thumb distinction between two broad categories of composites has proven useful. Major load-bearing structures and skins for fuselages, wing boxes, control surfaces and empennages typically are made of carbon/epoxy materials. Many cabin fixtures and furnishings are made of glass/phenolic materials.

The carbon/epoxy materials will "burn easily and produce thick, toxic smoke" and possibly noxious gases as the epoxy bonding matrix burns away. "Carbon/epoxy … has poor fire resistance, easily igniting and burning when exposed to fire," the report said. "The smoke from epoxies and vinyl esters can be extremely dense, making it difficult and disorienting for first responders to fight the fire. Toxic gases produced by decomposing bonding matrix materials are one of the most serious hazards for first responders and people in the vicinity of the accident site. … The greatest [toxic gas] hazard is the carbon monoxide released in the fire … epoxy-based composites release the highest amount of carbon monoxide."[1]

In contrast, the composite cabin materials have intrinsically low flammability. "Glass/phenolic structures have excellent fire-resistance properties, superior to most next-generation advanced composite materials," the report said.

Airborne Fiber Debris

The report makes distinctions between crash impact/fire scenarios involving an aircraft built largely of structural composites and those involving an aircraft built primarily with an aluminum structure (*ASW*, 4/08, p. 37). For fiber composites, a key concern is the physical characteristics of fiber shards and debris at ground level, and fibers and dust released into the air from structures shattering during impact, explosions or fire because of potentially serious skin and eye irritation. "More importantly, glass fibers can pose an inhalation threat … if handled improperly," the report said. "Less is known about the health effects of inhaled carbon fiber dust; however, laboratory tests show that unlike glass fibers, carbon fibers do not cause pulmonary fibrosis in animals.[2]

"After an accident, fiber composite materials can reduce passenger survivability of an accident due to the unique hazards they pose. … [Composite] fibers are very small and lightweight, and are likely to be in the atmosphere. They are also easily carried by wind currents and may travel substantial distances from the crash site. … In the event of a crash and post-impact fire, it is critically important for emergency services to evacuate passengers to a location upwind of the accident and away from fiber composite debris. Timely action will minimize passengers' exposure to these risks."

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The fuselage and wing are fiber composite structures on the Boeing 787.

The Australian study learned from an informal telephone survey that a disparity existed among states and emergency services in their levels of awareness of fiber composite issues in aircraft accidents. International[3] and national health and safety information on relevant equipment choices, procedures and training was used extensively by military services but not consistently by civilian agencies. "This survey found that knowledge of composite hazards and appropriate response methods are very disjointed between different emergency services in different states," the report said.

Aircraft-Specific Briefings

The report recommends that personnel sent to the site of a composite aircraft accident be briefed on the aircraft type and its major composite components before they begin this phase of their work. "There should not be any rush for accident investigators to enter the site until personnel have been briefed on the hazards present and the risks posed by fiber composites," the report said.

In the current fleet of large commercial jets built since 1985 and operating in Australia, the report said, first responders and accident investigators could encounter examples of composite materials in structures such as:

- Vertical fins made of carbon-fiber reinforced plastic on the Airbus A310 and A300-600 series, and other types of composites forming the wing leading edge, control surfaces and fairings;
- Empennage, control surfaces and engine cowlings on the A320 series;
- Empennage, control surfaces, keel beam and engine cowlings on the A330/A340 series;
- A composite center wing box and an extensive list of other fiber-composite components on the A380;

- Empennage, control surfaces and engine cowlings on Boeing 777s;
- Floor panels of cabins and cargo holds in 767s and some 747s;
- The fuselage and wing of the 787;
- Vertical fin box and ailerons on the Lockheed L-1011; and,
- Composite upper rudder on the McDonnell Douglas DC-10/ MD-11.

In the near future, some large commercial jets also will have a new generation of engines built with composite fan blades, containment casings and cowlings. Cabin components molded from glass/phenolic materials typically comprise overhead lockers, cabin ceiling and paneling, galley structures, cabin partitions and doors, the report said.

Dressed for Success

Personal protective equipment should include breathing apparatus, specially designed clothing and related procedures for decontamination. Health and safety require "wearing appropriate protective equipment, protecting electrical equipment, moving bystanders away from the crash site and applying fixant solution to all damaged composite structures to limit dust dispersal." A fixant is a substance — such as water-diluted liquid floor wax or polyacrylic acid — that traps dust and loose fibers as it dries after application with backpack-carried spray equipment and chemical stripper solutions. Aqueous film-forming foam or other ARFF foam normally would be preferred to standard fixant, however, for fiber debris and dust on an asphalt or concrete airport surface.

The ATSB specifies what accident investigators are required to wear at the crash site of a composite aircraft. The list comprises "rubber gloves beneath heavy leather gloves (as fibers may penetrate the skin, causing irritation); safety goggles; a [sturdy] pair of boots; full-face dust and mist respirator capable of filtering particles[4] below 3 microns [0.0001 in] in size (plus a supply of spare filters); self-contained breathing apparatus; chemical/biohazard protective suit; and Neoprene overalls." Training covers specific methods of donning this equipment, washing/showering on site before decontamination, and safely removing and disposing of contaminated items.

"Failure to wear adequate personal protective equipment is likely to cause severe bouts of coughing and choking, extreme eye irritation and long-term health problems caused by tissue and organ damage from exposure" to some of more than 100 toxic gases that may be generated by decomposition of various types of carbon/epoxy composites, the report said.[5]

The ATSB also specifies that anything used at the accident site be suitable for on-site decontamination, so some items typically taken to the site of an all-metal aircraft crash — such as writing pads and tool kits — must be excluded. The guidelines also call for the establishment of a temporary restricted airspace in the vicinity of the accident to prevent news media and other air traffic from inadvertently dispersing composite fiber dust over a wide area before the fixant has been applied to damaged or destroyed composite structures.

"After entering the crash site, the investigators' first priority should be to protect all electrical equipment," the report said. "Released composite fibers are highly conductive, and their small size means that they can easily interfere with and damage electrical components."

The report provides a comprehensive list of Australian and international source material with advice on the types of information each can provide. Among these is the ATSB's "Fire Safety of Advanced Composites for Aircraft," published in 2006, which "compares the fire resistance of composite materials against key criteria: time to ignition, limiting oxygen index, heat release rate, flame spread rate, smoke and toxic gas release."

This article, except where noted, is based on ATSB Aviation Research and Analysis Report no. AR–2007–021, "Fiber Composite Aircraft — Capability and Safety," by R.P. Taylor; this ATSB Transport Safety Investigation Report was published June 9, 2008.

Notes

1. The report cited Mouritz, A. "Fire Safety of Advanced Composites for Aircraft," a report to the ATSB, Department of Transport and Regional Services, Canberra, Australia, 2006.
2. The report cited Gandhi, S.; Lyon, R. "Health Hazards of Combustion Products From Aircraft Composite Materials," U.S. Federal Aviation Administration, Department of Transportation, Washington, 1998.
3. International Civil Aviation Organization (ICAO). "Hazards at Aircraft Accident Sites," ICAO Circular 315, 2008.
4. The dimensions of respirable glass fibers determine the degree of hazard. "Glass fibers with diameters smaller than 3 microns and shorter than 80 microns [0.0031 in] can be inhaled deep into the alveolar region of the lungs," the report said. "Fibers shorter than 15 microns [0.0006 in] are cleared naturally from the lungs by cellular activity. However, glass fibers between 15–80 microns remain in the lungs and can lead to pathological effects such as pulmonary fibrosis, which causes diseases such as mesothelioma and asbestosis. Respirable fibers may in addition adsorb toxic chemicals from the decomposing matrix material, which then enter the lungs and possibly cause acute or chronic effects. Temporary skin and eye irritation can be caused by exposure to sharp, fragmented fibers longer than 4–5 microns [0.00016–0.00020 in]."
5. The report cited Mouritz, A.; Gibson, A. "Solid Mechanics and Its Applications: Fire Properties of Polymer Composite Materials," Springer, Berlin, 2006.