Passenger safety aboard aircraft is the paramount concern of manufacturers and airlines alike. For the past twenty years, fire safety programs have reduced the number of fire incidents aboard aircraft. However, the impact of hidden fires and post-crash fires must be reconsidered when analysing the next generation of aircraft due to the greater proportion of composite materials in their structure. The AircraftFire project is a European collaboration determined to examine the effects composites have on aircraft fire safety and passenger survivability.

TEXT Derek Gransden, Post-doctorate Researcher, Aerospace Materials and Manufacturing, Structural Integrity

AIRCRAFTFIRE SYNOPSIS

Aircraft such as the Boeing 787 or Airbus A350 are constructed from considerably more composites than their predecessors, particularly in the fuselage and wing structural elements. However, from a safety standpoint, aircraft fires involving composite components are not well investigated. The current aeronautical regulations, based on empirical data collected from metallic aircraft, may not entirely apply to composite bodied aircraft. Aircraft are certified based on their performance in fire safety scenarios, and assessments of composite materials under thermal and mechanical loads are under-represented. Regarding fire safety, three main questions remain to be answered (AircraftFire, 2011a): Do composites aboard the aircraft increase the fire hazard? How does the fire growth respond in a composite-based aircraft? Will flashover, the point where the instantaneous combustion of air inside the cabin that marks the end of passenger survivability inside the fuselage, occur sooner or later than in existing commercial metal aircraft?

To answer the questions above, a partnership of European universities, institutions, the Civil Aviation Association (CAA), and companies such as Airbus and the European Aeronautical Defence and Space Company (EADS) proposed to the European consortium the AircraftFire project.

The objectives of the project are to investigate the impact of composites on the passenger survivability under certification conditions and to increase the knowledge base of the thermo-mechanical properties of structural composites for fire safety regulations. Results from the project will improve passive fire prevention and protection techniques and increase the efficacy of fire detection and extinguishing systems, thereby increasing passenger safety and minimizing fire structural damage (AircraftFire, 2011a).

SURVIVABLE AIRCRAFT FIRE SCENARIOS

The Federal Aviation Administration (FAA) acknowledges two priority scenarios involving composite aircraft fire research. The first scenario involves in-flight fires in specific zones, such as in the engine compartment and hidden areas aboard the aircraft not normally accessible by crew. Inaccessible areas are typically above the ceiling panel or near ventilation ducts, behind sidewall panels, below the cabin floor, or in the electronic compartments. These are areas where a fire cannot be easily identified, which causes a fire to be more challenging to extinguish. The second scenario under investigation is pool fires in post-crash incidents. A post-crash fire is one where the structural integrity of the aircraft may be compromised by impact with the ground or any other object before the initiation of a fire.

IN-FLIGHT FIRE CHARACTERISATION AND MATERIAL PROPERTIES

In-flight configurations within the engine compartment are examined because the fires exist in a complex aero- and thermodynamic environment and they affect the aerodynamic load-bearing structure of the aircraft. The AircraftFire project seeks to disseminate understanding of the sustainability of a fire upon the composite surfaces within and nearby the engine compartment at high altitudes where partial oxygenation, high airspeed, and lower atmospheric pressure change the characteristics of the blaze. Researchers examine composite material degradation by preheating the composite until it self-ignites. Next, they vary the external airflow and diminish the pressure to observe the flux and pressure effects on the speed of the composite degradation. The speed of degradation will be correlated to the ambient external pressure, airstream velocity, and external temperature to create a database of materials knowledge and to compare with burn-through studies from separate researchers. Tests are also done to examine the effect of the aerodynamic load on the fire characteristics and the effect of a fire on the mechanical properties of the structure. Unloaded structures
are subjected to heat and loaded in tension and bending, so that each face of the loaded member experiences either an extensional force or a compressive one, which is varied to correlate the burn-through and strength of materials.

Current FAA research involves the development of more stringent certification standards for fires occurring in hidden areas. The focus of the research is on the flammability of wiring, clamps, close-outs, ducts, etc., and identifying materials that will not propagate fires or, after combustion, produce noxious fumes. To examine hidden fires, an under-ventilated small enclosure with one composite wall is set afloat. The heat transfer mechanisms via cables passed through the enclosure rig wall will be studied for each family of composites commonly used in aircraft. Noxious fumes are studied using a small-scale wind tunnel modified with insulating walls. This set-up allows researchers to control the flow rate and ventilation of the fire and characterise its development over the combustible material. Effluents are passed through to a cone calorimeter to measure the heat release rate, smoke production, and the oxygen, carbon monoxide, and carbon-dioxide emissions.

**POST-CRASH POOL-FIRES AND EVACUATION SIMULATION**

Post-crash fires are initiated by the ignition of kerosene aircraft fuel on the ground (or water), which can form a pool around the damaged aircraft. These fires are uncontrollable and are further complicated by the disorientation and injury of passengers after the surface impact. In survivable post-crash fires, such as the Air France Flight 358 shown in Figure 1, there is enough time for passengers to escape the aircraft before the flashover point. The fire progression and flashover point depend on the structural integrity of the fuselage after the crash; even in cases where the fuselage remains whole, micro-fractures typically occur along the undercarriage of the vehicle and eventually a flashpoint occurs inside the cabin. Heat and smoke enters the cabin area through these cracks, the window casings, and through openings created by passengers attempting to exit the cabin (such as emergency exit doors).

Certification of crashworthiness is done experimentally by drop-tests in which a fuselage is dropped from a height and impacted upon the ground. In these tests, there is no component of horizontal velocity, but in a survivable aircraft impact there is always a component of forward velocity. Also, typically aluminium alloys allow for 8-15% strain before plastic failure, which accounts for a significant amount of energy stored mechanically before rupture. To visualize the extent of the damage and energy absorption, Figure 2 shows the results of a Boeing 737 fuselage section drop-test before and after impact. However, not only do composite bodies rupture with a different mechanism than metal alloys, they are sensitive to the load directions as well. Chemically, composites contain more stored energy than typical metal alloys, which means that they may actually feed the fire themselves. With these characteristics in mind, researchers at the Structural Integrity group of the Aerospace Materials and Manufacturing Department at TU Delft hope to experimentally and numerically simulate post-crash mechanical failure and energy absorption, to provide smoke and fire ingress data to the project group. Additionally, numerical modelling will be used to evaluate the validity of vertical drop tests on metal structures and compare them with similar aircraft with arbitrary velocities (that is, including horizontal components).

The last key part of the research proposed in the AircraftFire project is the safe evacuation of passengers in survivable post-crash fires. A simulation of passengers exiting a commercial aircraft is shown in Figure 3. Simulations are used to model the speed of typical passenger evacuation, depending on exit procedures defined by FAA certification, with various constraints, such as certain doors remaining closed or blocked due to fire. These simulations are coupled with fire flow pattern software, which calculates the flow of flame and smoke through the cabin and entrance provided by the Structural Integrity researchers. Through these simulations, better training procedures and more efficient evacuation plans are expected. And, in combination with the collected knowledge base of material properties under fire and thermal loads, AircraftFire members expect to have answers to the main questions posed above.

Students interested in this topic should contact me at D.J.Grandsen@tudelft.nl.

**References**


