

Small-scale burner test for the characterisation of the combustion of aeronautic composite materials

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Safety aboard aircraft is one of the main preoccupations of aircraft manufacturers and airlines companies. Although, for 20 years, the fire threat in aeronautics has decreased, more efforts are still necessary to reduce the incident/accident rate and increase the passenger and crew survivability. This fire threat must be reevaluated for the new generation of aircraft (A350 or B-787 types) by considering the increased use of composite materials for hull, wings and structure.

The aeronautic regulations are based on pass/fail standard tests applied on the aircraft materials (1, 2). These standard test output cannot provide a database on the flammability and burning properties of the composite materials, which are necessarily required for modeling and providing of scaling laws to extrapolate the numerical results to full-scale aircrafts.

The objective of this study is to analyze the burning behavior of composites (composed by carbon fibers embedded on epoxy resin) used in new generation of aircrafts for hull, wings, structure, and fuel tanks in representative thermal conditions during in-flight or post-crash fires. A new concept of laboratory scale test for composites is proposed to complete the pass/fail standard test set..

This study, supported by the FP7 AircraftFire project, is aimed to the determination of the thermochemical properties as well as thermal behavior of the aeronautic composite material.

The standard burnthrough test

To pass, one of the main standard tests for the materials is the “burn-through test” normalized by FAA (1,2). It consists of a liquid fuel (or gas) burner flame impinging the surface of a test sample. The working parameters (geometry of the burner, sample-burner exit distance, input thermal power, excess of air, etc.) are adjusted in order to provide a temperature and total heat flux to respectively 1100°C and 180kW/m² s at the material surface (Figure 1). This test is presently well adapted to test metallic materials (mainly Aluminum alloys) and the result consists mainly to the determination of the “burn-through time” of the sample which must be over a threshold time.

This test seems not well adapted to characterize burning materials like composites, as the working conditions does not take into account the influence of the combustion phenomena during the pyrolysis of the composite.

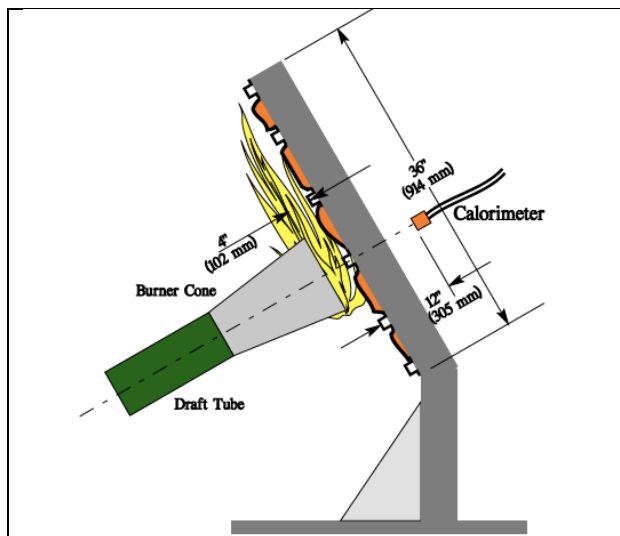


Figure 1: Standard burner test setup

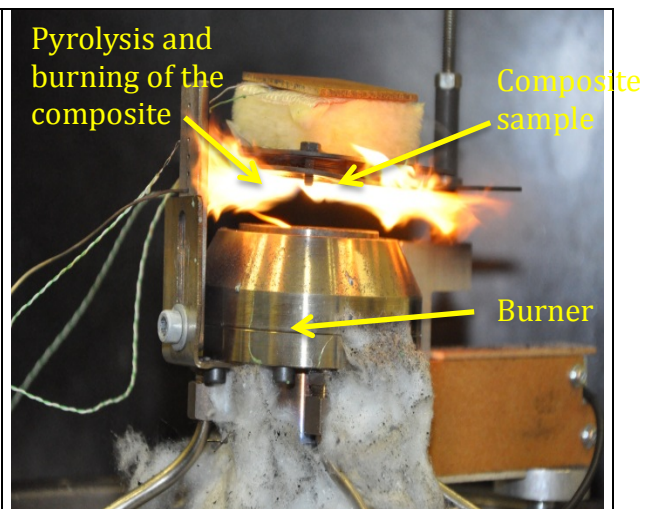


Figure 2: Small scale Pprime burner

Experimental set-up

An original laboratory scale set-up was designed and realized. It consists of a combustion product generator (propane or propylene / air premixed burner) providing a flow of hot gases at the thermal conditions (for temperature and total heat flux) compatible with standard test requirement, the high temperature flow impinges on a small scale ($3.5 \times 3.5 \text{ cm}^2$) sample (Figure 2). This assembly is installed in a pressurized combustion chamber to reproduce ambient pressure levels from 1024 to 250 hPa atmosphere to partly simulate the effect of altitude from sea level to 11000m. The parameters for the tests are the gas temperatures (correlated to the heat flux to the sample surface) and composition (mass fraction of oxygen in the flow of burnt gases) at the burner exit, the ambient pressure, the sample thickness (2 and 4 mm) and the shear stress at the sample surface (τ). During the test, it is measured the evolution of the mass losses of the sample (instantaneous burning rate), the temperatures of the impinging gas and the surface temperatures of the sample at the external (exposed) and internal (unexposed) sides by thin thermocouples.

The composite sample is installed at 1.5 cm from the burner exit (this distance can be increased to modify τ); an aeronautic thermo-acoustic material insulates the internal surface, which is not exposed to the flame.

The main advantages of this small scale setup are the low cost of a test (small size of the sample allowing a great number of tests for various parameters, small thermal input) and the determination of the effects of the aero-thermo-physical conditions on the

material burning rate. Particularly, it can be performed as trials to show the influence of the heat released by the burning of the material degradation products (pyrolysed gases) during the heterogeneous combustion of the composite.

Main results

It is measured the evolution of the burning rate of the materials: a fast degradation of the resin followed by a low oxidation of the carbon fibers. An increase of the heat flux at the surface, the combustion chamber pressure (from 0.2 to 1 atmosphere) and the excess of air in the hot gases (mass fraction from 0 to 0.3), i.e. all the above given parameters which were not considered in the standard tests, increases the burning rate of the solid sample. The influence of other parameters such as the sample thickness and shear stress at the wall is also studied.

Further, the burning behavior of composites is compared to those of a well-known polymer (PMMA) with the same test working conditions.

References:

Burnthrough Test Method Round Robin Task Group, FAA, available to download at the web address : <http://www.fire.tc.faa.gov/handbook.stm>
Aircraft Materials Fire Test Handbook, DOT/FAA/AR-00/12, available to download at the web address : <http://www.fire.tc.faa.gov/handbook.stm>