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Fully Instrumented Small-Scale Fire Resistance Benches for Aeronautical Composites Assessment

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Abstract : Stringent fire safety regulations are enforced in the aeronautical industry due to the consequences that potential fire event on an aircraft might imply. This is so much true that the fire issue is considered right from the design of the aircraft structure. Due to the incorporation of an increasing amount of polymer matrix composites in replacement of more conventional materials like metals, the nature of the fire risks is changing. The choice of materials used is consequently of prime importance as well as the evaluation of its resistance to fire. The fire testing is mostly done using the so-called certification tests according to standards such as the ISO2685:1998(E). The latter describes a protocol to evaluate the fire resistance of structures located in fire zone (ability to withstand fire for 5min). The test consists in exposing an at least 300x300mm^2 sample to an 1100°C propane flame with a calibrated heat flux of 116kW/m^2. This type of test is time-consuming, expensive and gives access to limited information in terms of fire behavior of the materials (pass or fail test). Consequently, it can barely be used for material development purposes. In this context, the laboratory UMET in collaboration with industrial partners has developed a horizontal and a vertical small-scale instrumented fire benches for the characterization of the fire behavior of composites. The benches using smaller samples (no more than 150x150mm^2) enables to cut downs costs and hence to increase sampling throughput. However, the main added value of our benches is the instrumentation used to collect useful information to understand the behavior of the materials. Indeed, measurements of the sample backside temperature are performed using IR camera in both configurations. In addition, for the vertical set up, a complete characterization of the degradation process, can be achieved via mass loss measurements and quantification of the gasses released during the tests. These benches have been used to characterize and study the fire behavior of aeronautical carbon/epoxy composites. The horizontal set up has been used in particular to study the performances and durability of protective intumescent coating on 2mm thick 2D laminates. The efficiency of this approach has been validated, and the optimized coating thickness has been determined as well as the performances after aging. Reductions of the performances after aging were attributed to the migration of some of the coating additives. The vertical set up has enabled to investigate the degradation process of composites under fire. An isotropic and a unidirectional 4mm thick laminates have been characterized using the bench and post-fire analyses. The mass loss measurements and the gas phase analyses of both composites do not present significant differences unlike the temperature profiles in the thickness of the samples. The differences have been attributed to differences of thermal conductivity as well as delamination that is much more pronounced for the isotropic composite (observed on the IR-images). This has been confirmed by X-ray microtomography. The developed benches have proven to be valuable tools to develop fire safe composites.

Keywords : aeronautical carbon/epoxy composite, durability, intumescent coating, small-scale ‘ISO 2685 like’ fire resistance test, X-ray microtomography
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