About dynamic nonlinear and rupture behavior of composite materials under a large range of strain rate and temperature conditions for safety applications

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During the exploitation life of modern aircraft, composite primary parts may be exposed to severe loadings and variations of temperature. Computational mechanics (FE methods) are commonly used today by industry to design complex composite laminated primary aircraft structures, dealing with an increasing variety of load requirements. To deal with extreme cases such as bird strike and crash analysis for civil aircraft, or ballistic hydraulic ram in fuel tanks for military aircraft, many of the most recently developed composite material models then FE simulations have been based on Damage Mechanics (initiation criteria and evolution laws).
Concerning the behavior of CFRP material, thanks to new measurement techniques (CIN, IR thermography) and exploitation methods, the tensile but also compressive composite material behaviors have been properly studied at ONERA even at low strain levels, under high strain rates, and low temperatures. The elastic yield and damage evolution of composite materials could now be accurately characterized directly from tests. Then their dependency to the loading speed (strain rate) and temperature can be analyzed. An extensive work has been performed for several years on T700/M21 CFRP material in the frame of several PhD and research works supported by the French DGA (MoD) and DGAC (Civil Aviation), especially in the running DGAC PHYSAFE project, which focusses on the crash performance of composite aircraft materials and structures. The first part of the proposed paper will focus on T700/M21 tensile shear test results obtained on a large range of strain rates and temperatures (below ambient), and the advanced mesoscopic ply models which were derived from them.

Concerning the behavior of CFRP materials under high temperatures (such as fire exposure), specific test protocols has also to be developed in order to characterize the thermo-chemical and thermo-mechanical properties of T700/M21. Such works are being performed by ONERA in the frame of the EU Future Sky Safety program and more specifically within P7 “Mitigating Risks of Fire, Smoke and Fumes” project. Future Sky Safety is part of Horizon 2020, the biggest European Union Research and Innovation program ever, with nearly €80 billion of funding available over 7 years (2014 to 2020). Among the research works performed in P7 MFS&F project, some test results would be presented which concern the mechanical behavior and degradation of organic composite materials at elevated temperatures, indeed there is currently a lack of well-established protocols to assess the degradation of mechanical properties (especially in terms of compressive properties which may be important for structural strength and evacuation in crash situations) of CFRP materials in such conditions.