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Towards the predictive FE analysis of a metal/composite booster casing's thermomechanical integrity

Thèse présentée par Adélie CAPRON
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et du Professeur Thierry J. MASSART, co-promoteur

SAFRAN
SAFRAN AERO BOOSTERS

Université libre de Bruxelles
École polytechnique de Bruxelles
Département 4MAT

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Abstract

In response to serious environmental and economic concerns, the design and production of aircrafts have been changing profoundly over the past decades with the nose-to-tail switch from metallic materials to lightweight composite materials such as carbon fibre reinforced plastic (CFRP). In this context, the present doctoral research work aimed to contribute to the development of a CFRP booster casing, a real innovation in the field initiated and conducted by Safran Aero Boosters. More specifically, this thesis addresses the matter of joining metal/CFRP hybrid structures, which are prone to possibly detrimental residual stresses.

The issue is treated with an approach combining experimental characterisation and finite element (FE) simulations. The multi-layered system's state of damage was systematically examined on hundreds of micrographs, and the outcome of this study is presented under the form of a statistical analysis. Further, the defects' 3D morphology is investigated by incremental polishing. A number of thermal and mechanical properties are measured by diverse physical tests on part of the constituent materials, i.e. the aerospace grade RTM6 epoxy resin, the structural Redux 322 epoxy film adhesive, and AISI 316L stainless steel. They are used as input data in a FE model of the multilayer that is developed and progressively refined to obtain detailed residual stress fields after thermal loading. These results are compared to experimental data acquired by X-ray diffraction stress analysis and with the curvature-based Stoney formula. Cohesive elements are placed at specific locations within the FE model to allow simulating progressive damage. Peel tests,

mode I, mode II and mixed mode I/II fracture tests are thus performed in view of measuring the joint toughness. The results of these tests are discussed and the presence of residual stress in the fracture specimens is highlighted. Key information for the calibration of the cohesive law is finally identified via inverse FE analysis of the mode I test, this being a significant step in the process of building a damage predictive FE model of the multilayered system.

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