

# DAMAGE TOLERANCE ANALYSIS OF IMPACTED COMPOSITE STRUCTURES SUBJECTED TO MULTIAXIAL LOADINGS

Joël Serra<sup>1</sup>, Antoine Trellu<sup>2</sup>, Christophe Bouvet<sup>1</sup>, Samuel Rivallant<sup>1</sup>,  
Bruno Castanié<sup>1</sup> and Léon Ratsifandrihana<sup>2</sup>

<sup>1</sup>INSTITUT CLEMENT ADER,  
3 Rue Caroline Aigle, 31400 TOULOUSE  
Email: joel.serra@isae-superaero.fr, web page: <https://institut-clement-ader.org/>

<sup>2</sup>SEGULA Aerospace and Defence,  
24 boulevard Déodat de Séverac, 31770 Colomiers, France  
Email: Leon.RATSIFANDRIHANA@segula.fr, web page: <https://www.segulatechnologies.com/>

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## ABSTRACT

The development and certification of aeronautical composite structures is still largely based on the pyramid of tests. This approach requires a large number of tests going from the coupon to the full-size aircraft. To reduce the associated costs, predictive modelling methodologies are developed in several research centers [1]–[4]. Out of plane stresses emanating from impacts are well known to be critical for the residual compressive strength of laminated composites. To design composites structures, engineers use a damage tolerance approach following standards of low velocity impact and compression after impact tests [1], [2]. These standardized tests do not represent real structural loadings because of their conservative uniaxial boundary conditions that do not allow post-buckling failures. In this work, medium-scaled specimens are impacted at medium velocities with a gas launcher then multi-axially loaded in order to analyze interactions between impact damage and post-buckling.

The material used in this study is a prepreg with carbon unidirectional fibers and epoxy matrix T700/M21 manufactured by HEXCEL of 0.25 mm-thickness ply. The selected stacking sequence is  $[45^{\circ}2/-45^{\circ}2/0^{\circ}2/90^{\circ}2/0^{\circ}2/-45^{\circ}2/45^{\circ}2]$  with a total thickness of 3.5 mm. This composite laminate is quasi-isotropic and is closed to aeronautical composite structures. Specimens are flat panels of 558\*536 mm<sup>2</sup> dimensions (Figure 1). Eight specimens are studied, seven of them are impacted to evaluate the delaminated areas and determine the impact damages. A multiaxial test rig for medium-scale structures has been developed at the Institut Clement Ader (Toulouse, France) and has already made it possible to test notched panels [7], [8]. Two actuators (1 and 2 - Figure 1) are used to generate bending of the central box and therefore tension or compression in the flat specimen that constitutes its upper side. The two other actuators (3 and 4 – Figure 1) are used to generate torsion within the central box and therefore shear in the specimen. Different loading paths have been investigated: compression, compression+shear and tension+shear. Two techniques of in situ monitoring have been used to characterize the failure scenarios: digital image correlation and infrared thermography.

Behaviors have been analyzed, differences have been highlighted and some explanations are proposed. B. Castanié and J. Serra have shown that it is very difficult to estimate stress flows directly entering the specimen because of the numerous structural redundancies [8], [9]. Therefore a specific methodology using Digital Image Correlation has been developed to extract experimental boundary conditions in terms of nodal displacements and to apply them on a finite element model. Numerical predictions have been performed first using an implicit non-linear elastic model then using the “Discrete Ply Model” [10], [11] to model accurately the damage propagation. Promising results have been obtained. The way is now paved to model more complex structures such as stiffened panels with defects (large cuts or impacts). This is the objective of the VIRTUOSE project [12].

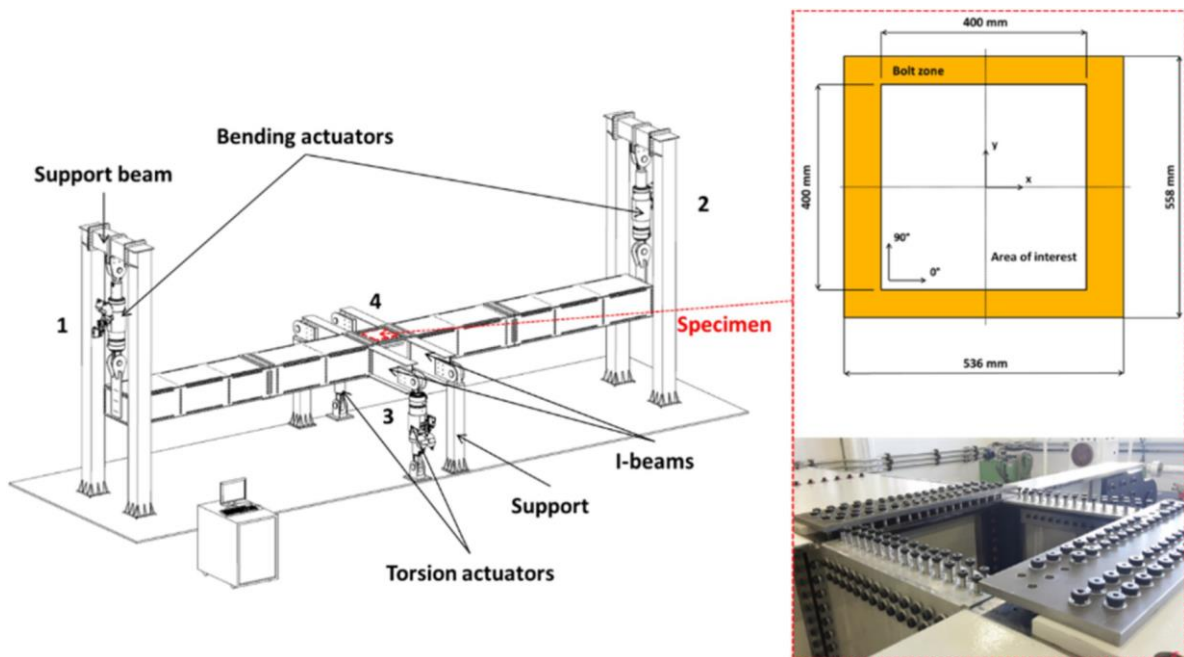


Figure 1: VERTEX test rig and specimen bolting area

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