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Validation of composite joint coupon models using full-field optical measurement techniques

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During the last decades, the use of fiber-reinforced composite materials in aircraft structures and other advanced engineering applications has been widely expanded, due to the inherent advantages of composites over conventional materials, such as aluminium and titanium alloys. The potential implementation of such complex and lightweight material systems imposes additional restrictions specifically when different composite parts are fastened together in order to construct the complete structure. These bolted / riveted joint areas are critical structural elements in designing safe and efficient structures from CFRP materials as they represent the potentially weakest points in the structure. Therefore, the design of the joint can have a large influence over the structural integrity and load carrying capability of the overall structure. Due to these reasons, the mechanical response of composite riveted parts, as well as the three-dimensional (3D) stress and strain fields which occur near the vicinity of the rivet / bolt – hole areas and leads into different macroscopic-failure modes (e.g. bearing, net tension, shear out, pull through) need to be fully understood and examined.

Engineering FE simulations have a significant role in the process of design and analysis of riveted / bolted joints at all scales and aim to provide light-weight, optimised designs. In order to demonstrate structural reliability and provide confidence in design and simulation processes, current practise tents to focus on identifying hot-spots in the data and check if the experimental and modelling results have a satisfactory agreement in these critical zones. The comparison is often restricted to a single or a few points where the maximum stress/strain occurs. This highly localized approach is the result of the traditional strain measurement approaches performed by strain gauges, but neglects the majority of the data generated by numerical analysis and full field measured techniques, carrying with it the risk that critical regions may be missed all together.

In the present work, different composite riveted configurations are examined through finite element analysis and experimental testing. The material used in this study is a UD carbon/epoxy system. All test coupons are made of AS4/8552 laminate comprising 16 plies in a quasi-isotropic layup [1]. The parts are jointed together with titanium countersunk rivets to produce the testing specimen. Some of the tested configurations are presented in the Figure 1.

A novel simulation methodology in the frame of FE, which is based on the stacked shell approach for composite laminates [2], is used for the modelling of the riveted coupons. In the stacked shell approach, one element through-the-thickness of composite material is used to represent one or a small set of plies, while cohesive interfaces are introduced between the elements. The specific methodology offers acceptable computational cost, combined to accurate out-of-plane damage prediction (delamination) and can be potentially combined with

Progressive Damage Modelling PDM approaches. LS-DYNA non linear FE code is used for the coupon simulation, Figure 2, while different representation capabilities of the cohesive zone modelling are examined [3].

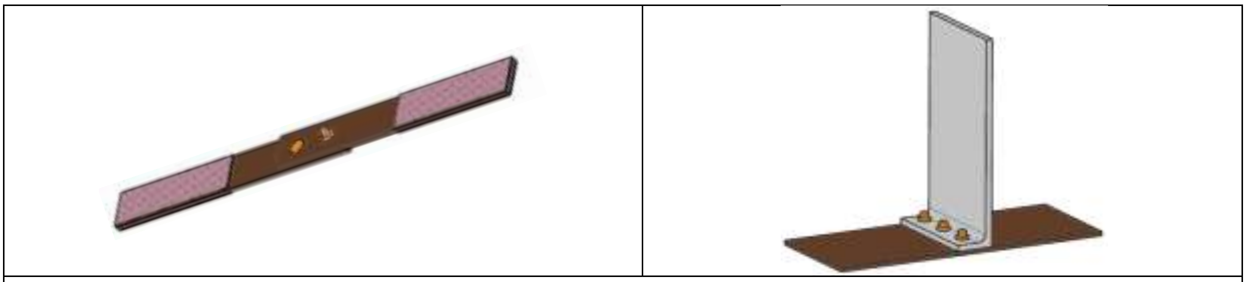

Figure 1: Single –lap double bolt and pull out + bending joint configurations

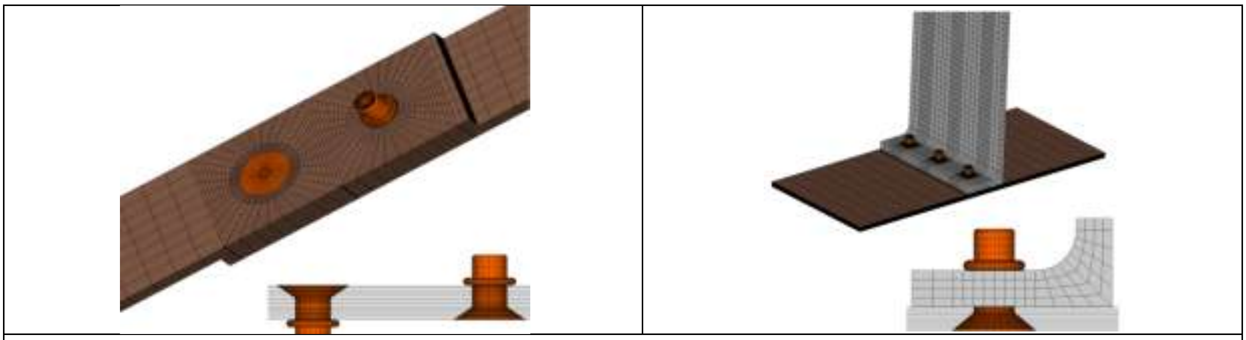

Figure 2: Stacked shell FE modelling of single –lap double bolt and pull out + bending joint configurations

The FE model validation was conducted via experimental tests covered by an advanced full field optical measurements. Specifically, displacement and strain fields are recorded during the experimental tests by the fast 3D Digital Image Correlation optical system Q-450 by Dantec Dynamics [4]; experimental results are successfully compared against the respective numerical results, by an appropriate validation methodology [5]. The recording of full field displacements provided qualitative understanding of damage evolution and allowed for the quantitative validation of the simulation models.

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REFERENCES

[1] SMAES: Smart Aircraft in Emergency Situations, FP7-AAT-2010-RTD-1, 2011-2014.

[2] L. Greve and A.K. Pickett, *Delamination testing and modelling for composite crash simulation*, Composites Science and Technology 66, 2006.

[3] LS-DYNA, *Theory manual*, March 2006.

[4] http://www.dantecdynamics.com

[5] E. Patterson, *A Guidline for the Validation of Computational Solid Mechanics Models Using Full-Field Optical Data*, 2011.