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NUMERICAL APPROACH FOR STIFFENER DEBONDING PREDICTION OF AIRCRAFT COMPOSITE STRUCTURES

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ABSTRACT

Green aviation is a key for the future of the aeronautic industry. So that, light weighting airframe using composite technology is one solution among others, especially for the next generation of business jets. In line with actual regulations and performance objectives, understanding and accurately predicting the different failure modes of composites structures is still a challenge. Modelling the behaviour of structures up to damage, debonding, cracking and failure with finite element computation gives promising results. The present work is carried out in collaboration with labs, which are involved in more academic approaches [6-8] as we focus on industrial applications, adapting academic breakthroughs. A major driver of this work is the need of robustness of the model that has to be fully applicable on complex structures in an industrial context.

This paper describes the way chosen to predict debonding and failure of co-cured stiffened composite structures under out of plane loading conditions, and the identification and validation of the proposed model through comparisons of numerical calculations with tests of increasing complexity.

The baseline behaviour of composite material is orthotropic linear elasticity. Introducing failure mode with non-linear behaviour only concerns dedicated zones (called interfaces) where damage and/or failure occur: bonded and/or localised failure surfaces as showed in figure 2a-2b.
The description of the interface behaviour in finite element was developed with the in-house Elfini finite element software as following:

- Progressive alteration of mechanical properties, modelled by a plastic behaviour
- Final failure of the material, modelled by deleting the broken element from the finite element analysis.

This model requires the identification of this mechanical behaviour in two steps. The first one is plasticity. As composite is strongly anisotropic, we choose a Hoffman plasticity law. The second one is final failure, so that we use an energy-release rate criterion. Hoffman criterion needs 9 parameters, reduced at 2 according to our assumptions, plus stress threshold σ_Y. For final failure, the energy-release rate (Gc) criterion has to take into account the evolutions from mode I (G1c) to mode II (G2c). The rate of mixed-mode is used to obtain Gc with a polynomial law. When the energy-release rates in the element reach the maximum value, failure is declared and the element is deleted from computation.

Identification of all these parameters is carried on following a progressive complexity approach based on complementary experiments and numerical calculations. Elementary specimens (DCB [1], ENF [2], MMB [3-4], Krueger [5]) give a first set of values of the Hoffman plasticity law coefficients and Gc. However, standard tests only consider 0° fibre lay-up whereas aircraft structures may involve more complex lay-ups. Therefore, we use modified specimens with real fibres stacking, so that we identify the actual interfaces behaviour. This is then applied on technological samples such as stiffened

specimens loaded on different ways (3 points bending, transverse traction, pull-out) to evaluate the capability, accuracy and robustness of the model for predicting the failure scenarios.
This work will be further extended to structures altered with damages like impact, to follow propagation of initial defects and evaluate associated residual strength.

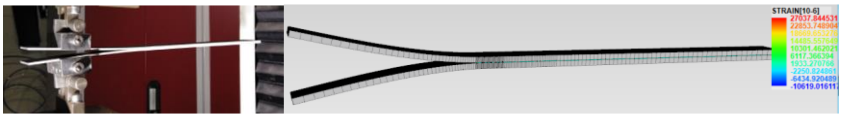

Figure 1: Elementary scale testing: DCB experiment and model.

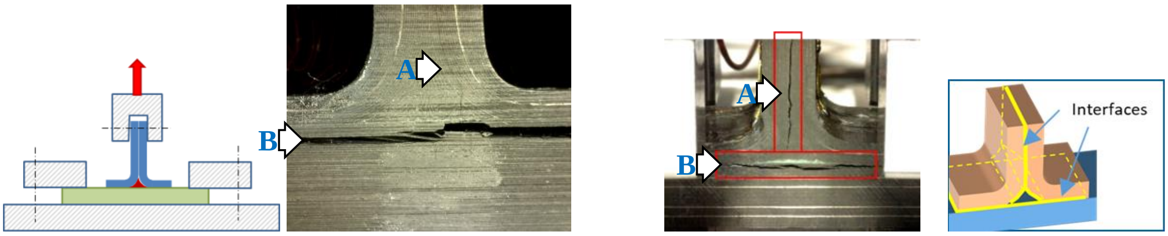

Figure 2a: Experimental pull-out test. (A: first damage, B: final failure).

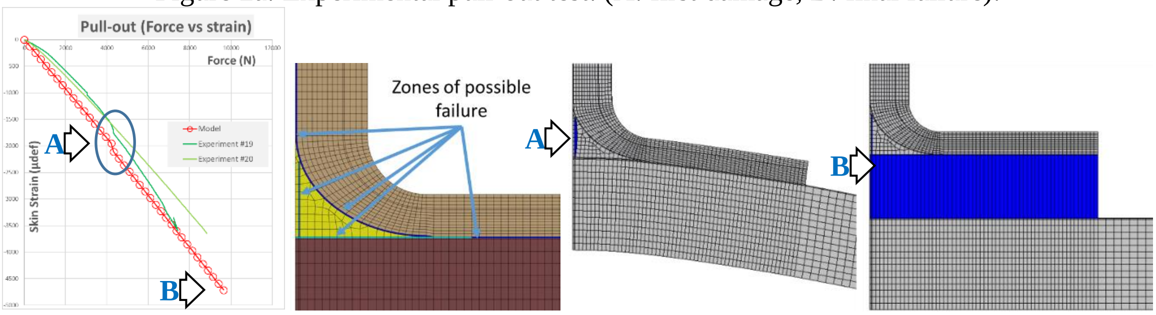

Figure 2b: Comparison of pull-out test experimental and computation results.

Figure 3: Technological sample testing: 3 points bending experiment and model.

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