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Identification of adhesive properties in GLARE laminates by Digital Image Correlation

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ABSTRACT

In this communication, a numerical-experimental procedure is presented to identify elastic and fracture properties of a structural adhesive on the basis of measurements provided by Digital Image Correlation (DIC). A joined assembly for aeronautical applications, produced by ALENIA, is made of a skin and a stringer fastened by an adhesive layer. The stringer and the skin are GLARE® composites with an overall thickness of 1.4 mm. Mechanical properties of the skin and stringer, playing the role of substrates in this joined assembly, are assumed to be known *a priori* with sufficient accuracy.

Non-conventional laboratory experiments have been performed to test the assembly. A Region-of-Interest (ROI), approximately 1 mm^2, was monitored with a camera and a long distance microscope. A sequence of digital images, focusing on the debonding zone of the interface layer, was processed by a DIC software, in order to re-construct incrementally the relevant sequence of displacement fields. The hierarchical DIC code adopted in this study [1-2] has particular features. (i) To increase robustness and accuracy of the image matching algorithm, correlation is performed hierarchically, by processing all the elements of a given size contained within the reference and deformed images, starting from the coarsest up to the finest level. Progressively, finer details are introduced in the analysis as the displacements are more and more securely and accurately determined. (ii) The code is based on a Galerkin, finite-element discretization of the displacement field, with Q4-(bilinear) shape functions. (iii) A specific procedure is available to update the reference image (and the adopted mesh), and to cumulate the estimated incremental displacements. Figure 1 shows a camera picture of the monitored region, and the displacement field normal to the adhesive layer, detected by DIC.

The experiments were simulated through a plane-strain finite element model. Mixed-mode debonding along the adhesive interface was modeled by elastic-cohesive finite-layer elements. Displacements measured along the boundary of the ROI were used as input for the numerical model, whereas the displacements inside the ROI, close to the adhesive layer, are utilized for identification purposes. The optimal parameters governing the elastic-cohesive response of the adhesive layer were estimated as a solution

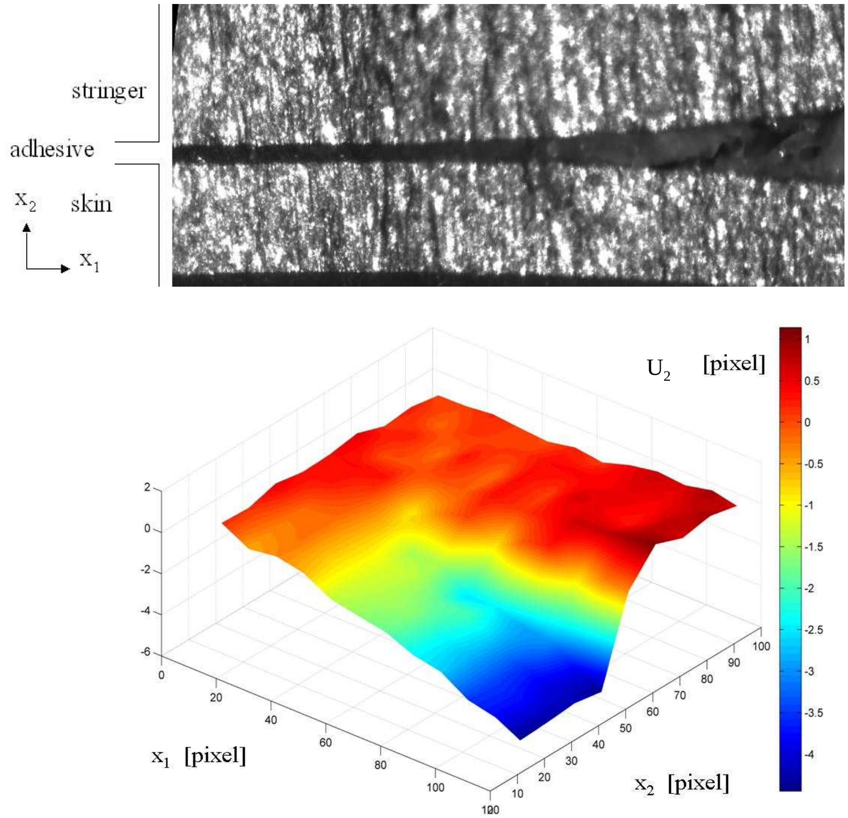

Figure 1: Fracture propagation along the interface layer: camera picture and displacement field detected by DIC. All dimensions in pixels, 1 pixel $= 1.5\ \mu$m.

of a nonlinear mathematical programming problem, in which a suitable least-squares (batch) objective function is minimized, quantifying the discrepancy between the experimental (measured) quantities and those computed by means of the model as a function of the unknown parameters [3]. The minimization is performed by means of a gradient-based, ”Trust Region” algorithm, allowing for box-constraints by an interior-point approach [4]. The repetitive computation of the sensitivity matrix, namely the gradient of the measurable quantities with respect to the unknown parameters, is performed through a Direct Differentiation Method by the same finite element code employed for forward analyses, with a low additional cost.

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