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Material model calibration for anisotropic elastic-plastic free-foils by cruciform tests, full-field measurements and inverse analysis

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Membranes and foils are more and more frequently employed in diverse technologies and engineering fields. In particular, thin foils of aluminium, polyethylene and other materials are generated and associated into laminates in factories which produce food containers. Free-standing foils with obviously different thicknesses and internal microstructures (usually textile embedded in polymeric layer) are widely employed in dam engineering as geo-membranes apt to prevent water infiltration and in architecture as membranes in tension structures and hanging roofs. Also most products of the paper industry have to be subjected to laboratory tests apt to assess properties such as elastic moduli, yield limits and possibly hardening coefficients of these usually anisotropic (mostly orthotropic) materials. Despite substantial differences, industrial products consisting of free foils exhibit usually anisotropic elasto-plastic properties which can be described by qualitatively similar constitutive models [1, 2, 3] to be calibrated by versatile procedures suitable to a routine applications in industrial environments.

Standard testing to assess material parameters requires specimens with a well-defined standardised geometry. For orthotropic material properties, different tests are needed in order to identify the parameters which quantify all the mechanical properties described by the material model. Actual structural components manufactured in factory or used in engineering practice are frequently submitted to complex (two- or three-axial) stress fields and therefore material models sometimes cannot be accurately calibrated by standard uniaxial testing. In those cases, inverse methods for material parameter assessment can improve the calibration.

The advantage of the inverse method is that non-standardised specimen geometries, boundary conditions, complex material models and the quantities to measure can be freely selected on the basis of sensitivity analysis. From an experimental point of view, the progress made during the last decade in the domain of optical full-field displacement measurement techniques now allows the experimental determination of complex strain fields. The aim of the method presented is to identify a multiplicity of material parameters, both elastic and inelastic on the basis of a single experimental set-up and by means of efficient fast and inexpensive computational procedure of inverse analysis. In the recent past several attempts have been made to identify material parameters based on inverse modelling of different experimental set-ups, see e.g. [4, 6]. Also the use of full-field measurement methods for the characterisation of orthotropic materials has been intensively studied by different authors [5, 6].

The method presented herein for the parameter identification of an orthotropic material is based on measurement of the displacements in the central part of a cruciform specimen subjected to biaxial loading. A biaxial tensile test is performed on a cruciform specimen with a hole (see Fig. 1) intended to make non-uniform the strain field. The responses of the system, i.e., the surface displacements are measured with Digital Image Correlation (DIC). A finite element model of the perforated specimen is used to generate so called "training examples" used for training of Artificial Neural Network (ANN) which represents a collection of M measurements $\mathbf{x}^m$. A collection of N training examples (also called "patterns" or "snapshots") generated by changing parameters on which the field depends, are stored in rectangular $M \times N$ matrix, (snapshot matrix). The whole process can be summarized as follows: (a) the "direct" problem is final element discretized and solved numerically; (b) the output of the system is represented by the discrete values obtained from the calculation which are sorted and stored in a vector $\mathbf{x}^n$; (c) the simulation is then repeated for N different input vectors $\mathbf{t}^n$, and the output vectors are sorted in a matrix $\mathbf{X}$. For all simulations the same discrete model is used, and only the input parameters are varying. Besides the snapshot matrix, another matrix should be kept, called targets matrix $\mathbf{T}$, which collects the sets of parameter vectors $\mathbf{t}^n$ used as input in the simulations. The ANN trained once for all by the above described techniques later can be used economically and routinely on a "small" computer for fast parameter identification.

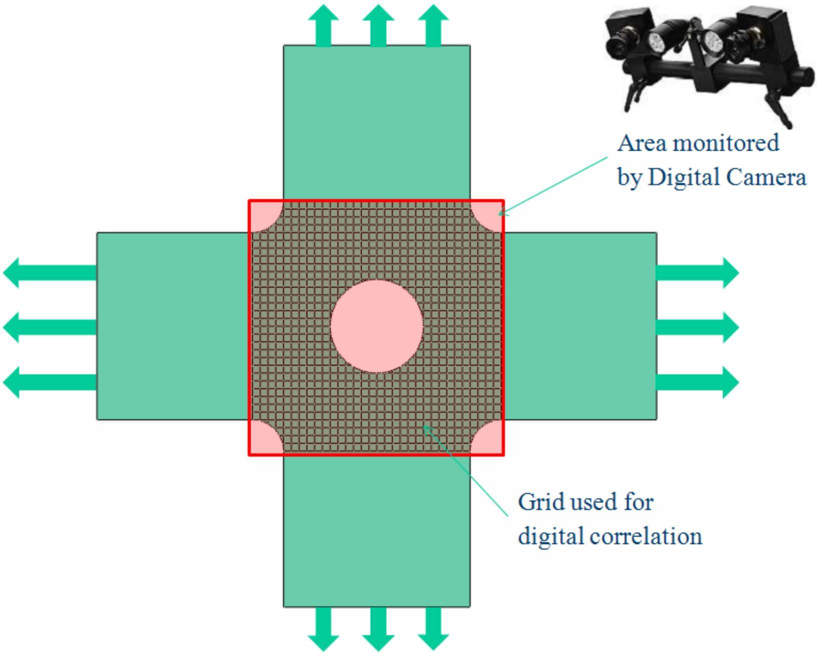

Figure 1: Cruciform-shape specimen with a hole

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