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MECHANICAL CHARACTERIZATION OF FREE-FOILS BY CRUCIFORM TEST AND FULL-FIELD MEASUREMENTS

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1 INTRODUCTION

The industrial production of foils to various purposes (e.g., paper, cardboards, metal sheets, membranes) usually gives rise to anisotropy in mechanical properties. Such properties are substantially affected by the manufacturing process and turn out to be meaningful in applications; their realistic accurate description by constitutive models is a recurrent practical problem.

The purpose pursued in this study is a contribution to novel methods for the calibration of orthotropic elastic-plastic models for paper and paperboard.

The experiments referred to here have the following features: (A) tests on cruciform specimens with a central hole to increase the non-uniformity of the stress fields generated by the tractions at the arm ends; (B) full-field measurements of in-plane displacements by Digital Image Correlation (DIC).

Test simulations are performed by conventional Finite Element (FE) structural analyses using the commercial code Abaqus.

The popular Xia-Boyce-Park (XBP) model [1], at present employed in various industries, is considered in a marginally modified version, characterized by a simpler non-linear hardening law and by 12 parameters to calibrate in biaxial tension situations. On the basis of full-field (pseudo-) experimental data achievable by DIC, the parameter identification is carried out by a “Trust Region Algorithm” (TRA), namely by minimizing the discrepancy function through a popular mathematical programming procedure which requires first derivatives of the objective functions.

Here the inverse analyses are “pseudo-experimental”, namely: reasonable values are attributed to the parameters, which represent the “targets” to be identified; the measurable quantities are computed and employed as input: resulting estimates are compared to the pre-assumed parameters as validation of the identification procedure.

Minimization of the discrepancy function by TRA evidences the identifiability of the parameters in the simplified XBP model by a single cruciform test and DIC measurements. An alternative inverse analysis procedure is developed based on Proper Orthogonal Decomposition (POD) in view of the correlation of the specimen responses (“snapshots”) to tests with different but reasonable parameter sets.

A preliminary computational effort consisting of POD (details e.g. in [2]) is employed for the generation of suitable input to a suitably optimized Artificial Neural Network (ANN) (details e.g. in [3]) which is "trained" and tested in order to make it a tool (implemented into a software for small computer) for economical and fast identification of the sought parameters.

Two kinds of ANN are developed in order to provide parameter estimates in the simplified XBP anisotropic model. Such procedure turns out to be apt for the parameter identification in a relatively inexpensive and routine fashion in an industrial environment, as evidenced by comparative numerical exercises.

Some comparisons will be pointed out with an alternative quite different approach to the mechanical characterization of free-foils in industrial environments; this "membranometric" procedure based on foil specimen pressurization has been recently presented in [4], with limitations on the number of parameters to identify. Prospects of future research will be briefly discussed at the end of this communication.

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