MECHANICAL CHARACTERIZATION OF FOILS WITH COMPRESSION IN THEIR PLANES

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Summary Identification of parameters in material models governing inelastic behaviour of foils under in-plane compression is considered to the purposes of food containers production. The novelties of the proposed procedure with respect to the state-of-the-art are: specimen stabilization by a “sandwich” apparatus; Digital Image Correlation measurements along the specimen and on surrounding surface of the stabilizing elastic “blocks”; Proper Orthogonal Decomposition for inverse analyses requiring sequences of test simulations in order to minimize a discrepancy function.

EXPERIMENTAL FEATURES

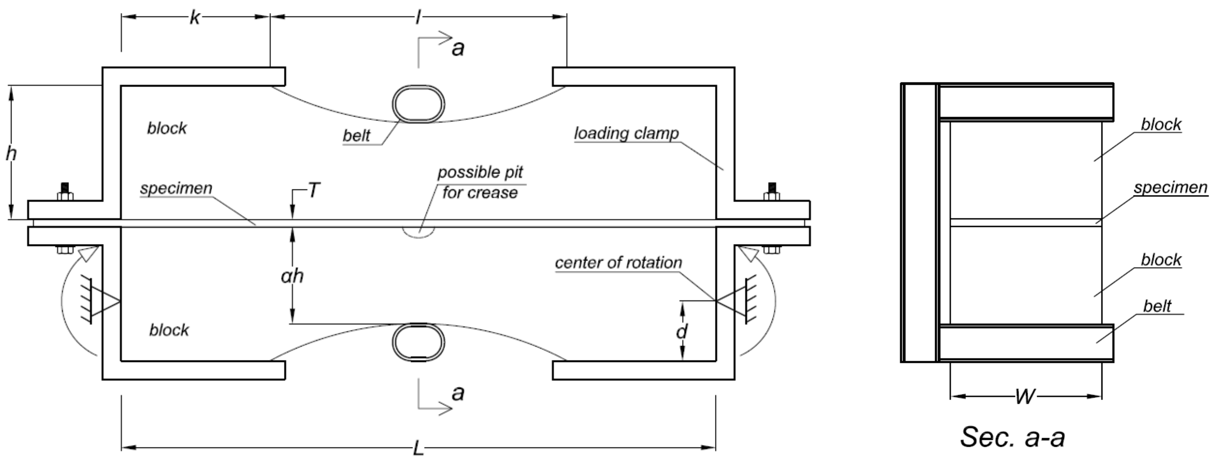
Paperboards or laminates as walls of containers are subjected also to compression in service (not only to tension, bending and shear already dealt with in the available literature, see e.g. [1] [2]). The laminate behaviour in the presence of compression, if compared to that (more frequent) under dominant tension, exhibits two features: there may be remarkable differences in the nonlinear inelastic range; it is obviously difficult to test with compression in view of specimen instability and wrinkling.

A contribution to solve the above practical problem is the purpose of the study presented herein.

The novel experimental equipment called “sandwich system” is schematically shown in the figure and can be briefly described as follows.

A rectangular specimen of the foil is inserted between two stabilizing components (“stabilizers” or “blocks”) of polymeric material with elastic behaviour accurately known “a priori”.

Stabilization of the specimen is achieved also by a transversal “belt” with a stiff vertical connection on the back side of the “sandwich”. The external actions consist of imposed rotations of two rigid metallic clamps; the hinges for such rotations are placed in order to achieve in the foil specimen a chosen combination of compression and bending. Symmetry with respect to the central vertical transversal plane is preserved by the stabilization of the specimen.



At each step of the planned rotations, many displacements are measured by the Digital Image Correlation technique (see e.g. [3]); computer simulations of the test are performed by a finite element commercial code, first for sensitivity analyses apt to design and optimize the procedure; subsequently for a Proper Orthogonal Decomposition procedure (e.g. [4] [5]). A test simulation is performed for each one of the grid nodes pre-selected in the space of the sought parameters within the “search domain”.

INVERSE ANALYSIS

Inverse analysis means here minimization, with respect to the sought parameters, of a “discrepancy function” between the experimental data and their counterparts computed as functions of the sought parameters. Such inverse analysis is

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performed by a popular mathematical programming algorithm, specifically here by a “Trust Region Algorithm” implying a sequence of steps, each one reduced to the solution of a quadratic programming in two variables, with Hessian approximations requiring only first-order derivatives (approximated by forward differences). The discrepancy minimization is here made fast and economical through the exploitation of the preparatory POD results by means of radial basis functions interpolations of “amplitude” vectors representative of measurable quantities vectors but with much reduced dimensionality.

For the above parameter identification by “sandwich tests” on a compressed and bended specimen, a “fictitious homogeneous material” is attributed to the foil and its behaviour is described by an anisotropic elastic-plastic Hill model. Subsequently, a fast transition to generalized variables is performed by adopting a traditional elastic-plastic beam model with isotropic hardening.

The present parameter estimation in two phases (first on the whole “sandwich” modelled as a heterogeneous continuum, then on the beam model) has been suggested by limitations of some popular finite element commercial codes.

CONCLUSIONS

Further developments in progress concern optimization of the novel sandwich geometry for each category of free-foils employed by the containers industries. Homogeneity assumption of the specimen is preserved, since modelling of laminates as a layer set is not suitable to practical purposes because of unpredictable changes in local properties of layers and interfaces due to the production processes.

The preliminary design of the experimental-computational method proposed herein rests on numerical validations only. Final design and realization of the operative equipment are likely to follow in the frame of the current collaboration with TetraPak company producing food containers.

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