Identification of Hyper-viscoelastic models from one heterogeneous test for elastomers

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Abstract. In this work, the identification of Hyper-viscoelastic models of elastomers is performed from only one heterogeneous relaxation experiment performed with a cruciform specimen. The identification procedure is based on the so-called Finite Element Model Updating (FEMU) technique. Even though the experiment induces heterogeneous kinematic fields, only the measured and predicted global force at the specimen edges has been used in the residual to be minimized. The minimization problem has been solved by using of the Inverse-PageRank-Particle Swarm Optimization (I-PR-PSO) algorithm. It has been found that such identification procedure coupled with the heterogeneous relaxation experiment were sufficient to identify both hyperelastic and viscoelastic parameters. The capability of the proposed methodology has been assessed by comparing both kinematic fields and global forces obtained experimentally and by using of the identified parameters. It has been found that the identified parameters predicted well the experiments, even the ones not used in the identification procedure.

Introduction. Thanks to their high elasticity, high damping and high elongation at failure, elastomers are widely used in several engineering applications such as automotive, aerospace and civil engineering applications. The mechanical behaviour of such material is modelled generally within the framework of hyperelasticity. The time-dependent character of the behaviour is modelled by associating a viscoelastic part to the instantaneous hyperelastic response; see [1] and references therein. This viscoelastic part is represented in terms of a Prony series. Classically, the hyperelastic parameters are identified from homogeneous experiments namely equi-biaxial tensile, pure shear and simple extension. In the recent years, a new method has been applied to perform the identification of hyperelastic models. It is based on performing one heterogeneous experiment, which induces several loading cases with a large strain distribution for each loading case. The hyperelastic parameters are identified either by the FEMU [2,3] or the Virtual Fields Method (VFM) [4,5]. On the other hand, the viscoelastic parameters are identified by using stress relaxation experiments at low strain levels following the assumption that nonlinear viscoelastic models should coincide with the linear viscoelastic model of Boltzmann in the small strain domain. In the present work both hyperelastic and viscoelastic parameters are identified from only one heterogeneous test of equi-biaxial tensile of a cruciform elastomer specimen. The identification is performed with the FEMU method by using the I-PR-PSO optimization.

Methods. The experimental setup is reported in Fig.1. It is composed by a biaxial tensile machine, a CCD optical camera, the cruciform elastomeric specimen and LED lighting system to ensure homogeneous distribution of cold lighting during the test. An equi-biaxial displacement of $70\,mm$ is applied to the four branches of the cruciform specimen at the same loading rate of $500\ mm/min$. This loading was followed by a $60\ s$ relaxation in order to highlight the viscoelasticity effects. During the experiment both the global forces and kinematic fields were measured. The latter were measured using DIC with 7D© Software. The FEMU method used in this work is based on the minimization with respect to the constitutive parameters of the global force between the experiment and numerical simulation of the experiment. During the identification process, the constitutive parameters are modified by the PSO following the objective function formulated in terms of the difference of the global forces. The objective function used in this work reads as follow:

$$\sum_{i=1}^{n}\left(\frac{F_{exp,i}-F_{num,i}}{F_{exp,i}}\right)^2, \qquad (1)$$

where the subscript (exp) and (num) corresponds to experimental and numerical data, respectively. At the end of the optimization process the retained parameters are the ones minimizing the objective function of Eq. 1.

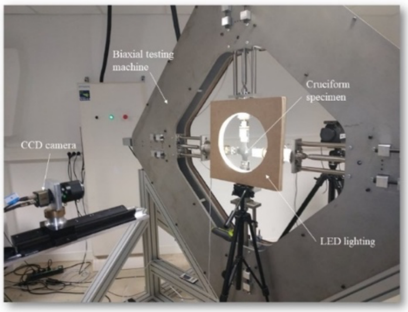

Figure 1: experimental set-up

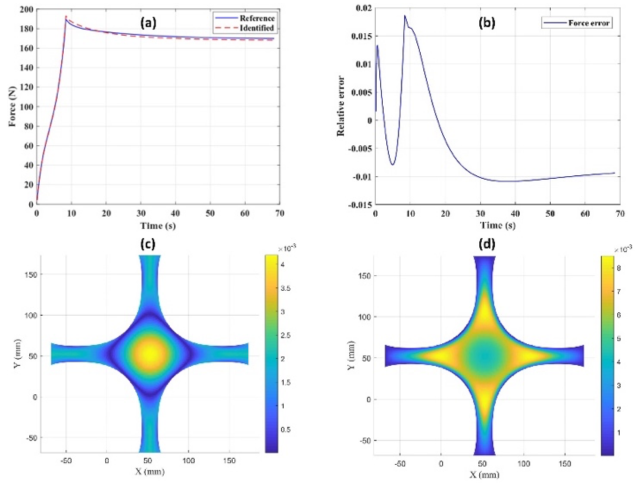

Figure 2: comparison of the obtained results with the reference data: **(a)** global force, **(b)** relative error of the global force, **(c)** relative error of the first in-plane principle stretch and **(d)** relative error of the second in-plane principle stretch

Results. The results of the identification procedure are the hyperelastic and viscoelastic constitutive parameters. The accuracy of the identified parameters to predict the experiments is assessed through the comparison of the global response force and kinematic fields. Fig. 2 shows these results. The relative error for the force is inferior to $2\,\%$ and under $1\,\%$ for the kinematic fields. These results have been obtained with simulated data and will be applied to real experiment data. It can be concluded that this identification procedure enables us to identify both hyperelastic and viscoelastic parameters with only one experiment and without full field measurement.

Conclusion. The identification of the hyperelastic and viscoelastic parameters from only one heterogeneous relaxation experiment is performed by using only the general force response. The method has been applied to both generated and experimental data and showed good results in terms of the ability to predict both the general force response and kinematic fields.

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