A structure-based data-driven nonlinear elastic model based on WYPiWYG hyperelasticity

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ABSTRACT

Modeling the behaviour of rubber-like materials is essential to design and to calculate some industrial components and to understand the behaviour of soft biological tissues. A rubber-like material can be regarded as a network of polymer chains. The uncoiling of these chains under loading results in a non-linear elastic response in the range of finite strains. True elastic (conservative) behaviour requires the fulfilment of Bernstein’s integrability conditions, which are automatically fulfilled through the hyperelasticity theory, assuming the existence of a strain energy potential. Traditionally, the shape of this energy function is predefined in terms of certain parameters which are obtained fitting the experimental results through optimization techniques. The models developed using this technique can be classified into phenomenological and structure-based models. The main difference between them is that structure-based models establish the macroscopic strain energy function as a direct function of the behaviour of the microstructural components. Furthermore, they need fewer tests to produce more reliable results under any loading condition. For isotropic materials, the phenomenological Ogden model and the structure-based eight-chain model are two widely used examples. The eight-chain model is based on Langevin statistics of chain configurations. Its most salient feature is that it can reproduce the overall response of isotropic materials with only two materials parameters obtained from a tensile test.

In contrast to these approaches, phenomenological WYPiWYG hyperelasticity has been formulated to determine numerically the macroscopic energy function. This function is obtained with high accuracy without predefining the shape of the energy function and, therefore, without accounting for any material parameter [1],[2].

In this work, a micro-structural data-driven model based on WYPiWYG hiperelasticity is proposed [3]. The model may be characterized with a single test. Thereafter, the predictions obtained with the model for general deformations improve substantially those from other phenomenological and structure-based models [4]. To this end, the behaviour of a single fiber/chain from macroscopic tests, under certain deformation conditions, is obtained. Then, assuming an isotropic distribution of fibers/chains, a continuum-based constitutive manifold is developed to reproduce efficiently, in any finite element program, the response of the solid under any loading condition.

REFERENCES