A new micro-macro transition for hyperelastic materials

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Various classic hyperelastic models fail to describe the stress response of hyperelastic materials in multi-axial loading conditions. To address this fundamental issue, we propose a new micro-macro transition for hyperelasticity modeling based on the Biot chain stretch, which is further integrated into the full network model. For a Gaussian chain distribution, this new mapping scheme yields an explicit one-parameter hyperelastic model in terms of principal stretch. The model achieves remarkable success in capturing the stress response in multi-axial deformation modes for soft materials with absence of strain stiffening effect, which is beyond the capability of the widely used neo-Hookean model. A new two-parameter hyperelastic model is further developed by combining the new micro-macro transition and non-Gaussian chain distribution. Compared with other hyperelastic models based on Langevin statistics, such as the eight-chain model, affine microsphere model, and equilibrated nonaffine microsphere model, the predictive ability of our new model on complex loading modes has been greatly improved. The new model is also implemented for finite element analysis, which shows the ability to capture the response of soft materials with heterogeneous strain distribution. In all cases, the parameters in the models based on the new micro-macro transition can be determined through the data of uniaxial loading tests, along with the behavior in other loading modes being well forecast, which is a challenge for various other existing hyperelastic models. Within the full network framework, this novel micro-macro transition is shown to properly capture the inherent correlations between different deformation modes, which may advance fundamentally modeling hyperelasticity and other constitutive behaviors for soft materials.

Reference:

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