20th European Mechanics of Materials Conference - EMMC20
Florence, Italy | May 27th-29th, 2026
www.emmc20.unifi.it

A discussion of preconditioned experimental data in constitutive modeling

Maximilian P. Wollner[1], Gerhard A. Holzapfel[2]

[1] Graz University of Technology, Austria. wollner@tugraz.at
[2] Graz University of Technology, Austria. holzapfel@tugraz.at

Paper ID: 22
Symposium S1: Mechanical behavior of polymers and biopolymers: theory, simulations and testing

Abstract

The mechanical behavior of a wide range of polymers and soft biological tissues is characterized by a damage mechanism referred to as the Mullins effect. From an idealized point of view, these materials exhibit an initial stress response upon primary loading, which is then permanently softened in unloading and reloading until the previous maximum level of loading is exceeded again [1]. Several constitutive models have been proposed for the description of the Mullins effect [2,3]. It is nonetheless common to disregard this type of softening based on the observation that repeated cycling leads to stable material behavior, i.e., additional cycles do not significantly alter the stress trajectory [4,5]. In many works, a constitutive model is then fitted to this stable but damaged material response without explicitly resolving the Mullins effect. For such a simplification to hold, the following is tacitly assumed: the maximum loading that a material point experiences during a general deformation is comparable to the maximum loading in the experiments used for calibration. In this contribution, we investigate the validity of the aforementioned assumption. To this end, we calibrate two distinct material models using the same set of experimental data. One model explicitly resolves softening and is therefore calibrated to the entire data set. The other model is only fitted to a single unloading and reloading cycle, neglecting primary loading and the Mullins effect. We then compare the predictions of both material models in a boundary-value problem not previously used in calibration. The subsequent discussion of the results highlights the interplay between theory and experiment.

References: [1] L. Mullins, 1948. Effect of stretching on the properties of rubber. Rubber Chem. Technol. 21, 281--300. [2] S. Govindjee and J. C. Simo, 1991. A micro-mechanically based continuum damage model for carbon black-filled rubbers incorporating Mullins' effect. J. Mech. Phys. Solids 39, 87--112. [3] E. A. De Souza Neto, D. Perić, and D. R. J. Owen, 1994. A phenomenological three-dimensional rate-independent continuum damage model for highly filled polymers: Formulation and computational aspects. J. Mech. Phys. Solids 42, 1533--1550. [4] L. R. G. Treloar, 1944. Stress-strain data for vulcanised rubber under various types of deformation. Trans. Faraday Soc. 40, 59--70. [5] S. Budday, G. Sommer, C. Birkl, C. Langkammer, J. Haybaeck, J. Kohnert, M. Bauer, F. Paulsen, P. Steinmann, E. Kuhl, and G. A. Holzapfel, 2017. Mechanical characterization of human brain tissue. Acta Biomater. 48, 319--340.

Keywords:

constitutive modeling Mullins effect damage mechanics mechanical preconditioning predictive power