Rubber multi-physics based on the analytical network-averaging concept

Vu Ngoc Khiêm[1], Mikhail Itskov[2]

[1] *Department of Continuum Mechanics, RWTH Aachen University, Germany, vu@km.rwth-aachen.de*
[2] *Department of Continuum Mechanics, RWTH Aachen University, Germany, itskov@km.rwth-aachen.de*

Continuum mechanics serves as the foundation of macroscopic theories of matter. It has become a powerful tool for analyzing engineering and physics problems. The continuum approach however neglects the discrete nature of matter, which consists of atomic and subatomic particles. Therefore, the application of continuum mechanics at multiple scales requires proper mathematical averaging equations. In this contribution, an attempt to bridge the gap between macroscopic and microscopic response of rubber multi-physics (such as damage, phase transition and electromechanical coupling) is made by means of the analytical network-averaging concept [1].
The concept postulates the existence of a probability distribution of polymer chains in the rubber network. The spatial arrangement of polymer chains is driven by external fields and consequently alters the mean field quantities. Nano-electronics study [2] reveals a mesoscopic separation between the worlds of quantum and continuum mechanics. Therefore, the mesoscopic deformations on the subnetwork level are computed by averaging the macroscopic deformations over the unit sphere. Whereas, the meso-micro bridging between the subnetwork and the single chain is done by a mesostretch amplification that is essential to capture the elastic limit of the polymer network.
In contrast to the previous works in rubber multi-physics, the free energy of polymer chains is developed from a closed-form of Rayleigh's exact non-Gaussian distribution function based on quantum mechanics. Thus, the inverse Langevin function is entirely bypassed. Furthermore, microscopic deformation measures and inelastic evolutions are analytically evaluated. As a result, a single physically-based constitutive model is obtained and demonstrates excellent agreement with all measurable experimental data of different types of polymer. From the computational point of view, this unified approach is of highly advantageous as only one finite element code is required for predicting a wide spectrum of multi-physics behavior of rubber (e.g. mechanoluminescence, strain-induced crystallization and electroelasticity)

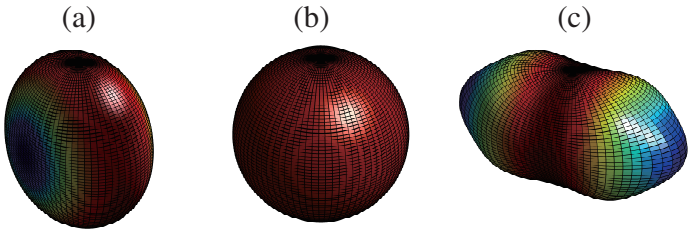

FIGURE 1 – Illustration of the spatial distribution of polymer chains for examples for : (a) stress softening, (b) rubber elasticity, and (c) strain hardening.

Références

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