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A FULLY MICROMECHANICAL MOTIVATED MATERIAL LAW FOR FILLED ELASTOMER

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Filled elastomers show a broad band of mechanical behavior, like Mullins effect and frequency depended damping. There are many available material models which describe this effects in a phenomenological way. A few material models are directly derived from the micromechanics, but there is no implementation of material tangent for FEM program use. To overcome this problem a new implementation of a micromechanical motivated material law is introduced. The main idea is to decompose the material into chain-chain network, chain-filler network and free chains, see Figure 1. The Mullins effect results

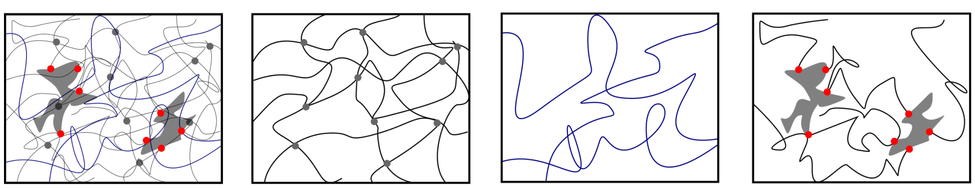

Figure 1: Network decomposition concept, grey curves: connected chains, grey dots: connection points, blue curves: free chains, red dots: chain-filler bonding, grey areas: filler particle

from continuous deboning of chains from the filler particle during virgin loading. The free energy function Ψ_D can be constructed for one dimension [1]

$$\Psi_D = \int_{N_{\min}}^{N_{\max}} P(N)\Psi_K(N,\lambda)\mathrm{d}N \tag{1}$$

where $P(N)$ describes the probability density, that the Nth chain element is connected to a filler particle and $\Psi_K(N,\lambda)$ is the free energy function of a single chain depending on chain length N and stretch λ. The free energy of a single chain is calculated by loss of entropy during stretching. Since the function $P(N)$ is to complicated integration can not be carried out analytically, therefore a polynomial approximation is introduced. Now the integral can be solved analytically and the derivative with respect to stretch can be calculated. Since the minimal available chain length N_{min} depends on the maximal stretch, it can be treated as an inner variable. To obtain a three dimensional material law integration on a unit sphere is carried out and the framework presented in [2] is applied. This approach shows good results and captures even the strain introduced anisotropy in Mullins effect, see Figure 2.

The frequency depended damping can be described by diffusion process of free chains

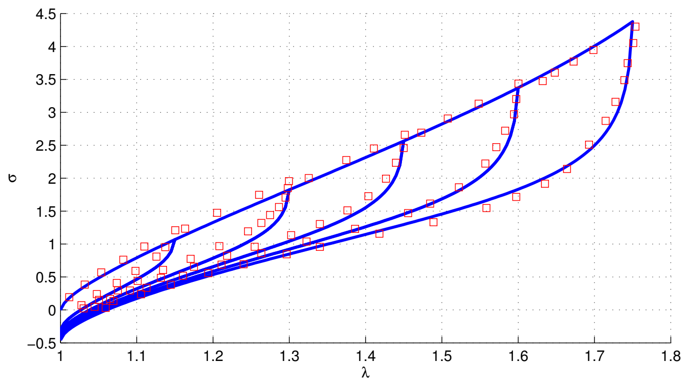

Figure 2: Stress strain curve for uniaxial loading for carbon black filled elastomer, blue curve: calculation, red squares: measurement, test data taken from [1]

c.p. [3]. This leads to a one dimensional diffusion equation. The solution of this equation is turned into a computable form for the three dimensional material law.
Finally the material description is the sum of the decomposed material chain-chain network for elastic response, chain-filler network for Mullins effect and free chains for frequency dependent damping. All material parameters have a physical meaning, so it is possible to develop new materials by virtual testing and a better understanding of filled elastomer material is achieved.

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