From Rubber Material to Rubber Components – Phenomena and Modeling Challenges

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1 Introduction

Rubber is a widely used material in engineering. As part of different components such as rubber bearings, engine mounts, tires or belts, rubber is commonly used to transfer and damp mechanical loads under cyclic conditions. Besides temperature, other influence fields (e.g. electromagnetical, chemical etc.) may affect the mechanical behavior of rubber and its evolution during service life. From an engineering point of view and with a focus on reliability, safety and cost aspects, a deep understanding of the rubber behavior in a multiphysical environment is of high interest. In this contribution, recently developed numerical simulation strategies involving different forms of thermo-mechanical couplings and numerical representations of material as well as structural changes over time of rubber components are presented.

2 Phenomena and Modeling Strategies

Starting on the material scale, an overview with respect to the constitutive modeling of rubber material (hyperelasticity, viscoelasticity, elastoplasticity) is given [7]. Due to the afore-mentioned inelastic material properties of rubber, mechanical input energy is steadily transformed into heat energy during cyclic loading (dissipation). In consequence, attention is paid to the temperature-dependent description of the mechanical behavior of rubber by considering the temperature and displacement field. Different coupling strategies in the form of strongly and weakly coupled solution schemes are presented to thermo-mechanically analyze e.g. cyclically loaded rubber bearings [1] or steady state rolling tires [3] by means of the finite element method (see figure 1).

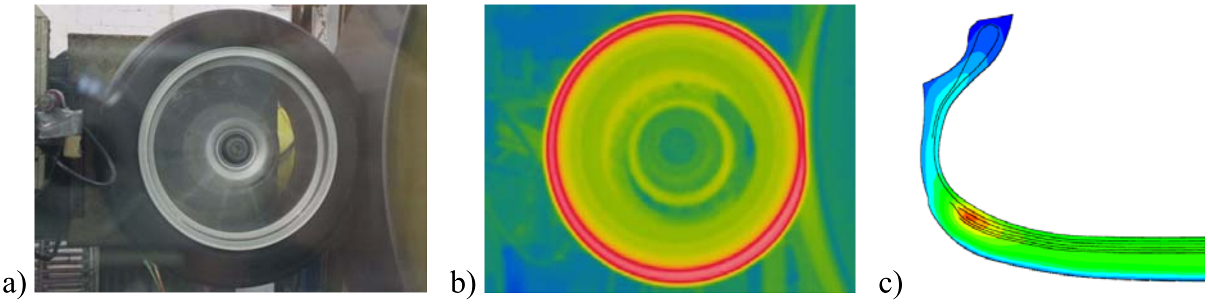

Figure 1 – Self-heating of a steady state rolling tire: a) tire on drum test rig; b) image taken from infra-red camera; c) simulated cross-sectional temperature profile (FE model)

To capture topological changes in the form of evolving cracks, different numerical strategies have been developed. Besides the characterization and representation of discrete cracks in inelastic elastomers at large deformation via the material force approach [8] or a scaled boundary finite element based approach for elastomers [4], a phase field approach [9] is discussed. To take into account the experimentally revealed increase in crack growth resistance due to strain-induced crystallization in strain-crystallizable rubber, a finite element based model for time- and temperature-dependent strain-induced crystallization has been developed based on the experimental observations reported in [5].

With elapsing time, irreversible material transitions and, in consequence, structural alterations may occur, i.e. in the form of ageing. As subphenomena, thermally induced ageing [2] as well as a model for material changes due to ageing-induced fracturing [6] are discussed.

3 Conclusions

Various highly developed models for special (sub)phenomena in rubber and rubber components have been developed over the last years and are still the object of current research. To face the growing demand of more and more realistic and "complete" models for the real multiphysical behavior of rubber components, interactions and couplings are studied by advantageously combining previously developed submodels in combination with adequate solution schemes.

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