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A MULTISCALE CONTINUUM MODELING OF CAVITATION DAMAGE AND STRAIN INDUCED CRYSTALLIZATION IN RUBBER MATERIALS

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Elastomers are important materials and widely used in many engineering applications, e.g., tires, springs, dampers, gaskets, bearings, oil seals, etc. Fracture and damage mechanics in elastomers are of great importance in the design process and it is fundamental in some applications such as adhesion technology, elastomers wear, etc.
Under deformation, rubber materials experience remarkable inelastic changes in their properties that are the stress softening (Mullins softening effect), hysteresis, permanent set and induced anisotropy. The experimental investigations have shown that these changes are associated with the development of cavitation damage and crystallization. Further, in the context of fracture mechanics, the creation of new crack surfaces process is associated with a complex process zone in the crack tip vicinity in which the cavitation and crystallization take place.

In this work, a multiscale continuum model for cavitation damage and strain induced crystallization is presented. A homogenization over a microscopic representative volume of a unit sphere is used to model cavitation damage and strain induced crystallization separately.
The cavitation damage is modeled as a growth of a pre-existing spherical cavity. The material around the cavity is assumed to be incompressible and defined by a strain energy function assuming affine full network approach. Hence, the deformation in spherical representative volume element is determined by a kinematically admissible deformation field. The cavity growth is modeled using energetic based evolution law.
In the stress-free state the rubber material is considered to be fully amorphous and the constitutive behaviour is given by a strain energy function assuming affine full network approach (similar to the case of cavitation). A phenomenological law is assumed to provide the crystallite nucleation law. The model is capable to determine the anisotropic crystal structure as well as the nucleation, growth and melting of the crystallite.

In comparison with experiments from a uniaxial tensile test, the model is able to predict the stress-stretch behaviour of including the hysteresis and the crystallinity. Further, the model provides a good understanding of two important phenomena and models the damage in rubber materials.