A network alteration model to describe and predict the thermal aging effects on the viscoelastic behavior of carbon-filled SBR

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Abstract:

The present work presents a predictive network alteration constitutive model for filled rubbers subjected to thermal aging. Experimental observations are reported on the thermal aging effects on the finite-strain viscoelastic response of carbon-black filled styrene-butadiene rubber (SBR) containing different filler fractions. Multi-relaxation cyclic experiments show that the thermal aging induces an increase both in elastic stiffness and in hysteresis area, these features being dependent on the aging temperature and the aging time. The rubber matrix is decomposed into cross-linked chains, source of the purely elastic response, and superimposed free chains, source of the viscosity. The amplified effect of the fillers is also considered in our decomposition to account for the interactions between cross-linked chains/fillers and free chains/fillers. A network alteration theory is proposed by considering both cross-linking and change in movements of free chains superimposed into the cross-linked network. The time-temperature equivalence principle, obeying to an Arrhenius law, is used to construct master curves of the network alteration kinetics for both the cross-linked chains and the superimposed free chains. The capabilities of the proposed network alteration constitutive model to describe and predict the carbon-filled SBR mechanical response are shown. The model is implemented into a finite element program and numerical applications are presented to illustrate our approach by analyzing the network alteration fields for different conditions of thermal aging.