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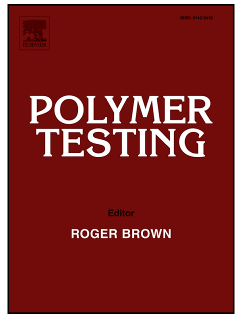

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Compression stress relaxation in carbon black reinforced HNBR at low temperatures

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Abstract
Findings of a study of stress relaxation behaviour of hydrogenated nitrile butadiene rubber (HNBR) at nominal compressive strains up to 0.4 and temperatures above and below the glass transition temperature T_g are reported. Two formulations of a model HNBR with 36 % acrylonitrile content and carbon black (CB) loading of 0 and 50 phr were investigated. The relaxation function of HNBR is found to be independent of strain at temperatures right above the T_g or at times longer than 10^{-3} sec for the deformations employed. CB imparts higher long-term stiffness and also larger relaxation strength at times longer than 10^{-4} sec to the HNBR, but it does not affect the relaxation behaviour of the rubber in the time span from 10^{-3} to 10^4 sec. In addition, the relationship between the strain energy function of HNBR and temperature is demonstrated to have a complex concave-downward shape which is affected by two competing contributions of entropy elasticity and the stress relaxation.

Keyword: stress relaxation, rubber, low-temperature, viscoelastic properties, glass transition, HNBR

1. Introduction

The mechanical behaviour of elastomers is known [1] to be affected by temperatures due to their entropic nature. In fact, from the Gaussian theory of rubberlike elasticity it follows that the strain energy function (W) of a deformed elastomer proportionally increases with temperature. For instance, the theory entails the following expressions for the strain energy function and the nominal stress S in uniaxial loading [1]:

$$W = \frac{1}{2} nkT\left(\lambda^2 + 2\lambda^{-1} - 3\right) = \frac{1}{2} G\left(\lambda^2 + 2\lambda^{-1} - 3\right) \qquad (0)$$

$$S = nkT\left(\lambda - \frac{1}{\lambda^2}\right) = G\left(\lambda - \frac{1}{\lambda^2}\right) \qquad (0)$$

where $\lambda = 1 + \varepsilon$ is the stretch ratio, n is the number of network chains per unit volume, k is the Boltzmann constant, T is temperature, and G is the shear modulus.