EFFECT OF TEMPERATURE ON THE STEADY STATE CREEP OF STYRENE BUTADIENE RUBBER LOADED WITH HAF CARBON BLACK

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Abstract: The isothermal creep of the HAF/SBR composite with carbon black concentrations 25, 50, 75 and 100 phr was carried out under different stresses ranging from 2.2 to 6.8 MPa and at different working temperatures ranging from 303 to 363 K. The steady state creep strain rate, the stress exponent m, the activation volume q have been found to decrease with increasing the concentrations of carbon black. These observations might be due to the fact that the increase in carbon black concentration raises the stiffnes of the test samples by increasing the obstacles where the rigid carbon black spheres act as barriers for the motion of the molecular chain segments. The activation energy of the steady state creep has been found to increase with increasing the carbon black concentration.

1. Introduction

Mixing of rubber with carbon black improves the mechanical as well as the electrical properties[1,2]. This is due to the formation of carbon aggregates, which restricts the plastic flow in polymer. The temperature and stress dependence of the creep rate $\dot{\varepsilon}$ in polymer is given by the relation[3]

$$\dot{\varepsilon}_{st} = A \exp\left(\frac{-Q - q\sigma}{KT}\right) \qquad (1)$$

where Q is the activation energy of the flow process, q is the activation volume, K is Boltzman's constant, T is the absolute temperature and σ is the applied STRESS. Besides, according to Cannon and sherby[4] the applied stress sensitivity parameter m was defined by

$$\overline{m} = \left(\frac{\partial Ln\ \dot{\varepsilon}_{st}}{\partial Ln\ \sigma}\right)_T \qquad (2)$$

The aim of the present work is to study the effect of temperature and the concentration of the high abrasion furnace (HAF) carbon black on the steady state creep characteristics of the styrene butadiene rubber.

2. Experimental

The styrene butadiene rubber with 25, 50, 75 and 100 phr of HAF carbon black was prepared according to the recipe mentioned in Table (1).

The test samples were shaped during vulcanization process into sheets of 2.5 cm long, 0.3 cm wide, 0.16 cm thickness. The rubber vulcanization was conducted at 143 c under a pressure of 40 kg.f/cm2 for 30 minutes. The steady state creep measurements were obtained by using a conventional tensile testing machine[5].

Table (1)

	(Phr)[a]
Styrene butadiene rubber (SBR)	100.0
Zinc oxide	5.0
Stearic acid	2.0
Processing oil	5.0
HAF	25,50,75 and 100.0
(MBTS) [b]	1.5
(Anox HB) [c]	1.0
(6 P P D) [d]	1.0
Sulpher	2.0

a. Part per hundred parts of rubber by wight
b. Debenzthiazole disulphide
c. Poly2,4,6 trimethyl – 1,2 dihydroquinoline
d. N. (1,3 Dimethyl butyle N-Phenyl-p- phenylenediamine

3. Results

The creep curves of the HAF/SBR of different carbon concentrations at 303 K under different applied stresses are shown in Fig. (1). The creep strain was found to increase by increasing the applied stress and decreased by increasing carbon concentration. The creep strain of the HAF SBR of different carbon concentrations was found to increase by increasing the working temperature (see Fig. 2). However, Fig. (3) shows that the steady state creep rate increases with increasing the applied stress and decreases with increasing carbon concentrations. The relation between Ln σ and

$Ln\ \dot{\varepsilon}_{st}$ for HAF/SBR of different carbon concentrations at a working temperature 303 K is shown in Fig. (4).

The temperature dependence of $Ln\dot{\varepsilon}_{st}$ for HAF/SBR was found to vary with carbon concentrations (see Fig. 5). The activation volume q and the stress sensitivity parameter ($\overline{m}$) of the HAF/SBR were found to decrease while the activation energy Q was found to increase with increasing the concentrations of carbon black (see Fig. 6).

4. Discussion

At room temperature (303 K), the increase in creep strain (ε %) by increasing the applied stress (see Fig. 1) was attributed to the stress enhancement of the motion and mobility of the flexible and rigid molecular chain segments. This enhancement has been achieved by the movement and arrangement of carbon black aggregates or agglomerates in the direction of creep strain. At various temperatures the creep strain for HAF\SBR are largely affected by raising the test temperature (see Fig. 2). This means that the tested samples are thermally agitated and the temperature induced free volumes, which facilitate the molecular chain mobility and slippage. The values of the steady state creep rate $\dot{\varepsilon}_{st}$ were found to decrease by increasing the carbon concentrations (see Fig 3). It is well known that the carbon black particles of the HAF form aggregates between polymeric chains, [6] which might lead to the diminishing of the mobility of the chain segments. The stress sensitivity parameter $\overline{m}$ as obtained from the slopes of the straight lines relating $Ln\dot{\varepsilon}_{st}$ vs Ln σ (see Fig. 4) was found to decrease with increasing the carbon black concentration due to the fact that increasing carbon black particles in SBR matrix hardened the butadiene rubber, thus causing the loss of its sensitivity towards the applied stress.

The activation energy of creep process was found from the slopes of the straight lines relating $Ln\dot{\varepsilon}_{st}$ vs $\frac{1000}{T}$ at constant stress (see Fig. 5). The activation energy was found to increase with increasing the concentration of carbon black. It was thus concluded that carbon black represented obstacles for the motion of molecular segments thus requiring higher activation energies when the concentration of carbon black is increased in the SBR matrix.

Finally, the activation volume q for creep mechanism was found from the slopes of the straight lines relating $Ln\ \dot{\varepsilon}_{st}$ vs σ as in Fig. (3). The activation volume was found to decrease with increasing the concentration of carbon black in sample as shown in Fig. (6). This result might be attributed to the expected reduction of the mobility of the chain segments by carbon black particles.

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