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Research Article

Study on Effect of Fillers in Stress Relaxation Characteristics

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Abstract

The increasing demand for rubber products in different applications necessitates the study of the deformation of the rubber material under long-term service. Stress relaxation tester can be used to study this rubber deformation. The effect of fillers on the stress relaxation characteristics of a Natural Rubber based compound by varying the applied strain at an elevated temperature has been considered in this work.

Keywords: Rubber; Carbon; Organic chemicals; Deformation; Particle size

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Introduction

Lower stress relaxation rate directs to high elastic properties and higher relaxation rate towards high viscous nature of the rubber compound [1]. Based on the literature review, several research works have been published in studying the stress relaxation behavior of rubber compounds and in related areas. In this present research, a focused approach has been applied to see the cumulative effect of strain and the temperature on Stress relaxation characteristics.

Experimental

Materials

Natural Rubber (RMA IV) was supplied by JK Industries Pvt. Ltd., India. The other ingredients were 2,2'-Dithiobisbenzanilide (DBD; Acmechem Pvt. Ltd., India) N134, N339 and N774 carbon black (Birla Carbon Black India Pvt. Ltd., India), Oil of aromatic grade (Raj Petro, Chennai, India), zinc oxide (rubber grade; Zinc-o-India, India), stearic acid (Godrej Industries Ltd., India), N-phenyl-N'-(1,3-dimethylbutyl) p-phenylene-diamine (6PPD; National Organic Chemicals Industries Ltd., India), N- tert-butyl-benzothiazole sulfonamide (TBBS; National Organic Chemicals, India Ltd., India), soluble sulfur (Jain Chemicals Ltd., India), and diphenyl guanidine (DPG; National Organic Chemicals, India Ltd., India) used for the compound preparation. All the ingredients used in these studies presented here were used as obtained. In this study, Natural rubber base with high structure carbon black by varying the particle size such as N134 (N1), N339 (N3) and N774 (N7) series fillers were utilized. The formulations of all the compounds are given in Table 1. Hardness of all the compounds are made similar by adjusting the curative package. The mixing of rubber compounds was carried out in a 1.5L volume Lab. Banbury mixer (Stewart Bowling, USA). The mixing sequence of Master and Final Batch is given in Table 2.

Table 1: Formulation of compounds. [a]phr, parts per hundred rubber by weight. [b]2,2'-Dithiobisbenzanilide, [c]Carbon black grade N134, [d]Carbon black grade N339, [e]Carbon black grade N774, [f]N,N'-diphenyl-p-phenylenediamine, [g]N-tert-butyl-benzothiazole sulfonamide, [h]Diphenyl guanidine.

Ingredients, phr[a]	N1	N3	N7
RMA-IV	100	100	100
DBD[b]	0.15	0.15	0.15
Carbon black[c]	50	-	-
Carbon black[d]	-	50	-
Carbon black[e]	-	-	50
Oil	14	14	14
Zinc oxide	2.5	2.5	2.5
Stearic acid	2.5	2.5	2.5
6PPD[f]	2.25	2.25	2.25
Sulfur	1.9	2	2.3
TBBS[g]	0.4	0.5	1
DPG[h]	0.1	0.2	0.4

Table 2: Mixing sequence.

Master Batch Mixing	
Mixing Speed (rpm)	60
Initial temperature (°C)	50
At 0 Second	Add Natural Rubber with peptizer into the Mixer
After 30 seconds	Add Dry Carbon black into the mixer
After 120 seconds	Add remaining carbon black along with Oil, Zinc Oxide, Stearic Acid, 6PPD, into the mixer
After 240 seconds	Ram sweep (20 secs.)
After completion of 330 Seconds	Dump the Master batch
Dump Temperature (°C)	140-145
Final Batch Mixing	
Mixing Speed (rpm)	30
Initial temperature (°C)	52
At 0 Second	Add Master Batch along with curatives into the mixer
After completion of 180 seconds	Dump the Final batch
Dump Temperature (°C)	90-100

Characterization

Stress relaxation study was performed by using Automatic Creep and Stress relaxation Tester (ACSR, Elastocon, Sweden). Photographic view of the Creep and Stress Relaxation Tester is shown in Figure 1. The test sample button is moulded at 141 °C for 60 minutes. The dimension of the cylindrical button sample specimen used for testing is with a Diameter of 13±0.2mm, and with a thickness of 6±0.2mm. Stress relaxation test was carried out in compression mode on three different strains such as 10%, 20% and 30%. Test Temperature was set at 70 °C and relaxation was captured in continuous mode for the study purpose. At Room temperature, the rubber cured products are well above the glass transition and well below the degradation temperature, in such cases the stresses under constant deformation, changes very minute as the time progress [2]. The duration of the test was 24 Hours and was carried out in accordance with ISO 3384.

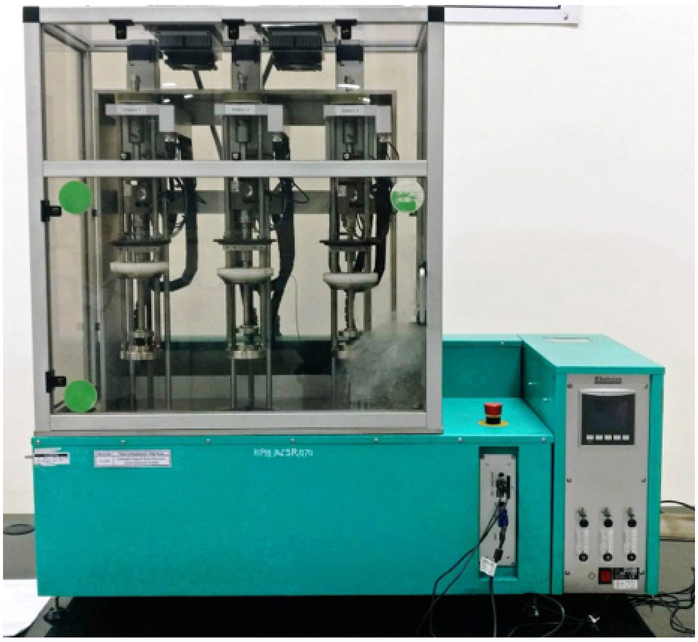

Figure 1: Creep and stress relaxation tester.

Results and Discussion

Table 3 illustrates the Stress relaxation data of the studied rubber compounds. It is observed that Stress relaxation property increases upon increasing the particle size. The effect of strain is not significant and did not show any remarkable difference in stress relaxation data in the experimental range. This was observed in earlier studies while stress relaxation carried out in different machines [3]. Normalized force against time is plotted in Figure 2.

Table 3: Stress relaxation (%).

Temp. (°C)	Strain (%)	N1	N3	N7
70	10	14.6	11.2	9.7
	20	13.9	11.3	10.1
	30	14.3	11.6	11.1

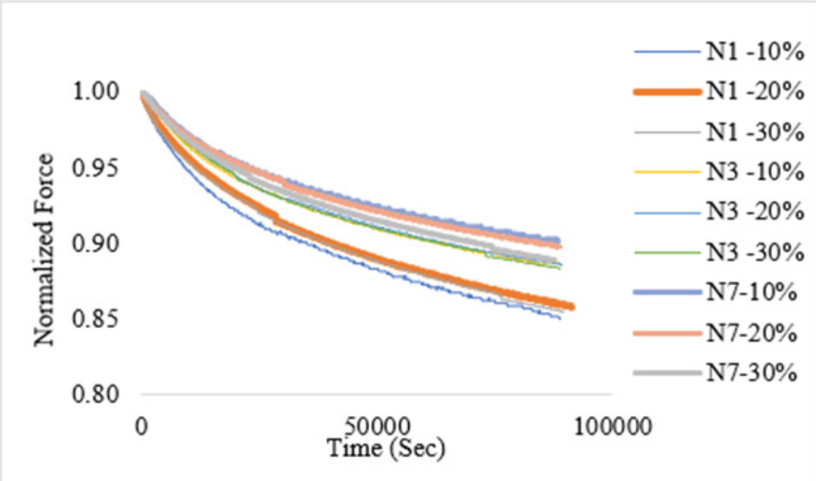

Figure 2: Normalized force vs time.

Conclusion

The results show that the Rubber matrix with the lowest particle size carbon black (N1) has the highest stress relaxation and the compound with highest particle size carbon black (N7) shows the lowest stress relaxation. The effect of strain has not made any impact on this study.

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