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Abrasion Resistance of Pre-stressed and Stressed Rubber Vulcanizates

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Synopsis

The abrasion resistance of carbon black-reinforced SBR-1500 vulcanizates has been shown to be drastically reduced by the application of tensile strain during the abrasion process. Pre-stressing of similar vulcanizates, however, has no effect upon the abrasion resistance.

INTRODUCTION

We have attempted to examine (*1*) the relation between stress-softening and abrasion resistance of carbon black-filled SBR-1500 vulcanizates, and (*2*) the related effects of abrasion testing of vulcanizates while under tensile stress. Blanchard and Parkinson[1] reported that abrasion of a carbon black (MPC)-reinforced natural rubber vulcanizate is reduced 20% by pre-stretching the material to 250% elongation before testing on a Dunlop constant energy abrasion machine. This observation was contradicted by Kendall and Moakes,[2] who showed that pre-stretching similar natural rubber-channel black vulcanizates to 40% of the breaking elongation had no significant influence on the abrasion resistance as measured on a Dupont or an Akron abrasion machine. Shallamach[3] has discussed the presence of a softened skin on abraded, filled rubber as observed by electrical resistivity measurements. Dannenberg and Brennan[4] attributed the greater abrasive wear of stressed ring samples to irreversible stress-softening that had occurred during prior stressing to 300% elongation.

EXPERIMENTAL

Pre-stressed Vulcanizates

Pre-stressing effects on Akron angle abrasion resistance of SBR-1500 vulcanizates (Table I) reinforced with an N220 or ISAF type carbon black (50 phr)* were tested by using strips (100 mm × 12 mm × 2 mm) of the rubber. These recap strips were stretched in a single extension to the desired elongation and held for 30 min. After allowing each strip to relax for five minutes, the required length was cut from the central section and

* Cabot Vulcan 6.

cemented with pressure sensitive polymerizing adhesive (Eastman 910) to the support wheel. No difference in abrasion resistance between strips subjected to this single extension and repetitively stressed strips was observed, therefore the bulk of our testing was confined to strips that had been pre-stressed only once. The recap strips containing higher loadings (80 phr) of N220 (ISAF) black or its graphitized version were repetitively stressed only. These repetitive cyclic extensions were accomplished on an Instron tensile tester, holding each strip in the extended position for ten minutes on the last cycle. Relaxation time before cementing was maintained at five minutes. Wheels recapped with unstressed strips were used as controls.

Stressed Vulcanizates

Abrasion under tensile stress was performed by placing stretched rings (41 mm O.D. × 36.5 mm I.D. × 2.25 mm thick) of SBR-1500 reinforced with N220 black (50 phr) over support wheels. The rings were cemented in place and testing on the Akron angle abrader conducted in the normal manner. The extension (24–52–78%) to which the ring inner diameter was subjected was governed by the outside diameter (26 mm) of the support wheel. Formulation (Table I) was the same as that of the recap strips used for the pre-stressing experiments.

TABLE I
Formulation of Abrasion Wheels, Recap Strips, and Tension Rings

SBR-1500	100 phr
Filler	See below
Paraflux	5
Circosol 4240	3
Zinc oxide	3
Stearic acid	1.5
Flexamine	1
Sulfur	1.75
Santocure	1.25

Fillers: (a) N220 (50, 80 phr); (b) Graphitized N220 (50 phr).
Recaps and rings cured 45 min at 293°F.
Abrasion wheels cured 60 min at 293°F.

DISCUSSION

Effect of Pre-stressing on Abrasion

Pre-stressing vulcanizates of SBR-1500/N220 to elongations as high as 90% of the breaking elongation had no effect upon the Akron angle abrasion resistance of the vulcanizate (Table II). There is no significant difference between the loss indices of the recap strips pre-stressed to 0–100–200–300–430% elongation. The greater abrasion loss of the recaps as compared to that of the unrecapped control wheel is probably due to squirming of the recap during testing. Carbon black, at either of two loadings, appeared to

TABLE II
Akron Angle Abrasion Weight Loss Indices of
Pre-stressed Recaps of SBR-1500/N220

	50 phr N220 black*					80 phr N220 black*		50 phr graphitized N220 black*	
Un-	Per cent elongation of recap								
recapped	0%	100%	200%	300%	430%	0%	200%	0%	300%
221	240	260	254	238	253	428	326	336	396

* ISAF black, Cabot's Vulcan 6.

play no role in developing any abrasion/stress-softening relation. Graphitized carbon black-filled recaps apparently yield increased wear loss after pre-stressing. Because graphitized black interacts with polymer, to a lesser extent than does ordinary black, as is evident from bound rubber measurements, the apparent crosslink density attained within the elastomer matrix in a given cure time is also lower. This results in a lower tensile modulus, which is reflected in lower resistance to abrasion of the vulcanizate than for that containing the regular non-graphitized black. This lower interaction level may also be the cause of the greater effect of the pre-stressing in abrasion resistance. The abrasion resistance depends on the capacity of the compound for heat dissipation and its ability to recover after a stress cycle (one rotation of the sample wheel) in order to dissipate energy again at the next cycle. With graphitized black less and slower recovery takes place[5] so that pre-stressing has a more profound effect on abrasion resistance. The observation of Kendall and Moakes[2] that pre-stressing a vulcanizate has no effect upon its abrasion resistance is considered to have been confirmed.

Effect of Strain During Abrasion

The application of tensile strain in the direction of abrasion test wheel rotation to ring samples of SBR-1500/N220 undergoing Akron angle abrasion testing results in increased abrasive wear (Table III), the increase being linearly related (Fig. 1) to the strain elongation above an extension

TABLE III
Akron Angle Abrasion Weight Loss Indices of
Strain Rings of N220* Reinforced SBR-1500

Ring I.D.	Support O.D.	Net elongation of ring I.D.	Weight loss index
36.5 mm	46.0 mm	26%	263
	55.6	52	430
	65.1	78	601
Ring dimensions:	41 mm O.D. × 36.5 mm I.D. × 2.25 mm thick		

* ISAF black, Cabot's Vulcan 6.

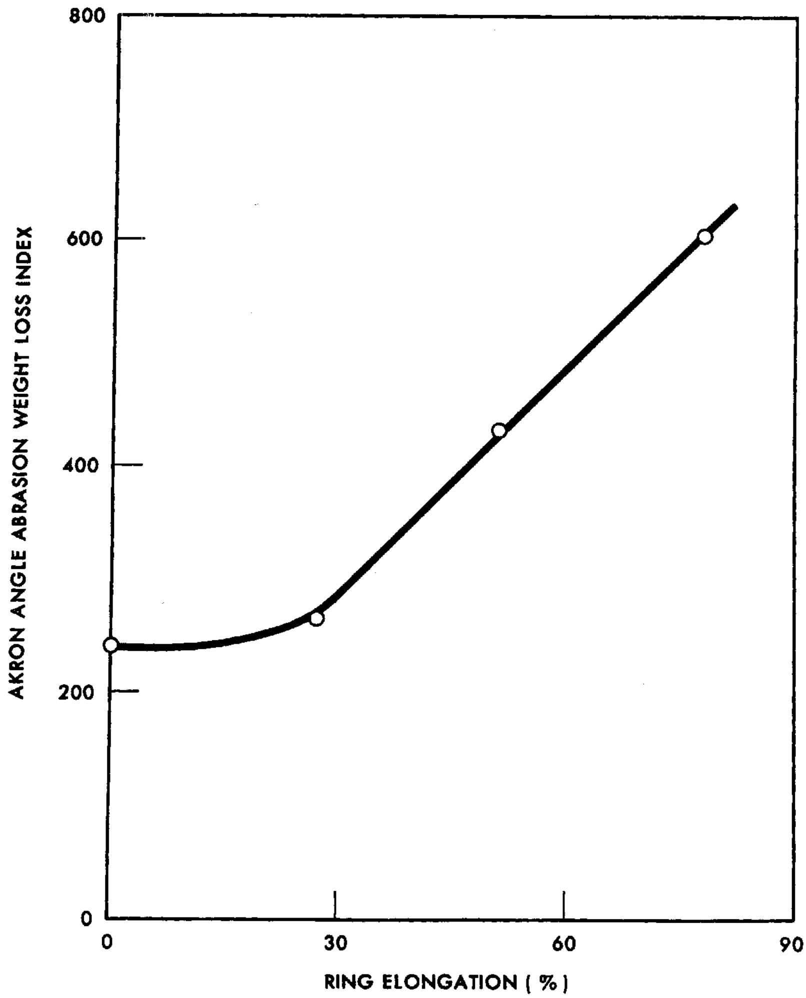

Fig. 1. Abrasion of SBR-1500/N220 vulcanizates while under tensile stress.

of 25%. The unstressed recapped abrasion wheel used in the pre-stressing experiments was assumed to be suitable control. This observed relation between elongation and abrasion resistance has been reported earlier by Dannenberg and Brennan[4] who give data on ring samples that had been pre-stressed to 300% elongation. They used rings that had 50 and 75% elongation during the test, so that both stress-softening and residual strain were present. The greater abrasive losses observed were attributed to irreversible stress-softening. Our results indicate that the deterioration of abrasion resistance is due to the residual elongation of the recap ring and that the effects of pre-stressing on abrasion loss are negligible. This effect of tensile strain on abrasion resistance may be a contributory factor in roadwear. As a given element of tread becomes extended, e.g., by squirming, its resistance to abrasion would be decreased and the next road asperity met by the extended tread element would result in a separation of the element from the bulk of the tread. The possible effects of carbon black loading and structure upon stressed abrasion testing have not yet been explored.

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