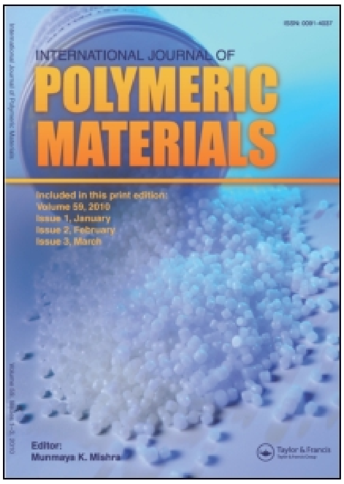

International Journal of Polymeric Materials
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713647664

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To cite this Article Poh, B. T. and Jalaluddin, Mohd.(2000) 'Tensile, Tear and Swelling Properties of ENR 50/SBR Blend', International Journal of Polymeric Materials, 46: 3, 663 — 672
To link to this Article: DOI: 10.1080/00914030008033904
URL: http://dx.doi.org/10.1080/00914030008033904

Intern. J. Polymeric Mater., 2000, Vol. 46, pp. 663–672
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Tensile, Tear and Swelling Properties of ENR 50/SBR Blend

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(Received 25 March 1999)

Tensile strength, tear strength and swell index of epoxidized natural rubber (ENR 50) blended with styrene-butadiene rubber (SBR) was studied. The blend ratio was varied from 0–100% of ENR 50. Accelerated-sulfur conventional vulcanization system was used throughout the study. Tensile property and tear strength of the blend were determined by Monsanto Tensometer (Model T10) and toluene was used as the solvent in the swell index experiment. Results show that tensile strength and elongation at break increases with ENR 50 up to about 70% ENR 50, whereas for the tear strength, it increases steadily with increasing ENR 50, an observation which is attributed to strain-induced crystallization of ENR. Similar behavior was observed with the aged sample though its absolute value is lower than that of the unaged sample. As for the swell index, it decreases gradually with increasing ENR indicating the increase in polarity of the blend as the blend ratio of ENR 50 is increased.

Keywords: Rubber; blend; tensile; tear; swelling

INTRODUCTION

Epoxidized natural rubber (ENR) is a chemically modified natural rubber. It has become a subject of recent research interest after the realization that its properties is akin to synthetic rubbers [1]. However, most studies carried out were based on the curing and mechanical properties of single component epoxidized natural rubber [2–8]. Research work on its blends is scarce. Varughese *et al.* [9] has reported

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the miscibility study of plasticized poly(vinyl chloride)/ENR blends as a function of blend composition. Nasir *et al.*, had studied the rheological property of PVC/ENR blends using a Brabrender Plasticorder [10], cure characteristics and mechanical properties of carbon black filled SBR/ENR blends using mainly efficient vulcanization system [11]. On the other hand, Ng *et al.* [12] conducted a differential scanning calorimetric study on ENR blends. Recently, we have studied the Mooney scorch time of ENR/NR and ENR/SBR blends [13]. In order to enhance the knowledge on the properties of ENR blends, we have carried out a systematic study of the effect of blend ratio on the ultimate and swelling properties of unfilled ENR/SBR blends using a conventional vulcanization system. These findings are reported and discussed in this paper.

EXPERIMENTAL

Materials

ENR 50 having 50 mol% of epoxidation and SBR (Buna Hüls, 1502) were used as the elastomers. The blend ratio of ENR 50/SBR was varied from 0 to 100%. The accelerator used was *N*-Cyclohexyl-2-benzothiazyl sulfenamide (CBS) and other compounding ingredients such as zinc oxide, stearic acid and sulfur and antioxidant (AO 2246) were of commercial grades and used as supplied.

Compounding

Conventional vulcanization system was used in the rubber formulation. Table I shows a typical recipe for the preparation of a rubber compound.

Preblended rubbers (ENR 50/SBR) were used as the base elastomer and standard mixing procedure as described by the American Society for Testing and Materials (ASTM) – Designation D 3184-89 [14] was strictly followed. The mixing procedure was carried out using a two-roll mill maintained at a temperature of 70 ± 5°C. The total time taken to complete one mixing cycle was 18 minutes. The rubber compound was conditioned at a temperature of 23 ± 2°C for 24 hours. Its

TABLE I Formulation of rubber compound

Ingredients	*phr*[a]
Rubber blend[b]	100
Zinc oxide	5
Sulfur	2.5
Stearic acid	2
CBS	0.6
Antioxidant	2

[a] parts per hundred parts of rubber.
[b] blend ratio for ENR 50/SBR (0/100, 20/80, 40/60, 60/40, 100/0).

optimum cure time was then determined by a Monsanto Rheometer (ODR 100) at 150°C.

Sample Preparation and Testing

Test specimen was obtained from molding the rubber compound in a hot press at 150°C using the respective cure times determined by the rheometer. For the tensile testing, dumbbell samples were cut from a 2 mm thick molded rubber sheet. The gauge length and width of the sample was 33 ± 2 mm and 6.3 ± 0.1 mm respectively. The testing procedure was conducted according to Test Method A of ASTM D 412-92 [15]. For the tear strength, the method described by ASTM D 624-91 [16] was used. Die B was used to cut the crescent test sample. A sharp razor blade was used to produce a nick (0.50 ± 0.05 mm) in depth. For both tensile and tear measurements, a Monsanto Tensometer (Model T10) operating at 50 cm/min was used. For the aging experiment, the rubber samples were aged at 100°C for 48 hours in an air oven.

For the swelling measurement, the method adopted by Ismail *et al.* [17] was used. The rubber vulcanizates were cut a in the dimension of $30 \times 5 \times 2$ mm and swelled in toluene until equilibrium swelling was achieved. The weight of toluene uptake per gram of rubber hydrocarbon (Q) was calculated according to the following equation:

$$Q = (M_2 - M_1)/(100 M_o/M_f)$$

where M_o, M_1, M_2, and M_f are the dry, deswollen, swollen and formula weights respectively of the rubber sample.

RESULTS AND DISCUSSION

Tensile Property

Figure 1 shows the variation of tensile strength with % ENR 50 in the ENR 50/SBR blend before and after aging. As the composition of ENR is progressively increased, the tensile strength increases correspondingly up to a maximum value at about 70% ENR blend ratio (interpolated value) for both the unaged and aged samples. This observation is associated with the strain-induced crystallization due to increasing amount of the crystallizable ENR. This effect reaches a maximum value due to the maximum compatibility between ENR 50 and SBR since it has been shown that ENR is more akin to SBR [11]. A slight drop in tensile strength after the maximum value is observed. For the aged sample, its tensile strength is slightly lower than the unaged vulcanizate below 40% ENR 50, but the difference becomes significant beyond 40% ENR 50 due to the increasing effect of ENR 50 which has been shown to have poor aging properties [18, 19]. After the maximum value, the tensile strength drops drastically in the aged sample. The poor aging

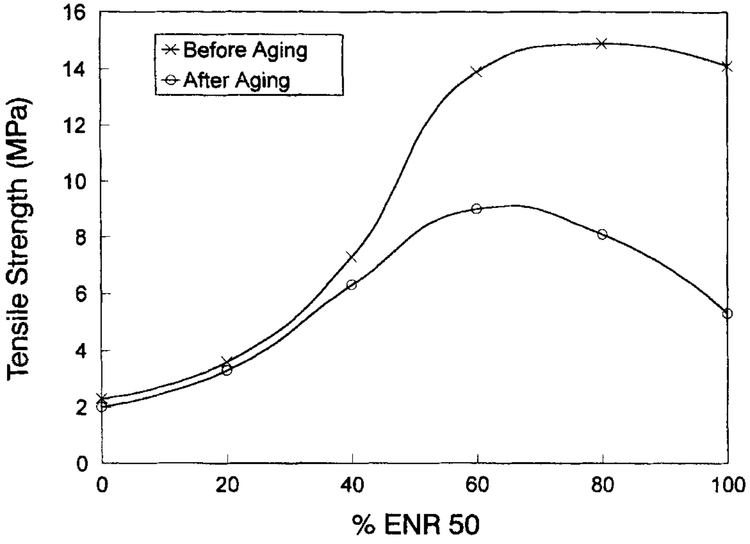

FIGURE 1 Variation of tensile strength of ENR 50/SBR blend with % ENR 50 for the aged and unaged samples.

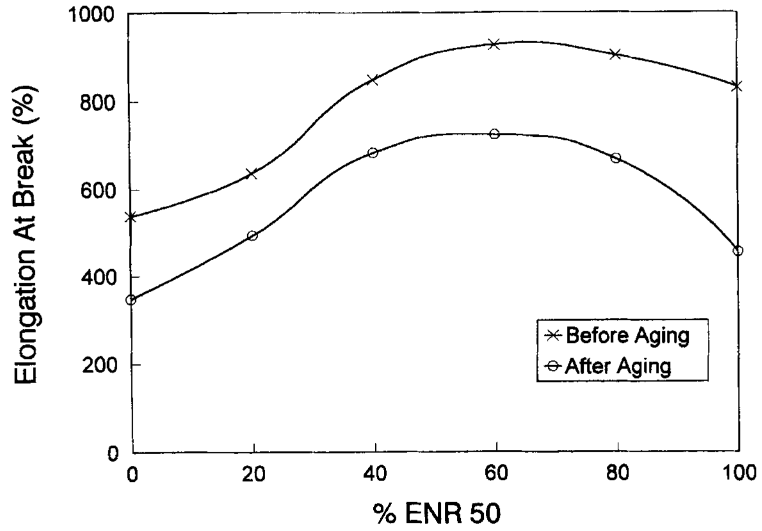

FIGURE 2 Variation of elongation at break of ENR 50/SBR blend with % ENR 50 for the aged and unaged samples.

property of ENR 50 is clearly reflected by the great difference in the tensile strength between aged and unaged of pure ENR 50 vulcanizates. On the other hand, pure SBR vulcanizate gives better aging resistance as shown by the small difference in tensile strength before and after aging because of the higher saturation of SBR molecule. Similar observation is obtained for the elongation at break as indicated in Figure 2. Again, elongation at break increases with ENR content up to a maximum at about 70% ENR by interpolation, after which a drop is observed where the rate being faster in the case of the aged sample. The ability of ENR to undergo strain-induced crystallization and compatibility of the blend accounts for the increasing value of elongation at break of the blend. Elongation at break is similarly affected by thermal aging which gives a lower value after aging.

Tear Strength

The variation of tear strength of the blend with % ENR 50 is indicated in Figure 3. In this case, the tear strength increases gradually with

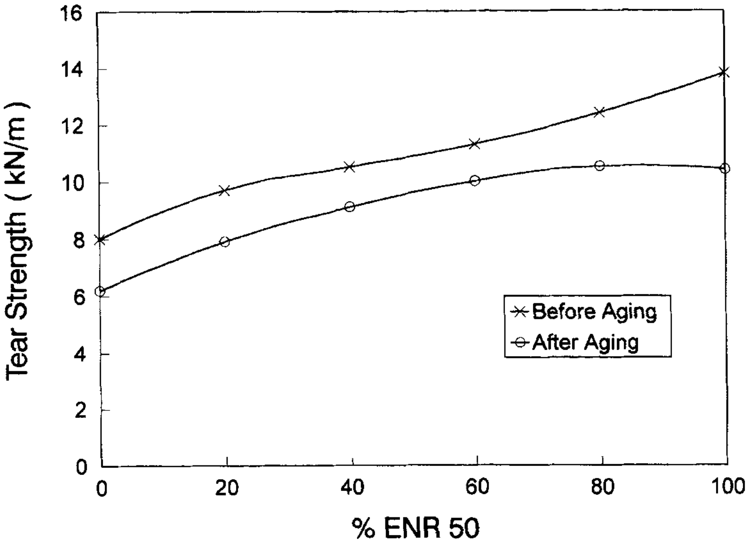

FIGURE 3 Variation of tear strength of ENR 50/SBR blend with % ENR 50 for the aged and unaged samples.

increasing ENR composition for both the aged and unaged samples. No maximum is observed in the tear behavior, an observation which may be associated with tear mechanism that is different from that of tensile strength. ENR and its blend shows consistently higher tear values than pure SBR vulcanizate for all blend ratios studied. This observation is attributed to the effect of strain-induced crystallization of ENR in the blend which increases with increasing ENR content. As in the case of tensile strength and elongation at break, aging also decreases the tear strength of the blends, a phenomenon resulting from the thermal degradation of the rubber network.

In order to quantify the effect of thermal aging on the various mechanical properties investigated, a plot of % retention of property *versus* % ENR 50 was carried out as shown in Figure 4. The graph shows that tensile strength gives the highest % retention value for a blend ratio of 40% ENR and below but a rapid drop in retention value is observed with higher ENR content. This behavior is also exhibited by the elongation at break. Results indicated that poor aging property of blend is obtained at higher ENR composition as discussed earlier. The % retention of tensile strength and elongation at break of pure

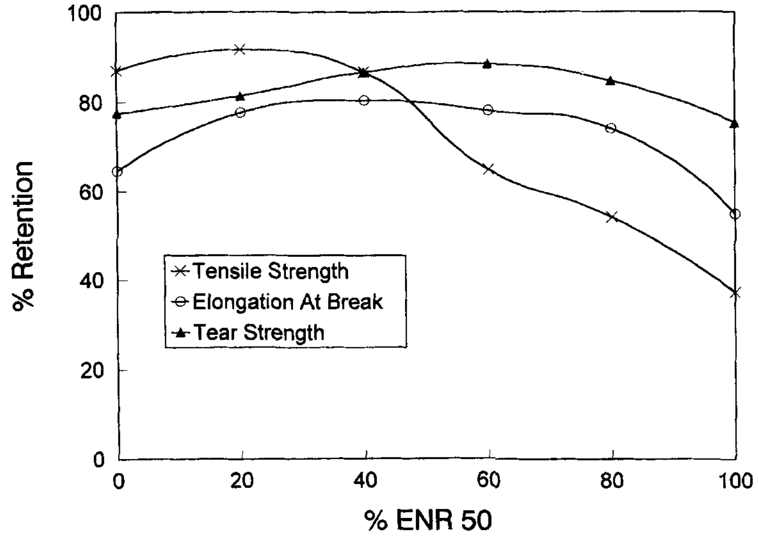

FIGURE 4 % retention of the various properties of ENR 50/SBR blend *versus* % ENR 50 after aging at 100°C for 48 hours.

ENR 50 vulcanizate is 37.2% and 54.8% respectively whereas the corresponding values for SBR are 87% and 64.6% which indicates that SBR has a better aging property than ENR 50 due to the presence of epoxide groups in the latter. However, the % retention of tear strength does not vary very much for the entire blend ratio studied. In fact, the % retention for the pure ENR is 75.4%, a value which is quite close to that of pure SBR, *i.e.*, 77.5%. This finding suggests that the individual rubbers and its blends essentially undergo similar transformation upon thermal aging. Also, the difference in % retention between tensile property and tear strength after aging shows that the mechanism of tearing differs from that of tensile strength as noted earlier. Owing to the better aging property of SBR, its blend with ENR shows better retention in the mechanical properties studied compared to that of the pure ENR 50 for all blend ratios studied as shown in Figure 4.

Swell Index

The swell index of the individual rubbers and its blends in toluene at 25°C is shown in Figure 5. The swell index decreases gradually as the ENR content is increased. This behavior is attributed to the increasing

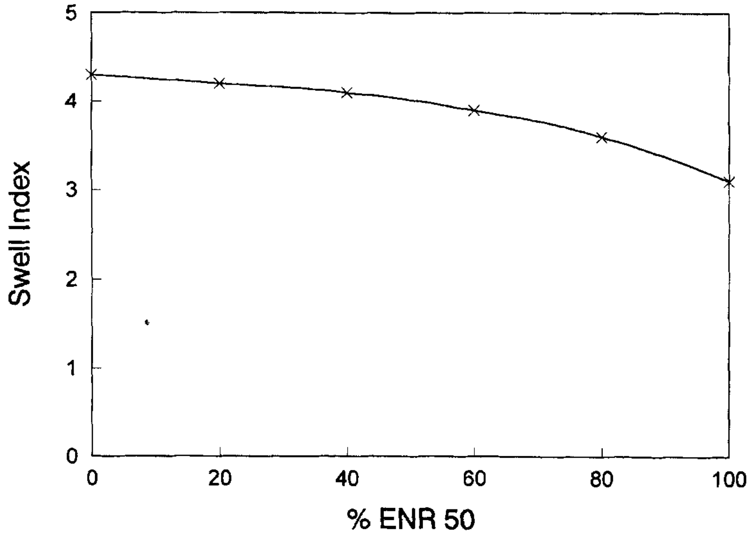

FIGURE 5 The dependence of swell index on % ENR 50 for ENR 50/SBR blend after equilibrium swelling in toluene at 25°C.

polarity of the blend as ENR 50 contains 50 mole% of epoxide group which is polar in nature. This means that less interaction occurs between toluene (a nonpolar solvent) and ENR 50 (a polar polymer) molecules which accounts for the lower values of the swell index as the blend ratio of ENR 50 is increased. On the contrary, SBR which is a nonpolar polymer, experiences more interaction with toluene molecules and hence swells more at higher SBR blend ratio. In fact, SBR vulcanizate swells about 28% more compared to ENR 50. This study shows that the presence of polar polymer like ENR 50 will affect the swelling behavior of a rubber/rubber blend towards a nonpolar solvent such as toluene.

CONCLUSION

From this study, the following conclusions can be drawn:

(1) Tensile strength and elongation at break increases with increasing ENR 50 composition in the ENR 50/SBR blend up to a maximum value of about 70% ENR. This behavior is attributed to the effect

of strain-induced crystallization of ENR. Thermal aging lowers the corresponding values as a result of thermal degradation of the rubber network.

(2) For the tear strength, it increases steadily with increasing blend ratio of ENR 50, a phenomenon which is also associated with increasing effect of strain-induced crystallization of ENR. However, no maximum is observed due to the different fracture mechanism in tear as compared to tensile strength. Similarly, the tear strength of the blend is lowered by thermal aging.

(3) The swell index drops gradually with increasing ENR 50 content due to the increasing polarity of the blend as ENR is increased. A nonpolar solvent such as toluene interacts weakly with polar rubber like ENR 50 which contains 50 mole% of epoxide group, thus less swelling is observed for higher ENR 50 blend ratio.

Acknowledgements

The authors acknowledge the research grant provided by Universiti Sains Malaysia, Penang that has resulted in this article.

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