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STYRENE BUTADIENE RUBBER/RECLAIMED RUBBER BLENDS

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Cure characteristics and mechanical properties of styrene butadiene rubber reclaimed rubber blends were studied. The blends showed improved processability, as indicated by the minimum torque values. Cure characteristics like minimum torque, (maximum−minimum) torque, cure time and cure rate decreased in the presence of reclaimed rubber. Tensile strength, tear strength, elongation at break were higher for blends. Resilience decreased with reclaim content. Compression set and abrasion loss were higher in the blends.

Keywords: Styrene butadiene rubber, reclaimed rubber, blend, mechanical properties

INTRODUCTION

The disposal of waste tyres has become a great environmental concern globally due to the growing stockpiles of used tyres and corresponding increase of disposal charge for discarded tyres. Reclaiming of these products by conventional reclaiming process such as Heater process, Reclaimator process and Thermal process are several of the major methods of utilization. The reclaimed rubber thus produced has a degree of plasticity comparable to vulcanized rubber and thereby enable it to be blended with natural or synthetic rubber.

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Swor [1] and Kazarnowicz [2] have reported that blends of reclaimed or ground vulcanized waste with natural rubber gives processing as well as economic advantages. Chopey and Wolk [3, 4] have reported that rubber powder can be mixed with virgin rubber but there is a significant drop in the tensile strength at the lower levels of addition of scrap rubber [5, 6]. An improvement in property can be achieved by compounding the scrap with new rubber and sulfur and subsequent vulcanization of the compound [7–9].

Production, properties and potential application of reclaimed rubber have been discussed by Bakhshandesh [10]. Hong has reviewed current methods and further prospects for reusing waste tyres [11]. The processing and mechanical properties of rubber vulcanizates containing reclaimed rubber were determined by Magryta [12]. The addition of reclaimed rubber resulted in some deterioration in mechanical properties. Cure and mechanical properties of rubber compounds containing ground vulcanizates have been studied by Gibala [13]. Seo has studied the cure and physical behaviour of EPDM vulcanizates containing ground rubber [14]. Cure and mechanical behaviour of elastomeric compounds containing devulcanized material have been studied by Theodore [15]. Recently we have reported the cure and mechanical behaviour of natural rubber – reclaimed rubber and NBR – reclaimed rubber blends [16, 17]. In the present work we investigate the cure and mechanical behaviour of SBR-WTR blends.

EXPERIMENTAL

Materials Used

Styrene butadiene rubber (synaprene 1502) was obtained from Synthetics and Chemicals Ltd., Bareilly. The Whole Tyre Reclaim (WTR) was procured from Kerala Rubber and Reclaims, Mamala, India. The characteristics of reclaim used are given in Table 1. Zinc oxide (ZnO) was obtained from M/s. Meta Zinc Ltd., Bombay. Stearic acid was procured from Godrej Soap (Pvt.) Ltd., Bombay, India. Dibenzothiazyl disulfide (MBTS) & 1,2-dihydro 2,2,4-trimethyl quinoline (HS) were obtained from Bayer India Ltd., Bombay. Tetramethyl thiuramdisulfide (TMTD) was supplied by NOCIL, Bombay, India. Standard Chemical Company Private Ltd., Madras, supplied sulfur.

TABLE 1 Characteristics of WTR

Parameter	Value
Acetone extract (%)	13
Carbon content (%)	39

TABLE 2 Formulation of the Mixes

	Mix no.				
Ingrediet	A	B	C	D	E
SBR	100	90	80	70	60
Reclaim	–	20	40	60	80

SBR-Styrene butadiene rubber, (Zinc oxide-4 phr, Stearic acid-2 phr, HS (1,2-dihydro 2,2,4-trimethylquinoline)-1 phr, MBTS (Dibenzothiazyl disulfide)-0.5 phr, TMTD (Tetramethylthiuram disulfide)-1.8 phr & Sulfur-0.3 phr are common to all mixes).

Processing

Formulation of the mixes is given in Table 2. The mixes were prepared in a laboratory size two roll-mixing mill. Cure characteristics were determined by using a Goettfert Elastograph Model 67.85 at 150°C. Vulcanization was carried out at 150°C under a pressure of 180 kg/cm^2 in an electrically heated hydraulic press. Tensile properties were measured using a Zwick UTM Model 1445 according to ASTM D 412 (die E). Tear test was done on Zwick UTM as per ASTM D 624 (die C). Abrasion resistance of blends was measured using a DIN abrader as per DIN 53516 and the values were expressed as volume loss per hour. Compression set at constant strain was measured according to ASTM D 395-86 method B. Resilience was measured according to ASTM D 2832-88. For ageing resistance, samples were aged in an air oven for 48 h at 70°C (ASTM D 573-88). The properties were measured 24 h after the completion of ageing.

RESULTS AND DISCUSSION

Cure Characteristics

The minimum torque values of the blends are given in Figure 1. The minimum torque values showed a reduction from 0.029 N/m at 0 parts to 0.017 N.m. at 80 parts of reclaim content. The decreased minimum torque values indicate improved processability in the case of blends. The presence of oil in the reclaimed rubber explains the decreased minimum torque values of the blends. The acetone extractable fraction of the reclaim, which is an indication of oil content of the reclaim, is 13%.

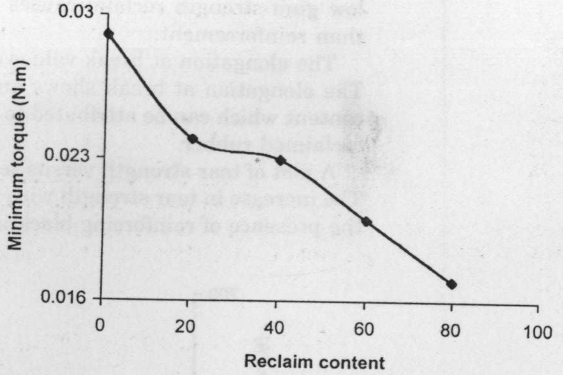

FIGURE 1 Variation of minimum torque with reclaim loading.

The (maximum-minimum) torque values show a reduction from 0.2424 N.m. at 0 phr to 0.1687 N.m. at 80 parts of reclaim loading (Figure 2). The decrease in (maximum–minimum) torque values with increase in reclaim loading is due to the higher oil content present in the reclaimed rubber. The oil content of the reclaim is about 13%. The low molecular weight of the reclaimed rubber also contributes to the lower maximum torque values.

The scorch time is not at all affected by the addition of reclaimed rubber (Figure 3). The cure time shows a drop in the 20–40 phr of reclaim loading (Figure 4). For mixes C–E the cure time values are almost constant. The reduced cure time may be attributed to the presence of accelerator relics present in the reclaimed rubber. However its effect becomes insufficient at higher reclaim loading as the number of available reactive sites for crosslinking becomes less when the reclaim content in the blend becomes higher. This is also reflected in the cure rate values which are lower for the blends (Figure 5). The partially crosslinked state of the reclaimed rubber limits its further crosslinkability.

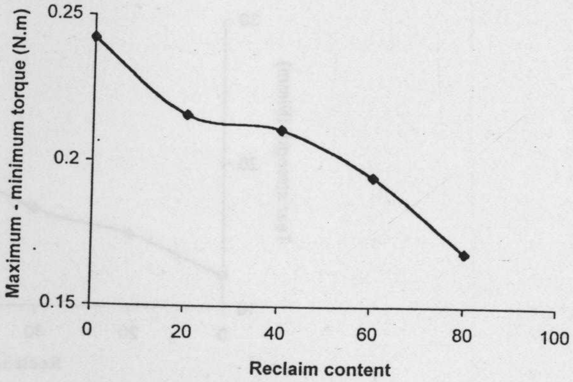

FIGURE 2 Variation of (maximum–minimum) torque with reclaim loading.

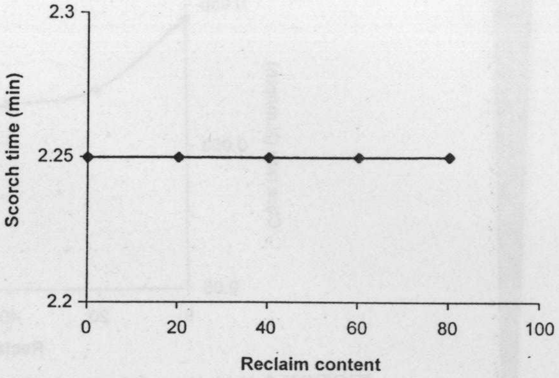

FIGURE 3 Variation of the scorch time with reclaim loading.

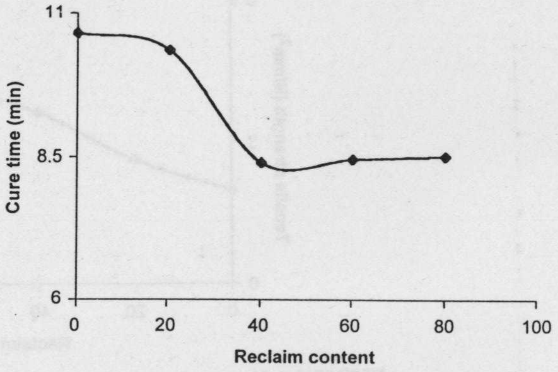

FIGURE 4 Variation of the cure time with reclaim loading.

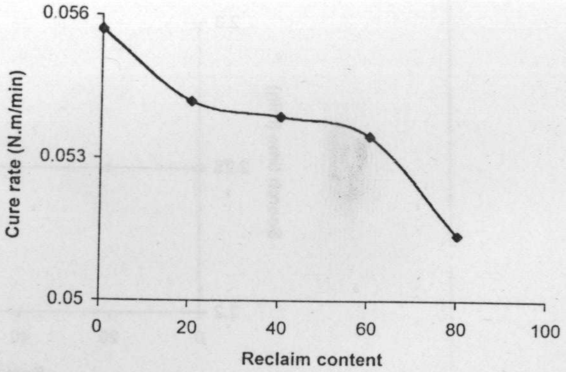

FIGURE 5 Variation of the cure rate with reclaim loading.

Mechanical Properties

The variation of tensile strength with the addition of reclaimed rubber is shown in Figure 6. The tensile strength shows an increase from 1.9 N/mm^2 at 0 parts to 5.07 N/mm^2 at 80 parts of reclaimed rubber. This is in contrast to the results reported in the case of NR – reclaimed rubber blends [16]. The difference can be attributed to the non-crystallizing nature of the SBR, which gives it poor gum strength. The presence of reinforcing filler in the reclaim rubber can contribute to the tensile strength of SBR. In the case of NR – reclaim blend, the low gum strength reclaim causes more of dilution of the NR matrix than reinforcement.

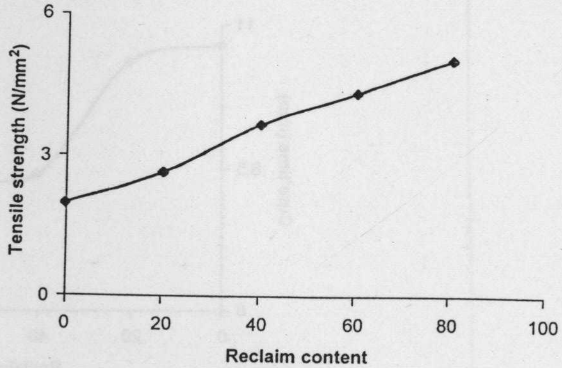

FIGURE 6 Variation of the tensile strength with reclaim loading.

The elongation at break values of the blends are given in Figure 7. The elongation at break shows an increase with increase in reclaim content which can be attributed to the higher oil content in the case of reclaimed rubber.

A plot of tear strength versus reclaim content is shown in Figure 8. The increase in tear strength with reclaim content can be attributed to the presence of reinforcing black in the case of blend.

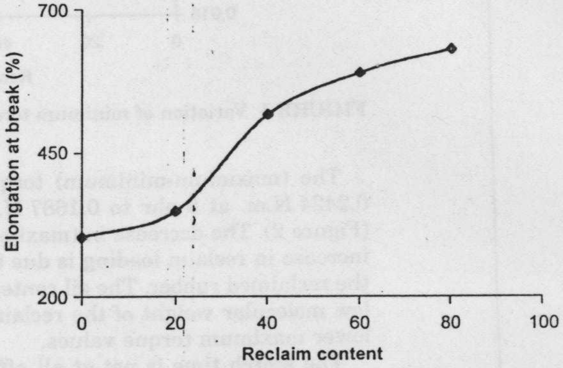

FIGURE 7 Variation of the elongation at break with reclaim loading.

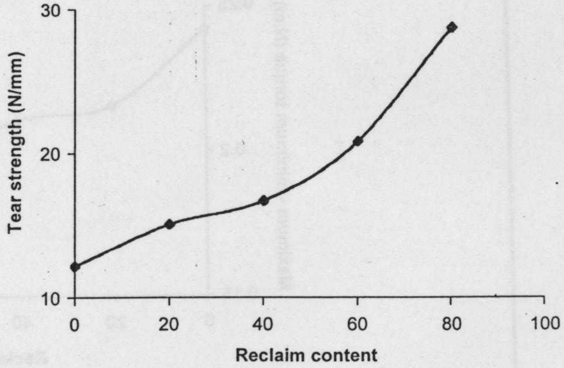

FIGURE 8 Variation of the tear strength with reclaim loading.

Resilience, a measure of material elasticity, is found to decrease with increase in reclaim content (Figure 9). The resilience decreased from 51% at 0 parts to 35% at 80 parts of reclaimed rubber. The higher the concentration of filler and plasticiser, the higher the chances of energy dissipation. The energy dissipation can be through loss at filler – matrix interface, friction between the chains or breakdown of filler structure. This will be manifested as lower resilience values.

The variation of compression set at constant strain is shown in Figure 10. The compression set increases with increase in reclaim loading which is in agreement with the observed reduced resilience. The increased compression set arises from the flowability of the compound under load at elevated temperature. The relatively lower molecular weight of the reclaimed rubber, or its oil content, renders the blend more plastic.

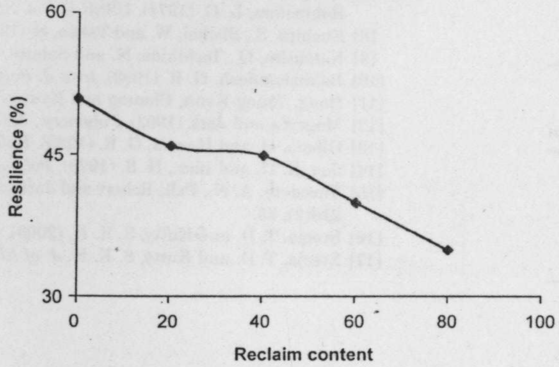

FIGURE 9 Variation of resilience with reclaim loading.

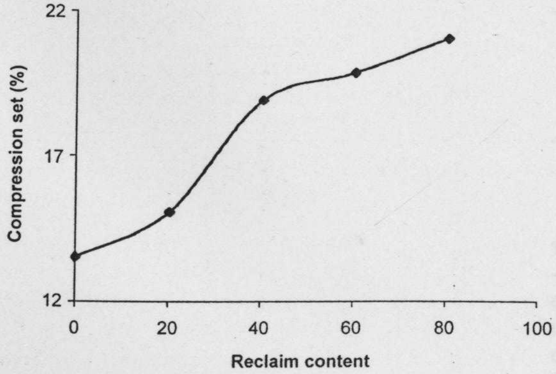

FIGURE 10 Variation of compression set with reclaim loading.

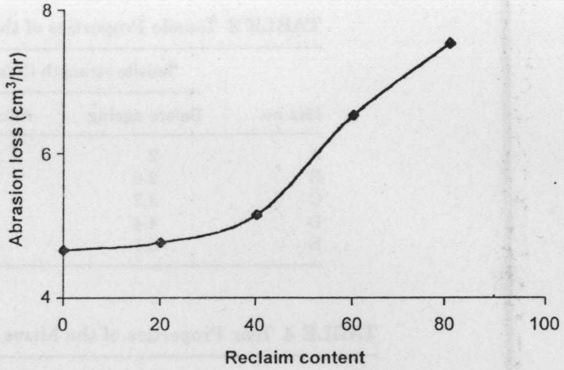

FIGURE 11 Variation of the abrasion loss with reclaim loading.

Figure 11 gives the abrasion loss of the blends containing different amounts of reclaimed rubber. The abrasion loss is small at lower reclaim loading but the rate of loss is higher at higher reclaim loading. This is due to the lower bonding between particles in reclaim vulcanizates as these particles are already vulcanized. The lower molecular weight of the reclaimed rubber is also contributing to the increased abrasion loss.

Ageing Resistance

The retention values of tensile strength after ageing are shown in Table 3. All mixes show retention marginally above 100%. This indicates a nominal level of post curing taking place during ageing. This is to be expected because of the characteristic cure pattern of SBR.

The tear strength values before and after ageing are shown in Table 4. All retention values are close to 100%. The tear properties are better when the sample is slightly undercured.

The aged values of elongation at break are found to be lower than those of the unaged ones at all reclaim loading (Table 5). This is in agreement with improved tensile strength values.

TABLE 3 Tensile Properties of the Mixes before and after Ageing

	Tensile strength (N/mm²)		
Mix no.	Before ageing	After ageing	Percentage retention
A	2	2.2	112
B	2.6	2.9	108
C	3.7	3.8	104
D	4.4	5	115
E	5.1	5.8	115

TABLE 4 Tear Properties of the Mixes before and after Ageing

	Tear strength (N/mm)		
Mix no.	Before ageing	After ageing	Percentage retention
A	12.2	10.8	89
B	15.1	15.2	100
C	16.7	18.9	113
D	20.8	21.8	105
E	28.7	31.3	109

TABLE 5 Elongation at Break Values of the Mixes before and after Ageing

	Elongation at break (%)		
Mix no.	Before ageing	After ageing	Percentage retention
A	304	261	86
B	349	345	99
C	517	391	76
D	588	496	84
E	629	525	84

CONCLUSIONS

The following conclusions are drawn: Introduction of reclaimed rubber to the SBR matrix increases the processability. Properties like minimum torque, (maximum−minimum) torque, cure time and cure rate decrease with reclaim content. Tensile and tear properties increase with increase in reclaim content. Elongation at break values are higher for blends. Compression set and abrasion loss increase and resilience decreases with reclaim loading.

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