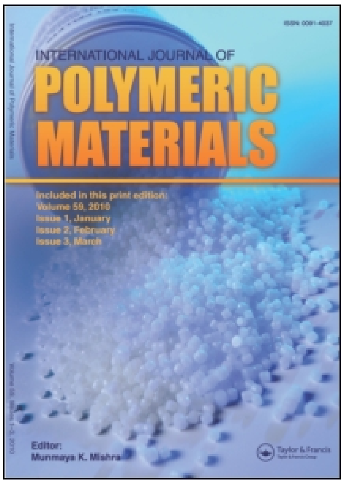

International Journal of Polymeric Materials
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713647664

Styrene butadiene rubber-short nylon fiber composites

T. D. Sreeja[a]; S. K. N. Kutty[a]
[a] Department of Polymer Science and Rubber Technology, Cochin University of Science and Technology, Cochin, India

Online publication date: 27 October 2010

To cite this Article Sreeja, T. D. and Kutty, S. K. N.(2003) 'Styrene butadiene rubber-short nylon fiber composites', International Journal of Polymeric Materials, 52: 3, 239 — 250
To link to this Article: DOI: 10.1080/00914030304894
URL: http://dx.doi.org/10.1080/00914030304894

International Journal of Polymeric Materials, 52: 239–250, 2003

0091-4037/03 $12.00 +.00
DOI: 10.1080/00914030390119389

STYRENE BUTADIENE RUBBER–SHORT NYLON FIBER COMPOSITES

T. D. Sreeja
S. K. N. Kutty
Department of Polymer Science and Rubber Technology,
Cochin University of Science and Technology, Cochin, India

The cure characteristics and mechanical properties of short nylon fiber reinforced styrene butadiene rubber were studied at varying fiber concentration. The plasticity of the composite was adversely affected by nylon short fibers. The minimum torque increased with fiber concentration. Scorch time and cure time showed a reduction in presence of short fibers. The tensile strength, tear strength, elongation at break and abrasion resistance were studied in both the orientation of fibers. Tensile strength, tear strength and abrasion resistance increased with fiber concentration and were higher in the longitudinal direction. Resilience showed a reduction with fiber content and compression set increased with fiber loading.

Keywords: styrene butadiene rubber, fiber, composite, cure characteristics, mechanical properties

INTRODUCTION

Short fiber reinforced elastomers have considerable importance due to the advantages in processing and good mechanical properties. The properties of short fiber reinforced composites mainly depend on the fiber matrix adhesion, aspect ratio of fiber, fiber dispersion and orientation, nature of matrix and type of fiber [1–5]. Arumugam et al., have reported that coconut fibers act as reinforcing filler for natural rubber when loaded above a volume loading of 10 phr [6]. De and coworkers have reported their studies on short jute fiber reinforced

Received 11 December 2000; in final form 17 December 2000.
T. D. Sreeja is grateful to CSIR, Government of India for financial assistance.
Address correspondence to S. K. N. Kutty, Department of Polymer Science and Rubber Technology, Cochin University of Science and Technology, Cochin 682 022, India. E-mail: sunil@cusat.ac.in

natural rubber and carboxylated nitrile rubber [4, 7, 8]. Short jute fiber and glass fiber reinforced SBR has been studied by Murthy [3] who concluded that jute fibers offer good reinforcement to SBR as compared to glass fiber. Natural rubber reinforced with short silk fiber was studied by Setua [9]. Bhatacharya have investigated the effect of short pineapple leaf fiber on natural rubber [10]. Senapati et al. reported that the mechanical properties of short polyester fiber reinforced natural rubber varied with fiber orientation, concentration and L/D ratio [11]. Varghese et al. have studied the curing characteristics and mechanical properties of short sisal fiber – natural rubber composites [12]. Polyester fiber reinforced ethylene propylene rubber was studied by Furukawa et al. [13]. Properties of short polyester fiber reinforced polyurethane composite have been studied by Suhara et al. [14–15]. We have reported the reinforcement of different matrices with nylon short fibers [16–18]. In the present study we report the result of our investigation on the cure characteristics and mechanical properties of short nylon fiber reinforced styrene butadiene rubber composite.

EXPERIMENTAL

Materials Used

Styrene butadiene rubber (synaprene 1502) was obtained from Synthetics and Chemicals Ltd., Bareilly. Nylon fiber obtained from SRF Ltd., Chennai was chopped to approximately 6 mm in length. Zinc oxide (ZnO) was obtained from M/s. Meta Zinc Ltd., Mumbai. Stearic acid was procured from Godrej Soap (Pvt.) Ltd., Mumbai, India. Dibenzothiazyl disulfide (MBTS) & 1,2-dihydro 2,2,4- trimethyl quinoline (HS) were obtained from Bayer India Ltd., Mumbai. Tetramethyl thiuramdisulfide (TMTD) was supplied by NOCIL, Mumbai, India. Sulfur was supplied by Standard Chemical Company Private Ltd., Chennai.

Processing

Formulation of the mixes is given in Table 1. These mixes were prepared as per ASTM D 3182 (1989) on a laboratory size two roll mixing mill. Fibers were oriented preferentially in one direction by passing once through tight nip at the end of mixing process. Schematic representation of fiber orientations in tensile and tear test samples is shown in Figure 1. Cure characteristics were determined by using Goettfert Elastograph Model 67.85 at 150°C. Mixes were

TABLE 1 Formulation of the Mixes

	Mix no.			
Ingredient	A	B	C	D
SBR	100	100	100	100
Short nylon fiber	0	10	20	30

SBR-Styrene butadiene rubber, (Zinc oxide – 4 phr, Stearic acid – 2 phr, HS (1,2-dihydro 2,2,4-trimethyl quinoline) – 1 phr, MBTS (dibenzothiazyl disulfide) – 0.5 phr, TMTD (tetramethylthiuram disulfide) – 1.8 phr and Sulfur – 0.3 phr are common to all mixes).

vulcanized at 150°C under a pressure of 180 kg/cm^2 in an electrically heated hydraulic press to their respective cure times. For thicker samples sufficient extra cure time was given. All the tests except resilience and compression set were carried out both along and across the direction of fiber orientation. The samples were aged for 48 hour at 70°C in an ageing oven to determine the ageing resistance of the composite.

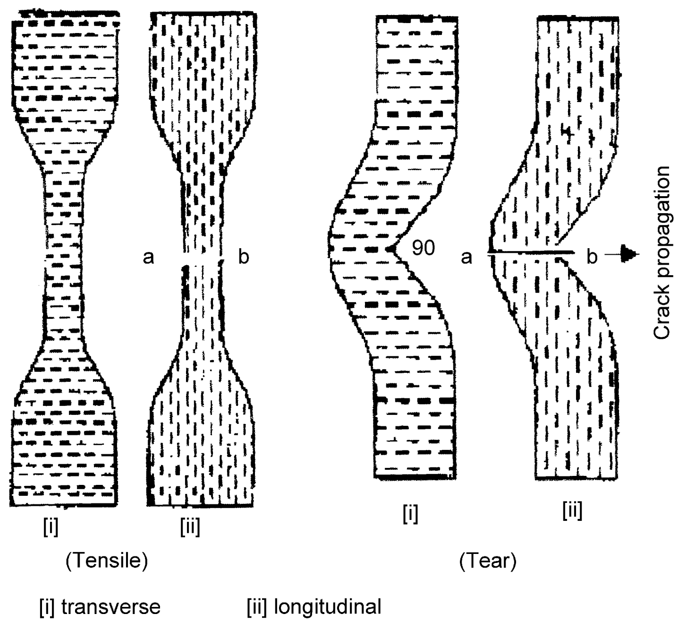

FIGURE 1 Schematic representation of fiber orientation.

RESULTS AND DISCUSSION

Cure Characteristics

A plot of minimum torque versus fiber content is shown in Figure 2. The minimum torque shows an increase from 0.029 N.m. at 0 phr to 0.083 N.m. at 30 phr of fiber indicating a loss in the processability of the composite. The presence of fibers restrict the flow of matrix and results in higher minimum torque values.

(Maximum–minimum) torque values show an increase with fiber loading as shown in Figure 3. The increase in (maximum–minimum) torque arises from the more restrained matrix in the case of composites in presence of short fibers. Similar results have been reported earlier in the case of NBR- short nylon fiber composites [17].

A plot showing the variation of scorch time with various amount of fiber is shown in Figure 4. The scorch time decreased from 2.25 minute at 0 phr to 0.75 minutes at 30 phr fiber. There is a reduction in cure time also with fiber content as shown in Figure 5. These results indicate that the cure reaction is being accelerated in the presence of short fibers. The cure rate increased from 0.0557 N.m/minute at 0 phr to 0.2442 N.m/min. at 30 phr fiber (Figure 6). This may be attributed to possible degradation of the nylon fibers at the curing temperature. The amine functionality of the degradation products may accelerate the cure reaction. Similar results have been reported earlier in the case of NBR- short nylon fiber composites [17].

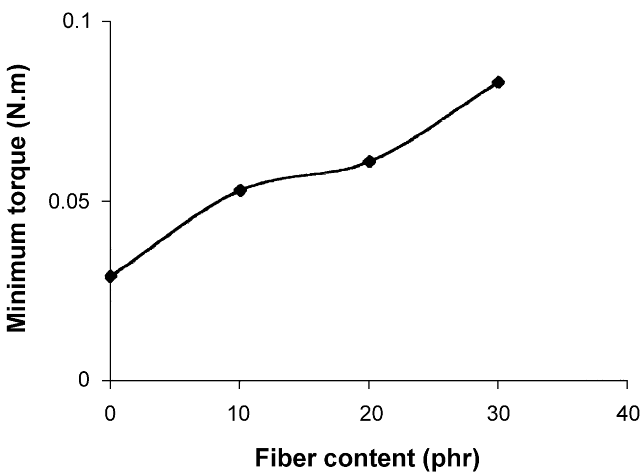

FIGURE 2 Variation of minimum torque with fiber loading.

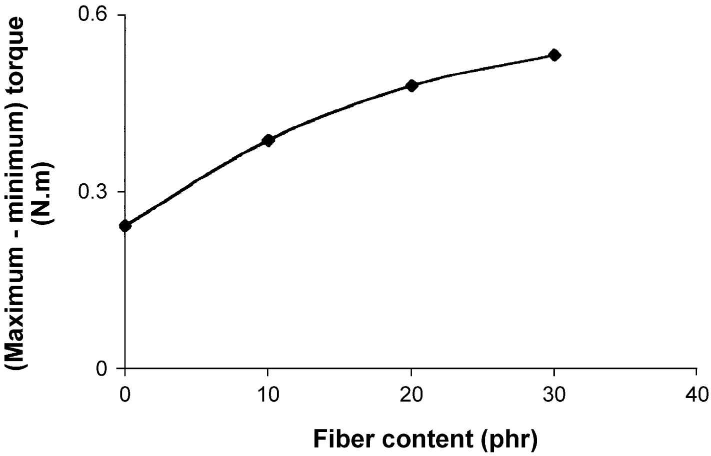

FIGURE 3 Variation of (maximum–minimum) torque with fiber loading.

Mechanical Properties

The variation of tensile strength with fiber content is shown in Figure 7. The tensile strength in both orientations of fibers (longitudinal and transverse) increased with fiber concentration. This is in contrast to the pattern reported for short nylon fiber–natural rubber composites, where the tensile strength-fiber relationship is non-linear with a

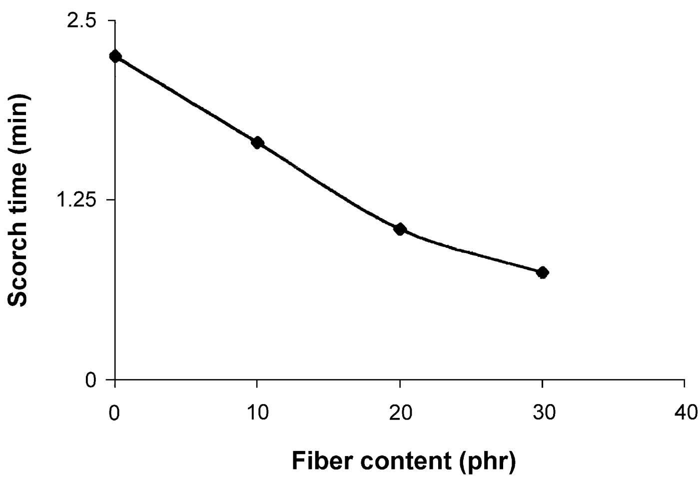

FIGURE 4 Variation of scorch time with fiber loading.

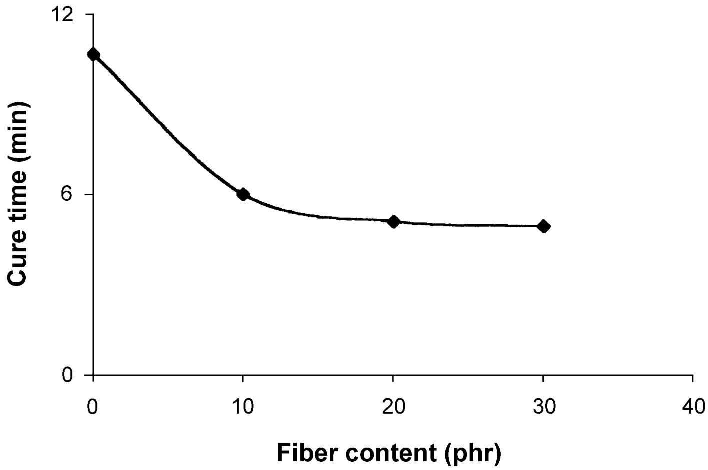

FIGURE 5 Variation of cure time with fiber loading.

minimum at lower fiber concentrations. This arises mainly from the fact that NR matrix has high gum strength due to strain induced crystallisation whereas SBR being a noncrystallising matrix, has a relatively lower gum strength. In the former case at lower fiber loading, the dilution effect due to physical presence of short fibers contributes to the initial reduction in tensile strength. At any given fiber loading the tensile strength values are higher in the longitudinal

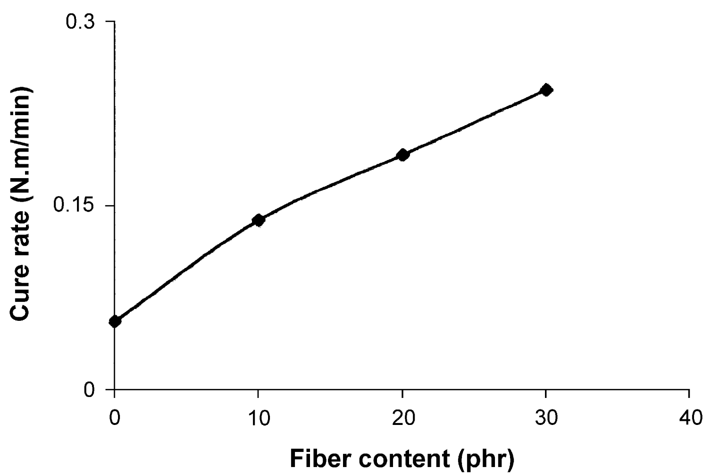

FIGURE 6 Variation of cure rate with fiber loading.

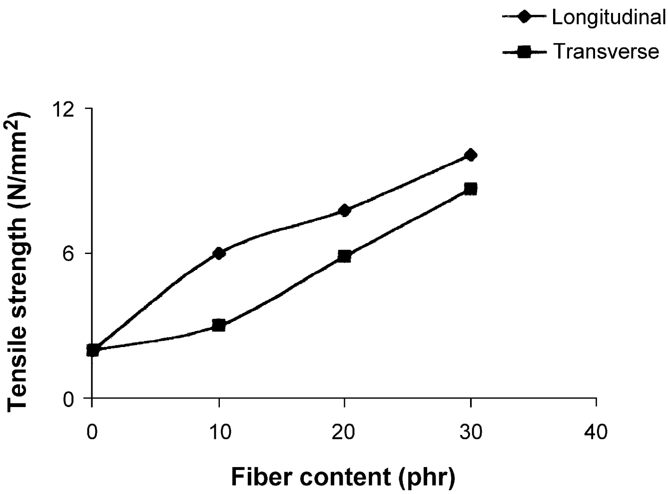

FIGURE 7 Variation of tensile strength with fiber loading.

direction. In the longitudinal direction the fibers are more effective in hindering the growing crack front and this results in higher tensile strength in that direction. As fiber concentration increases there are more and more fibers to hinder the crack front and tensile strength increases with fiber concentration.

The ultimate elongation shows a sharp fall upon the introduction of fibers (Figure 8), but with further increase the values tend to stabilize.

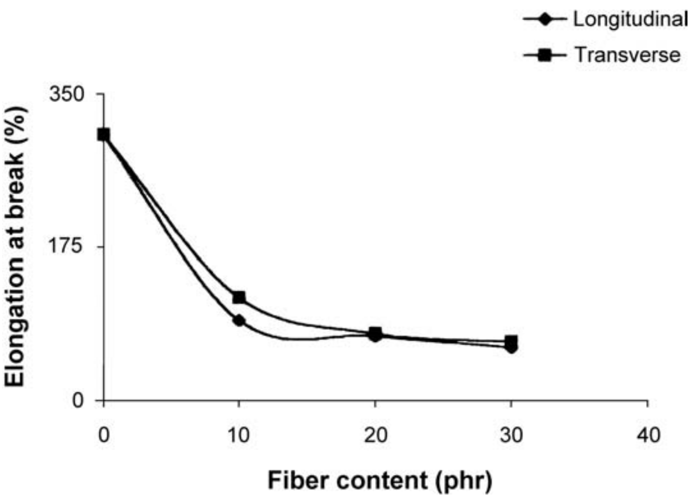

FIGURE 8 Variation of elongation at break with fiber loading.

In the presence of short fibers, the matrix is more restrained and the failure is initiated at multiple points, resulting in lower ultimate elongation values. At all fiber loading the elongation at break values are higher in the transverse direction.

The variation of tear strength with fiber concentration of the composites is given in Figure 9. Tear strength shows a continuous increase with increase in fiber content, both in longitudinal and transverse orientation of fibers. As fiber concentration increases there is more and more hindrance to the crack propagation. At any given fiber loading, mixes with longitudinal fiber orientation show higher tear strength than mixes with transverse fiber orientation. In the transverse direction fibers are parallel to the crack front, offering less resistance to propagation of tear, hence the lower tear values than in the longitudinal direction.

Resilience shows a reduction from 51% to 41% on introduction of fibers (Figure 10). With further increase in fiber amount it remains unchanged. The dissipation of energy at the fiber–matrix interface results in lower resilience value in the composite.

Figure 11 is a plot of compression set versus fiber content. There is a linear increase in compression set values with increase in fiber concentration. This is in agreement with the decreased resilience values.

Abrasion resistance registers an improvement with increase in fiber content in both longitudinal and transverse orientations of fibers (Figure 12). At any fiber concentration the loss is greater in the

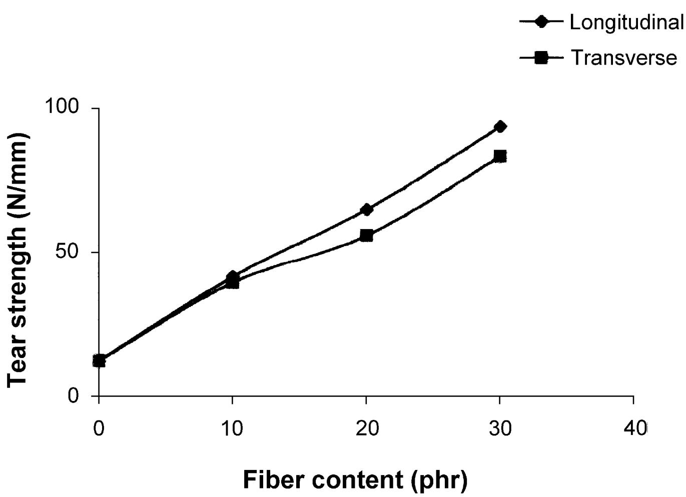

FIGURE 9 Variation of tear strength with fiber loading.

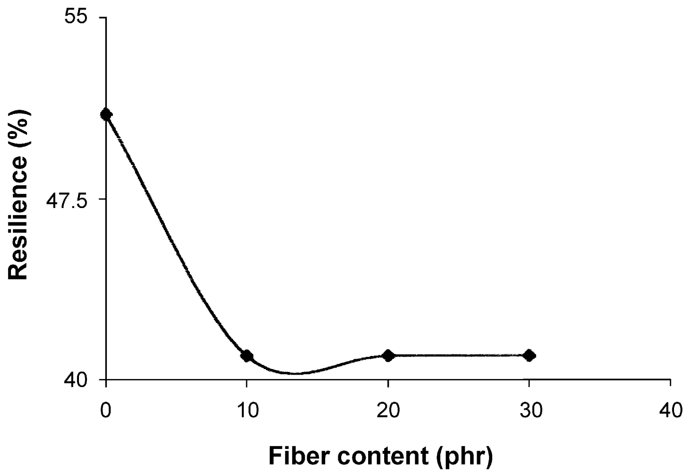

FIGURE 10 Variation of resilience with fiber loading.

transverse direction than in the longitudinal direction. The fibers get debonded and separated from the matrix more easily when the fibers are arranged transversely, resulting in higher abrasion loss in that direction.

Ageing Resistance

Table 2 shows the retention of tensile properties of the composites before and after ageing. In all cases the retention of tensile strength is

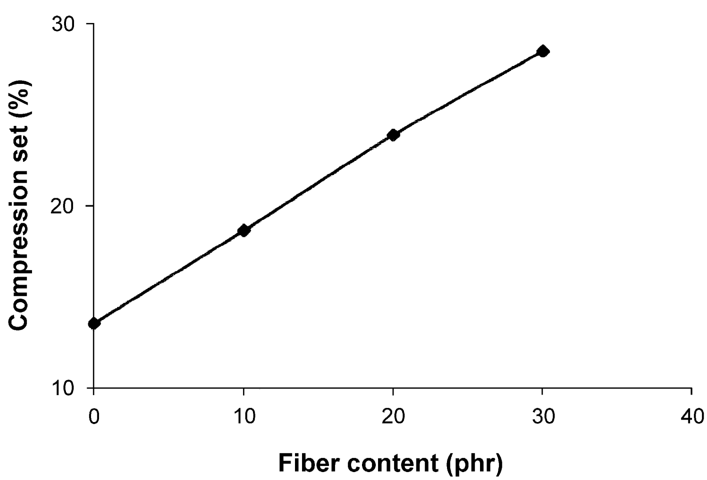

FIGURE 11 Variation of compression set with fiber loading.

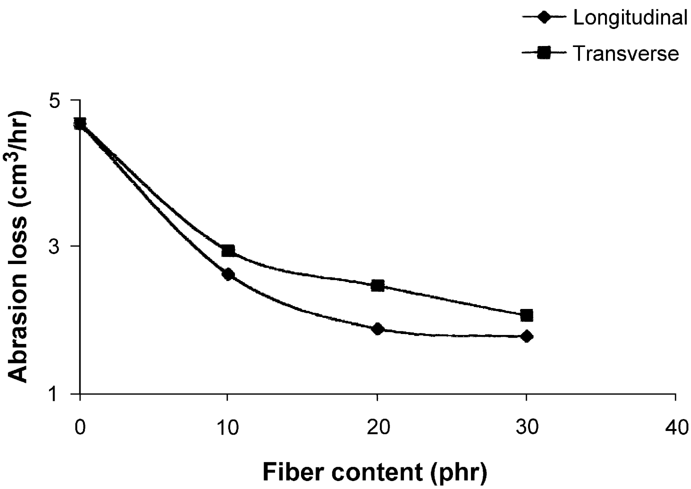

FIGURE 12 Variation of abrasion loss with fiber loading.

found to be better for the composites. This may arise out of improved fiber matrix interfacial bond during the ageing. The direction of fiber orientation does not seem to have much influence on the retention values.

The tear resistance of the gum compound (mix A) is reduced while those of all the fiber filled mixes (mixes B–D) are improved by ageing at elevated temperature (Table 3). This is because the tear resistance of an elastomer is better when the matrix is slightly undercured. Since ageing leads to further cure in the case of SBR, the tear resistance of mix A is lower after ageing. For the fiber filled samples, since the fibers

TABLE 2 Tensile Properties of the Mixes before and after ageing

		Tensile strength (N/mm^2)		
Mix no.	Orientation	Before ageing	After ageing	Percentage retention
A		2	2.2	113
B	L	7	10.4	150
	T	3	5.3	140
C	L	7.8	11.1	142
	T	5.9	8.6	147
D	L	10.1	13.5	134
	T	8.6	10.1	117

L – Longitudinal orientation.
T – Transverse orientation.

TABLE 3 Tear Properties of the Mixes before and after Ageing

Mix no.	Orientation	Tear strength (N/mm) Before ageing	After ageing	Percentage retention
A		12.2	10.8	89
B	L	41.4	44.3	107
	T	39.3	40.9	104
C	L	64.8	73.5	113
	T	55.7	65.4	118
D	L	93.5	94.3	101
	T	83.2	88.1	106

L – Longitudinal orientation
T – Transverse orientation

compensate for such losses with interfacial bonding that is improved during ageing, the retention values are better.

The percentage retention values of elongation at break is shown in Table 4. The retention values of the composites are almost similar.

CONCLUSION

Incorporation of short nylon fibers to SBR matrix reduces the processability. Minimum torque and (maximum–minimum) torque increase with fiber concentration whereas the scorch time and cure time show reduction with fiber concentration. The tensile and tear

TABLE 4 Elongation at Break Values of the Mixes before and after Ageing

Mix no.	Orientation	Elongation at break (%) Before ageing	After ageing	Percentage retention
A		304	261	86
B	L	92	94	102
	T	118	128	108
C	L	74	78	105
	T	77	85	111
D	L	61	71	117
	T	68	75	112

L – Longitudinal orientation.
T – Transverse orientation.

strength of the composites increase with fiber concentration and are higher in the longitudinal direction. Resilience of the composite is lower than that of the gum compound. Compression set is higher for the composite. Abrasion resistance is increased in presence of short fibers.

REFERENCES

[1] Coran, A. Y., Hamed, P. and Goettler, L. A. (1976). *Rubber Chem. Technol.*, **49**, 1167.
[2] Morghe, S. R. (1976). *Rubber Chem. Technol.*, **49**, 1160.
[3] Murthy, V. M., and De, S. K. (1984). *J. Appl. Polym. Sci.*, **29**, 1355.
[4] Murthy, V. M., and De, S. K. (1982). *Rubber Chem. Technol.*, **55**, 287.
[5] Derringer, G. C. (1971). *J. Elastoplast.*, **3**, 230.
[6] Arumugam, N. Tamere Selvy, K. and K. Venkata Rao, (1989). *J. Appl. Polym. Sci.*, **37**, 2645.
[7] Murthy, V. M. and De, S. K. (1982). *J. Appl. Polym. Sci.*, **27**, 4611.
[8] Chakraborty, S. K. Setua, D. K. and De, S. K. *Rubber Chem. Technol.*, (1982) **55**, 1286.
[9] Setua, D. K. and De, S. K. (1983). *Rubber Chem. Technol.*, **56**, 808.
[10] Timir Baran Bhattacharya, Amit Kumar Biswas and Jayadev Chattergee, (1986) *Plastics and Rubber Processing and Applications*, **6**, 119.
[11] Senapaty Kutty, A. K. S. K. N. Kutty B. Pradhan, and G. B. Nando, *Inter. J. Polymeric Mater.*, **12**, 203(1989).
[12] Siby Varghese, Baby Kuriakose, Sabu Thomas and Alex J. Koshy *Indian J. Nat. Rubber. Res.*, **4**, 5155(1991).
[13] Furukawa, Masatsugu, Walanabo, Hirosuke, Takada and Tadahiko, *Jpn. Kokai Tokkyo Koho*, Appl. 96/264,269, 4 Oct., 1996; 8 pp., 28 Apr., 1998.
[14] Suhara, F. Kutty, S. K. N. and Nando, G. B. *Polym. – Plast. Technol. Eng.*, (1998) **37**(2), 241–252.
[15] Suhara, F., Kutty, S. K. N., Nando, G. B. and Bhatacharya, A. K. (1998). *Polym. — Plast. Technol. Eng.*, **37**(1), 241–252(1998).
[16] Sreeja, T. D. and Kutty, S. K. N. *J. of Elasomers and plastics* (communicated).
[17] Sreeja, T. D. and Kutty, S. K. N. *J. of Elasomers and plastics* (communicated).
[18] Sreeja, T. D. and Kutty, S. K. N. *Inter. J. Polymeric Mater.* (accepted).