

Cure Characteristics, Morphology, Mechanical Properties, and Aging Characteristics of Silicone Rubber/Ethylene Vinyl Acetate Blends

B. Ganesh, G. Unnikrishnan

Polymer Science and Technology Laboratory, National Institute of Technology Calicut, Calicut, Kerala, India

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ABSTRACT: Silicone rubber/ethylene vinyl acetate (SR/EVA) rubber mixes with different ratios were prepared by using dicumyl peroxide (DCP) and benzoyl peroxide (BP) as curing agents. The vulcanization characteristics such as cure kinetics, activation energy, and cure rate of the blends were analyzed. The effects of blend ratio and curing agents on the mechanical properties such as stress-strain behavior, tensile strength, elongation at break, tear strength, relative volume loss, hardness, flex crack resistance, and density of the cured blends have been investigated. Almost all the mechanical properties have been found to be increased with increase in EVA content in the blends particularly in DCP-cured systems. The increment in mechanical properties of the blends

with higher EVA content has been explained in terms of the morphology of the blends, attested by scanning electron micrographs. Attempts have been made to compare the experimental results, from the evaluation of mechanical properties, with relevant theoretical models. The aging characteristics of the cured blends were also investigated and found that both the DCP- and BP-cured blends have excellent water and thermal resistance. © 2005 Wiley Periodicals, Inc. *J Appl Polym Sci* 99: 1069–1082, 2006

Key words: blends; morphology; mechanical properties; aging; silicone rubber; ethylene vinyl acetate

INTRODUCTION

Polymer blending, a process by which one component is dispersed within the continuum of another, is an accepted method for the development of products having unique properties.^{1–6} Silicone rubber (SR) has been studied extensively because of its superior performance in biomedical and industrial fields. Ethylene vinyl acetate (EVA) exhibits excellent ozone resistance, weather resistance and mechanical properties. Several polymers have been blended with SR and EVA to make high performance materials to compensate the need of new materials. Soares et al.⁷ studied the effect of mercapto-modified EVA on the curing parameters, mechanical properties, and thermal properties of vulcanized styrene-butadiene rubber (SBR/EVA) blends. They observed best mechanical performance for both compatibilized and noncompatibilized blends. The crystallinity of the EVA phase was found to be significantly affected by the presence of the modified EVA, whereas no substantial change was detected on the damping properties or the glass transition temperature of the SBR phase. Consider-

ing the aging properties, the presence of modified EVA in the blend matrix increased the thermal stability of the blends, vulcanized with DCP. Ramirez et al.⁸ studied the morphological characteristics and mechanical properties of polypropylene [PP]/EVA blends and compared this with those of polypropylene-(ethylene-propylene) heterophasic copolymer [PP-EP]/EVA systems. At EVA concentrations up to 20%, the elongation at break and impact strength slightly increased in both systems. However, PP-EP/EVA displayed higher values of these properties compared with PP/EVA. At higher EVA concentrations (above 20%), the indicated properties were enhanced in both polymeric systems, and the same proportional behavior was maintained. The decrease in tensile strength of PP-EP/EVA was not as marked as in PP/EVA with the addition of EVA, and it remained below PP/EVA at high EVA concentrations. The improvement in properties of PP-EP/EVA was attributed to the favorable interactions between the ethylene groups contained in both copolymers. These interactions rendered a high degree of compatibility between the PP-EP and EVA components. Varghese et al.⁹ developed blends of acrylonitrile butadiene rubber and EVA, with varying proportions of the components, vulcanized using different crosslinking systems, viz., sulfur (S), dicumyl peroxide (DCP), and a mixed system (S + DCP). They studied the mechanical properties

Correspondence to: G. Unnikrishnan (unnig@nitc.ac.in).

TABLE I
Formulation of the Mixes

Sample codes	Silicone rubber (phr)	Ethylene vinyl acetate (phr)	Dicumyl peroxide (phr)	Benzoyl peroxide (phr)
S ₀ D	0	100	2	—
S ₃₀ D	30	70	2	—
S ₅₀ D	50	50	2	—
S ₇₀ D	70	30	2	—
S ₁₀₀ D	100	0	2	—
S ₀ B	0	100	—	2
S ₃₀ B	30	70	—	2
S ₅₀ B	50	50	—	2
S ₇₀ B	70	30	—	2
S ₁₀₀ B	100	0	—	2

phr, Parts per hundred rubber.

such as stress-strain behavior, tensile strength, elongation at break, Young's modulus, and tear strength and reported that the mixed system exhibited better

mechanical performance than other systems. They also checked the applicability of various theoretical models to predict the properties of the blend sys-

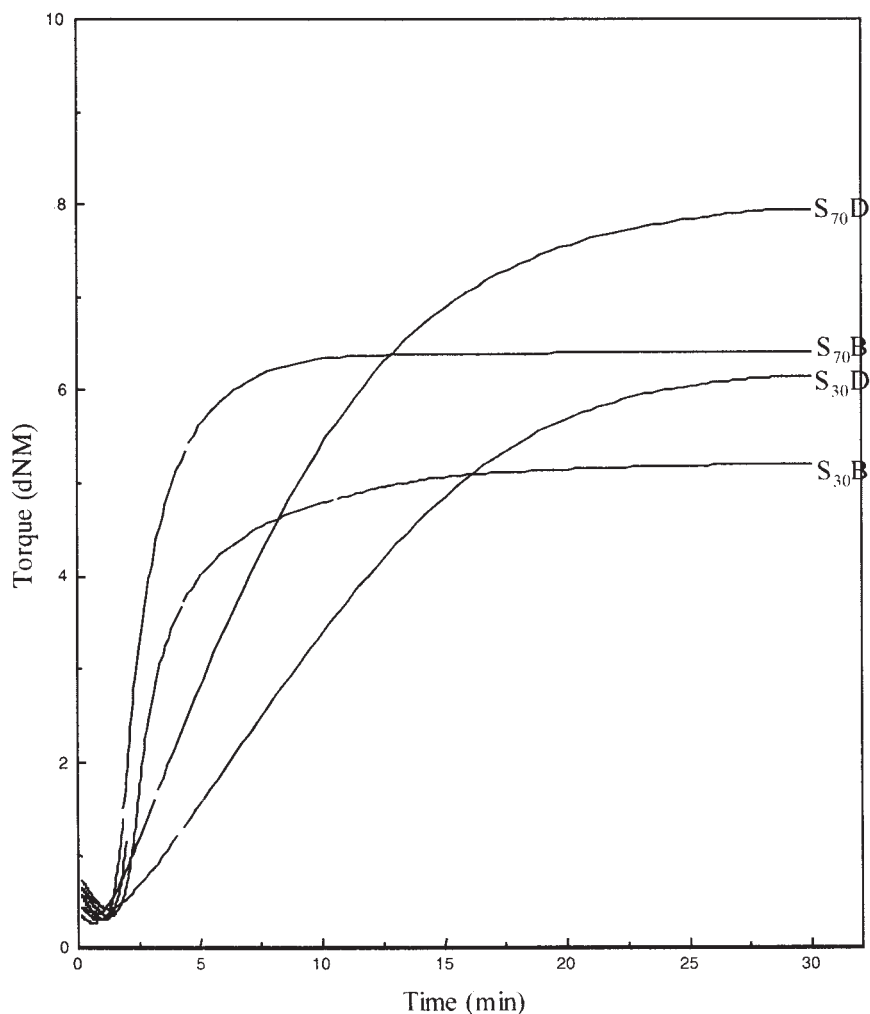


Figure 1 The rheometer curves of DCP- and BP-cured SR/EVA blends. S₃₀B indicates blend with 30 phr of SR cured with BP. S₃₀D indicates blend with 30 phr of SR cured with DCP. S₇₀B indicates blend with 70 phr of SR cured with BP. S₇₀D indicates blend with 70 phr of SR cured with DCP.

TABLE II
Rheometric Characteristics of DCP- and BP-Cured SR/EVA Blends at 160°C

Samples	Scorch time (t_2) (min)	Optimum cure time (t_{90}) (min)	Scorch time torque (dNm)	Torque at t_{90} (dNm)	Maximum torque (dNm)
S ₀ D	2.6	19.3	0.20	4.32	4.80
S ₃₀ D	2.1	15.4	0.34	5.54	6.15
S ₅₀ D	1.9	14.6	0.44	6.35	7.05
S ₇₀ D	1.7	11.3	0.53	7.16	7.95
S ₁₀₀ D	1.3	10.2	0.68	8.37	9.30
S ₀ B	3.1	27.4	0.17	3.43	3.94
S ₃₀ B	1.4	21.3	0.48	4.68	5.21
S ₅₀ B	0.9	16.7	0.89	4.86	5.40
S ₇₀ B	0.6	12.3	0.97	5.76	6.44
S ₁₀₀ B	0.5	6.6	1.03	7.02	7.82

tems. Thermal and mechanical properties of poly (L-lactic acid)(PLLA)-EVA blends were investigated by Yoon et al.¹⁰ It has been found that the blend of PLLA with 70% of EVA was immiscible because of nearly constant values of T_g and the spherulitic growth rate regardless of the change in the blend composition. On the other hand, the T_g , equilibrium melting temperature, and the spherulitic growth rate during the isothermal crystallization of the PLLA-EVA85 blend was decreased with increase in the EVA content. The tensile strength and modulus of the PLLA-EVA85 blend were dropped rapidly, followed by a more gradual decrease with increase in the EVA85 content. Strain-at-break, however, was increased rather slowly up to 70 wt % of EVA85 and then increased quite rapidly around 90 wt % of EVA85. The mechanical properties and morphology of polyamide 6 and EVA at a blending composition of 0–50 wt % EVA were studied by Bhattacharyya et al.¹¹ The tensile strength and the tensile modulus of the blends decreased steadily as the weight percent of EVA increased. Analysis of the tensile data using predictive theories indicated the extent of the interaction of the dispersed phase and the matrix up to 20 wt % EVA. Scanning electron micrographic

(SEM) studies indicated an increase in the dispersed phase domain size with EVA concentrations.

Kole et al.¹² studied the morphology and mechanical properties of silicone-ethylene-propylene-diene monomer (SR/EPDM) system at different blend ratios using two curatives at two different dosages. Ageing properties of the blends containing more than 25% of EPDM was found to be very poor. They also observed that two-stage cured vulcanizates improved the tensile strength and modulus of the system. SEM studies revealed a cocontinuous type structure for the two-stage vulcanizates, which accounted for their improved performance. Volume fraction and temperature dependence of the mechanical properties of SR particulate/epoxy (EP) blends were investigated by Miwa et al.¹³ At all temperatures, both the Young's modulus and tensile strength of SR particle/EP resin blends decreased as the volume fraction of SR particles was increased, and this decrease became greater with falling temperature. The aggregation structure and mechanical properties of liquid SR, polyurethane (PU), and EP blends were studied by Chiu et al.¹⁴ The molecular structure was evaluated by FTIR and the mechanical properties, including the tension, compression,

TABLE III
Activation Energy, Reaction Rate Constant, and Cure Rate of SR/EVA Blends

Samples	Activation energy (kcal mol ⁻¹)	Reaction rate constant (k)	Cure rate (at 160°C)
S ₀ D	24.24	0.131	0.25
S ₃₀ D	23.52	0.151	0.39
S ₅₀ D	21.70	0.165	0.46
S ₇₀ D	21.07	0.191	0.69
S ₁₀₀ D	19.04	0.201	0.86
S ₀ B	29.13	0.088	0.19
S ₃₀ B	22.46	0.075	0.48
S ₅₀ B	17.86	0.086	0.73
S ₇₀ B	12.70	0.087	0.92
S ₁₀₀ B	10.44	0.197	0.99

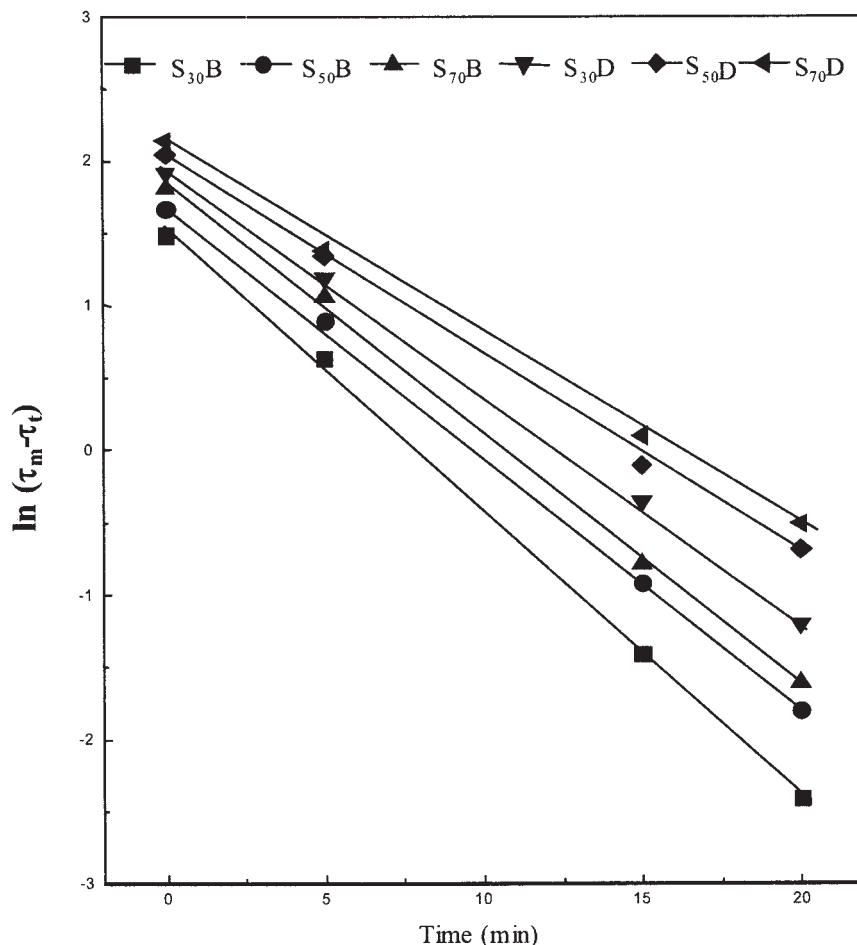


Figure 2 Plots of $\ln[M_t - M_i]$ vs. " t " for $S_{30}B$, $S_{50}B$, $S_{70}B$, $S_{30}D$, $S_{50}D$, and $S_{70}D$ blends. $S_{30}B$ indicates blend with 30 phr of SR cured with BP. $S_{30}D$ indicates blend with 30 phr of SR cured with DCP. $S_{50}B$ indicates blend with 50 phr of SR cured with BP. $S_{50}D$ indicates blend with 50 phr of SR cured with DCP. $S_{70}B$ indicates blend with 70 phr of SR cured with BP. $S_{70}D$ indicates blend with 70 phr of SR cured with DCP.

shear, and tear performance, were also measured. From the relationship between the intermolecular interaction and mechanical properties, it was found that the aggregation structure of the three-phase blends was influenced by the reaction between silicone and PU, silicone and EP, and PU and EP, which resulted in a change in the crosslinking density and an interpenetrating polymer network structure. Mechanical properties, crosslink density and surface morphology of SBR, SR and their blends cured with sulfur, peroxide, and combinations of both systems were analyzed by Popovic et al.¹⁵ Cure characteristics and vulcanizate properties were compared. The best results were obtained with 80/20 SBR/SR blend.

The main objective of the present study is to prepare and characterize blends of SR and EVA vulcanized by two agents viz., dicumyl peroxide and benzoyl peroxide (BP). The vulcanization characteristics such as cure kinetics, activation energy, and cure rate of the blends have been analyzed. The mechanical properties such

as stress-strain behavior, tensile strength, elongation at break, tear strength, relative volume loss, hardness, flex crack resistance, and density of the blends have also been investigated. The aging characteristics of the blends were evaluated in water and thermal environment. Attempts have also been made to correlate the mechanical properties with the existing theoretical models.

EXPERIMENTAL

Materials

SR was supplied by GE Bayer Silicone (India) Pvt Ltd, Bangalore, India, with 11 vol % of silica content and 0.45% of vinyl methyl siloxane. EVA having 18% of vinyl acetate content was supplied by Exxon Chemical Company (Houston, TX). The curing agents dicumyl peroxide (DCP) and benzoyl peroxide (BP) were supplied by Aldrich (Milwaukee, WI).

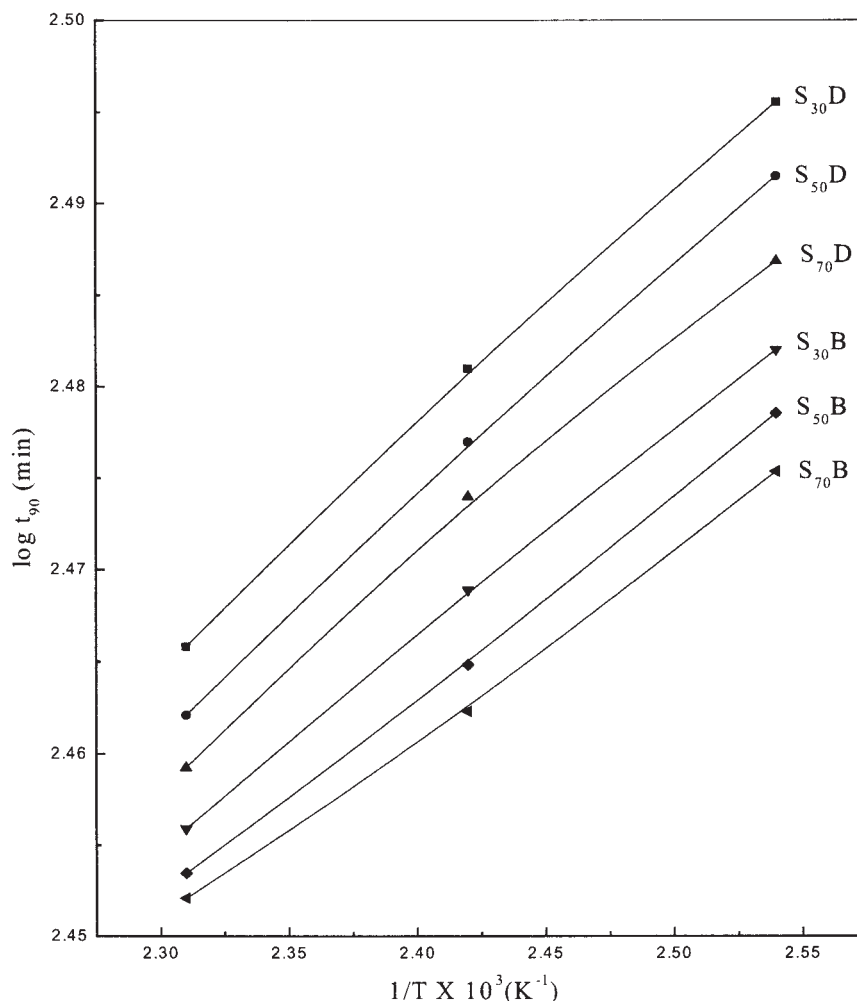


Figure 3 Arrhenius plots for $S_{30}B$, $S_{50}B$, $S_{70}B$, $S_{30}D$, $S_{50}D$, and $S_{70}D$ blends. $S_{30}B$ indicates blend with 30 phr of SR cured with BP. $S_{30}D$ indicates blend with 30 phr of SR cured with DCP. $S_{50}B$ indicates blend with 50 phr of SR cured with BP. $S_{50}D$ indicates blend with 50 phr of SR cured with DCP. $S_{70}B$ indicates blend with 70 phr of SR cured with BP. $S_{70}D$ indicates blend with 70 phr of SR cured with DCP.

Preparation of samples

The blends were prepared on a two-roll mixing mill (friction ratio, 1:1.4) as per the test recipes given in Table I. The cure characteristics of the blends were studied by a Monsanto moving disk rheometer (MDR-2000). The compounded blends were then compression molded using an electrically heated hydraulic press at 160°C under 30 tonnes for the optimum cure. The blends have been designated as S_0 (pure EVA), S_{30} (30/70 SR-EVA) and so on. The subscript indicates the weight percentage of SR in the blends. The suffixed letters D and B indicate the curing agent used i.e., DCP and BP, respectively. For green strength studies, blends without curative were prepared and were compression molded at 120°C for 2 min.

Morphology

The morphological observations of the blends were made by using a scanning electron microscope

(JEOL-JS IN-T330-A-SEM; ISS Group, Whittington, Manchester, UK). For the observations, surfaces of uncrosslinked blends, after the preferential extraction of one component, were sputter coated with gold and examined under SEM.

Mechanical properties

Tensile testing of the samples was done at ambient temperature according to ASTM D-412 test method at a crosshead speed of 500 mm/min using an Instron Universal Testing Machine (Series IX automated material testing system 1.38, model-441). Tear test was also conducted according to ASTM D-624 test method in the same instrument. The experimental temperature and cross head speed of the instrument for the tear test was kept the same as that for tensile testing. The hardness of the sample was measured according to ASTM D-2240 by a Mitutoyo Shore A. Abrasion resistance was measured

using Zwick made DIN Abrader as per DIN-53,516 standard. Monsanto model equipment with sensitive scale was employed in density test. Flex crack resistance of the samples was tested using a Demattia flexing machine as per ASTM D 813–95. The thermal and water resistances of the vulcanasates were tested as per ASTM D 573–04 and ASTM D-471–66, respectively. In all the experiments five samples from each formulation were tested and an average value has been reported.

RESULTS AND DISCUSSION

Cure characteristics

To optimize the curing system, parameters such as cure time, cure rate, activation energy (E), and first order reaction constant (k) were examined for SR/EVA blends. Since both the components of the blends have saturated carbon moiety in their structures, curing agents such as BP and DCP, which introduce carbon–carbon (C–C) crosslinks between the macromolecular chains, were used for the present studies. The typical rheographs of BP- and DCP-cured SR/EVA blends at 160°C are shown in Figure 1 and the rheometric characteristics of the blends are tabulated in Table II. For all the mixes, an initial decrease in torque was observed because of the softening of the matrix followed by an increase due to the onset of C–C crosslinks between the elastomer chains. The plateau region indicates the completion of the curing process. It can be seen from Figure 1 that a higher maximum torque (τ_m), which is a measure of crosslink density, was obtained for the DCP-cured samples than the BP-cured samples. This is due to the fact that at 160°C peroxide free-radical formation efficiency, which accounts for the number of crosslinks in the system, is higher for DCP than for BP.¹⁶ It is also found that the cure time of the blends increases with increase in EVA content, which is more prominent for BP-cured systems. It is clear from Table II that, for both the vulcanizing systems, as the EVA content in the matrix increased scorch time increased, indicating higher scorch safety. This increment in scorch time and thus the scorch safety is definitely associated with the semi-crystalline nature of EVA.

To understand the kinetics of vulcanization of the blends, the following kinetic equation was used.¹⁷

$$\ln(\tau_m - \tau_t) = -kt \ln C \quad (1)$$

where τ_m is the maximum torque developed, τ_t is the torque at time ' t ', ' C ' is the initial concentration of rubbers and ' k ' the specific reaction rate constant, obtained from the plot of $\ln(\tau_m - \tau_t)$ against ' t '. The computed values of ' k ' of the blends have been

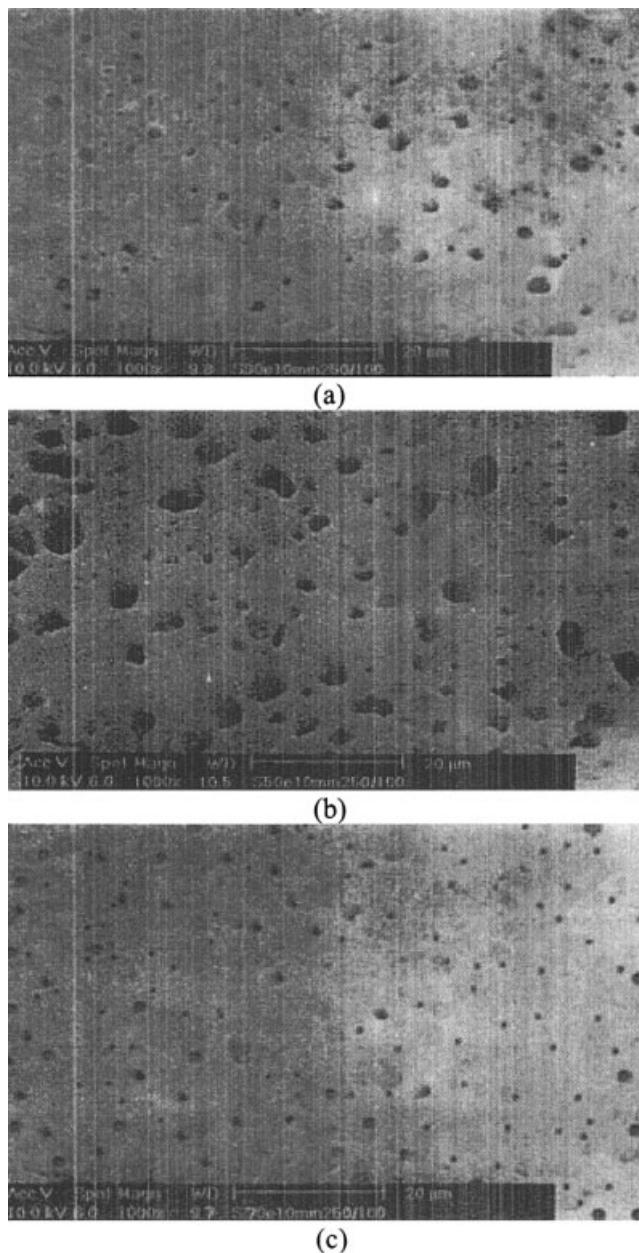


Figure 4 Scanning electron micrographs of SR/EVA blends—(a) S_{30} , (b) S_{50} , and (c) S_{70} .

tabulated in Table III. The observed lower k values for the blends for higher EVA content systems is due to the rigid carbon backbone of EVA, which is less reactive than SR with the curatives. Typical plots of $\ln(\tau_m - \tau_t)$ vs. ' t ' of the blends $S_{30}D$, $S_{50}D$, $S_{70}D$, $S_{30}B$, $S_{50}B$, and $S_{70}B$ are shown in Figure 2. The obtained graphs are straight lines, which indicate that the cure reaction of the present blend system follows first order kinetics.

To find out the activation energy of the vulcanization reaction, the modified Arrhenius equation was used.¹⁷

$$\log t_{90} = \log A + E/2.303RT \quad (2)$$

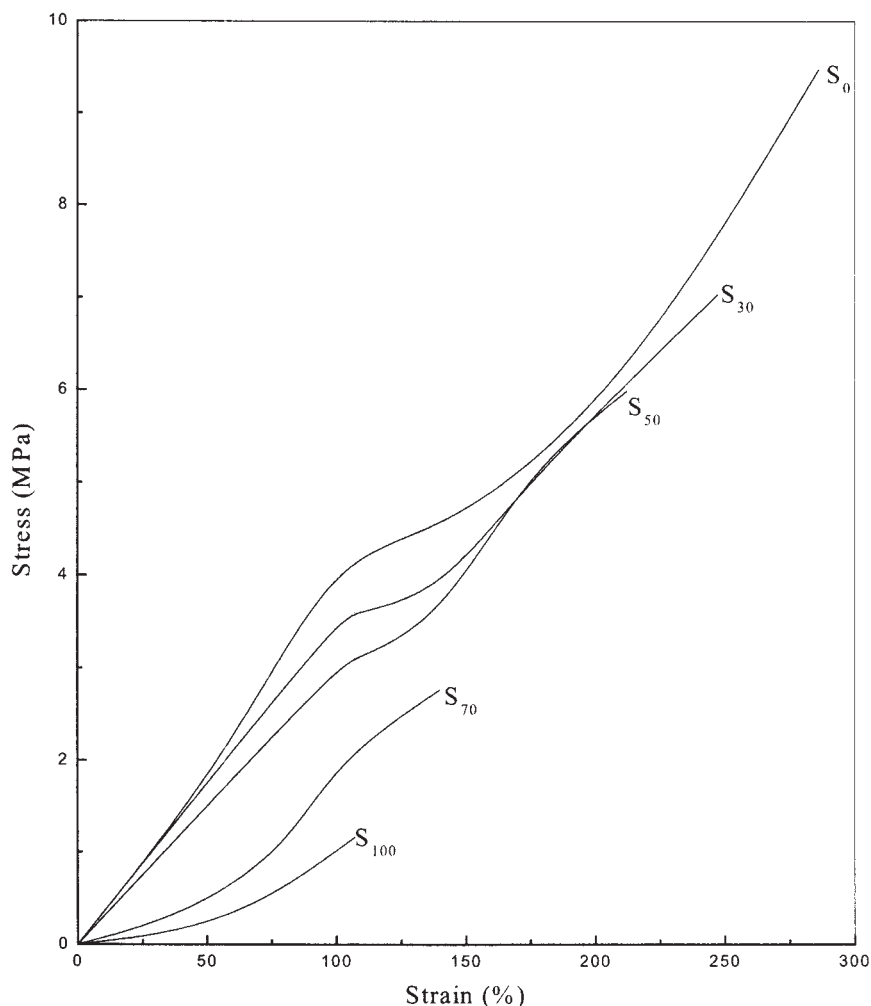


Figure 5 Stress-strain characteristics of uncured SR/EVA blend with different blend ratio. S_0 indicates uncured sample with 0/100 phr of SR/EVA. S_{30} indicates uncured blend with 30/70 phr of SR/EVA. S_{50} indicates uncured blend with 50/50 phr of SR/EVA. S_{70} indicates uncured blend with 70/30 phr of SR/EVA. S_{100} indicates uncured sample with 100/0 phr of SR/EVA.

where E is the activation energy, R the gas constant and T the absolute temperature.

The E values were calculated from the plots of $\log t_{90}$ against $1/T$ using regression analysis and are shown in Table III. Typical plot of $\log t_{90}$ vs. $1/T$ of the blends $S_{30}D$, $S_{50}D$, $S_{70}D$, $S_{30}B$, $S_{50}B$, and $S_{70}B$ are shown in Figure 3. The DCP-cured systems showed higher E values than the corresponding BP-cured systems at all temperatures. It is also clear from Table III that the activation energy for vulcanization of the blends decreases with increase in SR content, which shows that SR is the cure-activating component in SR/EVA blend systems.

The cure rate of the blends have been calculated as follows

Cure rate

$$= \frac{(\text{cure time torque} - \text{scorch time torque})}{(\text{cure time} - \text{scorch time})} \quad (3)$$

The calculated values of cure rate are also given in Table III. Significant difference in cure rate was observed for the DCP- and BP-cured blends. The difference in cure rate between DCP- and BP-cured systems is due to the difference in the solubility of the curative in the elastomers and also due to the difference in the rate of vulcanization of the two components even when they contain same dosage of curing agent.

Morphology

The SEM photographs of S_{30} , S_{50} , and S_{70} blends are shown in Figures 4(a)–4(c). The holes seen on the surface are formed by the extraction of one of the phases. It has been found that the component dispersion nature in the blends is not uniform, which indicates their heterogeneous nature. However, the relative distribution of phases in the blends is due to

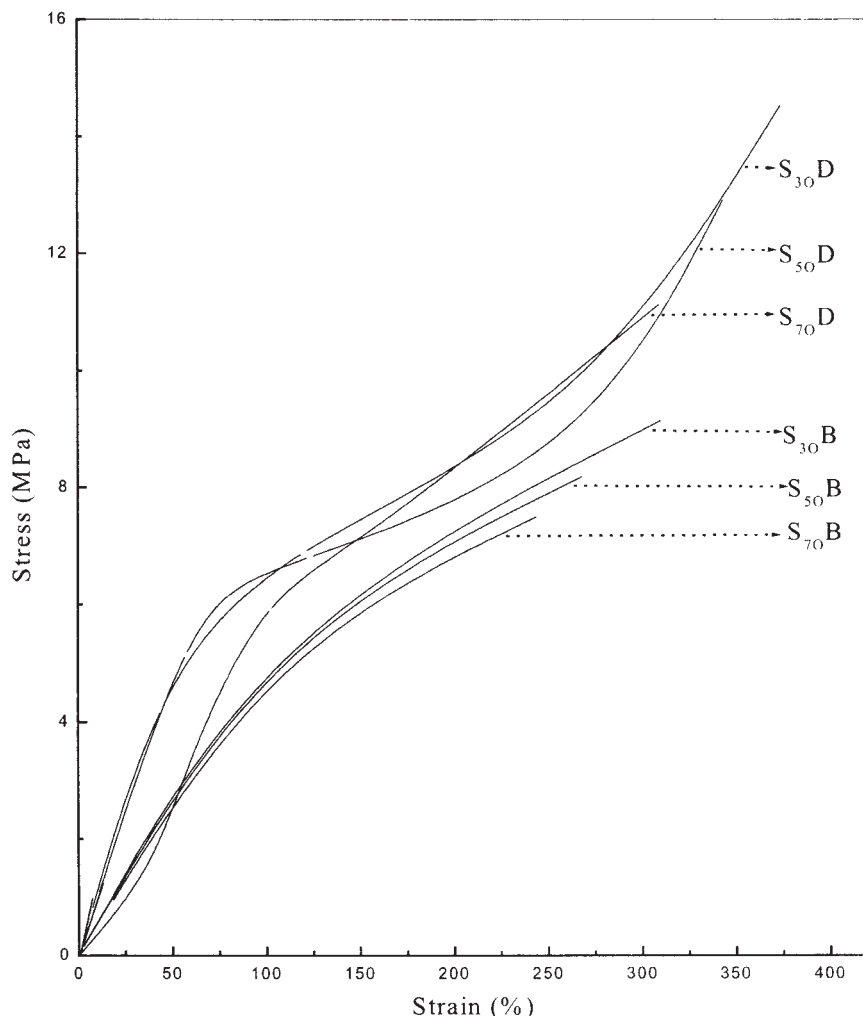


Figure 6 Stress-strain characteristics of DCP- and BP-cured SR/EVA blends. $S_{30}B$ indicates blend with 30 phr of SR cured with BP. $S_{30}D$ indicates blend with 30 phr of SR cured with DCP. $S_{50}B$ indicates blend with 50 phr of SR cured with BP. $S_{50}D$ indicates blend with 50 phr of SR cured with DCP. $S_{70}B$ indicates blend with 70 phr of SR cured with BP. $S_{70}D$ indicates blend with 70 phr of SR cured with DCP.

the difference in volume fractions and viscosities of the components. It is evident from the figures that in S_{30} , the minor SR component is distributed within continuum of the major EVA component, and in S_{70} , the EVA component is distributed as domains in the continuous SR matrix. Relative uniform distribution of components was observed for S_{50} blend.

Green strength

Green strength indicates the strength of unvulcanized blends. To measure this, the failure mechanism of the mixes was analyzed. Figure 5 shows the stress-strain curves of the uncured samples. It is evident from the figure that as the SR content in the matrix increases, the stress carrying capacity of the system decreases considerably. The incorporation of semicrystalline EVA into the amorphous SR matrix

enhances the strength of the system significantly. This is due to the relative distribution of crystalline hard segments of EVA in the continuum of SR matrix.

Mechanical properties

The stress-strain curves of BP- and DCP-cured samples are shown in Figure 6. The difference in the deformational characteristics of individual components and the blends under an applied load are evident from the stress-strain curves. From the figure it is clear that the stress carrying capacity of BP-cured blends is very poor when compared with the DCP-cured systems. This is because of the lesser number of crosslinks introduced by the BP with the matrices.

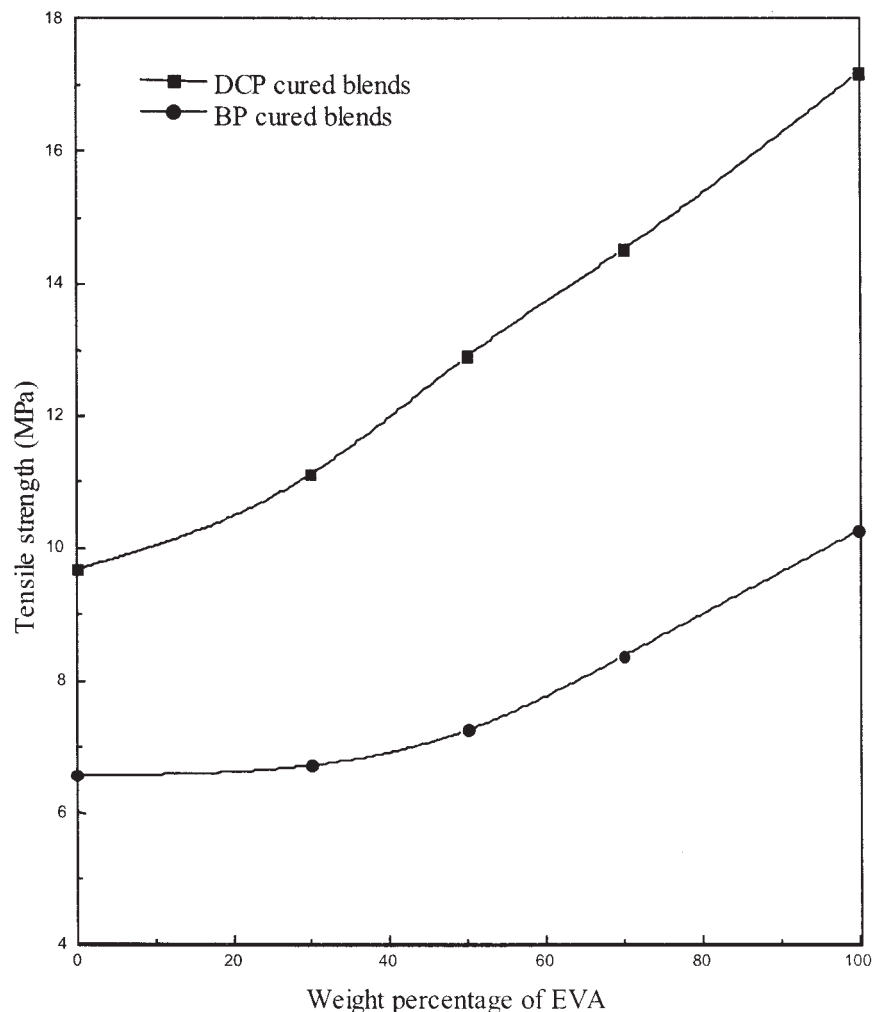


Figure 7 Variation of tensile strength of DCP- and BP-cured SR/EVA blends as a function of blend ratio.

The changes in tensile strength and elongation at break of the blends with weight percentage of EVA are indicated in Figures 7 and 8, respectively. It has been observed that as the EVA content in the blend increases, tensile strength as well as elongation at break increased. This is due to the fact that under an applied load the crystalline regions of EVA can undergo rearrangement to accommodate more stress, while exhibiting higher elongation. However, a low tensile strength and elongation at break values were observed for the BP-cured blends than the DCP-cured blends, which is attributed to the ineffectiveness of the BP to introduce higher number of crosslinks with the matrices.

The effects of blend ratio and curing agents on the tear strength is shown in Figure 9. It is observed that the tear strength values decrease with the weight percentage of SR. This can be attributed to the reduction in crystallinity of EVA upon blending with amorphous SR. However, higher tear strength

was observed for the DCP-cured blends when compared with the BP, because of their efficient crosslink formation with both the blend components.

The variations of hardness, relative volume loss, and density of the DCP- and BP-cured blends are given in Table IV. An increase in hardness has been observed as the EVA content in the blends increases, and thus the relative volume loss of the blends decreases from SR-rich blends to EVA-rich blends. The flex crack resistance of the blends has been tabulated in Table V. The vulcanizates with higher proportion of EVA possess significant flex crack resistance compared with that containing higher SR component. However, this is more prominent for DCP-cured systems than the BP-cured systems. The same trend is shown during the medium crack growth and deep crack formation. This increment in flex crack resistance of EVA-rich blends is due to the semicrystalline nature of the incorporated copoly-

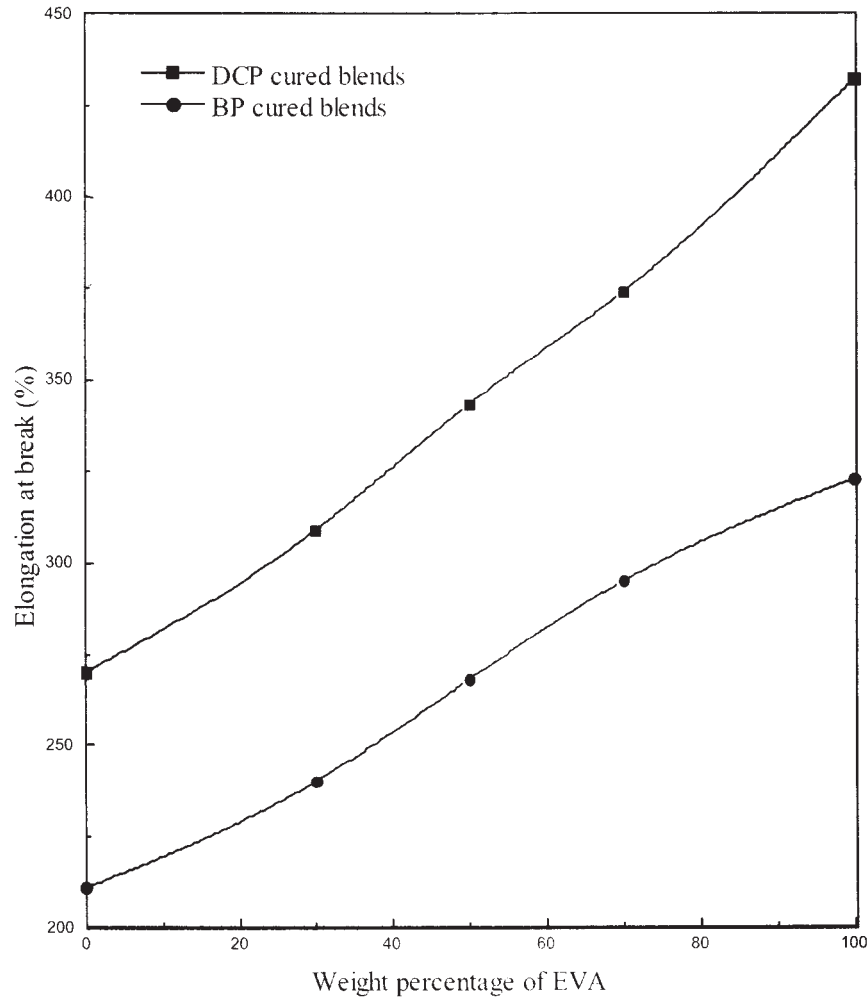


Figure 8 Variation of elongation at break of DCP- and BP-cured SR/EVA blends as a function of blend ratio.

mer, which provides better mechanical stability to the former.

Mechanical properties of blends were widely studied through a comparison of experimental results and predictions based on various theoretical models. Different theoretical models selected to predict the mechanical behavior of SR/EVA blend system include the parallel, series, and Halpin-Tsai equation

The parallel model (highest upper bound model) is given by the equation¹⁸

$$M = M_1\phi_1 + M_2\phi_2 \quad (4)$$

where M is the mechanical property of the blend, and M_1 and M_2 are the mechanical properties and ϕ_1 and ϕ_2 are the volume fractions of the components 1 and 2, respectively. In this model the components are considered to be arranged parallel to one another so that

the applied stress elongates each of the components by the same amount.

In the lowest lower bound series model, the components are arranged in series with the applied stress. The equation is¹⁸

$$1/M = \phi_1/M_1 + \phi_2/M_2 \quad (5)$$

According to the Halpin-Tsai equation¹⁹

$$M_1/M = (1 + A_i B_i \phi_2)/(1 - B_i \phi_2) \quad (6)$$

where

$$B_i = (M_1/M_2 - 1)/(M_1/M_2 + A_i) \quad (7)$$

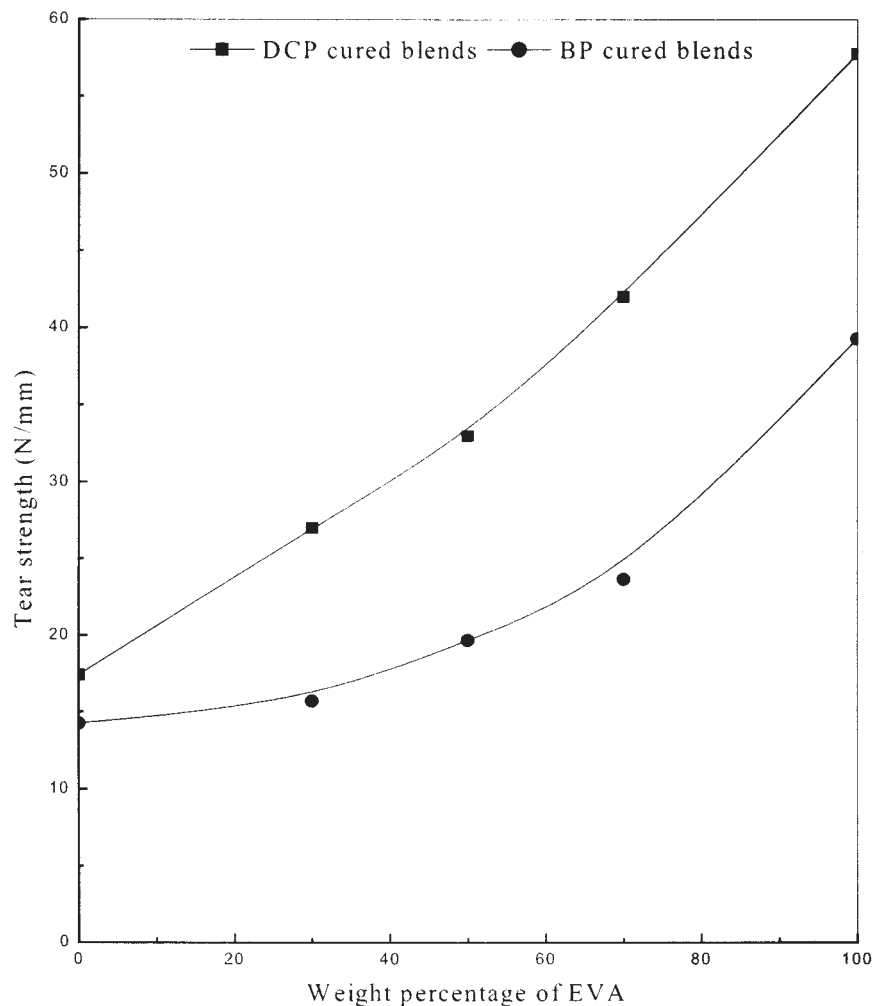


Figure 9 Variation of tear strength of DCP- and BP-cured SR/EVA blends as a function of blend composition.

In this equation subscripts 1 and 2 refer to the continuous and dispersed phase, respectively. The constant A_i is defined by the morphology of the

system. $A_i = 0.66$ when a flexible component forms the dispersed phase in a continuous hard matrix. On the other hand, if the hard material forms the

TABLE IV
Mechanical and Physical Properties of DCP- and BP-cured SR/EVA Blends

Samples	Relative volume loss (mm ³)	Hardness (shore A)	Density (g/cm ³)
S ₀ D	43.80	89.0	0.93
S ₃₀ D	157.45	86.8	0.98
S ₅₀ D	241.03	86.0	1.00
S ₇₀ D	316.49	84.6	1.06
S ₁₀₀ D	444.79	83.0	1.16
S ₀ B	76.54	84.2	0.94
S ₃₀ B	203.70	80.9	0.94
S ₅₀ B	294.66	81.4	0.97
S ₇₀ B	411.32	81.6	0.98
S ₁₀₀ B	531.24	82.7	1.20

TABLE V
Flex Cracking of DCP- and BP-Cured SR/EVA Blends

Samples	Crack growth (kilocycles)			
	Pin holes	Small cracks	Medium cracks	Deep cracks
S ₀ D	465	512	582	718
S ₃₀ D	176	244	312	442
S ₅₀ D	125	181	239	352
S ₇₀ D	96	144	193	292
S ₁₀₀ D	72	110	150	233
S ₀ B	284	305	420	583
S ₃₀ B	135	210	187	416
S ₅₀ B	113	159	202	264
S ₇₀ B	89	118	157	285
S ₁₀₀ B	66	93	121	179

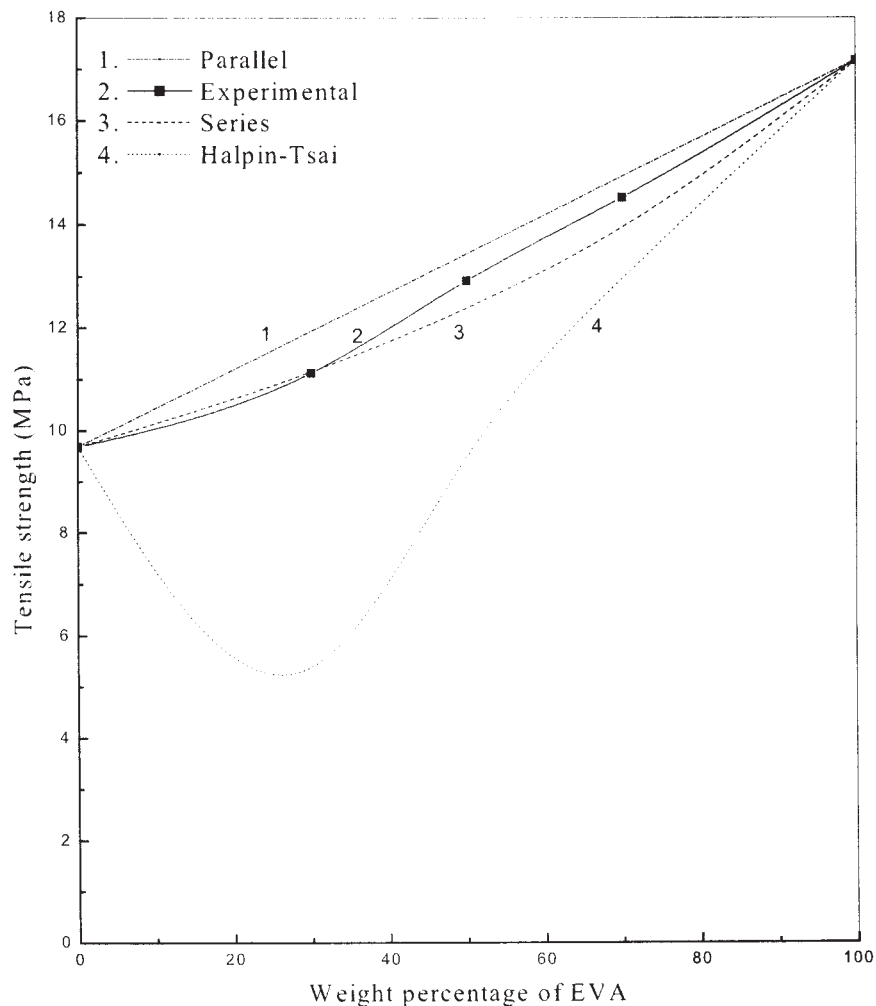


Figure 10 Comparison of experimental results and theoretical models on the variation of tensile strength of DCP-cured SR/EVA blends.

dispersed phase in a continuous flexible matrix, $A_i = 1.5$.

Figures 10 and 11 show the comparison between the experimental and theoretical curves of the tensile strength and tear strength of DCP-cured blends. In the case of tensile strength, the experimental values show a positive deviation at higher proportions of EVA, compared with the series and Halpin-Tsai theoretical predictions. The experimental values of the tear strength are very closer to the parallel model.

Ageing characteristics

The distilled water aging properties of SR/EVA blends cured with both the peroxide systems were investigated and the water uptake of the blends in six stages after 7, 14, 21, 28, 35, and 42 days has been presented in Table VI. It is found that the maximum

water uptake is 0.87% (for $S_{100}B$ sample), which indicates that SR/EVA blends have excellent water resistance.

It is well known that during thermal aging, main chain scission, additional crosslink formation, and crosslink breakage can take place. The tensile strength, modulus at 100% elongation, elongation at break, and percentage retention of the properties of blends, after 3 and 5 days of aging, has been tabulated in Table VII. It is clear from the table that there is no significant reduction in properties for both the cured systems for all the blend ratio, pointing that the blends have good thermal resistance characteristics.

CONCLUSIONS

The cure characteristics, morphology, mechanical properties, and aging properties of DCP- and BP-cured SR/EVA blends have been investigated. Rheo-

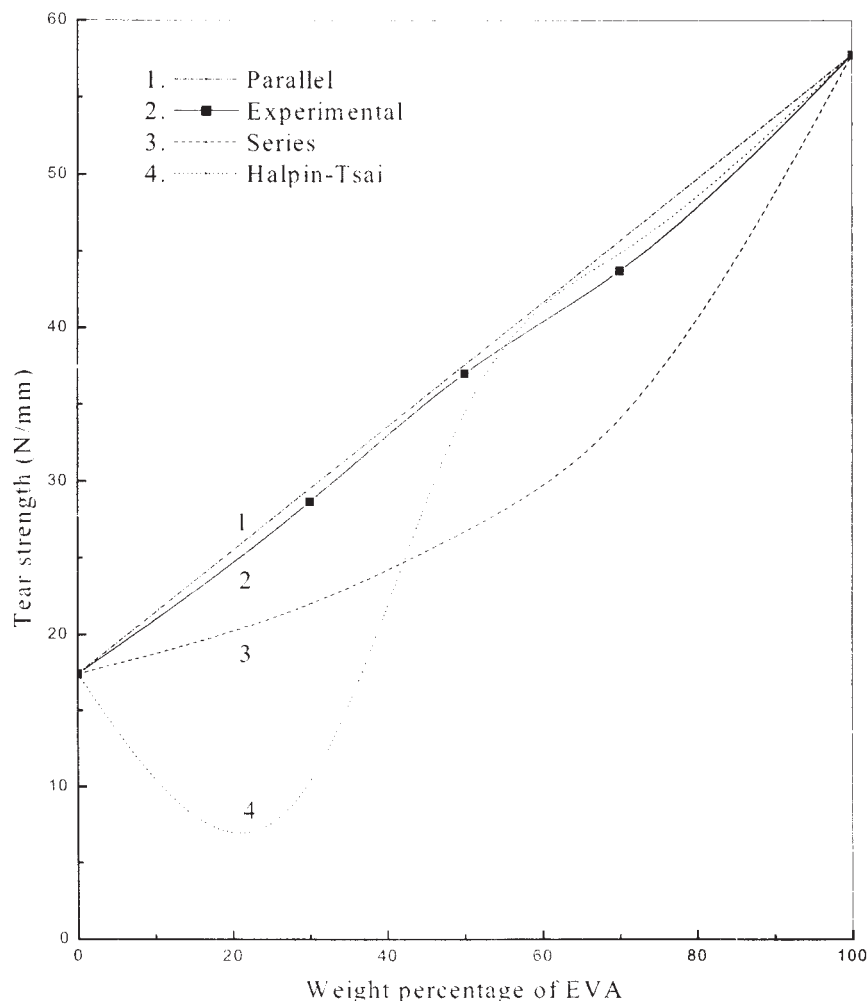


Figure 11 Comparison of experimental results and theoretical models on the variation of tear strength of DCP-cured SR/EVA blends.

logical studies showed that as the EVA content in the blend increased the optimum cure time and scorch time of both the vulcanizing systems increased con-

TABLE VI
Percentage Water Uptake of DCP- and BP-Cured SR/EVA Blends

Sample	Water uptake (%)					
	7th day	14th day	21st day	28th day	35th day	42nd day
S ₀ D	0.06	0.12	0.19	0.29	0.42	0.58
S ₃₀ D	0.08	0.14	0.21	0.31	0.44	0.61
S ₅₀ D	0.09	0.15	0.23	0.32	0.46	0.62
S ₇₀ D	0.14	0.21	0.28	0.37	0.51	0.67
S ₁₀₀ D	0.28	0.35	0.42	0.51	0.65	0.81
S ₀ B	0.06	0.13	0.18	0.25	0.47	0.61
S ₃₀ B	0.10	0.17	0.24	0.33	0.51	0.67
S ₅₀ B	0.19	0.23	0.31	0.46	0.63	0.82
S ₇₀ B	0.24	0.36	0.48	0.50	0.62	0.74
S ₁₀₀ B	0.33	0.42	0.51	0.69	0.78	0.87

siderably. The examination of vulcanization kinetics of the blends revealed that the curing reactions follow first order kinetics. The activation energy of vulcanization has been found to be decreased with SR content in the blends. The SEM analysis showed that the SR/EVA blends are heterogeneous in nature. The mechanical properties such as tensile strength, elongation at break, tear strength, hardness, abrasion resistance, and flex crack resistance increased with increase in EVA content of the blends, specifically for DCP-cured systems. Experimental observations have been compared with relevant theoretical models. The result of aging studies showed that distilled water and thermal resistance features are excellent for both the DCP- and BP-cured blends.

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TABLE VII
Stress-Strain Characteristics of Thermal Aged Blends at 100°C and Their Percentage Retention Values

Ageing period (days)	Samples	Tensile strength (MPa)	% retention of tensile strength	Modulus at 100% elongation (MPa)	% retention of modulus at 100% elongation	Elongation at break (%)	% retention of elongation at break
3	S ₀ D	17.02	99.13	7.21	99.54	374.99	98.77
	S ₃₀ D	14.37	98.97	6.73	98.31	370.20	99.02
	S ₅₀ D	12.73	98.57	6.46	98.22	339.38	98.82
	S ₇₀ D	10.88	97.83	6.06	97.74	302.73	97.95
	S ₁₀₀ D	10.35	97.02	5.77	97.19	292.12	97.31
	S ₀ B	10.04	97.88	5.80	97.76	316.54	98.00
	S ₃₀ B	8.92	97.54	5.53	97.43	302.90	97.71
	S ₅₀ B	7.96	97.35	5.34	97.22	261.43	97.55
	S ₇₀ B	7.74	96.75	5.05	96.65	236.27	96.83
	S ₁₀₀ B	7.52	96.58	4.75	96.68	204.25	96.80
5	S ₀ D	16.90	98.44	7.11	98.14	375.22	98.83
	S ₃₀ D	14.27	98.28	6.71	97.98	368.89	98.67
	S ₅₀ D	12.64	97.88	6.42	97.58	337.49	98.27
	S ₇₀ D	10.80	97.15	6.00	96.85	301.47	97.54
	S ₁₀₀ D	10.28	96.34	5.71	96.05	290.38	96.73
	S ₀ B	9.97	97.19	5.75	96.90	315.22	97.59
	S ₃₀ B	8.85	96.86	5.48	96.56	301.48	97.25
	S ₅₀ B	7.91	96.67	5.29	96.38	260.12	97.06
	S ₇₀ B	7.69	96.07	5.01	95.78	235.36	96.46
	S ₁₀₀ B	7.47	95.90	4.69	95.61	203.17	96.29

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