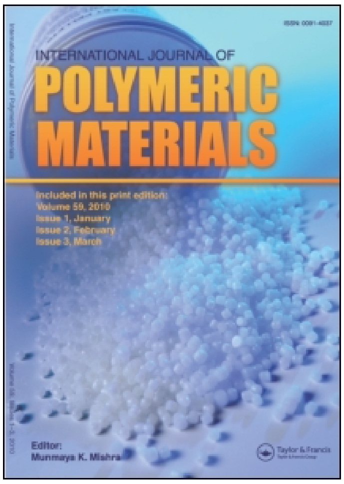

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Studies on the Rheological Behavior of Thermoplastic Elastomers Derived from NBR and PVC Using a Brabender Plasticorder

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The rheological behavior of thermoplastic elastomer compositions of butadiene-acrylonitrile rubber (NBR) and poly(vinyl chloride) (PVC) were evaluated on a Brabender torque rheometer. The power law index (shear dependence of viscosity), activation energy for viscous flow (temperature dependence of viscosity) were evaluated and found to depend upon the extent of fusion of PVC particles.

KEY WORDS Thermoplastic elastomers, rheological behavior, NBR, PVC, Brabender plasticorder

INTRODUCTION

Thermoplastic elastomers from blends of thermoplastics and rubber continue to represent a field of intense research activity. One of the key subjects of study relating to the behavior of the materials is under shearing action. The melt flow studies of thermoplastic elastomers have become important in optimizing the processing conditions and developing new processing equipment and the dies necessary for the production of various kinds of extruded or injection molded products.

Several studies on the rheological behaviour of cross-linked and uncross-linked polymer blends have been carried out.[1-4] Various factors affecting the die swell, melt fracture and deformation of extrudates have been reported.[5] Studies on the rheological behavior of thermoplastic block copolymers,[6] those of blends of thermoplastics and rubbers[7] etc. have become the subject of interest due to the growing importance of thermoplastic elastomers. The present study describes the flow behavior of thermoplastic elastomers derived from NBR and PVC using a Brabender plasticorder.

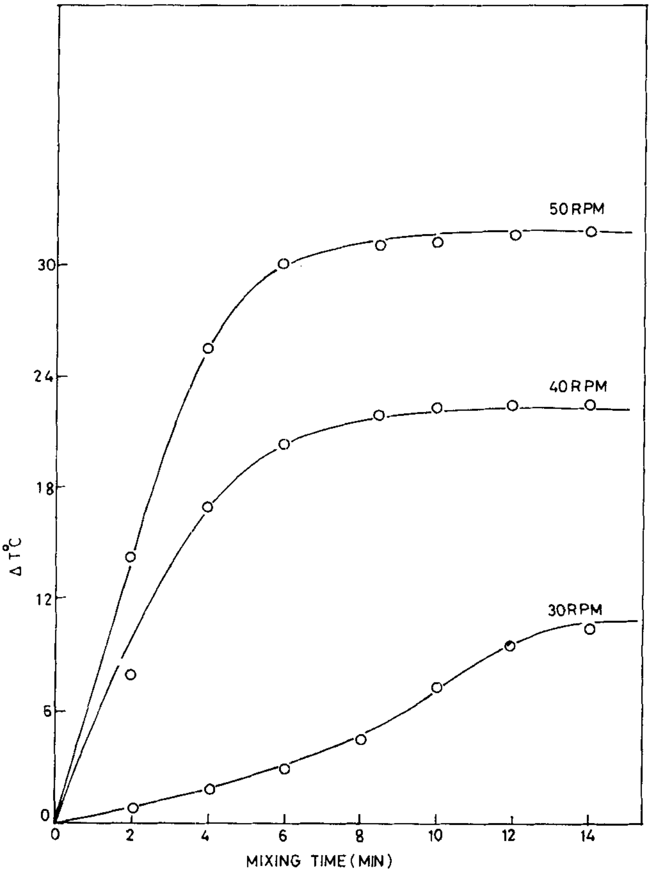

FIGURE 1 Temperature rise due to shear heating in a Brabender plasticorder for 50/50 NBR/PVC blend.

MATERIALS AND PROCEDURE

PVC Powder; suspension polymer; K value = 67 (supplied by IPCL, Baroda).

NBR Acrylonitrile content = 42%
Mooney viscosity [ML (1+4) at 100°C] – 50
(supplied by Synthetics and Chemicals Ltd., Bareilly).

NBR/PVC blends with 40 and 50 wt. per cent PVC were prepared by melt mixing in a Brabender plasticorder model PL3S at 170°C and at 40 rpm, with 5 phr TBLS (of the wt. of PVC) added as heat stabilizer for PVC. The mix from the Brabender was sheeted on a mill while it was hot and then pelletized for further studies.

Melt rheological properties of the cured (cured with 0.3 phr Dicumyl peroxide of the wt. of NBR and PVC) and uncured blends were evaluated on a Brabender plasticorder at 30, 40 and 50 rpms and at temperatures 130, 140 and 150°C.

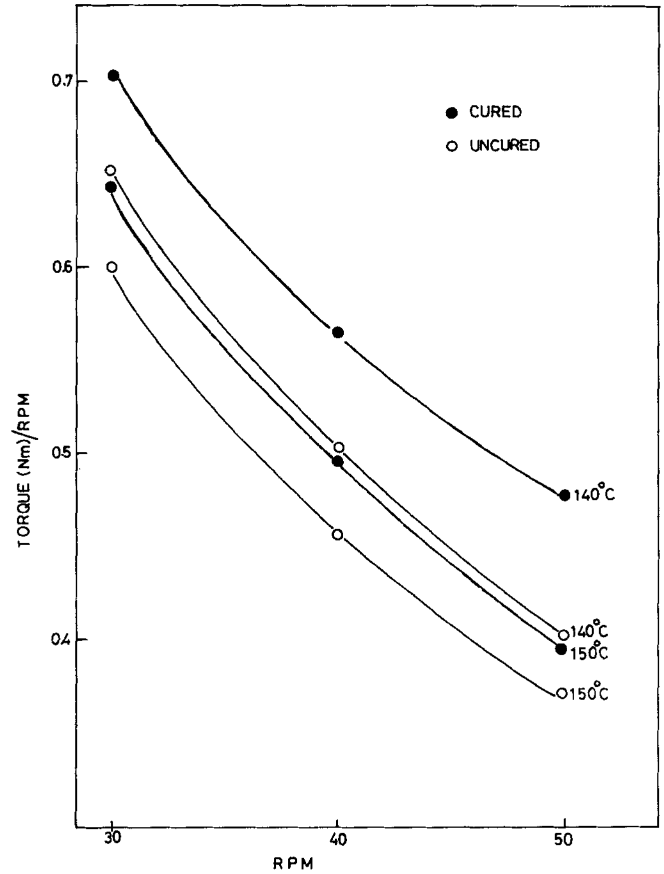

FIGURE 2 Variation of torque/rpm with rpm at different temperatures for 50/50 NBR/PVC blend.

RESULTS AND DISCUSSION

The Brabender plasticorder had been used to study the rheological behavior of polymer melts under processing conditions earlier.[8-10] It was shown that the relationship obtainable from this instrument,

$$M = CS^a$$

where M is the torque, S the rpm (revolutions per minute) and C and a are constants, resembles the familiar power law behavior.[9-11]

$$\tau = K(\dot{\gamma})^n$$

and hence could be used for calculation of the power law index n.

The temperature dependence of the viscosity was expressed in terms of an Arrhenius equation,

$$\eta = Ae^{E/RT}$$

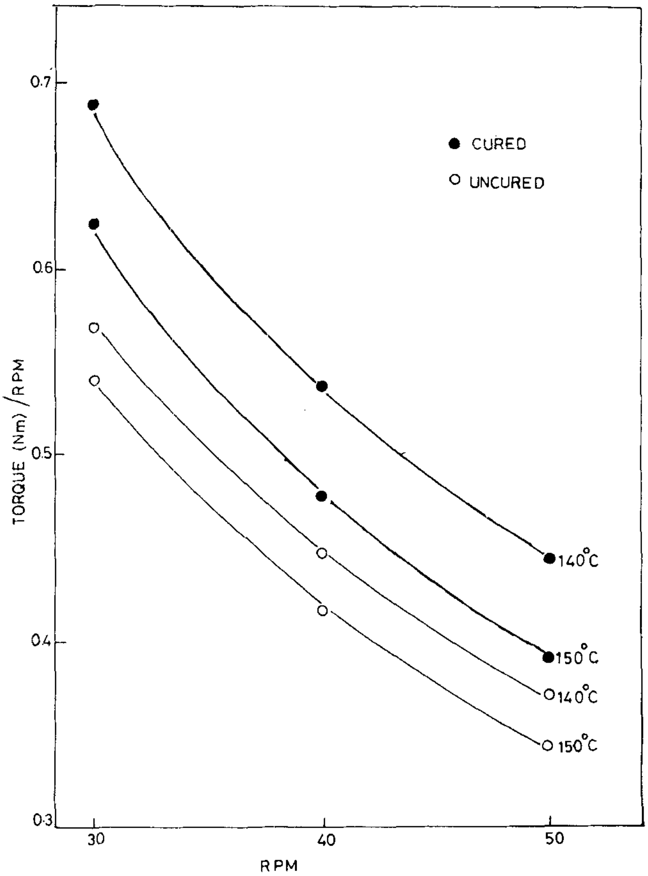

FIGURE 3 Variation of torque/rpm with rpm at different temperatures for 60/40 NBR/PVC blend.

where (torque/rpm) of the Brabender plasticorder represents viscosity η and hence activation energy, E, for viscous flow can be measured from log (torque/rpm) vs. $1/T$ plots where T is the absolute temperature.

The effect of shear heating (ΔT) in a Brabender plasticorder results in temperature rise and is given in Figure 1 for a 50/50 NBR/PVC blend where,

$$\Delta T = \text{Melt temperature} - \text{Set temperature}$$

The torque and temperature stabilize to constant values in about 12–14 mts. at 30 rpm and in about 5–6 mts. above 40 rpm. This suggests 40–50 rpm as the optimum mixing shear to keep the mixing time low and further mixing of the blend was done at 40 rpm.

Figures 2 and 3 show the variation of viscosity (torque/rpm) with shear rate (rpm) and temperature of 50/50 and 60/40 NBR/PVC blends (cured and uncured). As expected, viscosity decreases with increase in temperature and shear rate. The cured and uncured blends in both cases show the same type of viscosity variations, but the cured blends show higher viscosity. The differences seem to be quite marked

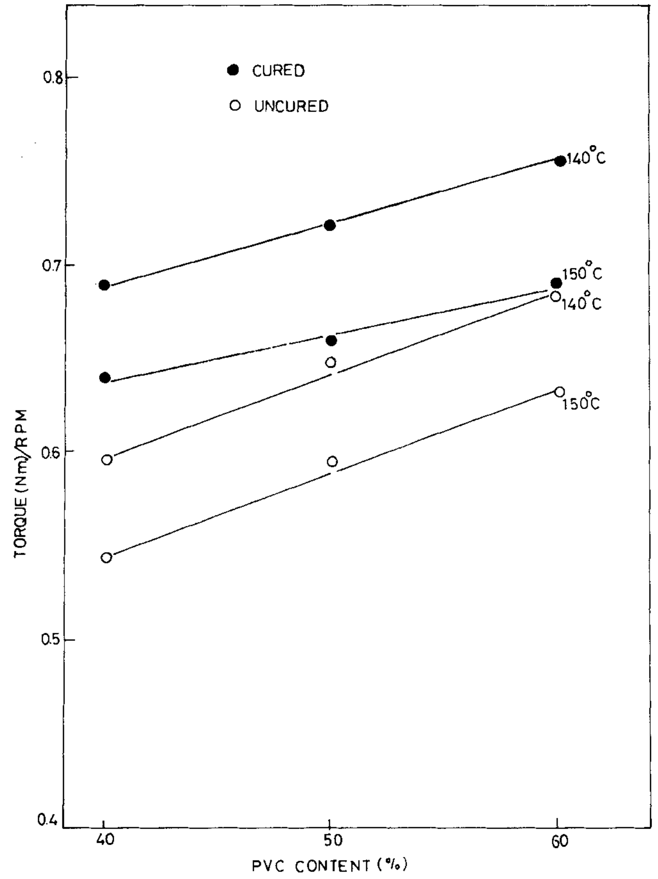

FIGURE 4 Variation of torque/rpm with blend composition of NBR/PVC blends at various temperatures.

resulting from enhanced frictional resistance introduced due to cross-linking as chains are not deformed easily by the shearing action of the mixer.

Figure 4 shows the variation of viscosity with blend composition. As the PVC content of the blend increases from 40 to 60%, there is a gradual increase in viscosity at all the temperatures. The increase in viscosity arises due to the higher viscosity of the PVC phase. The effective decrease in overall viscosity with increase in the concentration of NBR may also be due to the plasticization effect of NBR on PVC which also makes the behavior of PVC less non-Newtonian.

Figures 5 and 6 show shear stress (torque) vs. shear rate (rpm) plots of 50/60 and 60/40 NBR/PVC blends at 140 and 150°C. The data show the behavior of the melts as highly non-Newtonian. The behavior of the blends could be represented by a single power law index and the power law indices are given in Table I. The cured blends show a less non-Newtonian behavior compared to that of the uncured blends.

Figures 7 and 8 show the variation of torque/rpm vs. reciprocal absolute temperature of 50/50 and 60/40 NBR/PVC blends. The temperature dependence of the viscosity of the blends can be expressed by the flow activation energy calculated

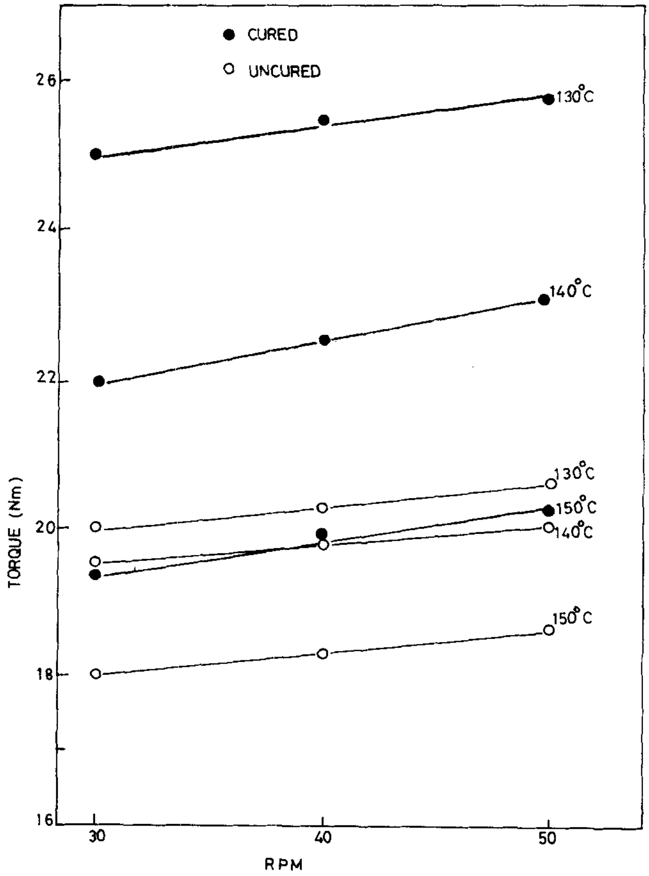

FIGURE 5 Variation of torque with rpm at different temperatures for 50/50 NBR/PVC blend.

from the Arrhenius equation.

The flow activation energies calculated from the slopes of the straight lines are given in Table II. The activation energy of viscous flow is found to decrease with increase in shear rate, obviously due to the strong non-Newtonian behavior arising from the fusion of PVC particles.[12] It is also observed from the table that the flow activation energy decreases with increase in PVC content at higher shear rates which may be due to the increase in fusion of PVC particles.

CONCLUSIONS

The melt rheology of NBR/PVC thermoplastic elastomer blends can be studied using a torque rheometer. NBR/PVC TPE blends are highly non-Newtonian. The temperature dependence of the viscosity of these TPE blends can be expressed by Arrhenius type behavior where the flow activation energy seem to depend on the fusion of PVC particles.

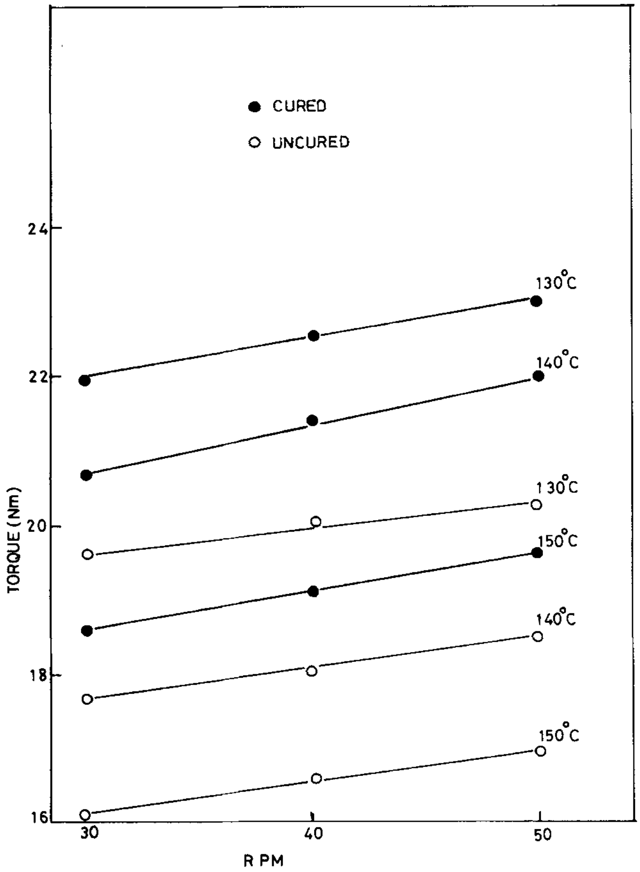

FIGURE 6 Variation of torque with rpm at different temperatures for 60/40 NBR/PVC blend.

TABLE I

Flow index values of NBR/PVC TPE blends

PVC content (%)	Temperature (°C)	Flow index values of	
		Cured blends	Uncured blends
	130	0.042	0.031
40	140	0.044	0.037
	150	0.050	0.043
	130	0.050	0.023
50	140	0.052	0.025
	150	0.054	0.027

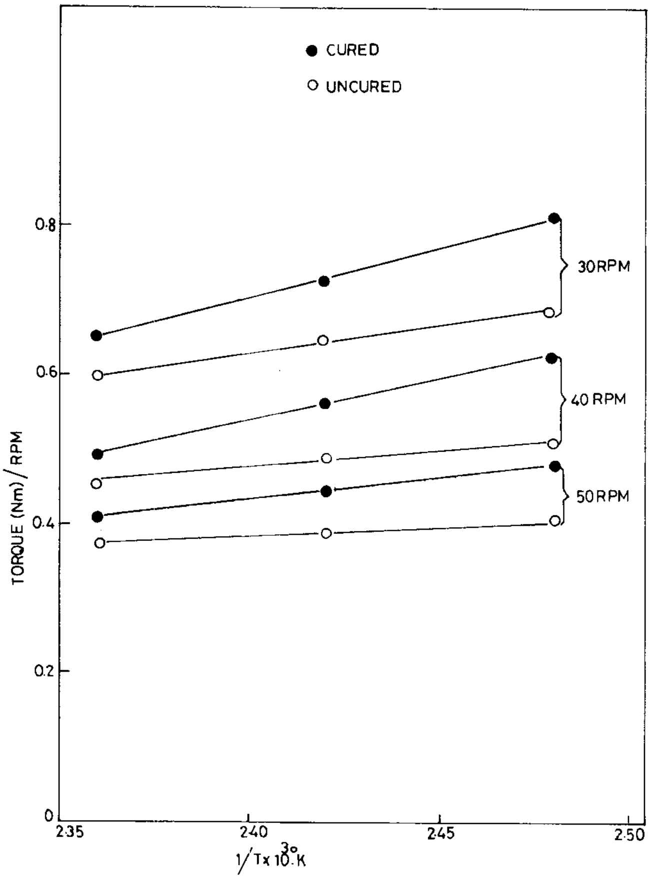

FIGURE 7 Variation of torque/rpm with reciprocal absolute temperature for 50/50 NBR/PVC blend at various rpms.

TABLE II

Flow activation energies for NBR/PVC blends

		Flow activation energies of (kJ/mole)	
PVC content	rpm	Cured blends	Uncured blends
	30	8	7.09
40	40	5.31	4.90
	50	3.98	2.45
	30	7.9	5.32
50	40	8.75	2.65
	50	3.54	1.60

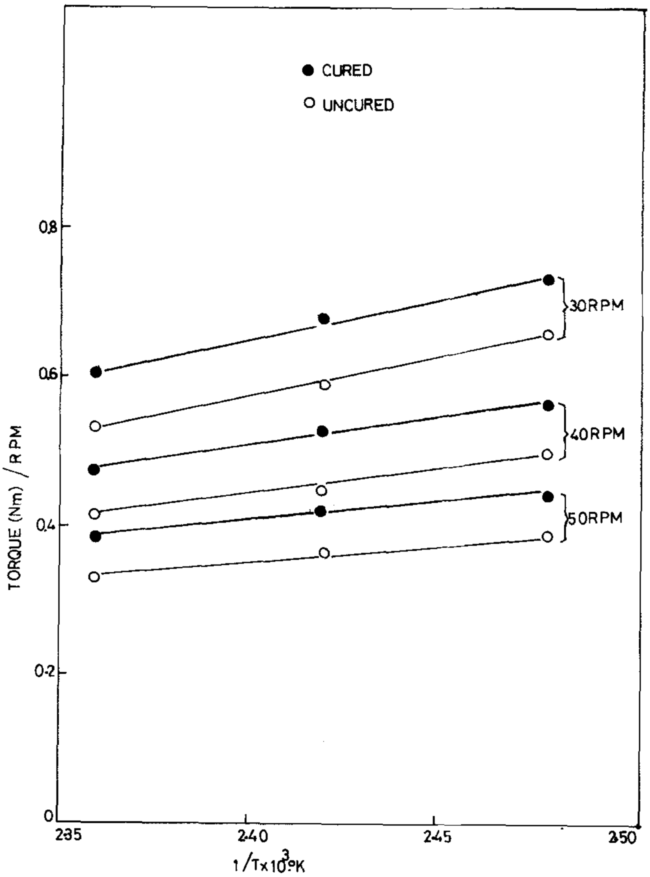

FIGURE 8 Variation of torque/rpm with reciprocal absolute temperature for 60/40 NBR/PVC blend at various rpms.

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