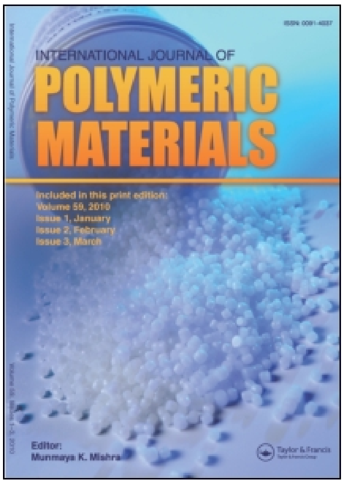

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Investigation of the Processability of NR/IIR and NR/EPDM Blends Using a Torque Rheometer

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The processability of modified NR/IIR and NR/EPDM blends was compared with that of conventional NR/IIR and NR/EPDM blends on a Torque Rheometer. The study shows that the pseudoplastic nature and activation energy of the modified blends are similar to those of the conventional blends even though the viscosity of the modified blends is slightly higher.

KEY WORDS Processability, blends, rheometry

INTRODUCTION

Melt flow behaviour of polymers is of great importance in optimising the processing equipments. The concept of the ‘processability’ of a rubber mix is closely related to its plasticity or its elastic recovery during shaping.[1] According to this ASTM standard[2] processability is the relative ease with which a raw rubber or mix is shaped in the processing equipment. Almost all large tonnage rubber compounds today comprise blends of two or more elastomers. A large number of indepth studies have been reported on the melt flow behaviour of elastomers and their blends.[3–10]

The rubber industry operates with devices imparting shear stresses and shear rates over a wide range. Therefore, the viscosity functions of a polymer as a function of shear rate and temperature are very important. To be able to investigate the processability of a material, laboratory conditions must simulate operating conditions as closely as possible. For determining the processability of a material, testing devices were developed whose operating principles were identical with those of operational devices, a common example being the Brabender plasticorder.[11–15] Essentially, this is a torque measuring rheometer to which various measuring attachments can be pre-coupled.

For improving the mechanical properties of NR/IIR and NR/EPDM blends, a novel method has been developed in this laboratory.[16] IIR or EPDM is compounded, precured to a low level and then blended with NR. Compounding ingredients for NR are then added and the final curing is done. This paper reports the processing characteristics of such modified NR/IIR and NR/EPDM blends in comparison with the conventional blends.

EXPERIMENTAL

Materials

NR(Natural rubber) = ISNR-5 – Mooney viscosity ML(1 + 4) 100°C – 85.3 (Rubber Research Institute of India).
EPDM(Ethylene propylene diene rubber) = ML(1 + 4) 100°C – 52 (JSR – EP 33).
IIR(Isobutylene isoprene rubber) = 0.8 mole % unsaturation; ML (1+8) 100°C – 50 (Exxon 065).
rubber additives = Zinc oxide, stearic acid, dibenzthiazyl disulphide (MBTS), tetramethyl thiuram disulphide (TMTD), sulphur, carbon black (HAF N-330) and naphthenic oil used were rubber grade.

The various elastomers and the blends used in this study are given in Tables I and II.

TABLE I

Formulations of NR/IIR blends

Materials	Designation of the blends							
	1	2	3	4	5	6	7	8
NR	100	--	75	75	50	50	25	25
IIR	--	100	25	--	50	--	75	--
IIR (modified)	--	--	--	25	--	50	--	75
ZnO	5.0	4.0	4.75	3.75	4.5	2.5	4.25	1.25
Stearic acid	2.0	2.0	2.0	1.5	2.0	1.0	2.0	0.5
MBTS	0.6	0.6	0.6	0.45	0.6	0.3	0.6	0.15
TMTD	0.2	1.0	0.4	0.15	0.6	0.1	0.8	0.05
Carbon black (HAF N.330)	50	50	50	37.5	50	25	50	12.5
Naphthenic oil	8.0	8.0	8.0	6.0	8.0	4.0	8.0	2.0
Sulphur	2.5	1.5	2.25	1.87	2.0	1.25	1.75	0.62

TABLE II

Formulations of NR/EPDM blends

Materials	Designation of the blends							
	1	2	3	4	5	6	7	8
NR	100	--	75	75	50	50	25	25
EPDM	--	100	25	--	50	--	75	--
EPDM (modified)	--	--	--	25	--	50	--	75
ZnO	5.0	4.0	4.75	3.75	4.5	2.5	4.25	1.25
Stearic acid	2.0	2.0	2.0	1.5	2.0	1.0	2.0	0.5
MBTS	0.6	0.6	0.6	0.45	0.6	0.3	0.6	0.15
TMTD	0.2	1.0	0.4	0.15	0.6	0.1	0.8	0.05
Carbon black (HAF N-330)	50	50	50	37.5	50	25	50	12.5
Naphthenic oil	8.0	8.0	8.0	6.0	8.0	4.0	8.0	2.0
Sulphur	2.5	1.5	2.25	1.87	2.0	1.25	1.75	0.62

Preparation of the Blends

Conventional Blends: Conventional blends were prepared by blending the rubbers and then adding the compounding ingredients for the rubbers together as per the formulations given in Tables I and II.

Modified Blends: IIR and EPDM compounds were prepared on a laboratory mixing mill. The optimum level of precuring was given to these compounds.[16] Precured samples were then blended with masticated NR on the mill and then compounding ingredients for NR were added (Tables I and II).

Processability studies of the above compounds were done on a Brabender plasticorder at different temperatures and rpms (revolutions per minute) and the dependence of viscosity of the mixes on the shear rate and temperature was evaluated keeping 15 minutes as the mixing time.

RESULTS AND DISCUSSION

It was shown that the relationship obtainable from a Brabender Plasticorder, $M = CS^a$ (where M is the torque, S the rpm [revolutions per minute] and C and a

are constants) closely resembles the familiar power law (Ostwald de Waale) model and hence could be used for calculation of the power law index. In the above equation '*a*' represents the power law index. Also torque/rpm represents viscosity and the activation energy could be measured from torque rheometer data[10] if log(torque/rpm) is plotted against $1/T$. Using the expression,

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

where

E = is the activation energy for viscous flow,
R = the gas constant,

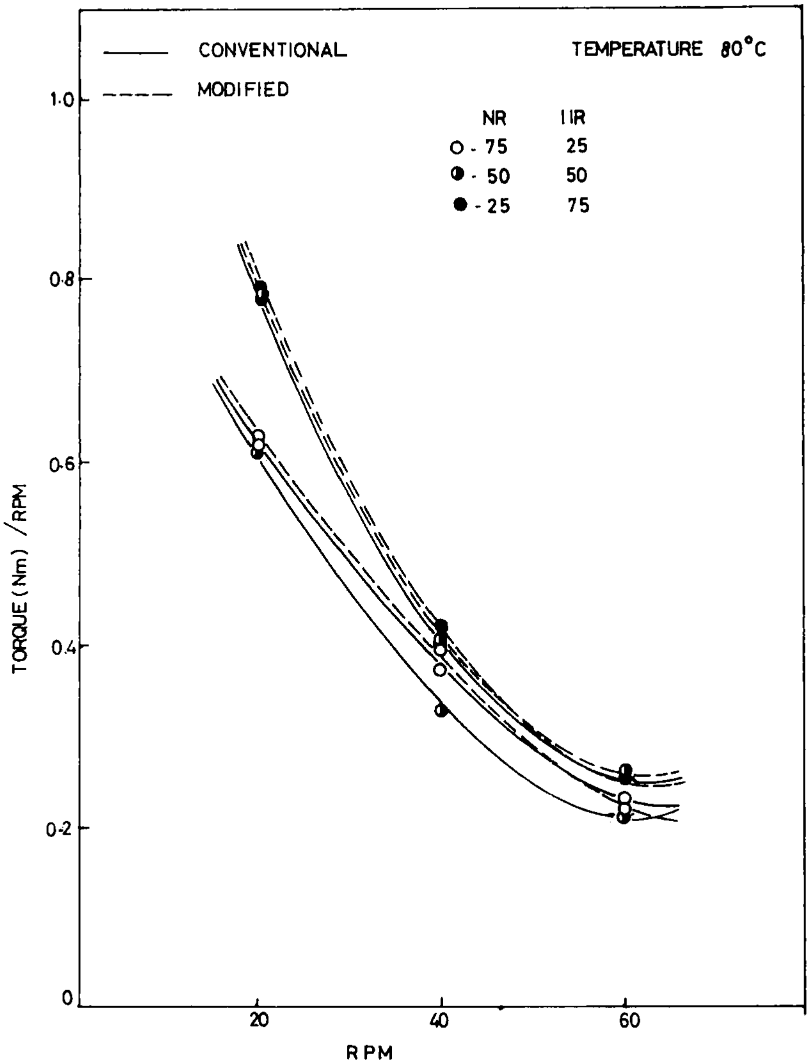

FIGURE 1 Variation of viscosity with rpm for NR/IIR blends at 80°C.

T = the absolute temperature, and
A = a constant.

Figures 1 and 2 show the variation of torque/rpm (viscosity) of NR/IIR blends with rpm (shear rate). The viscosity is strongly dependent upon the shear rate as expected for both conventional and modified blends. At higher temperature shear dependence of viscosity was found to become weaker. Change in viscosity of NR/EPDM blends with shear rate is given in Figures 3 and 4. As in the case of the NR/IIR blends viscosity is a strong function of the shear rate. Also the shear dependence of viscosity was found to weaken with increase in temperature. The power law index values calculated from the curves of log torque versus log rpm

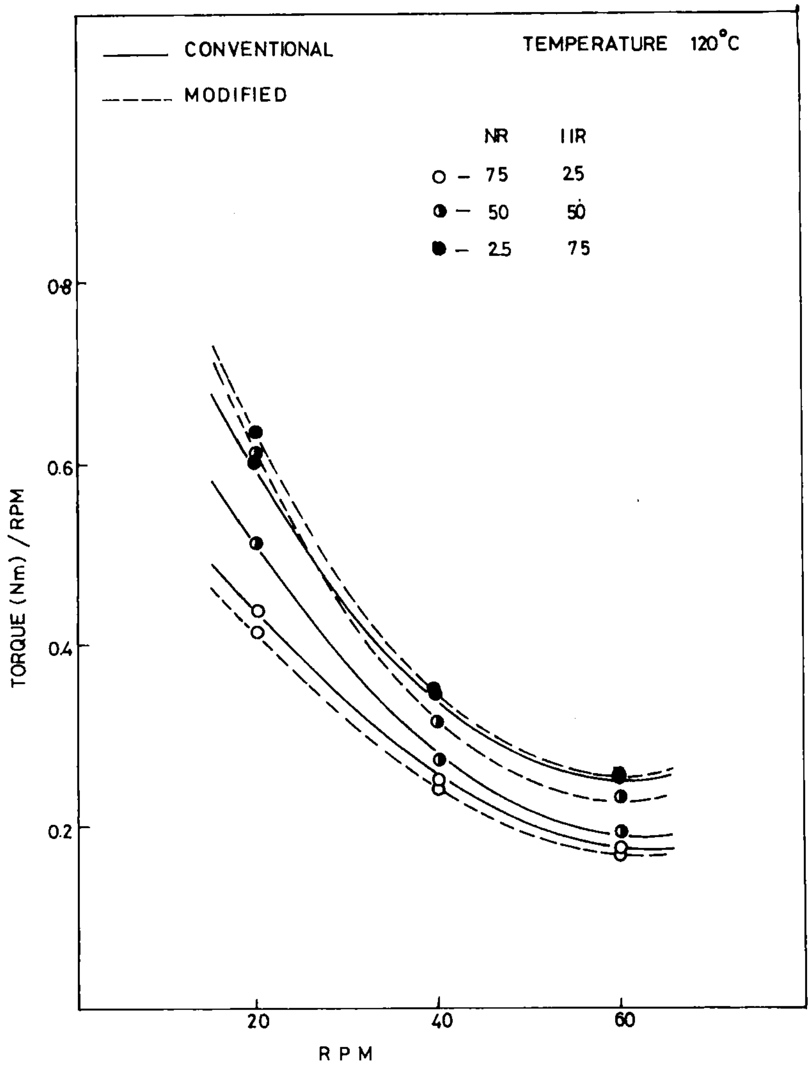

FIGURE 2 Variation of viscosity with rpm for NR/IIR blends at 120°C.

(curves not shown) are shown in Tables III and IV. The extent of non-Newtonian behaviour can be understood from these values. Both the conventional and modified blends are highly pseudoplastic in nature.

Figure 5 gives the variation of viscosity of NR/IIR blends with composition. The conventional blends show a linear variation of viscosity with composition indicating at least some degree of miscibility in the melt. The modified blends exhibits a positive deviation. This is obviously due to the precure introduced in the IIR matrix. Almost similar behaviour is observed for NR/EPDM blends too (Figure 6).

Figure 7 permits the calculation of activation energies of viscous flow for NR/IIR blends. In order to understand the influence of temperature on the viscosity of the blends, Arrhenius plots at constant rpm were made. In this figure, logarithm

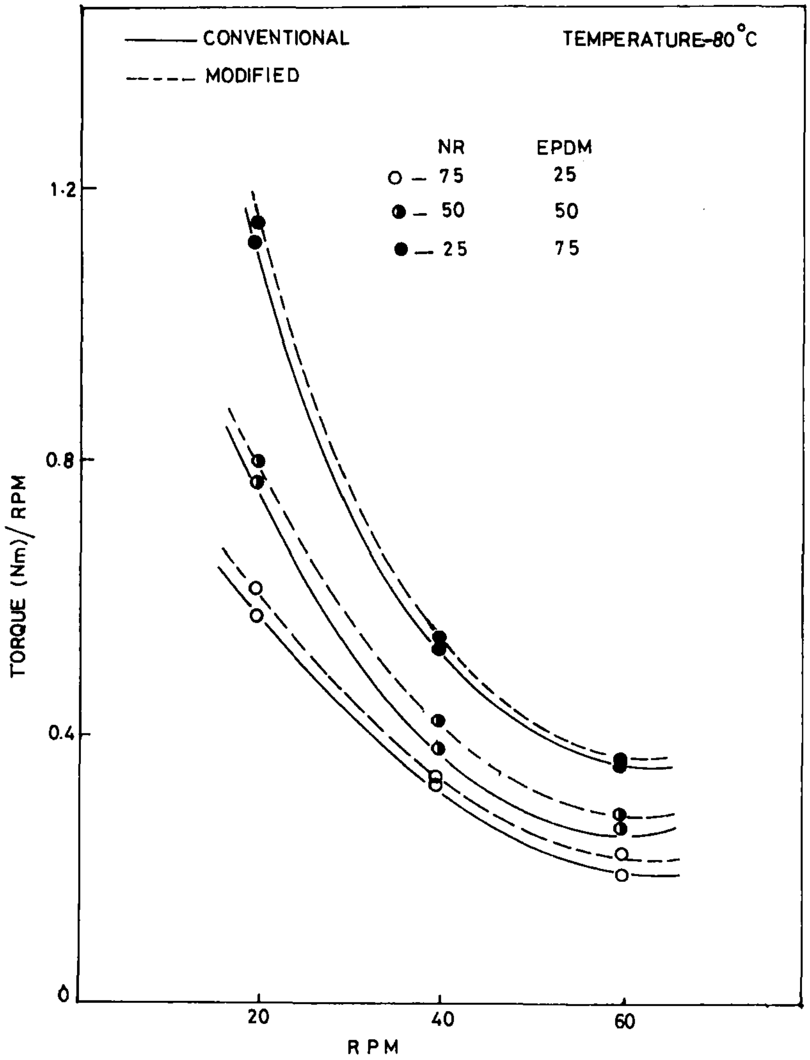

FIGURE 3 Variation of viscosity with rpm for NR/EPDM blends at 80°C.

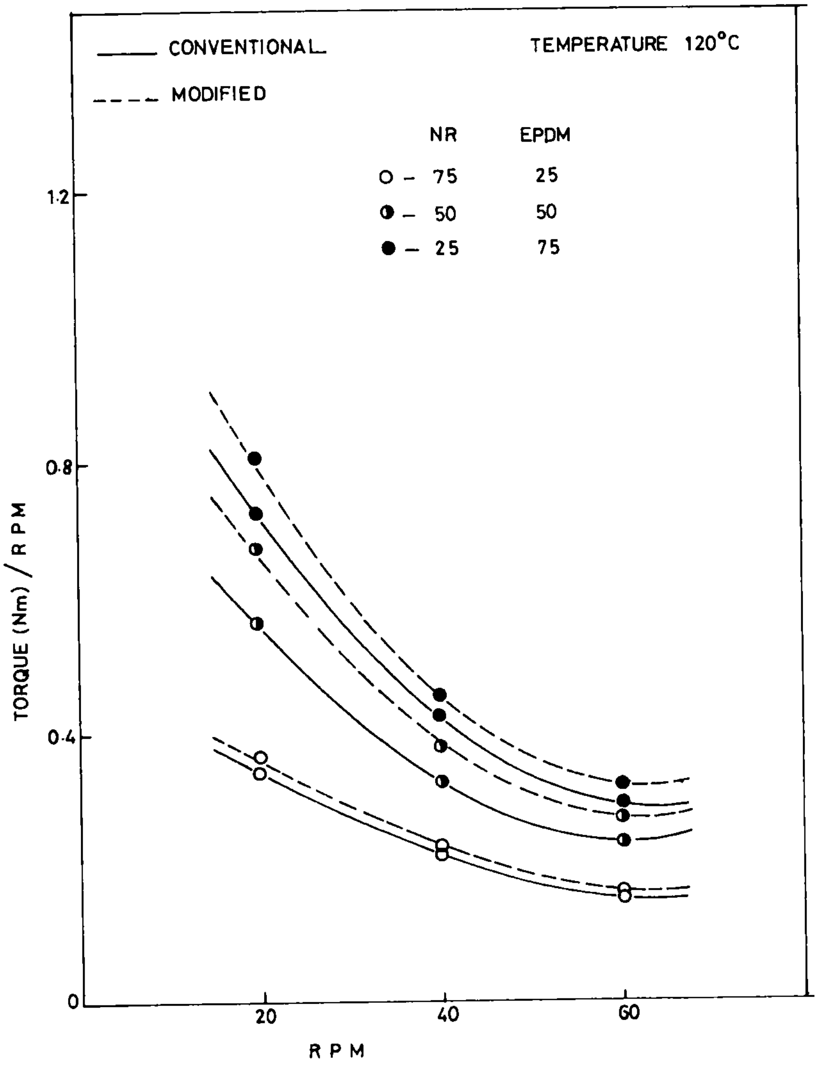

FIGURE 4 Variation of viscosity with rpm for NR/EPDM blends at 120°C.

TABLE III

Power law indices for NR/IIR blends

Blend composition, percentage of IIR	Power law index at a temperature of		
	80°C	100°C	120°C
0	0.22	0.4	0.57
100	0.01	0.08	0.20
25	0.1	0.25	0.27
25 (modified)	0.11	0.21	0.20
50	0.08	0.11	0.12
50 (modified)	0.04	0.13	0.11
75	0.05	0.10	0.24
75 (modified)	0.03	0.13	0.14

TABLE IV

Power law indices for NR/EPDM blends

Blend composition, percentage of EPDM	Power law index at a temperature of		
	80°C	100°C	120°C
0	0.22	0.4	0.57
100	0.13	0.12	0.21
25	0.15	0.19	0.31
25 (modified)	0.10	0.19	0.28
50	0.08	0.15	0.20
50 (modified)	0.08	0.15	0.17
75	0.10	0.17	0.20
75 (modified)	0.05	0.2	0.17

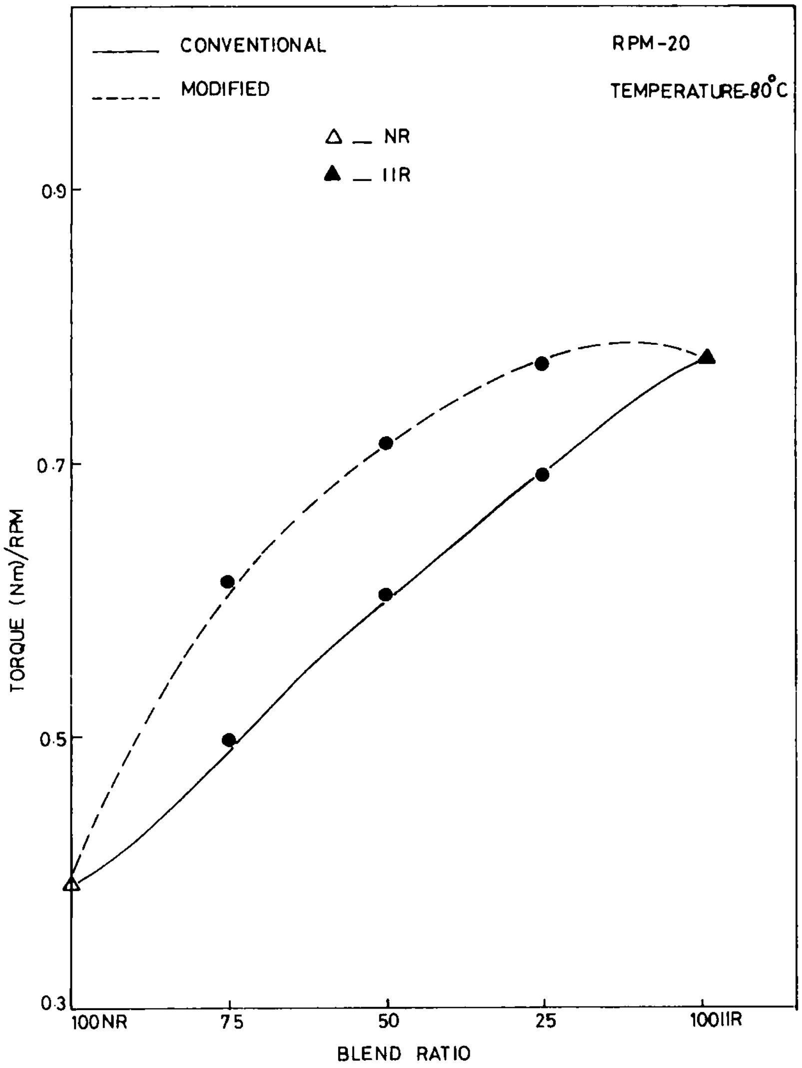

FIGURE 5 Change of viscosity with composition of NR/IIR blends.

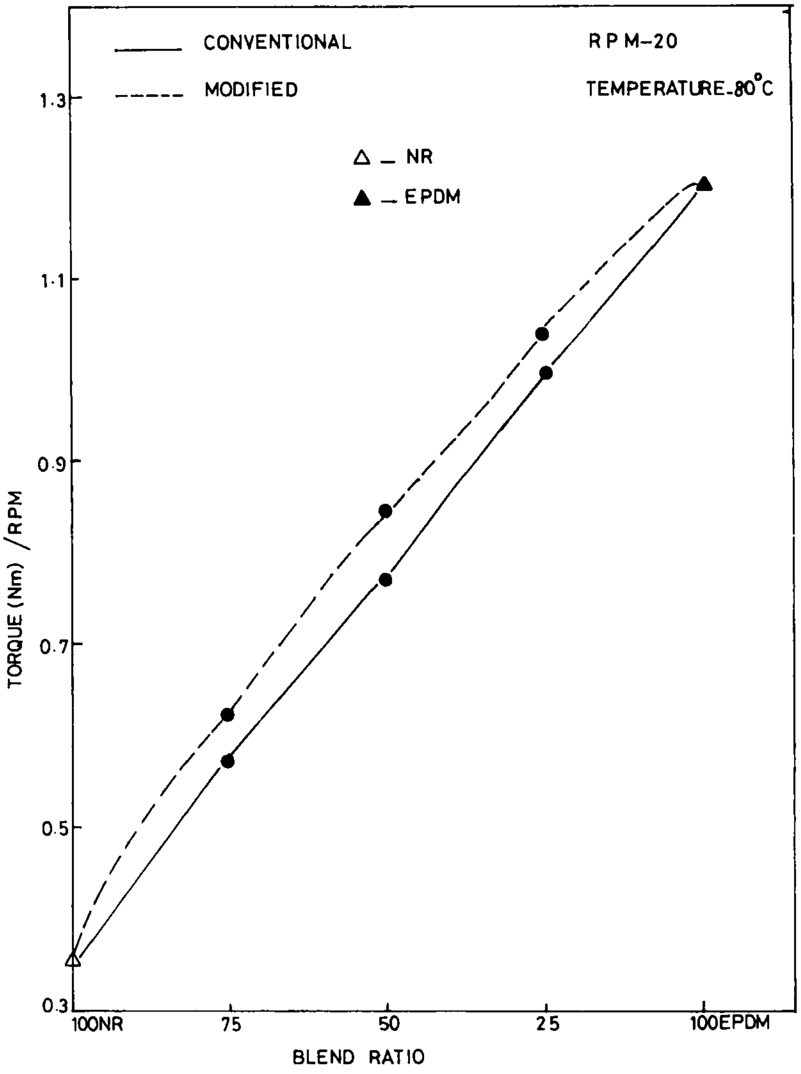

FIGURE 6 Change of viscosity with composition of NR/EPDM blends.

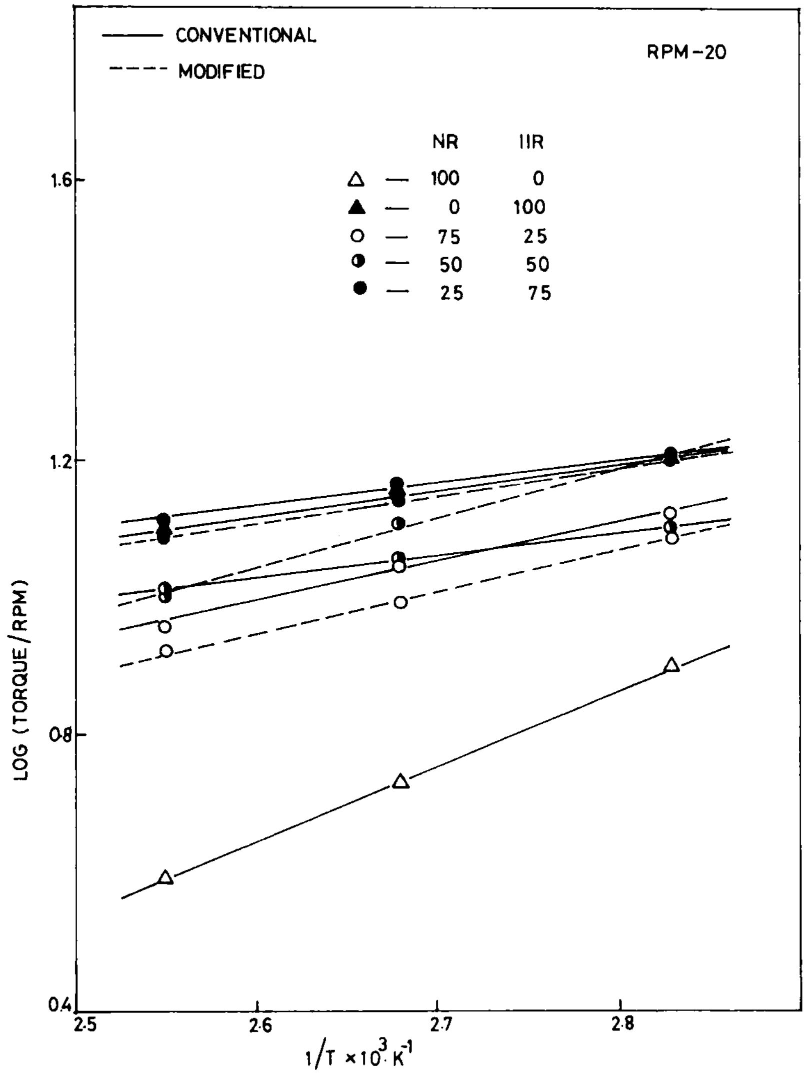

FIGURE 7 Variation of viscosity with temperature for NR/IIR blends.

TABLE V

Activation energy of viscous flow for NR/IIR blends

Blend composition, percentage of IIR	Activation energy ($kJmol^{-1}$) at various rpms		
	20	40	60
0	8.87	7.65	5.54
100	3.14	2.67	1.78
25	7.43	3.8	3.18
25 (modified)	4.84	3.09	2.6
50	2.29	1.94	1.44
50 (modified)	6.08	3.18	1.78
75	3.57	2.4	1.44
75 (modified)	2.88	2.34	1.44

TABLE VI

Activation energy of viscous flow for NR/EPDM

Blend composition, percentage of EPDM	Activation energy ($kJmol^{-1}$) at various rpms		
	20	40	60
0	8.87	7.65	5.54
100	4.59	2.53	1.77
25	6.82	5.33	3.86
25 (modified)	7.00	4.93	4.16
50	4.43	2.22	1.08
50 (modified)	3.70	1.62	0.79
75	6.05	2.70	2.60
75 (modified)	5.12	2.27	2.29

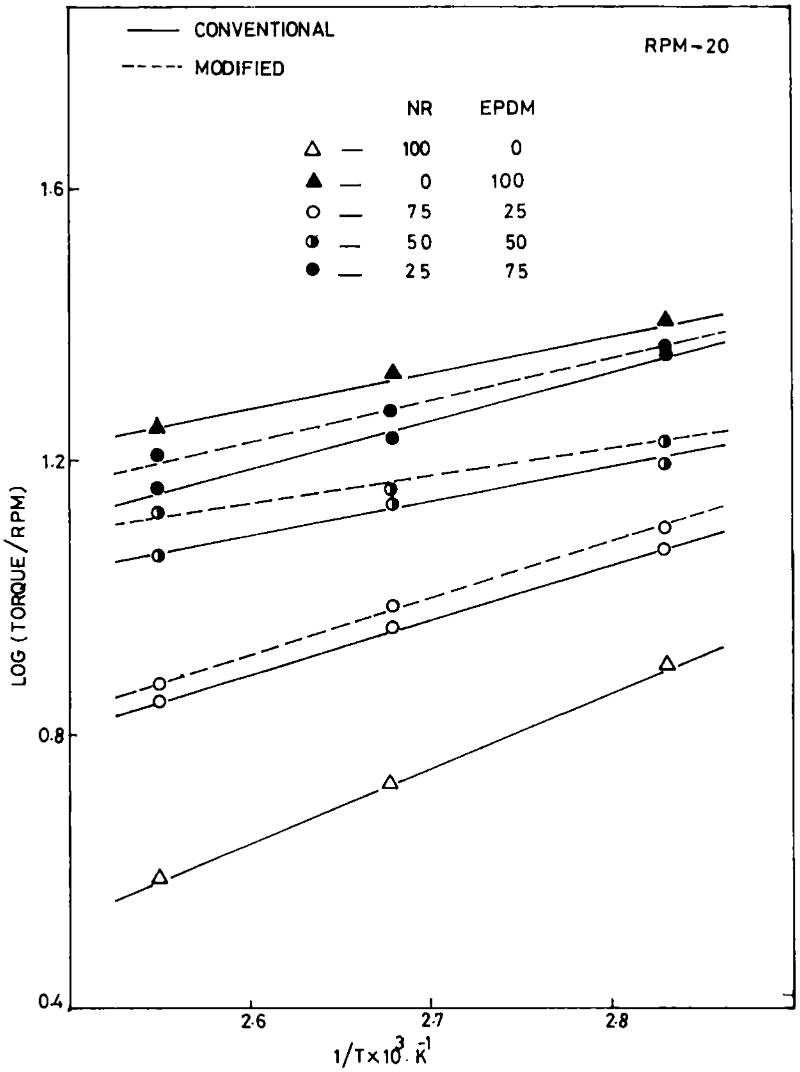

FIGURE 8 Variation of viscosity with temperature for NR/EPDM blends.

of viscosity is plotted as a function of reciprocal temperature. The activation energy (E) of flow calculated from the slope of these lines are given in Table V. It provides valuable information on the sensitivity of the material towards change in temperature. The higher the activation energy, the more temperature sensitive the material will be. From Table V it is clear that NR has a higher activation energy than IIR and that NR rich blends show a higher activation energy. However, all the blends have an activation energy intermediate between the components. The temperature dependence of viscosity for NR/EPDM blends is given in Figure 8 and Table VI shows the activation energies calculated from this figure which are comparable with those of the NR/IIR blends. In most cases the activation energy of the modified blends are less than that of the unmodified blends.

CONCLUSIONS

The modified NR/IIR and NR/EPDM blends show marginally higher melt viscosities than conventional blends but the pseudoplastic nature and activation energy of both conventional and modified blends are similar.

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