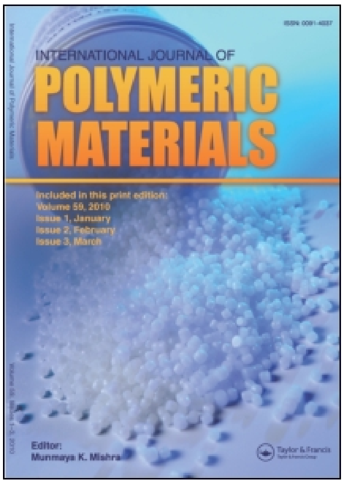

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Latex Stage Blending of Natural Rubber and Poly(Vinyl Chloride) for Improved Mechanical Properties

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Latex Stage Blending of Natural Rubber and Poly(Vinyl Chloride) for Improved Mechanical Properties

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A novel method of blending natural rubber with polyvinylchloride in the latex stage was developed, Dioctyl phthalate (DOP) and Amine terminated natural rubber (ATNR) were used as plasticisers, for improving the mechanical properties of these blends. Properties of the latex stage blends were compared with those of dry blends. Latex stage blends showed superior mechanical properties compared to the blends prepared in the dry state. The ageing resistance, oil resistance and processability were found to be improved by latex stage blending.

Keywords: NR latex; polyvinylchloride dioctyl phthalate; amine terminated liquid natural rubber; processability

INTRODUCTION

Polyvinyl chloride is one of the most widely used polymers because of its low cost and design advantages. It has the number one position in overall product volume and number of applications [1,2]. Modifying elastomers by blending with PVC is one of the promising methods of improving the oil, ozone and fire resistance of rubber vulcanizates [3,4]. Modulus, hardness and flame resistance of natural rubber can be significantly improved by blending with PVC [5,6], but developing moderate mechanical properties is a problem due to the immiscible nature of the two polymers. However, certain additives are capable

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of improving the miscibility of these polymers [7,8]. The incorporation of plasticizers in the blend was found to promote miscibility [9,10]. The mechanical properties of an immiscible blend are strongly dependent upon the blending method used. There are several methods of preparing polymer blends such as melt mixing, solution mixing, mixing of lattices, etc. [11]. Of these methods, mixing of lattices is advantageous in many respects because it does not use any solvent and does not require much energy.

In this study, latex stage blending of natural rubber and polyvinyl chloride was done. For improving the mechanical properties of these blends, DOP and ATNR were used as plasticizers. Properties of the latex stage blends were compared with those of dry blends. Rheological studies were also done.

EXPERIMENTAL

Materials Used

1. NR Latex: Field latex with 30% drc.
2. NR: Natural rubber ISNR–5 supplied by RR11, Kottayam, ML (1 + 4) 100°C–85.
3. PVC: Emulsion grade–K value 70.

The compounding ingredients ZnO, MgO, stearic acid and sulphur were of commercial grade. Tetramethylthiuram disulfide (TMTD) and N-cyclohexyl-2-benzothiazyl sulfanamide (CBS) were supplied by ICI India Ltd.

ANTR was prepared by U.V. irradiation of NR solution in toluene in presence of ethylene diamine.

A 50% dispersion of PVC was prepared using a ball mill, as per the formulation given in Table 1.

TABLE 1 Formulation of 50% PVC Dispersion

Ingredients	Dry weight (gm.)
PVC	100
MgO	4.0
ZnO	4.0
Stearic acid	2.0
Dispersol F	2.0
Water	100

Latex Stage Masterbatching of NR and PVC

NR latex and the PVC dispersion were blended properly in the ratio 80/20, 70/30, 60/40 and 50/50 using a high speed mechanical stirrer (4000 rpm) and the blend was coagulated using 2% acetic acid. After drying, the blend was mixed with other compounding ingredients except accelerators and sulphur at 150°C and 40 rpm in a Brabender plasticorder model PL 3S for 5 minutes. Later, sulphur and accelerators were added in a cold, two-roll laboratory mixing mill. In one sample DOP, and in the other ATNR, was used as the plasticizer. These blends are referred to as Latex stage blends. Dry NR and PVC were mixed in the Brabender Plasticorder at 150°C in the ratio 80/20, 70/30, 60/40 and 50/50 and compounded in a similar manner and the accelerator and sulphur were added on a mixing mill using ATNR and DOP as plasticisers. These blends are referred to as Dryblends.

Formulations of the compounds are given in Tables 2 and 3. The optimum cure time for all the compounds were determined on a Goettfert Elastograph model 67.85. The compounds were then compression moded up to their optimum curetime and the tensile properties were measured. The ageing resistance of all the blends was determined by measuring the retention in tensile properties after ageing for 48 hrs. at 70°C.

Rheological Studies

The rheological behavior of the latex stage blend containing ATNR as plasticizer and dry blend was evaluated using a capillary rheometer attached to a zwick UTM at different crosshead speeds (0.2–20 mm/min) at 150°C. Forces corresponding to specific speeds were

TABLE 2 Formulations of NR/PVC Compounds with DOP

Ingredients	(Dry wt.gm)				Ingredients (Dry wt.gm)				
NR latex	80	70	60	50	NR	80	70	60	50
PVC	20	30	40	50	PVC	20	30	40	50
ZnO	4	3.5	3	2.5	ZnO	4.8	4.7	4.6	4.5
MgO	–	–	–	–	MgO	0.8	1.2	1.6	2.0
Stearic acid	1.6	1.4	1.2	1.0	Stearic acid	2	2	2	2
DOP	8	12	16	20	DOP	8	12	16	20
NA 4020	0.8	0.7	0.6	0.5	NA 4020	0.8	0.7	0.6	0.5
CBS	0.8	0.7	0.6	0.5	CBS	0.8	0.7	0.6	0.5
TMTD	0.32	0.28	0.24	0.20	TMTD	0.32	0.28	0.24	0.20
S	2.4	2.1	1.8	1.5	S	2.4	2.1	1.8	1.5

TABLE 3 Formulations of NR/PVC Compounds with ATNR

Ingredients	(Dry wt.gm)				Ingredients (Dry wt.gm)				
NR latex	80	70	60	50	NR	80	70	60	50
PVC	20	30	40	50	PVC	20	30	40	50
ZnO	4	3.5	3	2.5	ZnO	4.8	4.7	4.6	4.5
MgO	–	–	–	–	MgO	0.8	1.2	1.6	2.0
Stearic acid	1.6	1.4	1.2	1.0	Stearic acid	2	2	2	2
ATNR	10	15	20	25	ATNR	10	15	20	25
NA 4020	0.8	0.7	0.6	0.5	NA 4020	0.8	0.7	0.6	0.5
CBS	0.8	0.7	0.6	0.5	CBS	0.8	0.7	0.6	0.5
TMTD	0.32	0.28	0.24	0.20	TMTD	0.32	0.28	0.24	0.20
S	2.4	2.1	1.8	1.5	S	2.4	2.1	1.8	1.5

measured. The force and crosshead speed were converted to apparent shear stress and shear rate and the shear viscosity was calculated. The extrudates were collected and the die swell was calculated.

Determination of Oil Resistance

The oil resistance of the 50/50 latex stage blend and dry blend vulcanizates was determined by keeping the sample in different oils at ambient temperature for one week. The percentage increase in weight of both samples was calculated.

RESULTS AND DISCUSSION

Table 4 shows the tensile properties of both latex stage blends and dry blends containing DOP. The tensile strength and elongation at break

TABLE 4 Tensile Properties of NR/PVC Blends Containing DOP

	Blend ratio	Tensile strength (N/mm^2)	Elongation at break (%)	Modulus (100%) (N/mm^2)
Latex stage blend	80/20	18	485	3.20
	70/30	17	390	3.78
	60/40	13	300	4.20
	50/50	11	189	4.75
Dry blend	80/20	12	460	2.20
	70/30	10	370	3.10
	60/40	7	215	3.90
	50/50	5	142	4.25

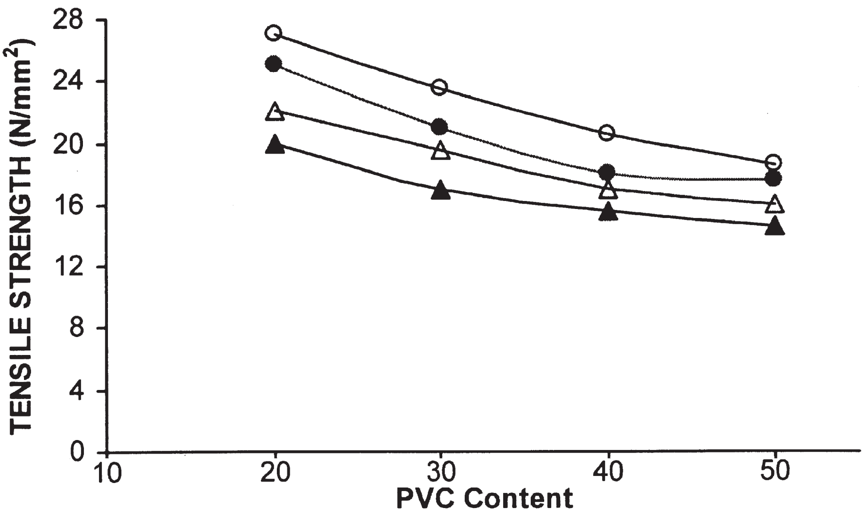

FIGURE 1 Variation of tensile strength with PVC content. '○' Latex stage blend, '●' aged at 70°C for 48 hrs. '△' Dry blend, '▲' aged at 70°C for 48 hrs.

are found to decrease with increase in PVC content. This may be due to the incompatible nature, but the latex stage blend shows superior tensile properties compared to the dry blends. This may be due to better homogeneity of the latex stage blend.

The variation of tensile strength of NR/PVC blends containing ATNR with PVC content (both unaged and aged) is shown in Figure 1. It shows that blending the polymers in the latex stage results in much improved tensile strength compared to solid state blending. This is obviously due to better homogeneity and dispersion resulting from the latex stage mixing and the effectiveness of ATNR as a compatibilizer. The ageing resistance of the blends prepared by latex stage blend is also higher than that of the conventional blends, which further shows the superiority of the latex stage mixing and the effectiveness of ATNR as a compatibilizer.

Figure 2 shows the variation of elongation at break of the blends with PVC content. As the PVC content increases, there is gradual reduction in elongation.

The blends prepared by latex stage blending show better elongation at break compared to dry stage blending both before and after ageing. This may be due to better distribution of PVC.

Figure 3 shows the variation of modulus of the blends with PVC content (both unaged and aged). Modules increases as the PVC

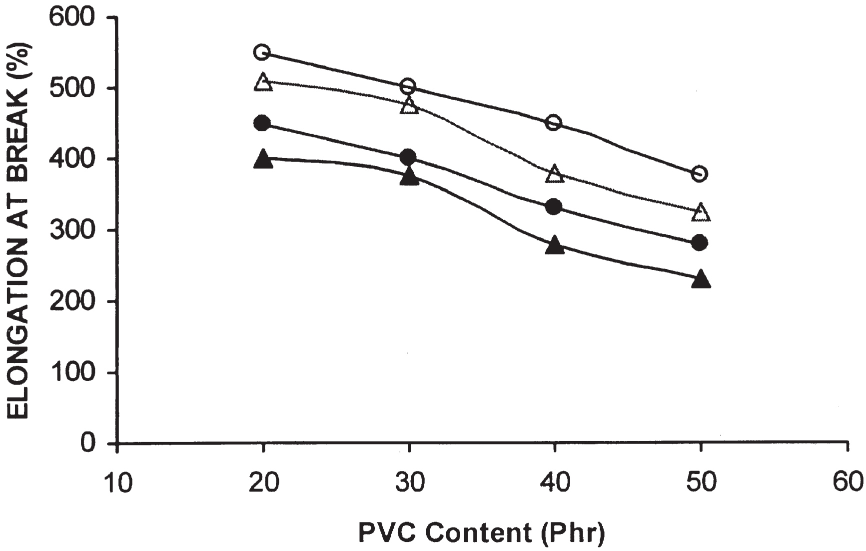

FIGURE 2 Variation of elongation at break with PVC content. '○' Latex stage blend, '●' Aged at 70°C for 48 hrs. '△' Dry blend, '▲' aged at 70°C for 48 hrs.

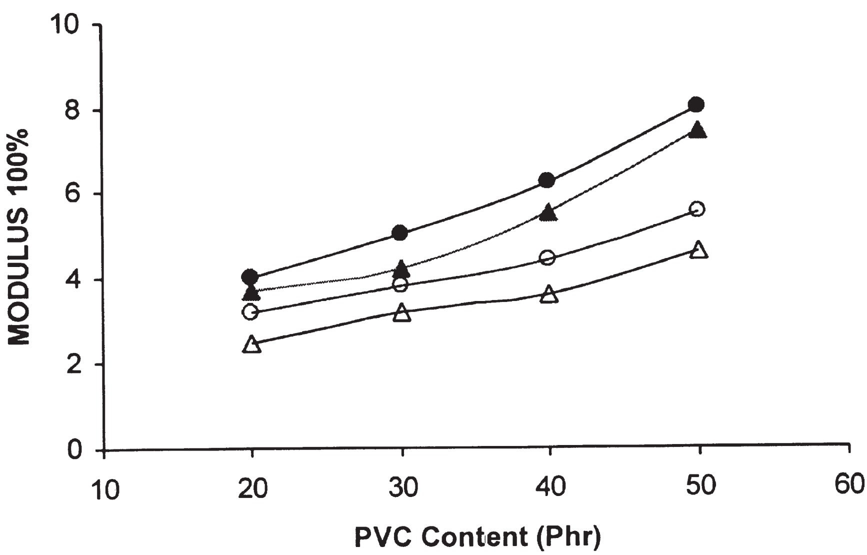

FIGURE 3 Variation of modulus with PVC content. '○' Latex stage blend, '●' Aged at 70°C for 48 hrs. '△' Dry blend, '▲' aged at 70°C for 48 hrs.

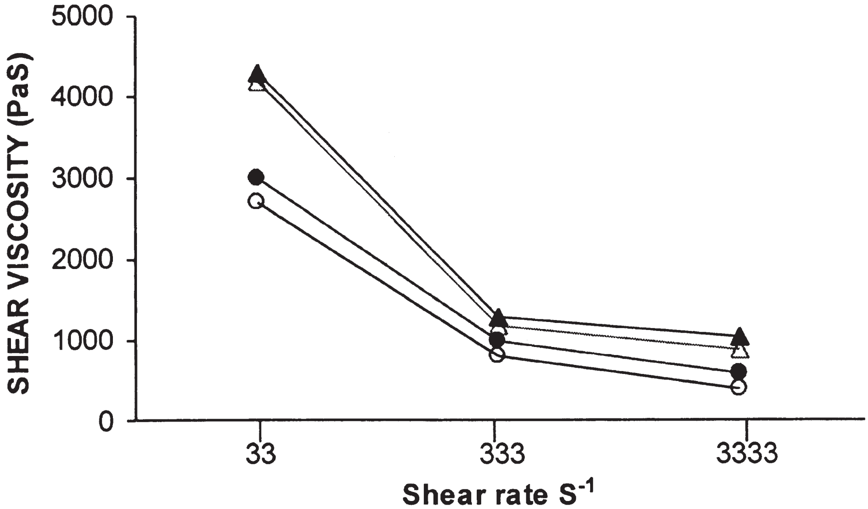

FIGURE 4 Variation of shear viscosity with shear rate at 90°C. '○' Latex stage blend with 30 phr PVC, '●' Latex stage blend with 40 phr PVC, '△' Dry blend with 30 phr PVC, '▲' Dry blend with 40 phr PVC.

content increases. Latex stage blends show higher modulus compared to dry blends both before and after ageing. This again proves the better particle distribution during latex stage blending.

The NR/PVC blends containing ATNR are found to show superior tensile strength and elongation of break compared to NR/PVC blends containing DOP as is found when Table 4 and Figures 1 and 2 are compared. This proves that ATNR can act as an effective combatibilizer in NR/PVC blend.

Figures 4 and 5 compare the flow curves of the NR/PVC blends at temperatures 90°C and 150°C respectively. The latex stage blends show lower viscosity than the corresponding dry blends at the same shear rate. This shows that the processing of latex blends will be comparatively easier than the dry blends. As the shear rate increases, shear viscosity decreases. This confirms the pseudoplastic behaviour of the material. At lower temperature (90°C) PVC does not melt and that may be the reason for the increase in viscosity with PVC content, shown in Figure 6.

Figure 7 shows that as the PVC content increases, the shear viscosity at 150°C decreases. In this case, the PVC has been melted and the viscosity decreases with PVC content. For all blend ratios (80/20, 70/30 and 60/40) latex stage mixed blends show lower

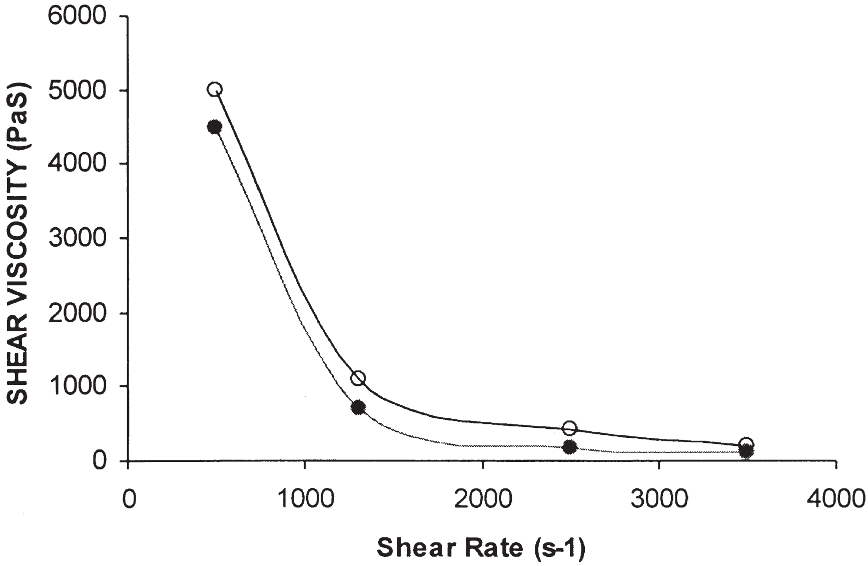

FIGURE 5 Variation of shear viscosity with shear rate at 150°C. '●' Latex stage blend with 20 phr PVC, '○' Dry blend with 20 phr PVC.

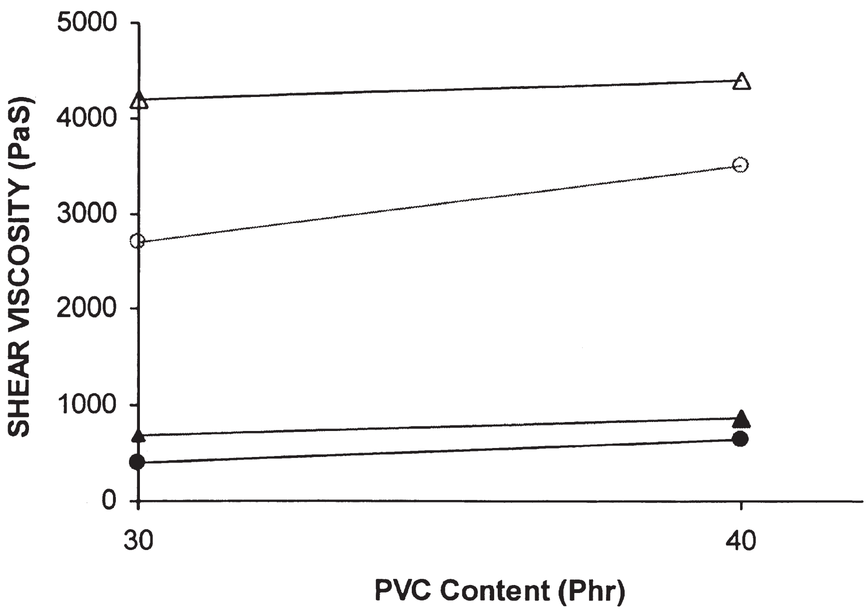

FIGURE 6 Variation of shear viscosity with PVC content at 90°C. '○' Latex stage blend and '△' Dry blend at shear rate 33 s^{-1}. '●' Latex stage blend and '▲' Dry blend at shear rate 333 s^{-1}.

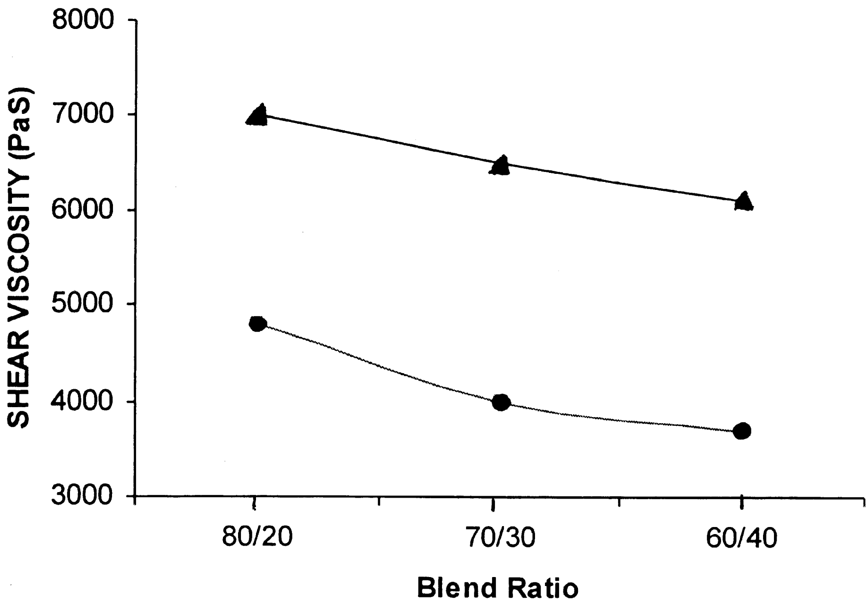

FIGURE 7 Variation of shear viscosity with PVC content at 150°C. '●' Latex stage blend and '▲' Dry blend.

viscosity than the corresponding dry blends. This again confirms the superior processability of latex stage blends.

Table 5 shows the die swell values of both latex stage blends and dry blends at different shear rates. The die swell of latex stage blends are lower than those of dry blends. All these results indicate the superiority of the latex stage blends.

Table 6 shows the oil resistance of both latex stage blends and dry blends. Latex stage blends show higher oil resistance than dry blends.

TABLE 5 Die Swell of the Extrudates at Different Shear Rates at 100°C

		Die swell at shear rate (s^{-1})		
	Blend ratio	33	333	3333
Latex stage blend	70/30	4.2	4.3	5.0
	60/40	4.1	4.4	4.9
Dry blend	70/30	4.9	5.0	5.2
	60/40	4.5	4.5	5.1

TABLE 6 Oil Resistance of NR/PVC Blends (50/50)

Blend	Percentage increase in weight		
	Napthanic oil	Engine oil	Transformer oil
Latex stage blend	51	9.5	43
Dry NR/PVC blend	61	12.5	50.5

This improved oil resistance may be due to the improved dispersion and interaction of NR and PVC due to latex stage blending.

CONCLUSION

Blending Natural Rubber and PVC in the latex stage is a promising method for improving the mechanical properties of the blends. Amine terminated natural rubber is an efficient compatibilizer for the system. The thermal ageing resistance, oil resistance and the processing behavior of the latex stage blends are superior to those blends prepared by direct mixing of the solid polymers.

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