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Studies on the Rheology and the Mechanical Properties of Thermoplastic Elastomer from Latex Product Waste and High Density Polyethylene

S. RAJALEKSHMI AND RANI JOSEPH*

*Department of Polymer Science and Rubber Technology
Cochin University of Science and Technology
Cochin 682 022, Kerala, India*

ABSTRACT: Latex waste products contain rubber hydrocarbon of very high quality, which is only lightly cross linked. Selected wastes such as thread waste and glove waste were modified into processable materials by a novel economic process and thermoplastic elastomers were prepared by blending these modified waste materials with high density polyethylene in various proportions. The mechanical properties as well as the rheological behaviour of these blends were evaluated and compared with those of the natural rubber-high density polyethylene blends.

KEY WORDS: thermoplastic elastomer, latex product waste, high density polyethylene, mechanical properties, fracture mechanism, rheology, morphology.

INTRODUCTION

THERMOPLASTIC ELASTOMERS ARE materials having the characteristics of thermoplastics at processing temperature and those of elastomers at service temperature [1-3]. They contain a soft rubbery phase and a hard thermoplastic phase. Thermoplasticity results from the melting characteristics of the hard thermoplastic phase at the high temperatures

*Author to whom correspondence should be addressed. E-mail: rani@cusat.ac.in

of processing, where as, the elastic properties arise from the soft rubbery phase at the low temperatures of use [4,5]. At low temperatures, the hard thermoplastic phase will act as cross links or as reinforcing filler particles between the soft rubbery phase [6]. This unique combination of properties of vulcanized rubber and the easy processability of thermoplastics, bridge the gap between conventional elastomers and thermoplastics.

Over recent years, blends of natural rubber with polyolefins have been widely studied [7,8] and found to behave very well as thermoplastic rubbers, within the category of olefinics.

Blending of an elastomer with a thermoplastic in an internal mixer at a temperature, above the melting point of the thermoplastic has certain definite advantages [9]. The desired properties can be achieved by proper selection of elastomer and thermoplastic components and their ratios in the blend. In polyolefin-elastomer blends, the effect of the characteristics of the components and blend ratios on the technical properties, processing characteristics and failure mechanism of the resulting thermoplastic elastomers have already been reported [10-14].

Scrap latex products contain rubber hydrocarbon of very high quality, which is only lightly cross linked. These waste materials can effectively be utilized by reclaiming processes and may be blended with other polymers. Various processes have been developed for reclaiming latex products.

This paper reports the chemical modification of latex thread waste and glove waste into processable materials and their utilization in the preparation of Thermoplastic Elastomers (TPEs) by blending with High Density Polyethylene (HDPE). The mechanical properties, rheology and morphology of these TPEs are compared with those of the NR-HDPE based TPEs.

EXPERIMENTAL

The latex thread waste and glove waste were modified as processable materials by a novel economic process using the formulation shown in Table 1. The additives used were zinc oxide, stearic acid, MBT, naphthenic oil and hydroquinone. The modified thread waste and glove waste are hereafter referred to as TW and GW respectively.

Blends of HDPE with TW and GW or NR were prepared as follows. Mixing was done on a Brabender plasticorder model PL3S at 150°C and 50 rpm. HDPE was melted in the mixer for 4 min and then TW, GW or NR containing the additives was added and the mixing was continued

Table 1. Formulation.

Ingredients	Phr
Thread waste	100.0
NR	20.0
ZnO	2.0
Stearic acid	2.0
MBT	0.5
Naphthenic oil	3.0
Hydroquinone	0.2

Table 2. Tensile strength values of NR-TW-GW with HDPE.

	Blend Ratio	Materials			
		T.S N/mm ²	HDPE	TW	GW
A	80	20	-	-	14.81
B	70	30	-	-	10.38
C	60	40	-	-	10.06
D	50	50	-	-	5.16
E	80	-	20	-	11.79
F	70	-	30	-	8.47
G	60	-	40	-	6.18
H	50	-	50	-	5.55
I	80	-	-	20	14.74
J	70	-	-	30	7.43
K	60	-	-	40	6.69
L	50	-	-	50	3.80

for 6 more minutes. The mix was then taken out and sheeted on a laboratory mixing mill at 20 mm nip gap setting. The sheeted material was cut into small pieces and again mixed in the plasticorder at 150°C for 4 min so as to get a uniform dispersion of the ingredients. After mixing, the blend was compression moulded in an electrically heated hydraulic press at 160°C for 6 min. A specially fabricated mould with nuts and bolts was used for this purpose so as to hold the material inside under pressure. The mould with sample was cooled by circulating cold water. Polyester sheets were used in between the mould surfaces to reduce shrink marks on the sheets.

Tensile testing of the sample was done as per ASTM D 638 test method at a cross head speed of 50 mm/min, using a Zwick universal testing machine model 1445. The tensile strength values corresponding to each blend ratio is given in Table 2.

Processability studies have been done with 80 HDPE-20 rubber blends both in a torque rheometer brabender model PL3S and in a capillary viscometer Goettfert model 1500 at 150°C.

Cross link densities of GW and TW were determined by swelling method and calculated using Flory-Rehner equation.

RESULTS AND DISCUSSION

The variation in tensile strength of the blends with the percentage of rubber is shown in Figure 1. For all the three blends, the tensile strength decreases with increase in the rubber content as expected [13] and the maximum tensile strength is obtained at 20% rubber. The modulus also decreases but the elongation at break increases. The decrease in strength with increase in rubber has been ascribed to the drop in crystallinity [15,16]. High tensile strength and low elongation on decreasing the rubber content implies that the dominant phase is the poly olefin for these compositions. In blends containing a higher proportion of HDPE, the elastomer phase remains as dispersed particles. Smaller size and uniform dispersion of the dispersed phase improve the tensile properties of the blends [17]. It is seen that the tensile strength of the blends with TW or GW is slightly higher than

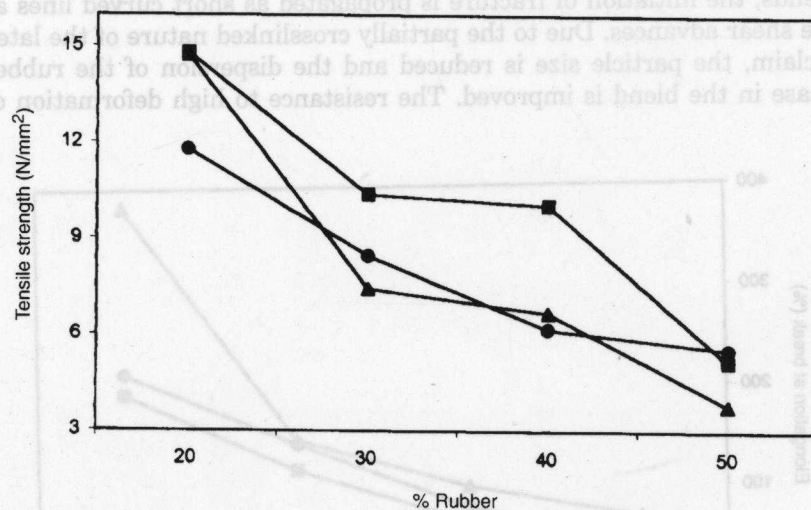


FIGURE 1. Variation of tensile strength with % of rubber. (▲) HDPE-NR (■) HDPE-TW (●) HDPE-GW.

that of the blends with NR. This may be due to the partially crosslinked nature of the TW and GW [18]. Of the two blends TW-HDPE and GW-HDPE, the former shows higher tensile strength values than the latter. This is due to the higher crosslink density of TW compared to that of GW. The values were calculated to be 4.1×10^{-5} g mol/cc for GW and 1.1×10^{-3} g mol/cc for TW.

Elongation generally increases with increase in rubber content, though the increment is only marginal for HDPE-TW and HDPE-GW blends, as shown in Figure 2. The HDPE-NR blend shows a higher elongation because of the uncross-linked nature of the NR phase.

The variation of tear strength with % of rubber is shown in Figure 3. The behaviour is similar to that of tensile strength and the reason is again the drop in crystallinity as the rubber content is increased.

The values of modulus and hardness of the blends are given in Table 3. The modulus decreases with increase in rubber content and hardness increases with plastic content.

Figure 4 shows the tensile fractographs of 80/20 HDPE-NR, HDPE-TW and HDPE-GW blends. For HDPE-TW and HDPE-GW blends, the initiation of fracture is propagated as short curved lines as the shear advances. Due to the partially crosslinked nature of the latex reclaim, the particle size is reduced and the dispersion of the rubber phase in the blend is improved. The resistance to high deformation of

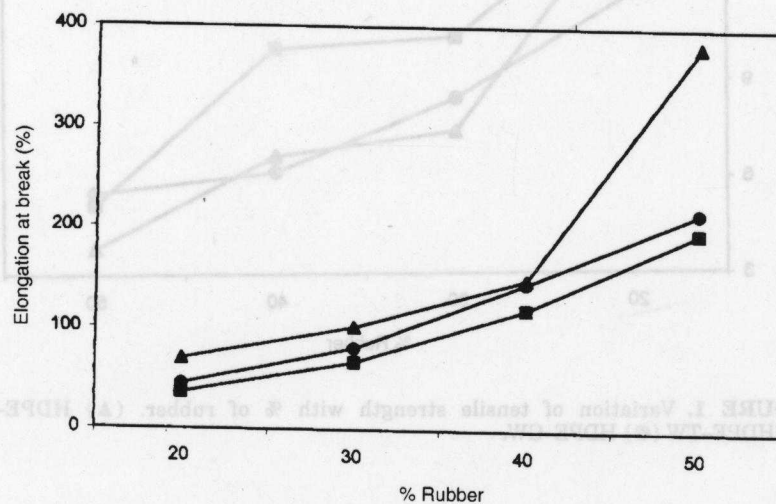


FIGURE 2. Variation of elongation with % of rubber. (▲) HDPE-NR (■) HDPE-TW (●) HDPE-GW.

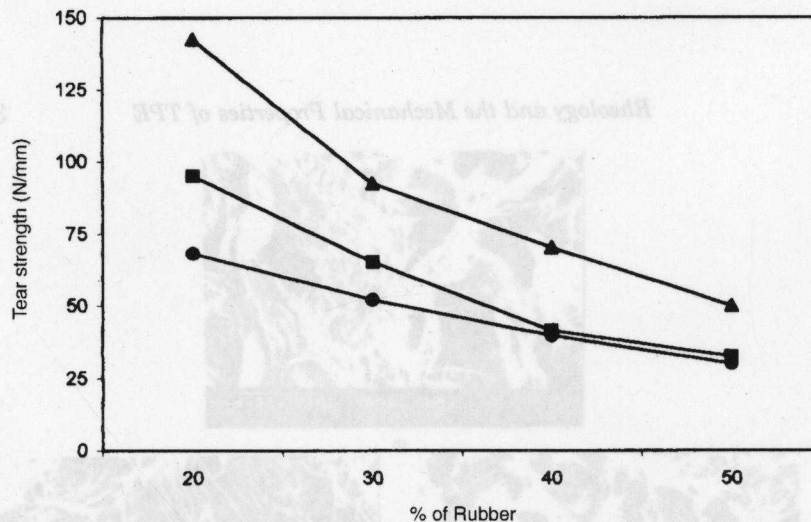


FIGURE 3. Variation of tear strength with % of rubber. (▲) HDPE-NR (■) HDPE-TW (●) HDPE-GW.

Table 3. Physical properties of HDPE-rubber blends.

Blend	Ratio	Young's Modulus (MPa)	Hardness (shore D)
HDPE-NR	50/50	92	26
	60/40	113	29
	70/30	141	35
	80/20	160	43
HDPE-TW	50/50	101	25
	60/40	127	30
	70/30	156	34
	80/20	198	43
HDPE-GW	50/50	97	23
	60/40	119	25
	70/30	151	29
	80/20	195	41

these crosslinked particles restricts the flow under stress. This is shown by the presence of many short curved shear lines on the fracture surface. But in the case of 80/20 HDPE-NR blend, the uncross-linked NR phase undergoes much higher deformation, resulting in multidirectional shear lines.

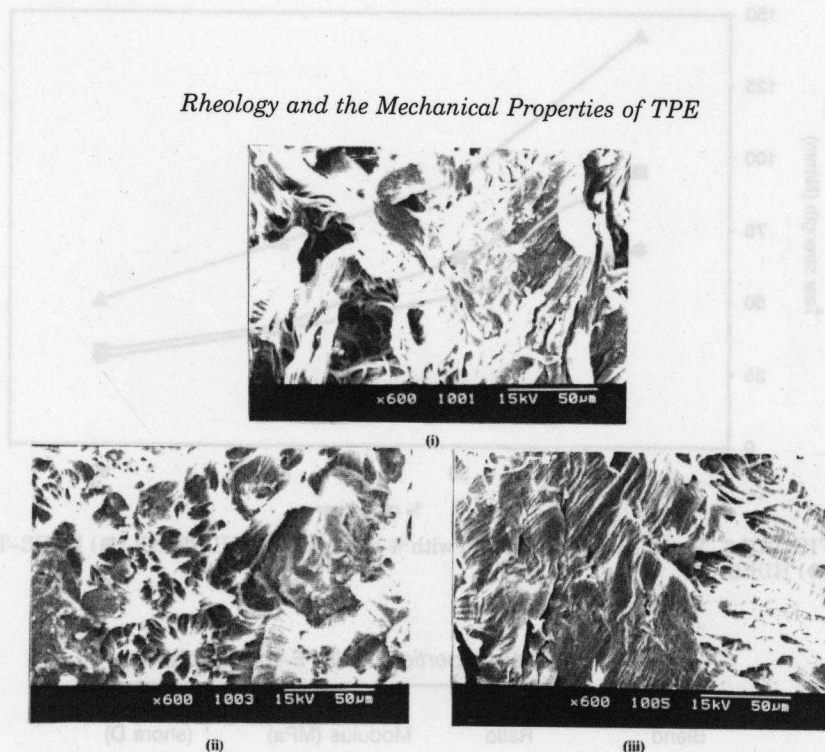


FIGURE 4. Tensile fractographs of 80/20 blends of (i) HDPE-NR (ii) HDPE-TW (iii) HDPE-GW.

The variation of viscosity (torque/rpm) with shear rate (rpm) is shown in Figure 5. The torque/rpm representing viscosity decreases with increase in shear rate (rpm) at constant temperature, viz., 150°C. From the figure it is seen that TW-HDPE and GW-HDPE blends show lower viscosity compared to NR-HDPE blend. This may be due to the partial devulcanization and molecular break down during the pre-processing of the waste material. GW-HDPE blends have lower viscosity than those of TW-HDPE blends due to the lower crosslink density of GW when compared to that of TW.

Log viscosity is plotted against log shear rate in Figure 6. It shows that as the shear rate increases, viscosity decreases. From this curve also it can be seen that there is no increase in the viscosity of HDPE-TW and HDPE-GW blends compared to the HDPE-NR blend even though the former blends were slightly cross linked. The reasons are again the partial devulcanization and molecular breakdown during the pre-processing. The decrease in viscosity with increase in shear rate shows that the blends are pseudo plastic in nature [19].

It is clear from Figure 7, which shows the relationship between shear stress and shear rate, that as the shear rate increases, shear stress also

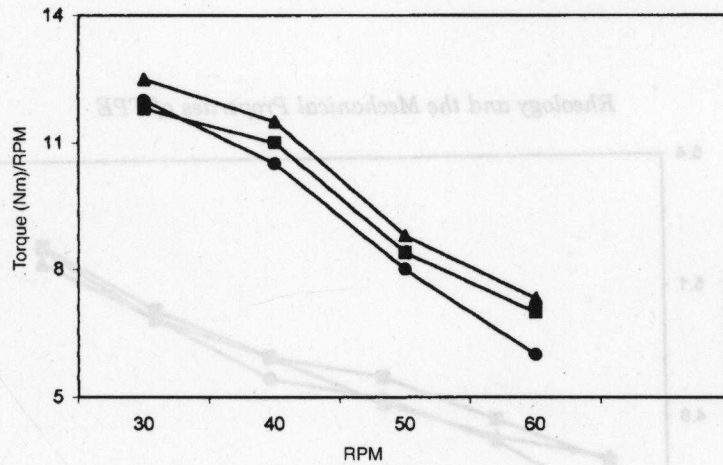


FIGURE 5. Variation of torque/rpm with rpm of 80/20 blends. (▲) HDPE-NR (■) HDPE-TW (●) HDPE-GW.

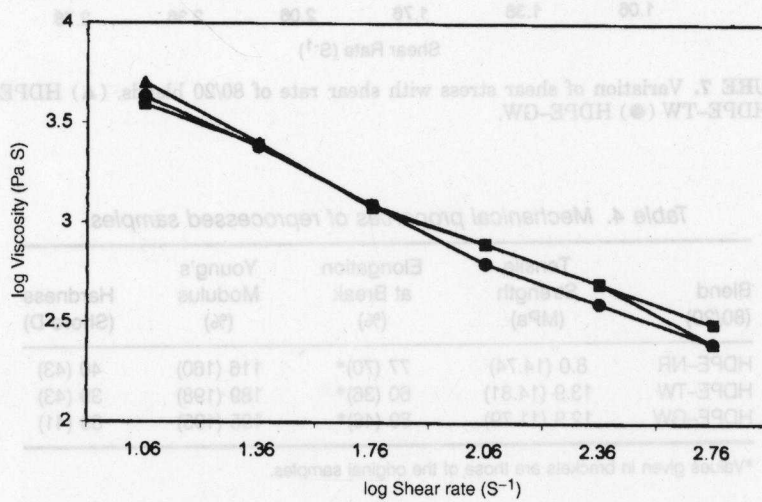


FIGURE 6. Variation of viscosity with shear rate of 80/20 blends. (▲) HDPE-NR (■) HDPE-TW (●) HDPE-GW.

increases as expected. It confirms the non-Newtonian behaviour of the blends.

Table 4 shows the values of tensile strength, elongation, modulus and hardness of the reprocessed samples. It can be seen that even after reprocessing, the materials could retain the mechanical

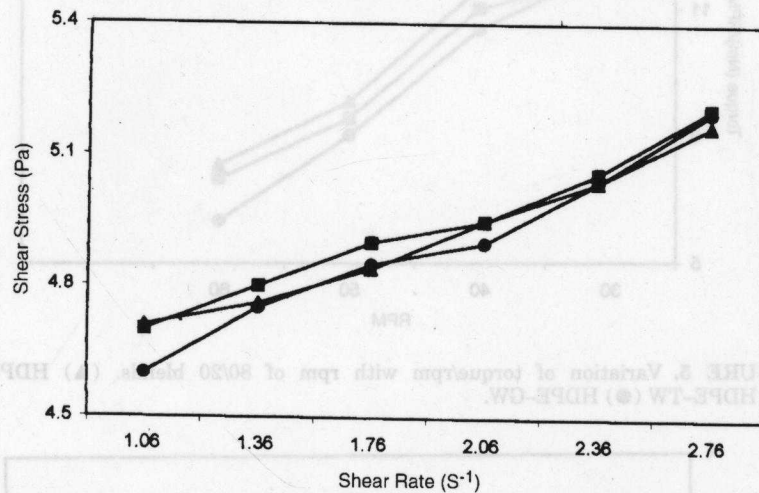


FIGURE 7. Variation of shear stress with shear rate of 80/20 blends. (▲) HDPE-NR (■) HDPE-TW (●) HDPE-GW.

Table 4. Mechanical properties of reprocessed samples.

Blend (80/20)	Tensile Strength (MPa)	Elongation at Break (%)	Young's Modulus (%)	Hardness (Shore D)
HDPE-NR	8.0 (14.74)	77 (70)*	116 (160)	40 (43)
HDPE-TW	13.9 (14.81)	60 (36)*	189 (198)	39 (43)
HDPE-GW	12.9 (11.79)	89 (46)*	195 (195)	39 (41)

*Values given in brackets are those of the original samples.

properties to a great extent, which implies that they are very much reprocessable.

CONCLUSION

Thermoplastic elastomer can be developed from latex product waste such as thread waste and glove waste and HDPE. The mechanical properties as well as processability characteristics are comparable with those of the conventional thermoplastic elastomers based on natural rubber and HDPE. Reprocessability is also appreciable for these materials.

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