



Physico-Mechanical and Thermal Behaviour of Binary Blends of EPDM and LLDPE

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ABSTRACT

The present investigation is aimed to prepare blends comprising of Ethylene Propylene Diene Monomer (EPDM) and Linear Low Density Polyethylene (LLDPE) with the help of two roll mill by melt blending process at various blend ratios. The effect of LLDPE on mechanical and thermal properties of the developed blends has been investigated. The results of mechanical properties reveal that there is significant increase in tensile strength, hardness and puncture resistance with increase of LLDPE content in EPDM. The elongation at break for the blend increases with increasing EPDM content. The reason might be attributed to chemical cross linking of EPDM which restricts the mobility of the polymer chains. The reduction in tensile property, hardness and puncture resistance at higher content of EPDM might be because of rubbery nature of EPDM. In addition, it is also observed that the increase of LLDPE content in EPDM matrix improves thermal stability of the blends. The improvement in thermal properties may be because of the increased chemical cross-linking into blends. Morphological studies of developed blends have been performed by scanning electron microscopy (SEM). FTIR study has also been carried out to study the structure property relationship of the blends.

Key words: LLDPE, EPDM, Puncture resistance, Tensile strength, Thermal stability

INTRODUCTION

Polymer blends are physical mixtures of structurally different homo or copolymers without any covalent linkage. An enormous amount of work has been documented on the blends of linear low density polyethylene (LLDPE) and ethylene-propylene diene terpolymer (EPDM) owing to their commercial importance [1-2]. Blends comprising of EPDM and LLDPE have got broad usage in automotive weather-stripping and seals, glass-run channel, radiator, garden and appliance hose, tubing, belts, electrical insulation, roofing membrane etc. EPDM has been found to be one of the most widely used and growing synthetic rubber having both speciality and general purpose applications. EPDM is a valuable elastomer for its excellent resistance to heat, oxidation, ozone and weather aging because of stable and separated polymer backbone structure. Literature survey reveals that very less study has been carried out on the blends based on EPDM and LLDPE. The impact of LLDPE and its blends is particularly strong in film blowing technology where it tends to displace LDPE. The resulting preparation of polymer blends depends on the proportion and properties of individual polymeric components and the mode of dispersion and interaction between the phases [3-7].

Homogeneity is essential at microscopic level for excellent performance of the polymer blends [8-9]. In the present investigation an effort has been made to prepare polymer blends comprising of EPDM and LLDPE by two roll mill and to investigate the mechanical, thermal and morphological behaviour of the developed blends.

MATERIALS USED

EPDM Rubber

Ethylene Propylene Diene Monomer (EPDM) was obtained from M/s Du Pont Wilmington USA, grade Nordel 2722, ethylene content 60% and TUFLIN Linear Low Density Polyethylene (LLDPE) from Dow USA, grade TUFLINTM HS-7001 NT7.

Method of Blend Preparation

In this research work, the blending process of EPDM/LLDPE involves the use of a two roll mill. Several formulations containing EPDM and LLDPE were prepared. EPDM was blended with LLDPE in different weight

ratios of EPDM/LLDPE (100, 90/10, 80/20, 70/30, 60/40, 50/50) tabulated in Table (1). These compounds were mixed at 110-120°C in open two roll mill for 10min to 20min. The open two roll mill was heated to 110°C and kept constant before use. LLDPE was first introduced into mixing mill. EPDM was added after the completion of melting of LLDPE. The sheets of developed blends were prepared by compression moulding at 140°C and then cooled down quickly by cold water to ambient temperature.

TESTING AND CHARACTERIZATION

Mechanical Properties

Mechanical properties such as tensile strength, hardness and puncture resistance have been measured by using universal testing machine (UTM) of the INSTRON Model 3382, USA with the maximum load capacity 100KN. Tensile tests have been conducted according to ASTM D-638 for each composition, five measurements have been taken and average value of strength have been reported. The hardness of the samples has been measured as per the standard ASTM D 2240 testing method, using a Durometer of Model 3062 type A. At least five measurements have been recorded and average value has been reported. The unit of hardness is expressed in (Shore- A). Puncture resistance is also carried out by using UTM, ASTM F1342.

Thermo-Gravimetric Analyzer (TGA)

It measures the amount and rate of weight change as a function of temperature to determine the thermal stability and decomposition kinetics of a material. Thermal studies have been carried out by using a Perkin-Elmer Pyres TGA thermo gravimetric analyzer in the temperature range 50°-600°C at a heating rate of 10°C/min in nitrogen atmosphere.

Surface Morphology Study

Surfaces of EPDM/LLDPE blends have been analysed using (JEOL JSM-6490 LV SEM). SEM has been used to check the dispersion of LLDPE content in the EPDM/LLDPE blends. Prior to SEM analysis the fractured samples obtained after tensile analysis have been gold coated with the help of gold sputtering unit to avoid the charging effect and enhance the emission of secondary electrons.

Fourier Transform Infrared Spectroscopy (FTIR)

Fourier transform infra-red spectroscopy (FTIR) study has been carried out with the help of Agilent Technologies (Cary 600 series) FTIR spectroscopy in a humidity free atmosphere with range of 4000-400 cm⁻¹ to investigate the possible interactions between EPDM/LLDPE blends.

Table -1 Compounding Formulation of EPDM/LLDPE Blends

S No	Material	Weight ratio (gm.)	Mixing time	Mixing temp.
A	EPDM	100	10mins	110 °C
B	EPDM/LLDPE	90/10	12mins	110 °C
C	EPDM/LLDPE	80/20	12mins	120 °C
D	EPDM/LLDPE	70/30	15mins	120 °C
E	EPDM/LLDPE	60/40	15mins	120 °C
F	EPDM/LLDPE	50/50	20mins	120 °C

Table -2 Mechanical Properties of EPDM/LLDPE Blends

Sample cede	Tensile strength at break (MPa)	Hardness (Shore A)	Puncture Resistance (kgf)
A	0.96	51	2.16
B	2.26	55	2.52
C	2.58	59	3.51
D	3.35	63	5.24
E	3.62	67	5.36
F	4.30	71	6.15

Table -3 Initial and Final Degradation Temperature of EPDM/LLDPE Blends with Different Loadings of LLDPE Content

Sample (EPDM/LLDPE)	Initial degradation Temperature	Final degradation Temperature	Residue weight loss %
100	209.34	555.26	0.346
90/10	238.08	601.91	0 (-5.885)
80/20	217.62	609.95	0 (-1.384)
70/30	240.27	569.77	0 (-0.193)
60/40	245.38	546.39	0 (-0.171)
50/50	240.27	590.95	0 (-1.063)

RESULTS AND DISCUSSION

Mechanical Properties

The mechanical properties results of developed blends comprising of EPDM and LLDPE demonstrate that there is significant improvement in tensile strength, hardness and puncture resistance. These results are tabulated in Table -2 and also shown in Fig. (1-3). It is evident from the mechanical properties results that maximum properties have been achieved in 50-50 (EPDM/LLDPE) of the blend. The enhancement in tensile strength, hardness and puncture resistance may be because of the chemical cross-linking of EPDM. The chemical cross-linking of EPDM restricts the mobility of the polymer chains. The other possible factors are good interfacial adhesion and the interaction between stress concentrate zones in LLDPE matrix. An increase of interfacial adhesion minimizes the creation of voids or flaws in the LLDPE matrix which might lead to crack formation.

The increased interfacial adhesion can facilitate the deformation to take place easily in the cross-section and provides shear yielding [10]. Shear yielding can be accelerated by the interaction in the stress concentrate zones. Such type of finding has also been observed by other investigators on PP/EPDM blend [11] and PP/NR blend [12]. The increase in interfacial adhesion between the phases comes from the presence of graft co-polymer of the components [10, 13-14]. Another reason for the improvement in tensile strength, hardness and puncture resistance might be because of the separation of interfacial de-boding.

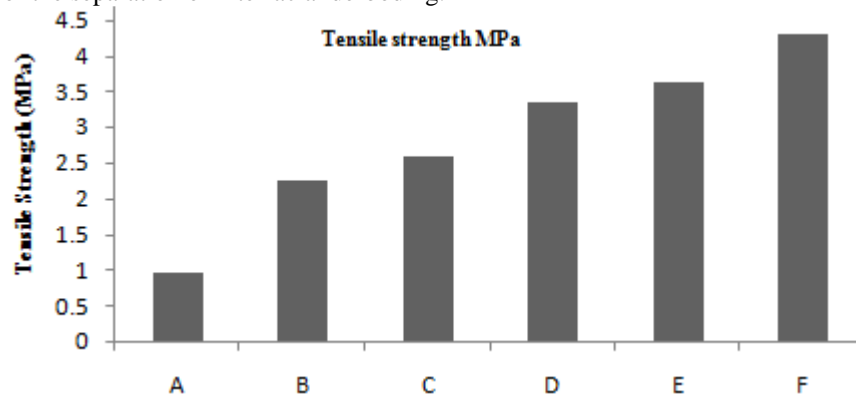


Fig. 1 Comparison of the Tensile Strength Value for Samples

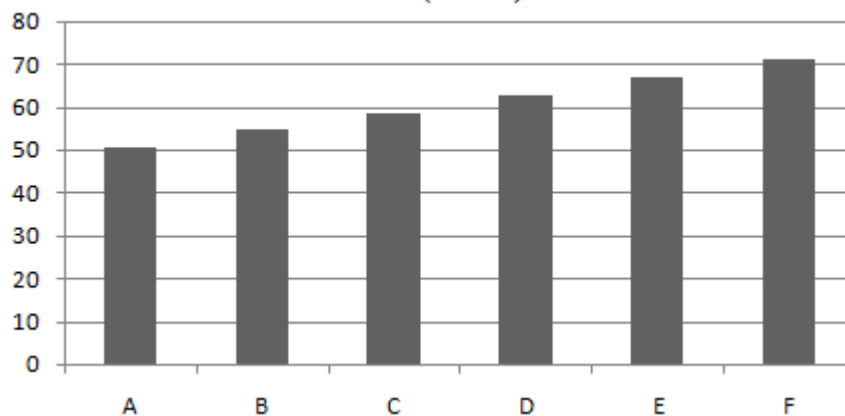


Fig. 2 Comparison of the Hardness Value for Samples

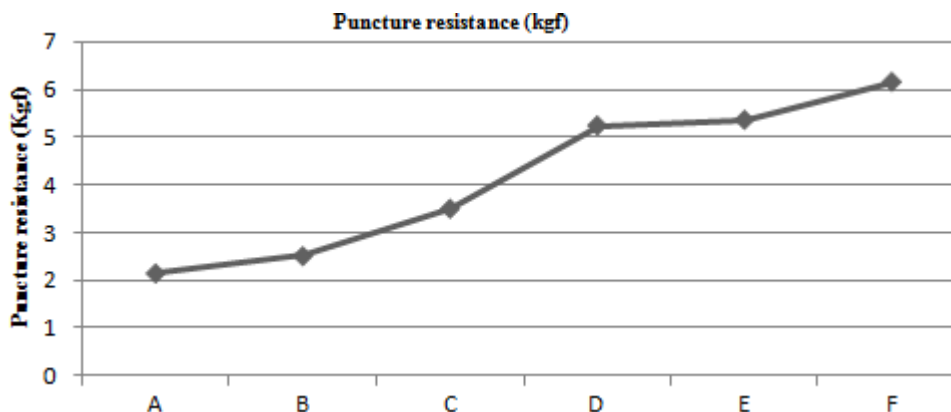


Fig. 3 Comparison of the Puncture Resistance Value for samples

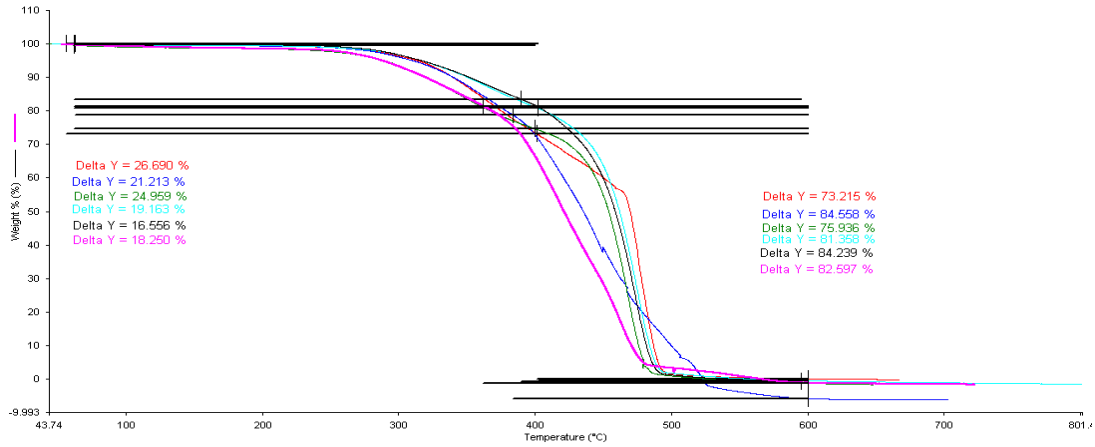


Fig. 4. TGA Curve of EPDM/LLDPE Blends

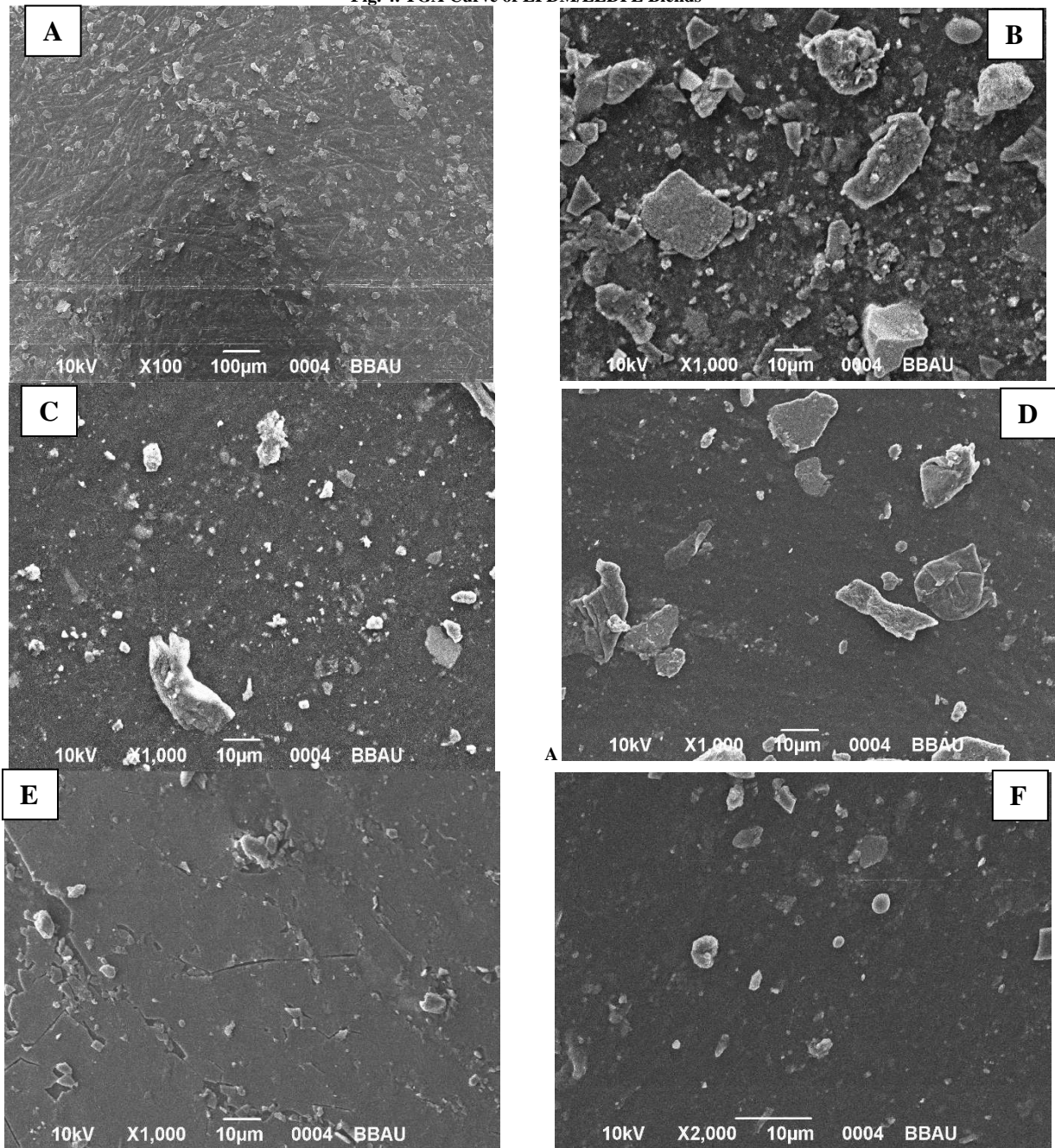


Fig. 5 (A-F) SEM Micrographs of EPDM/LLDPE Blends with Different Ratio of LLDPE Content in Blends

Thermo Gravimetric Analysis (TGA)

The thermal stability and degradation behaviour of EPDM/LLDPE blends have been determined by thermo gravimetric analyzer (TGA). TGA is used to investigate the effect of LLDPE on the thermal properties of EPDM/LLDPE blends. TGA studies have been performed for the various compositions of EPDM/LLDPE blends. Fig. 4 shows weight loss versus temperature curve for the developed blends in nitrogen atmosphere. All the blends have improved thermal stability than that of virgin EPDM. The decomposition temperature of virgin EPDM has been found to be at 209°C which increases to 245°C with the incorporation of 40 wt. % LLDPE. This might be attributed to the incorporation of LLDPE that reduces the chains mobility of the polymer matrix by imposing vast number of restriction sites and also the reduction of the thermal vibration of C-C bond [15, 17]. Therefore, the blends need much more thermal energy for the decomposition of polymer matrix which in turn enhances the thermal stability. Another reason may be for the improvement of the thermal stability of the blends is the formation chain, which acts as a physical barrier between the polymer and the superficial zone where the combustion of polymer is taking place [18]. It can be proposed that EPDM blended with LLDPE can improve its thermal stability including resistance to thermal degradation. It can be seen that with increasing LLDPE content, the degradation temperature of EPDM rubber continuously increases with addition of LLDPE content up to 40 wt.%. Degradation temperature can be raised by nearly 36°C. It is considered to be an appreciable improvement of the thermal stability of the blend which depends on the type of atmosphere.

Scanning Electron Microscopy (SEM)

The properties of polymer blends are dependent on the proportion and properties of individual polymeric components and the mode of dispersion and also the interaction between the phases. It is essential for hi-tech performance behaviour of polymer blends that there should be homogeneity at microscopic level. It is worth to study the morphology of polymer blends to assess the compatibility behaviour and homogeneity of mixing. The scanning electron micrographs of the developed blends with various compositions are demonstrated in Fig. 5. (A-F). Fig. (A) shows the morphology of virgin EPDM. It is obvious from micrograph that there is no voids and cavities on the surface of EPDM. In the case of the blends having various compositions, it is evident from SEM micrograph that LLDPE is in dispersed phase and EPDM is in continuous phase. In the case of blends with high percentage of LLDPE content average particle size of the dispersed domains increases with increase in LLDPE content. The increase in domains size may be due to the increase in the proportion of the particular component. Fig. 5 (F), represent the morphology of EPDM/LLDPE (50/50) blend and it is evident from the micrograph that blend exhibits homogenous morphology. Co-continuous morphology increases the adhesion between the component polymers. It can also be seen at this composition the domains size of dispersed phase is decreased which in turn make the blend system compatible. The compatibility of the blends results in the improvement of mechanical and thermal properties. This can be explained on the basis of efficient interaction between component polymers in the blends due to smaller domains size.

Fourier Transform Infrared Spectroscopy (FTIR)

In Figure (6) the characteristic peak of EPDM at 2919 and 2850 cm^{-1} shows the presence of -CH group which become more defined and sharp on blending with LLDPE. Other peaks at 1461 cm^{-1} is assigned to -CH₂ rocking along with the bending peak present at 720 cm^{-1} . It is well observed that on addition of LLDPE in EPDM, the peak at 2360 cm^{-1} appears showing the presence of -CH₂ stretching group in LLDPE. Moreover the peak intensity increases with increase in LLDPE content.

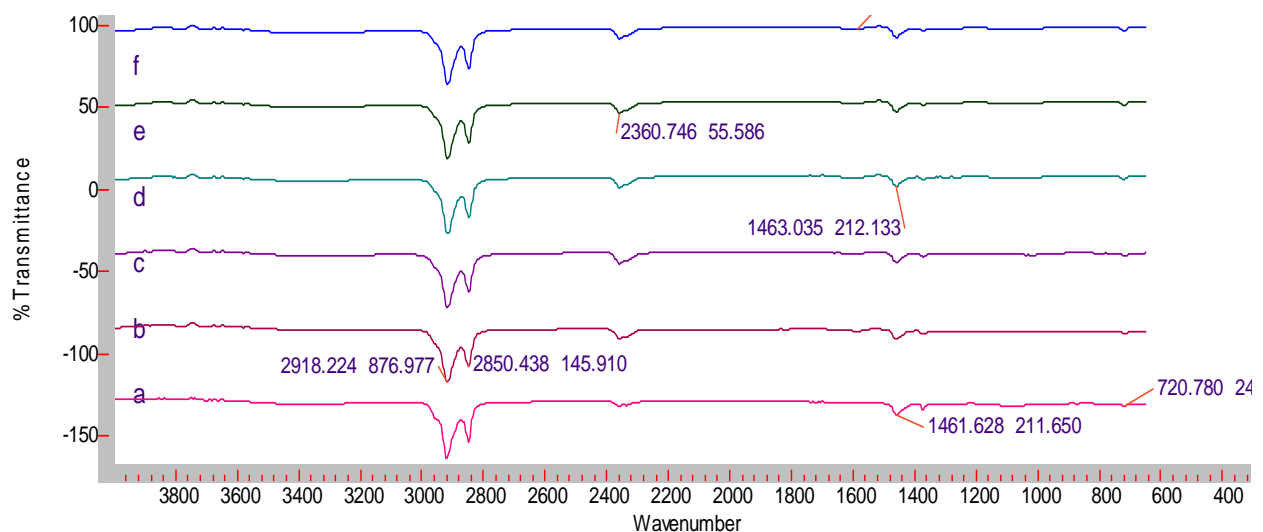


Fig. 6 FTIR Spectra of EPDM/LLDPE Blend with Different Loading of LLDPE Content

CONCLUSIONS

In this research work, the mechanical and thermal properties of EPDM/LLDPE blends are experimentally investigated. Mechanical properties such as tensile strength, hardness, and most importantly puncture resistance are increased with increases the LLDPE content in the blends. It is also observable that thermal stability, mechanical properties and puncture resistance are attained in EPDM/LLDPE (50/50) blend because of good interfacial adhesion.

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