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Effect of Resin Content in EPDM/Low-Density Polyethylene Blends on Their Mechanical Properties

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Abstract: Several formulations containing EPDM and LDPE were prepared. EPDM was blended with LDPE in different weight ratios of LDPE/EPDM (40/60, 30/70, 20/80, 10/90). These compounds were mixed at 150°C in open mill for 10 min at a speed of 19 rpm and then mixed with phenolic resin. Here, phenolic resin grade SP-1068 work as a tackifier resin. The result of mechanical measurement shows that mechanical properties such as tensile strength, modulus and elongation-at-break of blends can be enhanced with increase LDPE content in the formulation.

Key words – EPDM, LDPE, Phenolic resin sp-1068, Mechanical properties.

I. INTRODUCTION

Ethylene-propylene rubbers & elastomers (also called EPDM and EPM) continue to be one of the most widely used and fastest growing synthetic rubbers having both specialty and general-purpose applications. Sales have grown to 870 metric tons (or 1.9 billion pounds) in 2000 since commercial introduction in the early 1960's. Polymerization and catalyst technologies in use today provide the ability to design polymers to meet specific and demanding application and processing needs. Versatility in polymer design and performance has resulted in broad usage in automotive weather-stripping and seals, glass-run channel, radiator, garden and appliance hose, tubing, belts, electrical insulation, roofing membrane, rubber mechanical goods, plastic impact modification, thermoplastic Vulcanizate and motor oil additive applications. Ethylene-propylene rubbers are valuable for their excellent resistance to heat, oxidation, ozone and weather aging due to their stable, saturated polymer backbone structure. Properly pigmented black and non-black compounds are color stable. As non-polar elastomers, they have good electrical resistivity, as well as resistance to polar solvents, such as water, acids, alkalies, phosphate esters and many ketones and alcohols. Amorphous or low crystalline grades have excellent low temperature flexibility with glass transition points of about minus 60°C. Heat aging resistance up to 130°C can be obtained with properly selected sulfur acceleration systems and heat resistance at 160°C can be obtained with peroxide cured compounds. Compression set resistance is good, particularly at high temperatures, if sulfur donor or peroxide cure systems are used.

II. KEY FEATURES OF ETHYLENE-PROPYLENE ELASTOMERS

Vistalon 7001 EPDM rubber is a tailored MWD, high ethylene and medium diene polymer produced using Exxon Mobil Chemical's EXXPOL™ Technology for precise control of molecular composition and architecture. This product is sold in pellet form.

Key Features

Designed for good physical properties, improved mixing, mill handling and extrusion compared to typical narrow MWD grades.

Physical	Typical Value (English)	Typical Value (SI)	Test Based On
Mooney Viscosity (ML ₁₊₄ , 257°F (125°C))	60 MU	60 MU	ASTM D1646
Ethylene Content	73.0 wt%	73.0 wt%	ASTM D3900



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Ethylidene norbornene (ENB) Content	5.0 wt%	5.0 wt%	ASTM D6047
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Table 1:- specification for EPDM grade

III. LOW-DENSITY POLYETHYLENE

LDPE is defined by a density range of 0.910–0.940 g/cm³. It is not reactive at room temperatures, except by strong oxidizing agents, and some solvents cause swelling. It can withstand temperatures of 80 °C continuously and 95 °C for a short time. Made in translucent or opaque variations, it is quite flexible, and tough but breakable. LDPE has more branching (on about 2% of the carbon atoms) than HDPE, so its intermolecular forces (instantaneous-dipole induced-dipole attraction) are weaker, its tensile strength is lower, and its resilience is higher. Also, since its molecules are less tightly packed and less crystalline because of the side branches, its density is lower. LDPE contains the chemical elements carbon and hydrogen.

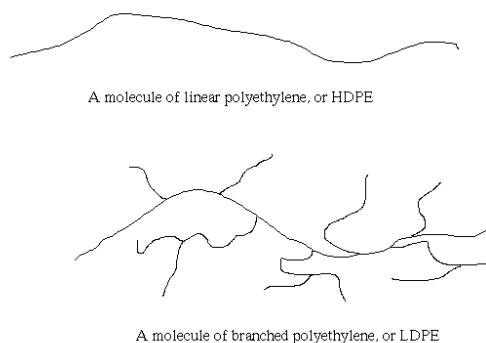


Fig 1. HDPE AND LDPE structure

Chemical resistance

- Excellent resistance (no attack) to dilute and concentrated acids, alcohols, bases and esters. Good resistance (minor attack) to aldehydes, ketones and vegetable oils. Limited resistance (moderate attack suitable for short-term use only) to aliphatic and aromatic hydrocarbons, mineral oils, and oxidizing agents. Poor resistance, and not recommended for use with Halogenated hydrocarbons.

A. Experimental study of the phase structure development

Formation of the phase structure at the initial stage of the mixing was intensively studied by Macosko's group. It was found that sheets of minor phase are formed after the start of mixing. Quite rapidly, holes are formed in these sheets that coalesce. Further, the sheets transform to fiber or co-continuous structures, which can pass (depending on blend composition and properties of the components) to a dispersed structure. If the softening or melting transition temperature of the minor phase is lower than that of the major phase, switching of phase continuity occurs at this stage of mixing. It was found that the reduction of characteristic size of phase domains from millimeters (characteristic size of polymer pellets) to micrometers is rapid. For application of polymer blends, type and fineness of their phase structure are important. In blends of immiscible polymers 1 and 2 with low content of 2, particles of component 2 are dispersed in the matrix of component 1. With rising fraction of 2, partially continuous structure of 2 appears. With further increase in the amount of 2, fully co-continuous structure is formed. After that, phase inversion occurs, where 2 forms the matrix and 1 the dispersed phase. Intervals of the blend composition related to individual types of the phase structure depend on rheological properties of the components, interfacial tension, and mixing conditions. Moreover, continuity of a component increases with its volume fraction only gradually. Several theories and empirical rules have been formulated for prediction the composition at which full or partial continuity of individual components appears. So far, no of them predicts conditions for continuity of the components quite satisfactorily.



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Fineness of the phase structure was studied mostly for blends with droplets in matrix morphology. As it is shown above, the droplet size is controlled by the competition between the droplet breakup and coalescence. Experimental studies of the droplet size should serve for verification of ability of various theories to describe the phase structure development in polymer blends at real mixing conditions. Further studies are focused on the investigation of time development of the droplet size for which adequate theory is not available so far, on the study of the phase structure development in ternary polymer blends, where the effect of the third component to the droplet size is not included in any theory and on the study of blends, where the phase structure development is complicated by changes of the components by chemical reactions, e.g. At chemical degradation of the components and dynamic vulcanization.

B. Effect of a Compatibilizer on the phase structure development

The presence of compatibilizers (block or graft copolymer, pre-made or formed in flow) at the interface has fundamental effect on the phase structure development in polymer blends. So far, no quantitative theory describing the effect of a compatibilizer on the type of the phase structure has been proposed. The effect of a compatibilizer on the size of dispersed droplets in a matrix can be predicted if the compatibilizer effect on the droplet breakup and coalescence and its distribution between the interface and bulk phases are known. The effect of copolymers on the droplet breakup and coalescence shares features with the related effect of surfactants in water-oil mixtures, broadly studied in the literature. The approach to the description of the both types of systems is similar but plausibility of various approximations and importance of various contributions to the effects can differ strongly due to the different molecular nature of the components and many orders difference in the values of rheological functions. Summary and discussion of the results of the studies of compatibilizer effects on the morphology of polymer blends can be found in. Analysis of the effect of a compatibilizer on the breakup and coalescence of droplets in flowing polymer blends is based on theories developed in the literature for low molecular weight emulsions containing a surfactant. The effect of a compatibilizer on the stepwise and transient breakup mechanisms is qualitatively different. For the stepwise mechanism, the presence of a compatibilizer causes a larger deformation and easier breakup of the droplet due to a decrease in interfacial tension. Inhomogeneous distribution of a compatibilizer on the interface due to its convection in flow supports and the dilution of a compatibilizer in the droplet deformation suppress the droplet breakup with respect to the neat system with the same equilibrium interfacial tension. Inhomogeneous distribution of a compatibilizer can also change a mode of the breakup, e.g. breakup into two halves to tip-streaming. Contributions of the individual effects are dependent on the rates of compatibilizer migration on the droplet surface and between the interface and bulk phases. In the transient mechanism, the presence of a compatibilizer causes an easier elongation of the droplet. It was showed that in description of the effect of a compatibilizer on the phase structure development in molten polymer blends, the following three processes must be considered:

1. A decrease in the interfacial tension,
2. The effect of a compatibilizer on the course of droplet breakup and coalescence, and
3. The effect of the competition between the droplet breakup and coalescence on the interfacial area.

The results of the theory show that the dependences of the average droplet size on the volume fraction of the dispersed phase are qualitatively different for cases where:

1. The ratio of the amounts of a copolymer and dispersed phase or
2. The total amount of the copolymer in the blend is a constant.

C. Variations of Polymer Blend Properties

The properties of polymer blends may vary depending on several contributing factors which are interdependent. Alger and Dyson (1990) list and summarize the factors as follow:

- I) Type of polymers;
- ii) Composition;
- iii) Compatibility; IV) Phase morphology;
- v) Method of blend preparation.

1 Type of Polymers

Elastomers or rubbers are polymers that may be deformed to quite large deformations and return to their original dimension once the stress is removed. In the absence of stress, elastomers are amorphous and contain molecular chains that are highly twisted, kinked, and coiled. Elastic deformation in elastomers represents partial



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uncoiling, untwisting and straightening of chains in the stress direction and the chains return to their original position once the stress is removed. Generally, elastomers possess the following characteristics:

- not easily crystallize;
- their chain bond rotations are relatively free in order for the coiled chains to readily respond to an applied force;
- And the onset of plastic deformation is delayed in order to experience a large elastic deformation.

2 Composition

The properties of polymer blends may vary depending on their compositions. The variations of properties are due to the changes in phase structure related to the composition. Variation in composition may affect phase morphology of polymer blends. For example, the polymer with higher concentration forms a continuous phase. In order to prevent phase separation and hence negatively affects the blend properties, the discontinuous phase of the other polymer blend constituent must have a small particle size.

3 Compatibility

Compatibility of polymer blends may refer to the ability of two or more polymers to exist in close and permanent association resulting in useful properties regardless of whether they are theoretically miscible or immiscible. Miscibility by itself is not the paramount criteria for utility. For instance, immiscibility is useful in the impact modification of relatively brittle polystyrene by rubber whereby energy absorption results from crazing of the polystyrene matrix in the region between the rubber particles.

4 Phase Morphology

Morphology is the order or arrangement of the polymer structure. The possible range of order between a molecule or molecule segment and its neighbors can vary from a very ordered highly crystalline polymer structure to the highly disordered amorphous structure as shown on the left side of Figure. The semi-crystalline polymer blends is formed by a combination of amorphous and crystalline structures as shown in the middle of the figure. It can be captured with an electron microscope.

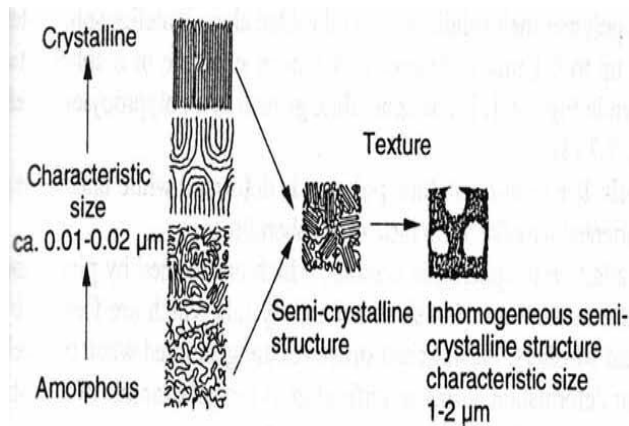


Fig:-2 Schematic diagram of possible molecular structure which normally occurs in thermoplastics

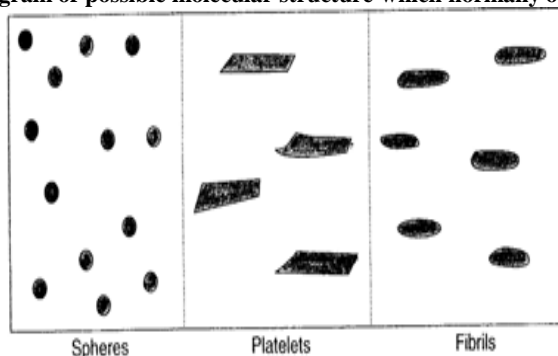


Fig:-3 Different morphologies exhibited by immiscible blends of polymers



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IV. Method of Blend Preparation

Polymer blends may be prepared by the following methods:

I) Mechanical blending;

ii) Dissolution in co-solvent then film casting, freeze or spray drying;

iii) Latex blending;

iv) Fine powders mixing;

v) Inter-penetrating polymer network technology. Due to economic reasons, the mechanical mixing predominates. The mechanical blending of polymers can be performed using a two-roll mill, internal mixer or extruder. In this research work, the blending process of LDPE/EPDM involves the use of a two roll mill.

V. EXPERIMENTAL STUDIES

Table: 2 Identification of materials

Material	Grade	Supplier
EPDM	Vistalon 7001	Exxon Chemical
LDPE	Reliance 24FS040	Reliance Petrochemical

Compound formula

Table:-3 Sample1. (EPDM:-60%, LDPE:-40%)

Ingredients	Weight ratio(gm)	Mixing time	Mixing temp.	Roll Spd.
Vistalon7001 EPDM	144	10 mins	150°C	19.03 rpm
LDPE	96			
Phenolic resin SP-1068	48			
Zno	12			

Table: 4 Sample2. EPDM:-70%, LDPE:-30%

Ingredients	Weight ratio(gm)	Mixing time	Mixing temp.	Roll Spd.
Vistalon 7001 EPDM	168	12 mins.	150°C	19.03 rpm
LDPE	72			
Phenolic resin SP-1068	48			
Zno	12			

Table: 5 Sample3. EPDM:-80%, LDPE:-20%

Ingredients	Weight ratio(gm)	Mixing time	Mixing temp.	Roll Spd.
Vistalon 7001 EPDM	192	15 mins	150°C	19.03 rpm
LDPE	48			
Phenolic resin SP-1068	48			
Zno	12			

Table:6 Sample4. EPDM:-90%, LDPE:-10%

Ingredients	Weight ratio(gm)	Mixing time	Mixing temp.	Roll Spd.
Vistalon 7001 EPDM	216	20 mins	150°C	19.03 rpm
LDPE	24			
Phenolic resin	48			



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SP-1068				
Zno	12			

Several formulations containing EPDM and LDPE were prepared (Table). EPDM was blended with LDPE in different weight ratios of LDPE/EPDM (40/60, 30/70, 20/80, 10/90). These compounds were mixed at 150°C in open mill for 10 min, 12min, 15min, and 20min at a speed of 19.03rpm and then mixed with phenolic resin and zno. The mixing machine open roll mill was heated to 150.c and kept constant before used .LDPE was first introduced into mixing mill. When it was totally melted, compatibilizer and rubber were added consecutively. The blend then was mixed within 10 mins to 20 mins which depend upon the types of formation and compression molded using at 150.c, in 12 mins into sheets approximately 1 mm thick with hot pressing equipment. Finally, the resulting sheet was cooled down quickly by cold water to ambient temperature.

VI. RESULTS AND DISCUSSION

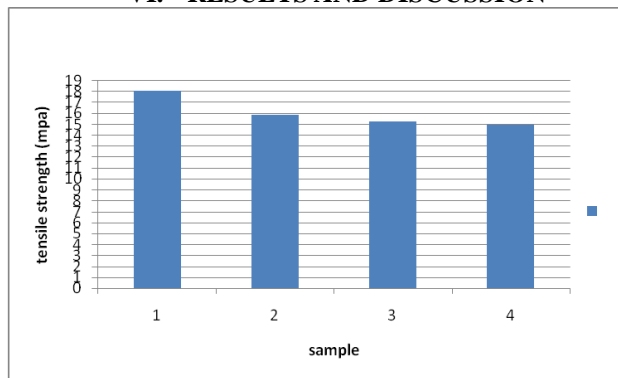


Fig:-4 Comparison of the tensile strength value for samples.

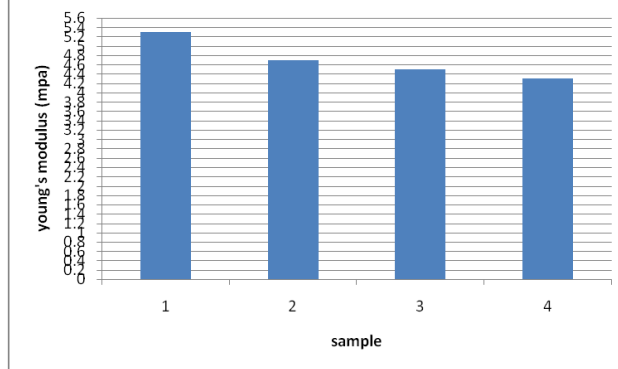


Fig:-5 Comparison of the young's modulus value for samples.

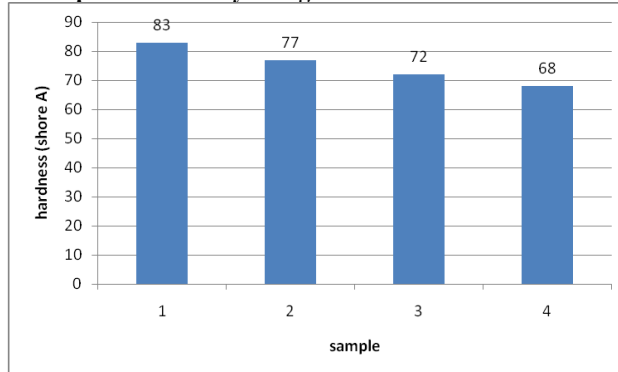


Fig:-6 comparison of the hardness value for samples.



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It can be seen from the result that SP 1068 resin was good compatibilizer in EPDM rubber. Dosage of LDPE increased then tensile strength and young modulus increased but percentage of resin also important for mechanical properties. Higher percentage of resin couldn't effect to properties. So nearly 2-2.5% resin added in polymer blends. Young's modulus were improved as increased the content of non reactive compatibilizer agent was increased. The rubber-rich blends can be used as thermoplastic elastomers and the plastic-rich blends can be used as rubber toughened plastics. Processing and final properties are dependent on the composition. Dosage of LDPE increased then hardness increased but percentage of resin also important for mechanical properties.

VII. CONCLUSION

Due to unsaturated bonds the extent of cross-linking in EPDM is much higher than LDPE in the presence of resin. The mechanical properties of cross-linked EPDM are weaker than LDPE. Therefore, changing the cross-link density of EPDM will not affect the blend properties significantly especially at high LDPE content. It can be observed that mechanical properties such as tensile strength, modulus and elongation-at-break increase with increasing LDPE content in the samples, implying that the phase of matrix governs the properties

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