



Impact Modification of Polyoxymethylene (POM)

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Abstract: Polyoxymethylene (POM) was blended with various weight percentages of ethylene propylene diene terpolymer (EPDM) and ethylene vinyl acetate copolymer (EVA) separately in a twin screw extruder under optimum conditions. The mechanical properties of the blends such as tensile strength, impact strength and % elongation were measured. Increasing content of EPDM and EVA up to 7.5% increases the impact strength of POM. Addition of elastomer beyond 7.5% decreases the impact strength due to the poor adhesion between plastic and elastomer phase. POM/EPDM blends compatibilised with EVA showed improved impact strength. The present study reveals that the impact strength of POM can be improved by blending with EPDM and EVA. The incorporation of EVA as compatibiliser into POM/EPDM causes significant improvement in impact strength. Scanning electron microscopy (SEM) reveals enhanced adhesion of POM and EPDM in the presence of EVA up to the extent 5 parts per hundred of resin (phr) resulting in improved dispersion of the elastomer in the plastic matrix.

Introduction

Polyoxymethylene (POM) conventionally called polyacetal is one of the major engineering thermoplastics because of its high strength, stiffness and excellent chemical resistance. However its poor impact resistance limits its range of applications. Generally toughening of such engineering resins is accomplished by blending them with small quantities of low modulus rubbers. In practice since most polymers are immiscible, during mixing it is necessary to introduce a third component called compatibiliser. If located at the interface between the two polymers it anchors the component phases together and effectively increases the interfacial adhesion. The process results in a blend with improved mechanical and impact properties. [1-5] Elastomer modified formulations are the most interesting developments in POM because the toughness of POM is markedly increased without a significant effect on typical POM properties. The present investigation aims at the development of impact modified POM by blending it with different elastomers like ethylene propylene diene terpolymer (EPDM) and ethylene vinyl acetate copolymer (EVA) and to study the effect of elastomer content on the mechanical properties. EVA is also used as a copolymer compatibiliser in POM/EPDM blends.

Results and Discussion

Mechanical Properties

The stress-strain properties of the POM/EPDM and POM/EVA blends depend on the composition. The tensile strength, % elongation at break and impact strength vary with composition.[6] The tensile strength and percentage elongation at break for the blends of POM/EPDM and POM/EVA as a function of blend composition are represented in Figure 1 and 2.

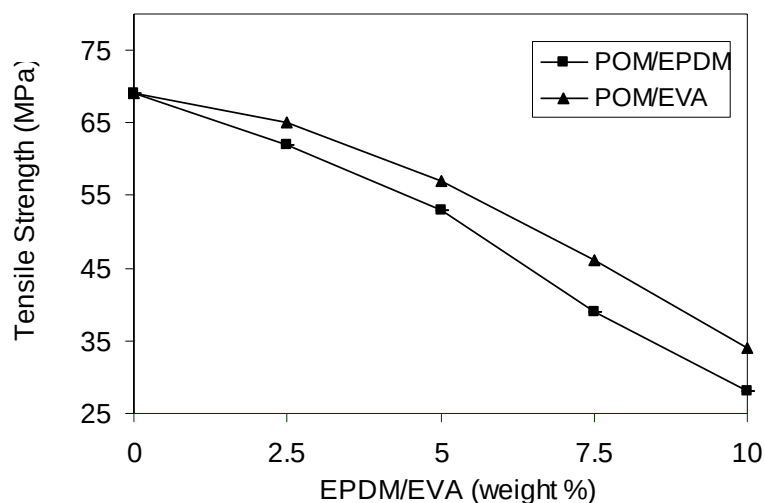


Fig. 1. Effect of blend composition on tensile strength.

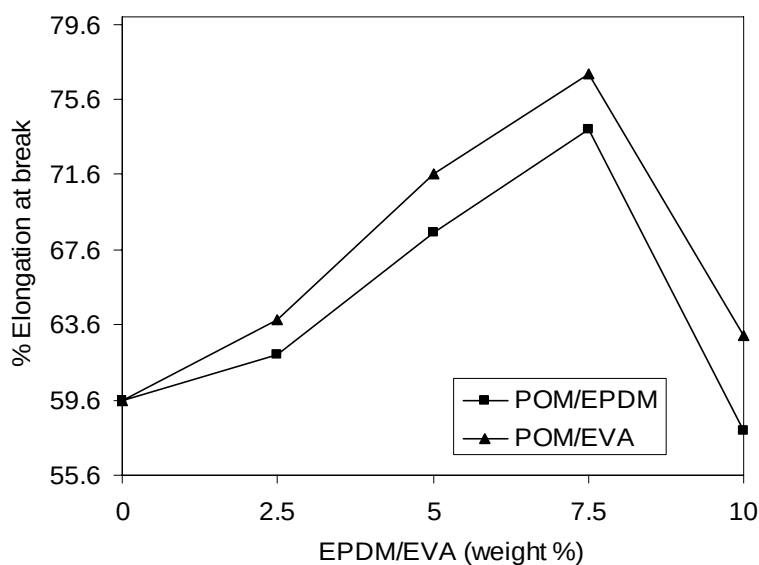


Fig. 2. Effect of blend Composition on % elongation at break.

It is observed that in both POM/EPDM and POM/EVA blends the tensile strength decreases with increasing elastomer content. This is due to the decrease in the degree of crystallinity with increasing content of elastomer.

The % elongation at break increases up to an elastomer content of 7.5% for POM/EPDM and POM/EVA blends. Addition of elastomer beyond this level drastically decreases the % elongation due to the poor compatibility of the component polymers with increasing elastomer content. [7]

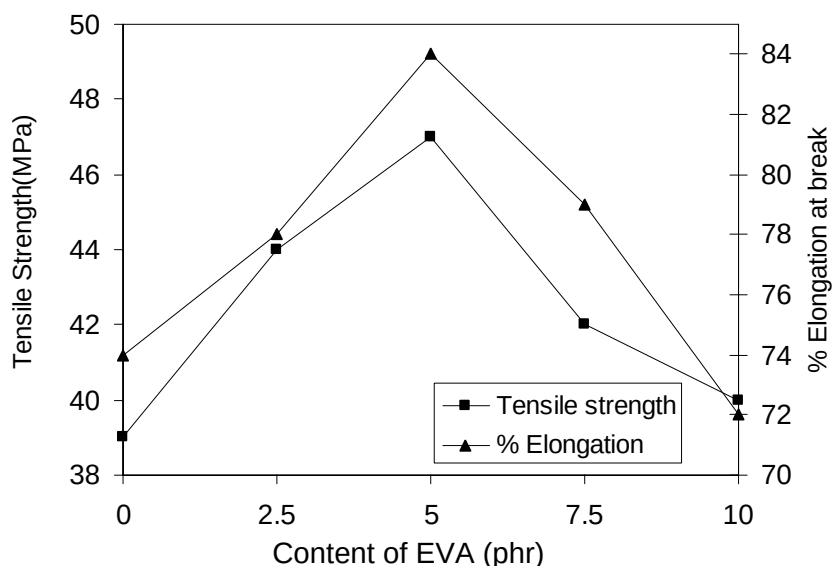


Fig. 3. Variation of tensile strength and % elongation of POM/EPDM blends containing different levels of EVA.

The effect of EVA as compatibilisers has been studied by incorporating various phr levels of EVA in POM/EPDM blend with 7.5% of EPDM. The values obtained for tensile strength and % elongation at break are presented in Figure 3.

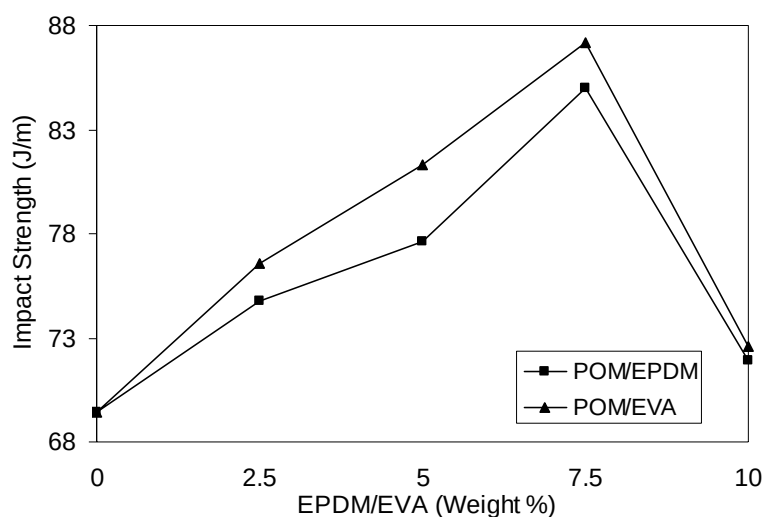


Fig. 4. Effect of blend composition on impact strength.

There is an increase in tensile strength and % elongation at break with the increasing content of EVA upto 5 phr. This shows that EVA acts as a polymer compatibiliser between POM and EPDM. A significant decrease in tensile strength and % elongation has been observed in blends containing EVA

content greater than 5 phr. This may be due to the coalescence of the elastomeric phase in the blend.

The notched izod impact strength for the blends of POM/EPDM and POM/EVA is presented in Figure 4.

The impact strength of POM increases with increasing elastomer content in both POM/EPDM and POM/EVA blends. In both the blends the elastomers are in the dispersed phase in POM matrix. A significant improvement in the impact strength is observed due to the increased energy absorption during impact. [8]

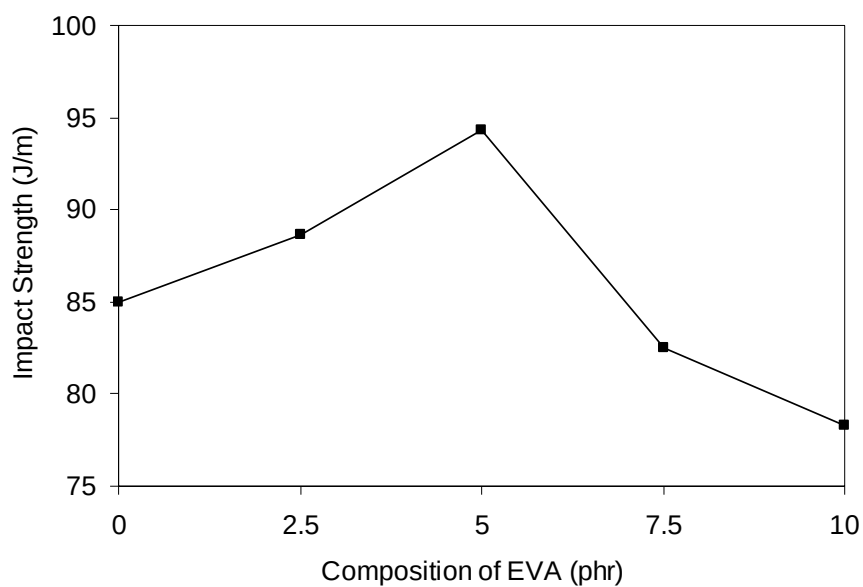


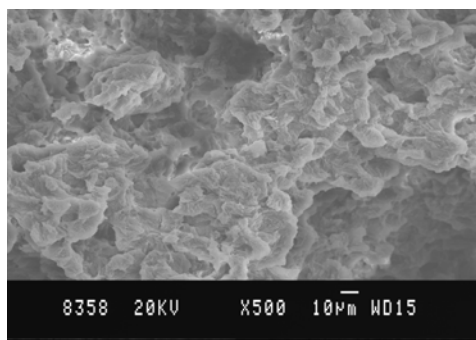
Fig. 5. Variation of impact strength of POM/EPDM blends containing different levels of EVA.

The blends containing elastomer content of 7.5 % show improved impact strength, the concentration of both EPDM and EVA beyond 7.5 % decreases the impact strength due to the reduced adhesion between the component polymers. To investigate the compatibilising effect of EVA on POM/EPDM blend, various phrs of EVA were added during the preparation of the blends. The impact strength was measured and presented in Figure 5. The incorporation of a small percentage of EVA greatly influences the impact strength of POM/EPDM blend. The impact strength of the blends increases with increasing content of EVA upto 5 phr. The results indicate that EVA acts as a compatibiliser between POM and EPDM. However, higher % of EVA (> 5phr) decreases the impact strength drastically because of the agglomeration of EPDM and EVA which reduces the homogeneity of the blend. [9-10]

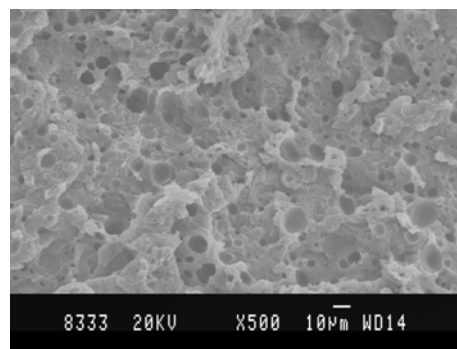
Scanning Electron Microscopy (SEM)

SEM micrograph is the most convenient approach to differentiate the morphologies between a compatibilised and uncompatibilised blend. An immiscible and incompatible blend results in coarser morphology than the corresponding compatibilised blend. In general the coarser morphology can be improved by the addition of a suitable compatibiliser. [11-14] The morphology of impact fractured samples of the compatibilised blends were examined in the entire range of composition and presented in Fig. 6 (a-e). In

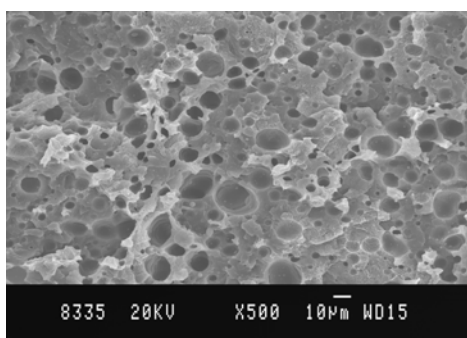
the case of compatibilised blends there exists a clear distinction between the POM matrix and elastomer phase. The holes indicating the elastomer phase have a wider distribution of particle size as their content increases. The size distribution becomes wide with increasing concentration of the dispersed phase due to coalescence effect in the case of PEPC_{7.5} and PEPC_{10.0} (indices denote EVA content in phr units). The bulk dimensions are dominating compared to the finer dimensions in these blends.



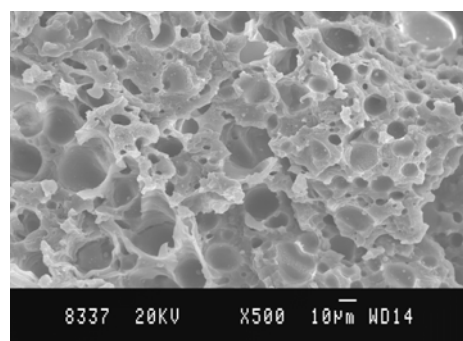
(a) PEP₀



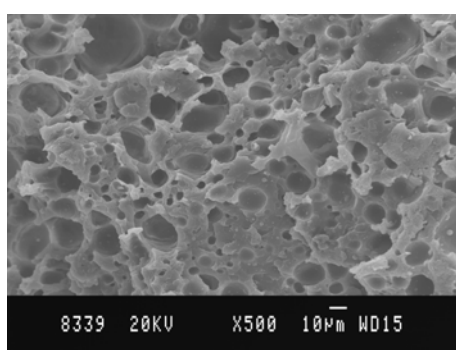
(b) PEPC_{2.5}



(c) PEPC_{5.0}



(d) PEPC_{7.5}



(e) PEPC_{10.0}

Fig. 6. SEM photographs of compatibilised POM/EPDM blends P: Polyacetal, EP:EPDM, C: Compatibiliser (EVA).

This fact is further supported by the decrease in mechanical strength. The incorporation of compatibiliser significantly reduces the size of the dispersed

phase and shows good interfacial adhesion up to a certain extent. There are more uniform and finer spherical particles of the dispersed phase in the blends containing 2.5 and 5.0phr of EVA. The particle size of the dispersed phase increases as a function of compatibiliser loading. The increase in domain size on addition of the third component indicates that EVA functions effectively as a compatibiliser up to 5phr in POM/EPDM blends. From the morphological characteristics it is inferred that EVA functions to reorganize the blend morphology and serves as an effective polymeric compatibiliser.

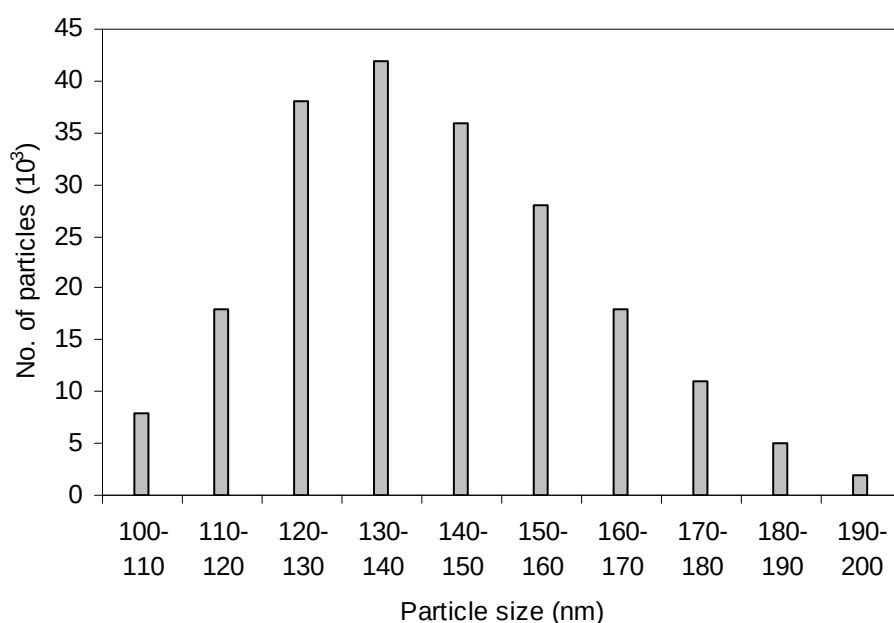


Fig. 7. Particle size distribution for PEPC_{2.5}.

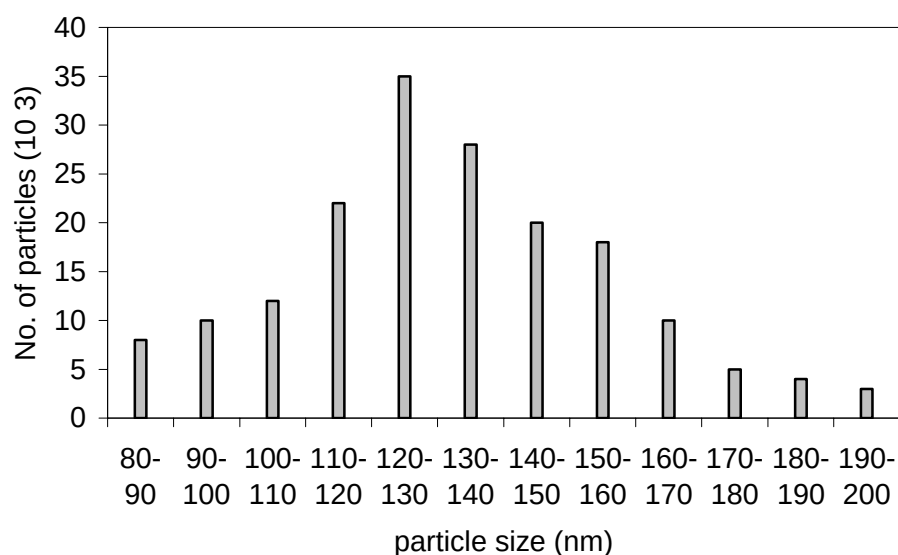


Fig. 8. Particle size distribution for PEPC_{5.0}.

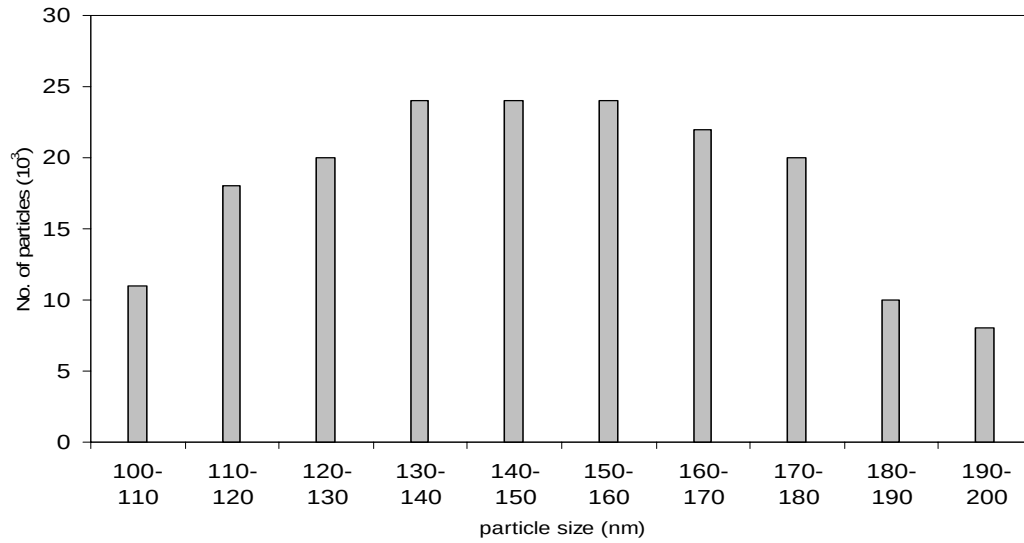


Fig. 9. Particle size distribution for PEPC_{7.5}.

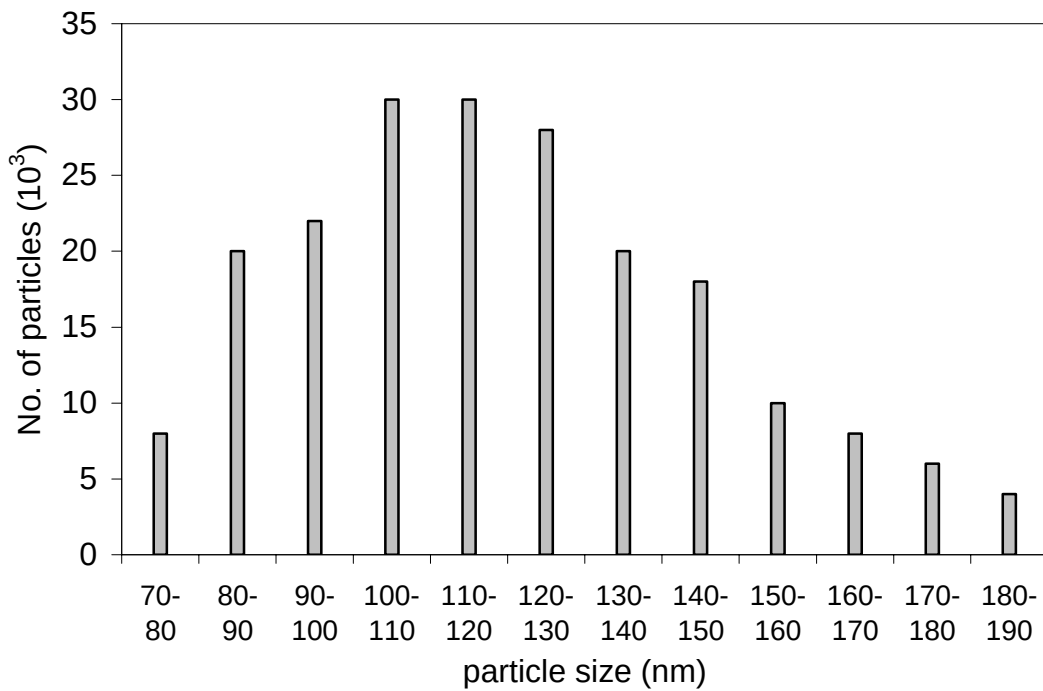


Fig. 10. Particle size distribution for PEPC₁₀.

From the above histograms (Figure 7-10), it is observed that the particle size distribution ranges from 70 to 200 nm. From Figure 8 and 9 it is inferred that the particles are uniformly distributed up to 170 nm. This gradual increase in the particle size is effective in bringing about increase in impact strength. The maximum number of particles 40×10^3 in the case of 2.5 phr compatibiliser content and 35×10^3 particles in the case of 5phr compatibiliser has size in the

range of 120-140 nm which is uniformly distributed to bring about effective changes in mechanical properties. In the case of higher loading of compatibiliser there is an agglomeration of particles and non-uniform particle size distribution is observed.

Conclusions

The mechanical properties of the blends of POM/EPDM, POM/EVA and POM/EPDM compatibilised with EVA have been studied. The % elongation at break of POM/EPDM and POM/EVA increases with increasing content of elastomer up to 7.5%; further addition of elastomer decreases the mechanical properties. POM/EVA blends possess improved mechanical properties when compared with POM/EPDM blends. Blending of POM with EPDM/EVA greatly improves the impact strength of POM. The incorporation of EVA as compatibiliser in POM/EPDM blends significantly improves the mechanical properties. This is supported by the improved interfacial adhesion and dispersion of the compatibiliser upto an extent of 5phr in POM/EPDM blends as revealed by the particle size distribution from SEM.

Experimental

Materials

Commercial homopolymer type polyacetal (POM) Delrin (Dupont) with melt flow index 24. Ethylene Propylene Diene Terpolymer (EPDM) Nordel IP NDR 3722 P (Dupont Dow Elastomer) having Mooney Viscosity ML_{1+4} at 125°C, 20 and Ethylene vinyl acetate Elvax 460 (Dupont) with melt index of 2.5 dg/min were used.

Preparation of Blends

POM was blended with various weight percentages of EPDM and EVA separately in a laboratory model co-rotating twin-screw extruder (Berstoff Model ZE 25) at 215°C at a screw rotation speed of 60 rpm. EVA is used as a polymer compatibiliser for the blends of POM/EPDM. Test specimens were prepared by injection moulding.

Characterization of Blends

Tensile properties were measured according to ASTM D 638 test method using Shimadzu Universal Testing Machine. The thickness of the test specimen was 0.3 ± 0.02 cm. The cross-head load was 500 kg at a speed of 5cm/min. Notched Izod impact strength was measured according to the ASTM D256 test method. The thickness of the test specimen was 0.3 ± 0.02 cm and the energy of the hammer was 60 kg-cm. Scanning electron microscope (JOEL JSM840A) was employed to study and record the fracture surface of all the blend samples. The fractured impact bars were immersed in xylene for 24 hours for preferential etching of the rubber phase. The fractured surfaces were then sputtered with gold in vacuum and surface characteristics were studied.

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