

Rheological Behavior and Processability of Polypropylene Blends with Rubber Ethylene Propylene Diene Terpolymer

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ABSTRACT: A study of the dynamic complex and steady shear viscosity of isotactic polypropylene (iPP), ethylene-propylene diene terpolymer rubber (EPDM) and three different blends of both polymers are presented over a range of temperatures and frequencies. Moreover, the processability of these materials is studied through torque measurements during blend mixing. The results obtained show that the viscosity gradually increases with rubber content in the blend and decreases with both temperature and frequency. Plots of η'' versus η' (Cole–Cole plots) show that the blend with the lower rubber content (25%), has a certain rheological compatibility with neat PP. Furthermore, torque curves measured during blend mixing confirm these results, demonstrating that the blend with 25% of elastomer has a similar behavior of iPP during processing. To analyze the morphological structure of the blends, a dynamic mechanical analysis of the solid state is also presented. It is observed that the blends have two distinct values of T_g close to the corresponding values of the pure polymers, confirming that this type of blends based on a semicrystalline polymer and an amorphous elastomer forms a two-phase system with a limited degree of miscibility between both components. In addition, the polymer present with the higher concentration forms the continuous phase and controls the rheological properties of the blend. © 2001 John Wiley & Sons, Inc. *J Appl Polym Sci* 81: 1–10, 2001

Key words: PP; rubber; rheology; dynamic mechanical properties; blend

INTRODUCTION

Taking advantage of their well-balanced physical and mechanical properties and easy processability at a relatively low cost, polyolefins such as polypropylene (PP) are the thermoplastics of higher consumption. However, in some cases, not all the characteristics of this material are suitable for product specifications. For instance, its rela-

tively high glass transition temperature and crystallinity limit the applications of PP at low temperatures. Thus, the flexibility and properties of PP at low temperatures^{1,2} need to be improved, for example, with the addition of impact modifiers. Among the impact modifiers commonly used for PP, ethylene-propylene–diene terpolymer rubber (EPDM) has been considered the most effective one.^{3–5} These blends, commonly referred to as TPOs (polyolefins thermoplastic elastomers), are a special class of TPE that combine the processing characteristics of plastics at elevated temperatures^{6–8} with the physical properties of conventional elastomers at service temperatures.^{9,10} The similarity of the chemical structure of these polymers, together with their

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Table I Characteristics of Materials Studied

	iPP	EPDM
Manufactured	Montell	Bayer
Designation	C 30 G	Buna EPT 6470 P
Density (g/cm ³)	0.905	0.86
Mooney viscosity	—	55 ± 5
Melt index (g/10 min)		
230°C	6	—
Hardness (Shore A)	—	68.7

different physical properties, makes it possible to combine them to produce materials of designed properties. However, to assess and optimize the processability of these materials the rheological behavior must be characterized and controlled.

The present study is part of a series of investigations that objective is a complete characterization of the blends between PP and EPDM in the whole range of compositions. Previous studies^{11–13} carried out in our laboratories have been focused on the determination of the morphology, mechanical properties, crystallization kinetics, and thermal degradation of these materials. The main goal of this study is to evaluate the processability and flow properties of thermoplastic elastomers based on blends of polypropylene and ethylene–propylene–diene terpolymer rubber, and to relate the effect of the composition of the blends on their physical characteristics. The methodology adopted includes a complete rheological study in dynamic and steady shear conditions and the determination of the optimum conditions of processing (temperature, velocity, pressure, time, etc.) by torque analysis during blend mixing.

EXPERIMENTAL

Materials and Blends Preparation

Commercially available grades of polypropylene (iPP) generously supplied by Montell, and ethylene–propylene–diene terpolymer rubber (EPDM) with 5-ethylidene-2-norborene (ENB) as a termonomer, were used in this work. The material specifications are listed in Table I. Melt-blended samples with different compositions were prepared in a Haake Rheomix 90 internal mixer, equipped with a pair of high shear roller-type rotors, at a temperature of 190°C, above the melting point of the polymeric matrix. The blending time was 10 min, and the rotor rate was set at 60

rpm. Immediately after the completion of mixing, the blends were compression molded at 200°C. From the molded plaques, samples were cut and tested. Five different formulations were analyzed in this work: pure PP, pure EPDM, and three different PP–EPDM blends: 75–25%, 50–50%, and 25–75%.

Measurements

Torque vs. time curves were obtained during the processing of the as-received polymers and their blends in the internal mixer. The rheological properties measurements were performed using a Rheometric Scientific ARES N2 with a parallel plate geometry. Tests were carried out in steady rate and dynamic frequency modes at four temperatures: 190, 210, 230, and 250°C. The steady rate tests were realized in a range of rate of 0.1 to 100 s⁻¹. Dynamic shear properties were determined as a function of angular speed of deformation 0.1 to 500 rad/s. For all experiments, the strain amplitude was maintained constant at 5%.

Dynamic mechanical properties of solid samples were determined by means of stress–strain oscillation measurements using a dynamic mechanical thermoanalyzer Rheometric Scientific ARES N2. Tests were carried out at a frequency of 5 Hz, and the temperature programs were run from –150 to 50°C under a controlled sinusoidal strain at a heating rate of 2°C/min in a flow of nitrogen. The oscillating dynamic strains amount to 0.15%. The viscoelastic properties, the storage modulus (G'), loss modulus (G''), and the mechanical loss factor (damping), $\tan \delta = G''/G'$ were recorded as a function of temperature.

RHEOLOGICAL MODELS

Typical rheological models, able to predict the shape of the general flow curve of a polymer, are represented by equations that need at least four parameters. One of such a model is the Cross equation,¹⁴ given by:

$$\frac{\eta - \eta_{\infty}}{\eta_0 - \eta_{\infty}} = \frac{1}{(1 + (K\dot{\gamma})^m)} \quad (1)$$

or, what is equivalent

$$\frac{\eta_0 - \eta}{\eta - \eta_{\infty}} = (K\dot{\gamma})^m \quad (2)$$

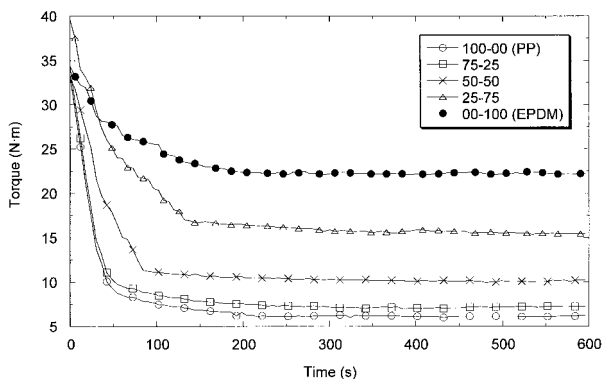


Figure 1 Torque curves for mixing of PP, EPDM, and PP-EPDM blends.

where η_0 and η_∞ refer to the asymptotic values of viscosity at very low and very high shear rates, respectively; K is a constant parameter with the dimension of time; and m is a dimensionless constant.

A popular alternative to the Cross model is the model due to Carreau¹⁵:

$$\frac{\eta - \eta_\infty}{\eta_0 - \eta_\infty} = \frac{1}{(1 + (K_1 \dot{\gamma})^2)^{m_1/2}} \quad (3)$$

where K_1 and m_1 have a similar signification to the K and m of the Cross model. For $\eta \ll \eta_0$ and $\eta \gg \eta_\infty$, the Cross model reduces to:

$$\eta = \frac{\eta_0}{(K \dot{\gamma})^m} \quad (4)$$

which, with a simple redefinition of parameters, can be written:

$$\eta = K_2 \dot{\gamma}^{n-1} \quad (5)$$

This is the well-known “power-law” model and n is called the power-law index and K_2 is called the consistency. This two-parameter model is the most used rheological equation for polymers, but must be used very carefully, in reduced shear rate intervals, as it can introduce a very high inaccuracy in rheological results out of the measurement range. Moreover, these rheological models are able to represent only viscosity changes due to shear thinning, while cannot take into account other effects like elastic behavior, thermal and stress degradation, phase segregation, or melt rupture.

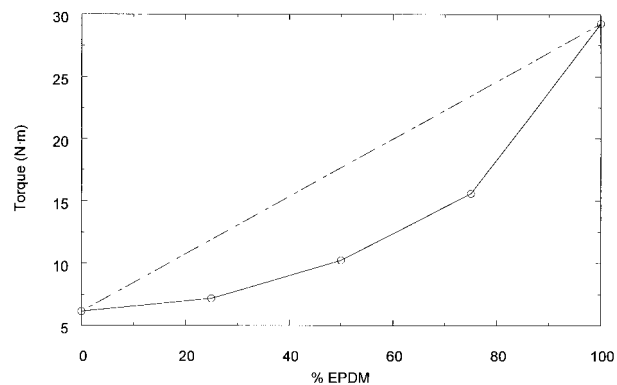


Figure 2 Torque as a function of rubber content measured during blend mixing.

RESULTS AND DISCUSSION

Torque vs. Time Analysis

The torque applied during blend mixing was registered, and the data obtained for the five materials prepared are presented, as a function of time, in Figure 1. The curves show a typical profile with three different stages. From Figure 1 results it is evident the influence of rubber content in the torque required for blend mixing. These results are clearly observed in Figure 2, where the torque is represented as a function of the EPDM content in the blend. The form of the curve suggests a direct relationship with the viscosity of the blend, which should present a negative deviation from the additive rule. This behavior will be analyzed in the next section of this work. On the other hand, it is possible to correlate torque data to viscosity of non-Newtonian materials at the temperature and shear rate involved. Torque values in the plateau region, obtained af-

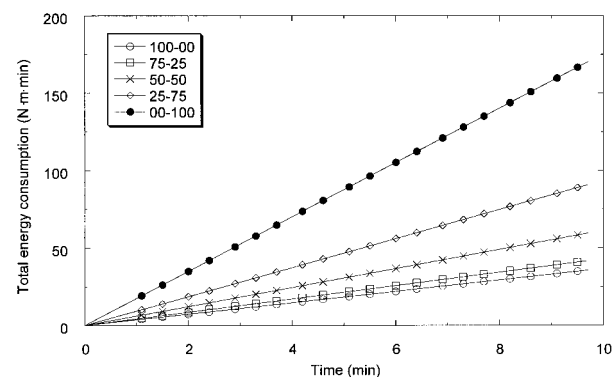


Figure 3 Total torque curves for PP, EPDM, and PP-EPDM blends.

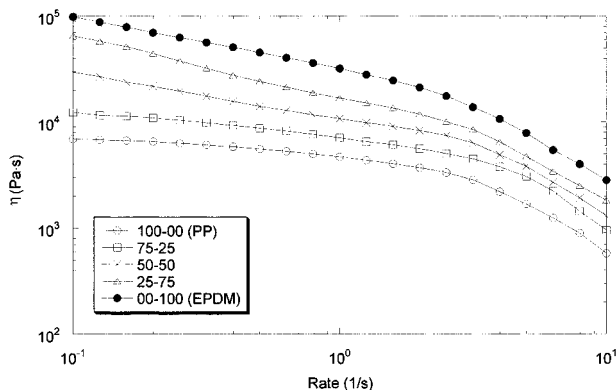


Figure 4 Variation of melt apparent viscosity with the shear rate for blends tested at 190°C.

ter stabilization in all cases, characterize the viscous nature of the melt. It can be easily appreciated that the torque increases with the EPDM content in the blend due to the higher viscosity of the rubbery component. However, this increment is nonlinear, and the experimental values are lower than those predicted by the linear additive rule of ideal blends, which is represented by the straight line shown in the Figure 1. This nonlinear behavior can be associated to the incompatibility of PP–EPDM blends. In fact, negative viscosity deviations have been observed for immiscible blends with high value of the interaction parameter as well as for systems approaching the phase separation.¹⁶ A drop in viscosity has also been related to a change in morphology¹⁷ or to an interlayer slip.¹⁸ On the other hand, it is also important to notice that there is not a sensible increase of torque for the PP–EPDM blend with a rubber content of 25% in comparison with the neat PP. Then, it would be possible to take advantage of the eventual better properties without deterioration of the processing behavior.

The area under the torque vs. time curves, reported in Figure 1, gives the total energy con-

sumption during blend processing. The results obtained are reported in Figure 3 as a function of the blend composition. As expected, the energy consumed increases with the EPDM content in the blend. However, at relatively low percentages (25%) of rubber in the blend, the energy consumption is similar to that of PP, which confirms the reported advantage in terms of processability. These results seem to indicate that up to an elastomer content of 25%, the blends can be processed with the same processing methodology used for polypropylene.

Rheological Study

Steady Shear Tests

Melt viscosity, η , results as a function of shear rate, $\dot{\gamma}$, at 190°C are shown in Figure 4, for PP, EPDM, and their blends at various blending ratios. It can be observed that the viscosity of the studied materials decreases with the shear rate and increases gradually with rubber content in the blend. Thus, at $\dot{\gamma} = 1 \text{ s}^{-1}$, the viscosity value goes from 4712 Pa·s for PP to 32,163 Pa·s for EPDM. From Figure 4 results, it is possible to calculate the power-law index (n) and the consistency (K_2) for all the samples, which values are reported in Table II at different temperatures. The power-law parameters were computed from the straight-line portion of the rheological curve, with K_2 and n related to the intercept and slope of the curve. From Table II results it can be observed that, in general, n increases with the temperature for all the samples and decreases with the elastomer content in the blend, which indicates that the blends present less Newtonian behavior than pure PP. Furthermore, K_2 decreases with the temperature for all the samples and increases with the incorporation of rubber in the blend.

Table II Power-Law Model Parameters of the Materials Studied

PP–EPDM (%)	190°C		210°C		230°C		250°C	
	n	K_2	n	K_2	n	K_2	n	K_2
100–00	0.63	4760	0.74	2900	0.74	1912	0.79	1683
75–25	0.64	7855	0.62	6221	0.66	3855	0.69	2649
50–50	0.61	10,824	0.67	7603	0.68	4654	0.70	4268
25–75	0.49	16,990	0.48	12,554	0.50	9519	0.51	7335
00–100	0.41	32,233	0.44	25,858	0.45	20,211	0.47	14,558

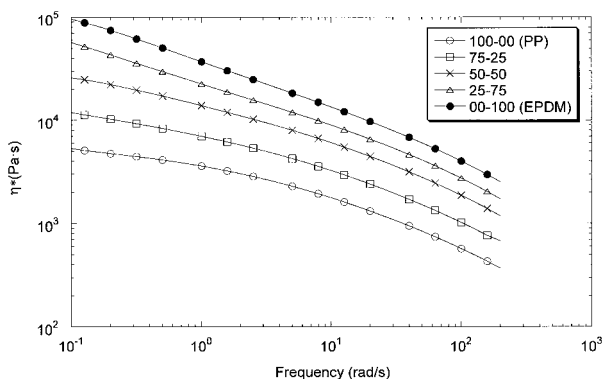


Figure 5 Variation of complex viscosity with angular frequency at 190°C in linear scale.

Dynamic Shear Tests

The variation of complex viscosity (η^*) as a function of the angular frequency in logarithmic and linear form is represented in Figures 5 and 6, respectively. From these results, it can be observed that the rheological properties are strongly dependent on both the composition and the morphology of the blends. Thus, the complex viscosity of all the materials decreases with the angular frequency and increases with rubber content in the blend, as can be observed in Figure 7, being these effects are more evident at lower angular frequencies. The effects of the blend composition are also reported in Table III where the reduced viscosity of the blends computed taking as reference base the viscosity of PP, is reported at different temperatures. The negative deviation of the viscosity as a function of the blend composition resembles the torque results reported in Figure 2, and follows the arguments discussed there.

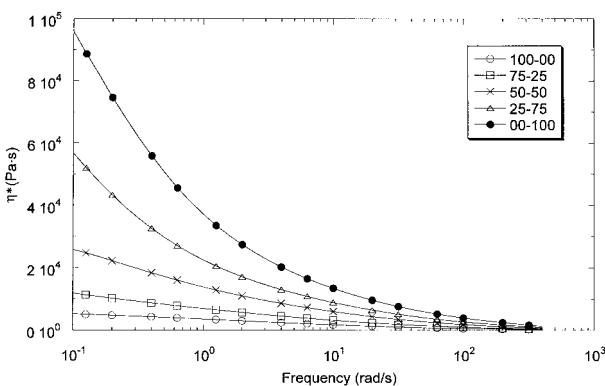


Figure 6 Variation of complex viscosity with angular frequency at 190°C in log scale.

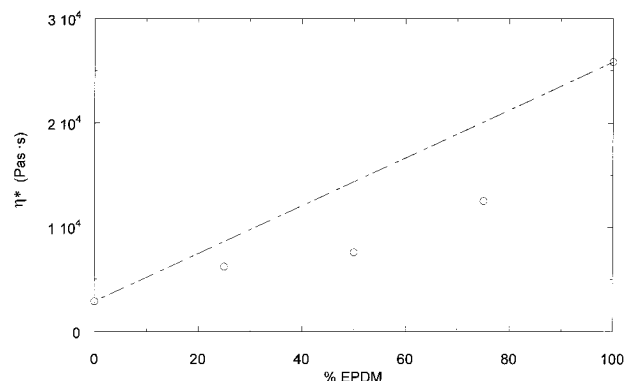


Figure 7 Variation of complex viscosity as a function of rubber content at 210°C.

The morphology of these materials can be easily deduced from Figure 6, where the complex viscosity is represented as a function of the angular frequency. It can be observed that at low elastomer content (25%), the blend confirms its similar rheological behavior compared to pure PP. At this composition, the elastomer forms particles dispersed in the PP matrix and the rheological properties are mainly controlled by the polymeric matrix. However, the incorporation of the rubber increases the viscosity of the material with an increment of the elastic modulus.

On the other hand, at higher EPDM content in the blend (75%), the elastomeric phase forms the continuous phase and the rheological properties are close to the neat elastomer. In this case, PP particles are dispersed in an EPDM matrix and the rheological properties are controlled by the elastomer. The PP phase decreases the viscosity and the elastic modulus of the rubber. In the intermediate zone (25–75%), the blend is characterized by rheological properties different from both pure components. At these percentages, PP and EPDM form a cocontinuous phase; thus, at low frequencies the properties are controlled by

Table III Viscosity Properties of PP-EPDM Blends at Different Temperatures

PP-EPDM (%)	$\eta_{\text{Blend}}^*/\eta_{\text{PP}}^*$ (1 rad/s)			
	190°C	210°C	230°C	250°C
75-25	1.9	1.8	1.5	1.6
50-50	3.9	4.1	5.3	4.9
25-75	6.3	8.6	11.4	11.9
00-100	12.3	17.1	21.2	17.8

the PP phase, while at higher frequencies, the rheological properties are similar to those of the elastomer with a higher storage modulus and viscosity.

This complex rheological behavior can be explained in terms of a limited degree of miscibility of polypropylene and the elastomer in the molten state. Thus, a two-phase system is observed, in which the continuous phase is formed by the polymer with higher concentration. These results are in agreement with the microstructure analyzed by scanning electron microscopy (SEM) and reported in a previous study,¹¹ where a two-phases system was clearly observed (Fig. 8).

Relation between Steady Rate and Dynamic Properties

To analyze the relation between the steady shear and dynamic complex viscosity data, η^* vs. ω and η vs. $\dot{\gamma}$ can be superimposed, and the results are graphically represented in Figure 9. It is possible to deduce the exact relationships in the lower limits of frequency and shear rate¹⁹:

$$\eta'(\omega)|_{\omega \rightarrow 0} = \eta(\dot{\gamma})|_{\dot{\gamma} \rightarrow 0} \quad (6)$$

$$\left. \frac{G'}{\omega^2} \right|_{\omega \rightarrow 0} = \left. \frac{N_1(\dot{\gamma})}{2\dot{\gamma}^2} \right|_{\dot{\gamma} \rightarrow 0} = \left. \frac{\psi_1(\dot{\gamma})}{2} \right|_{\dot{\gamma} \rightarrow 0} \quad (7)$$

The former relationship states that the viscosity measured in oscillatory shear in the zero-frequency limit is equal to the low shear viscosity measured in steady shear. Equation (7) is a relationship between the limiting values of dynamic rigidity and first normal stress difference. An empirical relationship between η and η' has been

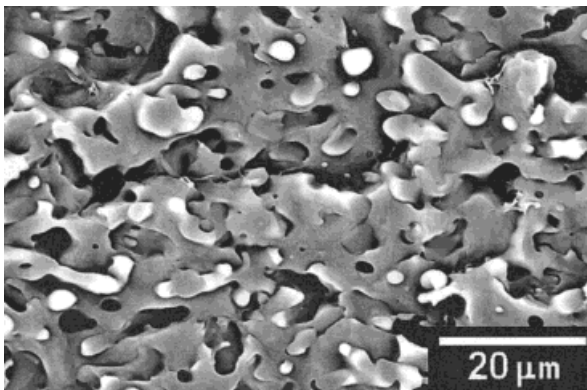


Figure 8 Fracture surface of PP-EPDM (50-50) blend.

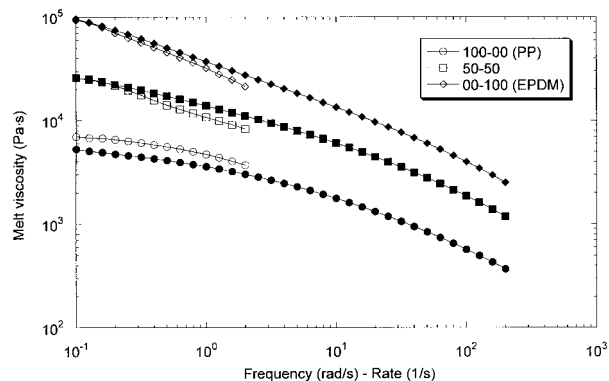


Figure 9 Relation of $\eta - \dot{\gamma}$ and $\eta^* - \omega$ for pure PP and EPDM and blend (50-50) at 250°C.

developed by Cox-Merz²⁰ for polystyrene, and has been observed to be generally applicable to flexible chain polymers. The Cox-Merz rule proposes that the steady shear viscosity, η , computed at $\dot{\gamma}$ coincides with the value of the modulus of the complex viscosity, $|\eta^*|$, computed at $\omega = \dot{\gamma}$:

$$\eta(\dot{\gamma}) = |\eta^*(\omega)| \quad \text{where } |\eta^*| = [(\eta')^2 + (G''/\omega)^2]^{1/2} \quad (8)$$

The Cox-Merz rule is generally applied in the shear thinning interval, far from the lower limits of shear rate and frequency. In addition, such a superposition can be justified by Bueche's theory,²¹ stating that a macromolecule can be approximated as rotating inside an envelope at an angular velocity of half the shear rate ($\eta = \eta^*$ when $\dot{\gamma} = 2\omega$). From the results obtained in Figure 9, it is possible to conclude that the Cox-Merz rule can be applied to the blends studied here. A slight difference was obtained for pure PP; however, as the temperature increases, the melt elasticity decreases because of a favoring molecular relaxation at higher temperatures and in consequence a better agreement between η_{app} and η^* occurs, as can be observed in Figure 10.

Study of the Compatibility of Blend Components

It is well known that the complex viscosity takes into account the viscous and the elastic components characteristics of a viscoelastic fluid through the following relation:

$$\eta^* = \eta' - i\eta'' \quad (9)$$

where η' is the in-phase elastic component and η'' is the out-of-phase viscous component of the dy-

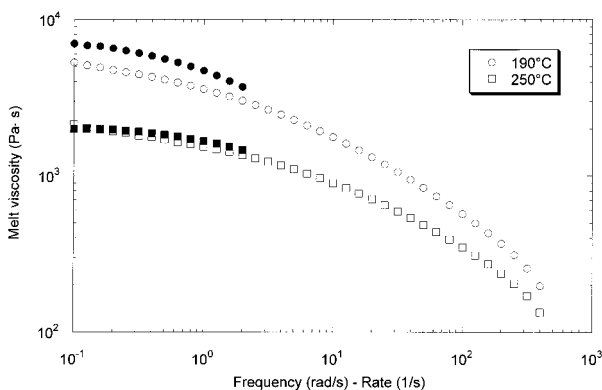


Figure 10 Cox–Merz rule for PP at 190 and 250°C.

dynamic complex viscosity. Moreover, these components are related to the energy stored and the oscillatory frequency by the equation:

$$\eta' = G''/\omega, \quad \eta'' = G'/\omega \quad (10)$$

where G' is the storage modulus (elastic component) and G'' is the loss modulus (viscous component). In addition, ω is the testing frequency. It is also well known that the representation of the dynamic shear data in Cole–Cole plots (η' vs. η'' , see Fig. 11) gives information about the relaxation processes occurring in a multiphase system. This type of representations can be also used to predict the compatibility of polymer blends. It is assumed that when a blend is compatible, a single curve is obtained in this type of plots, independent of the composition of the blend.²² From the results reported in Figure 11, a single curve can be observed for compositions with low content of rubber (0–25%), while at higher elastomer compositions different curves are appreciated, indi-

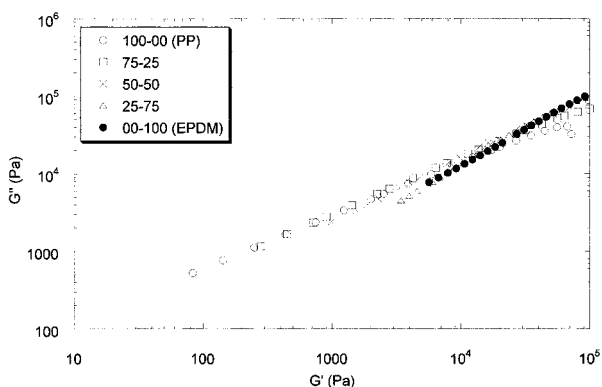


Figure 11 Cole–Cole plot.

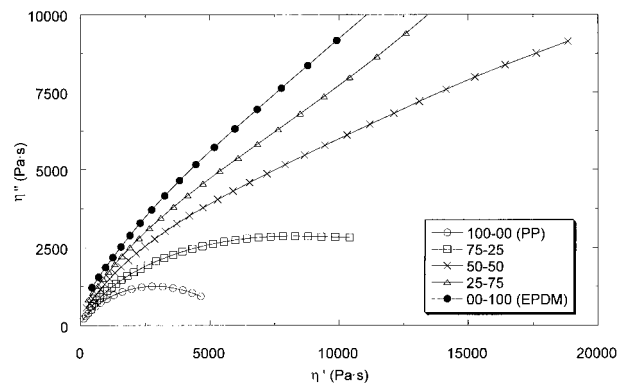


Figure 12 Computation of the zero shear rate viscosity from the Cole–Cole plot.

ating that the system presents a good compatibility only at low rubber content in the blend.

The Cole–Cole representations can be also used to determine the rheological parameters, such as the zero shear rate viscosity, η_0 , and the principal relaxation time, τ (Fig. 12). Zero shear is calculated by fitting the Cole–Cole representation and extrapolating to the x -axis (η' at $\eta'' = 0$),^{23–26} whereas the relaxation time is given by the inverse of the frequency at which the maximum occurs. These parameters can be equally calculated by the Utracki equation²⁷:

$$\eta' = \eta_0 [1 + (\omega\tau)^{m_1}]^{-m_2} \quad (11)$$

where η_0 is the zero shear rate viscosity, τ is the principal relaxation time and m_1 , m_2 are exponents. These parameters have been calculated for pure PP and the PP–EPDM blend (75–25) and the results at two different temperatures are reported in Table IV. The same approach could not be applied to the other blends with a higher rubber content due to the fact that a maximum in the Cole–Cole plot was not obtained, and then it was not possible to obtain a good model fitting. The values obtained for pure PP and the PP–EPDM blend can be compared to those obtained from the flow curve in the steady shear rate test as can be observed in Figure 13. It can be observed that, as expected, the zero shear rate viscosity increases with the incorporation of the elastomer in a similar form that the observed results of η' at all frequencies and of η obtained in steady shear rate tests, whereas a decrease is observed with the temperature.

Calculation of the Activation Energy

The temperature dependence of the viscosity can be described in the range of temperature investi-

Table IV Rheological Parameters of PP-EPDM Blends at 190 and 250°C

PP-EPDM (%)	Cole-Cole Plot				Flow Curve (Static Test)	
	$T = 190^\circ\text{C}$		$T = 250^\circ\text{C}$		$T = 190^\circ\text{C}$	$T = 250^\circ\text{C}$
	η_0 (Pa-s)	τ (ms)	η_0 (Pa-s)	τ (ms)	η_0 (Pa-s)	η_0 (Pa-s)
100-00	5933	631	2049	199	7000	2125
75-25	17,277	2511	4916	1000	18,000	4800
50-50					43,000	19,200
25-75					87,000	43,500
00-100					105,000	54,500

gated by the Arrhenius equation²⁸ and related to the activation energy, E_a , necessary for chains movement:

$$\eta = A \exp(\Delta E_a/RT) \quad (12)$$

where ΔE_a is the activation energy, R is the universal gas constant, T is the test temperature, and A is the preexponential constant. According to this equation, the representation of $\ln(\eta)$ vs. $1/T$ (Fig. 14) should give straight lines whose slope is proportional to the activation energy ΔE_a . The results obtained at different angular frequencies are shown in Table V. The E_a values obtained are in concordance with those presented in the literature for this kind of systems.^{29,30} In general, it can be observed that the activation energy of the material studied decreases as the angular frequency used is increased. Furthermore, a complex and not very clear tendency with the elastomer content in the blend can be observed. Although the activation energy of the rubber is clearly lower than that of PP, a maximum of the

activation energy is always obtained for the blend with 25% of rubber content indicating a higher sensibility of this system to temperature changes during processing.

Dynamic Mechanical Analysis of Solid Blends

The dynamic mechanical properties of PP, EPDM, and their blends at different compositions were studied over a wide temperature range (-100 to 50°C). Figures 15 and 16 show the storage modulus, G' , and the mechanical loss factor, $\tan \delta$, respectively, for the materials studied. The first decrease of G' curve corresponds to the glass rubber transition (α -relaxation) of the amorphous EPDM component. The loss-peak maximum is assigned to the glass temperature, T_g , of the rubbery phase detected at -32°C . At higher temperatures another significant decrease in the G' curve is observed at the glass transition (β -relaxation) of the amorphous regions of the PP component. The loss-peak is assigned to the glass transition temperature of PP detected approximately at 9°C . All the blends show two loss peaks, corre-

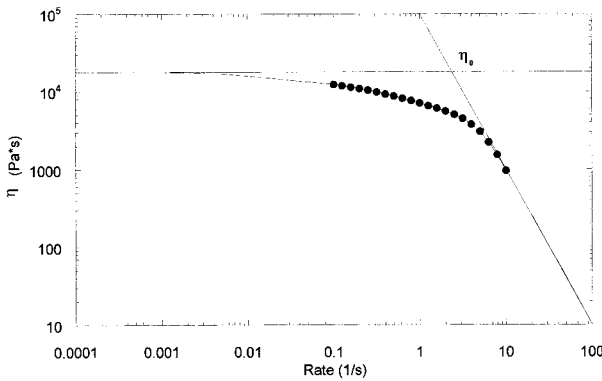


Figure 13 Computation of the zero shear rate viscosity from steady shear viscosity curves.

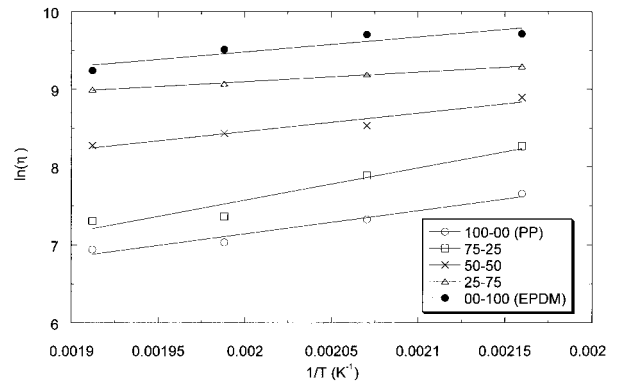


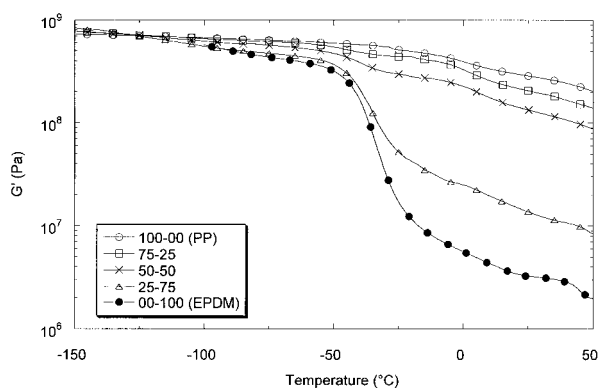
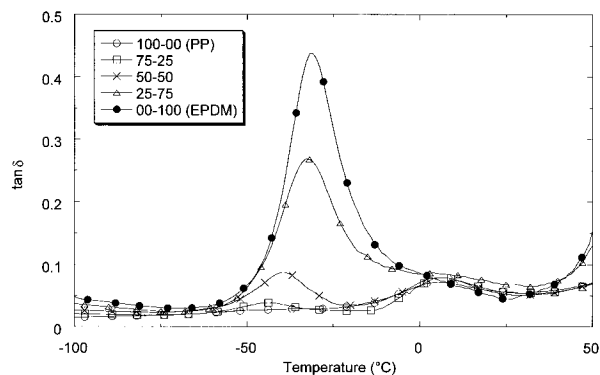
Figure 14 Computation of the activation energy.

Table V Flow Activation Energies of PP-EPDM Blends at Different Angular Frequencies

PP-EPDM (%)	E_a (KJ/mol)			
	0.1 Hz	1 Hz	10 Hz	50 Hz
100-00	30.5	24.7	18.5	14.3
75-25	39.1	34.5	27.6	21.9
50-50	19.4	19.8	15.9	11.9
25-75	6.3	10.3	8.7	5.3
00-100	10.1	16.0	17.2	14.6

sponding to those of their constituents, revealing the immiscibility of the blend at all the compositions studied. However, it can be observed that an increase of PP content in the blend gradually reduces the intensity and magnitude of the EPDM α -peak, and also a displacement of the peak to lower temperatures is observed (from -32 to -44°C). Moreover, as expected, an increase of EPDM content in the blend gives rise to a decrease of the degree of crystallinity, which is reflected in an increase of the mechanical loss factor, $\tan \delta$. On the other hand, the PP β -peak undergoes a little variation, shifting to lower temperatures, with the incorporation of the rubber and the increase of the amorphous phase in the blend. The results obtained by DMA are reported in Table VI.

This behavior was explained by Da Silva et al.,³¹ where a comparative study between polymer blends based on PP and two polyolefin elastomers was analyzed, considering that the elastomer has a higher thermal expansion coefficient than the PP matrix. Then, the cooling of the blend gives rise to a negative hydrostatic pressure that

**Figure 15** Variation of the storage modulus with the temperature for PP, EPDM, and PP-EPDM blends.**Figure 16** Variation of $\tan \delta$ with the temperature for PP, EPDM, and PP-EPDM blend.

acts on the elastomeric particles, and thus the thermal tensions that are generated can be responsible for the decrease of the EPDM phase glass transition temperature. Furthermore, the two transition peaks presented by the blends are similar to those of the pure homopolymers, confirming the formation of a two-phase system with a very limited degree of miscibility of the components, in which the polymer in higher quantity forms the continuous phase. These results are in concordance with the results previously obtained by the analysis of the rheological properties in the molten state, suggesting no further changes in the blend composition during solidification.

CONCLUSIONS

The processing behavior, rheological, and dynamic mechanical properties of blends of PP-EPDM in the whole range of compositions have been analyzed in the present work. A general processing behavior similar to that of PP was observed for blends with low content of EPDM (25%), indicating that the same industrial thermoplastic molding processes used for neat PP can be adopted with evident economic advantages. In particular, the blend with 25% of EPDM showed practically the same energy consumption during mixing as neat PP, indicating that no extra processing costs are expected for this material.

It has also been demonstrated that the blends between a semicrystalline polymer as polypropylene and a rubbery elastomer, ethylene-propylene-diene terpolymer rubber present a very limited degree of miscibility. These blends are not compatible to the degree where molecular mixtures (i.e., true solutions) are generated. The com-

Table VI Dynamic Mechanical Properties of PP-EPDM Blends Studied

PP-EPDM (%)	EPDM Phase			PP Phase		
	T_g (°C)	Tan δ	G' (Pa)	T_g (°C)	Tan δ	G' (Pa)
100-00	—	—	—	8.9	0.070	3.57E+08
75-25	-43.9	0.039	5.12E+08	8.1	0.079	2.71E+08
50-50	-40.1	0.087	3.88E+08	5.9	0.079	1.96E+08
25-75	-33.1	0.268	1.15E+08	4.0	0.087	2.67E+07
00-100	-30.0	0.504	5.24E+07	—	—	—

patibility, however, is sufficient to produce multiphase blends on the micron scale. They are mechanical blends with a two-phase system at processing and service temperatures, where the continuous phase is formed by the polymer present in a higher quantity. No further changes are introduced during blend solidification. In this manner, the properties are only dependent on the relative proportion of each component in the final blend.

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