

# Impact Modification of Polypropylene Copolymer with a Polyolefinic Elastomer

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**ABSTRACT:** Polypropylene copolymer (PP-cp) has a large number of applications and is preferred over the homopolymer due to its higher impact strength. These impact properties can be further improved by blending with polyolefinic elastomer (POE). Blends were prepared by using commercially available POE (Engage® EG 8150, Dupont–Dow Elastomers), by varying POE content up to 25%. The effect of processing conditions on the properties of the blends was studied. Although impact strength increased, flexural modulus decreased. Dicumyl peroxide caused chain scission of PP-cp rather than crosslinking of POE. The results seem to indicate that there may be optimum concentration of POE around 10% for the polymers used in the present work. The grade of PP-cp used in this work contained about 10–11% ethylene content (rubber phase around 17–18%). These results match with general observations that brittle–tough transition for PP occurs when total elastomer content is about 20–25%. © 2000 John Wiley & Sons, Inc. *J Appl Polym Sci* 76: 1480–1484, 2000

**Key words:** polypropylene copolymer; blends; impact modification; polyolefinic elastomers (POEs)

## INTRODUCTION

Polypropylene (PP) as well as polypropylene copolymer (PP-cp) are used very widely in a number of applications (e.g., in furniture and the automobile industry). The higher impact strength of PP-cp makes it a better choice over homopolymer PP for such applications. The impact properties of any thermoplastic material can be improved either by chemical modification or by blending with an elastomeric impact modifier.<sup>1</sup> Various aspects of impact modification of PP have been reviewed by Martuscelli.<sup>2</sup> Impact improvement by chemical modification is not always feasible. Most of the literature, therefore, pertains to blending the given polymer with an appropriate elastomer. Improving the impact properties of different thermo-

plastic materials has been discussed by a number of researchers.<sup>3–10</sup> It is known that the size of the dispersed elastomeric phase influences the impact properties of the matrix phase.

There is a large amount of data on the properties of blends of PP with elastomers such as ethylene propylene diene monomer rubber (EPDM) or ethylene propylene rubber (EPR).<sup>11–17</sup> Although the addition of rubber phases improves impact properties, the stiffness of the matrix seems to decrease. Use of fillers, to compensate for this effect of the elastomer, has been studied and reported by Long and Shanks.<sup>11</sup> The effect of processing conditions on the dispersion of the rubber phase and the resulting properties of the blends of PP have been studied by a number of researchers.<sup>16–19</sup> Use of mild crosslinking of rubber to improve the tenacity has also been reported.<sup>10</sup>

Although sufficient information exists on blends of PP, there are hardly any data on the

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**Table I Different Compositions of Blends Prepared**

Blend No.	PP-cp (wt %)	Engage® EG 8150 (wt %)	DCP (ppm)
1	95	5	—
2	92.5	7.5	—
3	92.5	7.5	500
4	90	10	—
5	90	10	500
6	85	15	—
7	75	25	—

properties of blends of PP-cp with elastomers. Engage®, a copolymer of ethylene and 1-octene, is a commercially available polyolefinic elastomer (POE). The effectiveness of this material in toughening of PP has been reported by Da Silva.<sup>20</sup> He also compared the toughening of PP due to the addition of another rubber, EPDM. The presence of the ethylene phase in PP-cp may improve the compatibility of POE, Engage®, with PP-cp. Therefore, the POE, Engage®, could be more suitable for PP-cp as compared to PP, because PP and polyethylene are not compatible. There are no such data on the blends of Engage® and PP-cp. The present work, therefore, looks at properties of such blends.

## EXPERIMENTAL

### Materials

Commercial grades of PP-cp, CO15EG (Reliance Industries Limited, India), and Engage®, the polyolefinic elastomer (POE) EG 8150 (Dupont–Dow Elastomers), were used in the present work. The melt flow index (MFI) of these two polymers were 1.61 and 1.0 g/10 min at 230°C and 2.16-kg load, respectively. Dicumyl peroxide (DCP) was procured locally.

### Blending

The required amounts of the two polymers were dry-blended initially and then compounded by using a Haake Rheomix TW 100, a counterrotating twin-screw extruder. The temperature profile was: Zone I: 120°C; Zone II: 150°C; Zone III: 190°C; and Zone IV: 210°C.

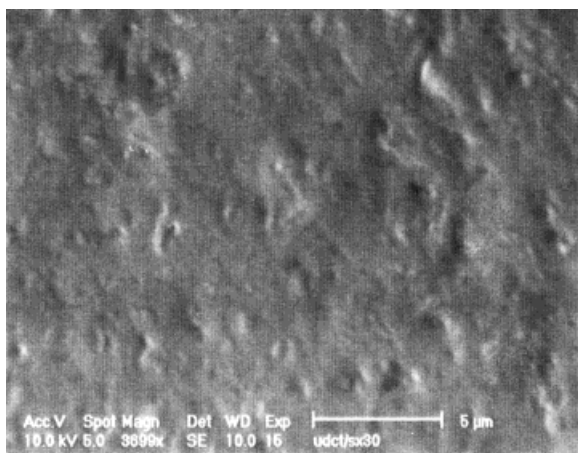
Initially, two blend compositions, namely 5 and 10% of POE, were compounded by using 30 and 60 rpm for each composition. The remaining blends were prepared at 60 rpm because the properties of blends compounded at 60 rpm were better.

The effect of adding DCP for possible crosslinking of POE was studied. For this, the required quantity of DCP, PP-cp, and POE were mixed together and blended. Two blend compositions containing 7.5 and 10% POE were studied for such effects. Table I shows the composition of all

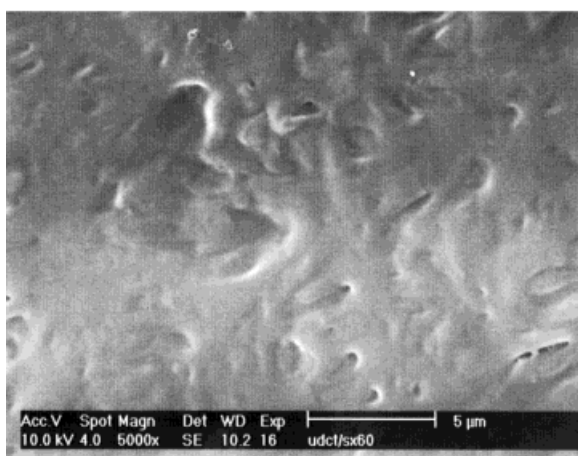
**Table II Mechanical Properties of PP–Engage Blends of Different Compositions**

% Engage	Max. Load (N)	E.M.L. (mm)	E.B. (%)	T.S. (MPa)	F.M. (MPa)	F.S. (MPa)	I.I.S. (kgcm/cm)
0	345.0	1.7	232.4	30.6	630.9	21.1	13.37
5 @ 30 rpm	304.9	5.8	343.7	24.3	427.6	18.3	33.88
5 @ 60 rpm	305.8	5.7	355.9	23.7	533.6	18.5	37.04
10 @ 30 rpm	289.5	6.8	408.1	22.6	491.6	15.8	53.06
10 @ 60 rpm	313.7	7.5	651.8	23.7	436.7	15.2	63.16
7.5 @ 60 rpm	311.8	6.6	598.4	22.3	513.1	19.4	48.04
7.5 with 500 ppm of DCP @ 60 rpm	347.0	5.6	637.5	26.8	489.4	18.8	20.4
10 with 500 ppm of DCP @ 60 rpm	332.9	7.2	780.0	26.1	307.9	15.5	24.48
15 @ 60 rpm	311.1	11.0	456.9	25.2	326.5	15.3	82.60 (not broken fully)
25 @ 60 rpm	282.0	11.3	339.8	20.8	190.7	9.2	Not broken

E.M.L., elongation at maximum load; T.S., tensile strength; F.M., flexural modulus; E.B., elongation at break; F.S., flexural strength; I.I.S., notched Izod impact strength.



(a)



(b)

**Figure 1** SEM photographs of blend containing 10% POE compounded at (a) 30 and (b) 60 rpm.

the blends studied.

### Testing

The extrudate strand was pelletized and then injection-molded samples were prepared by using a Windsor injection molding machine, SP 30. The test specimens pertained to ASTM standards [dumbbell-shaped samples for tensile test (ASTM D638M-91) and notched Izod impact strength (ASTM 256) and rectangular bar for flexural strength (ASTM 790M-92) specimens]. The temperature of injection-molding barrel was kept at 210°C, injection pressure at 100 kg/cm<sup>2</sup>, and mold temperature was between 35–40°C. The mechanical (tensile and flexural) properties were determined by using a Lloyd LR 50K tensile testing machine. The crosshead jaw speed was 50 mm/

min for tensile and 2.8 mm/min for flexural measurements and a load cell of 500N capacity was used. The elongation of samples were measured with laser extensometer Lloyd Laserscan 200.

The notched-impact strength was measured by using an Avery Denison impact tester. A 15-J striker was used and the striking velocity was 3.46 m/s. All results were the average of at least 10 measurements.

Phase morphology was studied by using scanning electron microscope (Philips XL 30) for cryo-fractured samples.

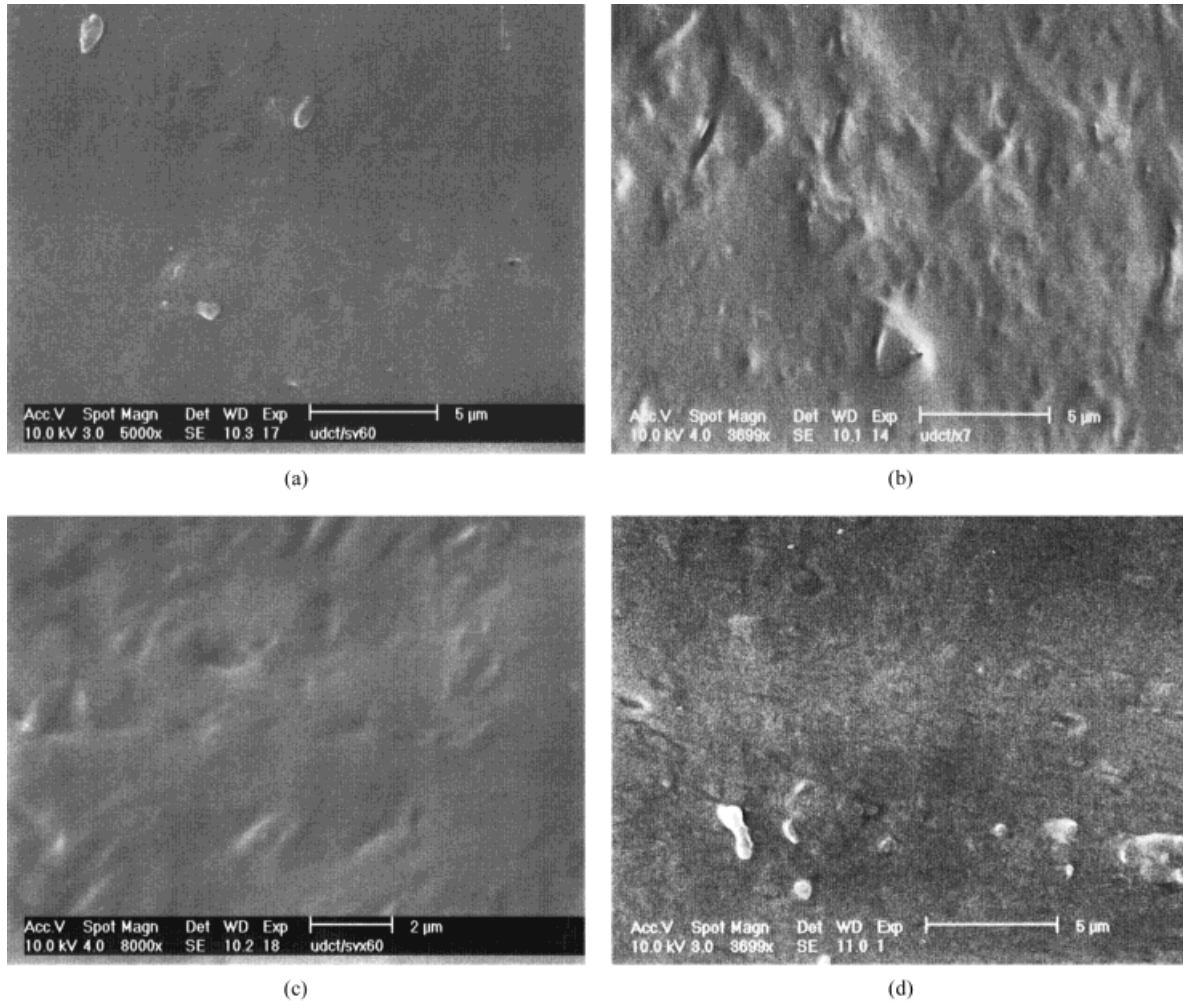
## RESULTS AND DISCUSSION

### Mechanical Properties

Table II shows the variation of mechanical properties of different blends. The blends containing 5 and 10% POE, compounded at 60 rpm, seem to show better impact strength, percentage elongation, and maximum load, as compared to the samples compounded at 30 rpm. Similarly, by increasing the amount of POE from 5 to 10%, the impact properties improved. Therefore, properties of other compositions blended at 60 rpm were studied. The tensile strength, although slightly less than that of virgin PP-cp, remained unaffected for all blends. At 25% of POE, however, the tensile strength decreased considerably. The maximum load values also were relatively unaffected for all compositions except 25% concentration. These results indicate that blends containing 25% or more of POE will not have very attractive properties.

Although Izod impact strength increased because of the incorporation of POE, the flexural modulus decreased steadily with increase in POE content. The results presented in Table II seem to show that tensile strength, flexural strength, and flexural modulus decreased as compared to those for virgin PP-cp only marginally until a POE content of about 15%. Although impact properties improved steadily, the percentage elongation was maximum for the blend containing 10% POE, indicating some sort of optimum concentration level of POE for the given grade of PP-cp.

It is well known that a brittle–tough transition for PP takes place when the elastomer content is about 20–25%. The PP-cp already contains some amount of rubber phase. The grade used in the present work contained 10–11% ethylene. Thus, total elastomer content of the system will be around 20–25%. The transition observed in the



**Figure 2** SEM photographs of blends containing (a) 5, (b) 7.5, (c) 15, and (d) 25% POE compounded at 60 rpm.

present work for POE concentration of about 10–15% would depend on the ethylene content of PP-cp.

#### Effect of DCP on Mechanical Properties

The effect of DCP is known to crosslink polyethylenes while it may also induce chain scission of PP-cp. If the dispersed POE phase gets crosslinked preferentially over the chain scission of PP-cp, then the use of DCP may improve the impact property further, especially the modulus. A slight reduction of molecular weight of PP-cp through chain scission may also help better dispersion of POE. The addition of DCP may also induce formation of graft copolymer of the matrix and dispersed components.<sup>13,17</sup> The data shown in Table II, however, indicate that when a small

amount of DCP was incorporated, the izod impact strength decreased, whereas the percentage elongation at break increased somewhat. The flexural modulus of blends containing DCP was less as compared to those without DCP at equal concentrations (7.5 and 10% of POE). These results indicate that chain scission of PP-cp to be predominant over the crosslinking of POE. Thus, incorporation of DCP right in the initial stages of compounding was not effective in improving the flexural and impact properties.

The effectiveness of DCP would really depend on the opportunity it may have to interact with POE. Therefore, adding DCP separately after the melt-blending of PP-cp and POE can also yield expected results. Perhaps incorporating an extra amount of antioxidant additive in PP-cp phase or

altering the DCP adding time and processing conditions may be worthwhile to study for possible crosslinking of POE phase.

### Morphology

Figure 1 shows the phase morphology for blends containing 10% POE blended at 30 and 60 rpm. The blend at 30 rpm showed spherical particles of a diameter of about 1  $\mu\text{m}$ . However, the blend at 60 rpm showed elongated particles. The dispersion seems to be much finer for this blend prepared at 60 rpm.

Figure 2 shows the effect of concentration of POE. No phase separation seems to be evident for any concentration, although a slight phase separation may be seen for 25% POE concentration. The dispersed phase seems to be in elongated form for blends containing more than 10% POE. The particle size of the dispersed phase appears to be comparable for 5 or 10% POE blend. For a blend containing 15% POE, the particle size seems to have increased somewhat, as compared to that at lower concentrations of POE. Perhaps some agglomeration may have taken place. For the blend containing 25% POE, a tendency to form co-continuous morphology is quite obvious.

The change in percentage elongation may be due to this phase morphology. The substantial increase in the impact strength for higher POE content can be explained on the basis of morphology.

### CONCLUSIONS

The present study shows that the impact properties of PP-cp can be enhanced to a large extent by incorporating Engage®, the POE, in the PP-cp matrix. The processing conditions seem to play an important role in the resulting blend properties. For a blend containing 10% POE, higher shear field generated much finer dispersion of the minor component. When the POE content increased from 10 to 15%, the domain size of dispersed

phase seemed to be higher, although still finely dispersed.

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