FRACTURE BEHAVIOR OF POLYPROPYLENE/ELASTOMER BLENDS

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1 Introduction

Polypropylene (PP) is a versatile commodity plastic with one of the largest global consumption per annum because of its low cost and other attractive properties. However, its application as a structural material is somewhat limited because of its relatively moderate fracture performance, especially at sub ambient temperatures. The impact toughness of PP can be improved by the addition of elastomers. Nonetheless, this toughness upgrade is achieved at the cost of stiffness and strength characteristics, since the incorporation of elastomers into PP leads to a reduction in the modulus and yield stress. Therefore, issues concerned with the simultaneous reinforcing and toughening of PP have attracted considerable attention. One way is vulcanizing the rubbery content. Dynamically vulcanized blends consist typically of a finely dispersed chemically crosslinked elastomer phase in a melt processable thermoplastic matrix.

Recently, the essential work of fracture approach (EWF) has been used increasingly to characterize the low rate fracture toughness of ductile polymers and their blends. However, no much research has involved blends of thermoplastic and elastomers, when the rubbery phase is vulcanized.

In this paper, effort has been undertaken to study in detail the fracture behavior of thermoplastic/elastomer (PP/SBS) dynamically vulcanized blends by analyzing the EWF test results.

2 Experimental

2.1 Materials and Specimens

Isotactic Polypropylene (PP) J-300 having a melt-flow index (MFI) of 7 dg/min (230 °C/2160 g) was supplied by *Propilven S.A.* Styrene-Butadiene-Styrene copolymer (SBS) SOLPRENE with a density of 0.94 g/cm^3 , a melt flow index of 6.4 dg/min (200 °C/5000 g) and a styrene content of 30 % was supplied by *INSA.*

Dynamically vulcanized PP/SBS blends were prepared with concentrations of SBS of 15, 30 and 40 %wt. Compounding was performed using a *Berstorff ECS 2E25* co-rotating twin-screw extruder at a temperature profile of 210 °C and a screw speed of 50 rpm.

Deeply double edged notched tension (DDENT) specimens were cut from injection molded plaques for fracture testing. The initial notches were subsequently made by saw cutting inserted perpendicular to the long edge of the plaques, followed by sharpening with a fresh razor blade.

2.2 Testing

The EWF method was applied to all prepared compounds on the above-described DDENT specimens. All the tests were performed at room temperature in a universal testing machine *Galdabini Sun 2500* with a crosshead speed of 10 mm/min. At least twelve specimens of each compound were tested, having different ligament length (l) ranging from 4 to 18 mm according to the ESIS protocol.

3 Results

3.1 Essential Work of Fracture

Figure 1 shows typical load-displacement curves of dynamically vulcanized PP/SBS blends at different ligament lengths. It should be highlighted that a total similarity between the curves was obtained for all ligament lengths and for all rubber contents, thus fulfilling one of the basic requirements of the EWF theory. All load-displacement curves show a smooth drop after reaching the maximum force. The peak load corresponds to a complete yielding of the ligament in the DDENT samples, so the two requirements for validity are satisfied and the EWF measurements are therefore valid at this deformation rate for all the blends studied. After yielding, the ligament necks down and is drawn out giving rise to a smooth load drop observed after the maximum load.

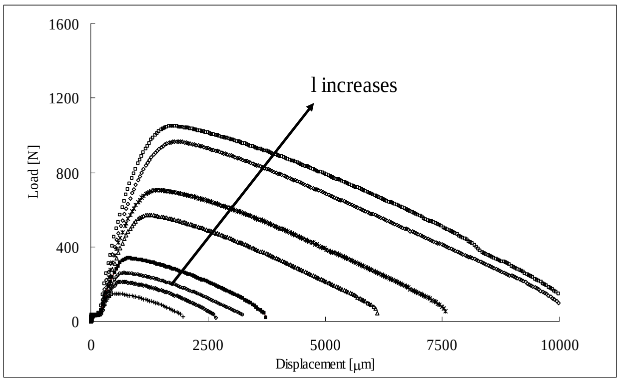

Fig. 1. Typical load-displacement curves of DDENT samples of PP/SBS dynamically vulcanized blends.

The specific total work of fracture (w_f) can be determined from the area under these curves. Accordingly, the specific essential work (w_e) associated with the initiation of the instability, and the specific non-essential work (βw_p) related to the plastic deformation in the plane stress condition, can be determined from the intercept and the slope of the regression line, respectively. Table 1 summarizes the w_e values together with the related correlation coefficients. It should be noted that the incorporation of the thermoplastic elastomer to PP seems to enhance fracture toughness. The elastomer particles contribute to the energy dissipation at the fracture surface and in the outer plastic zone in which various types of deformation might have been at work. Also, it seems that the fracture toughness value levels-off from 30 %wt rubber on. On the other hand, it has been established that the essential work increases, whereas the non essential work decreases with decreasing crystallinity. That is the case when PP/SBS blends are dynamically vulcanized. Hernández et al found that when PP/rubber blends are dynamically cured, the crystallinity degree of PP diminishes, since the crosslinked rubber particles may restrict the spherulitic growth and regular arrangement of the spherulites of PP, and subsequently, the essential work increases [1,2].

Table 1. Essential work of fracture parameters.

Blend	w_e [kJ/m^2]	βw_p [MJ/m^3]	R^2
Pure PP	8.45	2.14	0.9209
PP/SBS 85/15 DV	12.17	8.63	0.9972
PP/SBS 70/30 DV	14.17	6.68	0.9995
PP/SBS 60/40 DV	14.88	5.97	0.9959

3.2 Non-essential Work of Fracture

In order to determine the specific plastic work of fracture (w_p) an average value of the shape factor (β) had to be calculated for each material. The shape of the plastic zone developed around the specimen ligament length was elliptical in all cases and, according to this shape, β was measured in each test specimen. It can be clearly observed in Table 1 that the incorporation of SBS triggers a considerable plastic deformation, since βw_p increases compared to the value of pure PP. Nonetheless, a decrease in the non-essential work term (βw_p) is present with increasing amount of rubber, probably attributed to a change in the yielding behavior of the blends; yielding is strongly encouraged by adding the elastomer to PP.

4 Conclusions

The fracture behavior of dynamically vulcanized thermoplastic/elastomer (PP/SBS) blends by means of the Essential Work of Fracture (EWF) approach was investigated. The addition of SBS to PP affected both w_e and w_p; w_e increased with rubber content, whereas w_p seemed to decrease. So the EWF method revealed that the dynamic vulcanization method can impair fracture resistance to PP/SBS blends.

References

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