ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering, Volume XI (XXI), 2012, NR1

STUDY OF MECHANICAL BEHAVIOR OF REPROCESSING HIGH IMPACT POLYSTYRENE, RECOVERY WITH SEBS

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Keywords: polystyrene, reprocessing, mechanically characterized, blend, SEBS.

Abstract: The effect of reprocessing High Impact Polystyrene (HIPS) has been studied in this paper. To simulate recycled HIPS, we reprocessed virgin HIPS through 5 cycles. The HIPS has been mechanically characterized after the various cycles of reprocessing in order to evaluate their corresponding properties and correlate them with the number of cycles undergone. Our results show that tensile strength increases, while lengthening at break decreased as the number of reprocessing cycles increases.

1. INTRODUCCTION

High Impact Polystyrene is a thermoplastic formed in two phases: a styrene phase and a butadiene phase. Among the diverse applications of this material is its use in the manufacture of packaging materials. This type of product can be characterized as having a short life cycle, and consequently a huge quantity of domestic waste is generated, which must be dealt with to reduce environmental impact.

The problems which arise in the recovery of polymer materials are basically the variations that occur in their properties, due to either thermic degradation or the presence of impurities. Many studies have been carried out on the degradation of polymers. Su [3] analyzed the influence of the reprocessing cycles on the mechanical properties of polyamide 6 (PA6). Su’s work is relevant to our work because he carried out a study of mechanical and rheological properties, although it was with a different material. Su’s work is interesting, but we do not consider that reprocessing the material 16 times is very useful, because other studies show that the loss of property occurs in the first 5 reprocessed. [2,8] Other authors, including Santana [8] in their work in 2002 and Soriano [3] have carried out similar studies on HIPS. Santana investigated the themo-mechanical properties of post-consumer HIPS (from disposable cups) through five consecutive injection moulding steps to simulating the recycling cycles. Santana states that tensile strength, modulus of elasticity and elongation at break properties of HIPS were slightly reduced, which indicate an effect of decreasing of molecular weight.

Soriano analyzes influence of the number of processing cycles on the microstructure and macroscopic properties on a HIPS in coextruded sheet, maintaining a constant composition of 70 wt% of virgin HIPS and 30 wt% of recycled HIPS.

On the other hand, Balard [6] analyzed the compatibility of polycarbonate (PC) with acrylonitrile-butadiene-styrene (ABS) using waste material from the electrical sector, reaching the conclusion that the composition range comprised between 10 and 20 wt% PC is most interesting in order to obtain an industrial material with balanced properties, for different reasons: firstly, mechanical ductile properties do not decrease. Secondly, processing conditions are similar to other styrenic derivatives and finally, this composition range reflects the generation ratio of these wastes which is close to 4:1 for ABS/PC.

Finally, Navarro [7] and Garcia [1] analyzed mixtures of polymers with the aim of improving properties of the recovered material. Navarro, in his study of the influence of polyethylene (PE) on recycled polyethylene terephtalate (PET) analyzed, among other things, mechanical and rheological properties.

Studies on degradation of polymers are extremely numerous, as are studies on the effect of incorporating other polymers in order to improve and recover properties in the recycled material. But there appear to have been no studies which carry out a long term analysis of the recycling of these previously modified and then recovered polymers.

The objective of this present work is to study the mechanical behavior during the recovery process of High Impact Polystyrene waste, during the two stages of the recovery process. Firstly, we studied the reprocessing phase from virgin material through to the fifth reprocessing cycle. Secondly, we studied the phase of recovering properties of the material by adding styrene-ethylene-butylene-styrene block copolymer (SEBS).

2. EXPERIMENTAL

To develop this study, we used HIPS 6541 supplied by the company Total Petrochemicals ®. For the extrusion, we used a conventional double spindle extruder at a temperature of 210 ºC, with a pelletizer incorporated to obtain the pellet. We carried out five extrusion cycles (R1, R2, R3, R4 and R5) beginning with virgin HIPS (V). For the mixtures, we used SEBS supplied by Applicazioni Plastiche Industriali ® (Mussolente, Italy). For the mechanical characterization, we used a universal traction machine ELIB 30 (S.A.E. Iberstest, Madrid, Spain) in compliance with ISO 527.

3. RESULTS AND DISCUSSION

3.1 STUDY OF VIRGIN MATERIAL AND ITS DEGRADATION WHEN REPROCESSED.

The mechanical properties of any material are fundamental for its use in any particular application. The traction test is extremely important because it allows us to understand properties such as tensile strength and elongation at break.

Thermal degradation as a consequence of recycling processes causes changes in the internal structure of the polymer and these changes in turn cause variations in its mechanical properties.

In the study carried out on HIPS, figure1, showing the values of tensile strength with the extrusion cycles reveals an increasing lineal evolution in the values. Furthermore, the evolution of the elongation values with extrusion cycles is different to those obtained with the ultimate strength; in this case the loss of elongation is very significant between the first and third cycles, whereas after these extrusion cycles the values remain constant, figure 2.

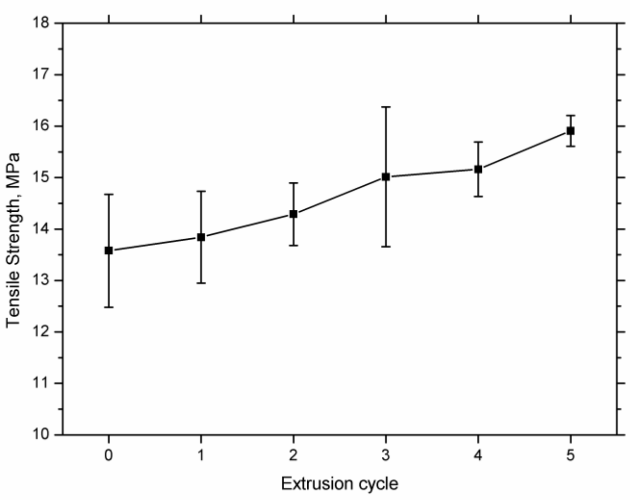

Figure 1. Tensile strength

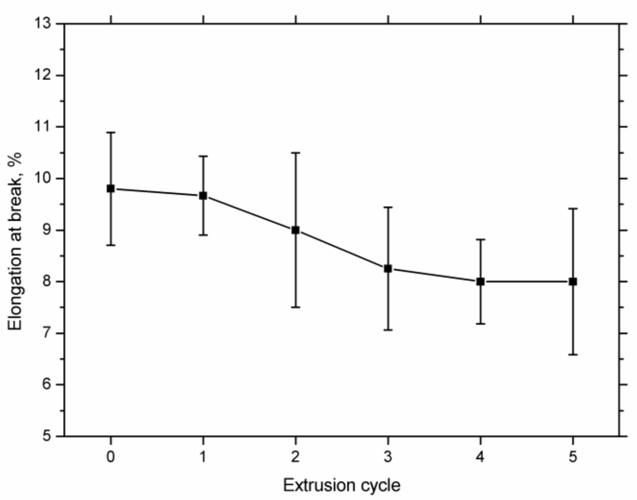

Figure 2. Elongation at break

Initially, the variations produced in the HIPS are not significantly noteworthy, and this behavior is logical given that the temperatures used in the extrusion process are not particularly high. Kalfoglou [5] showed that large variations only take place in the mechanical properties of HIPS when extremely high temperatures are used (290 ºC).

In spite of using relatively low extrusion and injection temperatures, the presence of a butadiene phase causes a degree of crosslinkimg of the chains, and as a consequence, an increase in rigidity in the HIPS.

Michaeli [10] carried out studies in this field and observed that significant variations in mechanical properties do not occur as a result of the slight interlacing of butadiene chains at processing temperatures of around 190 ºC. Soriano [2] studied the results of this crosslinking effect which is produced when the temperature of the thermoplastic is increased time after time on reprocessed HIPS obtained by coextrusion, and the same conclusion was reached.

3.2. EFFECT OF INCORPORATING SEBS ON THE PROPERTIES OF DEGRADED HIPS.

To degraded material (R5), we added 1% 2% 4% y 8% SEBS. For each of these mixtures, we carried out mechanical characterizations.

The loss of ductility in the recycled HIPS limits its use in some applications. Given that a change in properties is basically due to interlacing of butadiene chains, the addition of polybutadiene is common at an industrial level to increase the flexibility of the recycled HIPS. The quantities generally used are around 2% by weight with respect to the HIPS.

Our study takes this a step further and makes comparisons between different percentages by weight (1, 2, 4 and 8%) of SEBS.

The evaluation of the values of the different mechanical properties (tensile strength and elongation at break) has been studied. The ductility of the mixtures increasing in function of the SEBS content. Firstly, tensile strength falls gradually until it reaches values closest to those of virgin HIPS with a content of 8% (Figure 3).

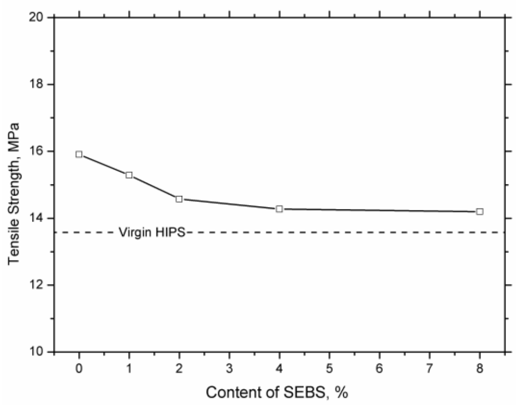

Figure 3. Tensile strength

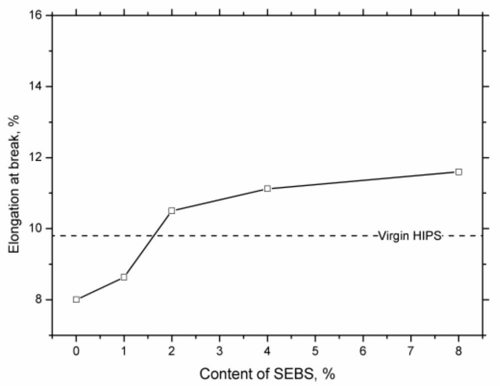

Figure 4. Elongation at break

In contrast, the addition of SEBS causes the opposite effect on elongation at break, where in this case the values increase significantly even with relatively low percentages; surpassing the initial properties of the virgin HIPS with 2% of SEBS, figure 4.

The incorporation of SEBS in HIPS after the fifth extrusion allows the recovery of the initial properties of virgin HIPS to a degree, and in some cases, even surpass them. Initially, the addition of 2% SEBS allows the recovery of the original properties of HIPS, due to the elastic character of SEBS.

Tasdemir [4] observed this same behaviour when mixing small quantities of SIS or SBS with a mixture of ABS/PC. SIS and SBS have very similar properties to SEBS. Santana [9] obtained similar results when they incorporated 5%, 6% and 7% SEBS to a mixture of PP/HIPS.

4. CONCLUSIONS

We studied the effects of reprocessing on HIPS thermoplastic material. Our study was centered on mechanical resistance properties. Figure 1 and 2 showing the values of tensile strength with the extrusion cycles reveals an increasing lineal evolution in the values. The results show that with respect to mechanical behavior, tensile strength increases by around 15%, while lengthening at break is reduced by 18%. As already commented, this behavior is caused by the crosslinking effect which is produced in thermoplastics when the temperature is raised time after time.

We also saw the effect of mixing different percentages of SEBS with HIPS that had been reprocessed five times, in order to try and recover the properties of virgin material. We again obtained information on mechanical resistance. The results show that with these mixtures, we can recover the mechanical behavior of virgin material.

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