ANNALS OF THE ORADEA UNIVERSITY
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2014, http://www.imtuoradea.ro/auo.fmte/

STUDY OF THE MECHANICAL PROPERTIES OF RECYCLED ABS AND RECOVERY THROUGHT MIXING WITH SEBS

Miguel Angel PEYDRO[1], David JUAREZ[2], Samuel SANCHEZ-CABALLERO[3], Rafael PLA-FERRANDO[4].
[1] Department of Mechanical and Materials Engineering, Universitat Politècnica de València, Plz Ferrandiz y Carbonell, s/n; 03801; Alcoy – Alicante (Spain), mpeydro@mcm.upv.es
[2]A Department of Mechanical and Materials Engineering, Universitat Politècnica de València, Plz Ferrandiz y Carbonell, s/n; 03801; Alcoy – Alicante (Spain), djuarez@mcm.upv.es
[3]A Department of Mechanical and Materials Engineering, Universitat Politècnica de València, Plz Ferrandiz y Carbonell, s/n; 03801; Alcoy – Alicante (Spain), sasanca@dimm.upv.es
[4] Department of Mechanical and Materials Engineering, Universitat Politècnica de València, Plz Ferrandiz y Carbonell, s/n; 03801; Alcoy – Alicante (Spain), rpla@mcm.upv.es

***Abstract*—** Recovery of recycled acrylonitrile–butadiene–styrene (ABS) through mixing with styrene-ethylene/butylene-styrene (SEBS) has been studied in this paper. To simulate recycled ABS, virgin ABS was processed through 5 cycles, at extreme processing temperatures, 220 ºC and 260 ºC. The virgin ABS, the virgin SEBS, the recycled ABS and the mixtures were mechanically characterized after the various cycles of reprocessing in order to evaluate their corresponding properties and correlate them with the number of cycles undergone. The results show that tensile strength of ABS remains practically constant as the number of reprocessing cycles increases, while in the material injected with SEBS the tensile strength decreases. Concerning the Charpy notched impact strength; the values of the ABS reprocessed at 220 ºC remain more or less unchanged, while the values for 260 ºC show a significant decrease. The adhesion of the SEBS causes, in both cases, an increase in impact strength.

***Keywords*—** Degradation, Recovery, ABS, SEBS, Additive

I. INTRODUCTION

THE current economic crisis has led to an increase in competition between companies, who in turn have had to significantly reduce production costs in order to remain competitive. These reductions must be found in areas such as raw materials, waste reduction, process optimization, etc. In the case of companies who transform polymer materials, the economic crisis, alongside a dependence on the price of petroleum, have led many companies to use recycled materials to obtain raw materials at a more stable price. There is also the added incentive of the environmental benefits gained by reusing waste materials.

One of the most important conditioning factors when substituting a virgin material for a recycled material is the question of whether the original characteristics are preserved in the recycled material. A disadvantage of thermoplastics is the variation in their properties, not only due to the effect of successive thermal processes, but also due to their exposure to atmospheric phenomena. Balart studied the properties of acrylonitrile–butadiene–styrene (ABS) derived from the electrical and electronic sector, to be more precise, from streetlights. These pieces are extremely exposed to atmospheric phenomena. Balart improved the properties of the waste material by mixing it with polycarbonate (PC) and then studied the miscibility of the mixture [1]. Another author, Liu obtained similar results using polyamide (PA) [2]. This variation in properties has been rectified by various authors through the use of additives or even by adding other polymers. For example, Tasdemir used styrene-butadiene-styrene (SBS) and styrene-isopren-styrene (SIS) also as compatibilizers in mixtures of ABS/PC [3]-[4]. SBS and SIS are materials that are very common in styrene-ethylene/butylene-styrene (SEBS), but there appear to be no studies into incorporation of SEBS in recycled polymers in order to recover their properties. Other examples are those of Li, who studied mixtures of polyphenylene oxide/polyamide 6 (PPO)/PA6 with maleated styrene-ethylene-butylene-styrene copolymer (SEBS-g-MA) and maleated acrylonitrile-butadiene-styrene copolymer (ABS-g-MA) and Yin, who studied mixtures of PC/ styrene acrylonitrile copolymer (SAN) with SEBS [5]-[6]. These studies are not comparable to our own as other materials were used, however, they show that there is an improvement in properties with the addition of SEBS to the materials used.

ABS is a technical thermoplastic that is widely used in a range of industries, such as the automobile, electrical, electronic, etc. sectors. Its main advantage is the good relationship between price and performance, although the presence of a polybutadiene phase brings certain problems when it is submitted to various processing cycles, either by injection or extrusion. The studies carried out by Bai [7], Boronat [8], Karahaliou [9] and Perez [10] clearly demonstrate this. Nearly all studies in this area highlight the crosslinking phenomena as the cause of the variation in properties that takes place (loss of ductility). In previous studies, such as those of Tasdemir [3]-[4], SBS, SIS and styrene-butadiene rubber (SBR) have been used with the aim of recovering the ductility that is lost in some polymers, but the use of these polymers may cause crosslinking in future reprocessing cycles as in all cases there is a double C=C. The objective of this work is to study the degradation process of ABS at extreme processing conditions, using the limit transformation temperatures (220 ºC and 260 ºC) and analyzing mechanical properties. Furthermore, with the aim of recovering these properties, we analyze the influence of SEBS on degraded ABS.

II. Experimental

A. Material

The ABS and SEBS used in the experiments are commercial products; ABS Terluran GP 35® (BASF, Ludwigshafen, Germany) and SEBS Megol TA 50 ® (Applicazioni Plastiche Industriali, Mussolente, Italy). Table I shows fresh material used in this study.

TABLE I
MECHANICAL CHARACTERIZATION VALUES OF THE VIRGIN ABS AND VIRGIN SEBS

	ABS	SEBS
Tensile strength (Mpa)	44	6.0
Elongation at break (%)	12	600
Charpy notched impact strength (kJ·m^{-2})	19	-
Hardness	75 (Shore D)	50 (Shore A)
Source	BASF	API

B. Sample preparations

The degradation process was conducted with a conventional injection machine (Meteor 270/75 de Mateu & Solé® (Barcelona, Spain)) at two injection molding temperatures (220 ºC and 260 ºC), which represent the upper and lower recommended values for ABS processing. This process was repeated until five cycles were completed. Prior to the injection process each of the samples was dried at 80 ºC in a dehumidifier (MDEU1/10 de Industrial y Comercial Marse S.L.®, Barcelona Spain).

The mixtures of degraded ABS and SEBS were obtained using a twin screw extruder at a maximum temperature of 220 ºC and varying the percentage of SEBS (0, 2.5, 5, 10 % by weight).

As there was a range of samples in the experiments, we used the code shown in Table II. For example, R5_260_2.5. 5 represents 5 recycling cycles at 260 ºC mixed with 2.5 % SEBS.

TABLE II
SAMPLES CODE

Material	Nº of cycles	Processing temperature	% of SEBS
R (Reprocessed)	1	220	0
	2	260	2.5
	3		5
	4		10
	5		

C. Mechanical properties measurement

Mechanical properties of ABS, reprocessed ABS and ABS-SEBS were obtained with a universal tensile test machine ELIB 30 by S.A.E. Ibertest® (Madrid, Spain) following the guidelines of ISO 527. All samples were 150 mm long and 10 x 4 mm^2 area, and were tested at 25 ºC and a relative humidity of 50 % using a crosshead rate of 50 mm min^{-1} with a load cell of 5KN. A minimum of ten samples were tested and average values of elongation at break (ductile mechanical property) and tensile strength (mechanical resistance property) were calculated.

The impact test was carried out using the Charpy axial impact pendulum (Metrotec®, San Sebastián, Spain) with adjustable masses for energy ranges of 1 and 6 J according to ISO 179.

Hardness of materials was determined using a shore hardness meter by J. Bot Instruments S.A.® (Barcelona, Spain) with the D scale following the guidelines of ISO 868.

III. Results and discussion

A. Characterization of degraded ABS over various injection cycles.

The mechanical properties of any material are fundamental for its use in any particular application. Traction and impact test are extremely important because they allow us to understand properties such as tensile strength, elongation at break and impact strength.

Fig. 1, Fig. 2, Fig. 3 and Fig. 4 shows the values obtained from the mechanical characterization of ABS in function of the number of cycles, both at 220 ºC and 260 ºC. A high level of stability in the ABS was observed after successive injection cycles; the tensile strength, elongation at break and Hardness values remained virtually constant. This behavior has been observed by a number of other authors such as Bai [7], Eguiazabal [11], Perez [10] and Salari [12]. However, different impact strength values for the two temperatures (220 and 260 ºC) were obtained. In the first case (220 ºC), impact energy remains more or less constant, but the values fall when the temperature used is 260 ºC. This phenomena was also observed by Bai [7] and Eguiazabal [11]. This decrease is due to the crosslinking phenomenon arising from the break in C=C double bond, which limits the later use and application of the recycled ABS.

Previously, results show that the 220 ºC temperature is better than 260 ºC, but the injection process is slower and more injection pressure is needed due to the higher viscosity shown by the ABS at 220 ºC.

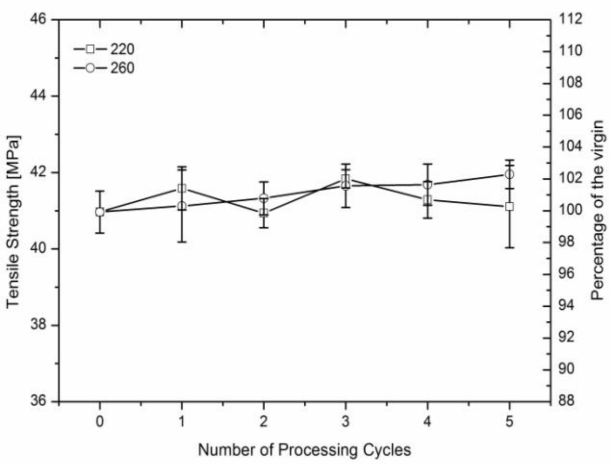

Fig. 1. Tensile strength for the reprocessed ABS.

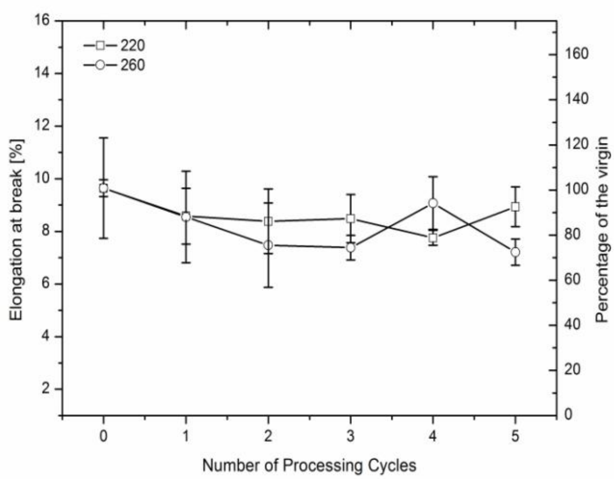

Fig. 2. Elongation at break for the reprocessed ABS.

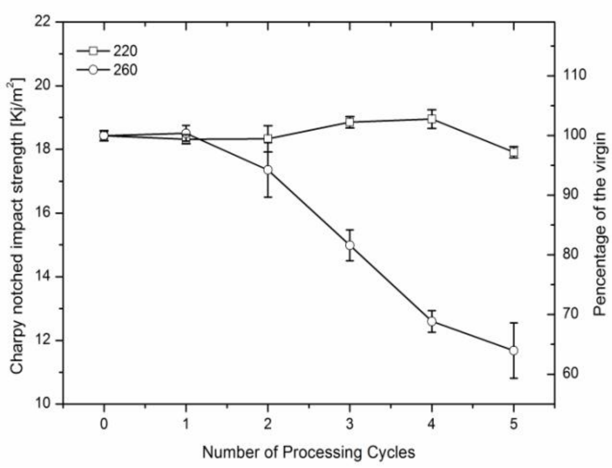

Fig. 3. Impact strength for the reprocessed ABS.

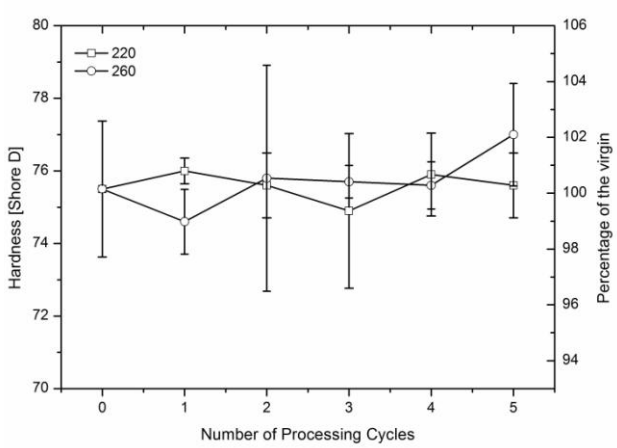

Fig. 4. Hardness for the reprocessed ABS.

B. The influence of the addition of SEBS on the properties of degraded ABS.

One of the principal objectives of incorporating SEBS is the recovery of impact strength, given that this is the property that shows the greatest decrease with repeated reprocessing cycles, above all in the ABS reprocessed at 260 ºC.

Error! Reference source not found.5 shows the evolution of the tensile strength values in function of the SEBS content. For both series, there is a linear decrease in in tensile strength with the increase in SEBS. On the other hand, elongation at break values increase in function of SEBS content, **Error! Reference source not found.**.

The addition of SEBS to reprocessed ABS causes an increase in impact strength, both at 220 ºC and 260 ºC. We saw that the evolution of the values is different, as for the ABS degraded at 260 ºC the increase in impact energy is linear, whereas the ABS degraded at 220 ºC has an initial stage in which impact energy increases rapidly up to 5 % SEBS content, and a second stage in which greater contents of SEBS only slightly increase this value, **Error! Reference source not found.**. Finally, the addition of SEBS to reprocessed ABS causes a decrease in hardness, both at 220 ºC and 260 ºC, Fig. 8.

The incorporation of SEBS and other elastic thermoplastics has been carried out by Ganguly [13], Tasdemir [3]-[4] and Yin [6] with similar results.

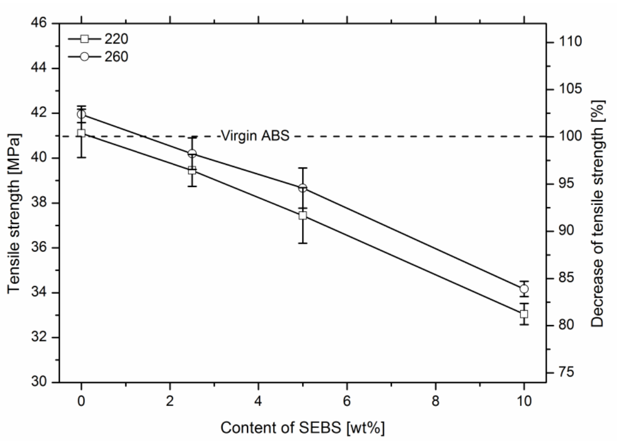

Fig. 5. Tensile strength for the blends of R5 + SEBS.

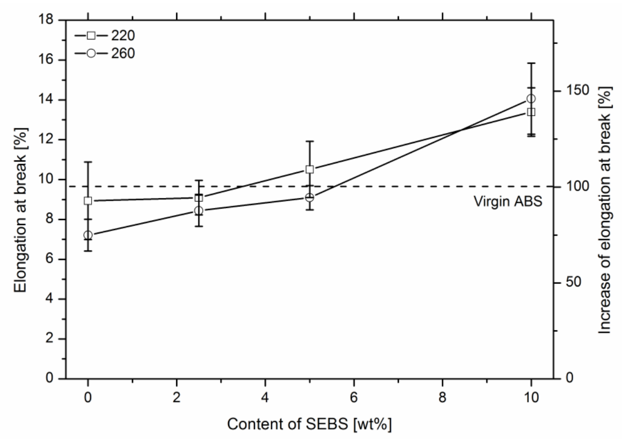

Fig. 6. Elongation at break for the blends of R5 + SEBS.

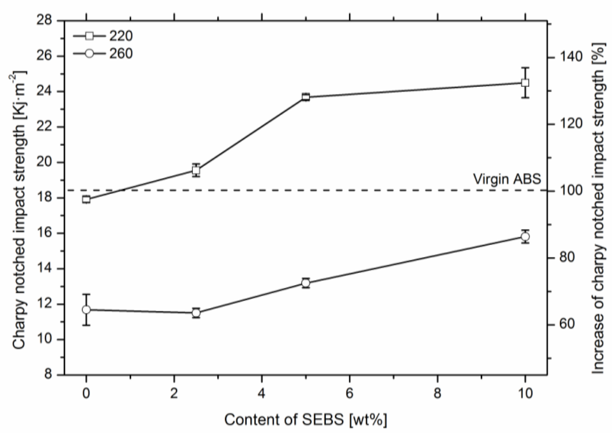

Fig. 7. Impact strength for the blends of R5 + SEBS.

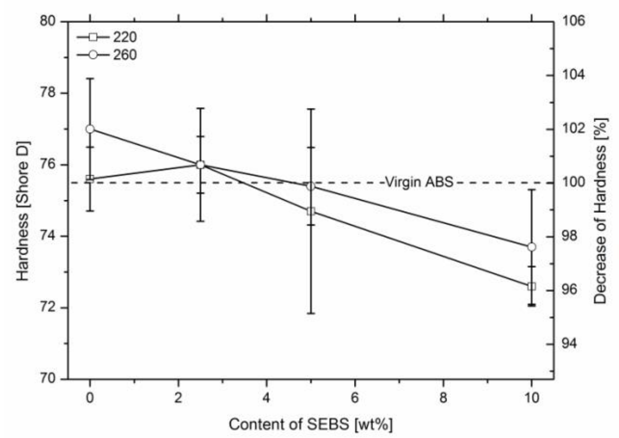

Fig. 8. Hardness for the blends of R5 + SEBS.

IV. Conclusions

The properties mechanical of ABS reprocessed at 220 ºC remain virtually unchanged with the number of cycles. On the other hand, when the ABS is reprocessed 260 ºC, variations in both the mechanical and rheological properties are seen. Of these variations, it is particularly worth highlighting the considerable loss of ductility in the ABS. This takes place due to the crosslinking effect of the ABS. With the aim of recovering the ductility of degraded ABS, this material was mixed with SEBS. The presence of SEBS in the degraded ABS allowed the recovery of the lost ductility, but in turn a decrease in the tensile strength values was seen. The material reprocessed at 220 ºC would not need to be mixed with SEBS. On the other hand, the material reprocessed at 260 ºC would have to be mixed with at least 5 % SEBS. This mixture would recover up to 75 % of the impact energy. Mixtures with larger proportions of SEBS would produce an excessive reduction in tensile strength.

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