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Material Properties

Glass fibre recycled poly(ethylene terephthalate) composites: mechanical and thermal properties

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Abstract

Investigations of thermal and mechanical properties of recycled poly(ethylene terephthalate) (PET) reinforced with glass fibre have been carried out, focusing on the influence of two variables involved in the extrusion process: screw speed and torque. A Factorial Experimental Design of the processing conditions during extrusion (screw speed and torque) was done to get the best thermomechanical properties versus processing conditions. Mechanical properties such as Young's Modulus and Impact Resistance increased after the addition of glass fibre in recycled PET matrix.

Keywords: Glass fibre reinforced recycled PET; Thermal and mechanical properties; Extrusion variables

1. Introduction

Poly(ethylene terephthalate) (PET) was first produced in 1946, and was commercially available in 1953 as textile fibre. Due to the good barrier properties of blow-molded containers made with PET, it became a very important commercial plastic used in food packaging and in film and carbonated soft drink bottles [1]. Unfortunately, the post-consumer soft drink bottles made of poly(ethylene terephthalate) (PET) are approaching 5 million tons/yr worldwide and cannot be reused. This is banned not only by hygienic requirements, regulated by consumer protecting acts, but also because of substantial degradation in the molecular structure of PET, which is followed by a decrease in melt viscosity and mechanical strength [2,3]. De Paoli et al. [4] showed that the mechanical properties and the degree of crystallinity of PET changed drastically after a number of reprocessing cycles. Moreover, an increase in melt flow index and carboxylic group concentration indicated a certain degree of mechanical and chemical degradation.

Other papers showed that the number of carboxyl end groups increased about three times after five recycling steps by injection. It was noted that the crystallinity was enhanced, going from 23 to 37%, which explains the changes in the modulus of elasticity, elongation at break and impact resistance [5]. Raw PET exhibited ductile behaviour (>200% of elongation at break), whereas post-consumer PET bottles were brittle (<10% elongation at break). This is a consequence of different degree of crystallinity, presence of impurities in the recycled PET and different thermal and mechanical histories of the raw and recycled materials [6].

An important application of recycled PET to be considered is to obtain reinforced composites. The use of reinforcement of polymeric materials by short fibres has grown rapidly over the past 30 years. The first polymeric composites to use chopped glass fibres were based on

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unsaturated polyesters and epoxy resins, but recently thermoplastics materials have gained acceptance [7]. Many studies dealing with short-fibre reinforced engineering plastics, such as poly(ethylene terephthalate) (PET) [8], polycarbonate [9,10] and polyamides [11,12] have been reported. Glass fibres are the most used reinforcing materials in structural reinforced thermoplastics. They have many desirable characteristics such as low cost, high tensile strength, high chemical resistance and excellent insulating properties [13,14]. As a consequence, composites based on thermoplastics and glass fibres have similar advantages [15,16]. The mechanical properties of glass fibre reinforced thermoplastics are affected not only by the interfacial adhesion between glass fibre and polymeric matrix but also by the length and the diameter of the fibres as well as by their volume fraction, orientation and distribution in the composite [17]. Good interfacial adhesion is necessary to transfer the stresses from the polymeric matrix to the reinforcing glass fibres; however, the different hydrophilic/hydrophobic characteristics between the glass fibres and the thermoplastics result in poor interfacial adhesion and mechanical properties of the composites. Therefore, this situation needs to be controlled by coupling agents or reactive additives that are normally used to improve the adhesion between the fibres and the polymeric matrix [18,14].

In addition, some papers have pointed out the effect of parameters of the injection process on the mechanical properties of polymers. Kim et al. [13], for example, studied the effect of the morphology on the mechanical properties of injection molded articles made of glass fibre reinforced poly(butylene terephthalate) (PBT). Velasco et al. [19,20] correlated microstructure, mechanical properties and processing conditions of short glass fibre reinforced PET composites by injection and considered three variables: mold temperature, holding pressure time and closed mold time.

With this aim, the present work intends to correlate thermal properties; mechanical properties and processing conditions of glass fibre reinforced recycled PET composites for extrusion. Although there are many variables involved in extrusion processing, this work focuses on two of them: screw speed and screw torque.

2. Experimental

2.1. Materials and componding

The following materials were used: recycled PET (PC 70) supplied in pellets by Recipet (M and G); chopped glass fibre (pricked 183 F, length = 4.5 mm and diameter = 11 μm) supplied by Owen Corning and antioxidant (Irganox B 900) by Ciba. Chopped glass fibre at 30 wt.%, and pellets of recycled PET (69.5 wt.%) were carefully mixed in PEAD bags for 1 min, adding 0.5 wt.% of antioxidant to the mixture.

Table 1
Processing conditions of recycled PET/Glass fibre composite

PET recycled + glass fibre (30%)	Processing conditions				
	1	2	3	4	5
Rotation (rpm)	100	100	200	200	150
Torque (%)	40	60	40	60	50

In order to avoid as much as possible the degradation effects of hydrolysis caused by moisture, pellets of recycled PET were dried at 130 °C for 6 h. Compounding was carried out in a Theysohn twin-screw extruder, with *L/D* ratio equal to 40. The process was carried out with the following temperature profile: 260–270–270–280–290 °C. A Factorial Experimental Design (FED) 2^2+1 was used for the processing variables: screw speed (100 and 200 rpm) and screw torque (40 and 60%), as shown in Table 1. The central point was set up in the intermediate levels of these factors.

The extruded spaghetti of recycled PET glass fibre composites was cooled in a water bath followed by dry air ventilation to eliminate water. After that, they were granulated.

The processing conditions for recycled PET without glass fibre (GF) were fixed at 200 rpm and torque of 60% (Table 1, experiment 4).

2.2. Injection-molding

The specimens were produced using an Arburg injection molding machine, model 320K. The basic process parameters were: melt temperature of 270 °C and cold time of 40–50 s.

3. Characterization analysis

3.1. Melt flow index—MFI

The analyses of melt flow index (MFI) were done using the same processing temperature used for the recycled PET/glass fibre composites. A plastometer MI-3 was used according to ISO 1133 1991.

3.2. Intrinsic viscosity—VI

Measurements of intrinsic viscosity [η] of the supplied recycled PET before and after extrusion were evaluated in dilute solutions using an Ubbelohde viscometer, ϕ = 0.75 mm (Billmeyer). A mixture of phenol and 1,1,2,2-tetrachlorethane (6:4 wt) was used to dissolve PET at a concentration of 0.12 g PET in 13 ml for measurement of intrinsic viscosity according to ASTM D 4603-91.