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Enhancement of the fatigue life of recycled opaque PET from household milk bottle wastes

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Introduction

Polyethylene terephthalate (PET) is one of the most widely used thermoplastic polymers of the polyester family. Opaque PET, obtained as PET filled with mineral nanoparticles, protects the content from UV radiation, minimises gas permeation, saves weight and brings a glossy white aspect to the bottles when other pigments are not used. However, its recyclability is nowadays an issue: the recycling channels are well established for transparent PET, the presence of opaque PET in the household wastes weakens the existing recycling channels. Many initiatives are launched in Europe to turn waste into resources, as one key to a more circular economy. In this work, the mechanical properties of recycled opaque PET collected from household wastes have been studied. A previous work focus on the fatigue life of opaque PET blended with polypropylene [1]. Recently, Candal et al. has demonstrated that recycled opaque PET can be regenerated by chain extension using Joncryl [2]. As a consequence, the tensile properties of so-called reactive extruded r-OPET are increased. Our work aims to analyse its fatigue life and to correlate the lifespan to the fracture morphology.

Experimental

Materials

Post-consumer opaque PET from opaque bottles, referred as r-OPET, was supplied by Suez RV Plastiques Atlantique (Bayonne, France) under the trade name Floreal in form of flakes of different

colours. Recycled PET flakes were processed to obtain three types of materials: flakes (not modified) recycled post-consumer opaque PET (denoted F-r-OPET), homogenized recycled post-consumer opaque PET (denoted r-OPET-hom), reactive extruded recycled post-consumer opaque PET (denoted REx-r-OPET).

Methods

Tensile tests following ISO 527-1 and ISO 527-2 standards were performed, in a thermoregulated room at 23 °C, using an electromechanical tensile test device Instron 5500R equipped with a 5 kN load cell. A displacement speed of 5 mm.min⁻¹ was applied.

In uniaxial fatigue tests, the stress or strain has oscillated about the same mean stress (strain). The tests were performed following the ISO 13003:2003 standard, in a load-control mode on a servo-hydraulic fatigue machine, Schenck retrofitted Instron equipped with a 40 kN load cell. All the specimens were loaded by a 5 Hz sinusoidal waveform at a constant loading amplitude based on tensile tests data.

The morphology of cryo-fractured and fatigue fractured surfaces of samples was analysed by Inspect F50 field emission gun SEM operated at 5–10 kV. To allow backscattered observations, samples were previously carbon-coated (Leica EM ACE200 coater).

Results and Discussion

The ultimate tensile strength was extracted from the strain-stress curves, and taken as the

maximum stress recorded during the tensile test. The tensile modulus, to respect the ISO 527 standard, has been calculated for a deformation between 0.0005 and 0.0025.

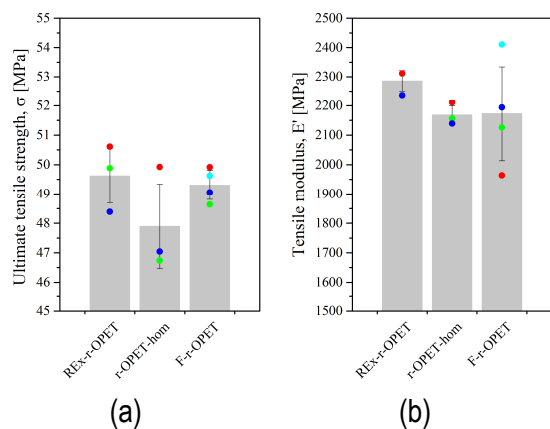


Figure 1. (a) Ultimate tensile strength (b) Tensile modulus

The homogenous r-OPET indicates a lower UTS than for REX-r-OPET and F-r-OPET, however, by considering the standard deviation, the results are comparable. The reactive extruded r-OPET has a slightly higher tensile modulus than the other materials.

From fatigue tests, the number of loading cycles to cause failure is recorded for a given %UTS, which allowed to draw an S-N curve. It is plotted with the cyclic stress (S) against the cycles to failure (N) on a logarithmic scale.

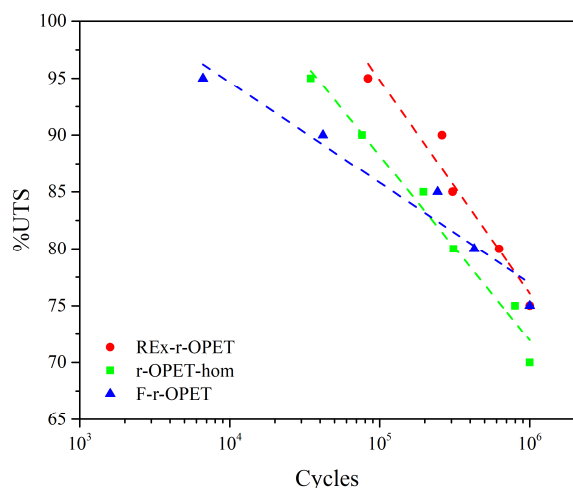


Figure 2. Fatigue life with S-N curves

The fatigue limit can be correlated to ultimate tensile strength. Improvement of fatigue life for reactive extruded r-OPET compared to homogeneous r-OPET was noted by higher lifetime for the same fatigue load rates and higher fatigue limits.

Microscope analysis made for low fatigue load did not show obvious differences between the materials. The morphology does not change compared to samples without any fatigue load. However, for high fatigue load rate, differences are highlighted, in particular to the material fibrillation.

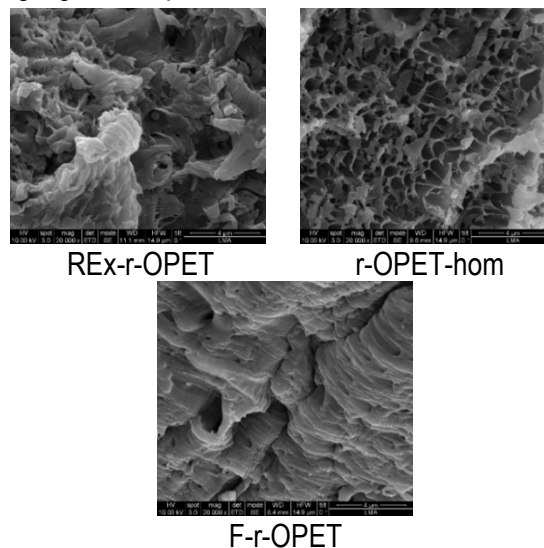


Figure 3. SEM images of fractured surfaces during T-T stressed at 95 %UTS

The presence of TiO₂ particles is observed inside huge cavities. Particles act as stress concentrators, helping in the void formation at multiple sites and promoting the fracture process.

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