

SIMULATING THE MECHANICAL RECYCLING OF PET- AND HDPE-BASED PACKAGING: THE INTERACTION BETWEEN PRESENCE OF CONTAMINANTS, DEGRADATION AND REPROCESSING

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INTRODUCTION

The increasing plastic production involves a greater need of recycling polymeric end-of-life items. One of the encountered difficulties is related to the heterogeneity of composition of plastic materials, which can entail a drastic reduction of final properties and variation of processability of the recyclates [1]. As concerns polyethylene terephthalate (PET) bottles, besides PET from the central body of the container, high-density polyethylene (HDPE) in the closure system and polypropylene (PP) as label are encountered, while HDPE flacons are constituted by a polyethylenic main body, a PP-based closure and a PET-based label. During mechanical recycling, if the different polymers have different densities, separation by flotation takes place, notwithstanding this there is the presence of some contaminants in the final material that cannot be separated efficiently.

In this work, the effects of the presence of the most common contaminants and different forms of degradation on PET- and HDPE-based systems were assessed, aiming at evaluating their possible impacts on the processability and the final properties of recyclates.

EXPERIMENTAL

Materials

Regarding PET blends, bottle-grade PET (Intrinsic Viscosity 0.8 dl/g) and injection molding-grade HDPE (Melt Flow Rate 7.6 g/10 min) were used in order to obtain three systems: pristine PET, PET+0.5%HDPE and PET+2%HDPE. For HDPE systems, flacon-grade HDPE (Melt Flow Rate 5 g/10 min), PP (Melt Flow Rate 12 g/10 min) and bottle-grade PET (Intrinsic Viscosity 0.8 dl/g) were employed for formulating HDPE, HDPE+10%PP and HDPE+10%PP+2%PET.

Processing

A co-rotating twin-screw extruder has been used for the melt compounding. For PET systems, die temperature and screw rotation were set at 270°C and 50 rpm, respectively; for non-aged HDPE blends the processing parameters were chosen equal to 230°C and 100 rpm; die temperature was increased up to 250°C for aged polyethylenic systems.

Aging and characterization techniques

Photoaging was carried out through SEPAP, while thermal aging was performed in oven in presence of humidity for PET systems and surfactants for HDPE ones. Rheological, mechanical, thermal, spectroscopic and morphological properties were evaluated through rotational rheometer, dynamometer, DSC, FTIR-ATR and SEM, respectively.

RESULTS AND DISCUSSION

The present study was carried out considering the three following different aspects, which concurrently verify in a real mechanical recycling scenario: (i) presence of polymer-based contaminants deriving from ineffective separations; (ii) photo- and/or thermo-oxidative degradation (also in presence of humidity and/or other agents) underwent by the materials

during their service life; (iii) thermo-mechanical degradation occurring during the polymer reprocessing in the recycling stage. Concerning the PET systems, the presence of HDPE-based contaminants entails a significant increase of the complex viscosity as compared to pristine PET, while its effect on the mechanical properties is almost negligible. On the other hand, a remarkable decrease of the system viscosity was observed after photo- and thermoxidative-aging and reprocessing, likely due to the occurrence of chain scission and/or hydrolysis phenomena which mainly affect the molecular weight of PET (Fig. 1a). Furthermore, the mechanical properties of the reprocessed materials mostly depend on degradation. In fact, a sharp reduction of the elongation at break was observed for the samples subjected to photodegradation and thermal degradation in presence of humidity. These results can be attributed to the already mentioned reduction of the PET molecular weight, hence causing a loss of ductility.

As far as HDPE blends are concerned, their behavior is influenced not only by the aging and presence of contaminants, but also by reprocessing. In this case, the presence of PP and PET involves an increase of the complex viscosity values, due to the formation of a droplet-like morphology typical of an immiscible blend. Besides, the UV exposure promotes the occurrence of chain scission reactions (leading to a decrease of the complex viscosity), while the thermoxidative treatment in presence of surfactants does not significantly affect the rheological response. Otherwise, the thermomechanical degradation underwent by the materials during the reprocessing step induces the obtainment of branched structures and crosslinking, promoting an increase of the viscosity as compared to that of the starting polymer. These noticed alterations of the microstructure strongly affect the mechanical properties of the HDPE-based samples and, especially, the elongation at break. In particular, as observable in Figure 1b, the aging treatment and the subsequent reprocessing induce a general embrittlement of the materials, which is even more severe in presence of PP and PET contaminants.

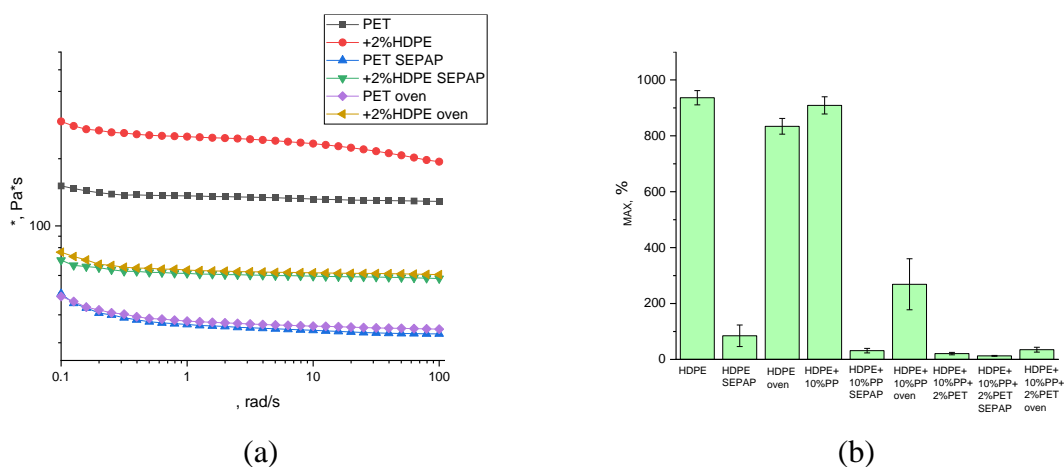


Fig. 1 (a) Complex viscosity curves for PET-based systems and (b) elongation at break for HDPE-based materials

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References

- 1) Roosen et al, Environ Sci Technol, 2020, **54**, 20, 13282–13293