Effect of processing on the rheological properties of branched polypropylenes obtained by electron beam irradiation.

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This work is devoted to the investigation of the impact of the processing history on the rheological and end-use properties of long branched polypropylenes (PP). Long chain branching (LCB) was found to have a significant effect on processability when branches are longer than twice the entanglement length in the melt [1]. The use of PP in industrial processes such as extrusion-blowing, foaming extrusion and thermoforming, is favoured by LCB that brings about stiffer and stronger polymers, avoiding or delaying break and thinning when stretching. The behaviour is related to the strain hardening phenomenon, which refers to a rapid increase of the uniaxial extensional viscosity beyond a critical strain [2].

The presence of long chain branches, however, leads to the so-called "shear modification" which is the rheological change that takes place under processing, as well as thermal history conditions. For example, processing in a single-screw extruder prior to forming, depresses the melt elasticity to a great extent for low-density polyethylenes [3]. Therefore, understanding the modification of rheological properties that occurs in the extruders is crucial for branched polymers in industrial applications.

The samples investigated were obtained from a commercial polypropylene, submitted to different electron beam irradiation doses. The detailed conditions describing the irradiation procedure were described elsewhere [4]. Gel Permeation Chromatography (GPC) coupled with three detectors found a reduction of molar mass and an increasing density of branching level with increasing dose.The strain hardening, absent in the linear PPs, together with the dynamic viscoelastic behaviour analyzed by SAOS (Small Amplitude Oscillatory Shear) and LAOS (Large Amplitude Oscillatory Shear) were all related to the degree of LCB. Further deformation, applied by means of an extruder, depressed the melt strength and strain hardening was eliminated. LCB still present in the sample was detected by GPC, although the level was considerably reduced. The structural changes were found quite stable, but reversible in the molten state. This reversibility indicates that the elongational behaviour must be related to the conformation change of the branch structure, i.e. the alignment of long branches to a backbone chain [5]. It is worth mentioning the fact that the alignment of long branches affected the elongational response more noticeably than the shear response. Results allow us to test the applicability of rheological methods to evaluate the presence of LCB structures, which is very useful for irradiated PP carbon nanotube nanocomposites where the GPC analysis is not possible.

References:

1. Dealy J M, and Larson RG. Structure and Rheology of Molten Polymers: From Structure to Flow Behavior and Back Again (Hanser, Germany, 2006).
2. Gotsis AD, Zeevenhoven BLF. Polymer Engineering and Science (2004) 44:973-82.
3. Yamaguchi M, Wagner MH. Polymer (2006) 47: 3629-35.
4. Huegun A, Fernández M, Muñoz ME, Santamaría A. Composite Science and Technology (2012) 72:1602-07.
5. Munsted H. Colloid and Polymer Science (1981) 259:966-72.