EVALUATION OF RECYCLED HDPE FOR PIPE APPLICATIONS

Magda M. B. de Oliveira Sampaio[1] and L. E. Pimentel Real[1]

[1] *Departamento de Materiais, Núcleo de Materiais Orgânicos*
Laboratório Nacional de Engenharia Civil, Av. do Brasil, 1700-066 Lisboa, Portugal

INTRODUCTION

The use of recycled polyethylene is an interesting environmental and economical solution but its performance needs to be improved. To attain this goal, the recycled plastics need to be upgraded and the additives need to be well dispersed in the polymer matrix.

To assess the quality of polyethylene pipes compounded with recycled polyethylene for applications in drainage and sewerage, several analysis techniques were applied, some of them being not previewed in the performance characteristic standards. The measured physical, chemical and mechanical properties of raw-materials, intermediate compounds and final products, were used to evaluate the performance of the different formulations. The present work attempts to characterize the recycled HDPE (AMBIENTE RHDPE samples 71-03, 71-30, 89-12, 89-20), virgin HDPE (REPSOL PE T100N) and its blends (10, 30 and 50%), as well as to evaluate effects of the recycling process on polymer properties.

Finally, we checked the effect of a nanoclay (*C*) in different formulations. The analysis of the results will help us to understand the thermo-mechanical effects of the several transformation processes and to optimising the manufacture parameters and the formulations, in view of its upgrading.

The results were compared with the reference values from literature [1-3].

EXPERIMENTAL

Commercial recycled HDPE is used in this research study. The analyses were conducted in accordance with the appropriate ISO and EN testing standards. The apparatus used to access the polymer properties are among the most interesting instrumental techniques that are used to investigate the degradation of polymeric materials and to evaluate the performance of pipes, namely a DMA TA Instruments Q800, a DSC NETZCH 200 F3 Maia, a Thermoscientific Nicolet Magna-IR 550 Série II, an Extrusion Plastometer DTS, a Setaram TG 92-1750, a Density Gradient Three Column Apparatus' RAY-RAN ENGINEERING, an IPT Carbon Black Tester Ro4/25, a Transmission microscope OLYMPUS BHT-A, a Reglerautomatik RPCS - Master II and an Instron 4302. A hot press Cortazar Vitoria was used for compression molding preparation.

RESULTS

Some of the results obtained are presented in the figures 1 to 11. They are typical from virgin HDPE, namely the XRD angle (fig.1). The OIT isothermal measurements by DSC (fig.2) show that the level of thermal oxidative stability of recycled polymers is very low, being only possible to obtain an acceptable value for this parameter (20 min) at too much low isothermal temperature (160ºC) and in a 10% blend, confirming that recyclates have low stabilization level, which is exacerbated by a depletion of antioxidant during the recycling process. FTIRS spectra (fig.3) contains the characteristics maximum absorption bands of PE, namely C-H stretching, CH_2 deformation bending and C-H rocking bending. The transmittance band corresponding to C=O bond from carbonyl functional groups is present (1680-1780 cm^{-1}), which suggest some oxidation of hydrocarbon chain. The melt flow rate (190ºC/2.16 kg) is in the acceptable range (0,2-1,4g/10min) for HDPE and transition temperatures are lower than expected for this polymer (fig.4).The recycled samples exhibits poorer viscoelastic (storage and loss modulus, tan delta) and tensile properties than virgin HDPE (figures 5-7). The OIT dynamic shows an improvement or a decreasing, respectively with clay or RHDPE addition (figures 8-9). The TG measurements show a premature mass loss (95.0-95.5%) in the recycled samples (fig.10). The microscopic structure of RHDPE 71_30 shows impurities (fig.11). Some preliminary extruded pipes (fig.12) have also presented too much low resistance to internal pressure. These no good results suggest that changes in the polymeric structure (crosslink and chain scissions) were occurred during the previous use of original goods, as well as due to thermo-mechanical actions during recycling and processing. The differences on the decomposition temperatures (Td 449.3 to 548.1º C), as well as in the crystallization/melting temperatures (31 to 38 %; 121-124º C and 122° C), indicate also different provenance of materials. The carbon black content and dispersion (1,95-4,41%) is higher and shows a bad dispersion (3,3-4,2) of this pigment, used mainly to mask different colors.

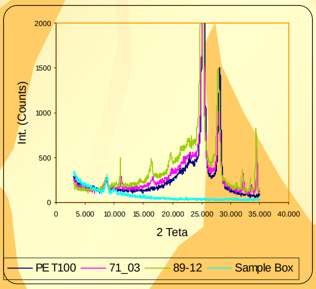

Figure 1. 2 Teta angles for HDPE samples

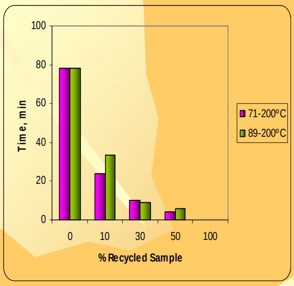

Figure 2. OIT for virgin HDPE and blends

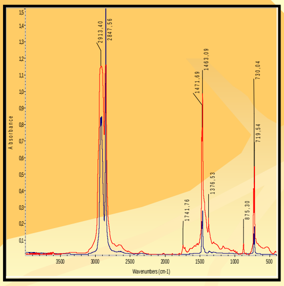

Figure 3. FTIR analysis for 71_30 and PE T100N samples

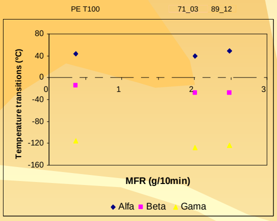

Figure 4. Transition temperatures versus melt flow rates

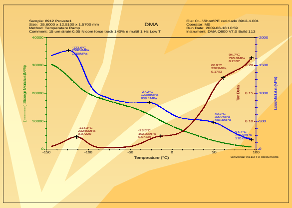

Figure 5. Viscoelastic properties for RHDPE 71_03

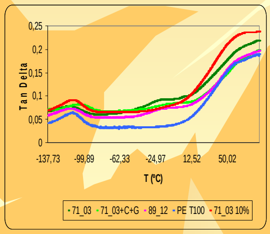

Figure 6. Tan Delta for five samples

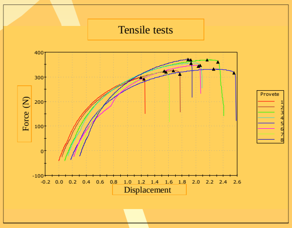

Figure 7. Tensile tests for RHDPE 89_12

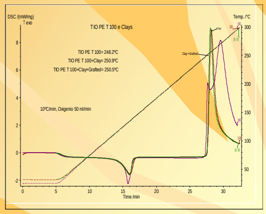

Figure 8. OIT dynamic for PE T100N and Clay/Grafted

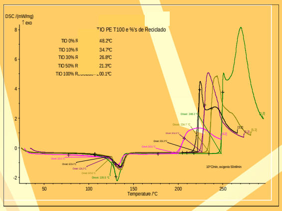

Figure 9. OIT dynamic for blends of PE T100N and % of RHDPE

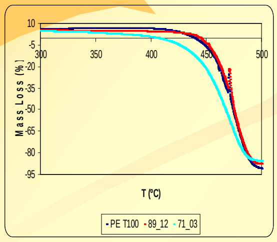

Figure 10. Mass Loss for HDPE and RHDPE

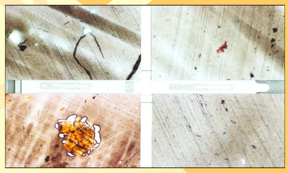

Figure 11. Microscopy images of RHDPE 71_30

Figure 12. Pipe extrusion ↓

CONCLUSIONS

We saw that the incorporation of recycled HDPE does not affect significantly some PE intrinsic properties, namely the specific gravity, the FTIR spectra, XRD angle and MFR. The major impacts of these additions were seen on mechanical properties and stabilization level. The recycled samples show high intrinsic variability, due to heterogeneity, which also results from difficulties of traceability. This influences the maintenance of some important properties inside the acceptable range of specifications established by the performance characteristics standards. To improve the pipe properties, the rheology need to be adapted and an intelligent upgrading must be made. As future perspectives for this study, it is previewed to continue optimization studies in extrusion and compounding.

REFERENCES

[1] LaMantia, F.-*Handbook of recycled polymers*, Rapra, 1st Ed., 2002
[2] Mark, J.-*Polymer data Handbook*, Oxford, 1999
[3] Peacock, A.-*Handbook of polyethylene*, Marcel Dekker, 2002

AKNOWLEDGEMENTS

The authors wish to thank to FCT for the M.Sampaio Grant SFRH/BPD 35122/2008, to Prof. Fengge Gao from Nottingham Trent University for the extrusions and to Baquelite, Ambiente and Sirplaste industries for their support.