The 9th International Conference and Exhibition on Masterbatch & Polymer Compounds
16-17 February 2025, Tehran, Iran

Effect of Carbon Black on the Rheological Properties of Mechanically Recycled Pipe-Grade HDPE

Reza Hosseini Biuki[1] , Sara Tarashi[1*], Gholamreza Pircheraghi [2]

[1] School of Chemical Engineering, College of Engineering, University of Tehran, Tehran, Iran (S.tarashi@ut.ac.ir)
[2] Polymeric Materials Research Group (PMRG), Department of Materials Science and Engineering, Sharif University of Technology, Tehran, Iran

Keywords: HDPE, Rheology, Recycling

INTRODUCTION

The impact of polymers on the environment, economy, and sustainable policies is significant and undeniable. Key features of these materials include their tunable properties, chemical and mechanical stability, ease of processing, and recyclability. Advanced methods such as rheological and dynamic-mechanical testing provide reliable insights into the performance and behavior of polymers, aiding in assessing their properties. These techniques enable researchers to predict material behavior under various conditions, optimize formulations, and ensure quality control in manufacturing processes. By understanding polymers' viscoelastic properties and mechanical responses, industries can develop more durable, efficient, and application-specific materials.
In this study investigated the impact of mechanical recycling on the microstructural characteristics of two commercial pipe grades of high-density polyethylene (HDPE): Neat (M) and Black (B) by a combination of rheological analysis and melt flow index (MFI) results. Using a twin-screw extruder, the samples underwent various reprocessing cycles (R1, R5, R10, R15, and R20).
The role of carbon black in HDPE is also vital, as it affects the material's Rheological behavior and processability.

Experimental

In this study, bimodal high-density polyethylene, referred to as PE100, was evaluated using two commercial grades: Neat (M) and Black (B), which contain 2-2.5% carbon black. Both Neat (M) and Black (B) polyethylene samples were processed in a twin-screw extruder at a temperature of 175°C, a screw speed of 80 rpm, and a residence time of 54 seconds. The samples underwent up to 20 reprocessing cycles (R1, R5, R10, R15, and R20) to assess thermomechanical degradation resulting from multiple recycling.

Result and discussion

According to the results of van Gurp-Palmen (v-GP) plots for Neat grade it can be concluded that long-chain branching due to the free radical's generation during mechanical recycling probably happened[2]. These radicals can form through chain scission, leading to a reduction in viscosity.(see *Figure 1A).* Similar behavior was observed with increased dropdowns in rheological properties and elastic behavior in R20 as seen in the v-GP plot due to polymer degradation and increased carbon black content (see *Figure 1B).*[1]

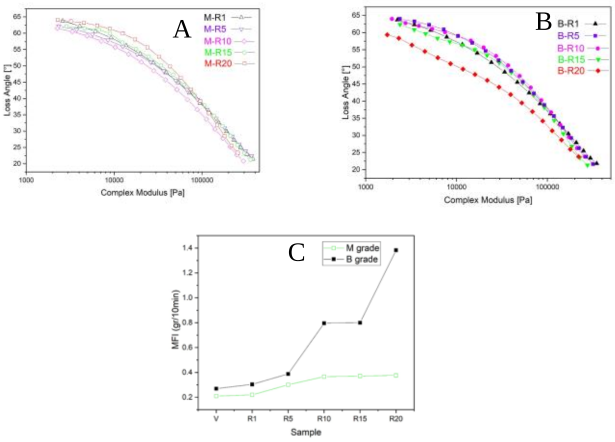

Figure1. (A) van Gurp-Palmen (v-GP) plot of neat grade (M-R1, M-R5, M-R10, M-R15, and M-R20) , (B) black grade , (C) MFI

A comparison of the melt flow index (MFI) showed less degradation and an increase in the MFI for the neat grade, whereas the black grade showed a more significant increase at R20 (see *Figure 1C).*[2]

Conclusion

The rheological analysis of mechanically recycled polymers showed significant changes in viscosity, elasticity, and structural behavior over multiple recycling cycles. The trends observed in the van Gurp-Palmen (v-GP) plots indicate the formation of long-chain branching, which is caused by the generation of free radicals during the recycling process. The melt flow index (MFI) analysis confirmed increased degradation in the black grade at the 20th recycling cycle (R20), while the neat grade exhibited improved melt flow properties.

References

[1]J. Zhang *et al.*, "Effect of mechanical recycling on molecular structure and rheological properties of high-density polyethylene (HDPE)," *Polymer (Guildf).*, vol. 297, p. 126866, Mar. 2024, doi: 10.1016/j.polymer.2024.126866.
[2]H. Ghadami Karder, G. Pircheraghi, and A. Rezaei Ghare Baghlar, "Degradation of high-density polyethylene (HDPE) exposed to chlorine dioxide-containing water: The effect of co-monomer and crystalline structure," *Polym. Degrad. Stab.*, vol. 232, p. 111154, Feb. 2025, doi: 10.1016/j.polymdegradstab.2024.111154.