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Characterization of Properties of Virgin and Recycled High-Density Polyethylene under Cyclic Loading

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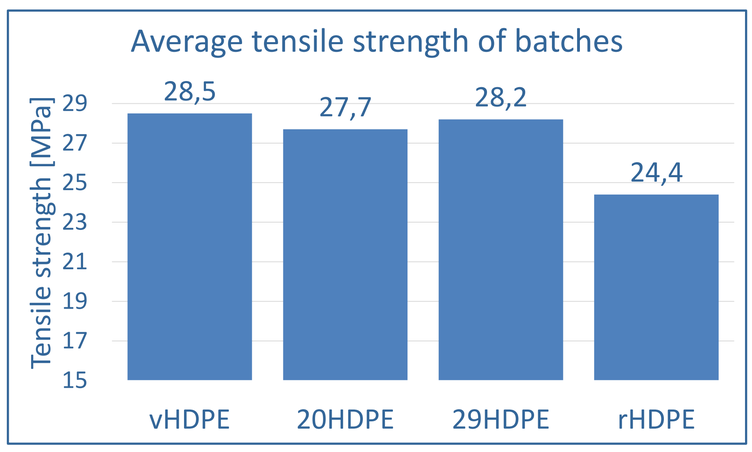
1. Introduction

For manufacturing usage, it is observed that the utilization of recycled HDPE (rHDPE) produces degraded products compared to virgin HDPE (vHDPE) products. Its nature can be investigated via short-term testing.
The focus of this project is to quantify differences between vHDPE and post-consumer rHDPE under cyclic loading, to achieve a higher confidence in material properties than found in tensile tests. By producing blends of vHDPE and rHDPE of different concentrations, the trend of material properties can be further distinguished.
Furthermore, rheometry and differential scanning calorimetry (DSC) experiments were carried out in order to research the thermal and rheological characteristics of the HDPE batches.
The composition of each injection molded HDPE batch used for further testing is listed in the following table with corresponding nomenclature:

Batch	% rHDPE	% vHDPE
vHDPE	0	100
20HDPE	20	80
29HDPE	29	71
rHDPE	100	0

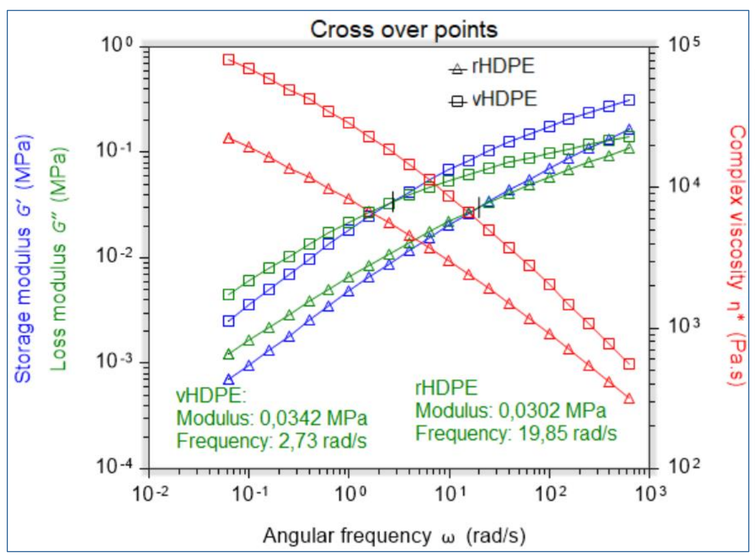
2. Experimental

Tensile testing of the produced specimens showed a minimal change in tensile strength between the batches, supporting the need for a more sensitive mechanical testing method.



Differences in the degree of crystallinity of the material can indicate possible changes as a result of production or recycling. DSC testing of vHDPE and rHDPE at a temperature range of 20°C to 300°C showed no changes in crystallinity due to injection molding, as well as no difference between the granulates used for production of the two batches.

Via rheometry testing, a polymer's mechanical properties can be correlated to its viscosity and its average molecular weight. There were no indications of degradation due to injection molding. The vHDPE specimens exhibited higher molecular weights than rHDPE, corresponding to stronger mechanical properties.

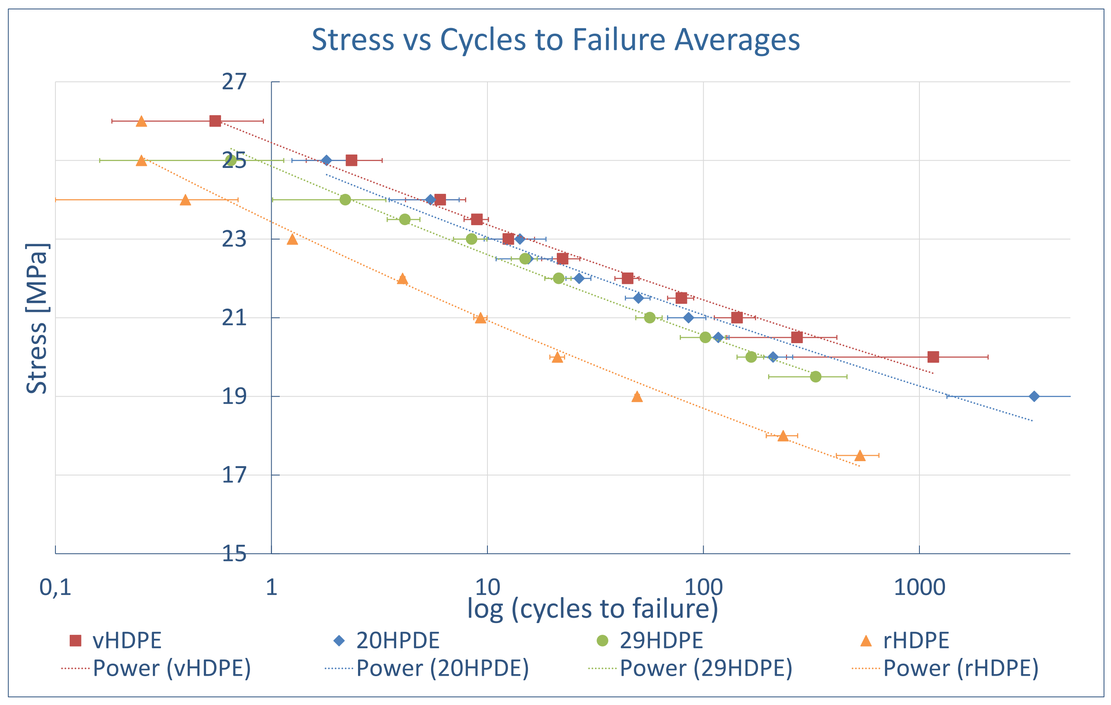


3. Cyclic Loading

Cyclic loading was performed until sample failure at a range of stresses between 17,5 MPa and 26 MPa, using a sinusoidal loading mechanism. Test data from cyclic loading was fitted using the following power law description:

$$\sigma_f = A \cdot N_f^b$$

Where σ_f is the failure stress, N_f is the number of cycles to failure at the given failure stress, and A and b are constants that depend on the batch. From this relation, model failure stresses for each batch can be calculated at a theoretical 50-year service lifetime.



Analysis of the collected data from cyclic loading shows 20HDPE and 29HDPE with trends significantly closer to vHDPE than rHDPE.

The rHDPE is distinguished by higher strain in fewer cycles than the vHDPE, 20HDPE and 29HDPE. From stress-strain curves during cyclic loading the stiffness of rHDPE decreases more rapidly as the number of cycles increase, which is a display of fatigue damage.

4. Conclusion

DSC showed no significant indications of degradation of rHDPE with regard to the vHDPE. Rheometry testing showed a lower average molecular weight for rHDPE than vHDPE supporting the weaker mechanical properties seen from tensile testing.

From the S-N curve, a significant difference of approximately a decade in the number of cycles for a given maximum stress was seen between vHPE and rHDPE. For a number of cycles to failure of N_f = 1000, corresponding to the tested stresses, the difference in fatigue stress between vHDPE and rHDPE proved to be 18%. Using the power-law to predict fatigue strength after 50 years, the difference increased to 36%. Thus, the cyclic loading results displayed increased sensitivity compared to tensile test results.

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