REPORT

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Effects of reprocessing of P-Life material with LDPE on the durability of the recycled materials

Background and aim

For the plastic waste management, mechanical recycling is of particular interest. It is therefore important for the producers of oxo-biodegradable materials to be able to supply relevant and scientifically based information on the effects of such materials on mechanical recycling of commodity plastics.

The aim of this investigation was to provide information about effects of unintentional incorporation of the P-Life oxo-biodegradable material into the regular plastic waste.

Commission

The investigation was conducted on the effects of mixing P-Life oxo-biodegradable material with low-density polyethylene (LDPE). The study was particularly focused on evaluation of the remaining service life of the recyclates using accelerated ageing tests. The effects of accelerated ageing were evaluated using measurements of mechanical strength and carbonyl index.

Materials

All materials were manufactured by SP Technical Research Institute of Sweden using a micro-compounder (DSM Xplore 15) as 40 mm wide and 50 µm thick strips for testing. The reference material used was Borealis LDPE designated CA8200. The P-Life material was mixed with the reference material at the ratio of 10 and 20 %. The reference LDPE was used in its original form as unstabilized as well as stabilized with 1000 ppm Irganox 1010. In addition to the mixtures of the pristine P-Life material, a mixture of 10 % pre-oxidized P-Life material with stabilized LDPE was produced and evaluated by the same procedure.

Accelerated aging

Thermo-oxidative degradation was performed on pre-cut test strips (10 mm wide) from each material in heating cabinets with low air flow at 70 ± 1 °C. After various periods, one set of the test samples (5-8 strips) was removed for testing of elongation at break and analysis by infrared spectroscopy.

Tensile testing

The tensile strain at break was determined based on standard ISO 527-3:1995 Plastics – Determination of tensile properties – Part: 3 Test conditions for films and sheets. The machine used was Zwick Z100 (Zwick GmbH & Co. KG, Ulm, Germany) equipped with a static load cell ± 100 N with force accuracy class 1 and elongation accuracy class A according to the standard ISO 5893. The initial grip-to-grip separation was 50 mm, the pre-load 0,1 N and the crosshead speed was set to 50 mm/min. Conditioning and testing was performed at standard atmosphere (23±2 °C and 50±10 % RH). The test specimens were conditioned for at least 2 h prior to the testing.

FTIR (Fourier Transform Infrared Spectroscopy)

The carbonyl formation during the heat aging was monitored by FTIR using a Nicolet 6700 FT-IR instrument (Thermo Scientific, Waltham, MA, US). The analyses were performed by collecting spectra (32 scans) from the films using a micro-ATR. The carbonyl index was calculated as the peak intensity ratio between the carbonyl peak at1712 cm^{-1} (terminal ketones) and a reference peak at 1472 cm^{-1} (-CH_2- groups). The carbonyl indexes are calculated as average values from at least two spectra from each sample.

Results

The service life of polyethylene is normally determined by its oxidative stability. The rate of oxidation at 70 °C was determined following changes in elongation at break as a function of exposure time. The results of the heat ageing tests using mixtures of the P-Life material with LDPE are summarized in Figure 1 and 2.

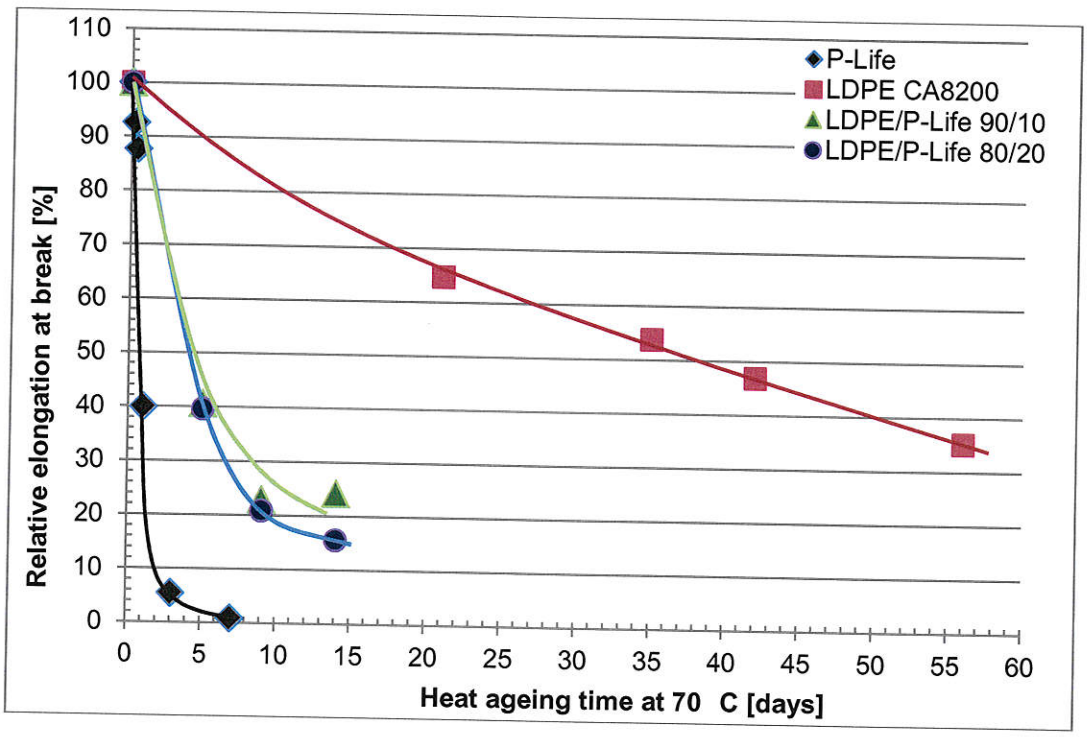

Figure 1. Effect of heat ageing at 70 °C on unstabilized films composed of LDPE and P-Life

It is demonstrated that the unstabilized LDPE without any prodegradant starts to degrade immediately and after about 38 days at 70 °C the elongation at break is reduced to 50 % of the original value. The corresponding value for the pristine P-Life material is one day. When the P-Life material is mixed with unstabilized LDPE, the 50 % reduction of elongation at break is obtained after 3 to 4 days which is most probably the result of prodegradant dilution.

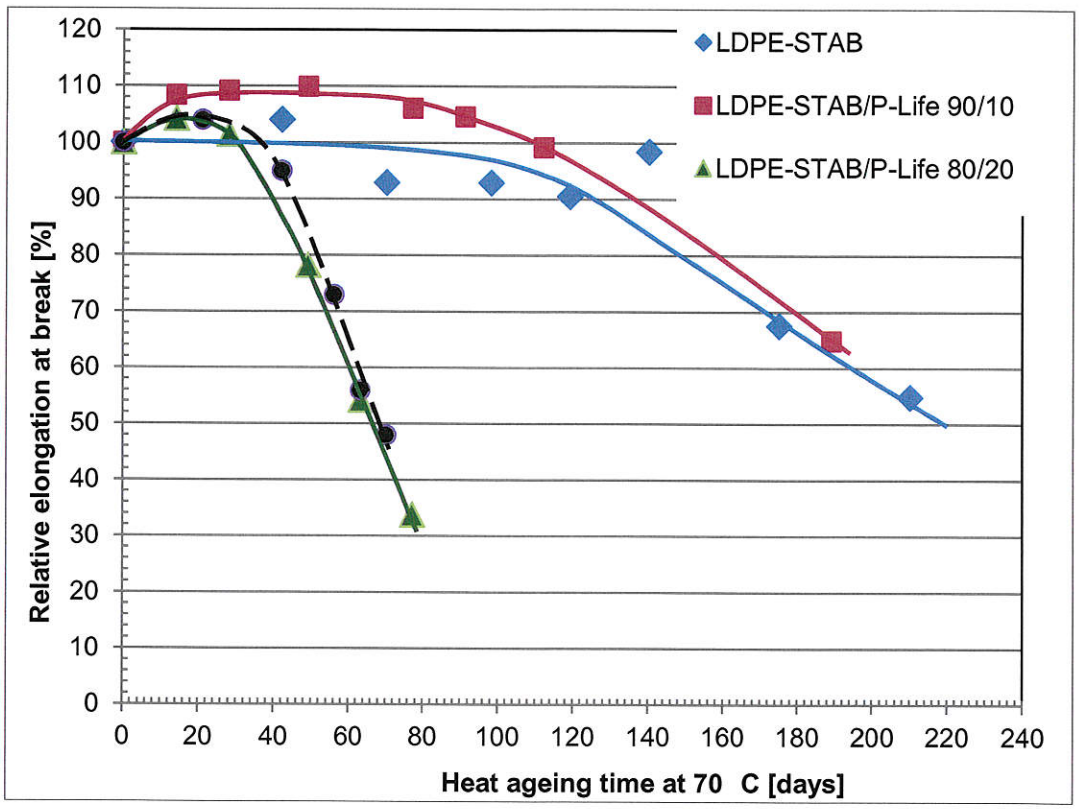

Figure 2. Effect of heat ageing at 70 °C on stabilized films composed of LDPE and P-Life

Equivalent investigation was conducted using stabilized LDPE. The elongation at break of the reference LDPE stabilized with 1000 ppm Irganox 1010 decreased to 50% after 224 days of heat ageing at 70 °C. Almost the same result was obtained with the mixture of stabilized LDPE and 10% P-Life material. When 20% P-Life material was used, the time to 50% reduction of elongation at break was reduced to 67 days. It must be emphasized that the reduction in the lifetime is not only due to the addition of the P-Life material but also to the fact that the content of stabilizer is reduced by 20% when 20% of an unstabilized material is added.

The oxidation process of the materials was also studied using FT-IR by monitoring the carbonyl index (CI). CI for aged mixtures of P-Life with unstabilized LDPE displays a steady increase over time (Figure 3). Similar behaviour is observed for the original unstabilized LDPE material. It is also seen that the time until oxidation occurs is related to the content of P-Life material in the mixture thus the material containing 20% P-Life displays the fastest increase in CI.

The corresponding curves for the mixtures with stabilized LDPE show a different behaviour as the CI remains low at shorter exposure times and then increases rapidly (Figure 4). This behaviour is attributed to the presence of the stabilizer which keeps the carbonyl formation low. Upon consumption of the stabilizer, the samples undergo rapid oxidation. When examining the mixture containing the pre-oxidized P-Life material, it is seen that this material

displays a shorter oxidation period compared to the mixture with pristine P-Life material. This is attributed to the partially oxidized material causing faster consumption of the stabilizer and being more susceptible to further oxidation.

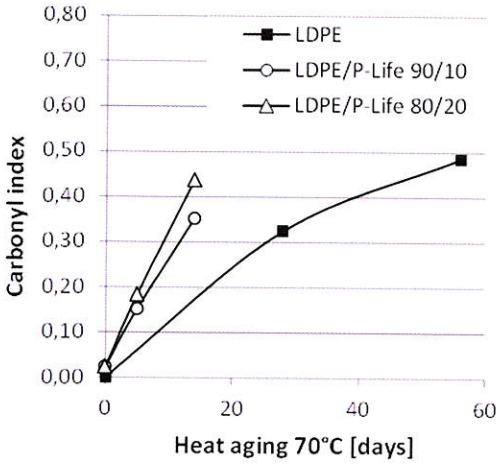

Figure 3. CI for unstabilized materials

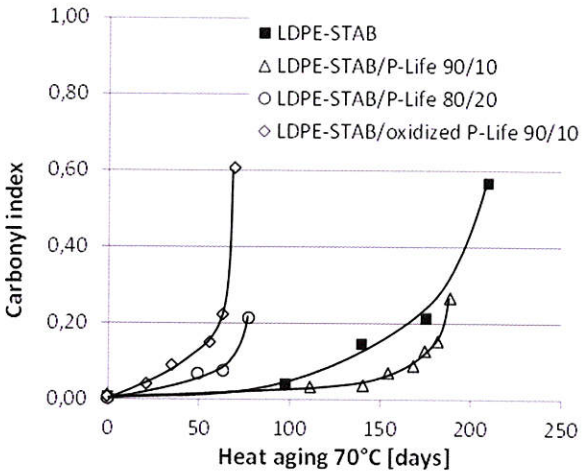

Figure 4. CI for stabilized materials

Conclusion

Assuming 80 kJ/mole as activation energy it can be calculated that the stabilized LDPE as well as the mixture with 10% P-Life will have the lifetime of more than 50 years at room temperature. The corresponding lifetime for the mixture with 20% P-Life as well as with 10% pre-oxidized P-Life material will have the lifetime of more than 15 years. It is therefore concluded that the incorporation of minor fractions of the P-Life material in the existing recycling streams will not present a severe effect on the stability of the recyclates, as long as the polymer mixture possesses a reasonable degree of stabilization.

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