Recycling of Cheap Packaging Waste versus Expensive Engineering Materials

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Abstract: The economical incitement is larger for recycling of expensive engineering materials than for packaging plastics. It should, however, be possible also for municipal waste industry to profit from recycling of packaging waste. At present, municipal waste plants already sell sorted plastics fractions on the order basis. The degree of mixing of these plastic fractions is the key question to be solved in order to obtain a high-quality product. The value of recycled HDPE fraction is lowered if it contains impurities of other polymers, e.g. PP, PS or PET because such impurities cause embrittlement. An addition of an impact modifier to contaminated HDPE was analyzed with respect to changes in morphology and mechanical properties. Oxidative stability of the polymer matrix decreased as a result of recycling, indicating decomposition of heat stabilizers, as shown for polyamide 66. The relation between expensive/cheap recycled plastics is discussed based on their long-term properties.

INTRODUCTION

Plastic recycling becomes more and more important in various industrial sectors. It is a topic of high priority, e.g. in automotive industry, due to its large consumption of plastics. Sweden has taken an action to increase the recycling of materials by the producer liability law (1994). It requires that the producer of a material has the responsibility to collect and handle the material after use.

The collection and sorting of plastic waste are critical steps in recycling. In many instances, manual separation is used, which is, however, not desirable from the economical and health viewpoints. Separation of plastics in individual streams is done by manual separation, density discrimination, digital colour image processing, and near and middle infrared spectroscopy (NIR, MIR). In European projects, we study factors affecting recycling of municipal solid waste factors to enable the construction of electrostatic separation plants (1).

In contrast to recycling of used products, in-plant recycled materials are generally not contaminated and have a well-specified composition. For some standardized applications with high requirements for performance, there exist restrictions to the permitted percentage of in-plant regrind in new products, although the degree of contamination is negligible. This is in

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particular the case in engineering applications and is attributable to uncertainties about long-term properties of new products. Recycled plastics will find acceptance as packaging and engineering materials only if plastic properties are guaranteed. The present paper will discuss long-term properties of recycled plastics with particular emphasis on service life and contamination.

EXPERIMENTAL

As examples of expensive engineering plastics, commercial grades of polyamide 66 (PA 66)-based resins, unstabilized unreinforced resin and heat-stabilized material reinforced with 30 wt.-% of short glass fibres were used (2). HDPE is discussed as an example of a cheap plastic which is a major part of packaging waste. Two EPDM polymers were evaluated as impact modifiers to upgrade recycled HDPE (3).

RESULTS AND DISCUSSION

The demand for recycled plastics is a function of their quality/benefit ratio in comparison with alternative products (4). The producer's liability is an important task in the complex question of recycling of polymers. Due to high quality requirements for durability and reliability, only limited quantities of engineering plastics are currently recycled. For packaging waste, this is done in plants, but recently collection and separation of hard and soft plastic packaging have started in the Stockholm area. On the order basis, manual separation is done and fractions of PP and HDPE are sold. These fractions may contain 1-20 % of contamination of other polymers, e.g. PS or PET. The costs of separations tend to increase if a high-purity plastic fraction is desired. It is therefore essential to know how impurities influence the performance of the materials and how negative effects of impurities might be diminished. Figure 1 shows the frequency sweeps at 190 °C for neat HDPE and blends with PP, PS or PET. At 190 °C, PET is present as solid particles, causing the viscosity of the HDPE melt to increase, markedly so at low frequencies (3). The rheological behaviour of a blend such as the one described above will be significantly affected by its thermal and shear histories.

It was demonstrated that using impact modifiers of the EPDM type, a blend consisting of HDPE with 4 % PS and 2 % EPDM has almost the same tensile impact strength and elongation-at-yield as neat HDPE, i.e., the negative effect of PS on these properties was compensated by about half the amount of EPDM at the expense of reduced modulus and yield strength (3).

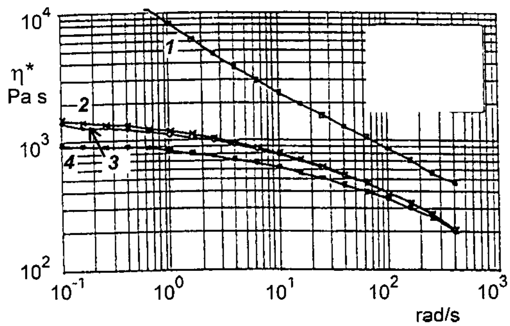

Fig. 1 Complex viscosity during frequency sweeps at 190 °C for neat HDPE (*1*) and blends with 80 % HDPE and 20 % PP (*2*), PS (*3*) or PET (*4*)

The degree of degradation of recycled plastics determines the quality and possible usability. Hence, service-induced and process-induced degradation of polyamide 66 were analyzed. Figure 2 shows the relative surface carbonyl content in unreinforced test bars based on unstabilized, unstabilized and re-extruded, or heat-stabilized polyamide 66 as a function of thermal ageing at 110 °C.

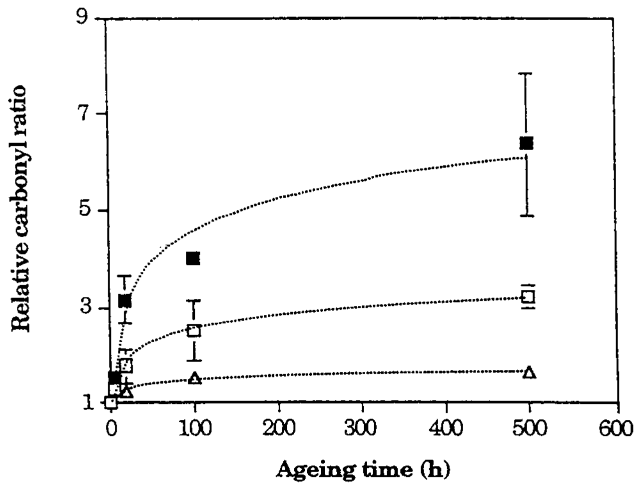

Fig. 2 Relative surface carbonyl content in unreinforced test bars based on unstabilized polyamide 66 (□), unstabilized and reprocessed polyamide 66 (■), and heat-stabilized polyamide 66 (Δ) as a function of thermal ageing at 110 °C

The relative carbonyl content increases as a result of ageing due to oxidative degradation. Re-extruded samples exhibit the largest increase in the carbonyl content, heat-stabilized samples show only a slight increase. The recycling process does contribute to the overall degradation of materials. Significant degradation is observed when increasing the number of recycling steps, but by adding new antioxidants and stabilizers to the recycled plastics, it is possible to get good service life of the new product made of recycled materials (2). New functional groups formed in the course of processing and first-life application enhance the sensitivity of the recyclate to thermal and photodegradation (5). Up-grading the recyclates is therefore necessary and all common antioxidants and stabilizers are useful in that context.

Plastics recyclates often contain contamination of different origin. In reprocessed HDPE, 70 compounds with concentrations above 0.5 μg/g were identified (6). Aromatic substances and preservatives were found in the range of 0.5 to 10 μg/g. Limonene and di(2-ethylhexyl) phthalate were detected in concentrations up to 200 μg/g (6). Protection of food from direct contact with recycled polymers is achieved by using a functional barrier made of virgin polymer (7). The efficiency of the functional barrier in reducing the migration of low-molecular-weight compounds is related to its thickness.

The key question for all uses of recycled plastics is the possibility of producing high-quality materials with predictable service life at prices which are competitive with virgin polymers. Deterioration of polymer properties during the use and reprocessing are factors which reduce the life-time of products made of recycled materials. Migrating low-molecular-weight compounds decrease the life-time and may also be harmful. The Food and Drug Administration (FDA) has proposed definitions and practical means for recycled materials in contact with food (8).

CONCLUSION

Long-term properties of recycled polymers are a function of degree of degradation during their first life and reprocessing, and also of contamination. The market for recycled "expensive" engineering plastics and "inexpensive" packaging waste is dependent on the degree of automatization in the course of collection and separation of mixed fractions and the quality of the recyclates. Designing recycling increases the possibility of easy separation of engineering plastics in, e.g., automotive applications.

ACKNOWLEDGEMENTS

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