rPET Blends for High Standards

Production of Injection-Moldable PET-Blends from Mixed Plastic Fractions

PET recyclates from different materials and colors pose big challenges for recyclers. Together with the University of Applied Sciences Magdeburg-Stendal, Germany, MultiPet GmbH is researching into injection-moldable blends that can be used to produce high-quality multi structured injection-molded parts from mixed PET. Only in the area of recycled clear PET samples the desired property profile was not achieved.

Colorful mixture: the recycling of mixed fractions from bottles, blisters and trays remains a major challenge

Compared to single-sorted PET bottles, the recycling of mixed PET fractions (bottles, blisters, trays, etc.) from the dual system is significantly more demanding.

Which Problems the Processing of Mixed PET Fractions Entails

Due to the large number of impurities, compound components and other plastics in PET mixed fractions, as well as the impairment of the PET through degradation that has already occurred, a number of difficulties can arise by recycling this material.

- PET can absorb a significant amount of water, which has to be extracted by thorough drying, to prevent a hydrolytic degradation during the compounding process.
- During the processing of the secondary raw materials (sorted mixed PET fractions) into flakes, a mixture of all dyes and pigments occurs, which remain in the blend after the compounding process and lead to a grey to brown mixed color.
- When PET recyclates are used in new products, additives like oxygen scavengers can lead to a yellowing effect due to the renewed thermal stress. Since all fillers also remain in the flakes after processing, opaque material can be the result after remelting.
- It is unknown how the variety of additives in the different types of plastic interact with one another and pander a degradation of the PET.
- The recycler does not know which types of other plastics are added in the mixed PET.
- The mixture can contain parts of polyamides (PA) as well as unwanted impurities which lead to degradation indications during the processing.

Accordingly, there are currently no commercially used material recycling options for PET mixed fractions. The aim is therefore to produce a recyclate from post-consumer PET plastic mixed fractions using suitable compatibilizers, which can be used for injection molding applications.

Desired Technical Functionality

The injection-moldable PET blend to be developed must show a certain technical functionality and has to be optimized accordingly. An intrinsic viscosity in the range of [n] = 0.7 dl/g to 0.8 dl/g of the PET types is to be aimed. The use of suitable compatibilizers should, by reducing the interfacial energy, lead to the finest possible distribution of the foreign plastics and thus a large surface area and preferably improve the impact strength/notched impact strength. Furthermore, the crystallization properties have to be adapted to the conventional PET in- »

jection molding type and may have to be adjusted by adding nucleating agents. The mechanical properties of the PET blends should correspond to those of commercial PET injection molding materials.

Sampling and Characterization

In the course of the selection and characterization of the required materials, quality analyses of the mixed PET 50/50 (328–3) and mixed PET 70/30 (328–2) specification were carried out. In the analysis, the fractions "other dimensionally stable PET packaging" were itemized into trays, trays with peeling film, and blisters and the existing fractions were separated into the food and non-food areas. The extracted samples of the sorted fractions were subsequently examined by means of Differential Scanning Calorimetry (DSC), Melt Flow Index (MFI), and roast test. On the basis of the results of the quality analysis a cadaster was created. This cadaster contains the mass distribution of the recyclable plastic in relation to the foreign materials and impurities found in the individual sorted fractions of both specifications as well as their belonging to the food or non-food area.

Expansion of the Recyclables Chain and Processing

Obstacles to the use of recyclates can be caused by material and process engineering factors such as discoloration, fine stone inclusions (black spots), IV degradation (intrinsic viscosity), etc. Due to the strong molecular weight loss of the post-consumer PET (PCPET), these were enriched with different additives in the extrusion process. In the further process, the created rPET blend compounds were injected into multi-purpose test rods and tested for their material properties. Small quantities were examined by means of DSC and MFI.

On the basis of the results, the appropriate additives and their required quantity were determined. At typical processing temperatures, the chain fragments react to linear and cyclic oligomers and fragments containing carboxyl groups in turn catalyze the decomposition process. These reactions have a negative effect on the viscosity and lead to a deterioration of the mechanical properties.

Due to the different additives of some of the already degraded post-consumer PETs, no fixed time value for pre-drying could be assumed. Furthermore, the residual moisture content of the samples was continuously checked, until the desired target value was reached. This process served to ensure that surface defects as well as further hydrolytic degradation and the appearance of streaks on the products are avoided. The production of the multi-purpose rods was based on the criteria of the respective DIN regulations, to ensure the comparability and reproducibility of the results.

After completion of the test specimen, those were checked for scratches, twists, gaps, sink marks and burrs. These were additionally checked via straight edges and flat plates.

Samples with deviations were excluded from the test and replaced by new ones. Until testing, the multi-purpose rods were protected in airtight containers from environmental influences, to prevent distortion of results. According to ISO 291 all test specimens were conditioned for 16 hours at 23 °C and 50 % relative humidity prior to testing.

After Injecting the Test Rods, Analysis and Optimization Follows

To characterize the properties of the post-consumer PET compounds, they were investigated in terms of their mechanical properties (tensile, flexural and impact tests) and in relation to their melt volume flow rate (MFR), intrinsic viscosity (IV) as well as physical and chemical transformation processes (DSC).

Highly reactive chain extender additives were used to counteract the degradation process during the processing. Phase mediators were used for finely dispersed distribution and phase mediation of the impurities within the matrix. By adding polycarbonate, the impact strength, flexibility and the desired crystallization behavior should be controlled.

On the basis of the results it was possible to determine that:

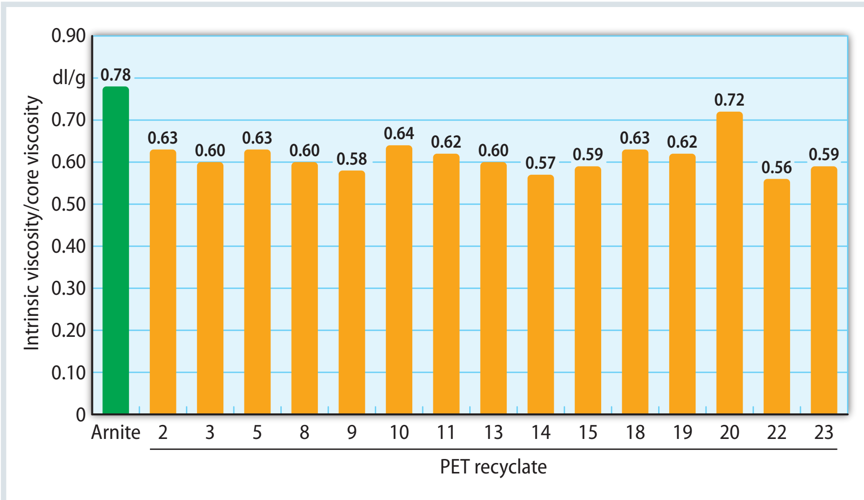
- the tensile modulus of the rPET blends with a quantity content of 20 % poly-

Bales of the specification mixed PET 70/30: during the material analysis the material was divided into the fractions other dimensionally stable PET packaging, trays with and without peeling film and blisters

© MultiPet GmbH/Veolia

rPET blend compound and injected multi-purpose test rods

© MultiPet GmbH/Veolia



Comparison of the intrinsic viscosity of PET blends and PET arnites Source: MultiPet GmbH/Veolia; graphic © Hanser

carbonate roughly corresponds to that of a high-performance material,
- the tensile strength and elongation at break are greatly increased by the addition of 1% SEBS maleated maleic acid anhydride,
- the flexural modulus and flexural strength are greatly increased by the addition of 1% ethylene-octene copolymer maleic anhydride,
- the impact strength of the blends is greatly increased by enrichment with approx. 1% oligomeric chain extender and
- the intrinsic viscosity of all measured blends is below the required value of 0.7 dl/g.

On the basis of the available results the following optimizations were made:
- addition of different epoxy-based chain extenders,
- use of a combination of polycarbonate and chain extender variants in different concentrations,
- addition of a combination of polycarbonate and several different chain extenders in different concentrations.

In the Practical Test, the rPET Blend with Polycarbonate Performs Best

Of the blends tested, the rPET blend with a significant amount of polycarbonate consistently achieved good results in all mechanical tests carried out. All other blends showed deficiencies especially in the tensile modulus and did not reach the stiffness of the reference plastic. The intrinsic viscosity of the rPET blend with polycarbonate was 0.63 dl/g, which was below the targeted property profile with a required intrinsic viscosity of conventional PET injection molding grades of 0.7 to 0.8 dl/g.

The rPET blend with polycarbonate and a special multifunctional reactive polymer recorded an increase of the IV to 0.72 dl/g. The blend is very suitable for injection molding and exhibited consistently high product qualities, which roughly correspond to the desired property profile of commercially available virgin PET. The material used (rPET) is suitable even for the production of finely structured components. Neither optical nor haptic differences can be perceived between the products made from virgin material and recycled material. Moreover, the mechanical properties of both products are at the same level.

In the further process, the already recycled clear PET fraction samples (bottles, trays and blisters) were examined for their properties. The fractions of trays and blisters recorded comparatively low performance in terms of mechanical properties. None of the tested fractions corresponded to the targeted property profile with an intrinsic viscosity of 0.7 to 0.8 dl/g. In particular, the fraction of peels from the food sector, which were coated with peeling film, achieved the lowest intrinsic viscosities of 0.52 and 0.53 dl/g. The results obtained provided indications as to which fractions potentially reduce performance in recycling. ■

Forward thinking: application examples for multi structured injection molded components made from mixed PET

© IKTR

The Authors

Anke Schadewald has headed the Institute for Plastics Technology and Recycling e. V. (IKTR) in Weissandt-Gölzau, Germany, since 2006;
anke.schadewald@iktr-online.de

Prof. Dr.-Ing. Gillian Gerke has been a professor in the WUBS department at the University of Applied Sciences in Magdeburg-Stendal, Germany, in the fields of resource management, life cycle assessment and international waste management since 2012. As team leader of the "Raw Materials Workshop" task force, she works in depth in the plastics recycling field.

Thomas Plumbohm is a project member in the work group "Raw Materials Workshop" at the University of Applied Science in Magdeburg-Stendal.

Dr.-Ing. Herbert Snell is managing director of MultiPet GmbH (Veolia), which has been recycling PET material from the deposit system and household collections for 20 years.

Service

Digital Version

- A PDF file of the article can be found at *www.kunststoffe-international.com/archive*

German Version

- Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de*