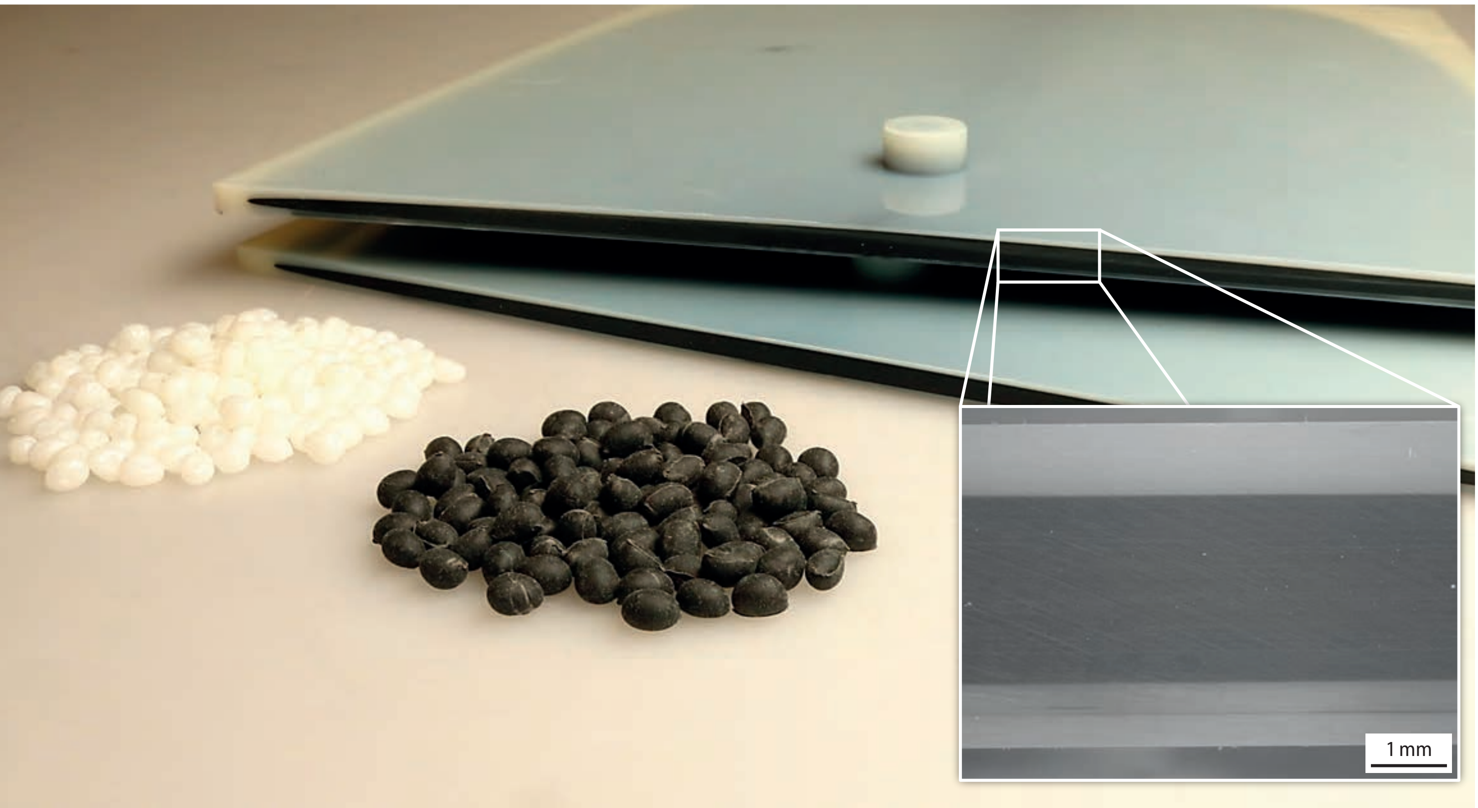
Part 1: How Innovative Technologies Are Paving the Way for the Widespread Use of Recyclate

Fit for the Circular Economy

The motivation to further increase the use of recyclates comes from many quarters: industry, consumers and legal requirements. The primary goal is to minimize CO_2 emissions. Therefore, when developing new recyclate processing technologies, Engel always keeps an eye on the energy consumption – and also the costs. After all, the circular economy only has a chance if it is energy efficient and affordable.



To determine the potential of skinmelt technology, plate-shaped parts were injection molded. Various PCR ABS grades (black) were combined with ABS virgin material (white). The sandwich structure can be seen in the plate cross-section. © Engel

Processing recyclate still too often means downcycling. In this case, the treated plastic wastes are processed into products that are subject to lower requirements than the original products from which the recyclate was obtained. However, the effect is that material cycles cannot be completely closed. The aim is therefore to produce high-quality products from recyclate, resulting in at least genuine recycling, if not upcycling. Engel is paving the way for this with innovative processing technologies.

Concealing Recyclate in Virgin Material in the Sandwich Molding

Sandwich injection molding makes it possible to develop parts with high recyclate content without the recyclate being visible or noticeable on the part surface. In the so-called skinmelt process – Engel markets a variant of sandwich injection molding under this name – the recyclate and virgin material are plasticized in two separate injection units and then injected into the cavity together. This allows the process to be controlled like a standard single-component injection molding process. Despite the second material component, the injection molding machine remains easy to operate. Changeover marks are a thing of the past.

In contrast to traditional co-injection, in the skinmelt process, the two melts are layered even before they are injected consecutively into the main injection barrel. The skin material, i.e. the virgin material, reaches the cavity first. It is displaced by the incoming stream of recycled material and pressed against the cavity wall, while the recycled material fills the core. The proportion of recycled material that can be achieved is largely determined by the part geometry and the cavity filling pattern. The chosen gate position and the viscosity ratio between skin and core material play a major role here. In this machine configuration, the second plasticizing unit for the skin material is mounted at a shallow angle above the horizontal injection unit, in which the recyclate is melted. This design is particularly compact (**Fig. 1**).

Another unique feature of the Engel solution is that the entire process is visualized as an animated display in the injection molding machine control unit (CC300). The mixing ratio can be very finely adjusted to optimize the proportion of recyclate.

Fig. 1. For the skinmelt process, the second plasticizing unit for the skin material is mounted compactly at a shallow angle above the horizontal injection unit, in which the recyclate is melted. © Engel

Up to 50 Percent Processing Post-Consumer Recyclate

Engel, together with Neue Materialien Bayreuth and Ineos Styrolution, has investigated the potential of skinmelt technology. Based on the overall part volume, up to 50% rABS from post-consumer recycling could be processed in the core without impairing the mechanical properties and, of course, without this being visible at the surface (**Title figure**).

As part of the research cooperation, plate-shaped parts were first injection molded with sequential co-injection molding as well as with the skinmelt process, and sorting boxes were molded in a further step. As skin component, various virgin ABS grades with different material properties – up to high impact strength – were used. For the production of the crates (**Fig. 2**), an Engel duo 450 injection molding machine and a mold from Bito-Lagertechnik Bittmann were used. The main unit consisted of a barrier screw with a diameter of 80 mm, the second unit, of a standard screw with 70 mm diameter.

The injection molded products were tested for their tensile strength, flexural strength and Charpy notched impact strength. It was found that the sandwich products are better, i.e. obtain higher values than the parts made of pure rABS. Compared to parts made entirely of virgin material, the mechanical material properties are retained (**Fig. 3**).

The joint research work showed that, with both the classical sequential co-injection process and the skinmelt process, it is possible to produce high-quality, geometrically complex parts with a high proportion of ABS regrind (up to 50% of the core component). This opens up new applications and fields of use for the material recycling of ABS.

For developing the circular economy, it is important to process only one material type in each case. The monomaterial approach ensures that the sandwich parts can be recycled at the end of their useful life.

The Two-Stage Process Saves Repelletizing and a Lot of Energy

Engel even goes one step further with the two-stage process, in which only recycled material is processed. The difference from other recyclate processing methods consists in the fact that the material does not need to be pelletized, but the flakes can be processed directly. This eliminates a complete plasticizing step, which saves considerable amounts of energy and CO_2 emissions and also reduces recycling costs. The prerequisite for this is that the injection molding machine takes over important functions of the repelletizing system. This mainly concerns filtration and degassing (**Fig. 4**). Engel presented the new two-stage process at K 2022, attracting great customer interest. Now, such machines are available in various sizes.

The effectiveness of the technology had already been confirmed in laboratory tests. The results are particularly promising as regards the degassing performance. In a joint project with Pöppelmann Kunststoff-Technik, Engel, at its pilot plant at the St. Valentin site in Austria, produced parts on a two-stage machine, from flakes originating from the Yellow Bag (local waste disposal). The base material was PP, though a small proportion of PE and contamination with aluminum and EVA were detectable (**Fig. 5**). »

Fig. 2. This sorting box, too, contains post-consumer rABS in the core. © Engel

On a two-stage machine based on an Engel-duo injection molding machine, base plates for battery housings with a shot weight of about 500 g were manufactured in a two-cavity mold (**Fig. 6**). The released gases were extracted using a vacuum pump from Busch; mesh filters in various finenesses were used for filtration.

The machine offers the possibility of fully automatically controlling the amount of material fed to the injection screw. This is performed by setting a so-called degree of feeding. If the machine operator chooses a high feed rate, the metering time is shortened, but the free surface area in the degassing zone is also reduced.

Degassing and Melt Filtration Integrated into Processing

The tests performed make the effects visible. The system was operated with a constant feed rate in each case. The influence of degassing under vacuum and the influence of different filter packages on the emissions of volatile organic compounds (VOC) and low-volatile substances (Fog) were investigated. The results are assessed according to the test specified for cars according to VDA 278 (thermodesorption analysis of organic emissions). This analytical method is used to determine the emissions from non-metallic materials used for vehicle parts. For determination, two semi-quantitative total values are determined, which permit a possible estimate of the VOC and Fog emission values. The samples were thermally extracted; the emissions were separated by gas chromatography and identified by mass spectrometry.

Result of the analyses (**Fig. 7**): The use of the vacuum pump and the resulting negative pressure in the system permit a reduction of the volatile substances by 13 % compared to atmospheric degassing. The proportion of volatile substances could be reduced by as much as 16 % in the tests.

Another parameter influencing the emission values is the fineness of the filter packs. In the test series, two different filter packs were tested. The filter weave for the first test was 200 µm, that for the second, 125 µm. The support

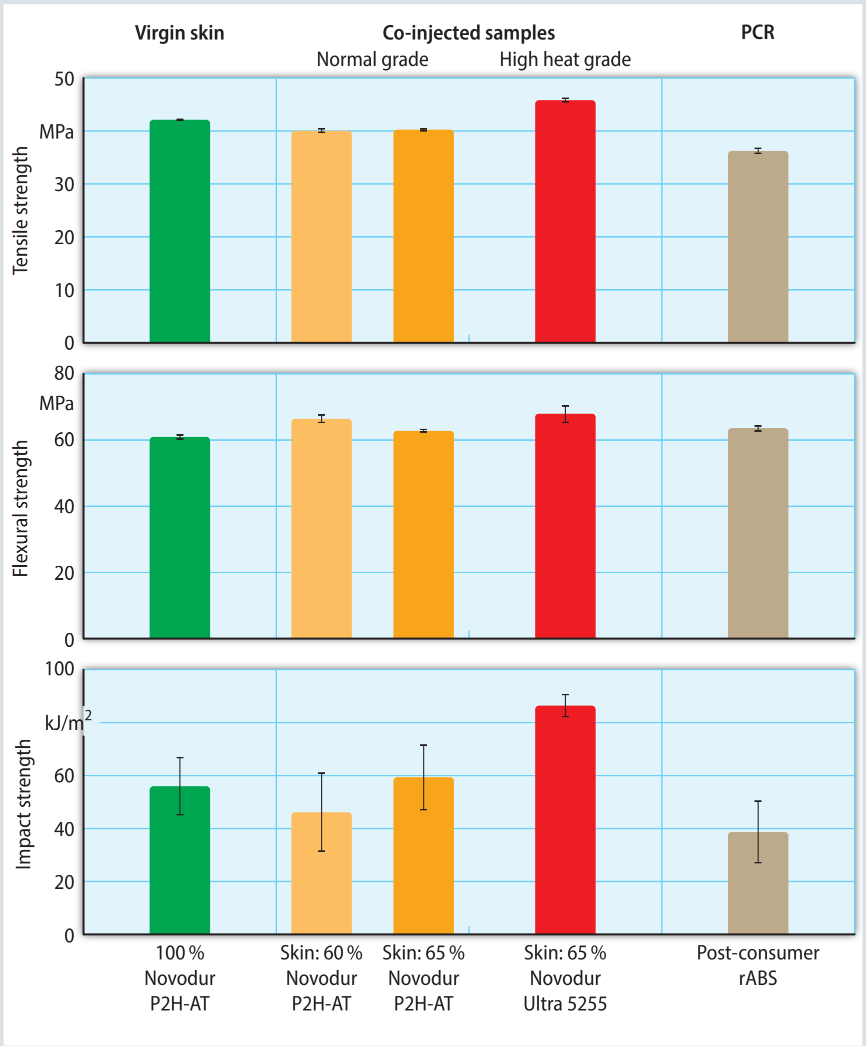


Fig. 3. The injection molded plates were tested for their tensile strength (top), flexural strength (center) and Charpy notched impact strength (bottom). It was found that, compared to parts of 100 % recycled material (PCR), the values of the sandwich products are higher (flexural strength marginally so) and similar to those of pure virgin material. Source: Engel; graphic: © Hanser

Fig. 4. A melt filter and a degassing unit can be connected between the plasticizing and injection units. © Engel

Fig. 5. The two-stage process operates with plastic flakes. For the tests, sorted and washed PP regrind from the Yellow Bag was used. © Engel

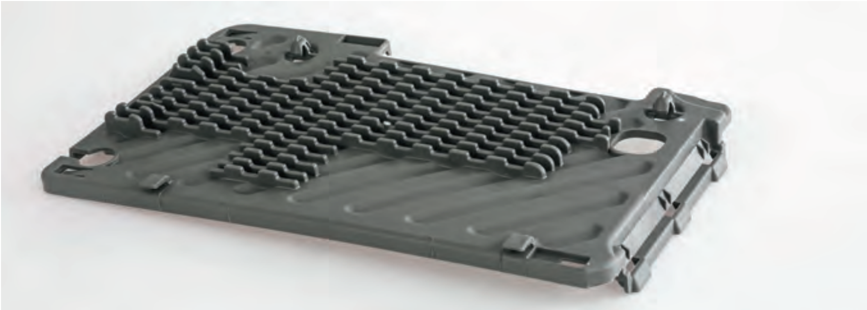


Fig. 6. On a two-stage machine, PP flake (with 10% talc masterbatch) was used to produce base plates for battery housings. © Engel

screens of the filter packs and the machine setting for the feed rate remained unchanged. Degassing was atmospheric. The tests showed that the finer filter weave leads to a better filtration result. The proportion of light-volatile aliphatic and aromatic compounds in the emissions was reduced by 35% and even the low-volatile compounds by 18% (**Fig. 7**).

New Development Brings Recyclates Cost-Effectively into New Applications

The degassing under vacuum and with a fine filter weave can improve both the VOC and Fog values. For an optimum result, however, it is important to coordinate the individual components precisely with one another. The influence of the feed rate is dependent on the metering time; it must be empirically determined for the various experiments. A finer filtration increases the amount of filtered-out emissions, but also increases the risk that the filter will clog. The integration of an entrainer could have further positive effects on the emission reduction, which is tested in further experiments.

The topics of outgassing and odor are also dealt with in further studies. If the melt has not been sufficiently degassed, this can lead to blistering during painting, streaking on the part surface and mold deposits. In addition, health protection requirements must be taken into account.

Based on the developments presented in this article, recyclates – both in the form of regranulate and flakes – will in the future be processed into a large number of high-quality products very cost-effectively in significantly higher amounts, and safe for the environment and human health. ■

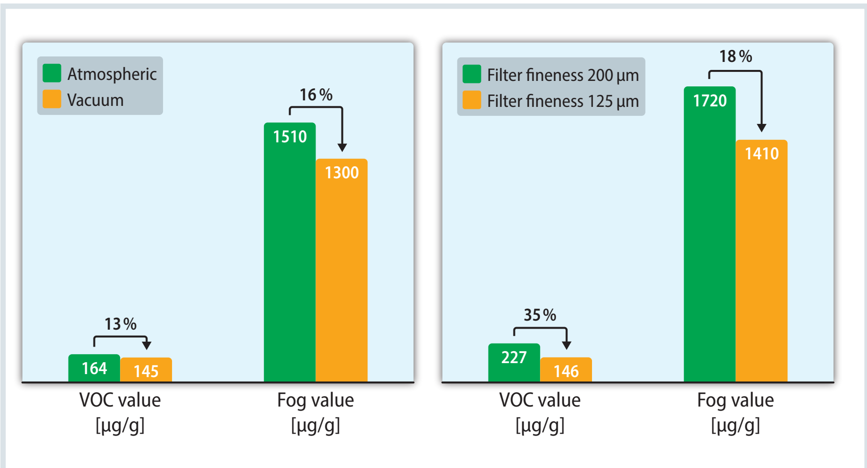


Fig. 7. The degassing type (left) and filter package (right, with atmospheric degassing) determine to what extent the emissions of volatile (VOC) and low-volatile (Fog) organic compounds are reduced. Source: Engel; graphic: © Hanser

Info

Text

Dipl.-Ing. Bianca Gubi is Product Manager for Circular Economy at Engel Austria GmbH, Schwertberg, Austria; bianca.gubi@engel.at
Dr. Thomas Köpplmayr is team leader for process development of plasticizing systems at Engel Austria at the St. Valentin/Austria site; thomas.koepplmayr@engel.at
Dr. Klaus Fellner is head of Application Technologies at Engel in Schwertberg; klaus.fellner@engel.at
Dipl.-Ing. Robin Fachtan is team leader for fiber composites/injection molding at Neue Materialien Bayreuth GmbH in Bayreuth, Germany; robin.fachtan@nmbgmbh.de
Dr.-Ing. Thomas Neumeyer is department head of plastics at Neue Materialien Bayreuth; thomas.neumeyer@nmbgmbh.de
Yvonne van Veen MSSc is Head of Advocacy at Ineos Styrolution Group GmbH, Frankfurt am Main, Germany, yvonne.van.veen@ineos.com
André Grote B.Sc. works in the preliminary development process & material at Pöppelmann Kunststoff-Technik GmbH & Co. KG, Lohne, Germany; AndreGrote@poeppelmann.com
Steffen Meyer M.Sc. is team leader for preliminary development process & material at Pöppelmann; SteffenMeyer@poeppelmann.com

To Be Continued

This article is the start of a three-part series on technologies for a more sustainable injection molding future. The series follows the motto **"Carbon Busters"** and describes the industry's commitment to significantly reducing the carbon footprint. In the next edition, the topics of tracing and energy efficiency will be discussed.

Service

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