Recycling that Gets under the Skin

Engel's skinmelt Sandwich Process Paves the Way for Increased Use of Recycled Material

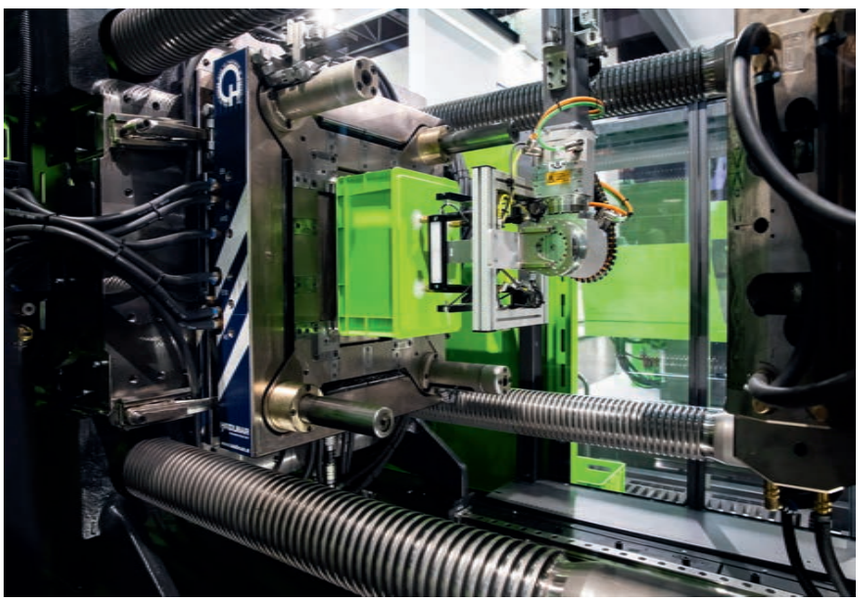
Process technologies for manufacturing multilayer and multicomponent products offer great potential for using reprocessed plastic wastes even for plastic parts that are subject to strict requirements for surface quality, product protection or consumer safety. The key: to place the recycled material in the interior while the surface is made of virgin material. Engel has developed a variant of sandwich injection molding that allows high proportions of recycled material to be used even with complex part geometries.

In its Strategy for Plastics in a Circular Economy and Circular Economy Action Plan, the European Commission specifies that, by 2025, the annual amount of recycled plastics reprocessed in the manufacture of plastics products is to be increased from its current 4 to 5 million t to 10 million t [1–4]. In addition, the Commission is reinforcing its intention to introduce an obligatory recycled content for specific plastics product groups.

Achieving this aim requires not only a voluntary commitment by the market players and a higher capacity for reprocessing separately collected plastic wastes, but also new processing technologies to allow recycled plastics to be used for a wider spectrum of products and in greater amounts [5]. Engel Austria GmbH, Schwertberg, Austria, is contributing to this goal by offering a special injection molding process.

The machine manufacturer and system supplier has developed the two-component skinmelt process for manufacturing sandwich parts, which have a core of reprocessed plastic wastes and a surface of virgin material. The new feature is that a high content of recycled material can be achieved even with complex part geometries. The new process was unveiled at K 2019 with the manufacture of transport crates (**Title figure**). The recycled material content was over 50 %. Both processed materials – recycled and virgin material – consisted of polypropylene (PP). As a single polymer type is used, the sandwich products, too, can be recycled again at the end of their life cycle.

In contrast to traditional coinjection molding, in the skinmelt process, the two melts are layered even before they are injected in sequence into the main injection cylinder. The skin material, i. e. the virgin material, reaches the cavity first. It is displaced by the subsequent stream of recycled PP 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.



The sandwich technology (skinmelt) hides the recycled material beneath a virgin material surface – for example in the transport boxes © Engel

Compact Manufacturing Cell

To maintain the product's stability and dimensional accuracy even with a high proportion of recycled material, the process must be reproducible. Therefore, Engel has developed a compact manufacturing solution based on the duo two-platen injection molding machine. With the duo 3660H/1560W/450 combi, which was used at K fair for manufacturing the transport boxes, the second plastication unit for the skin material is mounted at a shallow angle above the horizontal injection unit, in which the recycled material is melted (**Fig. 1**). This is a very space-saving machine execution.

Another unique feature of this solution is that the entire process is visualized as an animated display in the CC300 injection-molding machine control unit. In this way, the mixing ratio can be adjusted precisely and thereby the proportion of recycled material optimized.

For demonstration at the K show, Engel worked together with partner companies. The mold was manufactured by mold maker Haidlmair GmbH, Nussbach, Austria, which is specialized in molds for storage and logistics containers and uses the produced sandwich transport boxes for intralogistics in its own production site (**Fig. 2**). The recycled material (type: Systalen) was supplied by the Green Dot – Duales System Deutschland (DSD). It originated from household wastes that had been collected in the yellow bag or yellow container scheme.

Fig. 1. In the Engel duo injection-molding machine equipped for the skinmelt process, the second plasticating unit for the skin material is mounted at a shallow angle above the horizontal injection unit for the recycled material

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Confirming Fitness for Use

To confirm the fitness for use of the 2-component transport boxes, stacking pressure tests were performed at the TCKT – Transfercenter für Kunststofftechnik GmbH in Wels, Austria. Three stacked boxes were subjected to pressure at a constant rate of 10 mm/min, compressed, while the force and displacement signals were recorded (**Fig. 3**). To allow the measurement results to be assessed, and put into perspective, geometrically identical transport boxes without a sandwich structure were tested, some of which were manufactured completely from virgin material and some entirely from the recycled material.

The force-displacement curves determined in stacking pressure tests as well as the maximum forces achieved and the resulting compressions until the respective maximum force was reached show the mean value from three tests in each case (**Fig. 4**). It is interesting that those boxes that consist entirely of recycled material show the highest maximum force and compression values by far. However, both the profiles of the force-displacement curves and the extent of the standard deviation of the compression values show that, when reclaimed plastic wastes are used, significant scattering of the properties must be taken into account.

Tests on boxes made completely of virgin material, by comparison, show »

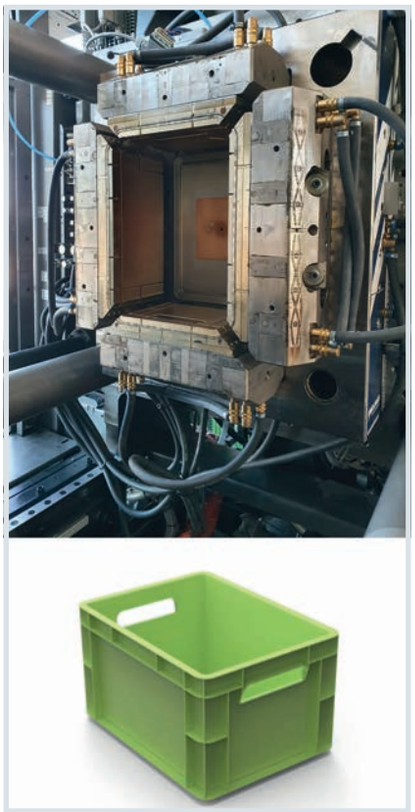

Fig. 2. The mold used at K2019 is from the mold maker Haidlmair, which uses the transport boxes for intralogistics in its own house

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approximately congruent curve profiles for the three tests, and the resulting standard deviations are small. The skinmelt boxes, analogous to the boxes made entirely from recycled material, show a slight tendency toward greater scattering; however there is no decline in the maximum force that can be withstood. The fact that the apparently higher load capacity of the recycled material does not translate into higher stability of the skinmelt boxes is very probably due to the comparatively low proportion of recycled material in the stabilizing reinforcing ribs.

Recycled Material Can Be Cheaper

The ribs form the end of the flow path and are therefore predominantly filled with skin material. This explains why the stability of the boxes in which the recycled material is only found in the core is comparable to the stability of the crates produced entirely from virgin material. Conversely, this means that, for the manufacture of the investigated boxes – at least with regards to the stacking properties – a lower-strength and correspondingly more cost-effective recycled material could be used as the core component.

In all cases, the higher scattering in the data obtained from mechanical tests of recycled materials is significant. This behavior, which is especially typical of post-consumer materials, must be taken into account in the part design phase, e.g. by means of adequate safety factors.

The tests confirm the fitness for use of the transport boxes produced in the two-component (skinmelt) process. To allow the product reliability to be subsequently assessed, further investigations were performed, particularly on the impact and continuous service properties.

Recycled Material Increases Strength

The mechanical properties were investigated in detail at the Institute of Polymeric Materials and Testing at Johannes Kepler University in Linz, Austria. For this purpose, small type 5A multipurpose test specimens according to DIN EN ISO 527–2 were punched from the side walls of the transport boxes. The side walls were identified as suitable places for removing test specimens for two reasons. First, there is a defined preferred flow direction of the melt during filling of the cavity from the crate base towards the top edge. The orientation of the test specimen longitudinal axis was chosen parallel to this preferred flow direction. Second, there is a balanced ratio of skin and core components in the side walls of the sandwich boxes. This ensures that the actual sandwich structure is tested and no component dominates over the other.

The mechanical characterization of the side walls yielded four individual results (**Fig. 5**). The Shore D hardness measurement confirms that, as expected from the preliminary tests, the boxes made of virgin material are equivalent to those with a sandwich structure. The higher surface hardness of the core material is covered by the skin material. Furthermore, monotonic tensile tests with a constant test speed of 10 mm/min were used to determine values for Young's modulus, strength and elongation at break for the various transport box walls.

While there is little difference in the Young's modulus of the side walls of virgin material and recycled material, and, correspondingly, the same stiffness values are also present in the sandwich laminate, the difference in their strength values is relevant. The strength of the recycled material, at 28 MPa, lies significantly above the strength of the virgin material (23 MPa), which has an influence – albeit small – on the strength of the sandwich material. In the comparison of the values for elongation at break, it is evident that the use of recycled material significantly reduces the plastic deformation capacity, even if the recycled material is only present in the core.

In comparison to the stacking pressure tests, the significant increase in the relative standard deviation, i.e. the size of the error bar as a ratio of the absolute bar heights of the recycled materials and sandwich laminates is conspicuous. For a large number of product properties and functionalities, however, this should not play a very significant role, so there is nothing standing in the way of the safe use of recycled material in these cases. This applies mainly to part properties that are determined by the elastic material behavior or the pre-yield behavior. For products whose functionality and safety depend to a large extent on the plastic de-

Fig. 3. Stacking pressure test with three stacked transport boxes with sandwich structure. Top: without pressure loading; bottom: strong pressure loading on the boxes visibly leads to a compression of the side walls and reinforcing ribs © TCKT – Transfercenter für Kunststofftechnik GmbH

formation, energy absorption and post-yield behavior, further solid expertise must be developed on the use of recycled materials.

Conclusion

The use of recycled plastics will increase significantly, not least due to regulatory requirements. Multicomponent injection molding, such as Engel skinmelt, offers the possibility of increasing the use of recycled material even in products with strict requirements for their optical appearance and surface functions. Since the skin material can be modified as required, even food applications are conceivable. With a skillful choice of process and mold design, the part surface can be made entirely of virgin material and thereby over 50% recycled material employed.

Some properties of the reprocessed recycled material in the part core, such as color or surface hardness, can be completely covered by those of the skin material. At the same time, other properties of the core, such as a possibly higher stiffness or strength, have a beneficial effect on the product performance in the sandwich laminate. For very sophisticated purposes, with more complex load profiles, the teamwork in the development organizations is important for mastering the challenges that occur there – in a similar way to the suitable choice and coordination of the skin and core components. ■

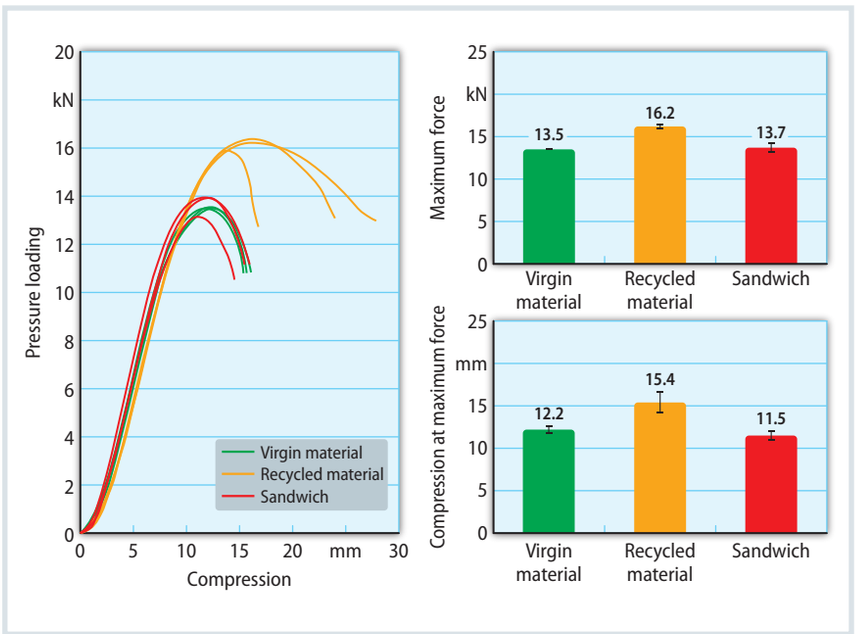

Fig. 4. The force-displacement curves (left) show the highest maximum force and compression values by far for those boxes that consist entirely of recycled material. However, the apparently higher load carrying capacity of the recycled material is not reflected in the stability of the skinmelt boxes Source: Johannes Kepler Universität, graphic: © Hanser

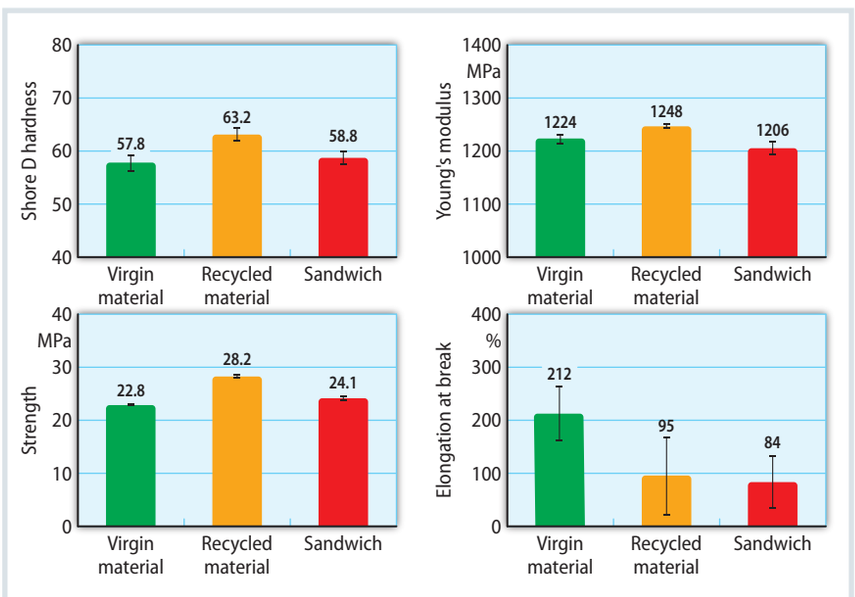

Fig. 5. Results of the mechanical characterization of the side walls: the Shore D hardness measurement confirms that, as expected from the preliminary tests, the boxes made of virgin material are equivalent to those with a sandwich structure Source: Johannes Kepler University, graphic: © Hanser

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