

Venting in a Two-Stage Process Boosts the Efficiency of Recycling Processes

High-Quality Recycled Plastics Obtained Directly from Flakes

ENGEL has developed a new way to process plastic scrap as flakes on an injection molding machine straight after grinding. This innovation eliminates the pelletization step and significantly boosts the economics of plastics recycling. The key to consistently high product quality is to vent the plastic melt.

In order to be able to process flakes by injection molding, ENGEL has developed a two-stage process that divides plasticizing and injection into two separate, coordinated process steps that shorten the recycling process. In the first stage, the feedstock, e.g. single-resin plastic flakes obtained from post-consumer or post-industrial collection, is melted on a conventional plasticizing screw. The melt is then transferred to another screw for injection into the cavity in the second stage. A melt filter and a venting unit can be integrated into the transition section for transferring the melt from the plasticizing to the injection screw. As a result, high-quality products can even be obtained from contaminated plastic scrap.

Usually, sorting, cleaning and grinding of post-consumer and post-industrial plastic scrap is followed by compounding, pelletizing and feeding it into the injection molding process as re-claim. The plastic is therefore melted twice. Pelletizing recycled regrind is an energy-intensive process that also normally entails a certain amount of logistics. ENGEL's two-stage approach eliminates this step entirely, thereby improving the carbon footprint and lowering the costs of recycling. The company calculates that the energy requirement is reduced by around 30 % as a result. This innovation is a further contribution made by ENGEL to greater sustainability and the development of a circular economy for plastics.

New Venting Unit Enhances Product Quality

A particular focus of the development work on the two-stage process was the venting unit. Venting is necessary because certain contaminants can pass the melt filter. These may be

residual moisture or low-molecular compounds produced by material degradation or printing ink residues. Unless they are removed before the melt is injected, pores and defects may form on the inside and outer surface of the parts and thus reduce their mechanical load-bearing capacity.

The venting unit developed by ENGEL forms the transition section between the plasticizing screw and the injection screw and consists of a transfer head through which the melt is pressed. This increases the surface area of the melted material and shears off the melt strand. The corollary is that the injection screw is only partially filled and volatile components can readily escape from the melt. To an extent depending on the application and the expected contaminants, negative pressure generated by a vacuum pump may also be employed.

Simulating Low-Molecular Contaminants

To test the performance of the new venting unit and demonstrate the potential of the new two-stage process, ENGEL conducted extensive trials on three different materials (**Fig. 1**):

- Deliberately contaminated virgin PP: the material was processed into sheets that were then shredded for the trials. The flakes were processed in a single-stage process without venting in one case, and in a two-stage process with venting in another.
- PP agglomerate from post-consumer film: this material was also processed both with and without venting. The study examined the influence of partial screw filling and the influence of the vacuum.
- Regrind from HDPE beverage closures: the material was processed in one case in a two-stage process with venting and, in another, it was cleaned up in the conventional way on a separate twin-screw extruder, with venting and melt filtering, and processed in a single-stage process without further venting.

The two post-consumer fractions were selected from feedstock frequently employed by injection molders. Pellets from HDPE closures are already being used nowadays in the production of pallets. ENGEL sees great potential in this area for replacing the conventional multi-stage process with the more efficient two-stage process. Film agglomerate has proved to be a very good feedstock for the two-stage process. Since shredded film scrap is not free-flowing, it is agglomerated before processing. No melting of the material is necessary for this: it is simply heated and compressed.

PP virgin material was used because, in this case, low-molecular contaminants can be simulated very readily with water. Natural fibers served as the carrier material for the water. It was shown that, with venting, residual moisture of up to 1.1 % can be removed from the melt stream.

All three test series were conducted at the ENGEL pilot plant in St. Valentin, Austria (**Title figure**). In addition to venting, a commercial melt filter was used in all test series. The samples were evaluated at the CHASE Competence Center in Linz, Austria.

High-Quality Product from Regrind or Agglomerate

Without venting, the sample parts produced from all three materials have very large pores. Venting the melt gives a substantial boost to part quality. Venting performance was found to increase with increase in the surface area of the melt. The size of the surface area can be controlled by the degree to which the injection screw is filled. When screw filling is reduced by 50 %, pore formation does not even occur at atmospheric pressure. If it is reduced by 25 %, negative pressure is required to prevent the formation of pores (**Fig. 2**). An absolute pressure of 0.1 bar was used. Venting leads to a higher elastic modulus, as confirmed by molding tests on test panels 2 mm thick. In other words, the parts become stiffer as a result of venting (**Fig. 3**).

The tests showed that the speed of the injection screw has hardly any effect on venting performance. Accordingly, even when the feedstock is heavily contaminated, the two-stage process can be used at high speeds and thus with short dosing times.

Parts of consistently high quality were obtained for all three materials in the two-stage process. Compared to conventional multi-stage recycling, there are no disadvantages in terms of attainable material properties. It can be assumed that better venting of the feedstock is achieved than when preparation and pelletization take place independently of the injection molding process.

The trials have confirmed that the new two-stage process is robust enough to handle both regrind and agglomerate from single-resin post-consumer collections. The shape of the flake feedstock has no impact on product quality. The only requirement is that the material be free-flowing.

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Test setup at the pilot plant in St. Valentin: for the two-stage process, ENGEL has combined a plasticizing screw with an injection screw.



Fig. 1. The tests were carried out on three different materials: pellets of virgin PP (left), PP agglomerate obtained from post-consumer film (center) and regrind obtained from HDPE beverage closures (right).

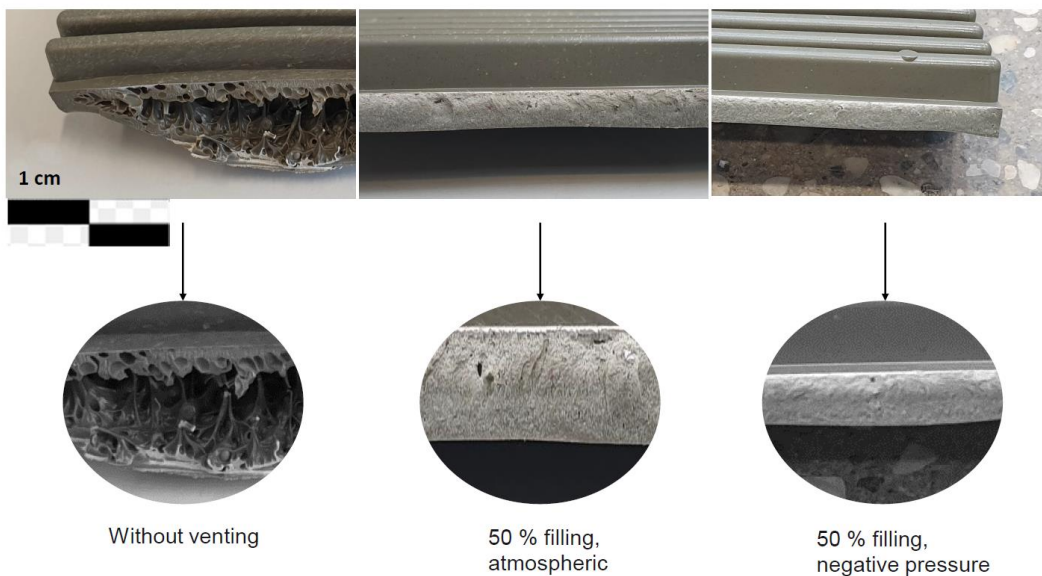


Fig. 2. Vacuum supports venting and further improves part quality. The picture shows the results of tests on PP agglomerate.

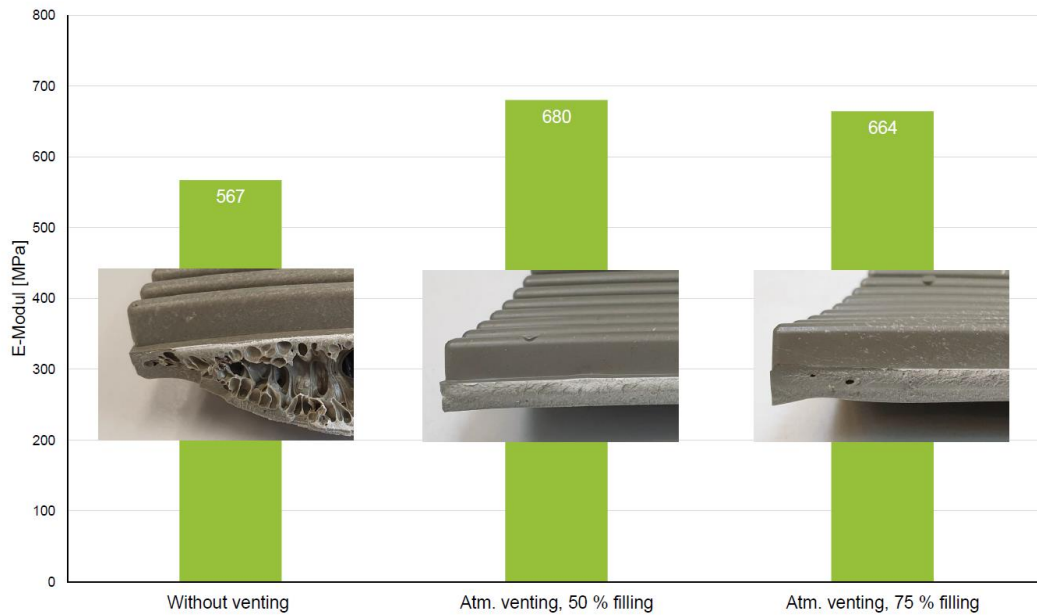


Fig. 3. Part quality depends on venting and the degree to which the injection screw is filled. Without venting, the sample part has very large pores. The picture shows the elastic modulus values for the test series conducted on PP film agglomerate.

Pictures. ENGEL