PET Recycling

Modular Concept for Industrial Waste Offers Flexible Solutions

In the manufacture of semi-finished products such as fibers or films, waste that can be recycled and reused as a raw material is repeatedly produced along the entire production chain. The recycling of PET is a particular challenge to the plant construction because of the hydrolytic polymer degradation.

By the processing of polyolefins, the recycling task is largely solved. There is a sufficient number of functioning concepts on the market that do this job and produce good qualities. Different is the situation at the area of PET recycling. Here, usually polyolefin solutions are adapted which are not tailored to the special properties of PET.

With the raw material polyester, one problem is the great affinity of the molecules for humidity that manifests itself during processing in the extruder in the shortening of molecules (hydrolysis) and that significantly reduces the mechanical properties of the polymer. When bottle flakes are used, the Multi-Rotation System (MRS) of Gneuss Kunststofftechnik GmbH, Bad Oeynhausen, Germany, has proved to be successful here. With the aid of very large polymer surfaces and the creation of a simple vacuum, the accumulated moisture is removed during the extrusion process and reverses the degradation.

In the production of PET films for thermoforming, there are established processes that immediately grind the punching waste and then return it to the production process straight away. The relatively low IV value (the IV value determines the physical or mechanical properties of the final product) is compensated by adding material with a higher IV value (e.g. bottle flake, high IV chip etc.).

If on the other hand biaxially oriented films or fibers are made from PET, the reprocessing of production waste is much more difficult to solve. This is due above all to the very low "bulk density" of the waste, which is often less than 100 g/l and thus causes great difficulty when this waste is supposed to be returned to the extruder (**Fig. 1**).

Fig. 1. Typical fiber recycling waste (figure: Gneuss)

This industrial waste comprised of biaxially oriented PET films or fibers cannot be processed in an extrusion process without additional measures.

These two types of waste must first be shredded until they are suitable for dosing. Various machine concepts are available for this process step.

Initial Shredding with Shredder or Cutting Mill

One possibility is the using of shredders. These can be loaded with whole bales of the recyclable material, and shred the fibers or films. A shredder suited to this task has a rotating shaft to which several blades are attached and guided against stationary cutting edges during rotation.

The machine often has a hydraulic pusher that presses the fed-in waste against the rotor, thereby regulating the system's throughput (**Fig. 2**). The rotor's rotation speed and circumferential speed tend to be low, this limits the thermal stress on the polymer.

Another characteristic is the unit's robustness, which also allows start-up with the machine already full. Even large pieces of waste are shredded without major damage. This also allows purgings to be used as the feed material (**Fig. 3**).

After shredding normally sieves are used, they define the dwell time and therefore the size of the discharge material. With a grain size of around 40 mm and larger, pellets are produced that can be transported moderately well.

Cutting mills deliver a cleaner cut. They also work with a rotor but with a much higher rotation speed and circumferential speed, and they cut the feed ma-

Fig. 2. Shredder (single-shaft shredder WLK 1500) used for shred of bales (figure: Weima)

Fig. 3. Shredder rotor: F-Rotor with welded Vautid wear protection (figure: Weima)

terial against fixed blades (**Figs. 4 and 5**). These machines are self-feeding, which means that endless fibers or films must always be divided into portions prior to being fed in. They also cannot be started up with the cutting chamber full, and feeding in purgings very quickly results in destroyed blades. On the other hand, the fine cut allows a flow of material with better dosing capability, which offers advantages during further processing. Loose pellets are produced here too, albeit of a defined size.

The flow of pellets prepared in this way can now either be fed directly to the extruder, or be compacted in a further process step. Once again there are two different methods for doing this.

Fig. 4. Cutting mill for preliminary size reduction (figure: Herbold Meckesheim)

Feed of Agglomeration or Pellets

In the case of agglomeration, the pellet is moved into a gap between a rotating disk and a stationary disk by assistance of a plug screw. The friction heat melts and compacts the material. A disadvantage here is that high thermal stresses sometimes occur, which can have a negative influence on the molecular weight and therefore the mechanical properties of the PET.

Basically, the pellet behaves exactly the same way in large containers with shear mixers, and the thermal stress for the polymer can result in an increase in the yellowness index and a reduction of the molecular weight. That's why agglomerators are primarily used in conjunction with polyolefins because in most cases they do not make sufficient allowance for the special properties of the PET.

Pelleting in edge recycling mills is much more gentle. Here, the feed material is pressed through specially designed dies with holes and is compacted at the same time. In this process step, new pellets that are very easy to both dose and process further are created from the original pellets that have poor dosing properties. This process step is therefore appropriate when other components such as bottle flakes, new plastics, additives or similar are to be added to the fiber or film waste in the subsequent extrusion stage.

If it is not necessary to add any additives, there is no reason why pellets or scraps cannot also be fed directly into the extruder with the aid of compaction units such as plug screws. With the help of an upstream screw, the high volume of the pellet is compacted here, the air can escape and sufficient bulk densities for processing are made available to the extruder.

Processing fiber waste on the Gneuss MRS extruder not only has the advantage that absorbed moisture is removed and therefore no major molecular degradation takes place. Spinning oils and other additives used in the spinning mill are also removed in the degassing stage. »

Fig. 5. Cutting mill rotor (figure: Herbold Meckesheim)

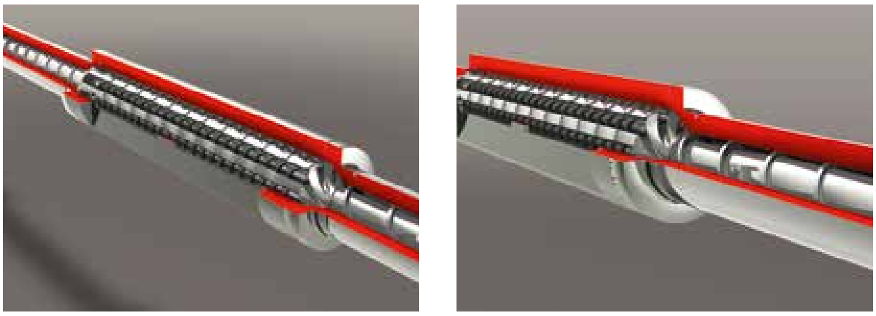

Fig. 6. Multi-rotation stage (left) and the transition of multi-rotation stage and discharge screw (right)

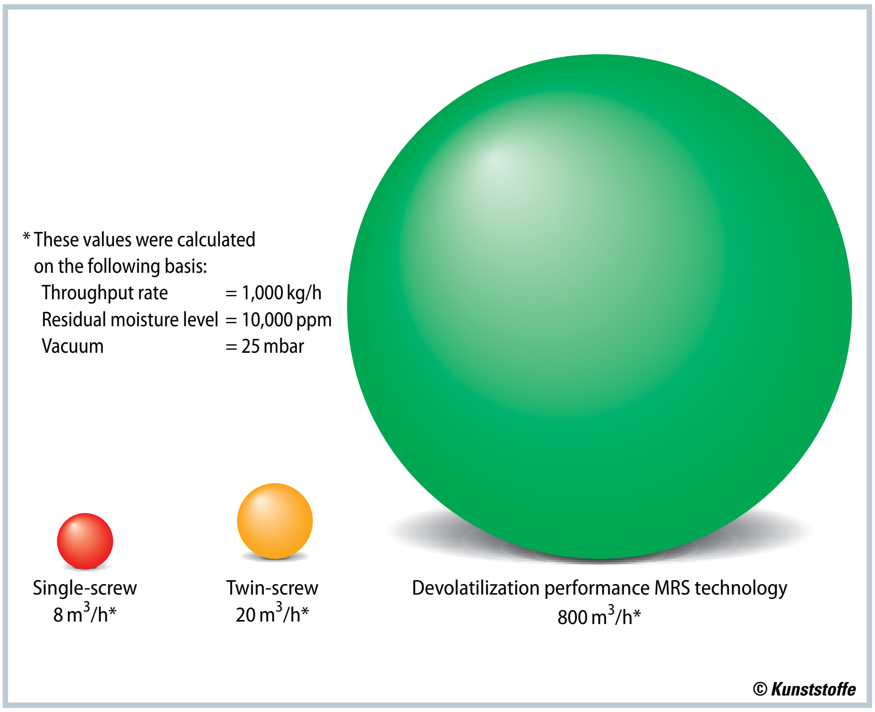

Fig. 7. Evacuation performance (figures 6-8: Gneuss)

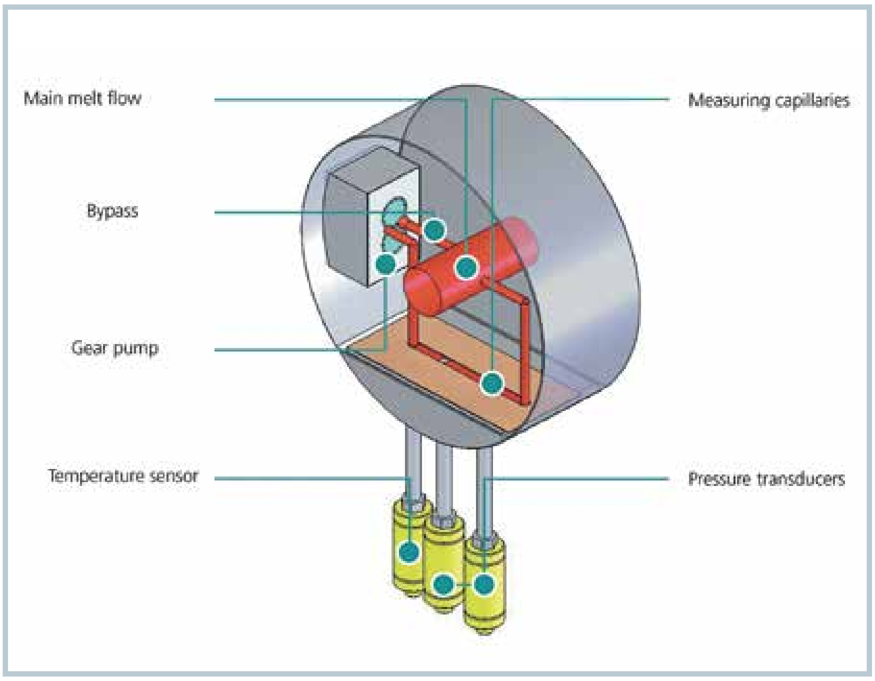

Fig. 8. Technical set-up of the online viscometer VIS

The resulting melt can be filtered down to 12 µm in the subsequent extrusion process, allowing the granulate produced to be used again directly in the spinning mill process.

MRS Extrusion Concept

The MRS extruder processes non-crystallized polyester granulate directly, without pre-drying. This involves enlarging the polymer surface several times during the extrusion, and quickly replacing it. So there is always a new surface available for the release of volatile substances.

The MRS extruder is basically a single-screw extruder with a special degassing zone. The polymer melt flow is fed onto a large rotating single-screw drum (**Fig. 6**). In the drum there are eight cylinder bore holes with recessed feed screws along the length of the rotation axis.

These screws are driven via a ring gear. They turn on their rotating circular path in the opposite direction of the extruder drum. This disproportionately increases the effect of the surface exchange of the melt.

The barrels located in the drum of the Multi-Rotation System are open approximately 30 % in the outer area, thereby guaranteeing optimum access to the melt and allowing degassing to take place unhindered. Targeted temperature control of the melt is also possible, since the temperatures of all surfaces that come into contact with the melt are easy to control.

Thanks to the patented multi-shaft section, the extrusion drum provides a very large polymer surface and thereby allows degassing performance that is second to none, even when there is only a moderate vacuum of 20–40 mbar. As a result, it is possible to extrude undried flakes or pellets with up to 1 % moisture.

The basic set-up of this degassing technology is based on the robust and proven concept of the single screw. In the multi-shaft section there are eight single-screw extruders arranged concentrically. As a result, the MRS extruder avoids the problems of alternative multi-shaft concepts, which are much more sensitive due to narrow, tangential gaps in the vicinity of the shaft.

Other positive effects of the MRS technology are apparent in the 100 % demoisturising of the polyester and the realization of a very constant intrinsic viscosity.

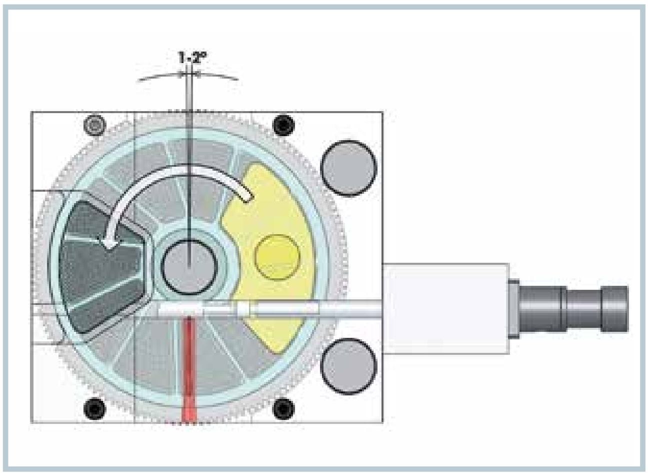

Fig. 9. Technical set-up of the Rotary Filtration System RSFgenius (figure: Gneuss)

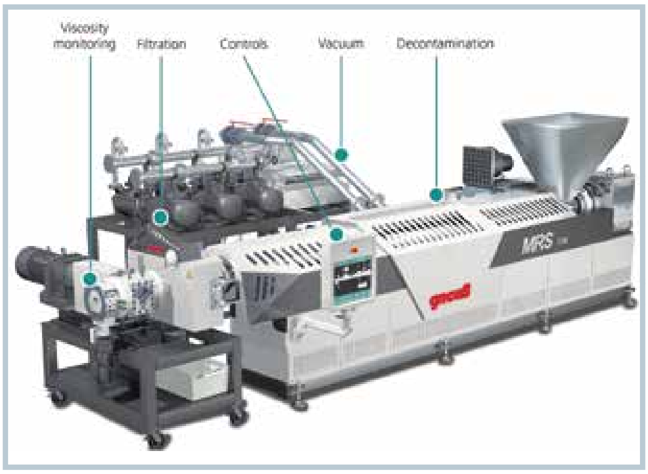

Fig. 10. MRS extrusion system with Multi-Rotation Extruder, Rotary Filtration System RSFgenius and online viscometer VIS (figure: Gneuss)

Due to the multi-rotation element, the surface available for the degassing is many times larger than of the usual extrusion systems available on the market. For example, the melt exchange surface created using MRS technology is about 25 times larger compared with a co-rotating double screw (**Fig. 7**).

The material is processed extremely carefully, with the result that the end product is of a particularly high quality for example with respect to the yellowness index.

In comparison with other multi-shaft technologies, the MRS impresses with its compact and robust set-up. The rotating screws run on individual bearings and as a result resemble a drum with multiple single screws.

The degassing technology is of a modular design and thanks to its extraordinary efficiency, it can be optimally adapted to the needs of the respective job. It is possible to vary the length and configuration of the different modules of the MRS.

The increase in viscosity in the evacuation zone can be influenced and controlled by different vacuums. The influence of the absolute pressure on the viscosity obtained is significant. The increase in viscosity of the melt coming out ahead of the shaping as the absolute pressure decreases is clear.

Online Viscosity Measurement

Thanks to the clever interconnection of melt pressure and temperature sensors, when the flow and geometry are known it is also possible to determine the flow resistance of a liquid and from that the material's dynamic viscosity. This is a measure of the polymer's average molecular weight and thereby characterizes mechanical properties such as elasticity and stretch.

For measuring the melt viscosity online the online viscometer VIS was developed. A small partial flow of the polymer melt is diverted out of the main melt channel with the aid of a high-precision, pressure-resistant gear pump. This is then pressed through a slit capillary that was produced with extreme precision. Both the melt temperature and the melt pressure (measurement in two places) are recorded. Based on internal calculations, the online viscometer records a value for the representative rate of shear and the corresponding representative viscosity.

The melt channel can be designed between 0.5 and 2 mm in size, in line with the customer's specifications. The unit is supplied complete with a pump drive, pump, pressure transducer, temperature sensors and controller. The process parameters, the evaluation and the display are set on an easy-to-use touch-screen panel, but can of course also be integrated into an existing controller.

With the aid of the online viscometer VIS it is now possible to keep the melt quality within a very narrow tolerance range when the input conditions (moisture) fluctuate during processing polyester. After the viscosity has been recorded with the aid of pressure and temperature sensors, the vacuum present at the evacuation zone is regulated so that the properties of the end product (viscosity, molecular weight and therefore the mechanical properties) can be maintained (**Fig. 8**).

Melt Filtration

When processing recyclates, filtration is an important element for ensuring quality and economy. The Gneuss Rotary Filtration Systems work fully automatically, with constant pressures and processes, and guarantee a pure and high-quality melt.

The Rotary Filtration Systems basically consist of three parts – an inlet block, an outlet block and a rotating filter disk between them. The seal is a metal-on-metal seal with very hard and absolutely flat metal surfaces. All components that come into contact with the melt are fully encapsulated in order to keep out environmental influences such as oxygen.

Filter elements that move through the melt channel are arranged concentrically on the filter disk. When plastic melt flows through the screen surface, the dirt particles are deposited on it and the differential pressure increases slightly. The controller reacts to this pressure rise and, if necessary, allows the filter disk to advance by approximately 1°. As a result, dirty screen surface is continuously moved out of the melt channel while fresh screen surface is moved into it, without the active screen surface changing. This method enables the filtration system to work with a constant process and pressure. The pressure difference variation over the filter (Δp) is max. 2 bar (**Fig. 9**).

The dirty filter elements are cleaned just before re-entry into the melt channel. This involves removing the dirt cake by way of high-pressure sequential self-cleaning. To do this, already filtered melt is slowly "loaded" out of the filtration »

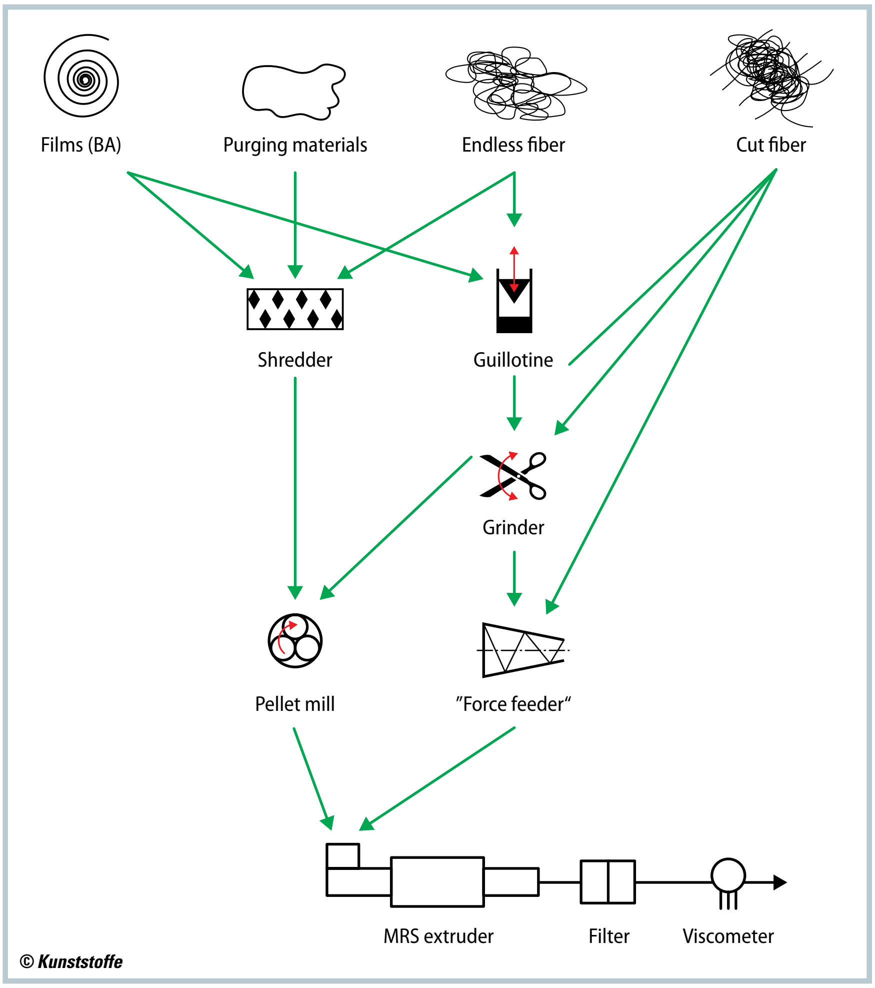

Fig. 11. Modular industrial waste recycling concept (figure: Gneuss)

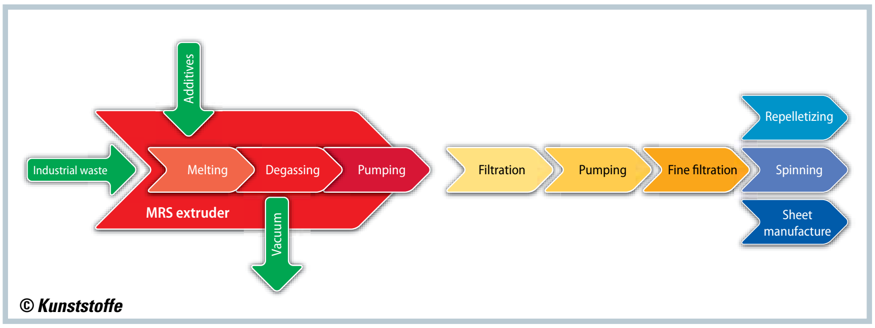

Fig. 12. Extrusion process chain for industrial waste (figure: Gneuss)

system's discharge channel and into a hydraulically operated shot pot, and is then shot under high pressure from behind through the filter disk, through the filter element and into the inlet block at approximately 30–80 bar, from where it is removed in a controlled manner. In each case, only a small segment (about 1% of the screen surface) is shot clear, with the result that a defined high pulse is available for cleaning every time.

This way of working cleans the filter elements completely and depending on the filter fineness, allows them to be used again up to 400 times, which means fully-automatic filtration for up to 1 month without any labor input whatsoever (**Fig. 10**).

Industrial Waste Recycling

A significant element of Gneuss industrial waste recycling is the modular setup of the individual components, combined with the MRS extruder (**Fig. 11**). The various modules that bring together the best possible combination of components are set up here on a platform. Depending on the feed product and the requirements profile, the "shredding", "compacting" and "extruding" segments are brought together to form a system, and the respective most optimum system solution is achieved for the user.

After the extrusion, the melt can be processed into pellets, depending on the throughput as simple strand pelletizing, as underwater strand pelletizing or also as underwater pelletizing. The direct production of film with the additional option of adding trim waste, other ground materials, additives or masterbatches is also possible. Both pelletizing systems as well as complete film lines for this are offered as "turnkey" solution. As far as processing the melt to produce fibers (nonwoven, BCF, staple fibers etc.) is concerned, Gneuss have worked with renowned system engineers for many years. The possibility of installing recyclate extrusion systems into existing fiber production systems later as solutions across the board is also offered.

The advantages of the modular design are obvious: The optimum process for feeding into the extruder is selected for every type of waste produced. The MRS removes moisture, spinning oils or other adhering volatile components and solid contaminants. Down to approximately 10 µm are removed in the subsequent filtration, with the result that the melt produced comes close to having the properties of new product (**Fig. 12**). ■

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Service

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