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Recycling line with the further developed, new TVEplus configuration

Printing Inks? No Problem!

Post-consumer Waste. The recycling technologies employed to date frequently came up against their performance limits when it came to processing heavily contaminated plastic wastes, and in particular intensively printed film packagings. Thanks to targeted further development it has now become possible to recycle even fully printed and multi-coat printed post-consumer wastes into high-quality regranulate in a single cycle.

GEORG WEIGERSTORFER

The recycling technology of returning clean, pedigree production wastes right up to post-consumer wastes from collection systems to the added-value cycle has reached a high standard. In the meantime, however, the waste materials are also making ever increasing demands on the processing technology. A typical example of this are packaging plastics that are entering the recycling cycle with increasing levels of printing ink. The example of the plant engineering technology from Erema, Ansfelden, Austria shows how the manufacturers of recycling plants are reacting to these demands: The further development from the TVE to the TVEplus **(Title photo)** that is used specially for the processing of problematical plastic wastes.

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Tailored to the Recycling Application

Recycling plants from the Austrian machine engineering company operate with a "cutter/compactor" with a tangentially connected, sturdy single-screw extrusion system. Charging is performed automatically – loose material is delivered on a feed conveyor, film on reels directly via a reel feeder. The cutter/compactor chops and blends the feed material with rotating cutting tools. At the same time the feed material is dried – purely by the friction heat generated in the reprocessing reactor – and compacted for feeding into the extruder. There, the material is melted, homogenized and pelletized after passing through a fully automatic, self-cleaning filter. Depending on the starting material, the processed melt must first be degassed in the extruder in order to remove residual moisture carried in with the material or gaseous decomposition products given off during processing. On conventional degassing extruders, this degassing station is located upstream of the melt filter, as in the Erema TE recycling plant **(Fig. 1, top)**.

The TVE technology reverses this order **(Fig. 1, middle)**: The feed and homogenizing section is followed by the filter unit and only then by the melt degassing. This offers numerous advantages for the processing of plastic wastes, particularly if these are contaminated with impurities that tend to form gases, or where high solids contents transported with the melt impair the degassing. Thanks to the early separation of these particle impurities, only the gaseous constituents enter the degassing section of the extruder with the melt. Furthermore there is no risk of melt escaping at the degassing openings in the event of clogging of the filter caused by the sudden appearance of large impurities (contamination peaks). As a result, the extruder has a practically uninterrupted, consistently high degassing rate.

Since the introduction of the TVE recycling system in the mid-1990s, over 600 plants have been able to confirm the effectiveness of this technology in practice. For the most part polyolefin wastes – generally heavily laden with contaminants (the range extends from used agricultural foils through to printed packaging films, often even with self-adhesive labels) – are processed on this line.

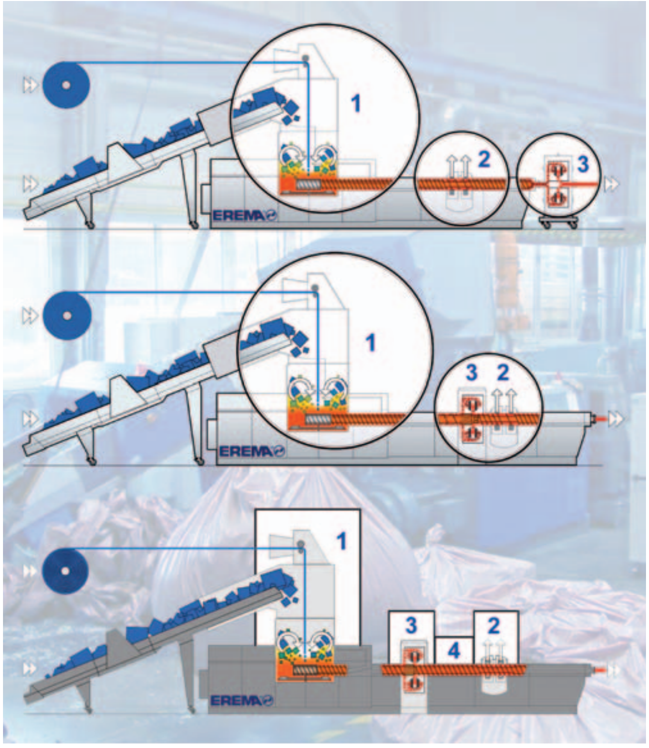

Fig. 1. Principle of the recycling lines Erema TE (top), Erema TVE (middle) and Erema TVEplus (bottom); 1: cutter/compactor with tangentially arranged single-screw extruder, 2: double degassing station, 3: melt filter, 4: special homogenizing zone (photos and charts: Erema)

From the TVE to the TVEplus Technology

The variety of colors and the intensity of the printing in the packaging sector has risen steadily in recent years. Film packagings today, for example, are frequently printed all over and in many cases also in multiple layers. Such high ink contents make the recycling of these waste materials more difficult. Problems are created in particular by the binders and other additives always contained in the printing inks which decompose to a certain extent at the processing temperatures of the plastic matrix and are thereby given off as gases. If notable contents of these products remain in the recycled material after processing, they may in some cases no longer be suitable for their intended application. In order to nevertheless obtain a serviceable recycled material there was frequently only the possibility of blending this problematical starting material with significantly less contaminated waste material before recycling.

The further development of the TVE Series therefore focused on this problem area. Design and process engineering measures implemented in the latest TVEplus configuration now result in an even more intensive degassing. That starts already with the entry of the processed material into the melt filter. The design of the feed and transition sections of the extruder have now been modified so that a very steep pressure gradient in the screw channel intensifies the "back venting" towards the extruder feed section and the cutter/compactor.

A further visually recognizable distinguishing feature compared with the former TVE is the larger distance between the melt filter and venting station on the TVEplus (**Figs. 1 and 2**). In this section of the screw, the melt relieved of the particle contaminants is intensively homogenized before it enters the degassing section.

The systematic investigations described below show the differences in the effectiveness of the former TVE and the new TVEplus generation in the processing of heavily printed packaging films. As a comparison for a degassing extruder of conventional design, the recycling system in TE configuration was also included in these investigations.

Fig. 2. On the TVEplus, the screw section between fully automatic screen changer (1) and degassing station (2) serves for intensive melt homogenization

System Configurations – A Performance Comparison

In order to exclude faults caused by uncontrollable and yet fluctuating foreign contamination, clean production waste of a full-surface printed and even multi-layer printed PE-LD film was used for the comparative investigations (**Fig. 3**). A pragmatic, comparatively easily determined criterion was selected for the assessment of the re-granulate quality obtained: The

Fig. 3. This intensively and fully printed PE-LD shrink film was used for the comparative investigations with the recycling lines Erema TE, Erema TVE and Erema TVEplus with different screw configurations

occurrence, number and size of the "fish eyes" on the film blown from the respective re-granulate. The results determined for the recycling lines Erema TE, Erema TVE and Erema TVEplus are visualized in **Figure 4** and summarized in **Table 1**.

The assessment of the blown films reveals the following picture: As was to be expected, the TE configuration produced the worst re-granulate – it would not have been considered for this processing application in any case, and served during the investigation only as a "poor comparison". Although the re-granulate was produced bubble-free, the film blown from this material is completely covered with practically continuous very large fish eyes and even plastered with bubbles on the surface **(Case 1 in Fig. 4)**. From this we can say that this re-granulate still contains a large quantity of the printing ink residues carried into the extruder with the melt that have a high tendency to form gas during processing.

As usual for the production of PE-LD blown films, the processing temperature was 200 °C. All other re-granulates produced with the TVE and TVEplus configurations, however, showed no fish eyes with this temperature setting at the film blowing die **(Table 1)**. The processing temperature at the film blowing die was therefore increased to 250 °C in order to cause any foreign matter still in the re-granulate to form gas. With this increased temperature, further differences were discovered in the decontamination rate.

The blown film made from the re-granulate produced on the TVE line with the former (old) filter-degassing combination still shows clear and comparatively large fish eyes **(case 2 in Fig. 4)**. Their number is, however, significantly lower than in the TE result. Fish eyes, albeit much smaller and in a significantly reduced number, are also visible in **case 3 in Figure 4**: In the test configuration TVE with triple degassing. For this the extruder barrel had two degassing positions downstream of the filter: A single vent had been additionally positioned upstream of the double vent installed in the normal configuration. Screw geometry and distance between the two degassing points had been selected such that a screw section completely filled with melt separated the two degassing points from one another.

Cases 4 and 5 in Figure 4 ultimately show the re-granulate result of the TVEplus, whereby the system configurations differ in the design of the homogenizing sections employed upstream of the degassing section. Both films blown from the respective re-granulate at 250°C are completely free from fish eyes.

Degassing alone Is not Sufficient ...

The results of this comparison series show several things. First, that when processing heavily printed polyolefin wastes, a considerable proportion of the ink constituents can pass through the filter (filter mesh size normally between 100 and 150 µm). A filter arrangement only immediately in front of the granulator is totally unable to cope with this processing task – even melt degassing before the filter can do little to remedy the situation here (see TE result). The TVE concept with the early removal of particles and a downstream degassing section already fulfills this task significantly better.

It is therefore fair to assume that an intensification of the degassing could further improve the decontamination result of the TVE. This is confirmed at first sight by the result of the blown film from the TVE test configuration with triple degassing **(case 3 in Fig. 4)**. The improvement between case 2 (TVE) and case 3 is un-

Configuration of the recycling line	Film blown at	Number of fish eyes/dm²	Size of the fish eyes
(1) TE with standard screw	200°C	approx. 300	very large
(2) TVE with standard screw	200°C 250°C	none approx. 40	– relatively large
(3) TVE with triple degassing (trial configuration)	200°C 250°C	none approx. 20	– small
(4) TVEplus with homogenizing section 1	200°C 250°C	none none	– –
(5) TVEplus with homogenizing section 2	200°C 250°C	none none	– –

Table 1. Number and size of the fish eyes, determined in the blown film test

Configuration of the recycling line	MFR (190°C/2.16 kg) [g/10 min]
(1) TE with standard screw	0.49
(2) TVE with standard screw	0.44
(3) TVE with triple degassing (trial configuration)	0.43
(4) TVEplus with homogenizing section 1	0.43
(5) TVEplus with homogenizing section 2	0.42
Film, unprinted	0.42

Table 2. Melt flow rate (MFR) of the re-granulates obtained from the recycling lines

doubtedly due to more intensive degassing, but not exclusively to the degassing downstream of the melt filter. As already mentioned at the beginning, the improved back venting of the TVEplus configuration means that not all the gaseous constituents occurring during the melting process have to be drawn off exclusively at the double degassing station. This proportion is therefore smaller from the outset than with the previous TVE. The improved blown film result for line configuration 3 is therefore not clear proof of a better degassing performance of the "triple degassing" arranged downstream of the melt filter.

... Dispersive Breakdown Is also Necessary

But even intensified degassing has limitations with respect to the decontamination.

The difference between the two homogenizing sections in the investigations lies in that homogenizing section 2 **(result 5 in Fig. 4)** is more "aggressive", i.e. has a stronger dispersing effect. The "blown film test", however, shows no difference to the result with homogenizing section 1. At best the – possibly better – decontamination of the PE-LD melt that can be achieved with homogenizing section 2 is reflected in the melt flow rate of the re-granulate **(see Table 2)**. Although the MFR values that were also recorded during the investigations allow no direct conclusions to be drawn as to the quality of the re-granulate achieved with the processing lines, but a trend is recognizable: The closer the MFR value of the re-granulate comes to that of the unprinted film, the better the melt processing and hence the degassing of the ink constituents has taken place on the recycling line.

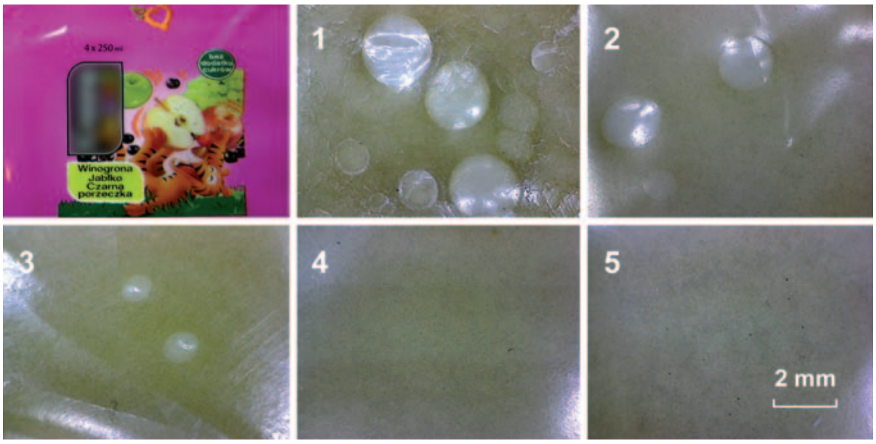

Fig. 4. Blown film test with re-granulate won from fully printed PE-LD film (top left) with the recycling lines Erema TE (1), Erema TVE (2), Erema TVE with triple degassing (trial configuration) (3), Erema TVEplus with homogenizing section 1 (4) and Erema TVEplus with homogenizing section 2 (5)

The blown film made with the re-granulate from the TVE with triple degassing still exhibits gas bubbles. Only the use of homogenizing sections installed in the screw sections between filtration and degassing position results in a re-granulate that gives a completely gas bubble-free blown film **(cases 4 and 5 in Fig. 4)**. In this case, just the double vent installed in the system as standard is used for degassing.

The homogenizing sections employed are designed such that they have not only a purely spatial distributive effect, but also a dispersion effect, i.e. a breakdown of the particles brought into the melt by exerting shear forces. In this way the constituents of the printing inks passing through the melt filter can be broken down (caused to evaporate) and subsequently drawn off in the degassing section of the extruder.

Process Window for Recycling Practice Widened

Available as standard since the beginning of this year, not only results from a large number of trials with a wide variety of waste materials on the new TVEplus are available, but also reports on the experience from day-to-day production. The size 1514 (diameter of the cutter/compactor 1,500 mm, screw diameter 140 mm) is being used in the meantime for routine processing of both heavily printed PE film and of transparent PE film flakes. In the blow film test up to 250 °C described, the re-granulate of the inked PE film produced film samples of very high quality – without having to "dilute" the feed material beforehand with unprinted waste material as in the past. The re-granulate from the transparent film flakes from building, agricultural and packaging films exhibits no discoloration. The focus here was on gentle processing in order not to thermally stress thermally instable constituents such as EVOH and PE-LLD.

According to feedback from the processors, the best re-granulate achieved to date with a recycling line has been produced with the TVEplus. At the same time, higher throughput rates were generally achieved, in individual cases even far higher. For example, a TVEplus with screw diameter 70 mm and designed for the processing of BOPP films achieved a more than 20 % higher throughput than the TVE predecessor of the same size.

A major role in these improvements is played by the homogenizing section between filter and degassing station of the TVEplus extruder. Depending on the intended application it can be designed to be predominantly distributive right up to intensively dispersing. In combination with the newly designed feed and transition section, the processing temperature can be reduced by up to 20°C compared with the former TVE generation, an aspect of particularly benefit when processing thermally delicate materials.

Overall, the new TVEplus configuration opens up a very wide process window for recycling and processing of plastic wastes, from gentle to intensively dispersing to produce high-quality re-granulate. The series of these recycling lines covers graded sizes for throughputs from 250 to around 2,500 kg/h. ■

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