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Upcycling. When recycling plastics ranging from production to post-consumer waste from collection systems, the process always has to cope with quality fluctuations in terms of the feed material. The combination of proven recycling and compounding technology now enables the production of better specified recyclate for varied and demanding applications.

Refining Recyclate

THOMAS HOFSTÄTTER

Plastic is becoming an increasing economic factor as a valuable secondary raw material. The reasons are plain to see. Whereas the production of plastics has increased by 8 % per year over the last decade, the decline in primary raw material resources is increasing on a drastic scale. The fact is that raw material prices are continuing to soar. This means that more and more importance is being attached to high-quality secondary raw materials. On the other hand, however, and in contrast to virgin material, plastic ranging from production to post-consumer waste from collection systems poses the problem of ever increasing quality fluctuations. Influencing factors here include not only mixed fractions of varying compositions, moisture, viscosity, type and degree of contamination but also the wide range of printed and laminated materials especially in the packaging sector. In practice this is often the limiting factor when using recyclates as both the possible applications and the recyclate share in potential end products are reduced with fluctuating properties. With its new product series Corema, the recycling system manufacturer Erema GmbH, Ansfelden, Austria, shows how proven recycling technology in combination with compounding technology enables the production of better specified recyclates (**Fig. 1**). Thanks to specific property enhancement, the materials which are processed can once again fulfil exacting requirements.

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Fig. 1. Recycling and compounding in a single step (figures: Erema)

How it Works

Corema brings together all the benefits of recycling and compounding in a single process step for the first time. Deviations in starting material quality can be compensated by the use of proven recycling technology and the admixing of fillers and/or reinforcing agents, thus realising a property profile which is in line with the end application. The compounding technology comes from the company Coperion GmbH Stuttgart, Germany, a global market leader in this segment.

In the first step, inexpensive recycling raw material (e.g. PP nonwoven, PE edge trim, PA fibres etc.) is turned into filtered melt using the proven, robust Erema technology. The recycling system works together with the patented cutter/compactor and a tangentially linked single-screw extrusion system. Feeding is automatic: loose material is fed in via a feed conveyor belt and film enters the system direct on rollers using a roller intake system. The cutter/compactor shreds and homogenises the feed material with rotating cutter tools. At the same time the feedstock is dried solely by the processing heat which is generated and compacted ready for intake in the extruder. The preheated material moves into the direct and tangentially connected single-screw extruder and is plastified, homogenised and cleaned in the fully-automatic, self-cleaning filter. For the second step the prepared and cleaned melt then goes via the melt pump directly to a co-rotating, self-cleaning twin-screw extruder from Coperion. This flexible part of the system is configured in such a modular way that thanks to its excellent mixing and degassing properties it can be adapted to any individual task. Besides the dosing of a wide variety of additives, both high amounts of fillers and reinforcing agents (e.g. 75 % $CaCO_3$, 70 % talc or 50 % glass fibres) can be admixed and also virgin material in the production of polymer blends. The compounded melt is degassed in the gas removal zone and sent to the respective tool **(Fig. 2)**.

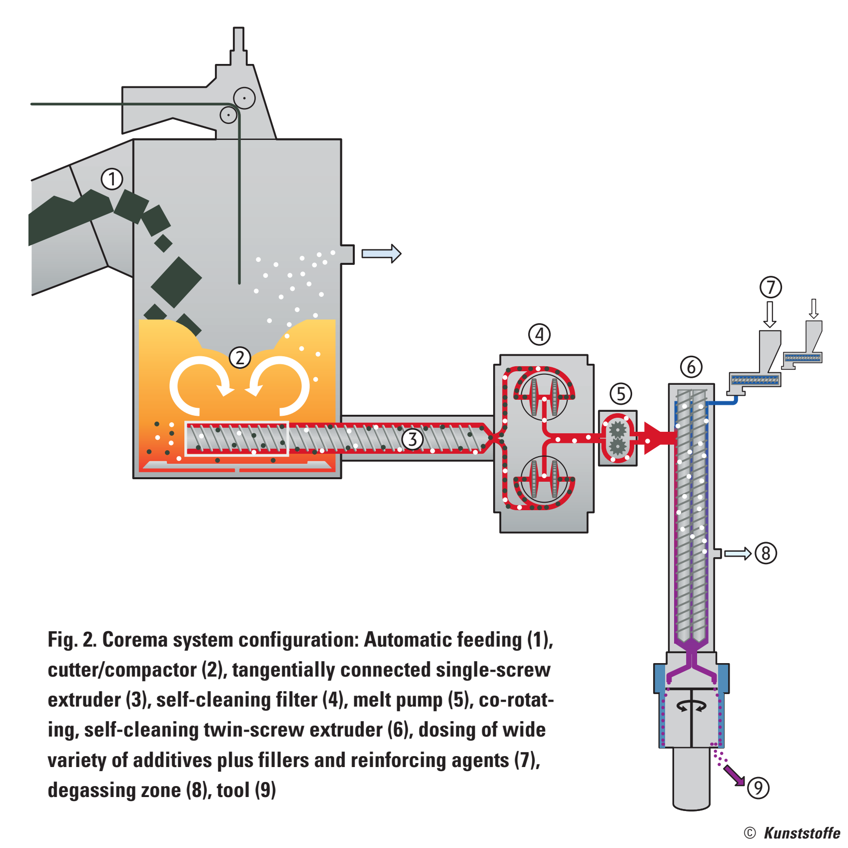

Fig. 2. Corema system configuration: Automatic feeding (1), cutter/compactor (2), tangentially connected single-screw extruder (3), self-cleaning filter (4), melt pump (5), co-rotating, self-cleaning twin-screw extruder (6), dosing of wide variety of additives plus fillers and reinforcing agents (7), degassing zone (8), tool (9)

In particular the short, defined dwell times and direct dosing of the melt in the twin-screw extruder reduce thermal stress on the material enormously. Additionally, operating costs are reduced and the modular system concept offers optimum adjustment to the respective application

In summary the Corema system is characterized above all through flexibility in terms of possible materials and plant configurations and is available for both smaller amounts of 300 kg/h and large amounts of up to 4 t/h.

Highly Filled PP/Talc Recyclates

With an amount of approx. 300,000 t/a, talc, besides calcium carbonate ($CaCO_3$) is one of the most important mineral fillers – primarily for polypropylene (PP) – in Europe. It improves stiffness, hardness and heat distortion stability and is, furthermore, acid-resistant, i.e. practically chemically inert. Some 600,000 t of PP/talc compounds with 20 % talc are used in Europe every year which means around 120,000 t of talc. It is used mainly for household goods and in the automotive, construction and electronics industries **(Fig. 3)**. Compounders already produce approx. 60,000 t of this annual amount based on recycling material. With a share of over 50 % the automotive industry processes the largest amount of these PP/talc recyclates. According to forecasts the overall annual figure is set to rise by another 47,000 t.

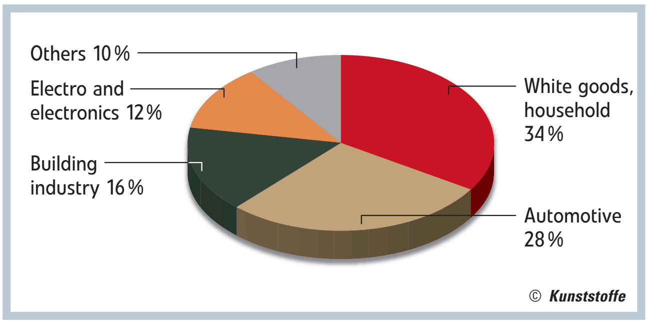

Fig. 3. Use of PP/talc in household goods and in the automotive, construction and electronics industries

One concrete example of use is nonwoven material production waste for the construction industry, which is processed using Corema to make highly filled recyclates with up to 70 % talc. **Table 1** shows the physical property profiles of various PP/talc recycled pellets based on nonwoven waste (with a talc share of up to 40 %).

To evaluate the quality of the dispersion the highly filled recycled pellets are processed to make a sample film on a laboratory flat film facility (producer: OCS GmbH, Witten, Germany). **Figure 4** documents the dispersion effect for a sample film made from recycled pellets with a talc share of 70 % and PP homopolymer.

Fig. 4. Flat film sample (width 60 mm) produced on an OCS measuring extruder ME25/25D-V3; material: 23 % highly filled PP nonwoven/talc recyclate (talc content 70 % Omya Talco SD 20) + 77 % PP homopolymer

The filled recyclates can thus be used directly for the production of end applications or as highly filled recycled pellets in the production of PP/talc compounds. The benefit of using the highly filled version is that fluctuations in quality of the recycled input material can be compensated by the mixing with a large amount of talc (in the example in question the PP nonwoven acts so to speak as the carrier material). This means that the use of recycling materials can be made more attractive, as higher recycled pellet amounts can be admixed to the end product and compounders can do business in a more sustainable way as a result.

Washed Silage Film and $CaCO_3$

With, according to the British market research institute Applied Market Information (AMI), plastic consumption amounting to around 545,000 t in 2011 (EU 27 plus Norway and Switzerland), agricultural films account for a substantial portion of recycling raw materials. On the other hand, the mostly very high degree of contamination through mineral and organic material **(Fig. 7)** of these soft and often only 25 to 100 µm films makes processing both difficult and time-consuming. As they consist of high-quality plastics such as LDPE (low-density polyethylene) and LLDPE (linear low-density polyethylene), however, they are in high demand as recyclates and can fetch good prices if the quality is high.

Figure 5. Washed shreds of severely contaminated agricultural film (left) processed with Corema 1108 T (filter system Erema SW 4/134 RTF, 300 µm) to make recycled pellets with 75 % $CaCO_3$ content

This recycling raw material is ideal as a carrier polymer, for example, for the production of highly filled calcium carbonate ($CaCO_3$) recycled pellets. With Corema technology, filling grades of up to 75 % $CaCO_3$ can be achieved. Washed LLDPE film pieces with a moisture content of up to 8 % serve as starting materials. Through the 2-stage design of the Corema system the washed agricultural film pieces are processed to make degassed, filtered melt in the first section of the system, the cutter/compactor-extruder combination. Air flushing also supports the process and ensures that a major part of the residual moisture evaporates from the preheated material. The processed melt is sent via the melt line directly to the second part of the system, the co-rotating twin-screw extruder, where it is mixed with up to 75 % $CaCO_3$. The result is highly filled LLDPE recycled pellets with narrower quality bandwidths and excellent distribution of the filler thanks to the dispersion performance of the twin-screw extruder. The quality of the dispersion can be seen in **Figure 6** which shows a film sample made from highly filled recycled pellets.

Airbags and Fibreglass

Fibreglass reinforced PA6.6 recyclates are another field of use for Corema. The input materials can be both fibre production waste and also (silicone-coated) fabric waste which is left over in the production of airbags, for example (see table of values PA6.6 **Table 2**). The challenge facing the recycling technology in the processing of fibre waste is the high specific surface of this input material. This makes it highly susceptible to contamination and moisture absorption, making effective drying and melt filtration essential. In this case Core-

				Nonwoven waste				
				Nature	Omya Talco SD 20			Lithos Talk LP 10
Properties	Test standard	Annotation	Unity	100 %	20 %	30 %	40 %	20 %
MFR	ISO 1133	(230 °C/2.16 kg)	[g/10 min]	35	31	25	21	51
Tensile Modulus E_t	ISO 527-2	(1 mm/min)	[Mpa]	1,400	2,300	2,900	3,600	2,700
Tensile Strength σ_M	ISO 527-2	(5 mm/min)	[Mpa]	34	27	26	26	30
Elongation at break ε	ISO 527-2	(5 mm/min)	[%]	>100	55	31	2	5
Charpy a_{cu}	ISO 179/1eU	(+23 °C)	[kJ/m²]	95	35	26	19	24

Table 1. Properties of filled PP/talc recyclates from PP nonwoven material production waste with varying talc types

				PA6.6 fibre and fabric waste from airbag production		
				Nature	Glass fiber	
Properties	Test standard	Annotation	Unity	100 %	15 %	30 %
MFR	ISO 1133	(230 °C/2.16 kg)	[g/10 min]	Not reported	Not reported	Not reported
Tensile Modulus E_t	ISO 527-2	(1 mm/min)	[Mpa]	3,200	5,400	9,500
Tensile Strength σ_M	ISO 527-2	(5 mm/min)	[Mpa]	83	120	165
Elongation at break ε	ISO 527-2	(5 mm/min)	[%]	14	3	2,5
Charpy a_{cu}	ISO 179/1eU	(+23 °C)	[kJ/m²]	95	39	40

Table 2. Properties of fibreglass reinforced PA6.6 recyclates from airbag production waste with varying fibreglass content

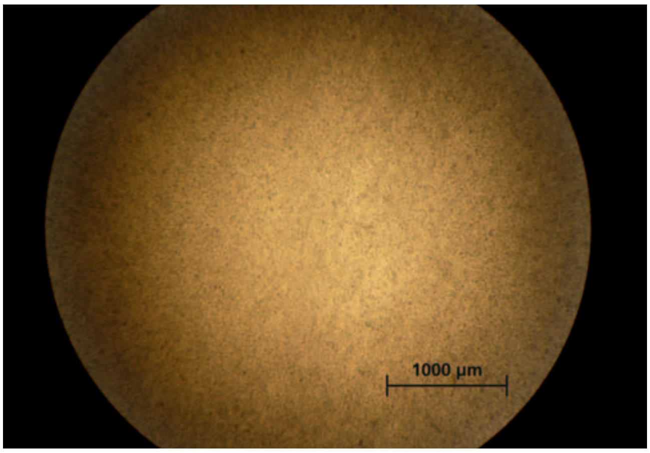

Figure 6. Light optical microscope image of a blown film sample produced on an OCS measuring extruder ME25/25D-V3; material: 23 % highly filled LLDPE agricultural sheeting/ $CaCO_3$ recyclate (calcium carbonate content 75 % Zetafil CST2) + 77 % LLDPE virgin material

Fig. 7. PA6.6 fabric/production waste from airbag production

Fig. 8. PA6.6 recyclate with 30 % fibreglass and masterbatch black from PA6.6 fibres and airbag production waste

ma, with its 2-stage combination consisting of the cutter/compactor and a tangentially linked single-screw extruder with efficient melt filtration, is the ideal solution. In the first section of the system the cleaned and dried melt is optimally prepared and then dosed into the second section, the twin-screw extruder, where up to 50 % fibreglass can be admixed. **Table 2** shows the property profile of fibreglass reinforced PA6.6 recyclates. A Corema 1108 T was used to recycle fibre and fabric waste from airbag production **(Fig. 7)**. The recycled pellets produced with a fibreglass content of 30 % are ideal for the production of technical injection molding articles, for example.

Rubber Flour as a Sustainable Filler Additive

The following example shows the potential of recycling material: rubber flour can be used as a sustainable filler additive to improve elasticity and absorbing properties and reduce costs. Austria alone accumulates over 50,000 t of scrap tyres every year. Besides thermal disposal and (not yet economical) raw material recycling such as depolymerisation or devulcanisation, there are various grinding processes in which scrap rubber can be turned into rubber pellets or rubber flour. These scrap tyre pellets are then reused as material fillers in thermoplastic mixtures.

Asamer Plastics in Austria produces these rubber recyclates under the trade names AsaBatch and AsaComp. Both mineral raw materials and recycled rubber flour from the group of companies are used for the specific recycled pellets of Asamer Plastics. Georg Weigerstorfer, director Erema R&D Centre: "One interesting example of how Corema technology can be used is heavily printed BO-PP (biaxially oriented polypropylene) production waste in combination with 50% AsaBatch, a highly concentrated rubber flour material. The recycled pellets produced with Corema is characterized through excellent absorbing properties and are suitable for outdoor use in the automotive, sport, leisure and household sectors plus building applications. These and similar, highly filled recycled pellets are sold under the trade name AsaComp." An example of the properties is shown in **Table 3.**

Properties	Test standard	Unity	Data
Density	ISO 1183	kg/m^3	1,116
MFR (190/2.16)	ISO 1133	g/10 min	1.4
Young's modulus	ISO 527	MPa	580
Tensile strength	ISO 527	MPa	14
Impact strength at room temperature	ISO 179/1eU	kJ/m^2	72
Imact strengt hat -20°C	ISO 179/1eU	kJ/m^2	61

Table 3. Properties of recycle compound AsaComp R10230C-60D

Conclusion

Thanks to the combination of the benefits of recycling and compounding technology in a single process stage, together with the particularly energy-saving and environment-friendly ecoSAVE design, cost efficiency, responsible use of resources, sustainability and thus higher value added are now possible. The positive aspects are reflected in Erema's statement: We close the loop. ■

THE AUTHOR

DI (FH) THOMAS HOFSTÄTTER, born in 1977, is responsible at Erema for the process engineering development of Corema.