Passes the Tensile Test

Strapping Band from Flake. The new Vacurema inline strapping technology is tailored for processing PET bottle flake into high-strength PET strapping in a single step. Compared to a conventional complex of individual machines, comprising crystallizer, dryer and extruder, it obtains a cost saving of up to 25 % for input material and an energy saving of more than a third.

CHRISTOPH WÖSS

As Rail Cargo Austria has reported in the past, serious threats to operations continually occur as a result of breakage of the steel straps binding the loading units. When the tensioned steel straps break, the free ends interfere with the high-voltage contact line and severely jeopardize operations. A recent incident occurred on January 6 this year in Thuringia, Germany. From February, 1, 2006, Railion Deutschland will therefore only accept consignments with the loading units secured with PET strapping of equal strength for transport on its rail network. […] As of May 1 of this year, rail networks will generally only accept consignments for shipping with loading units secured with PET strapping […].“ That was the text of a memo of February 23, 2006, by ProRail Internationale Speditionsgesellschaft m.b.H., Fürnitz, Austria, a rail shipping agent specializing in bulk goods, particularly timber.

The Advantages Speak in Favor of PET Strapping

Polyethylene terephthalate (PET) strapping is widely replacing classical metal strapping not only for securing the load in timber transport. There are several reasons for the advance of polyester strapping. With a tensile strength competitive with metal, PET strapping, thanks to its significantly higher elasticity, can even withstand repeated shocks. The packaged wares are therefore not shaken loose during transport. PET strapping is also not as sharp-edged as steel strapping, and therefore does not damage the packaged material, and the risk of injury during handling is much lower. PET is also more weathering resistant than steel and does not rust. Produced from PET bottle flake, the strapping is also very economically attractive and is superior to steel strapping as regards its carbon footprint.

These advantages explain the steadily growing use of PET-R in Europe for manufacturing PET strapping (Fig. 1). The 75,600 t that were used in this application in 2007 according to a PCI report [1] correspond to an increase of over 30 % over the previous year. Of the 738,200 t of PET-R that was recycled from bottle flake in 2007, 10.2 % was used in PET strapping production (in 2006 it was 9.2 % of a total of 622,300 t of PET-R).

The Austrian recycling system manufacturer Erema, together with its Italian technology partner Techno Plastic s.r.l., Castelfranco Emilia (Modena), designed a new inline strapping line operating with the “Vacurema” process. It can reprocess commercial PET bottle flake into high-

Growing Use of PET-R

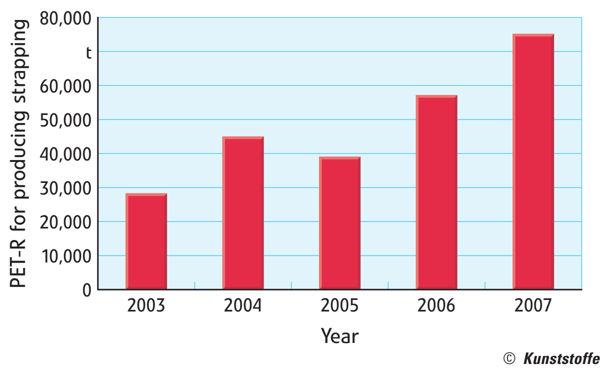

Fig. 1. Use of PET-R for producing PET strapping has more than doubled in Europe in the last four years (source: PCI reports 2005, 2006 and 2007)

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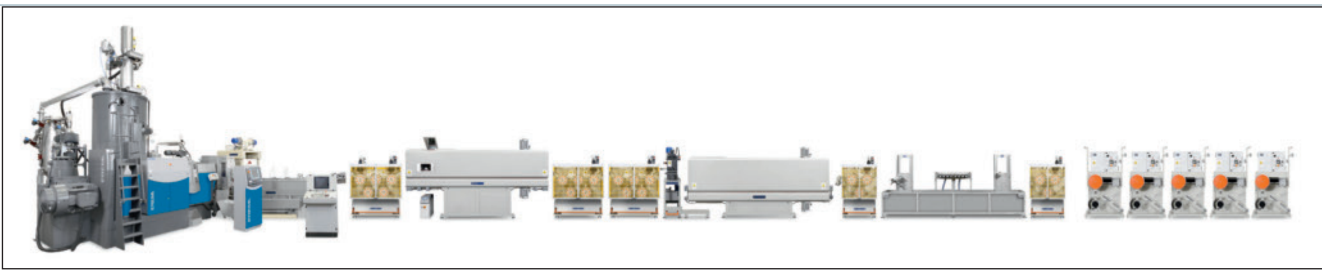

Fig. 2. The plant concept for inline processing of PET bottle flake into high tensile strength PET strapping consists of a Vacurema Strapping 1308 TE and a directly coupled Tight Strap 300 stretching line with up to 130 m/min take-off speed and a throughput of 300 kg/h (photos: Erema)

strength PET strapping in a single operation without further additives or treatment. In conventional strapping extrusion lines with a preliminary dryer, the PET flakes had to be augmented with a significant proportion (roughly a third) of PET virgin material to compensate for the material degradation taking place during extrusion (which reduces the intrinsic viscosity IV) (cf. e.g. [2]). The new Vacurema technology can therefore significantly reduce raw materials and manufacturing costs by using 100 % bottle flake as starting material.

In a Single Operation

The plant, which is optimized for inline processing of PET bottle flake into high tensile strength PET strapping, is a combination of the Erema extrusion system (type: Vacurema Strapping 1308 TE) and a directly coupled stretching line (type: Tight Strap 300 by Techno Plastic) (Fig. 2) with a throughput of 300 kg/h. A strap (embossed) recently produced in a practical demonstration, with a cross-section of only 15.75 × 0.84 mm^2, had a tensile strength of 517 N/mm^2 (smallest measured value), which corresponds to a breaking stress of the strapping of over 6,840 N (684 kg). The starting material was 100 % commercial, low-quality PET postconsumer flake that had merely been cold washed.

This is made possibly by Erema's Vacurema technology, which already has a proven track record in bottle-to-bottle recycling by reprocessing commercial bottle flake with a stable IV in a single operation. It does not require crystallizers or dryers as preliminary stages. The system operates with a vacuum reactor equipped with a rotating stirrer (patented), coupled with a robust single-screw extrusion system and optional high-performance degassing. The starting material, in this case PET bottle flake, passes, undried and without precrystallization, via a vacuum lock directly into the Vacurema reactor. Here, it is heated in a single operation (purely by frictional heat) and, by means of the applied vacuum, is dried, crystallized and freed of volatile contaminants. A single-screw extruder directly coupled

Parameter		Material 1	Material 2	Material 3	Material 4	Material 5
Feedstock						
Treatment		PET flakes, cold washed	PET flakes, hot washed	PET flakes, cold washed	PET flakes, hot washed	PET regrind from BOPET film
IV	[dl/g]	0.75	0.77	0.70	0.69	0.60
Bulk density	[g/l]	280	300	300	200	850
Residual moisture content	[%]	0.38	0.46	1.45	1.01	0.20
PVC	[ppm]	549	223	6	14	–
Polyolefins	[ppm]	45	38	30	456	–
Cellulose	[ppm]	3	–	591	–	–
Adhesive	[ppm]	–	–	2,235	357	–
Other contaminants		Oil residues	Oil residues	20 ppm sand	Oil residues, 66 ppm PET-G	–
Compounded melt / Process parameters						
IV of melt	[dl/g]	0.73	0.76	0.70	0.64	not measured
Throughput	[kg/h]	305	290	304	317	314
Specific energy absorption	[kWh/kg]	0.660	0.660	0.680	0.646	0.620
PET strapping, embossed						
Stretching	[%]	570	570	541	546	570
Tensile strength	[N/mm^2]	517–548	538	480	510	422
Elongation at break	[%]	12–15	12–15	15	15	12–15
Breaking stress	[N]	6,480–7,250	6,672	6,398	6,908	5,299
Strapping cross-section	[mm × mm]	15.75 × 0.84	15.9 × 0.78	15.5 × 0.86	15.75 × 0.86	16.1 × 0.78
Strapping weight	[g/m]	16.98	15.9	16.8	17.5	15.4
Splitting behavior[1)]	[no break/break]	18/02	19/01	19/01	20/00	18/02

1) In this test – not standardized – 20 samples are buckled in a defined manner in the stretching direction to estimate the splitting behavior of the strapping from the breaking behavior.

Table 1. Examples of PET strapping, manufactured by the Vacurema Inline strapping process from 100 % postconsumer PET

Parameter	Conventional with dryer + single-screw extruder	Vacurema Basic 1308 TE Inline-strapping
Production of PET strapping		
Throughput, nominal [kg/h]	300	300
Operating hours [h/a] (24 h/d, 300 d/a, availability 92.6 %)	6,667	6,667
Productivity [t/a]	2,000.16	2,000.16
Investment costs [EUR]		
Plant	1,200.000 (incl. crystallizer)	1,600,000
Freight	15,000	15,000
Commissioning	77,000	77,000
Import duty	Not considered	Not considered
Total investment costs	1,292,000	1,692,000
Fixed costs [EUR/a]		
Depreciation (5 years)	240,000	320,000
Financing (50% of investment costs at 6.5 %)	20,995	27,495
Hall floor area (required space 500 m^2 and 400 m^2 respectively; EUR 1.00/m^2 per month)	6,000	4,800
Total fixed costs	266,995	352,295
Variable costs [EUR/h]		
Personnel (2 operators à 13.00 EUR/h)	28.08	28.08
Maintenance	5.40 (3 % of plant investment/a)	4.80 (2 % of plant investment/a)
Energy (electricity) (EUR 0.15/kWh)	45.00 (power consumption: 1 kWh/kg)	30.60 (power consumption: 0.68 kWh/kg)
Total water costs (fresh water, cooling water)	10.75	10.75
Screen exchange (EUR 10.00/screen)	10.00 (2 screens in 2 h: Filter with 2 pistons with 1 screen each, without backflushing)	3.33 (4 screens in 12 h: Filter with 2 pistons with 2 screen each, with backflushing)
Total variable costs	99.23	77.56
Production costs [EUR/kg]		
Fixed costs	0.133	0.176
Variable costs	0.331	0.259
Total production costs	0.464	0.435
Operating costs		
Material costs [EUR/kg]	0.83 (1/3 original material à EUR 1.30 + 2/3 PET flake à EUR 0.60/kg)	0.60 (100 % PET flake à EUR 0.60/kg)
Material costs [EUR/a]	1,660,133	1,200,096
Production costs [EUR/a]	928,074	870,070
Total operating costs [EUR/a]	2,588,207	2,070,166
Payback		
Difference in operating costs [EUR/a]	+ 518,041	- 518,041
Difference in investment costs [EUR]	- 400,000	+ 400,000
Payback of the EUR 400,000 higher investment costs for the Vacurema system in 9.27 months.		

This calculation is an example and must be adjusted to individual conditions on a case-by-case basis.

Table 2. Comparative calculation of operating costs for the production of PET strapping

to the reactor, with a diameter of 80 mm in a specific case, plasticates and homogenizes the uniformly dried material. At the same time, it degasses the melt if necessary in the case of highly gassing foreign polymers or other contaminants. The material then passes without a melt pump directly into a fine filter, which is automatically self cleaning by backflushing.

The filtered melt is immediately processed inline into strapping by the Tight Strap 300 plant technology from Techno Plastic. The spinning head, equipped with a double melt pump splits the melt supplied by the Vacurema extruder into four strands, which then pass through a cooling bath. The solidified strands are then stretched and conditioned in multiple process steps (to more than five times the initial length on stretching rolls), then embossed and fixed. After cooling, the straps, with their final format, pass to the winding stations. The Tight Strap 300 line has an overall length of 50 meters.

Process Control Ensures Constant Quality

The aim of optimizing the Vacurema PET strapping plant technology was the economical recycling of bottle flake into a high-quality, IV-stable melt. This is the only way to ensure high levels of stretching of the strapping without impairing its strength. It was achieved by modifying the Vacurema basic reactor. Compared to the previous standard model, the volume of the vacuum reactor in the strapping plant (Fig. 3) was more than doubled, and at the same time adapted for a vacuum of below 10 mbar. The increased reactor volume and lower feed intervals thus lead to the desired positive effects: The prolonged treatment of the feedstock under high vacuum effectively removes contaminants and moisture, even with fluctuating batch contamination and moisture contents of 1.5 % and even higher. The result is thus a homogeneous melt obtained ▶

from the bottle flake with a constant, high IV (virtually without degradation).

Table 1 summarizes the data for some of the projects that have now been realized with the new plant technology. The feedstock for PET strapping production was always 100 % commercial postconsumer PET with the typical bandwidth of properties: variable bulk density, variable moisture content and variable treatment (cold or hot washed). As shown by the materials 1 to 3, the IV loss on compounding of the material with the Vacurema Strapping extrusion system is generally between 0 and 3 % (depending on the starting material). With these example materials it is also clear that even a moisture content up to 1.5 % (material 3) does not have an influence, i.e. decontamination under high vacuum in the Vacurema reactor is very effective. An IV loss of around 7 % as for material 4 is therefore the result of other contamination of the bottle flake, in this case particularly the relatively high polyolefin content (456 ppm), combined with oil residues. Nevertheless, the PET strapping manufactured from this melt still reaches very high strength values.

While high IV values are very important for good strapping quality, they are not the sole criterion. It is also important whether the strapping tends to split or not. The tests for simulating this behavior show a splitting tendency that is noncritical for practical purposes for all the PET strappings listed in Table 1, i.e. the strappings retain their tough elastic behavior despite stretching of well over 500 % (in the worst case, only two out of 20 samples broke in the buckling test).

Material No. 5 in Table 1 is an example that, with the Vacurema inline strapping line, even materials that are not normally used for PET strapping production result in serviceable strapping: The recyclate used, with an IV value of only approx. 0.6 dl/g, still results in a strapping with a breaking stress of 5,300 N (530 kg). This example shows at the same time that the plant can also process starting materials in pellet form, flakes, strapping production waste and pellets in any ratio. This generally robust and extremely stable method of compounding and generating the melt for the downstream stretching process leads to high dimensional stability of the produced strapping. On the Tight Strap plant, tolerances (deviation from the mean value) in the cross-sectional dimensions of all four strappings can be stably kept within ±0.2 mm.

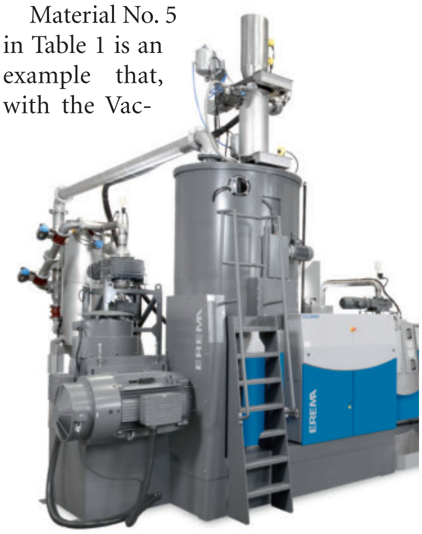

Fig. 3. For IV-stable processing of the melt from bottle flake, the Vacurema has over twice the volume of the former standard and is designed for a vacuum down to 10 mbar

Recycling of PET Beverage Bottles in Europe

The current situation in recycling of PET postconsumer bottle flake in Europe is illustrated by the consultancy PCI PET Packaging, Resin & Recycling Ltd., Derby, UK, in its report "Post Consumer PET Recycling in Europe 2007 and Prospects to 2012" issued in July 2007 [1]. The study included the 27 EU countries together with Norway, Switzerland and Turkey. PCI compiled the report for the European association Petcore, PET Containers Recycling Europe, Brussels, Belgium (www.petcore.org).

According to the report, the collection and return systems in Europe recycled a total of 1,131,000 t of PET beverage bottles in 2007, 19.8 % more than in the previous year. At a turnover of 2,754,800 t of PET bottles, that corresponds to a return quota of 41.1 % (the quota was 36.8 % in 2006). The total of 738,200 t of PET-R generated in 2007 by mechanical recycling was used to produce predominantly polyester fibers for the textile industry (47.1 %), followed by flat film and sheet (24.2 %), blow molded parts (16.8 %), packaging strapping (10.2 %) and injection moldings (0.9 %).

Efficiency Improvements Due to Energy and Material Savings

As mentioned above, the new Vacurema inline strapping technology as starting material only requires PET postconsumer material of simple standard quality. This results in cost savings of up to about 25 % in input material compared to conventional extruder processing. In addition, the Erema process has a specific power consumption that is more than a third lower than conventional extrusion systems with upstream crystallizer and dryer. The effect of this on production costs is given in detail in the comparative calculation in Table 2. The comparison is for a conventional production system comprising a single-screw extruder, including upstream dryer with the Vacurema Strapping-1308-TE Inline strapping line with the same throughput.

According to this, the Vacurema system involves EUR 400,000 higher investment costs and thus higher fixed costs for financing and depreciation, which must be paid off. Since, with this plant technology, fewer components need to be maintained than for the conventional strapping line, 2 % of the plant investment has been earmarked for this instead of the 3 % as in the conventional case. For the energy costing, the highest energy specific consumption of 0.68 kWh/kg measured from the practical tests has been used for Vacurema technology (cf. Table 1); however, in the vast majority of cases consumption was significantly lower than this. With these conditions, the Vacurema inline strapping system results in almost 22 % lower variable costs and an advantage of about 6 % in the total of fixed and variable costs.

However, if the raw materials costs are included in the calculation, at an annual production of about 2,000 t of PET strapping, there is a saving in running costs of EUR 518,041 annually for the Vacurema Inline Strapping System. The investment costs necessary for this plant technology, which are around EUR 400,000 higher, thus pay back in only nine (9.27) months. After that, the saving in running costs is booked as profit; in five years (write-off time of the plant), this would be – with the higher investment costs deducted – around EUR 2.2 million. ■

REFERENCES

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2 Steel Straps Superseded. Kunststoffe international 98 (2008) 8, pp. 49–50, document number: PE104335

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