Recycling of Polymer Materials

Dipl.-Ing. Günther Höggerl, MEng

Project PolyRegion
19.02.15.
Topics

- General Introduction
- Polymer Overview
  - Global role of polymers
  - End of life (waste) situation
- Creating high grade recycled polymers
  - Crushing /Cleaning
    - (Separation and sorting)
  - Granulation (Modification)
- Processing of recycled polymers
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- General Introduction

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  (Separation and sorting)
  Granulation (Modification)

- Processing of recycled polymers
since 2011 Müller Guttenbrunn GmbH (www.mgg-recycling.com) Recycling Industry, Head of Research & Development

HEC Engineering&Consulting


2004 - 2005 Harreither Intelligente Energiesysteme (www.harreither.com) Home energy systems, Head of Research & Development

1996 - 2003 EKB GesmbH - Dräxlmaier Austria (www.draexlmaier.com) Automotive Supplying Industry, Head of Product Development

1988 - 1995 Studies in Polymer Engineering and Science
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- Processing of recycled polymers
Global demand of raw materials

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron&amp; Steel</td>
<td>848</td>
<td>1.144</td>
<td>1.428</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+34%</td>
<td>+24%</td>
</tr>
<tr>
<td>Polymers</td>
<td>180</td>
<td>235</td>
<td>265</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+31%</td>
<td>+12%</td>
</tr>
<tr>
<td>Aluminum</td>
<td>53</td>
<td>65</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+22%</td>
<td>+31%</td>
</tr>
<tr>
<td>Copper</td>
<td>13</td>
<td>16</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+23%</td>
<td>+18%</td>
</tr>
</tbody>
</table>

Source: Plastics Europe, Wordsteel.org, world-aluminium.org, www.copper.org
Increasing global need of polymers

Source: Plastics Europe
European demand by segments/polymers

Source: Plastics Europe
European demand of polymers within segments

Source: Plastics Europe
Unique features of polymer materials

- Low density
- High spec. Strength/stiffness
- Low heat conduction
- Low electrical conductivity
- Chemical resistance
- Modifiability – „tailor made properties“
- Low processing costs
- High energy content
- Increasing cycle speed in developed countries
- Increasing interest in anthropological reservoirs = Waste („urban mining“)
- Functioning cycle of materials essential for competitiveness
European waste management

- European Frame Work Directive (EU RL2008/98/EG) defines strategic playing field
- Important: „Five steps waste hierarchy“
European waste management

Example: PET Bottle

End of life (waste) situation
European waste management

Reduce
Reuse
Recycling
Energy recovery
Disposal

End of life (waste) situation
European waste management

Reduce

Reuse

Recycling

Energy recovery

Disposal

End of life (waste) situation
European waste management

- Reduce
- Reuse
- Recycling
- Energy recovery
- Disposal

End of life (waste) situation
European polymer recovery overview

Figure 10: Recovery reached almost 60% in 2011 – and continues to increase (EU-27+N/CH 2011)
The 26.4% Others in Figure 10 refers to agriculture, furniture, household, leisure, sport, medical and machinery applications.
Source: PlasticsEurope Market Research Group (PEMRG), Consultic

Source: Plastics Europe
European polymer recovery overview

Source: Plastics Europe
European polymer recovery overview

- **Feedstock Recycling**
- **Mechanical Recycling**
- **Thermal Recycling**
- **Total**

End of life (waste) situation
Post consumer vs post industrial polymer waste (Germany)
Post consumer polymer waste....
Post consumer polymer waste....
Topics

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- Processing of recycled polymers
# Recycling paths for polymers

<table>
<thead>
<tr>
<th>Method</th>
<th>Mechanical Recycling</th>
<th>Feedstock Recycling</th>
<th>Energetic Recycling</th>
</tr>
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<tbody>
<tr>
<td>Processing</td>
<td>Extrusion/Injection molding</td>
<td>Hydrolysis Gasification Pyrolysis</td>
<td>Incineration</td>
</tr>
<tr>
<td>Products</td>
<td>Regenerate</td>
<td>Monomers</td>
<td>Heat</td>
</tr>
<tr>
<td>Side products</td>
<td>Strands, Lumps</td>
<td>Non crackable material</td>
<td>Ash, slag</td>
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</tr>
</thead>
<tbody>
<tr>
<td>No change in molecular structure</td>
<td>Cracking of molecular structure</td>
<td>Oxidation with oxygen</td>
<td></td>
</tr>
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<td>Extrusion/Injection molding</td>
<td>Hydrolysis Gasification Pyrolysis</td>
<td>Incineration</td>
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Creating high grade recycled polymers
Crushing / Cleaning
Crushing - Single shaft shredder

- Simple Design
- Robust
- Material feed necessary

Quelle: Herbold
Crushing - Multi Shaft Shredder

- Complex Design
- Robust
- Self feeding – no material feed necessary

Quelle: Lindner
Crushing - Grinder

- Simple Design
- Defined output material (particle size distribution)
- Sensitive to non plastic material

Quelle: CentriCut
Cleaning - Wet processing

- Cleaning in combination with conveying
- Process water treatment
- Waste water
Cleaning - Dry processing

- Centrifugal forces do cleaning and drying
- No process water
- Low energy consumption

Quelle: MAS
Separation and sorting

- Manual sorting
- Sorting by density
- Sorting by reaction to electromagnetic oscillation (Color, Infrared, X-ray)
- Sorting by triboelectrical reactions
- …
Granulation / Modification of recycled material

General material requirements:

– Low dirt/mud content
– Less „hard“ contaminations (metal parts, glass, etc.)
– Low fines content (particles <1mm)
– Pure polymer material without crosscontaminations
– Dry Material
Granulation / Modification of recycled material

General equipment requirements

– Material predrying system
– Wear protected Extrusion lines
– Twin screw extrusion systems preferred
– Dosing of additives
– Efficient degassing system
– Continuous melt filtration system
Creating high grade recycled polymers – Granulation (Modification)
Basic design parameters of a twin screw extruder

- Diameter ratio $\frac{D_a}{D_i}$ defines shear stress, degassing and dosing performance
- Specific torque $\frac{M_d}{a^3}$ defines filling degree and throughput performance
- Rpm $n$ defines shear stress and mixing performance
**Extrusion lines – specialized Layouts**

- Conical co-rotating twin screw layout
- Increased feed volumina due to bigger feed opening
- Increased torque due to increased screw diameter
- Higher pressure => lower melt temperatures

Quelle: MAS
Extrusion lines – specialized Layouts

– Homogenisation (single screw) separated from Compounding (twin screw)
– High pressure generation (single screw) with advantages in melt filtration
– Effective degassing and dosing of additives in twin screw extruder

Quelle: Erema
Polymer melt filtration (Extrusion)

- Filter screen designed as a disc
- Filter holes drilled with laser
- Continuously self cleaning filtration system
- Automated operation
Polymer melt filtration (Injection molding)
Effect of proper extrusion on mechanical properties
Effect of cleaning on mechanical properties

<table>
<thead>
<tr>
<th>Kennwerte vor und nach Reinigung der Mahlgüter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinigung</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td><strong>Polycarbonat Mahlgut</strong></td>
</tr>
<tr>
<td>Nein</td>
</tr>
<tr>
<td>Ja</td>
</tr>
<tr>
<td><strong>Polyamid Mahlgut</strong></td>
</tr>
<tr>
<td>Nein</td>
</tr>
<tr>
<td>Ja</td>
</tr>
</tbody>
</table>
Effect of polymer cross contamination

Purity - Impact (notched Izod) correlation for virgin ABS and PS

<table>
<thead>
<tr>
<th>Sample</th>
<th>Notched Izod (kJ/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% Polystyrol 485I (Leer)</td>
<td>13.5</td>
</tr>
<tr>
<td>05% Polystyrol 485I (Leer)</td>
<td>19.5</td>
</tr>
<tr>
<td>-</td>
<td>26.5</td>
</tr>
<tr>
<td>10% Teurlan GP 22 (Leer)</td>
<td>8.5</td>
</tr>
<tr>
<td>05% Teurlan GP 22 (Leer)</td>
<td>9.5</td>
</tr>
<tr>
<td>PS (BASF, Polystyrol 485I)</td>
<td>10.9</td>
</tr>
</tbody>
</table>

+7 kJ/m² = +35%
Effect of additives (impact modifier) on mechanical properties

<table>
<thead>
<tr>
<th></th>
<th>Mw E-Modul MPa</th>
<th>Mw $\sigma_M$ MPa</th>
<th>Mw $\varepsilon_B$ %</th>
<th>Mw Charpy U kJ / m$^2$</th>
<th>Mw Charpy A kJ / m$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Polycarbonat Erstextrusion</td>
<td>2646</td>
<td>62,5</td>
<td>7,7</td>
<td>112</td>
<td>5,5</td>
</tr>
<tr>
<td>100% Polycarbonat Zweitextrusion (Referenzprobe)</td>
<td>2630</td>
<td>60,8</td>
<td>5,9</td>
<td>115</td>
<td>7,1</td>
</tr>
<tr>
<td>98% Polycarbonat 2% Paraloid</td>
<td>2544</td>
<td>57,8</td>
<td>6,3</td>
<td>117</td>
<td>10,2</td>
</tr>
<tr>
<td>95% Polycarbonat 5% Paraloid</td>
<td>2417</td>
<td>54,4</td>
<td>6,6</td>
<td>122</td>
<td>13,2</td>
</tr>
</tbody>
</table>
Quality control in polymer recycling

- Product Knowledge is essential for long term success on the market
- In-house quality control procedures guarantee earliest „bad trends“ detection
- Costs for Invest and staff are compensated with reduced overall operational costs and claim risks
Quality control in polymer recycling

MFR variation of ABS standard grade on daily basis

Creating high grade recycled polymers – Granulation (Modification)
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Processing of recycled polymers
SAUBERE ROHSTOFFE

- Voller Verzicht auf Substanzen wie Zink, Cadmium und Blei
- Voller Verzicht auf PVC für die Herstellung unserer Stempel
- Permanentes Lieferanten-Screening nach Umwelt- und Qualitätszertifizierungen

SPARSAMER ENERGIEEINSATZ

- Wärmerückgewinnung aus der Produktion zur Gebäudeheizung
- Kühlung der Spritzgussmaschinen mit Außenluft
- 62% des Strombedarfs stammen aus erneuerbaren Energien

VERANTWORTUNGSVOLLE PRODUKTION

- Ca. 80% aller Produktionsabfälle werden wiederverwertet
- 100% Recycling bei mechanisch nicht beanspruchten Teilen
- Ausschuss in der Produktion ist kleiner als 0,3%
- Die gesamte Produktion ist völlig frei von Abwässern

WENIGER CO₂

- 1000 Tonnen Einsparung an CO₂ Emissionen rein durch Reduktion von fossilen Brennstoffen, Erdgas und Strom seit Mitte 2001
- 250 Tonnen zusätzliche Einsparung an CO₂ durch Umstieg von Heizöl auf Erdgas.

Wer Trodat Stempel verkauft, setzt also automatisch auf verantwortungsvoll hergestellte Artikel.
Processing of recycled polymers
Recommendation I – Lowering Temperature profiles

=> Temperature settings minus ~ 5%
Recommendation II – Lowering rpm (dosing)

\[ n \left[ \frac{U}{\text{min}} \right] = \frac{V_u \left[ \frac{m}{s} \right]}{D [\text{mm}] \times \Pi} \times 60000 \]

- \( n \)..... Revolutions per minute
- \( V_u \)..... max. peripheral speed
- \( D \)..... Screw diameter
- \( \Pi \)..... 3.1415

<table>
<thead>
<tr>
<th>Polymer</th>
<th>( Vu ) max [m/s]</th>
<th>( n ) max [U/min] (screw diameter 40mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>0.9</td>
<td>~400</td>
</tr>
<tr>
<td>ABS</td>
<td>0.4</td>
<td>~200</td>
</tr>
<tr>
<td>PC</td>
<td>0.2</td>
<td>~100</td>
</tr>
<tr>
<td>PA</td>
<td>0.3</td>
<td>~150</td>
</tr>
</tbody>
</table>

=> Minimized thermal stress to the melt
Recommendation III—Increasing backpressure (dosing)

- Homogeneous melt temperature
- Reduction of splays

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Backpressure [bar]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP</td>
<td>150-200</td>
</tr>
<tr>
<td>ABS</td>
<td>100-150</td>
</tr>
<tr>
<td>PC</td>
<td>100-150</td>
</tr>
<tr>
<td>PA</td>
<td>100-150</td>
</tr>
</tbody>
</table>
- Mechanical Recycling of polymer waste is in strong competition with energetic recycling (Incineration)
- Mechanical Recycling of post industrial or post consumer plastic waste makes sense in both, ecologically and economically.
- Effective and efficient logistics in collection of post industrial or post consumer plastics waste is the basis for success.
- Quality controlled effective logistics in combination with proper separation (if necessary) and granulation/modification technologies give high grade secondary raw materials suitable for high quality products
QUESTIONS?

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