Filled Thermoplastics

Filler-Polymer Interactions

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Outline

- Introduction
- BASF & Plastics
- General properties of filled polymers
- Importance of agglomeration
- Surface treatment to aid dispersion
- Results
- Conclusions
BASF & Plastics

- BASF is the world’s leading chemical company
- 95,000 employees
- Chemicals, Plastics, Performance Products, Agricultural Products & Nutrition, Oil & Gas
- Turnover 42.7 Billion Euros
- ~28 % of that is Plastics
- Plastics are: PS, HIPS, SAN, ABS, ASA, MABS, ABS/PA, SBS, PA6, PA6,6, POM, PBT, PSU, PES, PUR
## Reasons to use fillers

- Raise heat resistance
- Increase stiffness
- Increase strength
- Reduce shrinkage
- Improve dimensional stability
- Reduce flammability
- Modify flow
- Increase lubricity
- Decrease permeability
- Increase degradability
- Improve processability
- Reduce creep
- Change electrical properties
- Modify specific gravity
- Improve abrasion resistance
- Improve impact strength
- Improve thermal conductivity
- Improve moisture resistance
- Increase adhesion
- Appearance, opacity, gloss
**Tensile testing**

- Stress or Force (MPa)
- Strain or elongation (%)

**Increasing temperature**
- Lower testing speed
- Plasticiser added

**Brittle failure**
- Yield
- Ductile failure

**Break or ultimate**
- Energy to break
Fillers and Modulus

The graph shows the relationship between filler volume (in %) and modulus (in GPa) for various fillers:
- Glass Fibre
- Mineral Fibre
- Mica
- Talc
- CaCO3
- Wood fibre
- Nanoclay
- Wollastonite

As the filler volume increases, the modulus also increases for all fillers. The graph illustrates how each filler type affects the modulus differently, with Glass Fibre showing a significant increase in modulus compared to others at higher filler volumes.
Fillers and Yield Strength

- Glass Fibre
- Mineral Fibre
- Mica
- Talc
- CaCO₃
- Wood Fibre
- Nanoclay
- Wollastonite
Fillers and HDT

The graph shows the relationship between filler volume and HDT (Heat Distortion Temperature) for various fillers. The x-axis represents the filler volume (in %), and the y-axis represents the HDT (in °C) for a load of 1.8 MPa. The fillers include Glass Fibre, Mineral Fibre, Mica, Talc, CaCO3, and Wood Fibre. Each filler type is represented by a different color and line style on the graph.
Density & weight % filler

\[ \rho_c = \frac{\rho_f \times \rho_p}{\rho_p m_f + \rho_f \times (1-m_f)} \]

- \( \rho_c \) - density of composite
- \( \rho_p \) - density of polymer
- \( \rho_f \) - density of filler
- \( m_f \) - weight fraction of filler

Graph showing the relationship between density and weight % filler for different fillers: Talc in PP, Magnetite in PP, and Tungsten in PP.
Some reasons to surface modify

- Improved filler production, e.g. dewatering
- Filler protection (e.g. from water)
- Improved processing in polymer due to better flow (higher throughput)
- Less adsorption of catalysts, curing agents, antioxidants, antistatics and other additives
- Improved composite properties, especially impact strength
Two types of modifier

Dispersant

Coupling Agent
Surfactant amphiphilicity

Stearic acid

Alkyl silane

Surfactant tail

Surfactant head
Brittle & ductile fracture (unnotched impact)

40 weight % CaCO$_3$ in PP homopolymer

Brittle $\sim$20 kJ/m$^2$
Untreated filler

Ductile $\sim$40 kJ/m$^2$
Stearate treated filler
Particle size distribution

Particle size (µm)

% in range

Raise viscosity & agglomerate

Reduce impact resistance
## CaCO₃ Size and cost

<table>
<thead>
<tr>
<th>Cost Euro / ton</th>
<th>Cost Euro / litre</th>
<th>Size CaCO₃ d₅₀ microns</th>
<th>Approximate Polymer Prices</th>
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<tbody>
<tr>
<td>100</td>
<td>0.27</td>
<td>~2</td>
<td>PP 0.68</td>
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<tr>
<td>200</td>
<td>0.54</td>
<td>~1</td>
<td>PE 0.74</td>
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<tr>
<td>300</td>
<td>0.81</td>
<td>~0.5</td>
<td>PS 0.84</td>
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<td>500</td>
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<td>~0.1</td>
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<td></td>
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<td>PC 2.8</td>
</tr>
</tbody>
</table>
Twin screw extruded stearate coated CaCO$_3$ in polymer

D$_{50}$ 1.8 micron, D$_{98}$ 10 microns
Twin screw extruded stearate coated CaCO$_3$ in polymer

$D_{50}$ 0.85 micron, $D_{98}$ 5 microns
Twin screw extruded stearate coated CaCO$_3$ in polymer

Primary particles 70 nm
### PPC Particle size and energy input

<table>
<thead>
<tr>
<th>Light scattering</th>
<th>Value</th>
<th>Description</th>
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<tr>
<td>Light scattering weak U/S</td>
<td>20</td>
<td>Agglomerates</td>
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<td>Light scattering medium U/S</td>
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<td>Basic Aggregates</td>
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<tr>
<td>Light scattering strong U/S</td>
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<td>Stronger Aggregates</td>
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<tr>
<td>Electron microscopy</td>
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<td>Crystallites</td>
</tr>
<tr>
<td>X-Ray</td>
<td>0.07</td>
<td>Crystallites</td>
</tr>
</tbody>
</table>

Courtesy of Rothon Consultants
Actual particle size in composite and impact resistance

Impact resistance

Real particle / agglomerate size

Datasheet particle size
Conclusions

- Many properties vary linearly with the volume % of filler added
- Surface treatment of filler improves processing and properties
- Surface treatment can help dispersion and even change to failure mechanism of the material
- The properties are determined by the size of the filler / agglomerates in the polymer not the datasheet values