New Developments in Compounding Biomaterials

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Content

- IWK - Institute of Material Science and Plastics Processing
- Overview of the Compounding systems
- Process needs, machine requirements
- New developments in Compounding
  - Feed Enhanced Technology
  - Feeding of Liquids
  - Injection Nozzles
  - Side Degassing
- Project presentation “FluidSolids”
Biomaterials / Biopolymers

**Biomaterials:**
- Biopolymers as PLA, PHA (PHB), Starch, etc.
- Biofibers/Biomass as **Cellulose**, Hemp, Flax, Woodfibers etc.

**Material performance (concerning processing):**
- Shear sensitive -> low shear
- Temperature degradable -> low temperature
- Moisture sensible -> good degassing behavior
- Processed in water -> high moisture content
Typical steps in plastics processing:

1. Raw Material
2. Material Handling
3. Compounding
4. Injection Molding
5. Testing
Compounding systems

Single screw extruders | Buss-Kneader | Twin screw extruders | Multiple screw extruders

- Co-rotating
- intermeshing

- counter-rotating
- not intermeshing

Multiple screw extruders:
- Buss-Kneader
- Co-rotating, intermeshing
- Twin screw extruders
- Co-rotating, not intermeshing

New Developments in Compounding Biomaterials

HSR Hochschule für Technik Rapperswil
FH O Fachhochschule Ostschweiz
INSTITUT FÜR WERKSTOFFTECHNIK UND KUNSTSTOFFVERARBEITUNG
Bulk materials are solid goods, the behavior could vary between solid goods and liquids.
Bulk material handling

Bridgebuilding or flow problems in the hopper
Feed section design

Feed section: feed limitation

Wrong design:
- Filter bag
- Feeder
- Extruder
- Bulk density 0.25 g / dm³
- Specially fine powders are catching a lot of additional air in the feeding pipe.
- Bulk density 0.08 g / dm³

Correct design:
- Filter bag
- Feeder
- Extruder
**Process Length** = \( \frac{L}{D_a} \)
Scale up – Influence of cooling and heating

Cooling or heating surface versus volume or throughput

Diameter Ratio = \( \frac{D_a}{D_i} \)

- Area in sqm/40 D
- Volume in l/40 D
- Ratio l/sqm
- Scale up factor based on ZSK 25

Screw diameter in mm
Feed Enhancement Technology

FET: Technology to increase the throughput of feed limited products

Solids conveying is improved by applying vacuum in the feed zone to a wall section which is porous and permeable to gas

This wall section is realized by an insert with a filter membrane installed in an open barrel.
FET Installation possibilities

In the feed section of the ZSK upstream of the feeding point

In the feed section of the ZSK downstream of feeding point

FET can only be used for solids conveying!

In the side feeder (ZS-B)
Effects:
- air is removed $\rightarrow$ higher bulk density
- friction is changed in the area of insert
FET Mechanism

Friction and higher bulk density increase the conveying angle:

Conveying angle \( \uparrow \) \( \rightarrow \) capacity \( \uparrow \)

\[
Q = F \ast H \ast n \ast \varepsilon \ast \eta \ast \gamma
\]
SEI can be reduced by:
- increasing capacity at same screw speed
- reducing screw speed at same capacity

\[
\begin{align*}
\text{SEI}_4 &< \text{SEI}_1 \\
\text{SEI}_3 \\
\text{SEI}_2 \\
\text{SEI}_1
\end{align*}
\]
Biobased Materials processed with water

Steps in material preparation for the compounding process

1. Biobased Materials processes in water
2. Drying step (Milling)
3. Powder Dosing
4. Compounding

1. Biobased Materials processes in water
2. Drying step (Milling)
3. Dosing Liquids
4. Compounding with a high amount of water
Challenges with water based fillers

By adding Filler and water into the extruder, the water evaporates and cools the polymer down.

Energy input is needed, that the aggregate state of the polymer doesn’t change. Polymer should not “freeze”

(Energy input caused by conveying or mixing is not calculated.)
## Compounding water based Fillers/Fibers

### A calculation tool

<table>
<thead>
<tr>
<th></th>
<th>Input</th>
<th>Final Product</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3.5% Fiber + H2O</td>
<td>melted Polymer</td>
</tr>
<tr>
<td>Fiber+H2O</td>
<td>Fiber</td>
<td>Polymer</td>
</tr>
<tr>
<td>Quantity</td>
<td>100</td>
<td>3.5</td>
</tr>
<tr>
<td>Density</td>
<td>ρ</td>
<td>1.2</td>
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<tr>
<td>Volumetric Flow</td>
<td>V</td>
<td>3.76</td>
</tr>
<tr>
<td>Mass Flow</td>
<td>m</td>
<td>4.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.00125</td>
</tr>
<tr>
<td>Room Temperature</td>
<td>T1</td>
<td>20</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>T2</td>
<td>200</td>
</tr>
<tr>
<td>Melting Point</td>
<td>Ts</td>
<td>150 - 160</td>
</tr>
<tr>
<td>Enthalpie (20°C to</td>
<td>Δh</td>
<td>2591000</td>
</tr>
<tr>
<td>100°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific Heat Capacity</td>
<td>cp</td>
<td>4092.78</td>
</tr>
</tbody>
</table>

**Heat Flows of:**

<table>
<thead>
<tr>
<th></th>
<th>Result</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Capacity</td>
<td>Hh</td>
<td>3549.94</td>
</tr>
<tr>
<td>Polylactide</td>
<td>Hp</td>
<td>180.00</td>
</tr>
<tr>
<td>Input NFC+H2O</td>
<td>Hin</td>
<td>0.00</td>
</tr>
<tr>
<td>Output Water Vapor</td>
<td>Hw</td>
<td>3537.70</td>
</tr>
<tr>
<td>End product</td>
<td>Hpnfc</td>
<td>192.24</td>
</tr>
<tr>
<td>Temperature Endproduct</td>
<td>t</td>
<td>200.00</td>
</tr>
</tbody>
</table>
Compounding water based Fillers/Fibers

Needed Heat Capacity for Fibrous-Suspension

- end product 1% NFC, mp=3kg/h
- end product 3% NFC, mp=3kg/h
- end product 5% NFC, mp=3kg/h

Heat Capacity [W]

Quantity Fibrous Material in Input [%]

New Developments in Compounding Biomaterials
the spring load must be adjusted according to the extruder pressure to prevent entering of melt

extruder pressure ≤ spring preload

for opening, the pump pressure must be bigger than the spring preload

spring preload ≤ pump pressure
The lifting of the needle creates an annular gap. Only a small axial movement of the needle is necessary to create the full crosssection area.
Injection Nozzle Technology

Characteristics for throughput

![Graph showing throughput vs. pressure for different nozzle sizes and media (water and oil). Points labeled 1/1 mm; Water, 2/2 mm; Water, 3/3 mm; Water, 6/3 mm; Oil, 5/2 mm; Oil, 7/1.7 mm; Oil, 8/1.7 mm; Oil+Springs Loads, 4/1 mm; Oil. The graph highlights a problem in lab scale.]
Degassing of the process section / Side Degassing Unit

<table>
<thead>
<tr>
<th>Feeding section</th>
<th>Melting section</th>
<th>Conveying section</th>
<th>Mixing section</th>
<th>Venting section</th>
<th>Homogen section</th>
<th>Degassing section</th>
<th>Metering section</th>
</tr>
</thead>
</table>

![Diagram of polymer processing system](image)

**Polymer feed**

**Atmospheric vent**

**Vacuum degassing**

**Filler feed**

**Venting Port**

*Picture Coperion*
Project «FluidSolids»

Process optimization Compounding

- Goals
  - Analysis of the current process
  - Optimization of system configuration (screw design, position of feeding, process parameters, …)
  - Operating tests
- Partners
  - FluidSolids AG, Zürich
- Funding
  - Public and Private
New Developments in Compounding Biomaterials
Project: «FluidSolids®»

Umweltpreis der Schweiz 2016
Environmental Award of Switzerland 2016
Extrusion trials at the IWK Lab
Thank you very much for your attention!

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