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› materials handling
› service
Evolving from Batch to Continuous Production of Sealants Using Twin Screw Extrusion Technology

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Agenda

I. Discontinuous Sealant productions

II. Continuous Sealant production

III. Comparison & conclusion
Discontinuous Sealant production

- Batch kneader with discharge screw
- Blades according to process requirements
- Possibility to attach downstream equipment
- Middle- to high viscous hot melt
- Variant for low viscous hot melts: kneader with bottom valve for emptying in intermediate vessels

Planetary mixers

- Double planetary mixer with combined agitators
- Rotating on their own axes as they orbit on a common axis
- Various agitators useable
- Convertible agitators
- Mobile mixing vessel for transport

Source: Charles Ross & Son Company
Weighing of the raw materials

Addition and plasticisation/ mastication of the base polymers

Addition of fillers (if existent)

Addition of a subset of low-viscous and low-melting resins, waxes

Addition of residual amount of low-viscous and low-melting resins, waxes

Addition of softeners (if existent)

Addition of additives

Degassing

Discharging

Cleaning at recipe- or colour changes
Discontinuous Sealant production – Requirements and limiting characteristics

<table>
<thead>
<tr>
<th>Requirements for production technology</th>
<th>Limiting characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Flexibility</td>
<td>• Increased personnel expenses</td>
</tr>
<tr>
<td>• Economics</td>
<td>• Long processing times</td>
</tr>
<tr>
<td>• Efficiency</td>
<td>• Big cyclic cleaning effort</td>
</tr>
<tr>
<td></td>
<td>• Batch quality variations</td>
</tr>
<tr>
<td></td>
<td>• Degassing difficulty</td>
</tr>
</tbody>
</table>

Competitiveness correlates with the characteristics of the limiting factors of a production technology.
Continuous production machines

- Single screw extruder
- Co-Kneader
- Co-rotating
- Intermeshing

- Twin screw extruder
- Counter-rotating
- Tangential

- Multiple screw extruder
- Planetary extruder
- Ring-extruder
# Comparison of continuous extrusion systems

<table>
<thead>
<tr>
<th>Extruder systems</th>
<th>Single screw extruder</th>
<th>Twin screw extruder</th>
<th>Multiple screw extruder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single screw</td>
<td>Co-Kneader</td>
<td>Co-rotating</td>
</tr>
<tr>
<td>Characteristics</td>
<td></td>
<td></td>
<td>Intermeshing</td>
</tr>
<tr>
<td>Feed intake of bulk materials</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Downstream adding of bulk materials</td>
<td>+</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Downstream adding of liquids</td>
<td>+</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Melting capability of Powder</td>
<td>+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>Pellets</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>In axial direction</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td>Crosswise</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Distributive mixing</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Dispersive mixing</td>
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<tr>
<td>Degasing capability</td>
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<tr>
<td>Pressure build-up capability</td>
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<td></td>
</tr>
<tr>
<td>Self cleaning</td>
<td></td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Residence time distribution</td>
<td>wide</td>
<td>narrow</td>
<td>narrow</td>
</tr>
<tr>
<td>Modular design of Screws</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Barrels</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Possibility of heating and/or cooling of Screws</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Barrels</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>
Twin Screw History

Market introduction of the first co-rotating twin screw extruder (ZSK 83) in 1957

1879  Paul Pfleiderer founds the company in Stuttgart and Hermann Werner starts producing batch kneaders (universal kneader) UK

1953  License agreement with BAYER, Leverkusen, for continuous mixing- and kneading extruder (Erdmenger patents)
Continuous production of Sealant – Modular design

Operating principle

ZSK 125 MEGAvolume PLUS

Modular design for screw elements and kneading blocks

Intermeshing screw profile
Continuous production of Sealant – Process section of a co-rotating twin screw extruder

<table>
<thead>
<tr>
<th>Feeding</th>
<th>Melting, Mastication</th>
<th>Conveying, Side feeding</th>
<th>Mixing, Kneading</th>
<th>Venting</th>
<th>Homogenization</th>
<th>Degassing</th>
<th>Metering, Discharge</th>
</tr>
</thead>
</table>
Continuous production of Sealant – Components

Material Handling

- Big Bag unloading station
- Bag unloading station
- Raw material silo

Feeding Equipment

- Loss-in-Weight feeders (powder/pellets)
- Liquid feeders

Discharge Equipment

- Direct filling
Silicone Sealants

1 Extruder ZSK
2 Silicone Polymer feeder
3 Aerosil feeder
4 Cross linker feeder
5 Silicon-Oil feeder
6 Catalyst feeder
7 Vacuum system
8 Discharge Equipment
RTV Silicon - Sealant

1. Grav. feeder Aerosil
2. Grav. feeder Silicon-Pol.
3. Grav. feeder Silicon-Oil
4. Grav. feeder Crosslinker
5. Grav. feeder Catalyst
6. Extruder ZSK
7. Maindrive and gearbox
8. Vacuum
9. Start up valve
Continuous production of Sealant—Working principle

- Workflow continuously, regardless of product and batch size
- Automatic start-up and shutdown of the plant
- Automatic and gravimetrically controlled dosing of raw materials
- Intake, Conveying, melting, mixing, homogenizing and degassing
- Filtering and transport to downstream equipment
FET- 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.
FET: working principle

**Effects:**
- air is removed → higher bulk density
- friction is changed in the area of insert
Continuous production of Sealant—Temperature control

- Temperature/ time-stress decisive for achieved product quality
- Kneading time vs. temperature peaks and sheer speeds
- Integral value (product damage) drastically reduced in continuous process
Continuous production of Sealant—Cleaning and recipe change

• Self cleaning (intermeshing) screw profile
• Recipe changes possible within a few minutes
• Use of cleaning media and cleaning devices
Continuous production of Sealant—
Process advantages

- Optimal product intake
- Wide viscosity range (up to 100,000,000 mPas)
- Very good mixing quality
- High degassing efficiency
- Set-up time reduction by self cleaning screw profile
- Short thermal stress
- High degree of automation at low personnel expenses
- Reproducibility and proof of quality by process data storage
- Modular, highly flexible system
Continuous vs. discontinuous production of Sealant—Comparison

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Discontinuous kneader 900l with discharge screw</th>
<th>Continuous Extruder ZSK 54Mv Twin- screw 54mm Ø</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput (kg/h)</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Energy intake</td>
<td>mostly thermal conduction</td>
<td>mostly dissipation</td>
</tr>
<tr>
<td>Typical shear rate range (sec(^{-1}))</td>
<td>&lt; 200</td>
<td>&lt; 1800</td>
</tr>
<tr>
<td>Residence time (min) in melt phase (thermal stress)</td>
<td>60 -120</td>
<td>1 - 2</td>
</tr>
<tr>
<td>Self cleaning</td>
<td>poor</td>
<td>very good</td>
</tr>
<tr>
<td>Cleaning effort at recipe change</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Space requirement (m(^2))</td>
<td>ca. 150</td>
<td>ca. 180</td>
</tr>
<tr>
<td>Personnel needs</td>
<td>2 - 3</td>
<td>1 - 2</td>
</tr>
<tr>
<td>Quality</td>
<td>varies per batch</td>
<td>consistent</td>
</tr>
<tr>
<td>Investment</td>
<td>100%</td>
<td>150%</td>
</tr>
</tbody>
</table>
Conclusion

• A technical comparison between a discontinuous and a continuous plant is particularly led in regards of feeding, recipe changes, cleaning, thermal stress of the melt (degradation), personnel costs and quality consistency.

• The continuous production relies on the accuracy of feeding raw materials to the extruder. Complex systems enable the production of formulations with many different raw materials as well as frequent recipe changes.

• Due to the self-cleaning properties of the extruder, color and/or filler changes can be realized within less than half an hour. The new product cleans the process part in a very short time and purges the remaining residuals of the previous formulation. The amount of produced off-spec material is decreased tremendously.

• The thermal and oxidative degradation of the adhesive is limited due to the virtually closed system of the extruder (no oxygen in N₂ overlay) and the very short residence time (in the range of 1 min) extremely low.

• Sealant validation of quality consistency is mainly dependent on the feeding accuracy. Deviations of the gravimetric feeders are reported and documented by leading edge control concepts which allows for purging of off-spec material by a bypass until the quality is back on spec.

• Additional process quality parameters are screw torque, screw speed, temperature (melt & barrel steel), and pressure (melt, inlet, & discharge).

• The positives of discontinuous processing include small batches, very complex recipes and for raw materials which are not flowable.

• Economically, a continuous system is the right decision due to: consistent high quality, reproducibility, minimal setup & start-up time, and the high degree of automation at reduced personnel expenses.
Thank you for your attention!

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