High Viscosity Technology

Comprising

Thin Film Processing – Thin Film Processors

Large Volume Processors
Contents

- **Definition of**:
  - High Viscosity Technology
  - High Viscosity Processing (pp. 8)
  - Design Criteria (pp. 9)
  - Key Characteristics (pp. 10)
- **Thin Film Processing** (pp. 11)
- **Large Volume Processing** (pp. 16)
  - Single Shaft Technology
  - Twin Shaft Technology
- **Superabsorbent Polymers (SAP)** (pp. 22)
- **Process and Product Development** (pp. 31)
Definition High Viscosity Technology

- Comprises specialized processing equipment (pp. 4, 5)
- Handles fluids with viscosities in the range $\geq 20 \text{ Pa}\cdot\text{s}$ to $\leq 15,000 \text{ Pa}\cdot\text{s}$ (pp. 6)
- Primarily for the production of specialty chemicals and polymers
- For products undergoing phase change during processing (pp. 7)
Specialized Processing Equipment

Thin Film Processors

Filmtruder® units for various polymer applications: solvent separation, degassing, devolatilization, high viscosity spinning melt production, etc., based on pilot trials.

Shaft diameter: ≤ 410 mm
Weight, empty: up to 70 t
Drive power: 2.000 kW
Specialized Processing Equipment

Large Volume Processors
High Viscosity Fluid

Viscosity = 1000 Pas
Phase Change during Processing

Initial Conditions
Sugar Solution containing 10% w/w Water
Temperature = 90°C

Final Conditions
Sugar Solid containing 2.7% w/w Water
Temperature = 90°C
Definition High Viscosity Processing

Covers unit operations such as:

- Reaction (homogeneous/heterogeneous)
- Bulk polymerization
- Polycondensation
- Evaporation
- Devolatilization
- Compounding
Design Criteria

- Heat transfer limited
- Diffusion limited
- Residence Time
- Viscosity
- Pressure
- Temperature
- Vapour Volume
- Mixing requirement
- Melts vs. free flowing solids
- Capital cost
- Operating costs
Key Characteristics

Continuous processing
Externally heated shell
Heat transfer indirect
Mechanically agitated
Operating pressure from full vacuum to 30 bar
Operating temperature up to 400°C

Thin Film Processors
- Rotor fast moving
- Rotor unheated
- Thin Product Layer
- Short residence time
- Vertical design

Large Volume Processors
- Rotor slow moving
- Rotor heated
- Process chamber partly filled
- Longer residence time
- Horizontal design
- Single shaft rotor
- Horizontal design
- Twin shaft rotor
High Viscosity Technology

Comprising

Thin Film Processing

Thin Film Processors
**Thin Film Processors**

<table>
<thead>
<tr>
<th>Key Features</th>
<th>Key Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Short residence time</td>
<td>• High product quality, good color, no degradation</td>
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<tr>
<td>• Narrow residence time distribution</td>
<td>• Homogeneous product quality</td>
</tr>
<tr>
<td>• Unmatched surface renewal and film distribution</td>
<td>• Quick reactions</td>
</tr>
<tr>
<td>• Large free vapor space</td>
<td>• Excellent devolatilization</td>
</tr>
<tr>
<td>• Positive product transport</td>
<td>• No downtime/losses due to product entrainment</td>
</tr>
<tr>
<td>• Low product inventory</td>
<td>• Wide range of product grades handled in one unit</td>
</tr>
<tr>
<td>• Versatile adjustable designs</td>
<td>• Fast change from one quality to another</td>
</tr>
<tr>
<td></td>
<td>• Application tailored</td>
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</table>
High Viscosity Thin Film Processing

Mechanically agitated thin product films

Rotor system with pitched blades
- creates surface renewal
- resulting in high heat flux and mass transfer
Thin Film Processor Operation Mode

Countercurrent

Feed

Vapor

Product

Co-current

Feed

Vapor

Product
Application tailored Filmtruder® Rotor

Tirex® discharge

Copos® vapor disengagement space

Transad® rotor
High Viscosity Technology

Comprising

Large Volume Processors
Large Volume Processors

Characteristics

- Single shaft design
- Twin shaft design (co- or counter-rotating)
- Heated / cooled housing and shaft(-s)
- Large installed process volume
- Variable hold-up partially respectively completely filled with product
- Self-cleaning of the heat exchange surfaces
- Non-volatile and volatile components flow in mixed co- and counter-current patent to each other
Large Volume Processing

Characteristics

• Rotor(-s) system provides radial mixing with simultaneous positive transport to product in axial flow direction

• High surface renewal of exposed interfacial area and intensive radial mixing resulting in high heat and mass transfer rates
# Large Volume Processor

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
</tr>
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</table>
| Long residence time / Large net volume | Economic for long residence time reaction  
|                                 | Large production capacities                                              |
| Low shear capabilities          | High product quality, no degradation                                     |
| Plug flow                       | Homogeneous product quality                                              |
| Excellent mixing / surface renewal | Good for devolatilization                                                |
| All-in-one operation            | From liquid feedstocks to high viscous respectively solid final product in a single unit |
| Can handle solids               | Phase changing products can be treated / devolatilized  
|                                 | Adding / mixing of solids                                                |
Modular Large Volume Processors

- Application tailored drive systems up to 1.500 kW
- Single and twin shaft processors
- Internal pressures from 0,5 to 5 bar
- Discharge systems optimized for solids or high viscosity

- Pump extraction
- Twin screw extraction
- Friable solids

Increasing viscosity and solids
Reactootherm®, Conti., Single Shaft

Detail from the Process Chamber

Rotor Design
Reactor for the Continuous Production of Superabsorbent Polymers
Process Requirements

- On completion of the reaction
  - the water content in the polymer should be the lowest possible
  - the free monomer content in the polymer should be the lowest possible
- Minimum number of stages from the raw materials to the polymer
- The applied process technology should possess the feature of handling
  - a reaction mass undergoing various phase changes and
  - exhibiting viscosity increase
as the reaction progresses
- The processing technology should warrant constant temperature polymerization
Process Requirements

- The polymerization reactor
  - is agitated
  - possesses self-cleaning ability
  - operates continuously under atmospheric pressure
  - warrants a large space-time yield at a conversion rate of \( \geq 98\% \)
  - grants a mean reaction time in the range \( \geq 10 \) minutes to \( \leq 25 \) minutes
  - has the ability of discharging the final polymer with simultaneous chopping

- Under the effect of the agitation the polymerization mass would experience size reduction to rather particulate crumbles

- The reactor has the capacity of recycling and homogeneously incorporating fines of the final dry polymer in the reaction mass
Cinematic principle Single-Shaft Unit

- Feed
- Vapor
- Discharge
- Shaft heating Fluid

High Viscosity Processing
SAP Reaction Stage - PFD
Benefits

Technical / Process

• Low water content in the final polymer
• Lowest possible free monomer content in the formed polymer
• Efficient handling of the reaction mass in all phases and viscosities
• Constant temperature polymerization
• Continuous atmospheric operation
• Delivery of polymerization mass in partly wet rather particulate crumbles
• Discharge of the final polymer with simultaneous chopping
• Capacity to recycle and homogeneously incorporate fines of the final dry polymer in the reaction mass

Economic

• Low water content in the final polymer low drying costs
• Low power consumption
• Minimum number of stages from the raw materials to the final polymer
• Easy to operate
• Unrivalled large space-time yield minimizing investment and operating costs
• Low maintenance costs
• Minimization of operation effluents
Twin Screw Discharge System

Polymerization Reactor
SAP Production
The RTC Reactor
High Viscosity Technology

Comprising

Process and Product Development
Development Stages

- Process development from idea/lab scale to commercial plant using the appropriate processing equipment
  - Bench scale tests
  - Feasibility study
  - Pilot tests for process development
  - Optimization tests for process and product
  - Production of larger product samples for application tests
  - Long term testing production with semi-industrial plant at user's site
Reactotherm Conti Single Shaft 16 Liter
ReaMini™ Conti Twin-Shaft 3 l

Continuous or Batch operation

• Process testing
  ▪ feasibility studies
  ▪ process development

• Product testing
  ▪ small sample production
  ▪ development and confirmation
  ▪ of product quality
ReaMini™ Batch Twin-Shaft 8 liter

- **Process testing**
  - feasibility studies
  - process development

- **Product testing**
  - small sample production
  - development and confirmation
  - of product quality

- **Processes**
  - Polymerization
  - Polycondensation
  - Devolatilization
  - Mixing / Compounding
Modular Rotor System for Pilot Units
30 liter Unit with vertical Twin Screw

Disc rotor system in enlarged process chamber housing

Vertical twin screw discharge system
Application tailored barrel housing

Large free cross-sections for disengagement and flushing off gases and vapours
ReaSol® Pilot Plant, 60 liter