Mixing and Agglomeration in Eirich Mixers

PFI - Building
Gløshaugen, Trondheim

Welcome!

Marcus Müller
AGENDA:

1. Solid mixing
   1. Theory of solid mixing
   2. Homogeneity

2. Build-up agglomeration
   1. Particle size distribution
   2. Moisture
Mixing Technology

**Mixing:**

1. Process of thoroughly combining different materials to produce a homogenous mix
2. Mixing is a critical process
3. Quality of the final product attributes depend on the mixing performance

**Poor Mixing:**

1. Non homogenous product lacking consistency in chemical composition, colour, flavour, reactivity
2. Failed batches
3. Loss of high value product
4. Cost of poor mixing estimated as US $100 million per year!
Reasons for Poor Mixing:

1. Lack of understanding of material characteristics
2. Inadequate, inaccurate definition of mixing objectives
3. Incorrect selection of mixer
4. Wrong scale-up techniques
5. Limited knowledge on mixing equipment design, parameters
Mechanisms of Solid Blending

1. Diffusion Blending
2. Convection Blending
3. Shear Blending

These three mechanisms occur to varying extents depending on the type of mixers, blenders and the characteristics of the solids to be blended!
Mechanisms of Solid Blending

Diffusion Blending

• Diffusion blending is characterized by small scale random motion of solid particles

• Blender movements increase the mobility of the individual particles and promote diffusive blending

• *Diffusion blending occurs where the particles are distributed* over a freshly developed interface

• In the absence of segregation effects, the diffusive blending will in time lead to a high degree of homogeneity

• Tumbler blenders like the double cone blenders, v-blenders function by diffusion mixing
Mechanisms of Solid Blending

Convection Blending

• Convection blending is characterized by large scale random motion of solid particles

• In convection blending, groups of particles are rapidly moved from one position to another due to the action of a mixing agitator or cascading of material within a tumbler blender

• The blending of solids in ribbon blenders, paddle blenders, plow mixers is mainly a result of convection mixing
Mechanisms of Solid Blending

Shear Blending

1. Shear blending is the high intensity impact or splitting of the bed of material to disintegrate agglomerates or overcome cohesion

2. Shear blending is very effective at producing small-scale uniformity generally on a localized basis

3. Blenders with a high speed chopper blades, intensifiers are an example of shear blending.
Theory of Mixing

1. Moving of particles which are different in one or more properties or characteristics (particle size, particle shape, moisture, chemistry, density, reactivity,....)
2. Moving of particles in one closed process room
3. The aim is to achieve a homogeneous distribution of the particles in the process room
4. Different parts of the material must move with different velocities
5. The whole content must move with different velocities
Mixing Technology

Theory of Mixing

- Simultaneous **macro** and **micro** mixing

- **Macro mixing** = exchange of bigger parts of the material between the streaming lines

- **Micro mixing** = change of neighbouring particles

Impulse forces destroy adhesive strength in order to segregate the material
Mixing Technology

• Distributive Mixing
  *no input of shearing energy*

• Dispersive Mixing
  *high input of shearing energy*
Mixing Technology

• Distributive Mixing

*no input of shearing energy*

- Totally demixed
- Ideally homogenized mix
- Stochastically homogenized mix
Mixing Technology

• Distributive Mixing

*no input of shearing energy*
Mixing Technology

Totally demixed

Stochastically homogenized mix

Dispersive mixing

- Dispersive Mixing
  \textit{high input of shearing energy}
• Dispersive Mixing

high input of shearing energy
Eirich Intensive Mixer: R-Type

- **Mixing tool**
- **Wall and bottom scraper**
- **Rotating mixing pan**

**Topic:** basic training agglomeration
THE EIRICH MIXING PRINCIPLE
Homogeneity - mixing time

\[ \sigma_Z^2 = p(1-p) \frac{m_{x,p}}{M_p} \]

- Ideal mixing procedure
- Realistic mixing procedure
- Demixing effect
- Homogeneous random mix

Variation coefficient $\sigma_Z^2$ as a function of mixing time $t$.
Variations because of vol.-spec. energy densities

Vol.-spec. Energy density

- Ideal mixing procedure
- Realistic mixing procedure
- Demixing effect
- Homogeneous random mix

Variations because of vol.-spec. energy densities:

- Variations in energy density due to volume-specific energy densities.
Homogeneity - mixing time

Mixing time
pregiven mixing time \( t_M \)
Normally \( t_M = 0.5 - 5 \) minutes, special tasks longer: swelling, de-gasing, reacting; total batchtime mostly much more longer: \( t_{Ges} = t_{Füll} + t_{Misch} + t_{Ent} + t_{Rein} \)

Mixing time and Mix quality
• Mixing time and mixing quality are directly connected (bad quality → short mixing time).
• Different quality-parameters (sample sizes) might cause different mixing times (Macromixing, Desagglomerating).
• quality-development is a function of time.

\[
\sigma_z^2 = p(1-p)\frac{m_{x,p}}{M_P}
\]
Improvement of the homogeneity

\[ \text{Variationskoeffizient } V = \frac{s}{p} \]

\[ \sigma_F \]

\[ \frac{\sigma_z}{p} \]

Zeit t

Quelle: Prof. Habermann
Build-up agglomeration
Granulating process

- Ceram. raw materials
  Sinter additives

- Binder
  Softener
  Pressing agent

- Dispersing liquid
  Dispersing agent

Granulating process

**Mechanical granulation**
- Powder mix
  - Fluid bed agglomeration
  - Build-up agglomeration
    (rolling method, disk granulator, intensive mixer)
  - Press agglomeration
    EVACHTERM®

**Thermal granulation**
- Suspension
  - Fluid bed agglomeration
    (fluid bed, tumbling bed, spouted bed)
  - Fluid-bed coating
  - Spray-freeze granulation
    EVACHTERM®

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Dr. Nebelung, IKTS Dresden
Process technology: Build-up agglomeration

Spray on liquid

Granulating time

Granulating time
Verfahrenstechnik: Aufbau-Agglomerierung

Bedüsen
Flüssigkeitszugabe
Granulierzeit
Narrow particle size distributions, monodisperse distributions, are to be agglomerated with binder, especially if a high porosity is requested.
Granulat-Design: Porosität

Enge Partikelverteilung, monodisperse Verteilungen mittels Binder agglomerieren, vor allem, wenn eine hohe Porosität erzielt werden soll. 

Besprühen - Befeuchten - Verfestigen - Fertiges Agglomerat

Pulver - Flüssigkeitsbrücke - Fests toffbrücke - "Brombeer"-Struktur
Primary grain size distribution is too coarse !!!
Created micro pellets are moistend in a wrong way

```
| Dry mixing | Liquid addition | Agglomeration | Separation |
```

Primary grain size distribution
"Blackberry" structure
Process technology: Build-up agglomeration
Verfahrenstechnik: Aufbau-Agglomerierung
Trockenmischen
Flüssigkeitszugabe
Separation
Primärkornverteilung
"Brombeer"-Struktur
Agglomeration zu grobe Primärkornverteilung
Granulation in the Eirich mixer
Examples

- **Alumina**
  - Grinding balls

- **Steatite**
  - Grinding balls

- **Zeolite**
  - Molecular sieves

- **Zeolite**
  - Molecular sieves

- **Bauxite**
  - Proppants

- **Kaoline**
  - Proppants

- **Bauxite**
  - Molding compound

- **Perlite**
  - Lightweight aggregate
Granulation in the Eirich mixer

Examples

Corundum
Catalyst carrier

Clay powder
Animal food additive

Tile press compound

Lead glass batch

Glass powder, carbon
Foam glass

Ferrite

Ferrite

Aluminum
Granulation in the Eirich mixer
Examples

- Welding powder
- Zinc oxide Varistors
- Zinc oxide Pigment
- Iron oxide Pigment
- Steatite, colored Press compound
- Pigment mix, blue
- Pigment mix, yellow
- Oxide powders Varistors

Topic: basic training agglomeration
Granulation in the Eirich mixer

Examples

- **Al₂O₃-C**
  - Iso-press compound
- **Oxide powders**
  - Catalysts
- **Steatite**
  - Press compound
- **Porcelain**
  - Contact compound
- **Cyclon dust**
- **Cement**
  - (granulated without water)
- **Diatom earth**
  - Filter media
- **Gypsum**
  - Building materials
Granulation in the Eirich mixer

Examples

<table>
<thead>
<tr>
<th>Material</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon carbide</td>
<td>Abrasives</td>
</tr>
<tr>
<td>Tungsten carbide</td>
<td>Hard metal</td>
</tr>
<tr>
<td>Peat fertilizer</td>
<td></td>
</tr>
<tr>
<td>Sugar-beet seed</td>
<td></td>
</tr>
<tr>
<td>Mineral powders</td>
<td>Animal food additive</td>
</tr>
<tr>
<td>Phosphate fertilizer</td>
<td></td>
</tr>
<tr>
<td>Dolomite Fertilizer</td>
<td></td>
</tr>
<tr>
<td>Lime Fertilizer</td>
<td></td>
</tr>
</tbody>
</table>
Basic material:
lumpy material
dry, fine dispersed matter

Granulating liquid:
filter cake, suspension, solution, plastic bodies

Process technologies:
dispersive + distributive mixing
build-up agglomeration
Process technology: Build-up agglomeration
Granulating mixer

Liquid addition as filter cake, sludge, suspension or solution

Homogenizing by dispersive mixing

Powder, dust

Granulating time
Standard plant design

Standard system for dusts:
* dust-free agglomeration
** pelletizing

Pellet size: approx. 0.2 - 5 mm
Throughput: up to 150 t/h/unit

*Container for agglomerate material, only dust-free and pourable
**Container for granulate material
Particle size distribution

1. **Particle size distribution**
   1. Determines the result of agglomeration (structural distribution)
   2. Determines the granulation moisture

2. **Granulate size distribution**
   1. A given value and the primary target to be achieved
   2. Parameter determination
1. Essential parameter to be measured primarily
2. 100 µm is the natural limit for this process to be applicable
3. Coarse particles (return material, agglomerated nuclei, recycled material) are only incorporated if sufficient fine material is contained
4. Crushing in preparation for agglomeration
5. Fine material can determine the stability of agglomerates
6. Narrow particle size distributions, monodisperse distributions, are hard to agglomerate
7. Agglomerate coarse particles with binder, especially if a high porosity is requested
Criteria of pelletizing ability:

1. Grain size and grain size distribution range
2. Specific surface
3. Shape of the individual particles
4. The RRSB grain grid allows assessing a known grain size distribution as to its pelletizing ability
   - Steep curve + medium to coarse grain boundary = critical
   - Flat curve + medium to coarse grain boundary = satisfactory
5. Ultrafine material → flatter grain boundary curve
   → increases the specific surface
### Particle size distributions

#### Typische Kornverteilung einiger Stoffe im RRS-Körnungsnetz

<table>
<thead>
<tr>
<th>Stoff</th>
<th>Kornverteilung</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russ</td>
<td>1</td>
<td>Ungünstige Kornverteilung zur Pelletierung</td>
</tr>
<tr>
<td>Blanc Fix</td>
<td>4</td>
<td>Günstige Kornverteilung zur Pelletierung</td>
</tr>
<tr>
<td>Titandioxid</td>
<td>2</td>
<td>Mineral schwarz</td>
</tr>
<tr>
<td>Pigmente</td>
<td>5</td>
<td>35F, 45F, 55F Zementfeinheit</td>
</tr>
<tr>
<td>Mennige</td>
<td>3</td>
<td>38F, 55F</td>
</tr>
<tr>
<td>Mineralschwarz</td>
<td>6</td>
<td>38F</td>
</tr>
<tr>
<td>Keramische Pressmasse</td>
<td>9</td>
<td>35F</td>
</tr>
</tbody>
</table>

#### Diagram

- Nanometerbereich
- μm-Bereich
- mm-Bereich

H.B. Ries
Granules particle size distributions

Process of granulating in the Eirich – Intensive - Mixer

\[ D [%] \]

\[ x_{\text{Gran}} = k_{1} / n_{1} \quad > \quad x_{2} / n_{2} \quad \Delta t_{M} \quad x_{3} \quad >> \quad x_{\text{Gran}} / \quad n_{3} \ll n_{1} \]

\[ X = \text{moisture} \]
\[ n = \text{speed of the rotor} \]

Topic: basic training agglomeration
Example: Granulating pigments in the 250 L mixer

The higher the rotor speed, the smaller the particle diameters.

Particle size distribution

Sample

- V1
- V2
- V3
- V4
- V5
- V6

Cumulative distr. undersize in % (linear)

Diameter / µm

Volume

800 min\(^{-1}\)

700 min\(^{-1}\)

600 min\(^{-1}\)

500 min\(^{-1}\)

400 min\(^{-1}\)

The higher the rotor speed, the smaller the particle diameters.
Example: Granulating fertilizers in the 10 L mixer

Influence of granulating time

The longer the granulating time, the coarser the product
Example: Granulating proppants in the 750 L mixer

Slow secondary rolling causes the larger granules to grow.
Example: Granulating proppants in the 750 L mixer

The higher the peripheral rotor speed, the narrower the particle size distribution.

- 1080 min⁻¹
- 920 min⁻¹
- 770 min⁻¹

Cumulative distrib. undersize in % (linear)

100 80 60 40 20 0

Diameter / µm

10000 5000

Volume

14.12.2005
Maschinenfabrik Gustav Eirich
74736 Hardheim, http://www.eirich.de
CILAS 850 HR
R05_72mm

Sample
- V135
- V142
- V149
- V151
- V72
- V73

The higher the peripheral rotor speed, the narrower the particle size distribution.
Granulation moisture

Granulation moisture = \( f \) (Grain size distribution)

\( \chi < \chi_{\text{Gran}} \)
- Particle size distribution shifted toward smaller particle diameters, impeded growth of particles

\( \chi > \chi_{\text{Gran}} \)
- Particle size distribution shifted toward larger particle diameters, risk of plastification

\( X_1 = X_{\text{gran}} = X_2 \quad X_3 > X_2 \)

\( N_1 \gg N_2 \quad N_3 < N_1 \)
Example: Granulating proppants in the 750 l mixer

Influence of mixing time and moisture content

Example: Granulating proppants in the 750 l mixer

Influence of mixing time and moisture content
Granulation moisture

1. The free moisture content is important for the binding mechanism

2. Max. moisture content = 90 – 95 % of the pore volume

3. Exceeding this value just slightly may result in sludge (degree of saturation)

4. The feeding mode is decisive for growth and quality ⇒ The moisture content has to be lower

5. The wettability is the most important property because the green strength is determined by surface tension forces or capillary forces
Granulation moisture

• Moistening / wetting
  Distributing small amounts of liquid in the bulk material.

Liquid volume $V_F \ll$ cavity $V_H$.
degree of saturation

$S = \frac{V_F}{V_H} < 1$
Example: Granulating pigments in the 250 L mixer
Process technology: Improving the pourability/flowability

Moistening → Coating → Compacting → Thermal drying

Moistening → Coating → Compacting → Powdering
Granulation of fine iron ore concentrate

1. Trials in the Test Center 100 kg/batch scale
2. 3 days production tests with 50 t/h

Test Center:
- Moisture: 7.8-8.1 %
- Batch time: 5 min
- 1 min dispersive mixing 22 m/s
- 4 min build up agglomeration 7 m/s
- Binder: calcium hydroxide

Production Test:
- Capacity: 4800 kg/batch
- Batch time: 5 min
- 1 min dispersive mixing 20 m/s
- 2 min build up agglomeration 7 m/s
- Binder: calcium oxide + hydroxide
Granulation Iron Ore Concentrate

Particle size distribution

Diameter of the particles / µm

Cumulative distr. undersize in % (linear)

Volumen

18.01.2010
Maschinenfabrik Gustav Eirich
D-74736 Hardheim
CILAS 930e
10GH007

Probe
Iron ore

Volumen

Diameter of the particles / µm

Cumulative distr. undersize in % (linear)
Granulation Iron Ore Concentrate

Particle size distribution

Cumulative distr. undersize in % (linear)

Diameter of the particles / µm

18.01.2010
Maschinenfabrik Gustav Eirich
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CILAS 930e
10GH007

Probe
- V6 P1
- V6 P2
- V7
- V8
- V9

Volumen

Diameter of the particles / µm
Topic: basic training agglomeration
Results:

1. The productivity of the sintering can be higher than 40 t/m² h
2. Even when there is more than 10 % fines
3. If the fine iron ore is agglomerated
Granulation of fine iron ore + 60+80 % Pelletfeed

Trials in the Test Center 240 kg/batch scale
Mixing + agglomerating in the granulating mixer

Test Center:
- Moisture: 5.5 %
- 1 min dispersive mixing: 7 m/s
- 1-3 min agglomeration: 2 m/s
- binder: calcium oxide 4 %

Parameter study: adding water in the mixer/ granulator
  time difference between mixing and agglomerating
Sinter iron ore
Granulation of Iron Ore Concentrate + 60 - 80 % Pelletfeed

**Topic: basic training agglomeration**

- **Mixing drum**
- **Granulating mixer: agglomeration immediately after mixing**
- **Granulating mixer: agglomeration 8 min after mixing**

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*Autor: Marcus Müller Seite: 63*
Results

1. After 60 s mixing and 60 s granulating the permeability is very high
2. After 180 s agglomerating in the mixer the permeability is higher than after 240 s in the drum
3. Adding 90 % of the water during mixing and 10 % during agglomerating brings the highest permeability
4. The agglomeration should be done immediately after the mixing
5. 2 m/s tip speed of the rotor is ideal for agglomeration, 7 m/s for the mixing
EIRICH Test Center
Center for process technology
testing - developing - optimizing
Thank you for your attention!
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