Energy savings potential at ship discharge

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Agenda

- Measured Equipment in harbours for unloading and conveying
- Different removal phases in cargo holds and suitable equipment
- Impacts on an efficient discharge process of ship holds
- Savings potential during removal of residues
Background of the showed data

• In-house survey in the actual development status of conveyor equipment for bulk materials

• In-house survey in the clean-up efficiency of continuous ship unloader
  - Data ascertained in 16 European grain-handling companies
  - Acquisition of data for different types of handling equipment
  - Including all common kinds of unloading equipment for grain
## Comparison of equipment for unloading

### Conveying equipment

<table>
<thead>
<tr>
<th></th>
<th>Belt conveyors</th>
<th>En masse conveyors</th>
<th>Bucket elevators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (max)</td>
<td>~ 1000 t/h</td>
<td>~ 700 t/h</td>
<td>~ 1200 t/h</td>
</tr>
<tr>
<td>Efficiency</td>
<td>~ 85 %</td>
<td>~ 75 %</td>
<td>~ 60-70 %</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>~ 0.4 kWh/t</td>
<td>~ 0.9-1 kWh/t</td>
<td>&gt; 1 kWh/t</td>
</tr>
<tr>
<td>Distance/Height</td>
<td>30 – 1000 m</td>
<td>12 – 150 m</td>
<td>20 – 90 m</td>
</tr>
<tr>
<td>Raising</td>
<td>0° - 9.5°</td>
<td>0° - 38.3°</td>
<td>90°</td>
</tr>
<tr>
<td>Capacity</td>
<td>up to 1500 t/h</td>
<td>up to 1000 t/h</td>
<td>up to 1000 t/h</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>0.25 Wh/tm</td>
<td>1.30 Wh/tm</td>
<td>3.80 Wh/tm</td>
</tr>
<tr>
<td>(only horizontal)</td>
<td>(only horizontal)</td>
<td>(only horizontal)</td>
<td>(only vertical)</td>
</tr>
</tbody>
</table>

### Unloading equipment

<table>
<thead>
<tr>
<th></th>
<th>Chain Type</th>
<th>Screw Type</th>
<th>Pneumatic</th>
<th>Belt Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (max)</td>
<td>~ 1000 t/h</td>
<td>~ 700 t/h</td>
<td>~ 265 t/h</td>
<td>~ 1200 t/h</td>
</tr>
<tr>
<td>Efficiency</td>
<td>~ 85 %</td>
<td>~ 75 %</td>
<td>~ 55-65 %</td>
<td>~ 60-70 %</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>~ 0.4 kWh/t</td>
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Differentiation of the unloading process of one hold in 3 characteristic Phases

• Phase 1
  ➢ Normal removal by the unloader in one position
  ➢ Capacity near the maximum

• Phase 2
  ➢ Unloader has to change position often
  ➢ Use of wheel loader / bulldozer is profitable
  ➢ Capacity decreases

• Phase 3
  ➢ Unloader has to be fed by wheel loader / bulldozer
  ➢ Capacity is mainly influenced by the feeding, not by the unloader
Removal phases in cargo holds

Different Phases can be detected in a mass flow diagram:

- Phase 1
- Phase 2
- Phase 3
Which equipment can be used in the different phases?

- Not all kinds of unloader are suitable for all three phases

- Reasons are for example:
  - Kind of absorption of material
  - Minimum material height in hold
  - Restrictions by statutory provisions
  - Efficiency of unloaders
Which equipment can be used in the different phases?

- **Chain Type:**
  - Optimal working in Phase 1
  - Good working in Phase 2 with kick-in and kick-out and feeding is allowed
  - Less suitable in Phase 3 if conveyor with high capacity due to low efficiency

- **Screw Type:**
  - Same like Chain Type

- **Pneumatic:**
  - Less suitable in Phase 1 & 2 due to less capacity
  - Less suitable in Phase 3 if conveyor with high capacity due to low efficiency, optimal for final clean-up

- **Grab-Type**
  - Works in all phases, but not very optimal.
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Constraints for removal

**Ship**
- Number and size of holds
- Size of hatches

**Cargo**
- Kind of material in each hold
- Quantity of cargo to discharge

**Guidelines by captain**
- Strength of ship
- Sequence of holds

**Constraints by law**
- Noisiness, dust, …
- Working time

**Constraints by environment**
- Tide
- Weather

**Unloading equipment**
- Kind and number of unloader
- Applicability of unloader for cargo
How to evaluate a removal process

Efficiency of the removal process can be quantified by the achieved mass flow:

\[ \text{Efficiency} = \frac{\text{achieved mass flow}}{\text{installed capacity}} \]

Consequences of an efficient discharge are:

- Faster removal
- Less energy consumption
- Less personnel costs
- Higher Profitability
Factors on an efficient removal

According to the results of our survey is the efficiency of a ship discharge influenced by:

- Driving route on the quay
- Breaks by employees
- Interruptions due to breakdown of silo or quay conveyor
- Strategy of using different unloaders and feeding equipment
- Strategy of using the unloader in the hold
Example mass flow diagram of a ship discharge

Averaged mass flow: including all breaks and interruptions
Adjusted mass flow: pure conveying time
Simulation tools for ship unloading

Simulation tool developed at our chair for the Buhler AG
- Basing on the results of the survey
- Combination of different unloaders and strategies
- Simulation of the removal of one hold

Also Buhler AG developed a simulation tool
- Basing on long lasting know-how in ship removals
- Simulation of a whole ship

→ Comparison of different strategies and planning of removals possible
→ Systematic optimization to an efficient removal
Comparison of different strategies in a hold

Simulated removal strategies:

- Mechanical unloader with capacity of 600 t/h
- Phases 1 & 2 without any feeding
- Removal of residues unconsidered
- Breaks and interruptions not considered

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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3 stripes</td>
<td>9910</td>
<td>7466</td>
<td>14:08</td>
<td>528.3</td>
<td>88.0</td>
</tr>
<tr>
<td>5 stripes</td>
<td>9910</td>
<td>7604</td>
<td>14:36</td>
<td>520.8</td>
<td>86.8</td>
</tr>
<tr>
<td>5 points</td>
<td>9910</td>
<td>7371</td>
<td>13:59</td>
<td>527.1</td>
<td>87.9</td>
</tr>
<tr>
<td>7 points</td>
<td>9910</td>
<td>7458</td>
<td>14:12</td>
<td>525.2</td>
<td>87.5</td>
</tr>
</tbody>
</table>
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Options to advance the clean-up

- Avoid idle time
  - React to low fill level betimes
- Optimize removal of residues
- Increase time slice with max. capacity
  - Optimize geometry of hold
  - Use feeding device
    - Amass bulk material with wheel loader
  - Build up high conveying speed
    - Feed material
  - Build up high filling level around unloader
    - Assure high filling level
      - Build up bulk pressure at unloader
  - Feed material

- Use high conveying speed
  - Build up high filling level around unloader
Options to advance the clean-up

Amass bulk material with wheel loader / bulldozer

- Use suitable type
- Use optimal number of equipment
- Use optimal size of loader

→ Simulation of the use of 1 small, 2 small or 1 big wheel loader for the clean-up

Unloader with capacity of 600 t/h

<table>
<thead>
<tr>
<th>Achieved mass flow</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 small loader</td>
<td>388 t/h</td>
</tr>
<tr>
<td>2 small loader</td>
<td>482 t/h</td>
</tr>
<tr>
<td>1 big loader</td>
<td>488 t/h</td>
</tr>
</tbody>
</table>
Options to advance the clean-up

Use feeding device

- Sensible for mechanical unloaders
- Use in phase 2 to achieve a filling level of few decimetres
- Attachable for phase 2 to profit by efficient use of unloader in phase 1

→ Simulation of the discharge of the same hold, once with feeding device, once without it.

<table>
<thead>
<tr>
<th></th>
<th>Achieved mass flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>No feeding device</td>
<td>586 t/h</td>
</tr>
<tr>
<td>Feeding device</td>
<td>688 t/h</td>
</tr>
</tbody>
</table>

+ 17.4 %
Consequence

• Optimisation of residues removal is possible as a combination of:

  ➢ Use of one big wheel loader / bulldozer in phase 3
  
  ➢ Use of a feeding device for mechanical unloader in phase 2

→ Cooperation of our Chair of materials handling, material flow, logistics and the Buhler AG to design a feeding device for the Portalink ship unloader based on the results of our surveys
Simulation of feeding device with discrete elements method:

- Capacity of chain conveyor: 600 t/h
- Fill level in hold: approx. 350 mm
Efficiency of the clean-up process and thus total removal time can be reduced.

Power consumption of discharge process occurs not only at the unloader but also at the complete conveying line to the silo.

An efficient unloading process results in a short turn on time of the whole harbour installation and thus also in saving of energy.

By assuring an efficient discharge process energy and costs can be saved!
Thank you for your attention!