XXXI CONGRESO TÉCNICO FICEM
8 al 11 de Septiembre de 2014
Santo Domingo, República Dominicana.

FICEM
FEDERACIÓN INTERAMERICANA DEL CEMENTO
Improvements in New & Existing Cement Grinding Mills

by Tim Nowack
Agenda

1. Introduction
2. Types of cement mills in use today
3. Factors affecting ball mill performance
4. Ball mill improvements & case examples
5. Conclusions & question time
1. Introduction

Cement manufacture is energy intensive

- Cement manufacture consumes typically 3,100 - 3,400 MJ of fuel/t clinker & 90 - 130 kWh / t cement in a modern plant, & more for older or less efficient plants;

- Generally 2/3 of the electricity consumed is used in the grinding of raw materials, fuels & finished cement;

- Finished grinding may consume 25 – 50 kWh/t cement, depending on the feed material grindability, additives used, plant design & especially the required cement fineness.

➢ Cement grinding is the single biggest consumer of electricity in the manufacturing process.
1. Introduction

Whichever the mill types, grinding is inherently inefficient

- < 20% of energy absorbed is reckoned to be converted to useful grinding: the bulk is lost as heat, noise, equipment wear & vibration;
- For ball mills, only 3 - 6% of absorbed energy is utilized in surface production, the heat generated can increase mill temperature to > 120° C & causes excessive gypsum dehydration & media coating if mill ventilation is poor.
2. **Types of cement mills**

There are basically 4 types of cement mills in use today:

1. **Ball Mill** (BM): predominant despite higher energy consumption partly because of historical reason but partly also because it still offers considerable advantages over other mills, often operate with roller press for pregrinding or in combined grinding;

   ![Open circuit](image1)
   ![Closed circuit](image2)
2. Types of cement mills

There are basically 4 types of cement mills in use today:

2. **Vertical Roller Mill** (VRM): gained popularity in last decade due to lower energy consumption & higher capacity, relatively few plants in service;
2. Types of cement mills

There are basically 4 types of cement mills in use today:

3. **Roller Press** (RP): also a more recent choice especially after the advent of the V-separator & improved roller life, offers the lowest energy consumption but even few plants in service;

Ball Mill with Roller Press in combined grinding
2. Types of cement mills

There are basically 4 types of cement mills in use today:

4. **Horizontal Mill** (HM): also very few in service & found mainly in companies related to the mill developer.

Example: fives FCB Horomill
## 2. Types of cement mills

### Comparison of specific energy consumption

<table>
<thead>
<tr>
<th>Basis: 3200 g/cm² OPC</th>
<th>Ball Mill</th>
<th>BM + RP (combined grinding)</th>
<th>VRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill machinery</td>
<td>Ø4.6x14.25 m</td>
<td>Ø4.0x8.75 m +RP 16/10</td>
<td>Type 46</td>
</tr>
<tr>
<td>Main power absorbed</td>
<td>[kW]</td>
<td>4,350</td>
<td>3,400</td>
</tr>
<tr>
<td>Output</td>
<td>[t/h]</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Spec. Mill Power</td>
<td>[kWh/t]</td>
<td>29,0</td>
<td>22,7</td>
</tr>
<tr>
<td>absorbed</td>
<td></td>
<td>100</td>
<td>78</td>
</tr>
<tr>
<td>Spec. Power absorbed</td>
<td>[%]</td>
<td>5,0</td>
<td>8,0</td>
</tr>
<tr>
<td>relative to ball mill</td>
<td></td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Ancillaries</td>
<td>[kWh/t]</td>
<td>34,0</td>
<td>30,7</td>
</tr>
<tr>
<td>Plant total</td>
<td>[kWh/t]</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Total power relative</td>
<td>[%]</td>
<td>100</td>
<td>90</td>
</tr>
</tbody>
</table>
## 2. Types of cement mills

### Factors affecting TCO of a new cement mill

<table>
<thead>
<tr>
<th></th>
<th>Ball mill in closed circuit</th>
<th>BM + RP (comb. grinding)</th>
<th>VRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment cost</td>
<td>[%] 100</td>
<td>125</td>
<td>130</td>
</tr>
<tr>
<td>Annual plant availability</td>
<td>[%] 97 - 99</td>
<td>85 - 90</td>
<td>88 - 90</td>
</tr>
<tr>
<td>Operating cost (energy + maintenance)</td>
<td>[%] 100</td>
<td>116</td>
<td>107</td>
</tr>
<tr>
<td>Spares holding cost</td>
<td>[%] 100</td>
<td>115-125</td>
<td>115-125</td>
</tr>
<tr>
<td>Cement quality acceptance</td>
<td>Non issue</td>
<td>Non issue</td>
<td>May have issues</td>
</tr>
</tbody>
</table>

- TCO: Total Cost of Ownership
2. Types of cement mills

Consider all investment key aspects!

Ball mill in closed circuit has the

✓ lowest investment
✓ lowest operating cost
✓ lowest maintenance cost
✓ highest availability
✓ highest cement quality acceptance!
3. Factors affecting ball mills

Basically 6 key factors affecting mill performance:

- Feed characteristic (grindability, psd, moisture, etc.);
- Cement fineness;
- Equipment design & plant engineering;
- Operations & maintenance;
- Use of clinker extenders (Additives);
- Use of grinding aids (Admixtures).
3. Factors affecting ball mills

Effect of feed moisture on grindability

Use of synthetic / waste gypsum or additives can increase the total feed moisture & adversely affect the mill performance if not properly managed.

Empirical “rule-of-thumb”:  
- Every 1% increase in moisture content above 0.5% increases energy consumption by >10%, especially at higher product fineness  
- At moisture above 3 - 4%, a ball mill without drying chamber may not be operable
3. Factors affecting ball mills

Cement fineness vs. grindability

Every 100 cm²/g increase in cement fineness increases the mill power consumption by 1-2 kWh/t for a closed circuit mill & 2-3 kWh/t for an open circuit mill, a sheer waste if this is not required by the market!

Grindability of a 95/5 OPC at various Blaine fineness:

- 27-32 kWh/t at 3,000 cm²/g
- 39-47 kWh/t at 4,000 cm²/g
- 58-69 kWh/t at 5,000 cm²/g
3. Factors affecting ball mills

Equipment design:
Ball mill & mill internals

- Ball mill (L/D, speed, drives & reducers, etc.)
- Ventilation
- Liners
- Diaphragms
- Media composition & fill ratio

Ball mill typically accounts for 85% of the total energy consumed in the grinding plant & should be the focus of improvements.
3. Factors affecting ball mills

Equipment design:
Separators

- Material dispersion
- Air distribution
- Principle of separation
- Adjustability
- Regularity
- Efficiency

CPB QDK Next Generation high efficiency separator has a very low by-pass & can improve mill output / energy consumption by 20 – 25%!
3. Factors affecting ball mills

Equipment design:
Separators

<table>
<thead>
<tr>
<th>Generation</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>QDK - Next Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bypass [%]</td>
<td>30 - 60</td>
<td>10 - 35</td>
<td>8 - 20</td>
<td>4 - 10</td>
</tr>
<tr>
<td>Min. Cut size [µm]</td>
<td>&gt; 20</td>
<td>15 - 20</td>
<td>&lt; 15</td>
<td>&lt; 15</td>
</tr>
<tr>
<td>Imperfection [-]</td>
<td>&gt; 0.50</td>
<td>0.35 - 0.50</td>
<td>&lt; 0.4</td>
<td>&lt; 0.35</td>
</tr>
<tr>
<td>Sharpness of cut</td>
<td>-</td>
<td>&lt; 0.5</td>
<td>&gt; 0.45</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>Max. Blaine [cm²/g]</td>
<td>3,800</td>
<td>4,500</td>
<td>≈ 5,500</td>
<td>≈ 6,000</td>
</tr>
</tbody>
</table>

Note:  
Imperfection:  \[ I = \frac{(x_{75} - x_{25})}{2 \cdot x_{50}} \]  
Sharpness of cut:  \[ x = \frac{x_{25}}{x_{75}} \]

CPB QDK Next Generation high efficiency separator has a very low by-pass & can improve mill output / energy consumption by 20 – 25%!
3. Factors affecting ball mills

Plant layout & engineering

- Plant lay-out has an important impact on efficient operations & maintenance, as well as energy consumption;
- Choice of ancillary equipment such as material transport & electrical control systems including dampers, feed rates, etc, also affect the mill efficiency & energy consumption.

“Minimum Design Approach” coupled with process expertise & good engineering can reduce energy consumption by 10 – 15%! 
3. Factors affecting ball mills

Operations & maintenance

- **Training**: over-grinding / under-feeding is wasteful of energy, hence skills & motivation of plant operatives can impact performance;

- **Mill ventilation**: high mill temperature causes media coating & excessive gypsum dehydration & can affect both output & quality;

- **Maintenance**: frequency & quality of planned maintenance can improve plant availability & mill performance;

- **Feed variability**: early detection of changes in quarry, kiln or cooler affecting clinker grindability ensures early corrective actions;

- **Technical audit**: regular axial & circuit analysis, including adjustment of media composition & filling ratio ensures optimum operation.

Difference between good & poor mill operation & maintenance can result in performance variation of +/-10%, or more in some cases!
3. Factors affecting ball mills

Use of clinker extenders:
Additives

- Additives such as limestone, slag, fly-ash & pozzolana for clinker substitution can reduce the total energy consumption of cement manufacture by 50%;
- However, excessively wet additives, or difficult to grind materials can impact the mill performance negatively.

Additives are highly effective in reducing the overall energy consumption & CO2 emission of cement production due to clinker substitution!
3. Factors affecting ball mills

Use of grinding aids:

Admixtures

- Amine, glycol & increasingly polycarboxylate polymer (PCE) based grinding aids can improve grinding efficiency at low dosage rate of 0.02 – 0.05% by neutralizing the electrical charges formed on the surfaces & cracks of particles to reduce agglomeration and coating formation on media & liners.

- At higher dosage (> 0.2% by weight), early strength may be affected.

Output may increase by 5 – 10% for normal OPC, or more for finer cement.
4. Ball mill improvements

Plant & equipment design

- State-of-the-art ball mill
- Mill linings
- Mill diaphragms
- Grinding media
- Separator
4. Ball mill improvements

State-of-the-art ball mill

- Lateral drive & self-aligning slide shoe bearings;
- Integrated lubrication cooling;
- Large, standard size man-hole;
- Activator & classifying liners;
- Monobloc® low pressure drop flow control intermediate diaphragm;
- High efficiency separator;
- Efficient layout & system protection.

Europe’s largest ball mill supplied by CPB for Heidelberger Cement in Poland
4. Ball mill improvements

Mill shell lining design for optimum grinding actions

1\textsuperscript{st} compartment: “Cataracting”
Media optimally lifted to achieve maximize impact / compressive forces for coarse grinding without causing liners breakage.

2\textsuperscript{nd} compartment: “Cascading”
Media sufficiently activated to maximize shearing & compressive forces for fine grinding, good material distribution & flowability.
4. Ball mill improvements

Maintaining grinding efficiency over liners service life

Liner wear-rates are governed by the profile, incorrect design can reduce the effective lifting height over time & grinding efficiency in the 1st compartment.
4. Ball mill improvements

Low ΔP flow-control diaphragms to improve grinding

- CPB monobloc® diaphragm is highly robust & has a long service life;
- Large central opening & low ΔP maximizes mill ventilation;
- Flow control optimizes material levels to maximize grinding efficiency;
- Heat-treated, rolled steel slotted plates do not peen over & require almost no maintenance;
- Output/power can be improved by 5-7% & cement quality more consistent.
4. Ball mill improvements

Media filling ratio according to required production

Lowest grinding energy is achieved at a filling ratio of 24-26%; hence opportunity to reduce energy consumption if output is not needed.
4. Ball mill improvements

High efficiency separator to minimize over-grinding

Latest QDK high efficiency separators from CPB can achieve a bypass of <10% & improve an existing mill performance by 20% or more, as well as producing greater cement consistency.
4. Ball mill improvements

**Case Example 1**
- **Plant name (Country)**: Lafarge (Austria)
- **Cement mill type**: 2 compartment closed circuit mill, Ø 4.6 x 14.4 m
- **Scope of modifications**: Installation of new Flow Control Intermediate Diaphragm

**Diaphragm replacement (2011)**

<table>
<thead>
<tr>
<th>Results</th>
<th>Before</th>
<th>After</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement type</td>
<td>CEM II AM-SL 42.5N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fineness acc Blaine</td>
<td>cm²/g 4.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>t/h 122</td>
<td>130</td>
<td>+ 6.6%</td>
</tr>
<tr>
<td>Power consumption</td>
<td>kWh/t 35.1</td>
<td>33.0</td>
<td>- 6.0%</td>
</tr>
<tr>
<td>Mill exit temperature</td>
<td>°C 115</td>
<td>110</td>
<td>- 5</td>
</tr>
</tbody>
</table>
4. Ball mill improvements

Case Example 2
Plant name (Country)  Complete mill internals upgrade (2012)
Heidelberg Cement (Romania)

Cement mill type
2 compartment closed circuit mill, Ø 4,2 x 10,77 m

Scope of modifications
1st & 2nd comp. lining + flow control intermediate diaphragm

<table>
<thead>
<tr>
<th>Results</th>
<th>Before</th>
<th>After</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement type</td>
<td>CEM II A-S 32,5R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fineness acc Blaine</td>
<td>cm²/g</td>
<td>3.200</td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>t/h</td>
<td>69</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+ 17,4%</td>
</tr>
<tr>
<td>Power consumption</td>
<td>kWh/t</td>
<td>34,6</td>
<td>29,6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- 14,4%</td>
</tr>
</tbody>
</table>
4. Ball mill improvements

**Case Example 3**
- **Plant name (Country):** Phoenix Cement (Germany)
- **Cement mill type:** 2 compartment closed circuit mill, Ø 3,8 x 12,08 m
- **Scope of modifications:** Replacement of 1st gen. separator by CPB high efficiency QDK 143-Z

<table>
<thead>
<tr>
<th>Results</th>
<th>Before</th>
<th>After</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement type</td>
<td>CEM II A-LL 32,5R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fineness acc Blaine</td>
<td>4.100 cm²/g</td>
<td>3.450</td>
<td></td>
</tr>
<tr>
<td>Residue 63 µm</td>
<td>6,5 – 8,0 %</td>
<td>2 – 4,5</td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>68 t/h</td>
<td>84</td>
<td>+ 23,5%</td>
</tr>
<tr>
<td>Power consumption</td>
<td>37 kWh/t</td>
<td>30,4</td>
<td>- 17,8%</td>
</tr>
<tr>
<td>Cement quality – 2 D</td>
<td>24 N/mm²</td>
<td>25</td>
<td>+ 1</td>
</tr>
<tr>
<td>Cement quality – 28 D</td>
<td>48 N/mm²</td>
<td>49</td>
<td>+ 1</td>
</tr>
</tbody>
</table>
4. Ball mill improvements

**Case Example 4**

**Plant name (Country):**

**Cement mill type:**

**Scope of modifications:**

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**Biggest ball mill in Europe (2012)**

**Plant name (Country):**

**Cement mill type:**

**Scope of modifications:**

---

### Results

<table>
<thead>
<tr>
<th></th>
<th>Achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement type</td>
<td>CEM I 42,5R</td>
</tr>
<tr>
<td>Fineness acc Blaine</td>
<td>cm²/g</td>
</tr>
<tr>
<td>Output</td>
<td>t/h</td>
</tr>
<tr>
<td>Power consumption (mill only)</td>
<td>kWh/t</td>
</tr>
<tr>
<td>Power consumption (complete circuit)</td>
<td>kWh/t</td>
</tr>
</tbody>
</table>
4. Ball mill improvements

CPB ball mill system versus typical ball mill systems and vertical roller mills

Data of typical ball mill system and VRM system from Cement International article about Loesche, page 65, 2/2013
5. Conclusions

1. Of the 4 main mill systems in use for cement grinding, ball mills are by far the predominant, despite a higher energy consumption compared with a stand-alone Vertical Roller Mill or Roller Press;

2. Beside historical reason, ball mills are generally more reliable, simpler to operate & maintain, the wear parts readily available & stocking cost lower, the investment cost lower, and the cement quality more widely accepted by the market, especially for the industrial users;
5. Conclusions

3. For decision on new cement mill, it is essential to consider not only energy but also equipment reliability, maintenance requirements, plant availability, operational flexibility, cement quality, and of course also the investment cost, in order to arrive at the best Total Cost of Ownership;

4. For existing ball mills, production cost can be significantly reduced by changing to well designed & proven equipment such as the CPB activator linings, low pressure drop monobloc® flow control diaphragm, and QDK high efficiency separator to improve the plant efficiency.
5. More efficient grinding also means a lower carbon foot-print for the industry.
Thank you for your attention, any questions?

You will find us at our booth:

Christian Pfeiffer

Booth no. 52 / 53