Choosing the Right Motors for your Mills

Alex Doll and Derek Barratt
DJB Consultants, Inc., Canada
Overview of Mill Selection

• Grinding testwork to characterise the project's ore types
• Characterise hardness variability or load grinding results into block model
• Select mill sizes to achieve a desired throughput (or select a throughput based on desired mill sizes)
• Select motor(s) to fit the mills
Step 1: Mill overload power

• Determine a set of operating conditions that reflects the maximum “overloaded” condition that the mill should be able to handle:
  – SAG mills: 20% v/v ball charge, 30% v/v filling and 78% critical speed with worn liners
  – Ball mills: 36% v/v filling and 78% critical speed with worn liners
Step 1: Mill overload power

- SAG mill, use a Tent Diagram to identify the design requirements
- Example, SG=4.0 38'Ø × 19' EGL SAG
- Requires 21.5 MW at mill shell
Benchmarking Power

Large Mill Power

- First 42' mill
- First two 40' mills were underpowered
- 20% balls
- Upgraded Freeport mill
- Upgraded Pelambres mill

MW vs \( \frac{D^{2.5} \times EGL}{1000} \)
Step 2: Power measured where?

- The process conditions reflect power delivered to the mill shell
- The motor power reflects the motor output
- Motors with pinions and reducers must allow mechanical losses
  - makes the motor bigger to produce the same shell power
Step 3: Which Type?

- Three commonly used mill motor types:
  - Gearless drives
    - largest size, up to 28 MW
    - highest efficiency
  - Synchronous with pinion
    - one or two pinion configuration, up to 15.6 MW
  - Induction motor with speed reducer
    - one or two pinion configuration
    - cheapest capital, but poorest electric efficiency
Step 3: Which Type?

- **Electrical efficiency**
  - Gearless is highest
  - Induction is lowest
- **Directly affects operating costs**
  - Inefficient motors consume more power

<table>
<thead>
<tr>
<th>Mill Shell</th>
<th>Motor Output</th>
<th>Motor Input</th>
<th>CCV/Transformer Input</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.0</td>
<td>0.985</td>
<td>0.98</td>
</tr>
<tr>
<td>Gearless</td>
<td>0.97</td>
<td>0.96</td>
<td>0.97</td>
</tr>
<tr>
<td>Synchronous</td>
<td>0.96</td>
<td>0.96</td>
<td>0.99</td>
</tr>
<tr>
<td>Induction</td>
<td>0.96</td>
<td>0.96</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Step 3: Which Type?

• Gearless is always variable-speed
• Synchronous and induction are normally fixed-speed
  – Can be made variable speed by adding more equipment and sacrificing electrical efficiency
  – In almost all cases, variable speed is cost-effective for SAG mills
  – Variable speed for ball mills depends on the particular project and ore
Step 4: Select Speed

• The rated speed of a motor is nominated by the engineer
• The torque output of a motor is constant up to the rated speed
• The power output of a motor is constant above the rated speed
Step 4: Select Speed

- Want the widest possible range of operating conditions
Case Study

- South American iron-ore project
- Variability in ore density
- 60,000 tonnes/day on 75% of samples
- Single line
  - 1 SAG, 38' Ø × 19' EGL
  - 2 ball mills, 22' Ø × 38' EGL
# Case Study: Nominal operation

## Case 03: one 38'x19' EGL SAG and two twin-pinion 22'x38' ball mills

**Circuit Feed**
- \( F_{	ext{g}} = 150.0 \, \text{mm} \)
- \( \text{Density} = 3.08 \, \text{t/m}^3 \)

<table>
<thead>
<tr>
<th>Circuit Feed</th>
<th>Transfer</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_{\text{g}} = 150.0 , \text{mm} )</td>
<td>( \text{Transfer} )</td>
<td>( F_{\text{o}} = 150.0 , \text{mm} )</td>
</tr>
<tr>
<td>( \text{Density} = 3.08 , \text{t/m}^3 )</td>
<td>( \text{Product} )</td>
<td></td>
</tr>
<tr>
<td>( W_{\text{C}} = 9.48 , \text{kW/h/t} )</td>
<td>( W_{\text{L}} = 14.20 , \text{kW/h/t} )</td>
<td>( W_{\text{BM}} = 13.96 , \text{kW/h/t} )</td>
</tr>
</tbody>
</table>

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**SAG Mill 1**
- **Motor Rated Power**: 21,500 kW (28,832 HP)
- **Power available at shell**: 21,500 kW (28,832 HP)
- **Drawn Power at Shell**: 17,722 kW (23,766 HP)
- **Dimensions**: 38'Ø x 19' EGL (11.6 m Ø x 5.8 m)
- **Speed**: 9.8 RPM; 78.0% critical
- **Filling**: 25.0% v/v total, 16.0% v/v balls

**Ball Mill 2**
- **Motor Rated Power**: Twin 5,250 kW (7,040 HP)
- **Power available at shell**: 10,343 kW (13,670 HP)
- **Drawn Power at Shell**: 9,177 kW (12,307 HP)
- **Dimensions**: 22'Ø x 38' EGL (6.7 m Ø x 11.5 m)
- **Speed**: 13.0 RPM; 77.8% critical
- **Filling**: 33.0% v/v total, 33.0% v/v balls

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**Primary Mill(s)**
- **Usable shell power**: 17,722 kW
- **Dimensions**: 38'Ø x 19' EGL
- **Easag = 6.37 kW/h/t**

**Secondary Mill(s)**
- **Usable shell power**: 18,354 kW
- **Dimensions**: 22'Ø x 38' EGL
- **Ebm = 6.60 kW/h/t**

**Pebble Crushers**
- **Usable shell power**: 559 kW

**Estimated circuit throughput**: 2,780 t/h * 24 h/day * 92.0% = 61,391 t/d
Case Study, 21.5 MW SAG

- Density 4.0 t/m³
- Density 3.17 t/m³
Case Study, Design Speed

- 78% of critical
- 75% of critical
Case Study, Liners

(based on change in mill volume, does not consider charge motion)

- Worn (75 mm)
- New (150 mm)
Conclusion

• Size grinding mills for nominal operating conditions (throughput targets)
• Size motors for “overload” conditions that may reasonably be encountered
  – High ball charge, volumetric filling
  – High density ore
  – Worn liners