Increased production systems effectiveness through condition monitoring and prognostics

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AND
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product development for design out maintenance
Introduction

Mining and ore dressing plant mills are bottle necks for the mining industry. The downtime costs are very significant, thus the following questions needs to be answered:

• What are the optimum replacement intervals for rubber liner used in mills and how to measure the wear of liners?

• If cracks appear at the mill shells, how large can these cracks be, before the mill has to be stopped and repaired and how to measure the cracks?
Project

- Duration 2008-08-04-----2012-08-04
- Financed by Vinnova, Boliden Mineral AB, LKAB, Metso Minerals and Ringhals AB
- Total budget 10.5 MSEK
- 2 PhD students
- Project manager: Jan Lundberg
Methods

- Systematic testing and evaluation of measurement methods
- FEM calculations of the crack behavior at the mill shells using measured surface stresses during rotation
- Comparative analysis for gross profit during one replacement cycle is carried out for various replacement intervals.
- Time sampling is done to investigate the economic efficiency and observing the pattern for various parameters during life cycle of liners
- A trade-off is set up between total earnings and replacement cycles for getting optimum time for replacement
- Development of theoretical models using real process data for prediction of optimum replacement intervals of liners and the corresponding profit
Results

Developer: Damill AB
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<table>
<thead>
<tr>
<th>Method</th>
<th>Contact</th>
<th>Detection of internal defects</th>
<th>Temperature range</th>
<th>Flaw type</th>
<th>Wireless</th>
<th>Cost</th>
<th>Sensor type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasound</td>
<td>Yes</td>
<td>Yes</td>
<td>up to 250°C (higher temp special probes)</td>
<td>Surface &amp; embedded cracks</td>
<td>No</td>
<td>Moderate to high</td>
<td>Probe</td>
</tr>
<tr>
<td>Eddy current</td>
<td>Yes</td>
<td>Yes</td>
<td>up to 150°C (higher temp special probes)</td>
<td>Surface &amp; embedded cracks</td>
<td>No</td>
<td>Moderate</td>
<td>Probe</td>
</tr>
<tr>
<td>Acoustic emission</td>
<td>Yes</td>
<td>Yes</td>
<td>up to 150°C (higher temp special probes)</td>
<td>Surface &amp; embedded cracks</td>
<td>No</td>
<td>Moderate to high</td>
<td>Probe</td>
</tr>
<tr>
<td>Magnetic particle testing</td>
<td>Yes</td>
<td>Yes</td>
<td>up to 100°C</td>
<td>Surface cracks</td>
<td>No</td>
<td>Low to moderate</td>
<td>Magnetic particles/ wet magnetic fluorescent particles</td>
</tr>
<tr>
<td>Bleeding composites</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>Surface cracks</td>
<td>Yes</td>
<td>NA</td>
<td>Film/matrix</td>
</tr>
<tr>
<td>Fatigue damage sensor</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>Surface cracks</td>
<td>Yes</td>
<td>Moderate to high</td>
<td>Sensor/matrix</td>
</tr>
<tr>
<td>Fiber optic sensors</td>
<td>Yes</td>
<td>No</td>
<td>up to 200°C</td>
<td>Surface cracks</td>
<td>No</td>
<td>High</td>
<td>Optical fibre</td>
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<tr>
<td>Strain gauges</td>
<td>Yes</td>
<td>No</td>
<td>up to 250°C (higher temp special probes)</td>
<td>Surface cracks</td>
<td>No</td>
<td>Low to moderate</td>
<td>Gauge</td>
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<tr>
<td>Piezoelectric paint sensors</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
<td>Surface cracks</td>
<td>No</td>
<td>High</td>
<td>Film/electrode</td>
</tr>
<tr>
<td>Fluorescent crack sensors</td>
<td>Yes</td>
<td>No</td>
<td>220°C (special coatings high temperature)</td>
<td>Surface cracks</td>
<td>No</td>
<td>Moderate to high</td>
<td>Film/matrix</td>
</tr>
</tbody>
</table>
Parameters affecting liner replacement intervals & profit

- Feed flow
- Metal recovery Efficiency
- Production loss
- Relining cost
- Energy cost
- Inspection cost

Model

- Total cost
- Inspection Intervals

Optimum replacement Intervals

Instantaneous monetary Savings/ profits

Revenue

Optimum replacement Intervals

Instantaneous monetary Savings/ profits

Inspection Intervals

Optimum replacement Intervals

Instantaneous monetary Savings/ profits

Inspection Intervals

Optimum replacement Intervals

Instantaneous monetary Savings/ profits

Inspection Intervals
Case 1: Gross Profit \( (P_{350}) = (4A_{350} - 3C_{DC}) \)

Case 2: Gross Profit \( (P_{300}) = (4A_{300} + xA_{300} - 4C_{DC}) \)

Compare: If \( (P_{300} > P_{350}) \) Then Replace after 300 Days
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\[ P_{\text{timesample}} = \left[ \left( \sum_{i=1}^{k} M_i \right) \cdot \Omega \cdot \alpha \cdot \eta_p - \left( \sum_{i=1}^{k} E_i \cdot C_{\text{pow}} + \frac{C_{\text{rep}}}{(T_{\text{Cycle}} + T_{\text{rep}})} \cdot t_{in} \right) + t_{in} \cdot C_{\text{ins}} + \frac{C_{DT}}{(T_{\text{Cycle}} + T_{\text{rep}})} \cdot t_{in} \right] \]

\[ P = \sum_{j=1}^{s} P_{\text{timesample}} \quad \text{Where,} \]

Gross profit \[ P_{\text{gross}} = P \times \left( \frac{n \times 365}{T_{\text{Cycle}} + T_{\text{rep}}} \right) \]

For the period of “n” year the average profit per year will be \[ P_{\text{avg}} = \frac{P_{\text{gross}}}{n} \]

A computer program was made on visual basic to simulate the model for various replacement days (ex. 360 to 1)
Future research within the project

• The liner replacement model will be developed for multiple ores types. A demonstrator will be delivered. Eventually also the replacement of individual liners will be incorporated.
• FEM calculations, considering the influence of the wear of liners on the crack propagation at the shell will be performed.
Nominated to first price at the contest (Stora Produktivitetspriset 2010)

- Som det ser ut nu kommer vi förmodligen att skaffa oss en helt annan framförhållning och det innebär direkt pengar för oss så jag är väldigt nöjd med detta, säger Jonas Fjellner projektledare vid Boliden Mineral AB.
Publications so fare


3) "Mathematical model for optimum replacement interval of grinding mill liners”, International Conference on Quality, Reliability and Infocom Technology: ICQRIT 2009, 18-20 December 2009, Delhi, India


The first three publications will be found on the following link.
http://www.ltu.se/staff/r/rajdan?l=en
Conclusions

• A theoretical model is developed which have the capacity to predict the optimum replacement interval for liners in a mill and the corresponding profit.

• The results obtained for optimum replacement interval shows an approximate increase of 1.0152% in gross profit per year by changing the current replacement policy to the proposed policy.

• An alternate way of decision making without using periodic wear measurements of mill liners due to the unavailability of enough wear data to analyze is developed.

• The project has promoted the development (Damill AB) of a new laser based method for faster measurement of the wear of liners.
Thank You for the attention!

Questions?