APPLICATION OF ROUTINE HIT ORE HARDNESS TESTING AT THE GRINDING CIRCUIT, MEADOWBANK GOLD MINE

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AusIMM MetSoc Plant Operators' Forum, 28th August, 2018
Summary of Presentation

• Introduction

• Meadowbank Process Plant

• Hardness Index Tester (HIT)

• HIT Evaluation Program

• Results
• Located in the Kivalliq region of Nunavut in Canada
• Owner: Agnico Eagle Mines Ltd. (AEM)
• Throughput: 11,000 tpd
Process Plant Description

445 – 515 tph throughput depending on ore type, P80 75-110 microns
95 % Availability with 90.5 to 95.5 % recovery
What is the HIT?

• HIT means Hardness Index Tester

• Portable device performing rapid rock hardness determination

• HIT generates quantitative estimates of Axb and BWi

• Allows operational, on the spot determination of rock hardness variability

• Ideal for routine testing of mill feed samples to monitor performance / adjust mill settings for optimum performance or geometallurgical program
Initially developed for rapid low cost Axb estimation

Industrial trials demonstrated the possibility of using HIT for Bond BWi estimation

Calibration against standard tests may be required, especially Bond BMWi

Quality control protocols included

Online software access for Axb and Bond BWi calculations

Prototype V2
Patent Pending
62/241,852, PCT/I B2016/001591
• Program initiated by AEM Meadowbank in late 2017

• Can routine ore hardness testing, using SAG feed samples, assist in forecasting the SAB grinding circuit performance?

• Daily samples were collected over a two-month period

• Submitted for HIT testing at CSD laboratory to provide estimates of both the competency (Axb) and grindability (Bond BWi) hardness.

• Program extended until end of March 2018, with a further 107 days of sampling

• Meadowbank deposit is almost depleted and AEM is planning to open Amaruq mine and process ore in the Meadowbank plant.

• A geometallurgical program, including hardness characterization using the HIT, is ongoing.
Meadowbank and Amaruq Projects
AEM provided a summary of the triplicate HIT Axb and duplicate HIT Bond Wi results in Excel (for each apron feeder sample collected)

Daily operating information from Meadowbank

<table>
<thead>
<tr>
<th>Ore Zone Vault (%)</th>
<th>Crusher shut down (hrs)</th>
<th>Mill Down time (hrs)</th>
<th>Availability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput (TPH)</td>
<td>Tonnage (tpd)</td>
<td>SAG Power Draw (kW)</td>
<td>BM Power Draw (kW)</td>
</tr>
<tr>
<td>SAG F80 (inch) WipFrag</td>
<td>SAG %-1inch WipFrag</td>
<td>SAG T80 (if reliable)</td>
<td>Product P80 (cyc. OF)</td>
</tr>
</tbody>
</table>

Multiple least-squares regression analysis of SAG and BM performance

SAG specific energy S.E. kWh/t and grind size P80 (microns)

Inputs included HIT hardness parameters and operating variables expected to affect the mill performance.
Challenges

- HIT testing and feed sizing was conducted on material from a ~10kg sample of SAG feed (mix of grab samples and composites).
  - Inconsistent sample taking due to cross shift effect.
  - Manual sampling of coarse material challenging, despite lower F80.

- Operating data reflect the daily average performance/statistics, which may not align with the feed sample collected for HIT testing and size analysis.

- Daily performance may not reflect the optimum/maximum performance, for example, packing issues in the SAG due to new lifter liners.

- HIT Bond Wi estimates are derived from a default calibration model, which may need to be updated to reflect more accurately the grindability of Meadowbank ore types.
• Strong correlation confirmed the well-known expectation that feed size and hardness does affect the SAB grinding performance

• Improved sampling strategy may improve overall accuracy
• Use model developed from initial 53 days of monitoring to forecast performance for remaining 107 days not used in model calibration.
• Clearly not as accurate as the calibration, but still within 5% relative error.
• Results very encouraging, the model tracking a major change in SAG Specific Power and BM P80 in mid-February 2018.
Conclusions

• Variation in Axb was more significant than Bond Wi, 27 to 45 for Axb and 12.9 to 15.4 kWh/t for Bond Wi. – values align with range of standard test results from Meadowbank deposit.

• Observed variation in the grinding circuit performance is strongly correlated to the HIT ore hardness parameters.

• Other variables affecting the SAG and Ball Mill circuit performance are feed size, specifically the %-1", and ore SG as expected.

• Data from the HIT test was used to justify throughput issues in Q1 2018
  • Site has capacity to conduct BWi tests, but no information on Axb
  • Meadowbank wants to re-work the models to predict the TPH for a given target P80.
    • More adapted to the needs: maximizing TPH for a set grind target
    • Method to verify if the grinding circuit is performing optimally
Future Work

- Meadowbank has decided to extend HIT evaluation until end of 2018 as a tool to benchmark the performance of the grinding circuit.

- SimSAGe working to update the HIT Bond Wi calibration model once sufficient actual Bond Wi test results are available on the same samples.
  - Should provide a more reliable model in both cases, calibration and forecast.

- Validation using plant performance data around the time of sampling

- Use the new model to verify the actual TPH versus the predicted value as a measure of the circuit efficiency.
  - Justification of performance when faced with different feed types
  - Indicator that circuit performance is not optimal, requiring investigation

- Implement use of the HIT test to map the hardness variation in the future Amaruq deposit and develop an ore blending strategy based on the results.