SIMINE Asset Health Analytics Survey
Dr. Dan Fodor, July 2020

Courtesy © Penasquito Gold-Silver Operation in Mexico (Image: Newmont)
SIMINE Asset Health Analytics Survey

Contents

Customer Voice

Asset Health Analytics for Gearless Mill Drives
▪ Added Value for Operations
▪ Technology Pillars

Asset Health Analytics for Belt Conveyors

SmartMining

Demo/ Examples within each Chapter

Courtesy © Penasquito Gold-Silver Operation in Mexico (Image: Newmont)
Customer Voices* guide our Solution Development

"Where I see value being added is to have the alarms and event messages shown with detailed explanations and recommended actions."

Corporate Director of Performance, USA

"For future development, we will focus on digitalization and automation of the production processes."

Head of Process Control, Australia

"Raising to the challenge: Increasing equipment utilization."

Managing Director & CEO, South Africa

"We're trying to get more of a predictive vs reactive mode of Operation. Obviously the sooner you know about something you start getting ready for it."

Mine Manager, Australia

"I'm trying to turn the challenge into a benefit."

Managing Director & CEO, Mexico

"Within the mining industry the challenge is how to adapt technology to improve productivity, reduce costs and increase revenues. Multisystem capacities and teamwork are what allow people to understand that one single action could affect the entire process. That is how the success of digital transformation could be achieved."

Superintendent - Electrical, Instrumentation & Process Control, Chile

"Increasing utilization and reduce shutdowns. We are working with our fleet management and process control companies to check debottlenecking opportunities, because we do have some."

Superintendent - Electrical, Instrumentation & Process Control, USA

"Its Everybody’s dream to reduce shutdowns."

Therefore our Asset Health Analytics Solutions focus on (a) Process visibility (b) Predictive and (c) Counteraction information.

*) Company & Speaker Name intentionally deleted
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Reasoning – Added Value for Operations

Events leading to unexpected mill malfunction and shutdowns induce operational losses up to several Mio USD per day.

We see added value in:

- Early information that the mill or its components reveal deviations from normal operation
- Identifying the correct root-cause and
- Recommending counteractions

Goal is preventing/shortening unplanned shutdowns.

SIMINE Asset Health Analytics for Gearless Mill Drives
(Asset Health Analytics for Pinion Mill Drives and Belt Conveyors in the start phase)
SIMINE Asset Health Analytics Focus
From corrective towards proactive Mode of Operation

Remote Services
Shorten unplanned downtime by enhancing troubleshooting activities

Condition Monitoring Services
Minimize planned and unplanned downtimes by optimizing maintenance activities

Asset Health Analytics
Optimize the asset performance by expert support based on asset data

Asset Health Analytics GMD
Key Components Overview

Remote Support
(incl. On-Call Service)

Basic System
(GMD, Pinion Mill Drives, Belt Conveyors)

Options
(Wireless Rotor Monitoring, Vibration)

Corrective / Preventive

Corrective

Predictive / Proactive

Expert Analysis
Expert Report
Root-causes
Model calculations

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Page 6
SIMINE Asset Health Analytics for Gearless Mill Drives
Our Expert Solution to avoid “false Positives”

Key Messages

- Our solution is developed by experienced specialists with GMD-specific know-how hence is not a standard Condition Monitoring System

- The user of Asset Health Analytics receives the real root-cause(s)

- Our solution supports with timely information/recommendations and does not close any loop to Automation system i.e. there is no shutdown induced by Asset Health Analytics

- State-of-the-Art technologies (like modelling/Digital Twin) are implemented based on decades of own Gearless Mill Drives experience
SIMINE Asset Health Analytics
Value Proposition induced by “Mill Operator Voice”

<table>
<thead>
<tr>
<th>Operator Voice</th>
<th>Added Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Detect changes in Mill Operation</strong></td>
<td></td>
</tr>
<tr>
<td>“As maintenance engineer I want to receive early indication of looming incidents in order to avoid mill misfunction or damages”</td>
<td><strong>Information and transparency: “no surprise”</strong></td>
</tr>
<tr>
<td><strong>Analyze contributors and underlying root-cause(s)</strong></td>
<td></td>
</tr>
<tr>
<td>“As maintenance engineer I want to receive an interpretation of anomalies detected in the mill data”</td>
<td><strong>Understand what happens: ”opportunity to prepare”</strong></td>
</tr>
<tr>
<td><strong>Decision support for action</strong></td>
<td></td>
</tr>
<tr>
<td>“As operation manager I need to organize fast countermeasures”</td>
<td><strong>Support for “early appropriate counteraction”</strong></td>
</tr>
</tbody>
</table>

**Goal: Predictive/ proactive Mode of Operation**
### Functionality & Challenge

<table>
<thead>
<tr>
<th>Real-time monitoring (&quot;CMS&quot;)</th>
<th>Increased motor stator vibration over time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What happens/ happened?</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Data analysis

<table>
<thead>
<tr>
<th>Why did a change happen?</th>
</tr>
</thead>
<tbody>
<tr>
<td>– What triggered the change/ anomaly?</td>
</tr>
<tr>
<td>– Which is the root-cause?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Forecasts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anomaly detection, fault prediction</td>
</tr>
<tr>
<td><strong>What will happen?</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prescript action like equipment check, maintenance, service…</td>
</tr>
<tr>
<td><strong>What should be done?</strong></td>
</tr>
</tbody>
</table>

### Information & Recommendation ("Deliverables")

- **Notifications and warnings**
- **Online dashboards**
- **Data assessment**
- **Reports**
- **Online dashboards**
- **Remote support**

- **Online dashboards**
- **Remote support**

- **Online dashboards**
- **Remote support**

- **Online dashboards**
- **Remote support**

### Example Mill Vibration Analysis

- **Reduced torque in stator fixation bolts on motor foundation**

- **Mill vibration will reach the warning level in “x days, weeks…” if no change**

- **Inspect and plan re-torque of fixation bolts**

- **If required, realign**
SIMINE Asset Health Analytics Survey

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Asset Health Analytics for Gearless Mill Drives
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Asset Health Analytics for Belt Conveyors

SmartMining

Demo/ Examples within each Chapter
SIMINE Asset Health Analytics – Three Technology Pillars

Asset Health Analytics for grinding mills

Fingerprint Analysis
- Collection of fingerprints (measured data sets) from start-up as reference for later operation
- Comparison actual/reference

Mathematic Modelling
- Digital Twin
  - Calculation of (e.g. motor temperature) models
  - Comparison w/ real values and deduction of trends

Artificial Intelligence
- Beyond limits of mathematics
- Train AI-models with operational experience
Asset Health Analytics for Gearless Mill Drives – Example Vibrations Fingerprint Analysis (Siemens Patent pending)

Basics

- Original Fingerprints are
  - obtained by measurements during mill start-up
  - validated by Siemens specialists
  - stored (On-Cloud or On-Premise)
  - used as reference for comparison and analysis during the whole mill lifetime

- Analysis example – Comparison of Actual Measurement with Original Fingerprints

Vibrations

- Changes in level and frequency of vibrations might indicate abnormalities (selection):
  - Loosening of internal fixation bolts and/or
  - Loosening of fixation on foundation and/or
  - Deterioration of foundation
  - ...

![Graph showing Actual Measurement and Original Fingerprint comparison]
Comparing two slightly different operation points results in an increase trend (Fig. 1)…
… and leads to the false root-cause: problem in motor cooling system (heat exchangers, fans, etc.)

Correct root-cause is revealed by the consistent comparison (same operation point)…
… and leads to correct conclusion (Fig. 2): winding temperature constant, no change trend

**Fig. 1**
Stator winding segment 1 (average temperature)

**Fig. 2**
Stator winding segment 1 (average temperature)
Asset Health Analytics for Gearless Mill Drives – Example Digital Twin based Winding Overheating

Asset Data
- Current
- Voltage
- Speed
- Power
- Temp. cooling water
- Temp. cooling air

Mathematical Model Analytics considering
- Asset Data as well as
- Cooling characteristics
- Motor characteristics
- Temp. rotor/stator windings
- Winding characteristics

Digital Twin

OKAY
winding temperatures equal to calculated values

ABNORMAL
winding temperatures higher than calculated
Maintenance required during next scheduled downtime

IMMEDIATE ACTION
Backup info like
Root-cause Recommendations
Maintenance suggestions and other
Asset Health Analytics for Gearless Mill Drives – Example Digital Twin Winding Overheating

Segment 1 Temp. v/s Model

Segment 2 Temp. v/s Model

Segment 3 Temp. v/s Model

Segment 4 Temp. v/s Model

Notification 📣 ABNORMAL

- We recommend following actions
  - Check cooling water temp.
  - Check for clogged filter etc.
SIMINE Asset Health Analytics for Gearless Mill Drives – Example Dashboards, intuitive Status Overview as well as technical Insights

Intuitive overview of the 6 key components
- Mill Mechanic w/ bearings / accumulator / brake
- Drive & Control
- E-house
- External Cooling
- Ring Motor
- Power & Interfaces w. switchgear / circuit breaker / excitation

Intuitive status display

Example technical insights component status “Chiller”
- Ambient & water temperatures / operating hours pumps & cooling unit
Parameter values are correlated and displayed with associated Fingerprints & Process Data

- Lube accumulator (oil flow, temperature)
- Brake (oil temperature, release pressure)
- Bearings (temperature, oil flow/pressure)
  - Thrust
  - Feed
  - Discharge
- Bearing pads 1 to 4 (temperatures)
SIMINE Asset Health Analytics for Gearless Mill Drives – Example
Fingerprints Motor Air-gap, “OKAY” and “NOT OKAY” Status

Asset State

Fingerprints application

- Inner circle in first year of operation is ideal round, with tolerances according to the design
- Interesting are eventual long-term stator deformations
- After five to ten years, the circle might change to an oval
- Early detection is crucial
SIMINE Asset Health Analytics for Gearless Mill Drives

Example – Service Report answering „What will happen?“

Fingerprints- and Digital Twins- based Analysis and Trends reveal preventive Actions

Service Expert Report
Asset Health Analytics

2 Summary Expert Analysis – Status and Trends

This section shows a summary of the mill status. The Asset Health Analytics considers 6 main assets to be analyzed: Motor, Mill Mechanic, Drive and Control, E-House, External water cooling system and Power and customer interface.

Table 2 shows the legend for the assets summary status, shown in Table 3.

<table>
<thead>
<tr>
<th>Trend</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;</td>
<td>Intensity of anomaly has increased</td>
</tr>
<tr>
<td>≥</td>
<td>Intensity at constant level</td>
</tr>
<tr>
<td>&lt;</td>
<td>Intensity of anomaly has decreased</td>
</tr>
<tr>
<td>n.a.</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trend</th>
<th>Recommended Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;</td>
<td>Immediate action required</td>
</tr>
<tr>
<td>≥</td>
<td>Action recommended</td>
</tr>
<tr>
<td>&lt;</td>
<td>No action taken</td>
</tr>
</tbody>
</table>

Table 2 Table Legend

2 Mill Mechanic

2.1 High pressure system

2.2 Low pressure system

2.3 Accumulator system

2.4 Feed side Pads temperature

2.5 Discharge side Pads temperature

2.6 Feed side Pads flow

2.7 Discharge side pads of flow

2.8 Feed side Pads pressure

2.9 Discharge side Pads pressure

4 Mill Operation

Within the reported time frame (01.09.2018 to 31.10.2018) the mill was operated 41.28% of all time within the powerspeed range 0.56-8.84rpm / 16.75-20.63MW. The remaining time the mill was operated out of this range (very low load).

The normal operation range is used for further analysis. The distribution of mill operation time in this range is shown in figure 1.

The most run operating point (OP) was the number 56 with 12.65% of the time. This operating point represents a speed between 5.40 – 9.56 RPM and a power between 17.18 – 17.56 MW.

For analysis purposes, the most active operating point will be used to evaluate the mill relation.
SIMINE Asset Health Analytics for Gearless Mill Drives
Example – Service Report answering „What will happen?“

Fingerprints- and Digital Twins- based Analysis and Trends reveal preventive Actions

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### 5. Mill Eccentricity

Using the airgap measurements, the mill eccentricity is analysed.

Figure 2 and Figure 3 show the trend of the mill eccentricity at the operation point 56 (see Figure 1) between the 01.08.2018 and the 31.10.2018 and the exact dates when the mill operated at this operation point.

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### 6. Stator winding temperature and trend prediction

In this section, using the fingerprint concept of the Asset Health Analytics system, the winding temperature is measured at the operating point 56 shown in Figure 1 and the winding temperature trend is analysed.

Using the trend the Asset Health Analytics system provides a prediction of the winding temperature behaviour for the future operation. If the winding temperature prognosis trend reaches 100° and 110° a warning condition message and critical condition message will be generated respectively.

Each measurement point shown in Figure 4, Figure 5, Figure 6 and Figure 7 represents the average motor winding temperature when the mill was running at the operation point 56.

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### 7. Stator winding temperature compared to motor temperature model

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9.1 Thrust Bearing temperature

Figure 15 shows the trend of the Thrust bearing temperature at the operation point 56 between the 01.08.2019 and the 31.10.2019.
SIMINE Asset Health Analytics for Gearless Mill Drives
On-premise Solution under Development (Release E 2020)

Asset Health

- Asset health reflects operational conditions and is determined based on anomaly detection of critical measurements e.g. oil temperature and winding temperature of transformers.

Asset Integrity

- Asset integrity reflects maintenance conditions and is calculated based on expected maintenance tasks and intervals for every component.

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SIMINE Asset Health Analytics for Gearless Mill Drives
Wrap-up Value Proposition (Status Information only Examples)

Operational transparency, “no surprise”
- Mill status and trends
- Overview and detailed component views

Continuous Condition Monitoring and Expert Analytics identify relevant deviations:

Understand what happens, ”opportunity to prepare”
Event analysis (short term) to identify event including notification

Support for early appropriate counteraction
Decision support for (short term) action
Prescriptive analysis (long term): analysis of mill status, inclusive expert reports with service recommendations
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Demo/ Examples within each Chapter

Courtesy © Penasquito Gold-Silver Operation in Mexico (Image: Newmont)
SIMINE Asset Health Analytics for Belt Conveyors

Value Proposition

- **Early detect events** that cannot be predicted exclusively through mathematic models and simulation

- **Monitor operational status** e.g. belt misalignment or cord/edge damage etc.

- **Economics improvement** based on **Key Performance Indicators, Overall Equipment Effectiveness**, components lifetime etc.

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**Example OEE-based analysis**

Influences of e.g. ambient temperatures (seasons) or specific events (like BC03 in Autumn 2019) on operating performance can be identified and evaluated.
SIMINE Asset Health Analytics for Belt Conveyors
Intuitive Use at all Levels
SIMINE Asset Health Analytics Survey

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Asset Health Analytics for Belt Conveyors

Demo/ Examples within each Chapter
Our SIMINE Asset Health Analytics solutions are expandable to higher levels

e.g. grinding process, transportation process or entire mine location

through integration in Siemens SmartMining platform

SmartMining Platform for Grinding or Transportation Process or for entire Mine Location

Process Control System PCS7 / DCS systems - Historian / 3rd Party system
Siemens Mining Solutions

Immediate Action Abnormality

Motor Speed
- 8.04 RPM

Motor Power
- 16.35 MW

Bearing Pad Oil Flow
- 351.43 l/min
- 361.76 l/min

Power Consumption
- Average Power 24hrs (MW)

Anomalies (Showing 1 - 4 of 4)
- Mexico: Grinding (SAG1)
  - Dec 29, 2019 12:26:01 GMT
  - Unknown
  - Motor Vibration
  - Belt Misalignment

- Mexico: Grinding (SAG1)
  - Dec 20, 2019 10:25:29 GMT
  - Unknown
  - Belt Misalignment

- Mexico: Stockyard1
  - Belt Conveyor B3C
  - Dec 20, 2019 10:25:29 GMT
  - Abnormality

- Mexico: Stockyard1
  - Belt Conveyor B3C
  - Dec 20, 2019 10:25:29 GMT
  - Abnormality

Immediate Action
- This Anomaly is currently unknown please contact Siemens Support.

Abnormality
- Reduced torque in stator fixation bolts on motor foundation
- Material is not fed in the center of the belt
- Casing on pallets
## Example of SmartMining Microservice – Events, Root Causes and recommended short/long- Term Actions

<table>
<thead>
<tr>
<th>Event</th>
<th>Reason (Possible cause) (samples only)</th>
<th>Counter-measures (short-term) (samples only)</th>
<th>Preventive measures (long-term) (samples only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mis-alignment of belt</td>
<td>Material is not fed in the center of the belt</td>
<td>Change the conditions in the feeding station</td>
<td>Install off-track detectors (misalignment switches) behind the feeding station</td>
</tr>
<tr>
<td>Caking on pulleys</td>
<td></td>
<td>Increase the efficiency of the belt cleaner</td>
<td>Increase the inspection interval for the belt cleaner</td>
</tr>
<tr>
<td>Alignment of idler-stations are wrong</td>
<td></td>
<td>Check the idler-stations</td>
<td>Increase the inspection interval for the idlers (e.g. use thermal camera)</td>
</tr>
<tr>
<td>Wind or rain influence the local friction conditions between belt and idlers</td>
<td></td>
<td>Install covers or hoods on the conveyor</td>
<td></td>
</tr>
</tbody>
</table>

- **Identified risky changes** appear on the screen with details and relevant signals
- **Root cause(s) and counteraction(s)** corresponding to the change(s) are displayed
- **Own expert classified changes can be permanently added**
SIMINE Asset Health Analytics for Grinding Mills
Our expert Solution to avoid “false Positives”

Example

Courtesy © Penasquito Gold-Silver Operation in Mexico (Image: Newmont)
Example Fingerprint Analysis – Abnormality “Winding Temperatures increase during Sommer Months”. Which is the Root-Cause?

01.08.2018–31.10.2018

01.11.2018–28.02.2019

Example of Expert Analytics to avoid “false Positives”

„First shot“ explanation of the root-cause:

There is a possible problem in the motor cooling system i.e. with the motor fans or heat exchanger

Siemens “Expert Analysis” based explanation needs additional information, therefore…→
Winding Temperatures increase during Sommer Months. Which is the Root-Cause? Let us analyze the external cooling as well.
Abnormality “Winding Temperatures increase during Sommer Months.” – Which is the Root-Cause?

Summary of the Facts

- Winding temperatures are constant during Spring¹) months but increase during Summer months

- First root-cause explanation is a possible problem in the motor cooling system (i.e. motor fans or heat exchanger)

- Siemens “Expert Analysis” needs additional information, therefore the external cooling system is analyzed as well

- In the external cooling system, cold water temperature increases during the Summer months as well

- Siemens Asset Health Analytics support information for immediate action:
  - There is no problem with the motor cooling system
  - Suggestion to the customer: check the chiller (motor external water cooling system) due to increased inlet cold water temperature

1) Seasons acc. Chile location
Example Fingerprint Analysis – Did we solve the problem?
Yes, we did, as the following months confirmed

01.03.2018–30.05.2019

Motor winding temperatures got back to normal in the months after 01.03.2018–30.05.2019

Hence: Health Analytics from Siemens Experts to avoid “false Positives”
Example Fingerprint Analysis (Siemens Patent pending)
Did we avoid here a “false Positive”? Yes, we did.

In our example, the „false Positive“ root-cause for Winding temp. increase is:

- **External cooling is OKAY**
  (induced by “Motor cooling has malfunction”)

Identified | NOT Identified
--- | ---
**False Positive** | **False Negative**
**True Positive** | **True Negative**

01.11.2018–28.02.2019

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Takeaways
SIMINE Asset Health Analytics

Our SIMINE Asset Health Analytics solutions are...

▪ … available for Gearless Mills, Pinion Mills, Belt Conveyors and Mine Winder
▪ … focused on process visibility, predictive and counteraction information
▪ … based On-Cloud or On-Premise as specified by the user
▪ … expandable to higher levels (e.g. grinding, transportation process or entire mine location) through integration in Siemens SmartMining platform
▪ … supporting miners for having
  “no operational surprise”
  "opportunity to prepare against unexpected"
  “early indication for counteractions"
Many Thanks for Your Attention!

Questions

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