ECO-EFFICIENCY IN MINING INDUSTRY

COMMINUTION FOCUS (CRUSHING CONTRIBUTION)

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CHALLENGES IN MINING INDUSTRY

- Innovation
- Ore complexity, decreasing grade, plus energy and water
- Productivity improvement
- Infrastructure access
- Capital dilemma
- Balancing talent requirements
- Resource nationalism
- Sharing the benefits
- Price and currency volatility
- Cybersecurity
TOWARDS ECO-EFFICIENCY

Eco-Efficiency, what does it mean?

- **WBCSD (World Business Council for Sustainable Development) introduced Eco-Efficiency in 1992**
- **It brings the essential ingredients economic and environmental progress, necessary for economic prosperity to increase with more efficient use of resources and lower emission:**

  Product or services
  Environmental influence

In general term it is aimed to:

- Reduce material intensity
- Reduce energy intensity
- Reduce dispersion of toxic substances
- Enhance recyclability
- Maximize use of renewables
- Extended product life
- Increased Service intensity

MINING INDUSTRY - ENERGY

Why Energy?

- World’s Energy Consumption is about $105 \times 10^{12}$ kWh (IEA, BP, 2016)

  - Energy consumption in Mining Industry: 6-7% of total world’s energy: ($\sim 6.8 \times 10^{12}$ kWh)
  - Commination counts for 2-3%: (i.e., $\sim 2 \times 10^{12}$ kWh)
ECO-EFFICIENCY: WHY COMMINUTION?

- Comminution energy efficiency is low, in particular in grinding, however, crushers are much more energy efficient than tumbling mills.
- Embodied energy in media production in milling (6-7 MWh/t - 0.5-1 kg/t of media consumption).
- Adding transportation energy and related cost (e.g., Cerro Verde - 31MW installed for conveying).
- Water consumption and pollution (future big future challenge):

\[ \text{Water Consumption (m}^3/\text{t)} = 167.7 \times G^{-0.9039} \]

Consequently, It is logic to push Comminution towards crushing as far as practically possible.

EFFICIENCY IN MINING & COMMINUTION

- Sandvik Mining & Rock Technology (SMRT) – Activities in a glance.

Crushing: 50% & Milling: 1%
ECO-EFFICIENT COMMINUTION

- Comprehensive Perspective:
  - Characterize and optimize feed size and choosing the best comminution circuit accordingly
  - Energy for liberation and how to improve it (optimize product size, improve/optimize the methods, liberation at coarser size/grain)
  - Waste removal as early as possible (e.g., coarse size screening and sorting)
  - More efficient equipment (development and innovation)
  - Upgrading the feed to the mill (pre-concentration/grade engineering)
  - Measurements and monitoring different process steps from mining till end of processing through effective and fast ways of measurements and evaluations
  - Digitalization (data collection, data storage and processing) to serve customers for improving plant performance
  - Introducing wear resistance materials to improve productivity

RDI STRATEGY

MORE SCIENCE – LESS TRIAL AND ERROR

- From Trial and Error to Knowledge Driven
  - Developing and manufacturing more efficient machines and solutions for crushing
  - Modeling and Simulation
  - Measuring and data analytics
  - Scaled experiments and quick verification cycles
  - New tools and methods
ECO-EFFICIENT COMMINUTION

- Introducing Prime Crushers (higher energy/force to crushing chamber, e.g., CH860 & CH865)
- Different Crushing Chambers for Quality and/or Quantity improvements (both crushing chamber design and material chosen)
- Wear improvement by choosing wear resistant materials in accordance with application (mineralogy based crushing chamber and screening panel choice)
- Smarter Control System (e.g., ASRi / SanRemo)
  - By having automatic control to adjust the crushers about 2.5% to 4% increasing in production for each crusher within two shifts can be expected
- Smart Data Collection and Digitization to Improve Productivity

IMPROVE EFFICIENCY - SANREMO

CERTAINTY IS THE KEY: SANREMO GIVES YOU THE CERTAINTY OF CONTROL

- CONTROL OF MACHINE CONDITIONS
- CONTROL OF PARAMETERS
- CONTROL OF DATA

Good Automation Control of Crusher enables in Reducing Down-Time and Increasing Productivity (2.5-4%)
AUTOMATION

HISTORY

1961  "Harry up"  "SanRemo"  "Sandvik Service"
1967  ASR1  ASR2  ASRC
1978  ASRPlus
1987  ASR1
1992  ASR2.0
2003  SRC-Cones
2007
2017

Marching through technology
> 5000 systems sold around the world!!!

AUTOMATION WEB INTERFACE

SANREMO

SanRemo Service views

Operation & service data

Customer control

Sandvik Service
CRUSHING CHAMBER SOLUTIONS

Flexifeed

✓ Sandvik has a unique innovative solution to avoid:
  - Problems with occasional stones with top size exceeding the intake crushing chamber
  - Unfavorable wear in the lower part of chamber and liner with lifetime shorter than expected

✓ Flexifeed feature:
  - Flexifeed’s intake is smaller in certain parts of the upper mantle circumference which results in a larger fraction of the feed is crushed earlier in the chamber

✓ Benefits:
  - Extended liner lifetime measured as ton of products/liner by a better utilization of the liner, i.e. a more even wear (+20% in all cases)
  - Increased reduction by around 5%
  - Maintained production levels throughout the mantle’s lifetime

CRUSHING CHAMBER SOLUTIONS

Optiagg

✓ Delivers predictable and measurable improvements according to desired output.
  - Reduce in fines production or Increase reduction

✓ Optiagg is all the hardware and accessories you need for a complete crushing chamber upgrade including
  - Including our brand new, high-efficiency mantle design
  - Plus a real computer modeling and analysis to improve productivity

✓ Optiagg Procedure: is all the hardware and accessories you need for a complete crushing chamber upgrade including
  - Sample current crushing product
  - Enter results into software
  - Optimize crushing chamber selection and improve process
  - Install hardware and fine-tune setup
  - Verify output result
A COMPLETE PACKAGE

• The smart upgrade for Sandvik’s crushing chambers

FINE CRUSHING – POTENTIAL SAVING

➢ Conservation in operation cost by improving feed size in mill (gold ore @2.7Mt/y)
➢ Or increasing mill throughput in accordance with the total installed power

✓ Gold grade @ 1.6 ppm, recovery of R=90%, Ore competency @ Wb=18 kWh/t and A_i=0.6
✓ Gold price @ 1240 US$/oz, Production cost @ 750 US$/oz

<table>
<thead>
<tr>
<th>Feed size (mm)</th>
<th>$E_{total}$ (kWh/t)</th>
<th>Energy reduction from base case</th>
<th>Media (kg/t)</th>
<th>Liner (kg/t)</th>
<th>Operation cost saving (MUS$)</th>
<th>Gaining by increase throughput MUS$</th>
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<tr>
<td>15</td>
<td>20.97</td>
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<td>1.45</td>
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</tr>
</tbody>
</table>

➢ Note: steel media @1500 US$/t, liner @1200 US$/t, energy @ 0.1 US$/kW-h
CONCLUSION

We believe that energy conservation up to 20% can be achieved by available technologies. Sandvik design and develop crushers, as well as wear materials, soft-wears and instrumentation to control and improve comminution:

- **Instrumentation, Measurements, Control and Process Optimization**
- **Classification and Size Control (efficient screening is paramount important)**
- **Energy Efficient Comminution (towards effective fine crushing/comminution)**
- **Materials Engineering and development for crushers (towards choice of material by application in corporation mineralogy and ore competency)**
- **Expert Team(s) to service and offer and develop flow-sheets, solution, and consultancy to the Mining Industry**

EFFICIENCY IN MINING & COMMINUTION

**Sandvik Mining & Rock Technology (SMRT)**

*Comprehensive Perspective for Mining and Processing to improve efficiency*
CONCLUSION - FUTURE STRATEGY

- **Sandvik Mining & Rock Technology (SMRT) –**
  - Being innovative in providing solutions by considering mining and process as one scenario
  - Developing energy efficient and reliable machines equipped with sophisticated soft-wears for measurements, control and process optimization (bridge the gap in comminution)
  - Data collections and digitalization towards complete automation and strategies in optimal use of the information (cybersecurity, easy to access and improving personnel knowledge)
  - Materials engineering and development in order to track product performance through its life cycle (life cycle management for productivity)
  - Building expertise at different levels for design, manufacturing, training, educating, and consultancy – Having competent talents for future development and skill storage

CONCLUSION - OBSTACLES

- Sustainability in Mining is a paradox, we need to be smart and innovative
- Cycle times between knowledge generation and implementation are often long
- Scaling up the new developed technologies is rather difficult
- It is difficult to justify changes and incorporate the new technologies in practices (more fundamental the change the longer is the time for implementation)
- Mining Industry is knowledge-based with a short term focus on staying viable, but with long timeframes for implementation of new technologies (e.g., 10-15 years)
- Investment in R&D (more than current rate of about 1% for major companies)
- Fluctuations in global economy influencing long term vision and investment
- R&D infrastructure (change needs to embrace a greater part of external research)