Monitoring of Mineral Processing to Improve Productivity

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INTELLIGENT MINING AND RESOURCE MANAGEMENT / MINERAL RESOURCES FLAGSHIP

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Introduction

• (MultiFactor) Productivity – output produced per unit of combined inputs of labour and capital

• What is the problem with productivity in mining and mineral processing?

- Highly capital intensive plant
- Long investment lead times
- Resource depletion
- Increasingly complex processes
- Economies of scale + metal price variations → high operating efficiency required for profitability / return cost investment

- Investment → Production
• Australian mining multifactor productivity (MFP) has declined by ~30-40% in last decade

![Index 1989-90 = 100](image)

- Mining industry MFP -4.9% 2012-13 (ABS, 2013 / PC Update, 2014)
- Labour productivity +2.2% this year (PC Update, 2014)
• Confluence of issues –
  ▪ Deposits more expensive / difficult to mine
  ▪ Lower grade / finer-grained ores
  ▪ Penalty elements

Average Ore Grades Over Time

Over last 30 years –
  ▪ Average ore grade halved
  ▪ Average overburden waste doubled

(CRC Ore)
Resource boom led to rising demand & lagging supply -

In 10 years till 2011 -

- ‘Value’ ↑ 250%
- ‘Volume’ ↑ 23%

(ABS, 2011)

• Post-boom stabilisation? → Slowdown in mining investment
  Falling commodity prices
• **Increasing running costs (energy + water)**

Energy intensity and cost of production as ore grade

60% rise in energy consumption in last 10 years

(ABARES, 2011)

• Comminution is an energy-intensive process (~40% mineral processing energy, ~4% world electricity)!

• Increasing environmental and social expectation considerations
Industry Response

• Cancellation of some new projects
• Changes in design of existing projects
• ‘Care and maintenance’ mode
• Focus on efficiency not just production

Innovation and technology

• Requires settings for a highly skilled workforce with focus on R&D including transfer to industry
The Mechanics of Increasing Mining & Processing Efficiency?

- Increase metal content of mined ore
- Decrease energy consumption (mining & processing)
- Decrease water consumption (processing)
- Higher efficiency new processes and plants
- Higher efficiency existing processes and plants
• What are some possible solutions?

A) *Step changes in mining practices & processing technologies*

- Open-cut + automation (Topp Report, 2008)
- In-situ processing
- New comminution processes (eg fine grinding)
- New separation processes
- New hydrometallurgical processes
- New pyrometallurgical processes
B) Doing more with what you already have - change of management practices

- Selective mining & ore sorting
- Process / flowsheet monitoring
- Process / flowsheet control
- Process / flowsheet optimisation
The Role of Process Monitoring and Automation in Industrial Systems

• Fault detection and diagnosis
• Improved process safety
• Increased plant availability
• More efficient resource usage (ore + energy + water)
• ‘Driving’ industries – chemical, oil, gas & biotechnology

Est. US$ 20 billion pa losses in US petrochemical industry due to abnormal process conditions (Jamsa-Jounela, 2007).
Process Automation Components

- **Process Drivers**
- **Sensing Technologies**
- **Communication**
- **Data → Information**
- **Control & Optimisation Technologies**

Human Factors
Monitoring, Control and Optimisation for Mineral Processing Plants

- Features of operation of mineral processing plants –
  - Often strongly disturbed processes (highly variable feed characteristics)
  - Complex processes poorly modelled / understood
  - Process state difficult to measure
  - Process difficult to control / optimise
  - Complex, strongly interlinked processes
Mineral Processing Flowsheet

Run-of-mine ore → Crushing → Grinding and Size Classification → Liberated Minerals

Separation Processes:
- Flotation
- Leaching
- Magnetic
- Gravity

Regrinding

Rejects → Concentrate

Metals

Electrometallurgy
Pyrometallurgy
Solvent Extraction...
“Before I begin, one of the acronyms I’m going to use is completely made up. See if you can figure out which one.”
Value of Monitoring, Control & Optimisation

- Higher throughput
- Reduced operating cost
- Lower product variability
- Quick ROI

- Higher recovery
- Higher metal grade
- ‘Modest’ capital investment

(Thwaites – XPS, 2007)
Facilitating Technologies

- **New monitoring technologies** (nuclear, X-ray, γ-ray, MR, optical, acoustic, ultrasonic, MW, electrical impedance, *soft sensors*)
- **Better communications** (Fieldbus systems, wireless networks)
- **Improved signal and image processing & interpretation methods**
- **Improved process modelling methods** (first principles, phenomenological, statistical, AI, fuzzy logic, *hybrid*, Expert Systems)
- **Improved computing speed, storage & portability** (*Big Data*)
- **Improved control** (PID, MPC, SPC) & **optimisation** methods
CSIRO Intelligent Mining and Online Analysis

We are a Science Driven Technology Innovation Group

28 staff (4 teams)

Core business

- Development of on-line measurement technologies (elemental, mineralogical, physical)
- World leader in development of on-line analysis systems
- 30 year record of analyzer commercialization
Development Path

• Our industry advisors/clients provide **focus for potential impact**
• **Industry demonstration projects** demonstrate client and commercial value and leverage the technology development
• Strong **METS partnerships** are critical in achieving **impact**
Monitoring Options for Process Flowsheets

- Monitoring Options:
  - Acoustics
  - Ultrasonics
  - X-ray diffraction
  - X-ray fluorescence
  - Microwave res.
  - Nuclear
  - MR
  - LIBS
  - PGNAA

- Process Flow:
  - Mine/stockpile
  - Grinding
  - Crushing
  - Stockpile
  - Elution
  - Multi-stage concentration
  - Electrowinning
  - Smelting
  - Product
  - Tailings disposal + water recovery
Nuclear and X-ray Instruments

• Neutron/gamma methods – high-level analysis in bulk materials
  • Down-hole logging (PGNAA), open-cut monitoring, on-belt analysis
• Base-metals analysis using X-ray fluorescence (XRF)
  • High accuracy measurements in slurries
• Trace and ultra-trace XRF analysis
  • Measuring gold and platinum group metals at sub 1 g/ton levels
• On-stream mineralogy analysis with XRD
  • Real-time monitoring of mineral phases in slurries without sampling
• Rapid, chemistry-free gold analysis using gamma activation
  • Non-destructive, fire-assay replacement technology
Measurement on primary conveyors (continuous flow), installed close to mining process
Independent batches of rock measured (as low as 0.5 tonne)
Rely on deposit inhomogeneity at small scale to provide ore grade variability
Divert ore batches using conventional technology.
High Tonnage Ore Sorting

Potential Impacts –

Increase head grade (by ~25%) for same capital and operating intensity provides for the following impacts:

• More metal production for the same cost
• Increased reserves, in-situ and stockpile
• Extension of mine life
• Reduction in plant capital (new plant)
• Lower energy and water usage
• Transforming marginal mining towards sustainability

“When, either through ignorance or carelessness, the miners while excavating have mixed the ore with earth or broken rock...it should be examined, and that part of the ore which is rich in metal sorted from that part of it which is devoid of metal”.

Agricola, De Re Metallica 1556

Est. $1B in value over the life of a large copper mine
CSIRO Acoustic Emission Analyser

• Passive Acoustic Emission (AE) monitoring system – ‘electronic ear’

• Purpose:

  Processing device performance and condition monitoring

• Applications:

  **Comminution** – stirred mills, crushers, grinding mills

  **Separation** – flotation cells, dense medium cyclones, hydrocyclones, electrowinning

  **Materials transfer** - pipes in plant, slurry, oil and gas pipelines
IsaMill™ Stirred Grinding Mill (Xstrata Technology)

AE sensor housing

Stirring discs
AE influenced by

- Grinding media loading
- Particle size, particle sg, solid fraction
- Volumetric flow rate
- Ore type
- Mill wear
Key Indicators of Process Performance

Grinding Media Relative Load (Commercial system)

Particle Size Indicators (Module under development)

M10000 IsaMill™ results (Jackson et al., 2014)

SAG mill feed & charge results (Spencer et al., 2006)
Conclusion

- Mining + mineral processing → highly complex systems

- Monitoring + control + optimisation → INCREASED PRODUCTIVITY

- Systems approach + deep process knowledge

- Stable development pipeline:
  - Targettled R&D → engineering → plant implementation

- Innovation, technology and a highly skilled workforce are key requirements
"It's an open and shut case... He drowned in acronyms."
Thank you

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