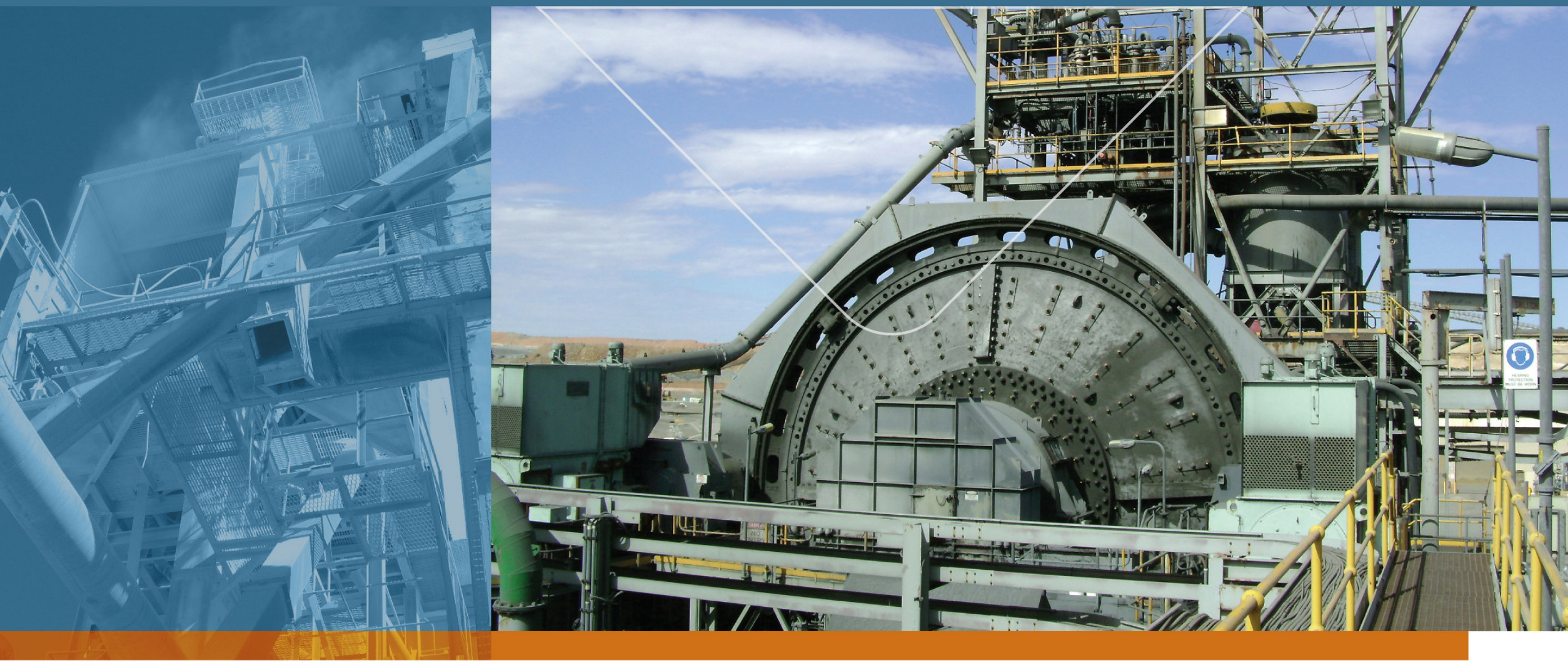
COMMINUTION CIRCUIT OPTIMISATION

Maximising Cash Flow for the Existing Asset

OMC
orway mineral consultants



WHITE PAPER

Introduction

Orway Mineral Consultants (OMC) is a Perth and Toronto based metallurgical consultancy established in 1983, with a reputation for the delivery of high quality studies and practical engineered solutions in the areas of comminution, beneficiation and hydrometallurgy. OMC optimise and audit comminution circuits worldwide with involvement in over three thousand (3,000) different projects including four hundred (400) surveys across more than one hundred (100) separate optimisation projects.

Optimisation is a critical process for maximising the profitability of all metallurgical facilities within the constraints of the project. As Figure 1 shows, comminution is generally the most power intensive process and generally consumes in excess of 50% of total site power. In the US mining industry, 40% of all energy consumption is estimated to be attributed to grinding, inclusive of mining (drilling, blasting, hauling) and processing [1]. Grinding power alone can account for around 20% of direct operating costs in a typical gold plant, inclusive of salaries, wages, fuel, reagents, wear parts, and maintenance [2]. These percentages can be higher for ore types requiring high power input during comminution.

The impact of comminution on project economics is also increasing with the observed quantum shift in the minerals industry to low grade disseminated ore reserves. OMC work closely with their clients to set optimisation goals; not only tonnage and grind size but improved project economics and or cash flow. The priority of these two aspects is not always the same and this difference is often not well understood by operators focussed on the process plant. Although optimisation is project specific, cash flow for the existing asset is typically targeted first, particularly in tough financial times, and project economics are targeted second, as the latter is often more capital intensive. Optimising the throughput of the grinding circuit can have economic benefits well beyond the processing plant allowing optimisation of key project features such as cut off grade in mining which significantly alters project economics.

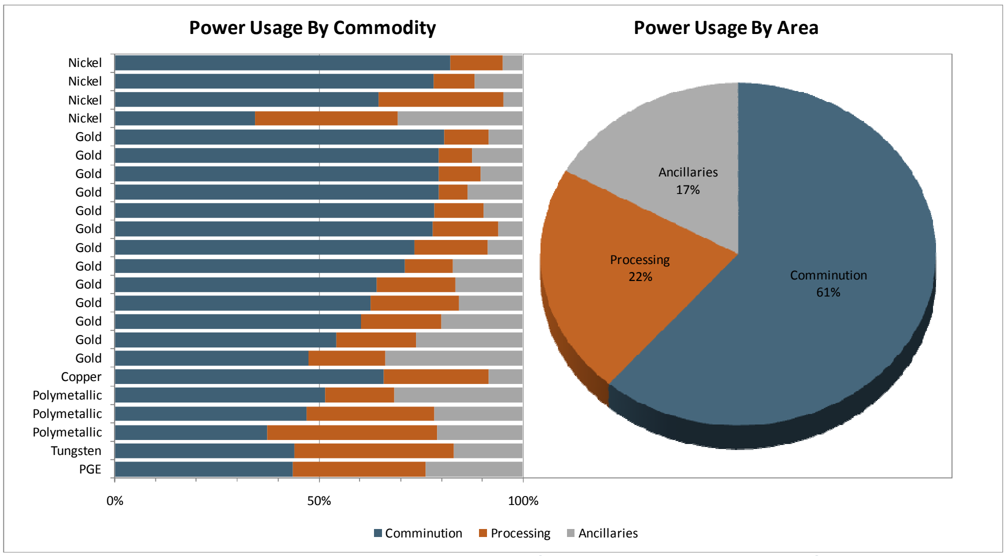


Figure 1 - Power Usage Based on Commodity and Area, Global

Optimisation typically involves three principal criteria; a knowledge of the process, a methodology by which to apply this knowledge to the objective of optimisation, and a baseline by which to judge the outcome of optimisation studies. This paper will discuss the methodology which OMC has developed with proven examples of successes in industry.

Methodology

It is OMC's view that optimisation is a continuous process that is most successful when there is a healthy ongoing relationship between the operations team, corporate team and the consultant. OMC prides itself on the strong operations and engineering background of its personnel, and with the aid of modelling tools developed over 30 years, aim to provide options that can be implemented successfully. OMC typically follow a structured approach to optimisation which can be tailored to suit individual project requirements:

- Analyse production data and compare with the theoretical performance for the current equipment and configuration.
- Based on the analysis and site observations, recommend changes to the operating parameters and/or philosophy if applicable. The optimisation strategy is determined at this point, but to quantify the likely benefit of certain changes, a detailed circuit survey is generally recommended.
- If the circuit is adequately stable with regards to throughput and product size whilst treating ore expected to be treated in the medium to long term, a circuit survey may be conducted. The survey conditions are benchmarked against the historical operating data to ensure the conditions are sensible. Once the survey data is mass balanced and model fitted, simulations can be run to quantify the effect specific changes will have on the circuit.
- Training of site personnel is a useful consequence of the optimisation process. This training is often undertaken informally as part of the process however OMC also has formal training packages. These focus on the needs of frontline managers (metallurgists & supervisors) and operators.
- Ongoing support can be provided with OMC's Remote Grinding Support (RGS) service. This entails an automatic transfer of data on key operating parameters to OMC, who then analyse the data and provide the site with a "Dashboard" report which includes recommendations for ongoing optimisation.

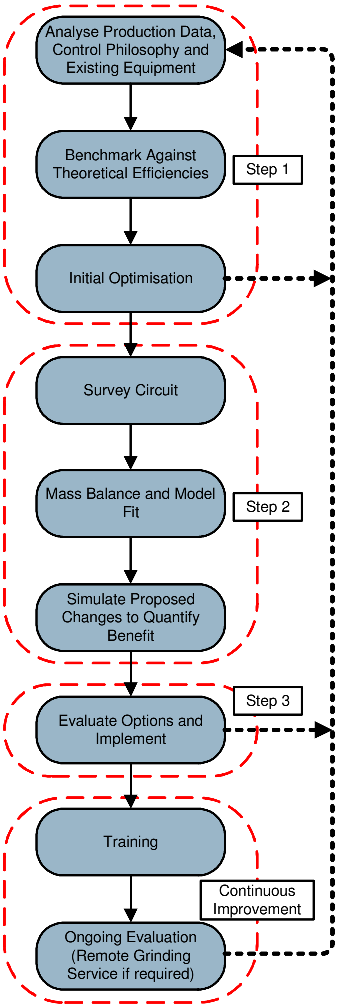


Figure 2 - OMC's Optimisation Approach

Case Studies and Examples

Even slight modifications can sometimes lead to substantial increases in throughput and/or efficiency. In some cases, improvements can be achieved simply by changing the equipment operating philosophy or improving control strategies. More substantial changes such as grate and lifter design modification, pump upgrades, or the addition of a secondary crushing circuit may necessitate higher capital expenditures. In these cases it is generally recommended that the changes are simulated in order to quantify the potential benefits and rank options according to their merit. Table 1 provides some examples of optimisation projects undertaken by OMC.

Table 1 - OMC Optimisation Project Examples

Project	Circuit Modifications	Improvement	Ref.
Henty (2003)	Change SAG mill ball size. Increased cyclone diameter. Increase SAG grate open area.	44% increase in throughput.	
Kambalda (2007)	Grate design modification. Changes to Control and operating Philosophy.	15% increase in throughput.	[3]
Leinster (2006)	Steel addition to AG mill.	10% increase in throughput.	
Mt Rawdon (2003)	Addition of a secondary crushing circuit.	48% increase in throughput. 14% increase in power efficiency.	[4]
Pillara (2000)	Change SAG mill ball size. Increase ball charge levels.	15% increase in throughput. 22% decrease in product size. 3% increased in power efficiency.	
Boroo (2008)	New cyclone cluster. Upgrade pumps. Gravity circuit modifications.	8.8% increase in throughput. 9.5% increase in power efficiency. Increased circuit recovery.	[5]
Sepon Gold (2005)	Grate design modification. Decreased SAG mill ball diameter. Changes to Control and operating philosophy.	24% increase in throughput.	
Varvarinskoye (2008)	Changes to crushing and stockpile management. Cyclone reconfiguration. Control philosophy and System implementation.	Ramped up production from a 250 tph base to 450 tph in a 6 month period.	[6]
Geita (2010)	Changes to control and operating philosophy. Modifications to crushing circuit and cyclones.	Greatly increased circuit stability allowing throughput to be maintained on harder ore types.	[7]

Two case studies have been selected to demonstrate the opportunities and potential benefits of optimisation exercises. The first case study examines a partial secondary crush, SABC circuit and concentrates on improving circuit stability with a key focus on controlling crushing circuit product size and stabilising circulating load. The second case study examines a primary crush SAB circuit and focuses on maximising throughput and improving energy efficiency with minimal capital investment.

Case Study #1 – Improving Circuit Stability

OMC have been assisting an African gold mine in optimising the comminution circuit, with a focus on operations practices and plant utilisation. The original circuit configuration consisted of a primary crusher followed by a SAG mill with a pebble crusher and a ball mill (SABC). Design throughput could not be maintained due to the presence of magnetic minerals in the ore, rendering the pebble crusher inoperable. The operation pursued an expansion to a partial secondary crushing SABC circuit with the pebble crusher bypassed to overcome this issue. The expansion crushing circuit arrangement and selected equipment specifications are detailed in Figure 3.

The initial partial secondary crushing process route was adopted to minimise “critical size” material in the SAG mill feed. However the initial partial secondary crushing circuit did not operate effectively as a result of blinding of the vibrating grizzly and the secondary crushers were producing critical size material that was not conducive to SAG milling with 80% passing sizes (P_{80}) between 50 and 90mm.

A crushing plant survey (undertaken by OMC in 2010) was analysed and used as the basis for optimisation modelling. Comparison of the surveyed plant capacities and the recorded plant P_{80} with predicted plant capacities using crushing plant models indicated that a target P_{80} of around 30mm should have been achievable with the installed equipment. The plant was however not achieving this result and target throughput levels could only be maintained by including high proportions of soft material in the feed blend. A phased approach was eventually taken to upgrade the crushing circuit.

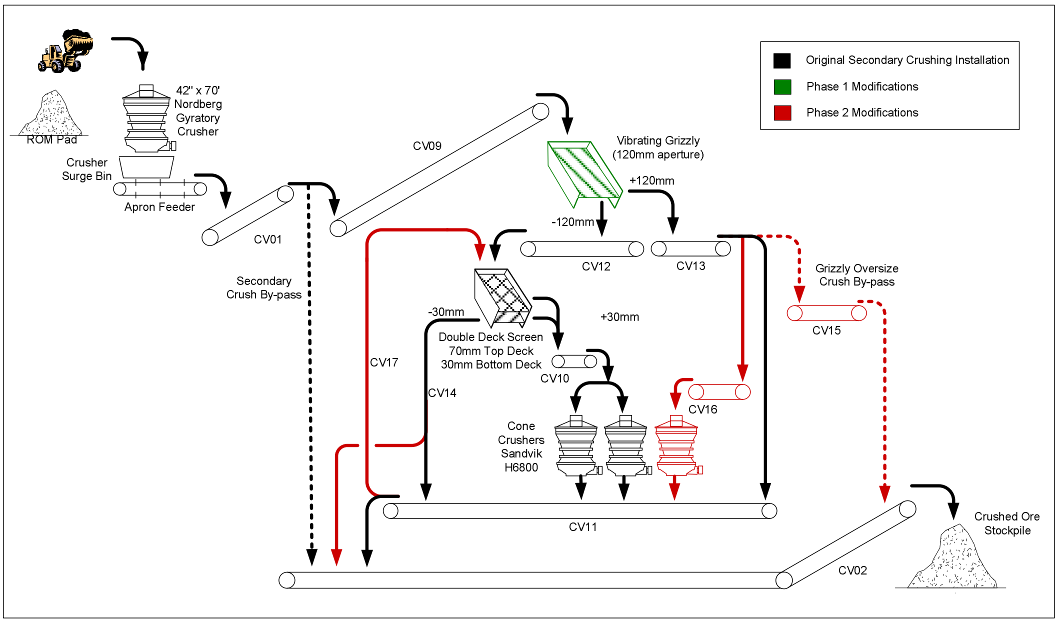


Figure 3 - Partial Secondary Crushing Circuit with Phase 1 and 2 Modification Details

The first phase was to replace the vibrating grizzly with a more efficient unit to reduce the blinding of the deck. This was required to effectively scalp the oversize from the secondary crusher feed to achieve a more consistent and finer secondary crusher product size. The installation was completed by the middle of 2011. The second phase was to install the new crusher and the ability to control the amount of oversize retained for grinding media.

The positive effect of phase 1 on the circuit is best shown by the improved secondary crusher product size. Secondary crusher product data is shown in Figure 4 with the grizzly installation date shown with the green line.

In addition, the grinding circuit suffered from extremely high circulating loads of 800% or greater often recorded. As a result, the ball mill power draw (which should typically operate at a more or less constant power draw), was fluctuating considerably and grinding media was being consumed much more rapidly than under normal circumstances. It was believed that the reason for the observed power fluctuations was due to high volumetric flows through the ball mill, increasing the scatting rate of fine grinding media. Pump impellor change outs were also exceedingly frequent and pump power consumption was high as the pump needed to operate near maximum speed at all times.

A number of changes were implemented to address these issues. The cyclone control loops were changed so that the mill discharge pump speed was altered to maintain fixed cyclone pressure and the mill discharge dilution water addition was varied to maintain a constant sump level. The cyclone operating pressure was reduced (by slowing down the mill discharge pump (MDP), not by opening more cyclones) to achieve a cyclone U/F density of 1.9 – 2.1 SG (72 – 80% solids). This reduced the number of cyclones on line to target a lower circulating load. Furthermore, the fuzzy logic control loops in the classification circuit were tuned and regular manual density sampling was introduced.

It can be seen from the green line in Figure 5 that once these changes were implemented, the circulating load was significantly reduced, the ball mill was able to maintain a constant power draw and pump impellor life increased significantly.

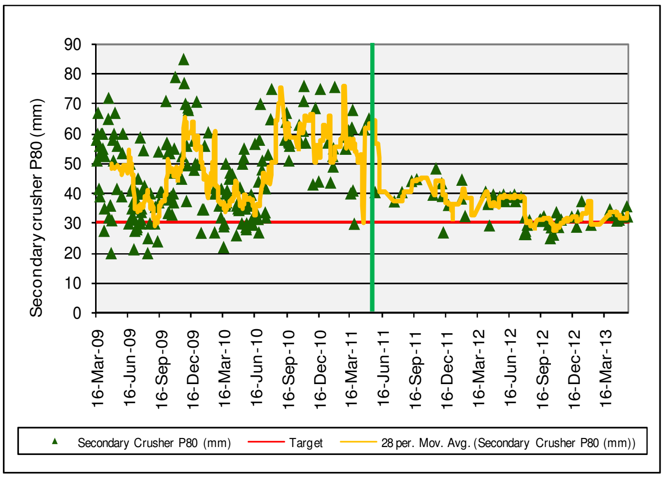


Figure 4 - Secondary Crusher Product Size

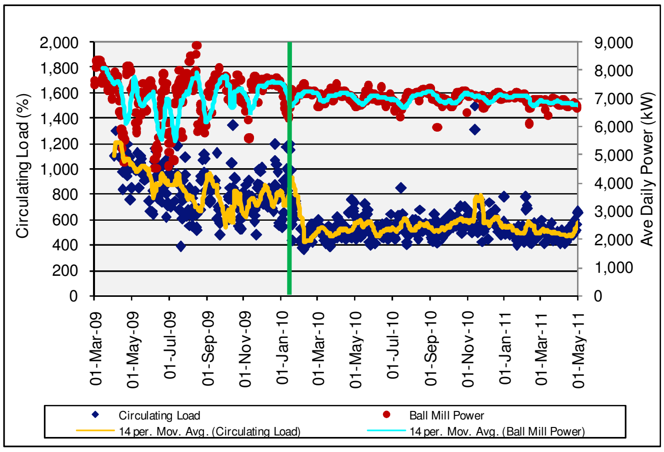


Figure 5 - Circulating Load and Ball Mill Power Draw

Case Study #2 – Improving Circuit Throughput

OMC provided assistance to a nickel sulphide mine in Brazil. The comminution circuit comprises of a primary crushing circuit (Gyratory and Jaw), a live stockpile, a SAG mill operating in open circuit, and two ball mills operating in closed circuit with classification. The operation was experiencing very low recoveries and was in the process of modifying the flotation circuit to optimise the process. In the interim, OMC were requested to investigate strategies to increase throughput to compensate for the low recoveries.

It was observed on site that the SAG mill was being operated at a low ball charge and high rock load. Under these conditions, the SAG mill was drawing an average of 6.6MW and was underutilised with regards to the installed power of 8.0MW.

During the site visit, the SAG mill power was incrementally increased from 6.4 MW by adding more grinding media to the SAG mill and gradually increasing the throughput until load in mill stabilised. The impact of this can be seen in Figure 6.

By increasing the ball charge, the SAG mill was able to operate at a lower total load. It is believed that this improved the breakage rate and resulted in more efficient “toe impact breakage”. It can be seen from Table 2 that based on the changes recommended by OMC, throughput increased by 11% and overall energy efficiency was improved by 6%.

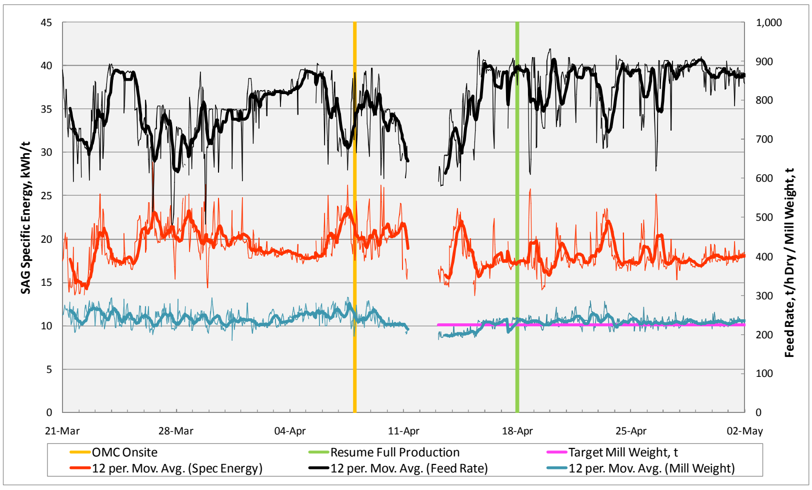


Figure 6 - SAG Mill Operating Data

Table 2 - Comminution Circuit Performance Comparison

	Mill Feed, t/h Dry	Mill Weight, t	SAG Mill Pinion Power, kW	Total Ball Mill Pinion Power, kW	SAG Spec Energy, kWh/t	Ball Mill Spec Energy, kWh/t	Total Spec Energy, kWh/t
Average (Before)	768	242	6,110	8,537	8.0	11.1	19.2
Average (After)	850	233	6,371	8,894	7.5	10.5	18.1
Variation	82	-9	261	357	-0.5	-0.6	-1.1
Variation, %	**10.7**	**-3.6**	**4.3**	**4.2**	**-6.2**	**-5.8**	**-5.9**

Conclusion

It has been shown that the comminution process accounts for a large portion of operating costs and is the main consumer of energy for most mining and mineral processing operations. In addition to this the throughput of the comminution circuit is a major driver for overall project economics and cash flow generation. Optimisation projects associated with the comminution circuit are consequently essential for improving the overall profitability of mining operations. To harness this potential, a systematic approach and methodology is required. As shown in the OMC optimisation project examples, throughput benefits in the order of 10% to 40% and energy savings of up to 10% can be achieved, often with minimal capital outlay.

In a world of increasing energy costs and the treatment of harder, lower grade ores, the need to optimise grinding circuit performance and maximise project economics has never been greater. Given these needs, OMC with 30 years experience in the optimisation of projects across the globe is best placed to help.

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Further Reading

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