STUDY APPROACHES

Mintrex has been intimately involved with various studies (from scoping to feasibility studies) over the last few years. Some of the feasibility studies we are and were involved in required some new thinking and innovation in the process design due to the nature of the ore body and material being treated. This document is a summary of some examples of the new and innovative ways Mintrex approaches feasibility studies and designs for these more complex ore bodies.

Optimal Comminution Circuits

Two of our major feasibility study clients, West African Resources (WAF), Sanbrado Project and Gascoyne Resources (GCY) Dalgaranga Project treated ore bodies with similar comminution challenges (hardness and variability) and the approach we took in developing a comminution circuit for both feasibility studies is depicted below.

Single-stage comminution SAG mill circuits are becoming increasing popular within ore processing[i]. A key limitation to the wider adoption of single-stage circuits is the efficiency loss experienced when ore variability exists[ii], i.e. single-stage crushing SAG circuits are conventionally designed for ore of low competency. Historically single-stage milling circuits have been notoriously difficult for many reasons, with issues mainly stemming from a lack of understanding of ore's complex inter-relationships between abrasion and impact breakage. Typically more complex milling circuits have been selected to overcome issues associated with ore variability. The development of a single-stage SAG mill circuit that can treat highly variable ore, i.e. variability in hardness or oxidation state, represents a step jump in ore processing.

Mintrex Pty Ltd (Mintrex) undertook work to determine the optimal comminution circuits for the Sanbrado (Burkina Faso, West Africa) and Dalgaranga (WA, Australia) projects mentioned above. The main aim of each project was to:

1. Develop a simple comminution circuit that can effectively mill both hard and soft low gold grade ore. – Gascoyne Resources' Dalgaranga Project;

2. Develop a simple comminution circuit that can effectively mill ore from four metallurgical domains of varying degrees of oxidisation: Strongly Oxidised (SoX), Moderately Oxidised (MoX), Weakly Oxidised (WoX) and freshly mined ore (non-oxidised) from average to low gold grade ore – West African Resources' Sanbrado Project.

The overall objective of these studies was to design and develop a > 2 million tonnes per annum (Mtpa) processing plant capable of treating gold ore (Au) with a low head grade of < 2 grams per tonne (g/t). The

mintrex
engineering your success

design sought to achieve a reliable, robust and efficient performance yielding a minimum gold recovery of > 90%. Critical to the success of this approach was the ability of the system to effectively mill both hard and soft ores at the design throughput. The idea was to see if a simple comminution circuit can effectively grind/treat low grade soft non-abrasive oxide ore and low grade hard fresh ore (more abrasive and tougher than oxide ore) to achieve consistent throughput at a consistent grind size to achieve consistent high gold recoveries.

The technical sub-objectives to achieve this include:

- Testing the viability of using a comminution circuit consisting of a single-stage crushing and milling circuit to accommodate both hard and soft ore without the need for multiple crushing circuits.
- Testing if such a single-stage crushing and milling circuit was implemented would it reduce power consumption (less crushing stages and implement SAG mill which uses less power) and reagent consumption (optimise grind sizes) without compromising gold recovery.
- To minimise expansion of the process plant footprint (clearing requirements); leveraging wherever possible discarded mine infrastructure and stockpiles for the new processing plant.
- If such a circuit could not be implemented, what were the constraints and what would be the next best comminution circuit option and why?

A review of Australian comminution circuits by Lane et. al. (2002) found that milling ore of variable competency at a throughput of 2 Mtpa or greater is conventionally achieved through the use of more intensive circuits such as SAG/Ball Mill/Crusher (SABC). Lane et. al (2002) also established operability issues are commonly experienced with single-stage SAG circuits when milling ore of variable competencies. Consequently, single stage SAG milling circuits are generally selected for low throughput plants (usually less than 2 Mtpa) for ore with a low competency[iii]. The identification, therefore, of a low-grade ore body consisting of soft oxide material and harder fresh and transitional material, ensured that the development of a 2.5 Mtpa throughput single-stage SAG comminution circuit went beyond ‘business as usual’. The challenges of such a variable low-grade ore body are that the operating cost needs to be low and throughput needs to be consistent to make it work.

The proposed single-stage SAG comminution circuit was developed through an extensive systematic evaluation of recent and historical test work, production records and simulated process runs. The data from the test work contributed to validating the models and design criteria of the comminution circuit hypothesised. In conjunction with this work, resource and comminution circuit modelling, undertaken by independent consultants, fed into verifying the technical success of this study. A simple progression of works cannot determine if this project will be viable or not, because it was a combination of power cost, reagent costs, throughput, grind size and recoveries based on the technical decisions that will make such a project economically viable or not. It required thinking outside the box.

The material (oxide and fresh) can either be treated separately or as a blend. The variability of the ore competencies (hardnesses) were modelled in the proposed comminution circuit to determine if the optimised blend could achieve the design throughput (> 2 Mtpa); ensuring > 90% recoveries will be achieved at that specified grind size and operating cost (thus overcoming major variability in the ore). Then it had to be shown that it was possible to deliver that blend economically.

It was determined that the Dalgaranga ore showed variable ore characteristics ideal for the testing of an improved single-stage SAG mill circuit (SSAG) as it contained highly variable ore. The Dalgaranga project had both very hard and very soft ore. However, the Sanbrado project had ore from four distinct metallurgical domains of varying oxidation states and thus hardnesses. For Sanbrado it was decided the best option would be a SABC circuit (crushing, SAG, ball) as it will handle the variability in later years better than a SSAG circuit (even though the SSAG could manage the ore variability). For both projects, ore variability was a known limitation that would typically render a single-stage milling circuit ineffective. The success of the approach may see the wider adoption of single stage SAG milling into mine sites known to have highly variable ore domains.

Processing Circuits

Two of our major feasibility study clients, Emerald Resources' Okvau Project and Explaurum's Tampia Project treated ore bodies with similar processing challenges (refractory sulphatic ores) and the approach we took in developing a processing circuit for both feasibility studies are depicted below.

Mintrex Pty Ltd (Mintrex) undertook work to determine the optimal comminution circuits for the two projects mentioned above, the Okvau (Cambodia) and the Tampia (WA, Australia) projects. The main aim for each project was to develop a simple, integrated CIL circuit to effectively treat flotation concentrate and flotation tails, with an overall nominal residence time of less than 40 hours and which can extract gold from both the concentrate and flotation tails to recover > 90% gold.

Gold ores are usually categorised into two types – free milling and refractory. Free milling ores are easily processed via gravity techniques and/or direct cyanidation. The liberation of gold from refractory gold ores (where gold is either locked or slow leaching due to its mineralogy) typically includes some pre-processing treatment, such as flotation, ultra-fine grinding, gravity concentration, etc. Currently, standard processes treat flotation concentrate and flotation tails in two separate circuits rather than simultaneously. Thus, after flotation the treated concentrate and tails report to separate cyanidation process streams, so the concentrate and tailings streams are individually processed to extract the gold.

The overall objective of this project was to design an integrated cyanidation process capable of simultaneously extracting gold from both the concentrate and tail streams of a flotation circuit. Conventionally, gold found within aboth the flotation tails and concentrate are extracted by individual cyanidation processes.

There are very limited similar or closely related CIL configurations and field data and design information on these is not available in the public domain, so Mintrex had to conduct research and development work to determine whether an integrated CIL could be developed and if it could be economically feasible with regards to reagent consumptions, capital costs and operating costs

The proposed integrated circuit was developed through an extensive systematic evaluation of recent test work and simulated process runs. The data from the test work contributed to validating the models and design criteria of the integrated circuit hypothesised. In conjunction with this work, modelling (undertaken by independent consultants) also fed into verifying the technical success of this project. A simple progression of works could not determine project viability, because it was a combination of reagent costs, residence time, throughput, grind size and recoveries based on the technical decisions made, that makes the project economically viable or not.

In conclusion, Mintrex was able to design a single integrated Carbon-in-Leach (CIL) process capable of simultaneously and economically extracting gold from both the concentrate and flotation tails streams for both projects. The designs were adapted slightly to incorporate differences in mineralogies, gold deportments and deleterious elements from these two projects.

---

[i] Powell, MS. and Bye, AR. (2009), Beyond mine-to-mill: Circuit Design for energy efficient resource utilization, Tenth Mill Operator's Conference AUSIMM

[ii] Putland B, Kock F & Siddal, L, **Date unknown**, Single Stage SAG/AG Milling Design, Orway Mineral Consultants
Accessed: https://orway.com.au/wp-content/uploads/2015/10/Single-STAGE-SAG-AG-MILLING-DESIGN.pdf

[iii] Lane GS, Reynolds K and La Brooy, S, 2002, Selection of Comminution Circuits for Improved Efficiency, Crushing and Grinding Conference Kalgoorlie
Accessed https://www.ausenco.com/download/10934