Secondary crushing: worth the cost?

Ausenco's experts discuss the viability of secondary crushing in SAG mill circuits and provide advice for mines considering such a set-up

Ausenco designed secondary and tertiary crushers for Newcrest's Cadia East mine

Over the past few decades, the size of mineral processing plants and equipment has increased to meet the growing global demand for resources. During recent boom times, mining companies have expanded old processing plants and built new high-throughput plants as quickly as possible.

However, as ore grades decrease and orebodies become harder and more competent, the strain on plant throughput and energy efficiency increases. This affects the selection of comminution equipment, and plant capital and operating costs.

In the past 60 years, the use of semi-autogenous grinding (SAG) mills has developed from the original concept of autogenous grinding (AG) mills. In the 1950s, AG milling was considered to offer the potential for lower operating costs than alternative solutions, better liberation characteristics and greater energy efficiency. The concept provided a much simpler flowsheet compared with stage-crush, rod and/or ball-mill circuits.

The concept was developed in two ways, as high-aspect 'pancake' mills in a two-stage AG and ball-mill circuit in North America, and as a single-stage run-of-mine (ROM) low-aspect mill in South Africa.

The addition of balls to the AG mill to form a SAG mill, and the use of pebble crushing, was introduced to enable management of the 'critical size' within the SAG mill, and improve operability and throughput.

In parallel, the South Africans developed methods to control the AG mill charge by managing feed-size distribution, and the Scandinavians developed a similar approach to two-stage AG milling that has culminated in some of the largest mills in the world being installed at Boliden's Aitik copper mine in northern Sweden.

Typical SAG mill ball charge has increased from around 3-8% in the early 1990s to 20% and above. This has occurred either because the ore was fine and soft, such as that found at PT Freeport's Grasberg copper-gold complex in Indonesia, or to optimise SAG mill throughput by maximising mill power draw when treating competent ore, such as at Antofagasta Mineral's Esperanza copper-gold mine in Chile.

However, this approach has its limitations in that the breakage within the mill is a function of the maximum energy imparted by collision with a large steel ball, and the lower the rock-to-ball ratio and the lower the mill load (required to maximise throughput), the more damage is done to the mill liners by ball-on-shell impacts.

AG milling is all about mill charge management to maximise throughput. AG mills do not benefit from a universally finer feed as coarse rock is required as media. Some mines have used coarse rock and fine feed (with the mid-size removed) in order to maximise throughput. As the ball load increases in SAG milling of competent rock, the use of finer ROM feed ore, finer primary and secondary crushing can substantially increase throughput.

SECONDARY CRUSHING RETURNS

Historical mining projects, such as Bronzewing , St Ives , Porgera and Granny Smith, Kidston and KCGM in Australia, Troilus in Canada and Geita in Africa, have implemented secondary (and in some cases tertiary) crushing to manage the critical size fraction inside an SAG mill and increase throughput.

More recently, Newcrest Mining's transition from processing ore from the Cadia open-pit mine to Cadia East underground ore resulted in Ausenco designing a retrofit of secondary and tertiary crushing high-pressure grinding rolls (HPGRs) at the Cadia concentrator to increase SAG mill throughput.

In recent years, many projects (eg Osiko's Malartic and Teck's Andacollo) have used a retrofit of secondary crushing ahead of SAG milling to optimise throughput after start-up and to de-bottleneck SAG mills when treating competent ore.

"Many projects have used secondary crushing ahead of SAG milling to optimise throughput and de-bottleneck SAG mills"

FLOWSHEET OPTIONS

Secondary crushing of competent ores in open circuit is the simplest approach. This is particularly applicable if the ore is fines-deficient, as many competent ores are. Open-circuit secondary crushing will yield SAG mill F80s as low as 25mm, but more typically 50-60mm.

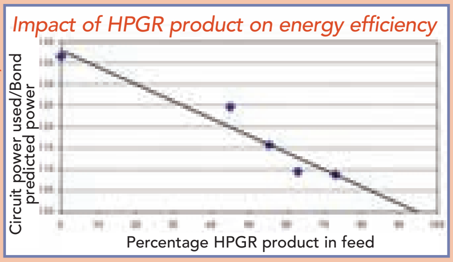
Control of the feed to any cone crusher is important for optimal operation. Poorly presented feed is the most common issue with secondary crushing installations, and Ausenco would typically recommend some ►

When does secondary crushing make sense?

Secondary crushing makes most sense when the ore is extremely competent. Without secondary crushing, the SAG mill-based circuit tends to be energy-inefficient, with low throughput and a fine mill product. This is accompanied by large amounts of energy dissipation as heat.

Ausenco's rules of thumb for the addition of secondary crushing to an existing circuit are that:

- reducing the F80 (80% of the feed size) to the SAG mill by 10mm will result in a 3-6% increase in SAG mill throughput, with the magnitude depending on the ore characteristics and the mill operating conditions;
- reducing the F80 will also result in an improvement in overall comminution-circuit energy efficiency when treating competent ores. Bond calculations define the efficiency of a fine stage-crush ball mill circuit as 1.0 to 1.2 depending on ball mill feed size, and some SABC (SAG/ball mill/pebble crusher) circuits operating with an efficiency of 1.3-1.4 or higher on coarse feed. If the coarse feed size is reduced, the circuit efficiency will approach that of the stage-crush and ball mill circuit (see graph).



Source: Lane and Siddall, 2002

Hence, if the JKDropWeight test Axb parameters (a measure of rock competency) are less than about 40, then secondary crushing is worth considering.

Secondary or pre-crushing ahead of SAG milling is finding increasing acceptance, often as a de-bottlenecking device, either where SAG milling capacity is below design due to inadequate allowance for the behaviour of highly competent ores, or where a successful SAG milling application becomes constrained as the mining operation moves into deeper, more competent ores.

Retrofitting secondary crushing increases ball-mill energy needs. This is a key consideration, and other options such as adding a tertiary ball mill may be needed to maintain the final product's grind size.

type of surge capacity ahead of the crusher to allow good control of crusher feed.

The introduction of a screen to 'close circuit' the crusher complicates the flowsheet and increases maintenance, but will increase throughput.

Due to the difference in availability of the SAG mill and secondary crusher, the latter may be linked to the primary crusher and must then match availability at a higher throughput, or the secondary crusher can be in direct line with the SAG mill and bypassing the crusher is required when maintenance is conducted. This crusher outage will result in markedly reduced throughput (say 30%) that may justify the installation of a redundant crusher.

The Ridgeway Deeps development project at Cadia

The need to screen secondary crusher feed in open-circuit applications depends on the fines content of the primary crusher product, which is often a function of the competency of the ore. Highly competent ores produce fewer fines in the primary crusher product, and screening ahead of secondary crushing can often be avoided in these cases. In contrast, less competent ores generally produce products that are rich in fines, and screening is necessary to ensure the secondary crusher feed is properly prepared; excessive fines, particularly if the ore is moist, can cause packing in the crusher chamber leading to 'ring bounce' and ultimately mechanical damage of the crusher.

Manufacturers tend to use rules of thumb to de-rate crusher capacities for the treatment of highly competent ores that display high Bond crushing work indices (CWi). One such rule is the following: de-rate = (16/CWi)^0.5

However, care is required when using this rule as CWi test methods vary and simplistic approaches do not address all of the relevant issues.

Greenfield projects

Secondary crushing of SAG feed has been included from the outset in some projects, to reduce SAG energy use and mill size. However, there are disadvantages to this: the circuit is more complex than a standard SAG circuit; and the only major de-bottlenecking device applicable to SAG-based designs is no longer available if the mill is found to be too small, or if ore becomes more competent.

If secondary crushing is indicated from the outset to provide a viable design, it could be that SAG milling is not the most appropriate technology for the application, with stage-crushing, either conventional or HPGR-based, possibly more suitable. Nevertheless, secondary crushing of SAG feed can be a legitimate approach depending on the project.

Secondary crushing in greenfield applications, as at Detour Gold Corp's Detour Lake mine in Canada, can be driven by many factors, including ore competency, but can also be used as risk mitigation. For example, keeping the mill small enough to use geared drives might pay for the increased cost and complexity of secondary crushing.

Applying secondary crushing in a greenfield design cuts opportunities for future expansion and de-bottlenecking. In many cases, the best option is a SABC circuit with space left to add secondary crushing later. There is always a complex trade-off between capital cost and operating cost for the addition of secondary crushing, and each project should be examined in a trade-off study.

SUMMARY

Secondary crushing prior to SAG milling adds complexity and, in some regards, is a return to the stage-crush type approach. However, it does have valid applications with very competent ores, as do other technologies such as HPGR. In a greenfield context, a study is required to examine project-specific issues.