# SAG AND BALL MILL EFFECTS FROM ORE SORTING SYSTEM IMPLEMENTATION

*J. Starkey[1,2], B. Hilscher[1], S. Reeves[1], and J. Hedderson[1]

[1]Sacré-Davey Engineering
*212 - 151 Randall Street*
*Oakville, Canada L6J 1P5*
*Corresponding author: jstarkey@sacre-davey.com*

[2]Starkey & Associates Inc.
*212 - 151 Randall Street*
*Oakville, Canada L6J 1P5*

## ABSTRACT

As ore sorting becomes more common, it is important to quantify its impact on comminution circuits in order to precisely predict its effect on throughput, grind, and mill operating conditions. Since sulphides and other valuable minerals are often softer then the surrounding waste rock, the ore kept by a sorting system is typically softer than the average ore. In order to accurately forecast production, new measurements of hardness need to be performed on the new concentrated mill feed. This paper proposes a methodology to examine this effect quantitatively at an early stage of project development using the SAGDesign test.

## KEYWORDS

**Ore Sorting, SAGDesign, Comminution**

## INTRODUCTION

The application of ore sorting in the mining industry is one of the most promising recent technologies with the potential to cause step change in the way concentrators are designed. Most typically, ore sorters are used to sort a given ore flow for grade, either to reject waste from the mill feed, or rescue ore from the waste pile. Ore sorting technologies have been successfully applied at many mining properties in various forms and while the technology has reached or is reaching maturity in other industries, it is still in development in the mining sector. As a result, there is not yet a general consensus on the considerations that need to be made when designing a plant with ore sorting from a feasibility level above and beyond what is commonly performed as best practice.

This paper will discuss those considerations and propose a methodology for integrating ore sorting into a comminution circuit at the design phase. Due to the linearly additive nature of the SAGDesign Test results, a "hardness balance" can be developed to estimate the ore hardness which would be measured in any sorting mass split using only two data points. This will allow a design engineer to make more informed decisions as to the most appropriate mass split to select in relation to the incurred operating costs and grinding circuit sizing.

## THE BENEFIT AND CHALLENGE OF ORE SORTING IN COMMINUTION

Ore sorting can be a hugely advantageous process for specific ore types once the process has been demonstrated by laboratory testing but at the same time it introduces a significant complication when applied to projects without care. By design, ore sorting changes the fundamental composition of the feed to the grinding circuit by selectively picking or rejecting particles on the basis of grade, or a proxy measurement of grade. At the current level of technology, the ore sorter gives no internal consideration whatsoever to the recoverable value or geometallurgical performance of that particle in the decision. For example, a poorly applied ore sorter may accept a high grade particle that generates a negative profit due to high operating costs (e.g. a highly refractory ore type or a high penalty metal content) , while rejecting a lower grade profitable particle. By sorting for grade alone, there is a risk that we are simultaneously concentrating other undesirable qualities of the ore which must be confirmed prior to installation of a new unit. Alternately, there is a potential benefit to be realized if we can simultaneously concentrate both grade and other desirable properties. To this end, it is a future opportunity for design engineers to leverage their knowledge of the deposit gained through testing into ever more efficient selection and sorting of particles.

The potential problem of misapplied sorting is further exacerbated when ore sorting is treated as an "add-on" process after the completion of other fundamental testing wherein all of the process design criteria are established on the basis of un-sorted ore. In this case, the mill will be designed to process an ore which it will never actually receive in practice and will generally be significantly overdesigned for the required duty. This then sabotages one of the primary benefits of ore sorting to a design engineer, which is to reduce capital expense of a new plants by reducing the size of required equipment, particularly for "big ticket" capital items like the comminution circuit while also potentially invalidating the design criteria, requiring major rework.

The impact of adding ore sorting to a comminution flowsheet is very large, requiring a significant rework of all design elements. Most notably, ore sorters require a reasonably fine, well classified feed, in the order of 0.5" to 4" inches. This necessitates that the ore be crushed and pre-screened prior to sorting, which will already lead to a change in the design criteria for any downstream grinding equipment. Care also needs to be taken when fully or semi autogenous milling is considered to ensure that the selected equipment is capable of managing the pre-crushed and screened feed.

## A PROPOSED SOLUTION FOR ORE SORTING IN COMMINUTION DESIGN

In order to fully leverage the benefits of ore sorting in a comminution circuit, it is first necessary to gain an understanding of how ore hardness, which is not measurable by an ore sorter, concentrates with grade. To that end, this paper proposes the following methodology:

1. Select a representative sample of coarse rocks or drill core to be tested
2. Crush the sample to the desired size for a 200 rock ore sorting test, or 80% passing 19mm, whichever is larger, reserving any fines generated

3. Riffle split 15 kg from the coarse rocks and 15 kg of fines for SAGDesign testing (SAGDesign Tests 1 and 2)
4. Complete a SAGDesign test on the 15 kg sample, reserving the final products
5. Complete the 200 rock test on the remaining sample
6. From the sorted concentrate product, randomly select rocks for a total mass of 15 kg
7. Conduct a SAGDesign test on the third 15 kg sample (SAGDesign Test 3).
8. Complete assays by particle for the remaining ore sorting rocks, and size by size assays for the SAGDesign test products

Using this methodology, a design engineer can simultaneously receive measurements of the grade and ore hardness concentration achieved by the ore sorter. By virtue of the linearly additive blending characteristics of the SAGDesign test, the ore hardness of the remaining unmeasured ore sorter product can be calculated from a basic "hardness balance" as shown in Equation 1 below, i.e the hardness measured in the bulk SAGDesign is equal to the mass weighted hardnesses of the two sorted products, termed "sorted" and "rejected" herein. Knowing the relative mass split of the two products allows for the calculation of the missing hardness.

$$Ff = Ss + Rr \tag{1}$$

Where:

F, S, R are masses of feed, sorted and rejected fractions and;

f, s, r are SAGDesign Specific Grinding Energies.

The SAGDesign test includes measures of both AG/SAG grindability and Bond Ball Mill Work Index and so can be used to design any of the common single or multi stage grinding circuit flowsheets up to ball mill classification, which allows for a robust and flexible design process from a small and manageable test program.

This test program could also be completed in a similar manner on a particle by particle basis using SMC testing, though the ore hardness calculation for the third fraction becomes a non-trivial exercise beyond the scope of this paper.

It should also be noted that because the fines generated in crushing typically bypass a particle by particle ore sorting system, they do not influence the hardness selection function and so are tested separately in this program. Crusher fines are generally too small to be retained by the grates of an AG or SAG mill and so will receive only a small portion of grinding energy in a typical two stage AG/SAG mill. They can potentially generate a very high circulating load around that grinding stage if not accounted for in the design process because the sorter is simultaneously enriching proportion of fines in the mill feed by rejecting coarse waste rock.

## POTENTIAL APPLICATIONS

Using this methodology, a surprising amount of information can be gained to aid in the design of both the comminution section, including the ore sorter. First and most evident is the relationship between grade and hardness in the sample. This test program delivers an easy to use function between sorting selectivity, as a fraction of total mass, and hardness of the resulting sorted product. Knowing the grade of a given product at a certain selectivity, a complete curve of grade and hardness can be roughly approximated.

If this test program yields a strong relationship between sorting sensor data and hardness, the ore hardness selectivity function could be further expanded. This would be done by adding additional data points from more grinding tests on different sorted fractions to provide a more accurate hardness selection curve and to explicitly confirm the hardness balance.

Knowing the relationship between grade and hardness is a powerful tool in the hands of a design engineer. A strong hardness to grade relationship also support the possibility of other hardness related classification, such as rejecting specific size fractions by screening or the sorting/complete rejection of circulating SAG mill pebbles in the scenario where the waste rock is harder than the ore. Such configurations can eliminates the need for a costly pre-crushing circuit and reduces the number of sorting units required by only treating a portion of the stream which has already been pre-classified for grade by the SAG mill.

This test program is also very useful for the development of accurate trade off study models for the calculation of operating costs which can adapt to changes in the selectivity of ore sorting. Grinding represents one of the major costs for a mineral process plant both in terms of energy and consumables. By factoring in the effect of the ore sorter on hardness, a design engineer can build a dynamic model of grinding cost that is responsive to changes in head grade, regardless of if the ore is sorted or not. Ultimately, once this relationship is better understood over a variety of ore types, this would allow for full integration into a geometallurgical model of the ore body.

## NEXT STEPS

The integration of ore sorting technologies into the commonly applied suite of metallurgical testing is ongoing and the industry is still adapting to its use. While this program was designed to provide some insight into the effect of sorting on comminution design, it does not address the impact of sorting on other operations. To that end, the mining industry still has some work to do in order to fully integrate the potential for a changing feedstock into their testing programs at an early stage through the careful design of experiments.

In this paper, it was also assumed that the sorter was operating primarily as a filter for grade and as such, a relationship was developed between grade and hardness. However in actual practice, particle by particle ore sorting decisions are not made for grade, but are instead made on a proxy of grade which is measured by one or more potential sensor technologies (X-Ray Transmission, Laser, etc). To take this analysis program to a more fundamental level, the relationship between this sensor data and hardness should be investigated. Using this approach a more complete understanding of sorting for geometallurgy rather than grade could be developed.

## CONCLUSIONS

This paper has presented a methodology for determining, at a very preliminary stage, the relationship between ore hardness as measured by the SAGDesign test, and ore sortability which can be achieved on a relatively small sample mass of drill core. Due to the linearly additive nature of the SAGDesign Test results, a “hardness balance” can be developed to estimate the ore hardness which would be measured in any sorting mass split using only two data points. This will allow a design engineer to make more informed decisions as to the most appropriate mass split to select in relation to the incurred operating costs and grinding circuit sizing.