IsaMill Ultrafine Grinding for a Sulphide Leach Process

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ABSTRACT

Fine grinding mills have improved in design and efficiency in recent years, allowing major opportunities for treatment of materials where liberation to grind sizes below fifteen microns are required. The successful development of the IsaMill, a horizontal stirred mill, has produced equipment capable of grinding the larger tonnages which exist in mineral processing operations, to product sizes below ten microns. Initially developed for use with base metal flotation circuits, significant test work conducted in 1998 shows that major economic gains can be achieved by producing finely ground material for leaching.

IsaMill development and operation is reviewed. Results from test work to produce a feed stock for both straight cyanidation and sulphide leaching are discussed, with emphasis on energy consumption, product size and leachability. A number of options for ultrafine grinding and leaching are also discussed.

INTRODUCTION

In operations where flotation products are produced as a saleable concentrate, decreasing liberation size may result in decreased metallurgical performance due to gangue impurities and lower recoveries. Ultra fine grinding is gaining significant acceptance as a cost effective means to provide an optimum grade/recovery response in flotation.

In some gold leaching operations, ores contain gold in close association with sulphide minerals such as pyrite and arsenopyrite. Ultrafine grinding provides an effective method of liberating physically locked gold, or for producing a feedstock that is amenable to oxidative processes.

ISAMILL DEVELOPMENT

Decreasing liberation size and increased amounts of refractory pyrite in Mt Isa's lead/zinc ore resulted in a gradual decrease in concentrator metallurgical performance over time. Work had been conducted at Mt Isa between 1975 and 1985, involving regrinding to ultra fine sizes to increase liberation, using conventional grinding technologies. It was found that the conventional technologies had a very high power consumption to achieve the required sizing and the flotation performance was worse than expected due to contamination from the iron media used.

In 1990, there was no accepted technology for regrinding economically to ultra fine sizes in metalliferous operations. Test work in 1990 and 1991 indicated that high speed horizontal mills could efficiently grind to a product of 80%

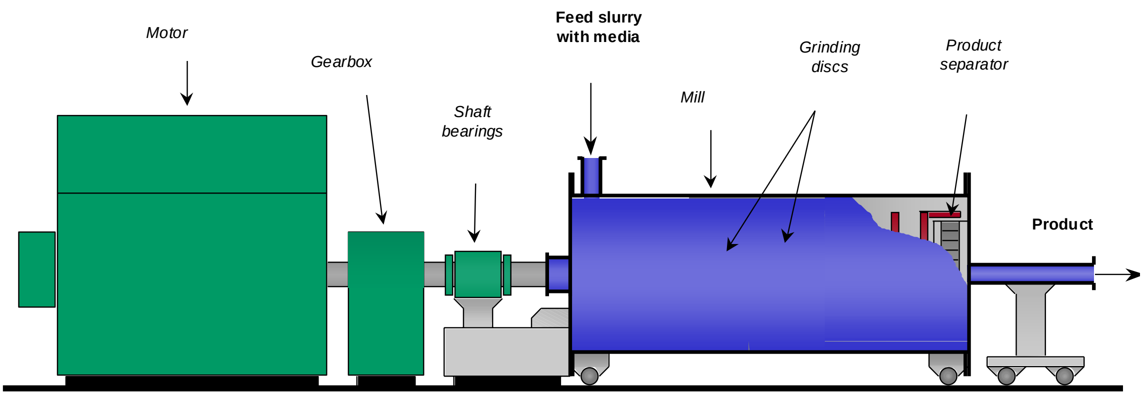

Figure1. The IsaMill.

passing 7 microns at laboratory scale and subsequently provide a major increase in metallurgical performance. To make an ultrafine grinding mill capable of treating the tonnages required at Mt Isa, a program of development was undertaken between Mount Isa Mines Limited in association with NETZSCH-Feinmahltechnik GmbH (NFT).

Scale-up was tested using trial installations at the Hilton and Mt Isa lead/zinc concentrators. By the end of 1994, the first full scale IsaMill (1.1MW) was installed in the lead/zinc concentrator. This has allowed a suitable, low cost grinding media to be proven in operation and provided a system for separating grinding media from product, without the disadvantages of screens or sedimentation zones. Furthermore, it has allowed development of cost effective wear materials. A diagram of the 1.1MW IsaMill is shown in Figure 1.

In 1998 the rights for commercialisation of the IsaMill where transferred from Mount Isa Mines Limited to MIM Process Technologies and under an exclusive agreement with NFT, on the 14^{th} of December, 1998 the IsaMill technology was launched to the metalliferous industry as a cost effective means of grinding down to and below 10 microns. There are currently two 1.1MW IsaMills operating in Mount Isa, treating lead concentrate and five 1.1MW IsaMills operating at the McArthur River site, treating bulk lead/zinc concentrate. A further six 1.1MW IsaMills will be installed in Mt Isa to treat zinc concentrates from the George Fischer Mine, commencing June, 1999.

APPLICATIONS

Ultrafine Grinding for Flotation

Several 1.1MW IsaMills have been installed in both the lead and zinc cleaner flotation circuits at Mount Isa.

Operations on lead rougher concentrate have shown that a throughput of 73tph per mill could be achieved at 45% solids. The net energy consumption for reducing a feed of 20 microns to a product 80% passing twelve microns was 6kWh/t. Figure 2 shows the improvement in silica rejection with and without the IsaMills in operation.

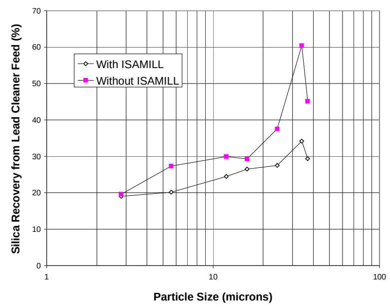

Figure 2. Improved silica rejection from concentrates.

IsaMills were also installed to treat zinc retreatment circuit cyclone underflow. From a feed of 80% passing 46 microns a product of ten microns could be produced with a specific energy of 65kWh/t. Figure 3 shows the improvement in the zinc grade/recovery curve after ultrafine grinding with the IsaMill.

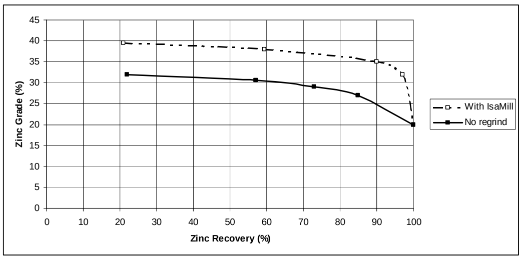

Figure 3. Improvement in the zinc grade/recovery curve after ultrafine grinding.

Of specific interest in the Mount Isa operations is the wide choice of grinding media available for use in the IsaMills. Mt Isa has variously used heavy media plant reject and lead or copper smelter slag for grinding media. These materials had previously been considered waste and provided an extremely inexpensive grinding media. In addition they are inert, having no effect on flotation chemistry, unlike steel media.

Ultrafine Grinding for Direct Cyanidation

Many refractory gold bearing ores contain gold in close association with sulphide minerals, such as pyrite and arsenopyrite. Refractory gold may be present in several forms, ranging from fine free gold housed on boundaries between mineral grains, to gold that is in solid solution with the sulphide matrix. Techniques used to recover gold from refractory ores range from ultrafine grinding for improved liberation of physically locked gold, to oxidative processes where the sulphide matrix is wholly or partially destroyed through chemical oxidation.

The effectiveness of ultrafine grinding as a method of liberating physically locked gold is illustrated in Table 1. The data in Table 1 is also displayed graphically in Figure 4.

A sample of pyrite ore, grading 4.59 g/t gold and 4.85 % sulphur was finely ground in a laboratory scale IsaMill to 80 % passing 20 and 10 microns respectively. The finely ground product was then leached in a conventional agitated cyanide leach test for a period of 48 hours at pH 10, and a free cyanide level of 500 ppm.

80 % passing size - microns	***% gold recovery***	***NaCN cons kg/t***	***Specific Energy Requirement – kWh/t***
74	23.4		
20	39.5	1.44	17
10	70.2	1.73	42

Table 1 .The Effect of Ultrafine Grinding on Gold Recovery from Pyritic Ore.

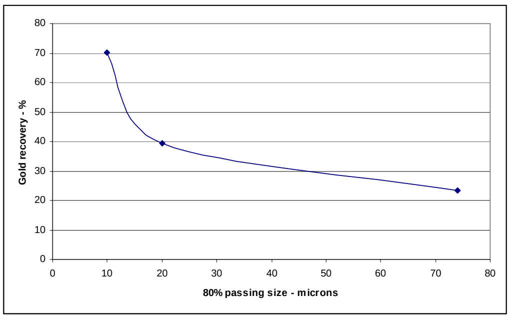

Figure 4. Gold Recovery versus Particle Size for a Refractory Gold Ore

Ultrafine grinding resulted in a significant improvement in the gold recovery through cyanidation. Typical gold recoveries for the ore sample, when ground to 80 % passing 75 microns in a conventional ball mill, were in the range 20 – 25 % w/w. The gold recovery from the ore after grinding to 80 % passing 20 and 10 microns improved to 39.5 and 70.2 %, respectively.

<u>Ultrafine Grinding for Chemical Oxidation.</u>

Not all refractory gold ores, however, will show an improvement in gold extraction through fine grinding alone. Many ores require oxidative breakdown of the mineral sulphides to achieve sufficient liberation of gold for recovery through cyanidation. The most common oxidative processes used to recover gold from refractory sulphides are pressure leaching, bacterial leaching and roasting.

Pressure leaching involves the oxidation of sulphide minerals in acidic solutions at elevated temperatures and pressures, where the aggressive leaching conditions are used to improve the kinetics of the oxidation process.

In bacterial leaching, microbes that occur naturally in acidic mine waters are utilised as a catalyst to increase the rate of mineral oxidation. The catalytic effect of the bacteria allows bacterial leach plants to run at considerably lower temperature and pressure than pressure leaching plants.

Roasting involves the reaction of sulphide minerals with hot gasses containing oxygen, at temperatures in the range 500 - 800 ^{o}C. Sulphur dioxide gas, a byproduct of the roasting process, is usually captured for production of sulphuric acid.

In recent years, there has been a considerable amount of development carried out on processes which couple ultrafine grinding and oxidative leaching in an effort to reduce the capital costs associated with Pressure Leaching, Bacterial Leaching and Roasting. One such processes is MIM Holdings' ALBION Process.

CASE STUDY

Comparative fine grinding and oxidative leaching testwork was carried out on a sample of pyrite concentrate using MIM Holding's proprietary ALBION process and two common laboratory scale ultrafine grinding mills. The two mills tested were the IsaMill and a Vertically Stirred Mill (VSM). A head analysis of the pyrite concentrate is listed in Table 2.

Element	***Assay***
Fe	28.5
S	23.6
Au	50
Ag	18

Table 2. Head Analysis of Pyrite Concentrate Sample used in the Fine Grind/Oxidative Leach Testwork.

Samples of ground concentrate were produced from both mills at a range of particle size distributions. The ground concentrate samples were then leached under the conditions typically specified for the ALBION process, which involves oxidation of sulphide minerals at atmospheric pressure in conventional agitated tanks. Cyanide leaching of an oxidised concentrate produced from each type of mill was also carried out.

Experimental Setup

The laboratory scale IsaMill consisted of a horizontal milling chamber, drive motor and 6 disc radial impeller. The mill was fitted with a 4.0 kW variable speed drive and Yokogawa power meter to determine the specific energy requirements of each grind. A diagram of the laboratory ISAMILL set up is shown in Figure 5.

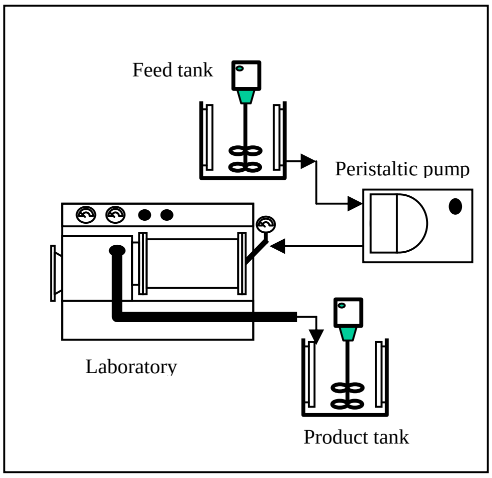

Figure 5. Diagram of the IsaMill Experimental Setup

The pyrite concentrate sample was pumped by variable speed peristaltic pump from a feed tank to the IsaMill feed port. Slurry exited the mill through a separator located before the mill mechanical seal, which allowed slurry to pass but retained media within the mill.

Ground slurry was discharged from the mill through a slurry discharge port and was collected in a sealed product tank. Samples of ground slurry were collected for the leaching tests, and each of the slurry samples was filtered and the filter cake stored frozen prior to the leach tests. The mill media was 0.8 – 1.2mm steel shot.

The Vertically Stirred Mill consisted of a 10 litre chamber and pin style impeller. The mill shaft held seven radial arms, each 160 mm long and 10 mm in diameter. The mill motor was a 2.7 kW variable-speed drive, fitted with a 3 phase AC inverter for power consumption measurements. The mill media was 2.3 – 6.6 mm steel shot. A diagram of the laboratory Vertical Mill set up is shown in Figure 6.

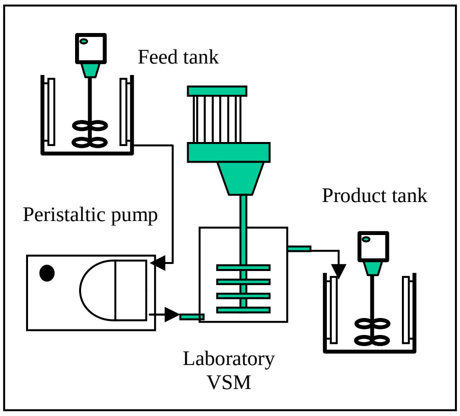

Figure 6. Diagram of the Vertically Stirred Mill Experimental Setup

Feed slurry was pumped through the mill feed port located at the base of the mill, and was discharged from the mill overflow port. Ground slurry was collected in a sealed product tank. Each of the slurry samples was filtered and the filter cake stored frozen prior to leaching.

Results.

The results of the ultrafine grinding and oxidative leaching tests are listed in Table 3. Figure 4 shows the effect of particle size on the extent of sulphur oxidation achieved for the two different types of fine grinding mill.

The IsaMill was the most efficient of the two mills tested, grinding to 80 % passing 8.61 microns at a specific energy input of 64 kWh/t. In comparison, the Vertically Stirred Mill required 105 kWh/t to achieve a product at 80 % passing 8.2 microns. The relationship between specific energy and particle size for both of the mills is shown in Figure 7.

The specific energy curves for the two mills were similar for product sizes down to 80 % passing 25 microns, at which point the slope of the curve for the Vertically Stirred Mill increased significantly relative to the IsaMill. The curves in Figure 4 show that the IsaMill was much more efficient at grinding in the particle range below 12 microns.

Mill Type	Specific energy Input – kWh/t	80 % passing size	% sulphur oxid.
Head	0	108.39	24
IsaMill	11	51.9	61
IsaMill	19	36.4	76
IsaMill	31	17.94	91
IsaMill	41	13.64	96
IsaMill	52	11.71	96
IsaMill	64	8.61	96
VSM	12	41.5	74
VSM	24	26.7	88
VSM	75	10.68	96
VSM	105	8.2	96
VSM	148	7.54	94

Table 3. Results of ultrafine grinding and oxidative leaching of a pyrite concentrate sample.

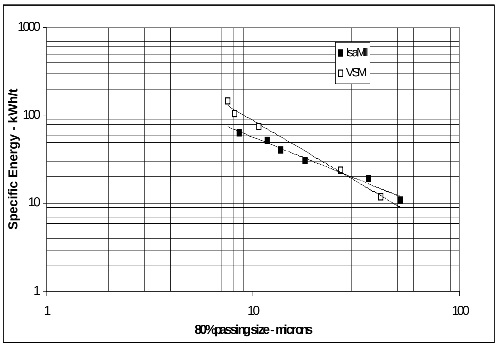

Figure 7. Comparative Milling Curves for the IsaMill and Vertically Stirred Mill.

In terms of breakage rate, the mill residence time to achieve a specified grind showed a similar pattern to that of specific energy. The relationship between mill residence time and particle size for both of the mills is shown in Figure 8. The residence time for the two mills were similar for product sizes down to 80% passing 25 microns and below this point the IsaMill required significantly less residence time to achieve a specified grind. At the target grind of 80% passing ten micons the IsaMill required 12.49 minutes grinding time, compared to 18.46 minutes residence time for the Vertically Stirred Mill.

The superior efficiency of the IsaMill in grinding to below 12 microns was believed to be due to the smaller media used in the mill. It is well known that the efficiency of any fine grinding process improves with finer media, and the mechanics of the IsaMill allow for agitation of finer media at higher tip speeds than is possible for a vertically stirred mill.

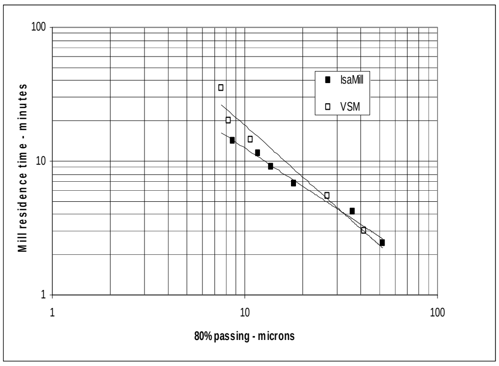

Figure 8. Comparison of residence time for the IsaMill and Vertically Stirred Mill.

The degree of oxidation achieved from leaching the concentrate samples did not show a large variation with type of mill, as indicated by the closeness of the oxidation versus particle size curves in Figure 5, below. Both mills achieved a maximum of 96% oxidation at approximately 80% passing 15 microns.

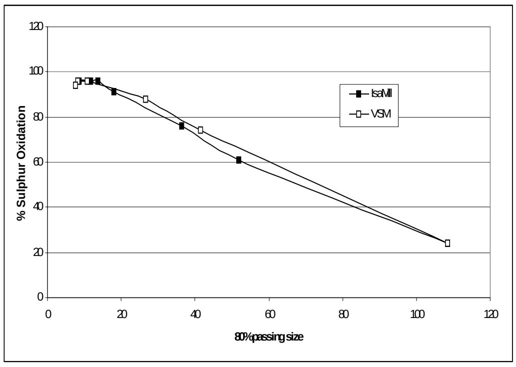

Figure 9. The Effect of Particle Size on Sulphide Oxidation for the two Mill Types

CONCLUSIONS

The use of ultra fine grinding in combination with cyanidation or chemical leach processes is a viable alternative to traditional expensive treatment of refractory gold concentrates.

A laboratory scale case study comparing an IsaMill (a horizontal stirred mill) and a vertical stirred mill has shown that a more energy efficient outcome is likely with the former.

In addition, a superior residence time performance of the IsaMill suggests a more compact, lower cost mill, when installed.