EVOLUTION OF THE ISAMILL INTO MAGNETITE PROCESSING[1]

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Abstract

IsaMill technology was developed from the stirred milling technology of Netzsch Feinmahltechnik GmbH in the 1990's for use in the fine grained lead zinc ore bodies of Northern Australia in a drive to bring about a step change in grinding efficiency required to make these ore bodies economic to process. The following two decades have seen the technology evolve from its development in relatively small tonnage, ultrafine grinding duties to a technology that is equally at home in large throughput, standard coarse regrind and mainstream grinding duties. With this evolution has come the realisation that more energy efficient circuits are achievable by using technology that is tailored to the grinding duty. The expansion of magnetite projects in Australia has embraced the opportunity to take advantage of newer technologies that were not necessarily available when the magnetite industries of North America and Europe were maturing. Among these has been IsaMill technology which has allowed the Australian Magnetite industry to take advantage of improved energy efficiency coupled with tight product size distributions that originally made the IsaMill so attractive to the base metals processing industry. This paper investigates the effect of the IsaMill grinding technology on the full scale Australian Magnetite operations at Ernest Henry Mining along with pilot and lab scale demonstrations of optimization.

Key words: IsaMill; Comminution; Grinding; Energy efficiency; Beneficiation; Concentration.

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1 INTRODUCTION

IsaMill™ technology was developed to address the metallurgical requirements of Mount Isa Mines Ltd's (now Glencore Xstrata) fine grained lead/zinc deposits at Mount Isa and McArthur River in northern Australia. The complex nature of the mineralogy in both deposits required ultra fine grinding (UFG) to P_{80} of 7 µm to make a saleable concentrate. This was a size that was not possible to achieve economically with the technology available in the early 1990's.[1,2] Further attempts to use conventional ball and tower mill technology to do this duty resulted in high power consumption, high media consumption, contamination of mineral surface and pulp chemistry and ultimately lacklustre performance in subsequent flotation stages.

In the early 1990's Mount Isa Mines started investigations into the applicability of high speed horizontal stirred mill technology, traditionally used in the pigment and pharmaceutical industries, to grinding duties in metalliferous applications. Pilot scale testwork showed that these mills were capable of grinding to the fine sizes required for mineral liberation and a subsequent development program ensued between Mount Isa Mines and Netzsch-Feinmahltechnick GmbH (the manufacturer of this strirred milling technology) to "move" the small scale, batch, industrial equipment into the large scale, continuous, mining industry.

The first full scale 1.1 MW, 3000 litre IsaMill™ was installed in the Mount Isa Lead Zinc Concentrator in 1994 followed by further installations at both this and the McArthur River concentrators over the next couple of years. The IsaMill became the enabling technology for both McArthur River and Mount Isa orebodies and ensures their ongoing viability today. The history of McArthur River and the development of the IsaMill™ by MIM and Netzsch Feinmaltechnik of Germany is well documented elsewhere.[3,4]

Since the first installations in northern Australia in the early 90's and commercialisation in 1999 there are now over 120 IsaMill installations and over 200 MW of total installed IsaMill power operating globally. IsaMills have moved from the ultrafine duties of their inception to operating predominantly in coarser regrind duties and mainstream inert grinding applications formerly the domain of ball and tower mills. The 3 MW and 8 MW models available make IsaMill technology a viable alternative to large throughput operations required for the global Magnetite industry.

2 OPERATION AND ADVANTAGES OF ISAMILL TECHNOLOGY

As discussed by numerous authors[2,5] the IsaMill is horizontal stirred milling technology. The mill internals consist of a series of discs mounted on a rotating shaft driven through a motor and gear box. Disc tip speeds range from 21-23 m/s and energy intensities are up to 300 kW/m3.

The unique design of the IsaMill™ has resulted in a number of key advantages:

- high energy efficiency – the ability of the IsaMill™ to use small media (IsaMills generally use 2 – 6 mm media depending on feed and product particle size) means more media particle collisions and a higher energy efficiency when compared to alternative technologies using larger media;
- the high energy intensity in the IsaMill™ (>300 kW/m3) means the grinding volume is about one tenth of the equivalent ball or tower mill. As a result IsaMills require a much smaller footprint than conventional ball and tower mill technology resulting in cheaper, simpler installations;

- steep product size distribution – the 8 effective grinding chambers, internal classification system and lack of inefficient product classification cyclone (and recirculating loads) results in a steep product size distribution – less “over ground” fines and less unground coarse composites;
- with testwork run under exactly the same conditions as full scale mills (horizontal configuration, same media size and slurry properties, same mill configuration) IsaMill™ testwork has been proven to scale up 1:1 from laboratory / pilot scale to full scale operation;
- the open circuit configuration of IsaMill™ circuits results in less over-grinding, and simpler, cheaper circuits;
- the horizontal configuration of the IsaMill™ has meant it has been easily scaled up with mills available from 75 kW to 8 MW.

The features of the IsaMill™ has made the technology easily transferable across a range of industries. Although it started out as a grinding technology for ultrafine base metals duties 20 years later it has now been widely accepted in regrind and mainstream application in a range of industries including platinum and magnetite.

3 UNLOCKING THE VALUE OF WASTE: ERNEST HENRY MINING CASE STUDY

Ernest Henry Mining (EHM) is situated 38 km north-east of Cloncurry in the Mount Isa – Cloncurry mineral district of north-west Queensland. EHM’s Ore Reserve Estimate as at 30 June 2010 is 88 million tonnes at a grade of 1% copper, 0.5 grams per tonne gold and 23% magnetite. The copper concentrator has the capacity to produce 350,000 tonnes of concentrate annually containing around 100,000 tonnes of copper metal and 120,000 troy ounces of gold.

As reported by Siliezar, Stoll & Twomey(6) in December 2009 Xstrata Copper announced a $589 million investment to extend the life of EHM to at least 2024, through the transition of open pit mining operations to a major underground mine, together with an associated magnetite plant. The magnetite processing operation at EHM was designed to produce approximately 1.2 million tonnes of premium quality magnetite concentrate per annum for export to Asia allowing EHM to maximise the value of its resources by creating a revenue stream from a material that had traditionally been discarded as tailings. Construction of the magnetite extraction plant commenced in July 2010 and first magnetite concentrate production was achieved in December 2010.

The EHM Magnetite plant is shown in Figure 1. The process consists of an extraction plant to separate and upgrade the concentrate which includes a regrind facility to maximise liberation and therefore final concentrate grade and a dewatering facility to remove water prior to transport.

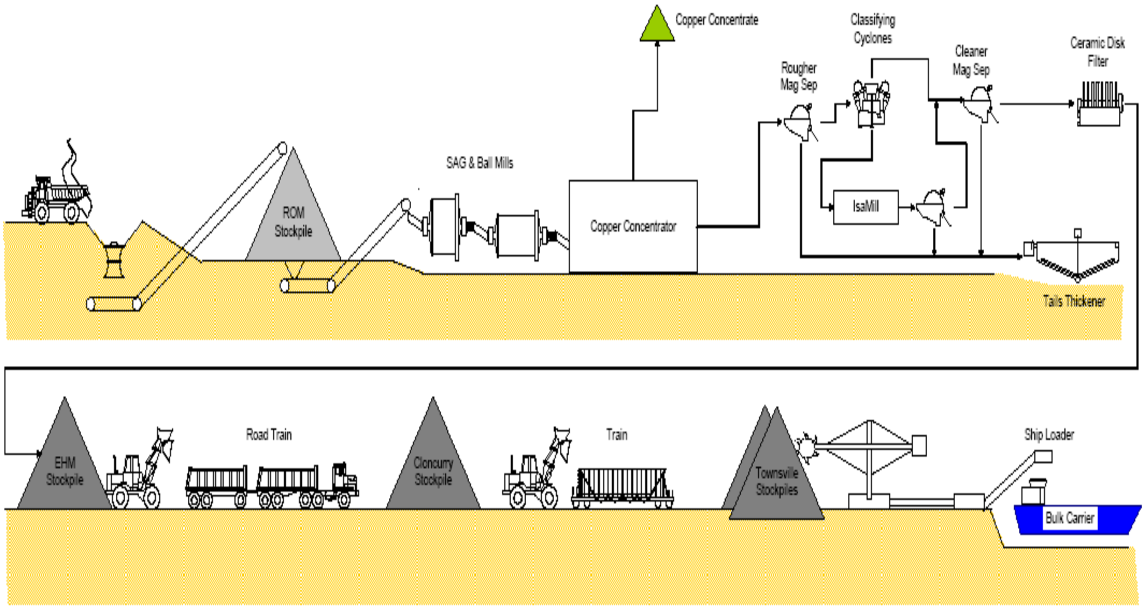

Figure 1. Overview of the EHM Magnetite plant.[6]

The EHM Magnetite plant is divided into 3 circuits- extraction, regrind and dewatering circuits. The extraction (magnetic separators) and dewatering (filters) form the base plant where commissioning commenced in December 2010 followed by commissioning of the regrind circuit in August 2011 allowed production of a high grade magnetite product.

While the IsaMill had been used exclusively in regrind duties in the base metals and platinum industries the inclusion of the IsaMill in the EHM flowsheet was unique for magnetite processing. The decision to use IsaMill technology was based largely on 2005 testwork on comparing the efficiency of tower and IsaMill technology on EHM tails material conducted by CSIRO, Australia.[2] The testwork as shown in Figure 2 demonstrated that large improvements in energy efficiency were possible if using the IsaMill over the tower mill when grinding to product sizes less than 75 µm. The testwork was restricted by the ceramic media size commercially available at the time (a maximum of 3.5 mm media) in the IsaMill tests (the tower mill test used 12mm media as the smallest size that can be realistically used in a full scale tower mill). It is envisaged that if 5-6 mm media had been used as is now available, the crossover product size where IsaMills become more efficient than tower mills would be significantly larger than 75 µm.

The coarser media ensures a more complete top size reduction vital for magnetite operators to make final silica grade and also further reduces the already low amount of ultrafines created. The ceramic media has an advantage over steel media in that it is far less elastic and transfers energy more efficiently to the ore rather than in just being deformed.

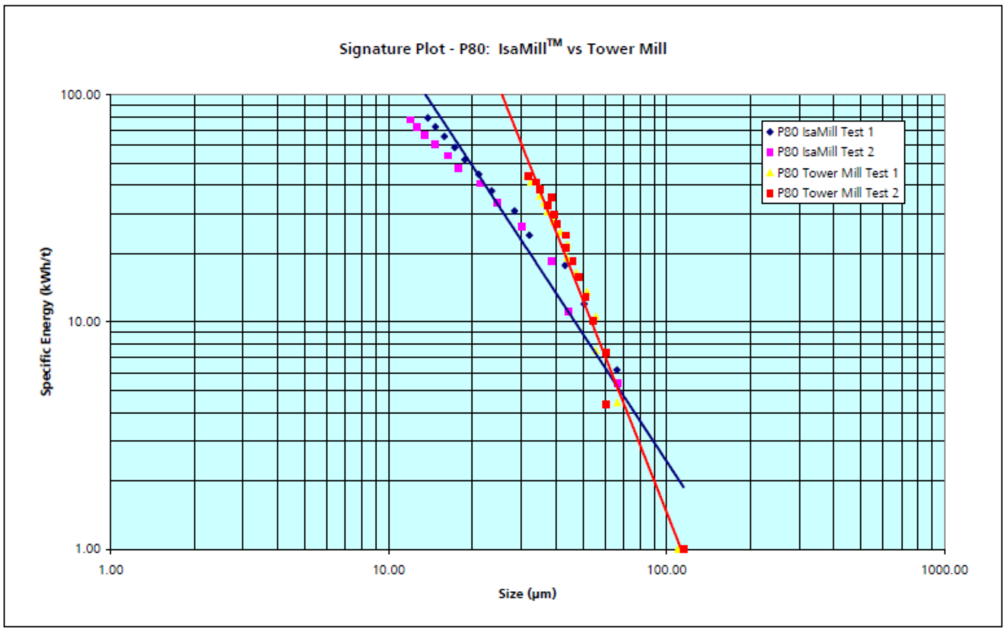

Figure 2. EHM Tails Tower Mill vs IsaMill testwork.[2]

As reported by Larson et al.[7] the first year the IsaMill typically received an F_{80} of 250-300 microns (compared to a design feed size of ~150 um) and an absolute top size in excess of 1 mm. Cenotec ceramic media with a top size of 6.5 mm was used in the IsaMill with the goal of being able to better handle (or grind) the coarse end of the feed.

The deviation from design was realized prior to commissioning. This feed was similar in size to that tested at ALSGlobal's Ammtec Laboratories in May 2011. Some limited survey results are plotted on Figure 3 showing the Ammtec signature plot with the good scale-up correlation typical of IsaMill installations. The mill net power draw (gross power – 80 kW) was also used as the Ammtec results are expressed in net energy required. The Ammtec tests were performed with a top size 6 mm of Cenotec CZM media while the plant uses 6.5 mm Cenotec.

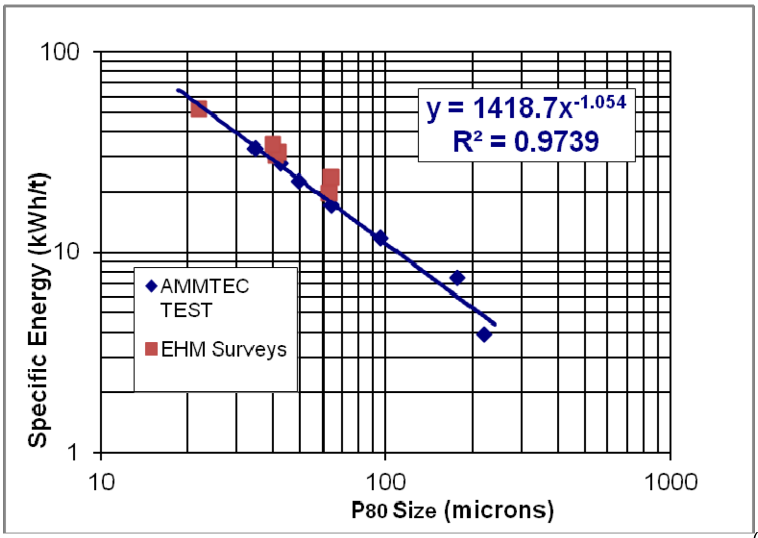

Figure 3. Ammtec signature plot with EHM M10,000 survey data.[7]

Also included in Figure 4 is an example of the IsaMill product size distribution. Considering the coarseness of the feed the steepness of the product size distribution is more than acceptable. Much of the coarse material in the product appears to be silica reporting to the discharge due to density differences with the finer higher specific gravity magnetite. The regrind magnetic separators concentrate during this survey contained zero material above 106 microns and minimal material above 75 microns.

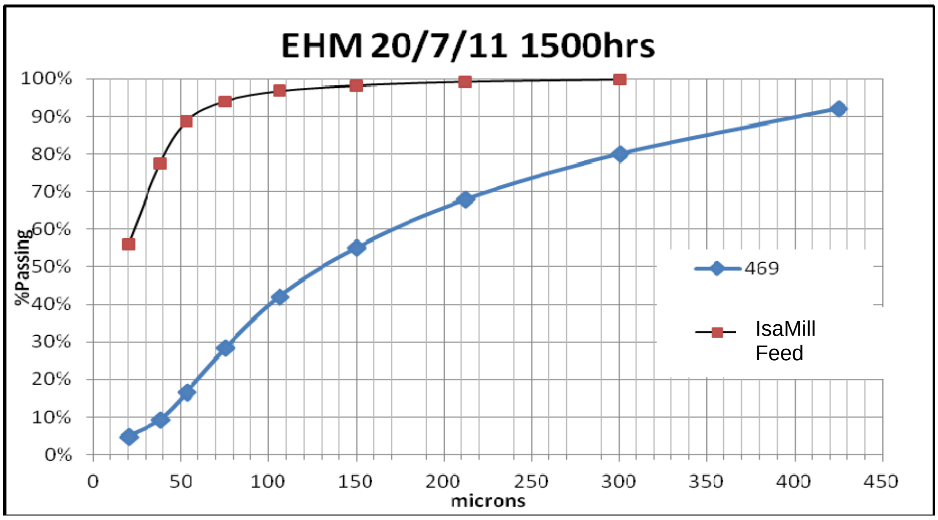

Figure 4. EHM M10,000 IsaMill feed and discharge product size distributions.

As reported by Larson et al further optimization of the EHM magnetite circuit being investigated includes removing the coarse fraction of the rougher magnetic separator feed, concentrate or the cyclone underflow and returning this fraction to the main copper concentrator. Early investigative work has shown that this ~212 micron size fraction grades about 0.45% copper and 40% silica. The benefits of removing this stream would be an improvement in overall copper recovery at the EHM and a reduction in the amount of silica reporting to the magnetite cleaner circuit. Additionally removing this material would increase IsaMill throughput or allow a reduction in IsaMill product size and the removal of excess silica from the IsaMill circuit would improve downstream grade and filtering performance.

4 QUESTIONING TRADITIONAL CIRCUIT DESIGN - WESTERN AUSTRALIAN CASE STUDY

The development of Western Australian magnetite deposits has resulted in the design of some of the largest grinding mills and plants in the world. As a result of the predicted power consumptions required coupled with the remoteness of the proposed installations the push to design ever more energy efficient circuits has been paramount. As reported by David, Larson and Li[8] the development of one of these deposits with a feed tonnage of 3800 tph and a final product size requirement of 34 µm meant the grinding requirement would be extensive. The testwork design therefore had to look at optimization of the process flowsheet to take advantage of the strengths of various grinding technologies to reach the final grind size while ensuring adequate liberation and gangue rejection along the way.
Laboratory and pilot plant work was done in late 2010 / early 2011. Additional to a final grind of 34 µm a lower than typical final silica grade of sub 3% SiO_2 was desired as well as the rejection of pyrrhotite using a final flotation step to meet sulfur requirements. The flowsheet examined previously proven technologies from existing plants with the aim of optimizing each step of the process. Laboratory and pilot work

was combined to ensure maximum economical efficiency while still maintaining a quality product

As explained by David, Larson and Li(8) the testwork (conducted at Ammtec, Perth Western Australia) consisted of

- grinding work - pilot autogenous primary milling, laboratory work (Levin test) and pilot secondary ball milling, laboratory and limited continuous secondary IsaMill testing, laboratory tertiary, limited continuous and pilot IsaMill testwork;
- magnetic separation testwork - Davis tube and pilot magnetic separation tests of the different intermediate and final products;
- hydroseparating tests of the final isamill magnetic concentrate;
- sulfide flotation tests of the final magnetic concentrate; and
- final concentrate filter testing by vendors.

The primary AG grind has been designed to 420 µm prior to rejection of gangue material via magnetic separators to reject 40% of the feed material resulting in 2200 tph feed to the secondary grinding stage at a P_{80} of 770 µm (the magnetics will have a coarser grind size than the gangue material)

Secondary ball (using the Levin test) and IsaMill™ testwork was completed to establish the most efficient energy use of the two technologies. As can be seen in Figure 5 by plotting the Levin test and the secondary grind IsaMill test together the gain in efficiency with the IsaMill over ball milling is evident. The efficiency gain is primarily a function of the type of grinding mechanism (attrition vs impact) and the media used (5-6 mm in an IsaMill vs 25 mm in a ball mill). With this ore the efficiency gain starts at a product P_{80} of approximately 100 µm. At product sizes above that point the ball mill is more efficient. This is mainly a function of media size and a media larger than 5-6 mm in the IsaMill would achieve more efficient size reduction to 100 µm but would not be as efficient to the finer 34 µm final target.

From the testwork ball mill technology was selected for the secondary grind duty to grind from F_{80} 770 µm to P_{80} 80-100 µm using 40 mm balls to minimise media wear while still ensuring top size reduction.

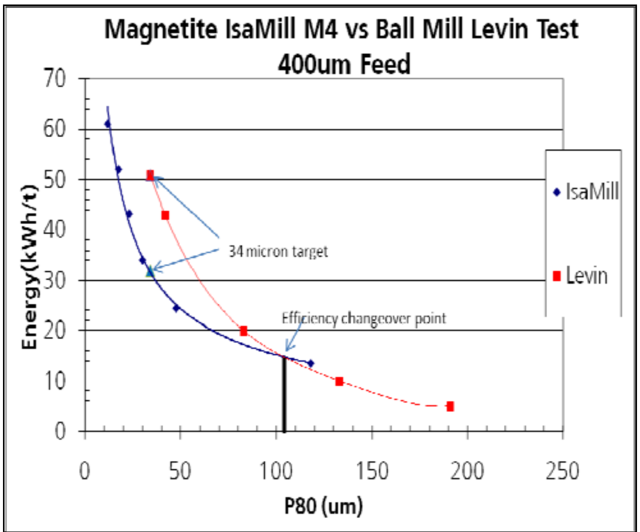

Figure 5. IsaMill™ - Levin test comparison.(8)

The secondary grind product was treated with magnetic separators to reject a further 20% of the mass prior to tertiary grinding using the IsaMill™ to 34 µm.

Table 1 shows the relative energy and media costs comparison in using a single stage ball mill vs a single stage IsaMill™ vs two stage ball and IsaMilling to achieve

34 µm product. As is evident from the table while the single stage IsaMill circuit has a significant benefit over ball milling combining the two technologies is far more efficient than either would be on its own. When compared against a traditional single stage ball mill circuit the flowsheet designed for this circuit has resulted in grinding power savings of nearly 50% (56 MW) and $60 million annual savings in grinding media.

Table 1. Circuit comparison[8]

	Section Feed Rate (t/h)	Specific Energy (kWh/t)	Installed Power (MW)	Annual Media Cost Estimate ($AUD million)
Autogenous Mill 770 µm Product	3800	8.5	40	$0
Option 1:Single Stage Ball Mill 34 µm Product	2200	47	114	$86
Option 2: Single Stage IsaMill 34 µm Product	2200	34	78	$57
Option 3: Ball Mill 100 µm Product	2200	12	34	$13
IsaMill 34 µm Product	1720	13	24	$11
Option 3 Total			58	$24

5 CONCLUSIONS

The evolution of IsaMill™ technology from an ultrafine grinding technology to a mainstream and regrind technology has resulted in wide acceptance in many metalliferous applications where utilizing the IsaMill™'s key advantages of energy efficiency, high intensity and circuit efficiency. These advantages have now been transferred to the magnetite flowsheet development and plant design.

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