Letters to Editor

FINE GRINDING IN AUSTRALIAN MINERALS INDUSTRY

A. Janković

Julius Krutschnit Mineral Research Centre, Australia

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Abstract

Fine grinding of metalliferous ores has become increasingly important for Australian mining industry, as many of the remaining orebodies are very fine-grained and refractory. It is however the energy intensive process and as conventional equipment is not capable to provide economically sound production, new solutions are being implemented. The most successful application has stirred milling technology as it meets three major criteria: capacity, efficiency and reliability. Several major ore deposits classified as “untreatable” in the past were developed recently thanks to stirred milling technology. Different types of stirred mills are being used in various applications and demand for stirred mills is growing rapidly.

Keywords: stirred mills, fine grinding, energy, particle size, efficiency

1. Introduction

A fundamental purpose of comminution in minerals processing is to liberate the constituent mineral that makes up an ore so those valuable components can be separated from the gangue. The effective liberation of val-
ues remains one of the major challenges in treating modern ore, which, due
to increasing complexity and finer grain sizes, requires finer grinding to
achieve necessary degree of liberation.

In comparison to mineral concentration, coal cleaning is normally car­
rried out at relatively coarse sizes. However, when deep physical cleaning is
carried out to produce super clean (less than 2% ash) and ultra clean (less
than 1% ash) coals, increased liberation of finely disseminated mineral mat­
ter is required. Microscopic examination of many coals reveals that suffi­
cient liberation may not occur until the coal is ground finer than 20 μm
(Mankosa, 1989).

As particle becomes smaller, the probability of flaws in them decreas­
es and their strength increases. Hence, for very small particles, higher
applied forces may be needed and, additionally, relatively high probabilities
for successful application of the stress on the particles. Such high probabili­
ties do not exist in the conventional ball mills as they use relatively large
grinding media. As particle size decreases, so grinding media size has to
decrease for efficient grinding to take place. As grinding media size
decreases, media velocity has to increase in order to generate sufficient
energy for particle breakage. Stirred mills can achieve very high media
velocities and energy densities (300 kW/m$^3$ of mill volume) by stirring the
media at high (25 m/s tip speed) rate.

There is a considerable range of equipment that can be utilized in the
process of fine grinding. The more common mill types used in fine particle
processing can be broadly categorized into two main groups: media mills
and non-media mills. However, to be used in minerals processing industry,
mills are required to have high capacity and reliability to survive hash-oper­
ating conditions. Several stirred mills were developed in the past that can
meet above criteria and they will be described in this paper.

2. Market review

There are ten types of stirred mills commercially available and seven
of them are actively competing in the minerals industry. They can be clas­
Letters to Editor

Classified into low and high-speed mills. The speed is defined as the tangent (tip) speed of stirrer tips (m/s). The low speed mills normally operate at 3 m/s with an effective size reduction to about 15 microns (80% passing size). The high-speed mills operate at a speed higher than 15 m/s with an effective size reduction to about 5 microns (80% passing size) [1, 2].

Svedala manufactures three low speed stirred mills, namely, Vertimill, Sala Agitated Mill (SAM) and English China Clay (ECC) mill. These three mills have covered all basic designs of low speed stirred mills, thus putting Svedala in a very strong position as a fine grinding equipment supplier. The Svedala mills may not be most energy efficient for very fine grinding below 15 microns, but they are reliable and provide expected performance for their duties.

Kubota in Japan manufactures the Tower mill. It was the first low speed stirred mill applied in the minerals industry. There have been many installations of the Tower Mill in base metal mines as regrinding mills and they are efficient for size reduction from 70 microns to 20 microns (80% passing sizes). Kubota in recent years is losing the Tower Mill market to Svedala’s Vertimill due the fact that the largest Vertimill (1.25MW) is more than twice the size of the largest Tower Mill and its design is very similar to that of the Tower Mill.

Metprotech mill is another low speed mill that has been actively promoted in the last ten years and was the one most extensively tested by the minerals industry. The biggest problem of the mill is the stirrer wear that has caused frequent shutdowns for maintenance during trials on large scales. ANI has acquired the license of the mill and is working on the wear problem.

Union Process in the United States was the first manufacturers of low speed stirred mill in the world. Union Process does not promote their mills to the minerals industry, but their customers are widely spread in other fine powder industries such as pigment, paint, cement, industrial minerals, cosmetic and food.

Draiswerke GmbH in Germany has a long history of manufacturing high-speed stirred mills for pigment industry.
Letters to Editor

Klausson in Switzerland and Union Process are the other two well-known manufacturers for high speed stirred mills. They produce high quality mills for variety of applications in fine powder industries. They are not showing serious interest in the minerals industry at this stage.

The ISAMILL, which has been jointly developed by Mount Isa Mines and Netzsch GmbH in Germany, is the only high-speed stirred mill in operation in the minerals industry. The advantages of the mill such as the high throughput above 10 tph at 80% passing size of 7 microns (MacArthur River application), high energy efficiency, low cost natural grinding media, innovative system for media and slurry separation, low components wear, and the unique gland sealing system have left other high speed mill manufacturers such Draiswerke GmbH behind.

The competitiveness of the low speed mills lies in the facts that they cost less to build and cheaper to maintain. These mills are designed mainly for size reduction from 200 microns to 15 microns (80% passing sizes). For

Fig. 1. An example of high-speed horizontal and low speed Vertical stirred mill.

Draiswerke GmbH

SAM mill

J.Min.Met. 36 (1-2)A 2000
products finer than 10 microns, they are less productive and less energy efficient. But if the capital and operation costs are accounted for, the cost effectiveness of the overall process may turn out to be similar to that of the ISAMILL.

Tower, Verti, ECC mill and ISAMILL will be discussed further as they are the most important fine grinding mills in Australian minerals industry [3-5].

3. Tower and Verti mill

The tower and Verti mill are low speed Vertically stirred grinding mills, which uses either steel balls or pebbles as the grinding media (Fig. 2). The mills have basically the same design, the major difference being the size. Tower mill was developed in Japan in the 1950's by the Japan Tower Mill Company Ltd, later renamed the Kubota Tower Mill Corporation, KTM. Verti mill is being manufactured by Svedala and appeared in Australia 5 years ago. The tower and Verti mill consists of an internal screw flight agitator driven by a motor, a stationary Vertical grinding cylinder, a settling classifier and a pebble port which is used to remove the grinding media. The agitators used are “double start” helical screw configuration wound around a central shaft. “Double start” refers to two screw flights being wrapped around the same shaft to increase the screw density. The ball movement and resultant grinding action within the mill are the direct result of the rotating and lifting action generated by this agitator (Stief et al, 1987).

The screw assembly is wear protected from abrasion by covering surfaces with vulcanized rubber and/or wear resistant steels, depending on the nature of the material being ground. For wear resistant steels, hard-faced surfaces are welded to the screw surface to provide wear protection. With respect to vulcanized rubber, the rubber is attached by bolts to the screw. The wear life of the liners is now reported to be in excess of 4 months (Jankovic at all, 1999). The application of using different liners has shown that the greatest wear rates occur at the bottom of the grinding chamber.
where the greatest ball to ball pressure exists. The toe or leading edge of the screw therefore experiences the highest wear rates. The unique grid bar assembly as illustrated in Fig. 2 protects the tall, cylindrical stationary wall of the mill against wear. This grid system traps particles along the mill wall, thereby using the medium itself as a wear liner, similar to the use of grid liners in ball mills. To protect the shell of the mill from wear, the inner wall of the grinding chamber is itself rubber lined. To reduce downtime experienced in removing this grid bar system, magnetic liners are now replacing the grid bar system. The ease of removal and replacement of these liners has increased their usage to such a point now that manufacturers specifies mag-

Fig. 2. Schematic of Tower and Verti mill.
netic liners only.

Tower mills have been installed at Mount Isa, Hilton, Hellyer, New Celebration concentrators and a list of Verti mill installations is given in Table 1. There are over 220 Verti-mill installations worldwide (Kalra, 1999) and more than 250 tower mill installations.

Table 1. Verti mill applications in Australia (After Kalra, 1999).

<table>
<thead>
<tr>
<th>Company</th>
<th>Size &amp; Qty</th>
<th>Product Material</th>
<th>Product 80% pass</th>
<th>t/h</th>
<th>Application</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granny Smith, Placer</td>
<td>VTM-500-WB</td>
<td>Gold ore</td>
<td>20</td>
<td>12</td>
<td>Regrinding</td>
<td>95</td>
</tr>
<tr>
<td>Pegasus Gold, Mt Todd</td>
<td>VTM-1250-WB x 2</td>
<td>Gold ore</td>
<td>15</td>
<td>34</td>
<td>Regrinding</td>
<td>96</td>
</tr>
<tr>
<td>BHP Cannington</td>
<td>VTM-800-WB x 2</td>
<td>Lead rougher</td>
<td>20</td>
<td>30.9/38.2</td>
<td>Regrinding</td>
<td>96</td>
</tr>
<tr>
<td>BHP Cannington</td>
<td>VTM-200-WB</td>
<td>Silver</td>
<td>20</td>
<td>9.8</td>
<td>Regrinding</td>
<td>96</td>
</tr>
<tr>
<td>MIM Ernest Henry</td>
<td>VTM-1250-WB</td>
<td>Copper ore</td>
<td>45</td>
<td>155</td>
<td>Regrinding</td>
<td>97</td>
</tr>
<tr>
<td>Newcrest Cadia</td>
<td>VTM-650-WB</td>
<td>Gold ore</td>
<td>53</td>
<td>54</td>
<td>Regrinding</td>
<td>97</td>
</tr>
<tr>
<td>Wanadium Australia</td>
<td>VTM-800-WB</td>
<td>Magnetite</td>
<td>75</td>
<td>67</td>
<td>Regrinding</td>
<td>99</td>
</tr>
<tr>
<td>Worsley Alumina</td>
<td>VTM-300-WB</td>
<td>Lime Slaking</td>
<td>45</td>
<td>18</td>
<td>Slaking</td>
<td>99</td>
</tr>
</tbody>
</table>

As can be seen from Table 1, majority of Verti mills working in regrinding duties achieving sizes as fine as 80% passing 15 μm. The most commonly used grinding media in regrinding duties is ½ inch diameter chrome steel balls and 10mm mild steel cylpebs media. For coarser grinding applications larger media is required [6].

4. Isamill

Development of ISAMILL (Fig. 3) started in 1990 between Mount Isa Mines Limited and NETZCH – Feinmahltechnik GmbH. At that time the largest horizontal stirred mill was 500 litre in volume manufactured by NETZCH and a sequence of mechanical modifications and metallurgical testing was undertaken to design a larger mill, capable of high throughputs, fine product sizing and efficient energy utilization (Enderle et all, 1997). As the result of this development, a 3000 litre and 1.1 MW motor power unit was designed and installed first in Mount Isa Mines lead/zinc concentrator
(1994, two mills) and then at McArtur River Mining (1995, five mills). This year six more mills will be installed at Mount Isa Mines lead/zinc concentrator. The summary of the ISAMILL performance is given in Table 2.

It can be seen from Table 2 that very fine products can be produced using ISAMILL at relatively low energy consumption. It should be noted that this finess of grind is far bellow conventional minerals processing experience. Being able to achieve such as fine product at an economic level opens the door for processing deposits that were considered in the past as "untreatable".

Table 2. Summary of the ISAMILL operating parameters at Mount Isa and McArtur river sites - (After Enderle et all, 1997).

<table>
<thead>
<tr>
<th>Site</th>
<th>Solids Flowrate (t/h)</th>
<th>% Solids by weight</th>
<th>Net energy (kWh/t)</th>
<th>Product temperature</th>
<th>80% passing size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mount Isa</td>
<td>65</td>
<td>40</td>
<td>7.6</td>
<td>40-45</td>
<td>20</td>
</tr>
<tr>
<td>McArtur River - Open circuit</td>
<td>20</td>
<td>20</td>
<td>28</td>
<td>40-50</td>
<td>30</td>
</tr>
<tr>
<td>- Closed circuit</td>
<td>15</td>
<td>20</td>
<td>36</td>
<td>40-50</td>
<td>30</td>
</tr>
</tbody>
</table>

It should be noted that high rotating speed of the discs inside the mill generate high wear conditions and to increase the component life for any giving grinding media, the optimum balance between the resilience and tear
Letters to Editor

resistance must be determined. At present, maintenance period for McArtur river site is 8 weeks and for Mount Isa operation, 10 weeks. Grinding media used is granulated slag from the lead smelter at Mount Isa and screened ore at McArtur river [5, 6].

5. English China clay (ECC) mill

ECC International developed its first mill in the 1960s and currently around 200 mills operate in the kaolin and calcium carbonate processing plants (Fig. 4.). The first installation in Australia was at Elura lead/zinc mine where two mills are in operation. Recently 15 ECC mills were installed at Century zinc mine concentrator for zinc rougher concentrate grinding down to $P_{80} = 7 \mu m$.

![Diagram of ECC mill](image)

**Fig. 4.** Drawing of top screen ECC mill.

The mill consists of an octagonal body which supports suspended internal multi-armed impeller. Mill feed slurry is introduced through the top
and the ground product lives through grinding media retention screens which can be situated around the top or at the base of the mill body. Mills with the top screen arrangement are normally utilized for low energy input applications, below 100 kWh/t, while "bottom" screen arrangement is used in applications over 100 kWh/t. Top screen mills have installed 185 kW motor, while bottom screen have 355 kW motor. Silica sand is commonly used as grinding media and media size depends on the product size. Use of other natural materials is also possible.

6. Conclusion

A number of fine grinding stirred mills are being used in the Australian minerals industry for beneficiation of fine grained ores base metals ores. These mills have superior performance compared to conventional ball mills and demand is growing rapidly. Application of Tower and Verti mills become "routine" in recent years as they were proven to have exceptional operational performance for product sizes down to 20 μm. For finer products mills using "natural" grinding media (silica sand, granulated slag etc) were found to be more energy efficient. These mills (ISAMILL, ECC mills) were adopted from other industries and developed to suit minerals processing requirements. Application of this mills has enabled very rich but very fine grained deposits (Century zinc, McArtur river, George Fisher) to be economically treated and based on these experiences other companies are becoming increasingly aware of this new technology. The era of fine grinding mills application in minerals industry has just started and the best is yet to come.

References


