Optimization of Comminution Circuit Throughput and Product Size Distribution by Simulation and Control

Quarterly Technical Process Report

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Authors: S. K. Kawatra – Principal Investigator
T. C. Eisele – Engineer/Scientist
H.J. Walqui – Graduate Student

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Submitting Organization

Department of Chemical Engineering
Michigan Technological University
1400 Townsend Drive
Houghton, Mi 49931 - 1295

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Abstract

The goal of this project is to improve energy efficiency of industrial crushing and grinding operations (comminution). Mathematical models of the comminution process are being used to study methods for optimizing he product size distribution, so that the amount of excessively fine material produced can be minimized. This will save energy by reducing the amount of material that is ground below the target size, and will also reduce the quantity of materials wasted as "slimes" that are too fine to be useful. This will be accomplished by: (1) modeling alternative circuit arrangements to determine methods for minimizing overgrinding, and (2) determining whether new technologies, such as high-pressure roll crushing, can be used to alter particle breakage behavior to minimize fines production.

In the seventh quarter of this project, analysis of the plant operation identified sources of overgrinding in the circuit. Overgrinding was primarily caused by two effects: (1) The hydrocyclones used to close the circuit and remove fully-ground particles from the circuit were preferentially returning high-density ore particles to the secondary mills for regrinding even after they were already ground to pass the desired product size, and (2) The primary grinding mills were operating at less than full capacity, suggesting that a shift of grinding load to the primary mills could liberate more material before it reached the secondary mills, allowing more complete liberation with a coarser grind. Circuit modeling is underway to determine how best to modify the circuit to reduce these effects.

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Introduction

When grinding iron ore to liberation size, many of the iron oxide particles are ground beyond the size where they are liberated from the silicate grains. This overgrinding of the mineral grains is a significant waste of energy. In order to increase the energy efficiency, this excess grinding must be prevented. The objective of this project is therefore to sample and simulate a full-scale iron ore processing plant to determine methods for increasing grinding circuit energy efficiency by minimizing overgrinding.

Executive Summary

The goal of this project is to use comminution modeling to study methods for optimizing the product size distribution, so that the amount of excessively fine material produced can be minimized. This will be accomplished by (1) modeling alternative circuit arrangements to determine methods for minimizing overgrinding, and (2) determining whether new technologies, such as high-pressure roll crushing, can be used to alter particle breakage behavior to minimize fines production.

In the previous quarters, analysis of plant samples showed that fine liberated material that should have reported to the overflow instead reported to the underflow and was reground. This is a major source of energy inefficiency in the grinding process. If the magnetite rich fine fraction of the underflow could be recovered before reaching the pebble mill, it would not be overground. The benefits of this would be improved energy efficiency due to reduction in the amount of energy wasted on grinding liberated particles, and increased circuit capacity proportional to the reduction of the amount of material overground. Modeling of the circuit is critical for determining methods for overcoming this problem.

During the current quarter, the results of plant sampling and modeling were used to determine whether modifications at points other than the hydrocyclone could allow the magnetite rich fine fraction of the ore to be ground and liberated before reaching the pebble mill. The benefits of this would be improved energy efficiency due to reduction in the amount of energy wasted on grinding liberated particles, and increased circuit capacity due to more complete utilization of the primary grinding mill capacity.

Experimental

Based on sampling results from previous quarters, it was determined that the primary grinding mills were operating below capacity, and the overall grinding circuit capacity was limited by the secondary grinding mills. This was a result of changes to the circuit that had improved the effectiveness of the primary comminution stage. One potential approach to improving the circuit capacity is therefore to increase the amount of grinding that is done by the primary grinding mill. Sampling results were therefore examined to determine whether it would be practical to use a screen to remove the coarser fractions of the secondary mill feed, and return it to the primary mill to be ground there. This would have two benefits: (1) the grinding load could be more evenly distributed between the primary and secondary mills, so that the secondary mills would no longer be the limiting factor in the capacity; and (2) a larger fraction of the ore would be completely ground and liberated without having to pass through the secondary mill, which is expected to reduce the amount of overgrinding.

The current flowsheet, in simplified form, is shown in Figure 1.

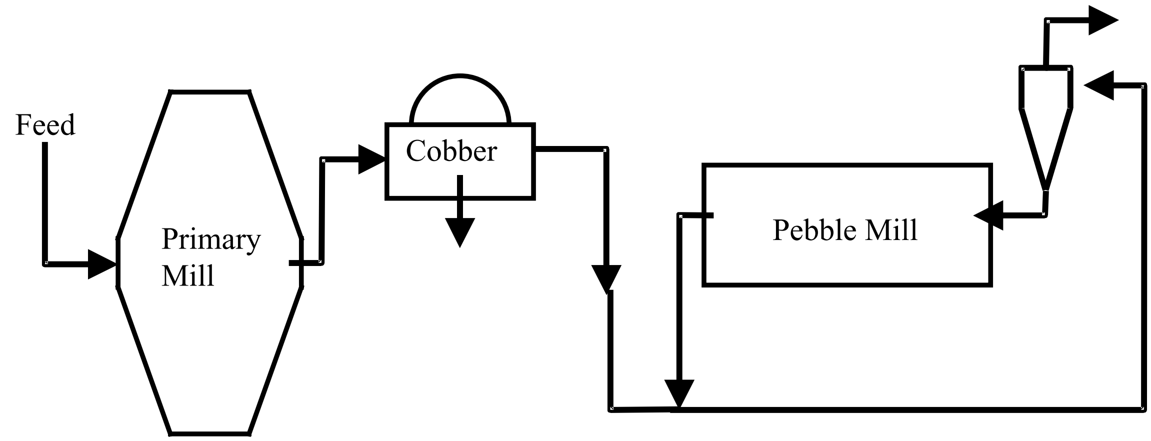

Figure 1: Current flowsheet. All of the product from the primary mill is processed by a cobber (a magnetic separator) to remove liberated gangue minerals. Only locked magnetite/gangue particles and liberated magnetite are sent to the secondary pebble mill for further grinding.

From previous sampling campaigns, the data in Tables 1 and 2, and Figure 2, is available.

Table 1: Flows estimated for the cobber concentrate stream to a single pebble mill, from the circuit mass-balance based on nine grinding circuit sample sets.

	Average	**Average**	**Stdev**	**Stdev**
	LTPHr	**GPM**	**LTPHr**	**GPM**
Dry Solids	120.4	136.8	8.7	10.7
% Solids (by wt)	52.5		2.9	
Sp.Gr. of Solids	3.9		0.1	
Water Flow	109.5	489.8	14.3	64.1
Slurry flow	229.8	626.6	20.3	70.1

Table 2: Average size distribution for the Cobber concentrate produced by the grinding circuit.

Size		Average	Average	Stdev	Stdev
Mesh	Microns	Ind % ret	Cum % passing	Ind % ret	Cum % passing
8	2360	-	100.00	0.00	0.00
10	1700	0.13	99.87	0.02	0.02
14	1180	2.44	97.43	0.11	0.11
20	850	5.83	91.60	0.32	0.43
28	600	7.68	83.92	0.17	0.44
35	425	8.41	75.51	0.06	0.48
48	300	7.96	67.55	0.14	0.60
65	212	7.10	60.45	0.05	0.61
100	150	7.14	53.30	0.12	0.71
150	103	5.67	47.63	0.06	0.74
200	75	4.86	42.78	0.19	0.65
270	53	4.63	38.14	0.14	0.78
325	44	2.24	35.90	0.17	0.74
400	38	2.39	33.52	0.13	0.72
500	25	4.16	29.36	0.22	0.76
-500	15	29.36		0.74	0.20

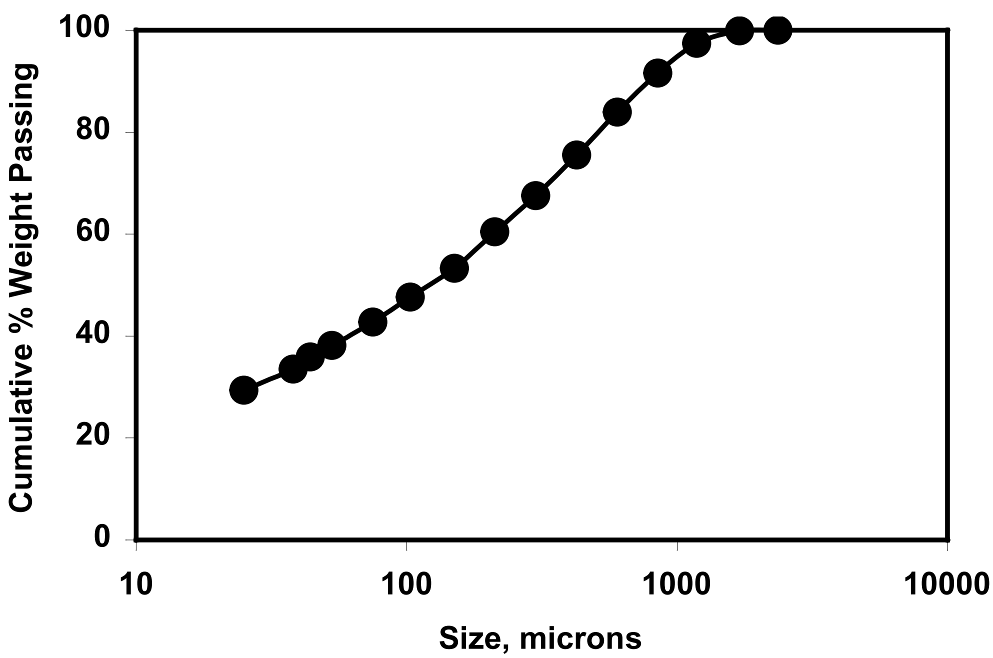

Figure 2: Size distribution of cobber concentrate, averaged from four samples.

Results and Discussion

From these size distributions, it can be seen that, for example, a screen as coarse as 48 mesh (300 microns) could return 32.46% of the total mass of the cobber concentrate to the primary mill rather than allowing it to go on to the pebble mill. The pebble mill would no longer be the bottleneck in the grinding circuit, and the circuit capacity could then be increased. A screen of this size would be easy to maintain compared to the very fine screens that have been considered in the past, and would have a relatively high capacity. Also, by screening just the cobber concentrate, it would be possible to avoid having the screen be overloaded by the circulating load in the pebble mill.

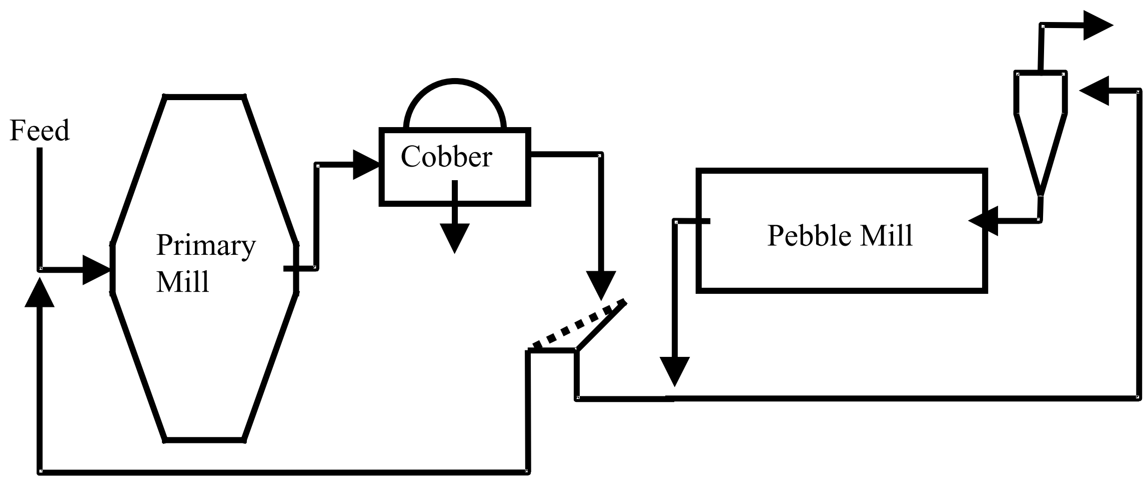

Figure 3: Modification to basic grinding flowsheet to allow a portion of the grinding load to be shifted from the secondary pebble mill to the primary mill.

Another likely benefit is that the coarser fraction of the cobber concentrate, which is expected to consist mainly of locked particles, will be reground and recirculated through the cobber, which would increase the quantity of gangue that could be rejected prior to the pebble mill.

Conclusions

Examination of data collected from a grinding circuit showed that there was an imbalance in the distribution of grinding energy between the primary mills and the secondary mills. This was resulting in the capacity of the overall circuit being restricted by the secondary mill capacity.

Based on the size distributions of material at various parts of the circuit, it is expected that screening a portion of the cobber concentrate and returning the coarse fraction to the primary mill will shift grinding load from the secondary mills to the primary mills. This will have the benefits of increasing the overall circuit capacity; liberating and rejecting a larger fraction of the gangue minerals before they reach the secondary mill; and allowing a larger fraction of the ore to be sufficiently ground that it can bypass the secondary mill altogether, reducing the opportunity for overgrinding.

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