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The link between operational practices and specific energy consumption in metal ore milling plants – Ontario experiences

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ABSTRACT

An energy audit was conducted on a base metal milling facility where a top-down, bottom-up approach was presented to balance data measurements and estimates. The relation between throughput and specific electricity consumption, presented as a part-load efficiency curve for a milling operation, was established from the audit data. Unsurprisingly, the most efficient use of electricity occurred when the mill was operating at design capacity, but a survey of 14 metal mills operating in Ontario showed that 12 were operated under design capacity during 2012. For base metal flotation mills, 16–36% electricity cost savings could be realized by modification to the operating schedule, which would ensure that these facilities operated at design capacity even if plant operation was intermittent. With the Ontario electricity tariff arrangements, additional cost savings from strategic scheduling could reduce demand during coincident peak hours, which could provide financial benefit to these milling facilities.

1. Introduction

With milling costs representing 43–45% of total costs for a mining operation (Curry et al., 2014), mills present an excellent opportunity for managing expenditures within the mining sector. It was also reported that in a mineral processing plant, comminution energy consumption may correspond to as much as 60% of total energy (Sayadi et al., 2014), which provides incentive to improve efficiencies in these plants. As efficiencies for comminution processes correspond to 1–2% and grinding at 2–3% (Sadrai et al., 2011), there appears to be significant room for improvement. Methods for improving efficiencies in milling have been investigated and a summary illustrating the various research areas was presented in Curry et al. (2014). These included: pre-concentration, more efficient grinding technologies, and coarse particle separation.

In 2008, an energy audit was conducted at Vale's Clarabelle Mill by Byron Landry & Associates in order to identify potential energy savings (Landry, 2009), precipitated by rising energy costs and market conditions. A review of this work was undertaken to gain a better understanding of energy use in mineral processing facilities and to determine whether additional energy and cost savings existed at Clarabelle Mill. Furthermore, an analysis was conducted for the 2012 census year to determine potential cost savings that could arise due to a revised Ontario billing rate structure, implemented in 2011. The analysis was also extended to other metal ore milling facilities operating in Ontario to determine the possible savings that could be achieved across the industry.

2. Clarabelle Mill flowsheet and process description

Clarabelle Mill has been in operation since 1971 (Pickett et al., 1978) and processes ore from various Vale and QuadraFNX mines (now KGHM International) (Barrette et al., 2012). Flowsheet design and modifications have been described in various books, journal and conference publications (Pickett et al., 1978; Tenbergen and Throssell, 1989; Damjanovic, Goode & Canadian Institute of Mining, Metallurgy and Petroleum, 2000; Xu and Wilson, 2000; Kerr et al., 2003; Doucet et al., 2010; Barrette et al., 2012). The process flowsheet in place at the time of the 2008 energy audit consisted of a comminution stage followed by a flotation circuit.

A simplified illustration of the comminution circuit, produced from the aforementioned sources, is presented in Fig. 1 whereas the flotation circuit is illustrated in Fig. 2.

The comminution stage comprised two routes: a SAG mill circuit, and a crushing and grinding circuit, controlled by an Expert Grinding Control System. Throughput was maximized through the SAG circuit, which can process half of the ore based on total

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mill design capacity. When throughput exceeded the SAG capacity, ore was processed via the alternate crushing and grinding circuit. The crushing and grinding is performed by four lines of standard and shorthead crushers followed by two rod mills (Damjanovic, Goode & Canadian Institute of Mining, Metallurgy and Petroleum, 2000; Kerr et al., 2003). Subsequently, the ore from both circuits is fed to five ball mills, which are equipped with cyclones, where the cyclone overflow is pumped to the magnetic separation stage of the mill.

Once the magnetic and non-magnetic fractions are divided, various flotation circuits further separate the minerals from the waste. The result is the production of a copper concentrate which is sold to market and a bulk nickel concentrate which is fed to a smelter for further refining (Lawson and Xu, 2011).

Lawson and Xu (2011) stated that after 2008, the ball mills were removed from the non-magnetic flotation stages; the 1500 kW ball mill was moved to the comminution circuit whereas the 750 kW ball mill was damaged and thus retired from operation. Although the flowsheets between 2008 and 2012 differed, the equipment used at the facility was the same with the exception of the 750 kW ball mill in the latter year. It is estimated that the impact of this difference is negligible for the purpose of the energy analysis because the retired ball mill demand corresponded to less than 5% of the plant total demand.

3. Electricity audit

In 2008, a significant amount of effort was applied from Landry and Vale personnel to collect the data for the Clarabelle Mill audit. The dataset consisted of historical values retrieved from the company's PI system, which allowed calculation of electricity use for each piece of equipment, on an hourly basis for the entire year. The data was organized into 12 equipment categories which included: SAG mill, Ball mills, Rod mills, Crushers, Agitators, Pumps, Blowers, Compressors, Fans, Conveyors, Heat trace, and Misc. process. The collated values consisted of: energy (kW h), current (Amps) or run time (hours). Subsequently, the non-energy data was converted to energy units and the hourly values were summed to obtain annual consumption for each piece of equipment.

Detailed data analysis ensued, as part of the energy audit process, to examine areas for potential savings. The following ten opportunities for reducing electricity consumption at the plant by 5% were identified, with payback periods ranging from zero to nine years (Landry, 2009):

- Optimize blower operating sequence to maximize use of more efficient units.
- Minimize idling of conveyors.
- Utilize process control measures on main sumps.
- Refine SAG mill process control system.
- Reduce compressed air leaks.
- Implement motor rewind and replacement strategy.
- Optimize amount of water use in the crushing section of the plant.
- Replace existing light fixtures with more efficient units.
- Exploit energy in tailings pond discharge with installation of micro-hydro turbine.
- Replace fluid coupling pump drives with more efficient variable frequency drives.

All of the aforementioned measures were considered as good candidates from an energy management standpoint, where implementation could deliver electricity savings. Subsequently, a review of the audit was conducted to gain a better understanding of how electricity is consumed in a mineral processing facility and to possibly identify additional energy savings.

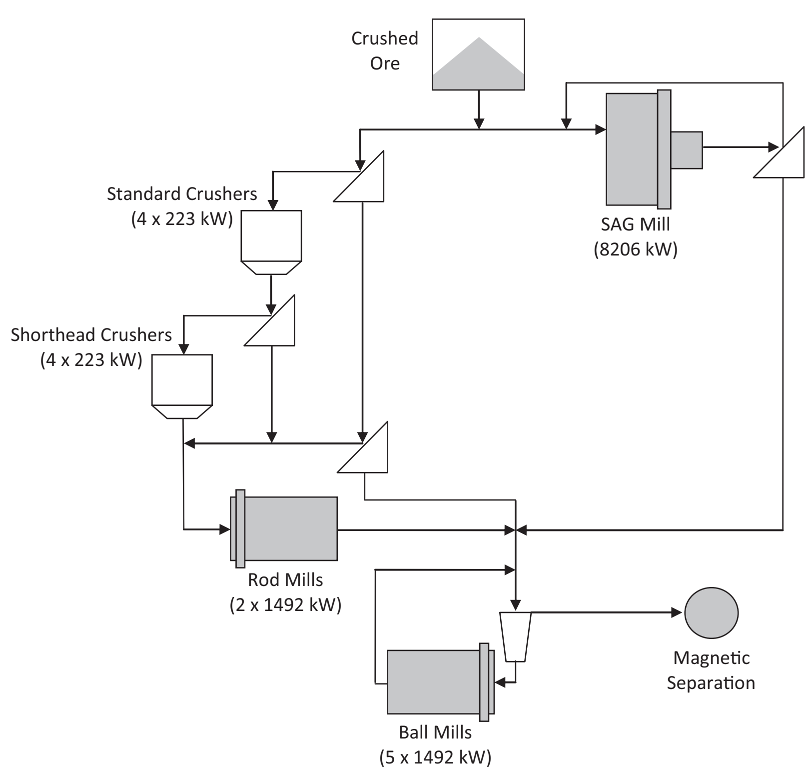

Fig. 1. Comminution circuit flowsheet in 2008.