Minerals Engineering 21 (2008) 826–831

Contents lists available at ScienceDirect

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

Mass balance and mineralogical analysis of flotation plant survey samples to improve plant metallurgy

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ARTICLE INFO

Article history:
Received 13 December 2007
Accepted 25 May 2008
Available online 11 July 2008

Keywords:
Flotation depressants
Liberation
Mass balance
Ore mineralogy
Particle size

ABSTRACT

A comprehensive plant survey was conducted in the flotation circuits at Vale Inco's Thompson Mill. Results from the survey were validated by internal and external references.

The Mill was operating with a feed of 1.8% Ni during the survey. A Ni concentrate assaying 13.8% Ni was produced at a Ni recovery of 84.9%. An additional 1.5% Ni recovery was achieved in the Cu concentrate, giving an overall Ni recovery of 86.4%. The Ni loss to the scavenger tails and scavenger cleaner tails was 6.5% and 7.1%, respectively.

Chemical analysis and mass balance revealed the major diluent of the Ni concentrate and the main source of the diluent. A size-by-size mass balance identified the sources (streams and size fractions) of Ni losses. A mineralogical analysis using an MLA revealed the forms of lost Ni in terms of liberated versus locked particles, and in the case of locked particles, the mineral components that formed composite particles with pentlandite.

The information gained from the above analyses has been used to develop a research strategy. Preliminary laboratory flotation tests on increasing Ni concentrate grade have produced promising results. More detailed and systematic experimental studies will follow.

1. Introduction

Vale Inco's Thompson Mill, located in northern Manitoba, Canada, processes a blend of ores from the Thompson and Birchtree Mines. The Thompson ore is from a massive sulphide ore body hosted in schist, quartzite and skarn rocks with very little ultramafic rock association. The Birchtree ore is also from a massive sulphide ore body but surrounded by peridotite and schist. It contains a significant amount of magnesium silicates such as serpentine, chlorite, amphibole and talc.

Due to the very different mineralogy of the two ores, the Mill used to process Thompson ore and Birchtree ore separately, switching between the two ores about every 12 h. This caused significant instability of the circuit. In 2003, the Mill started a separate grinding–combined flotation flowsheet. This not only avoided process upset during switch over, but provided the smelter with more consistent feed as well.

In late 2005, due to changes in throughput and mining plan, the two ores had to be ground together. This, though simplifying the operation, caused other process difficulties. The Thompson ore requires a grind size of 80% passing 220 μm (P_{80}) while the Birchtree ore requires a grind size (P_{80}) of 130 μm. These target grind sizes were determined in laboratory grinding–flotation tests. They can also be determined by mineralogical analysis such as the work by Fragomeni et al. (2005). Grinding the two ores together in a single grinding circuit cannot meet the grind size requirements of both ores at the same time. The consequence of this is a reduction in Ni concentrate grade and recovery.

Requirements to reduce SO_2 emissions and energy consumption at the Thompson nickel smelter necessitated an increase in nickel concentrate grade from typically less than 15 to 18%, while maintaining MgO grade below 3% (Muinonen, 2006). Increasing the concentrate grade is normally accompanied by a reduction in the recovery of values. Therefore the Thompson Mill was facing the challenge of increasing the Ni concentrate grade while minimizing the decrease in Ni recovery.

A plant survey was conducted in 2006 in order to identify opportunities for improving Ni concentrate grade while maintaining acceptable Ni recovery. A size-by-size mass balance and mineral liberation analysis were conducted. The information obtained from the above analyses has been used to identify:

(1) The main diluents in the Ni concentrate.
(2) The streams, size fractions and the forms (liberated or locked) in which Ni was lost.

The ultimate objective is to develop a modified flowsheet with operating conditions for Thompson Mill to improve metallurgy, i.e., to produce a high-grade Ni concentrate at maximum Ni recovery.

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doi:10.1016/j.mineng.2008.05.008

This paper summarizes the information obtained from the survey and how the information is being used to improve Mill metallurgy.

2. Mill flowsheet, sampling and Ni mass balance

A simplified format of Thompson Mill flowsheet is shown in Fig. 1. Two concentrates are produced in the Mill. The Cu cleaner concentrate is the only source of the Cu concentrate. The Ni concentrate is a combination of three streams, i.e., the Cu rougher tails, the Cu cleaner tails and the scavenger recleaner concentrate, with the Cu rougher tails comprising about 80% of the Ni concentrate. The Mill produces two tails, namely, the scavenger tails and scavenger cleaner tails. The two tails streams are combined and report to the tailings pond.

An extensive discussion on the theory and practice of sampling was published by Lotter and Laplante (2005, 2007). Normal best practice was observed during this survey. The Mill was operated at a feed rate of 300 t/h, with a 50:50 ratio between Thompson ore and Birchtree during the survey. The stability of the feed rate and metallurgy during the sampling periods was confirmed by readings on an on-line Illuminator system.

Five sets of samples were taken from 17 streams during the survey. Each set of samples was taken over a 3–3.5 h period (the Mill retention time is about 2.5 h). One cut was made every 0.5 h so that each sample was a composite of 7 or 8 cuts. The mass of each sample was arbitrary but much more than the minimum sample mass determined by Gy's model (Pitard, 1993).

Each of the five sets of samples were assayed by ICP and mass-balanced using the BILMAT program. A modified Z-score method (Yu et al., 2004) was used to compare the five sets of mass balance data and to identify outliers. The median and deviation of the five sets of data were used as an internal reference. The percentages of data points identified as outliers were 7.1%, 4.0%, 2.1%, 3.0% and 14.7% respectively for samples Set 1–Set 5. An arbitrary value of 10% was used as a criterion by which Set 5 was defined as an outlier.

Mill production data around the survey period (3 weeks before and 3 weeks after the survey) were used as an external reference to test the validity of the samples. During the reference period, the feed to the Mill was known to be typical blended Thompson–Birchtree ore with an average Ni head grade of 1.81% and a standard deviation of 0.14%. Set 5 again was identified an outlier while the other four sets of samples were within the range of variation in plant metallurgical results for the reference period. Set 5 was therefore eliminated in further analysis. The other four sets of samples were combined for more detailed analyses. All results published in this paper are from analyses of the combined samples. A mass balance of the combined four sets of samples indicated that the Ni grade of the Mill feed, the Cu concentrate and the scavenger tails was within the average plus/minus one standard deviation of the plant production data during the reference period and the Ni grade of the Ni concentrate and the scavenger cleaner tails was within the average plus/minus two standard deviations. The relative error for Ni between the four sets of samples was between 5% and 10%, depending on the stream.

The nickel mass balance during the survey is also shown in Fig. 1. For a feed of 1.82% Ni, a Ni concentrate assaying 13.8% Ni was produced at a Ni recovery of 84.9%. The Ni loss to the scavenger tails and scavenger cleaner tails was 6.5% and 7.1%, respectively.

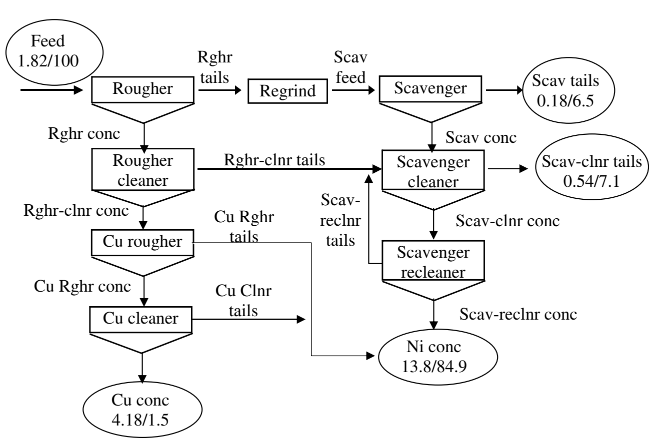

Fig. 1. A simplified illustration Thompson Mill flowsheet. The Ni mass balance among the feed and the four products during the survey is shown as Ni grade/Ni distribution in percent.

3. Particle size distributions of various streams

A complete size analysis, consisting of wet screening–dry screening–cyclosizing, was conducted on each stream of the combined samples. All size fractions were submitted for chemical assays. The assay results were used to calculate the distributions of Cu, Ni and their sulphide minerals on a size-by-size basis. It was found that the particle size distributions of sulphide minerals were always finer than those of the entire solids for all streams. The P_{80} of sulphides and entire solids for all streams are shown in Table 1. The finer particle sizes of sulphide minerals are primarily due to their higher specific gravity compared with that of non-sulphide minerals such that fine sulphide particles tend to deport to hydrocyclone underflow and are re-circulated for repeated grinding.

4. Ni size-by-size recovery

The size-by-size recoveries of Ni in the four products are shown in Fig. 2. Ni recovery to the Ni concentrate decreased noticeably in the −C5 fraction (−8 μm) and particularly in the +150 μm fractions. The low Ni recovery to the Ni concentrate was accompanied by high Ni losses to both tails streams. For the +150 μm fractions, the Ni recovery to the Ni concentrate was only 43.6% while the Ni loss to the scavenger tails and scavenger cleaner tails were 43.4% and 12.3% respectively.

Ni recovery to the Cu concentrate was very low throughout the entire particle size range. However, due to the very small amount of the Cu concentrate produced (0.6% mass recovery), even a very low Ni deportment to this product caused a high Ni grade of the Cu concentrate (>4%).

Table 1
A comparison of P80 (μm) of entire solids with that of sulphides

Stream	Entire solids	Sulphides
Rougher feed	176	96
Rougher concentrate	104	84
Rougher tails	194	131
Scavenger feed	173	105
Scavenger concentrate	119	80
Scavenger tails	171	104
Rougher cleaner concentrate	86	78
Rougher cleaner tails	102	69
Scavenger cleaner concentrate	84	71
Scavenger cleaner tails	109	71
Scavenger recleaner concentrate	126	102
Cu rougher concentrate	88	65
Cu rougher tails	84	78
Cu cleaner tails	92	60
Cu concentrate	87	75
Ni concentrate	92	78