PROCESS OPTIMISATION OF MIXED COPPER ORES THROUGH REAL-TIME MINERALOGICAL ANALYSES

Paquot, F.X.[*], K. Keet[**] & Mumbi, M.[*]

[*] Kansanshi Copper Mines, First Quantum Minerals, Zambia

[**] Blue Cube Systems (Pty) Ltd., South Africa

ABSTRACT

Open cast mining on the Zambian Copperbelt is challenged with transitional zones containing both copper sulphides and copper oxides. Depending on the degree of oxidation and consumption of acid by gangue minerals, these mixed ores are either treated through standard sulphide flotation, sulphidisation or flotation followed by acid leaching. The performance of each of these process routes depends on the degree of oxidation as predicted by the proportion of acid soluble copper present in the ore. Process parameters must be aligned to optimize the recovery and grade profile. This can only be achieved with the availability of reliable real-time data. On-line analysers based on XRF are limited to certain elemental analyses and cannot differentiate between mineral species. A technique based on diffuse reflective spectroscopy has recently been introduced at Kansanshi Copper Mines. The method matches optical data to analytical results and can successfully analyse total copper (TCu), acid soluble copper (ASCu), sulfur and iron. Analysers were installed on the feed, concentrate and tails lines and provide data at 15 second intervals. This is a first in the Zambian base metals industry and is aimed at optimising the recovery of copper in the flotation circuit.

1. Background

It was documented by Morse[1] in 1922 that many of the largest copper deposits contain both sulphide and oxidised copper minerals. Ninety years later ore complexity is still challenging metallurgists when attempting plant-specific process optimisation.

When optimising a process there are three critical factors to keep in mind.

Firstly, data should be available at short turnaround times to ensure relevance. Controlling a process on outdated results has no benefits.

Secondly the sample frequency should be sufficient to combat aliasing (Du Plessis and Keet, 2010)[2] when using the data for process control.

Thirdly, the correct components must be analysed to enable relevant process changes. In the case of a mixed copper ore the main factor affecting the performance is the proportion of acid soluble copper (ASCu) in the feed.

Elemental analysers have the disadvantage that they do not distinguish between the total copper (TCu) and ASCu. An alternative technology based on diffuse reflective spectroscopy that can be used for this purpose have been introduced at Kansanshi Copper Mines.

The technology has successfully been implemented in mineral beneficiation industries in South Africa, Australia, Namibia and Botswana. Kansanshi Copper Mines are the frontiers of this technology in Zambia.

2. Case studies from Kansanshi Copper Mines, Zambia

The variability of the Kansanshi mixed ore in terms of total copper and acid soluble copper grades has a major impact on the flotation recovery. In March 2011, three Blue Cube MQi (in-line mineral quantifier) analysers were installed on the mixed ore flotation feed, concentrate and final tails respectively. A trial was started after the commissioning and calibration of the three units. Approximately 180 samples were collected for the calibration of the three streams. Two case studies evaluating the response of the technology to process changes will be discussed. For confidentiality reasons, the values of the grades are not disclosed.

Case study 1: Response of flotation concentrate to NaHS dosage

Figure 2 illustrates the result of a test that was done to prove the sensitivity of the analysers over a three hour period. The TCu and the ASCu grades of the flotation feed were compared to the TCu in the final tails.

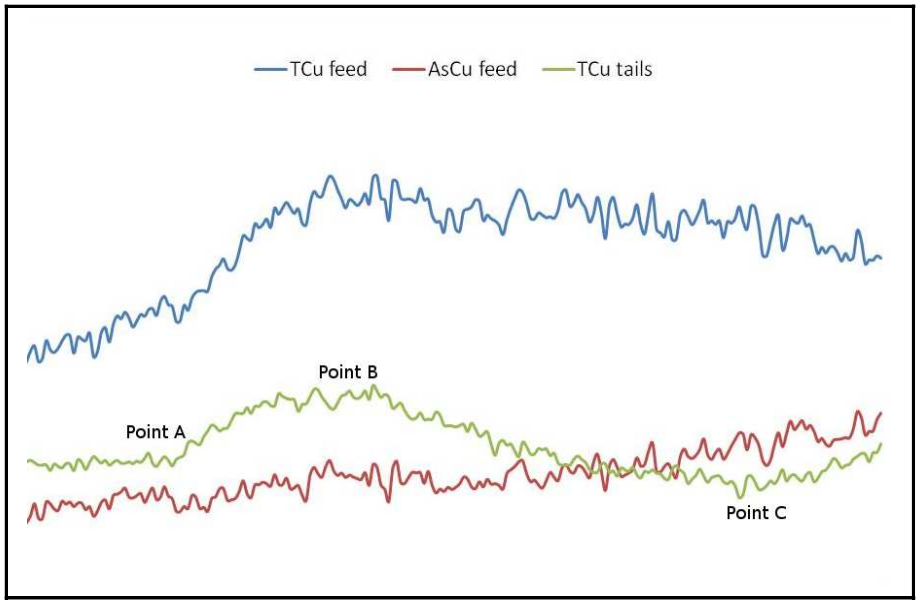

Figure 1: Comparison between %Tcu and %ASCu in the feed with %TCu in the tails

The effect that NaHS has on flotation has been explained by Freeman et al. (2000)[3] as resulphidising the sulpide surfaces which has undergone oxidation prior to reporting to the flotation cells. At point A (40 minutes into the test), the dosing of NaHS was stopped completely. Almost immediately the TCu in the tails increased and reached a maximum at point B (an hour into the test). Directly thereafter, the dosing of NaHS was started again and the TCu in the tails started to reduce despite the fact that the ASCu feed grade was increasing. At point C (75 minutes into the test) TCu in the tails started increasing again because of the continuous increase of the ASCu feed grade without increasing the dosage of NaHS accordingly. This test proved that efficient plant performance optimization will only be achieved through a real-time tool that can differentiate between TCu and ASCu. The effect of changing the dosage of a reagent was immediately captured by the analyser. The TCu tails grade is related to the ASCu feed grade but The ASCu feed grade is not proportional to the TCu feed grade and can fluctuate significantly in a short period.

Case study 2: Investigating the relationship between TCu, ASCu, Fe and S in the flotation feed and tails

Figure 2 illustrates the fluctuation of the TCu, ASCu, iron and sulphur for the mixed ore flotation feed for a period of two days.

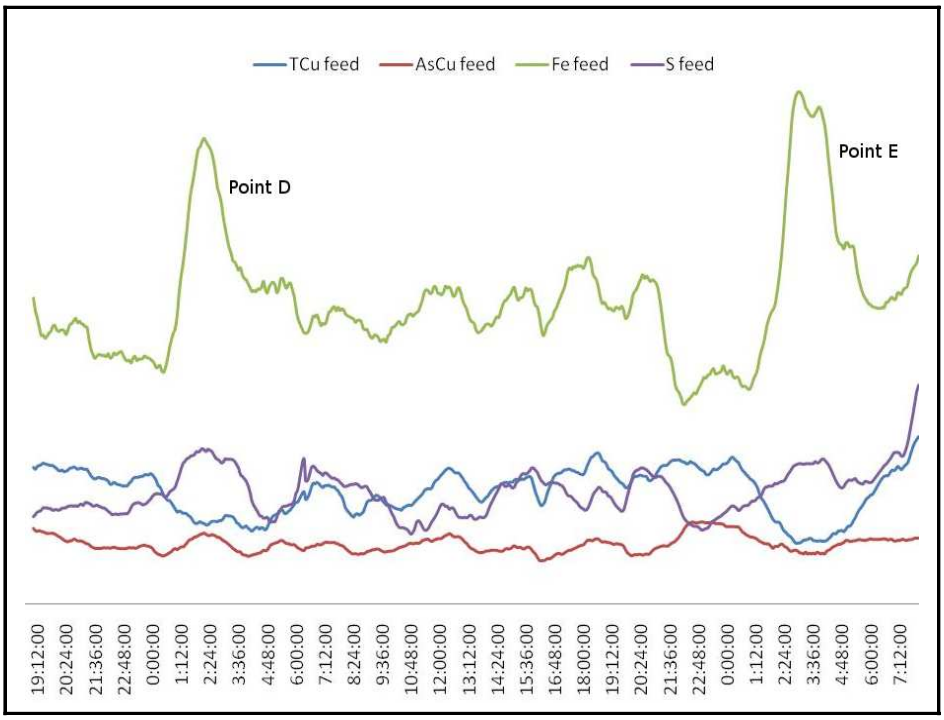

Figure 2: Tcu, ASCu, Fe and sulphur grades in the flotation feed

The TCu feed grade can increase significantly in a couple of hours and the ASCu feed grade is not always related to the TCu feed grade. Two spikes in the iron feed grade are noticeable at around 3:30 for each day (points D and E). A higher proportion of pyrites in the feed caused the high iron grade associated with a higher sulphur grade and lower TCu and ASCu grades. Note that the sulphur and iron feed grade are not always related due to the variable presence of iron oxides in the gangue. It is assumed that the copper is only distributed between Chalcopyrite and Malachite and that the sulphur is distributed between Pyrite and Chalcopyrite. The repartition of the floatable minerals in the feed can henceforth be calculated and are summarised in Table 1.

Table 1: repartition of the floatable minerals in the feed

	Repartition of the floatable minerals		
Time	Chalcopyrite	Malachite	Pyrite
20:00:00	56	29	15
04:00:00	26	21	53
12:00:00	53	28	19
20:00:00	58	18	24
04:00:00	10	20	70

Figure 3 illustrates the fluctuation of the TCu, ASCu, iron and sulphur in the final tails for the same period as illustrated in Figure 2. As expected, the TCu in the tails follows the ASCu in the tails because oxide minerals are the most difficult to recover. The iron tails grade is high because of the presence of iron oxide in the gangue but is not related to the iron feed grade because of the pyrite recovered to the concentrate.

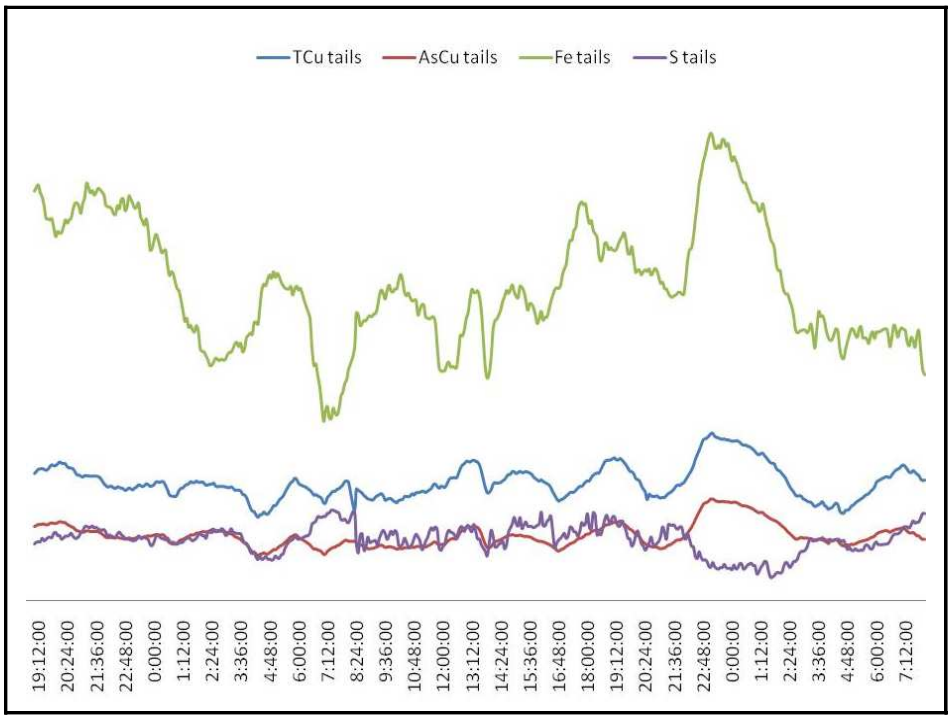

Figure 3: TCu, ASCu, Fe and S tails grade

Figure 4 confirms the strong relationship between the TCu in the tails and the ASCu in the feed as the oxide ore associated ASCu is not recovered through sulphide flotation. Note that the 30 minutes delay between the two trends are due to the residence time through the flotation banks. This clearly indicates the importance of having a real-time analyser that can differentiate between different mineral species.

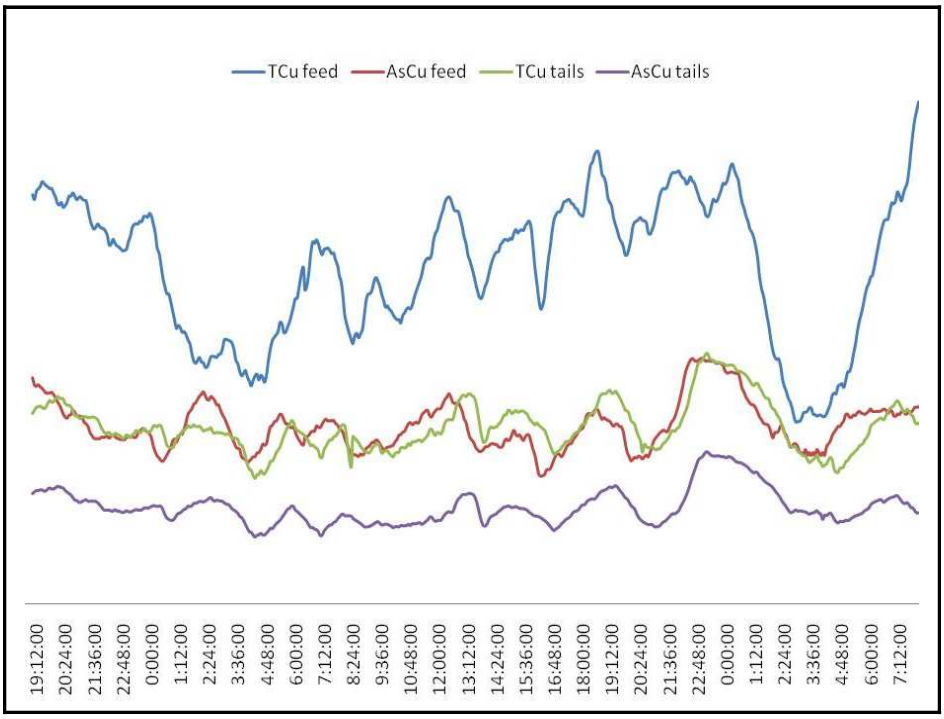

Figure 4: Comparison of the TCu and ASCu tails grade with the TCu and ASCu feed grade

Final comments following case studies

The accuracy of the in-line analysers are highlighted by the similarities between the feed and tail trends despite the fact that the calibrations of the three units are completely independent. The sensitivity of the in-line analyser is proven by its response to changes made to reagent dosages The two case studies proved that the analysers are efficient in-line tools that can successfully differentiate between various mineral species.

3. Conclusions

Mixed copper ores are treated through different processes depending on the degree of oxidation as well as the consumption of acid. With the availability of real-time technology that can reliably measure differences between oxide and sulphide minerals, it is now possible to control a mixed copper ore process.

From case studies done at Kansanshi Copper Mines, it became evident that:

- the effect of changing the dosage of a reagent can immediately be identified through the availability of an in-line measurement of minerals, Fe and S
- The relationship between the TCu and the ASCu in the flotation feed is changing and can only be pro-actively addressed through in-line measurement.

4. References

1. Morse, H.W., *Treatment of Mixed Sulfide-oxide Ores of Copper* (Excerpt from paper read at meeting of San Francisco Section), Mining and Metallurgy, 1922(Sept), pp.15-19.
2. Du Plessis, F.E. And Keet, K., *The Importance of a High Sample Frequency Measurement of Grade to Avoid Aliasing*, IFACMMM2010 Conference Proceedings, Cape Town, 2010.
3. Freeman, W.A., Newell, R. and Quast, K.B., *Effect of grinding media and NaHS on copper recovery at Northparkes mines*, Minerals Engineering, Vol. 13, No. 13, pp.1395-1403, 2000, Elsevier Science Ltd.