The Importance of a High Sample Frequency Measurement of Grade to Avoid Aliasing

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INTRODUCTION

The efficient control of grade and recovery in a mineral beneficiation process requires an adequate sample frequency of grade measurement. According to Bartlett (2002), the grade of flotation concentrate varies considerably over a short time span and Haavisto (2009), confirmed that these changes are only revealed through high-frequency slurry analysis.

RAPID IN-LINE GRADE MEASUREMENT

Blue Cube Systems (Pty) Ltd ('BCS') has developed a technique for in-line measurement of grade aimed at sampling at a high frequency. The technique is based on diffuse reflective spectroscopy combined with proprietary chemometric methods. A BCS In-line Mineral Quantifier (MQi) was installed in a platinum Rougher concentrate stream. Chrome grade data was collected at a short sampling period of 15 seconds. The objective was to find the minimum rate of sampling that would enable acceptable process control.

FOURIER AND NYQUIST-SHANNON

A Fourier Transform (Figure 1) was used to investigate the frequency components of concern. The cumulative fraction of total signal variance, that is explained by measuring up to a certain frequency, is also shown.

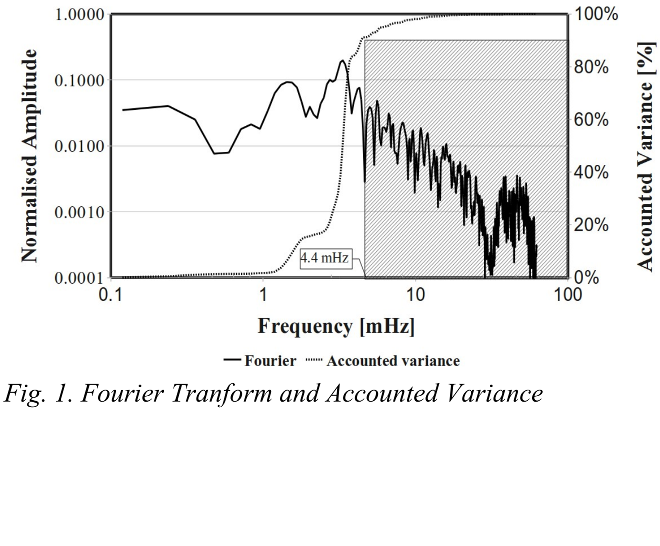

Fig. 1. Fourier Tranform and Accounted Variance

A frequency bandwidth of 4.4 mHz accounts for 90% of the variance in the data.The sampling period corresponding to this frequency is 3.8 minutes.

However, according to the Nyquist-Shannon Sampling Theorem as derived by Shannon (1949), a minimum sampling rate (f_s) of more than twice the highest frequency component (B) within a signal is required to avoid aliasing:

$$f_s > 2B$$

Aliasing can be understood through the wagon-wheel effect or stroboscopic effect, where the motion perception that is created is dependent on the instances of visibility or sampling.

In line with the sampling theorem, a sampling period of shorter than 1.9 minutes (~2 minutes) is therefore required for successful process control of this stream.

MEASUREMENT OF INSTANTANEOUS DATA

When evaluating the instantaneous chrome grade over different sampling periods (Figure 2) the wagon-wheel effect of aliasing becomes clearly visible at a sampling period of 15 minutes.

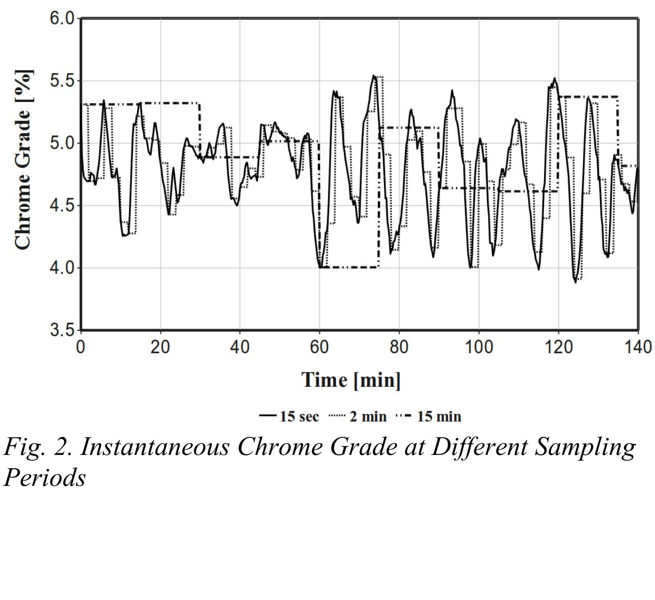

Fig. 2. Instantaneous Chrome Grade at Different Sampling Periods

The slow rate of data acquisition creates the illusion that the grade remains constant over a period, whereas significant changes and oscillations can be seen from the 'real-time' data captured every 15 seconds. At some instances, grade changes are suggested in an opposite direction to actual changes in the process.

This phenomenon is equivalent to the wagon wheel in classic movies where the wheel is perceived as either stationary, moving slower than the actual motion or moving in the opposite direction to reality.

MEASUREMENT OF AVERAGE DATA

Measurements on composite samples accumulated over 15 minutes were also investigated. Here the grade measurement effectively represents an average over the 15 minutes prior to the sampling instant. These averages appear to be closer to the real process and are effective in being used for metal accounting purposes. However, due to the lag involved (Figure 3), the data is not suitable for 'real-time' process control.

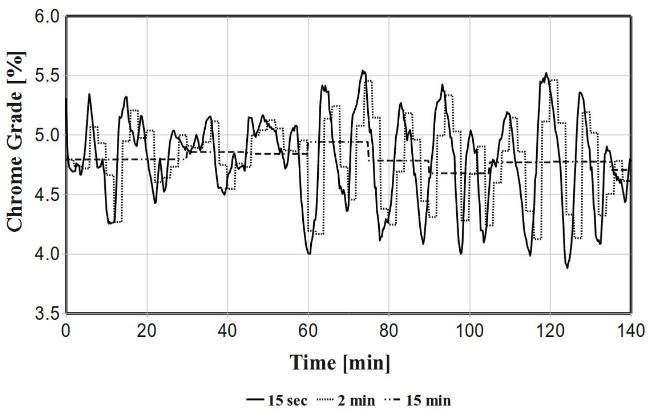

Fig. 3. Averaged Chrome Grade at Different Sampling Periods

CORRELATIONS

The data collected every 15 seconds were compared to the data collected over longer sampling periods (Figure 4). When compared with the continuously sampled data, correlation is lost rapidly between 1 and 4 minutes and after a period of 5 minutes there is no correlation at all.

In the case of the averaged data, between 1 and 3 minutes, the correlation drops off quicker than for the continuous data. This confirms what has been ascribed to lag previously and implies that the sampling period for averaged data should be even shorter to ensure relevancy for process control.

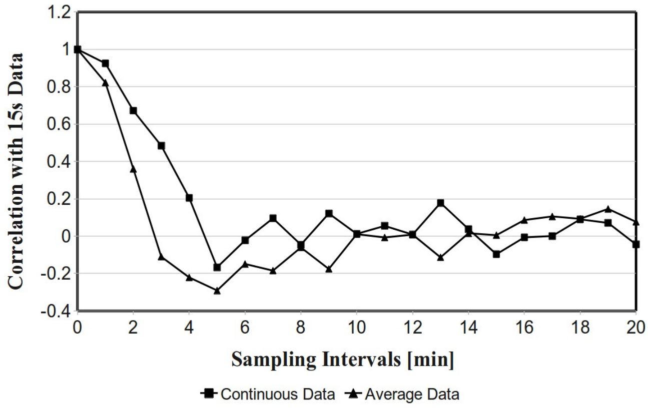

Fig. 4. Correlation Between Data Collected at Various Periods

CONCLUSION

For the case investigated, valid grade measurement required a sampling period shorter than 2 minutes to avoid aliasing. This sampling period accounted for 90% of the variance in the process grade. Any sampling period longer than 4 minutes produced data with no significant correlation to reality and is therefore of zero value to either 'real-time' process control or monitoring.

REFERENCES

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