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X-ray computed tomography: Practical evaluation of beam hardening in iron ore samples

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ABSTRACT

X-ray computed tomography is a non-destructive 3D analytical technique, which in recent years has gained more widespread applications to characterise the internal structure of materials in minerals processing and metallurgical studies. Successful application of the technique relies on effective X-ray penetration. Ore samples with high average specific gravities (e.g. iron ore, massive sulfide ores) inhibit X-Ray penetration causing beam hardening artefacts that reduce data quality and limit further analysis. This contribution presents a practical way to evaluate the degree of beam hardening using a case study iron ore sample. The method quantifies the degree of beam hardening that leads to a loss of sample information, through comparing the known pore surface area of an aluminium standard sample with that of an iron ore sample. This comparison is defined as a %Error. Porosity and sample mineralogy are confidently quantified when the %Error is less than 10%. Above 10%, there is inconsistent loss of sample information (porosity and relatively low dense sample mineralogy) and the results from the volumes cannot be trusted which indicates that smaller sample sizes need to be scanned. This practical method can be routinely applied in other applications and samples with density higher than iron ore.

1. Introduction

The ability to characterise and quantify the internal structure of rocks, minerals, particles, drill core and packed particle beds has made X-ray computed tomography (XCT) an increasingly popular method of 'ore characterisation' within both the geosciences and minerals engineering studies (Cnudde and Boone, 2013; Mees et al., 2003; Wang et al., 2015). Its non-destructive ability to rapidly scan samples, and easily locate dense phases typically representing valuable base metal sulphides, gold and platinum group mineral (PGM) grains, further adds to its attractiveness, especially when dealing with low grade ores (g/t). In addition, the method does not suffer from stereological error which is encountered when measurements are made from 2D particle sections (Evans and Morrison, 2016; Spencer and Sutherland, 2000), for example those routinely prepared for process mineralogy using automated scanning electron microscope with energy dispersive spectrometry (auto SEM-EDS) technologies such as QEMSCAN, MLA, TIMA, and Mineralogic.

Specific uses of XCT with respect to minerals engineering include characterisation and quantification of mineralogy and texture within drill core samples, which is important since it provides an indication of the ore characteristics ahead of mining and processing (Jardine et al., 2018; Lin et al., 2017). This would include quantification of the grain size distribution of valuable minerals that can be used to define the required grinding for liberation (Evans et al., 2015). Following grinding, XCT provides a means of assessing the potential separation efficiency (Lin et al., 2017; Miller et al., 2009). Other applications of XCT in process engineering include the analysis of the distribution of defects within particles after comminution to further understand the mechanisms of particle breakage, as well as differences between comminution devices (Charikinya et al., 2015; Garcia et al., 2009). In leaching studies, XCT has been used to understand leach progression on both the particle scale, as well as through a packed bed (Dhawan et al., 2012; Fagan-Endres et al., 2017; Ghorbani et al., 2011). Possible future applications of XCT could even extend to its use as an online technology for routine characterisation of run of mine ore (Lin et al., 2017).

In all of the above examples, efficient application of the XCT relies on the ability of the X-ray beam to be able to penetrate the sample in order to resolve the internal geometry. This condition is best met when there is a pronounced variation in atomic composition between

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