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Utilization of optical image analysis and automatic texture classification for iron ore particle characterisation

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Abstract

Optical image analysis is a very convenient tool for obtaining comprehensive information about fine iron ore size fractions. Data can be obtained on mineral abundances, porosity, particle shape and ore textures with a high level of accuracy. A range of techniques has been used to characterise iron ore samples on a particle-by-particle basis. Automatic textural classification of iron ore particles was used to establish classes containing particles with very similar mineral composition and texture. Image analysis coupled with probe analysis and mineral density measurements provided information about the chemical composition and density of each particle class. The combination of these results enabled a "virtual feed" to be created, which can be a key input into a beneficiation unit model for predicting its performance. Identification and classification of the textural type of each particle was performed according to the CSIRO-Hamersley Iron Ore Group Classification Scheme. If more detailed classification is needed, further classification can be performed based on dimensional, chemical or mineral criteria, such as the presence of certain minerals in particles or total iron content. Some deficiencies of the current image analysis procedures and their further improvement and automation are also discussed.

Keywords: Iron ores; Mineral processing; Ore mineralogy; Particle morphology; Liberation

1. Introduction

To understand the behaviour of fine iron ores in downstream beneficiation operations or in subsequent processing operations such as granulation and sintering, and to reliably predict such processes, a large amount of information about the ore fines needs to be obtained (Clout, 1998; Donskoi et al., 2006a,b). Generally it should be information about particle mineralogy and class, porosity, mineral associations, texture, hardness, size distribution, mineral liberation, class densities and mineral composition, as well as the molecular composition of each mineral. Combinations of different techniques such as sizing, density classification by heavy liquids, pycnometry, chemical analysis, XRD, probe analysis, microscopy and image analysis can provide the required information.

Determination of the mineralogy of iron ore particles can be carried out by several methods – indirect or direct measurements. Indirect methods usually assume that the minerals in the examined ore are stoichiometric, which is not always the case. Diagnostic leach tests and calculation of mineralogy from assays can be included in this category (Zhang and Whiten, 2001; Benson et al., 2001).

Among the direct techniques are quantitative XRD (e.g. Mandile and Johnson, 1998), optical image analysis (Danti et al., 1993) and automated image analysis using scanning electron microscopy (SEM)-based techniques, such as QemSCAN (Gottlieb et al., 2000) and the Mineral Liberation Analyser (Gu and Guerney, 2000). The advantage of

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using an electron microscope for these purposes is that, together with information about mineral liberation and association, the chemistry of the minerals can be simultaneously provided. However, to distinguish reliably between different iron oxides and hydroxides, the analysis time has to be significantly increased, which may not be economical. Also, determination of closed pores and micro porosity in particles can be problematic if the epoxy used for sample preparation can not penetrate the pores.

Optical image analysis systems are capable of identifying porosity in different minerals and differentiating between various iron ore minerals. This differentiation is based on the distinctive reflectivities of different iron oxides and hydroxides.

The image analysis described in this paper is based on utilization of two software packages: KS400 (ZEISS) and Recognition2 (see also Donskoi and Clout, 2005). KS400 is used for initial image analysis and calculation of a range of parameters for individual particles. Recognition2, developed by CSIRO Minerals, is used for individual classification of every particle according to its iron ore textural group, calculation of information about every textural group and comprehensive characterisation of the entire group of particles. Information about the abundance of different iron ore textural types and their chemical composition is very important for predicting downstream processing performance and product characteristics (Clout, 1998; Box et al., 2002).

The ore texture group identification is performed according to the CSIRO-Hamersley Iron Ore Group Classification Scheme described by Box et al. (2002). Classification by ore textures provides classes of particles with similar mineral composition and density. The reason for this is that mineral abundances and porosity are the main criteria used for particle classification.

Recognition2 also has the option of classifying particles by mineral content or by total iron. The "Selection" procedure in Recognition2 can select particles based on their dimensional, chemical or mineral characteristics. When linked together, these capabilities enable a set of classes with distinct characteristics to be built. This set of classes represents the iron ore size fractions under investigation. If beneficiation modelling is the goal of the characterisation, and if the ore will be used as feed to specific beneficiation units, the full data set of classes is called the "virtual feed". During subsequent modelling, the virtual products can be calculated and compared with the measured properties of actual products using the same procedures as for the feed material.

Information obtained from Recognition2 enables "virtual feeds" to be constructed for feeding into a hydrocyclone model (Donskoi et al., 2006a) implemented within the USIM PAC (©Caspeo/BRGM, France) steady-state plant simulator package. The modelling generates calculated overflow and underflow streams and the abundances of different ore texture groups in these calculated streams. These outputs can then be used as inputs for modelling unit operations following hydrocycloning, such as magnetic separation or flotation.

2. Initial image analysis in KS400

For optical image analysis each sample (size fraction) is mounted in an epoxy resin block, which is polished on one side and image analysed under reflected light (Danti et al., 1993). Images of particle sections (see Fig. 1) are collected using the AxioVision (ZEISS) program, and are further processed using the MINERAL software developed by CSIRO Minerals (Fig. 2). The MINERAL software is based on the KS400 (ZEISS) image analysis package.

Improvement of the quality of the image is the initial stage of image processing within the MINERAL software, where contrast and sharpness improvement as well as further background correction are performed. Background correction is a special procedure which compensates for non-uniform illumination across the image. For this purpose, a reference image has to be obtained, which involves imaging a highly uniform surface without any inclusions or scratches using the same focal length lens and illumination

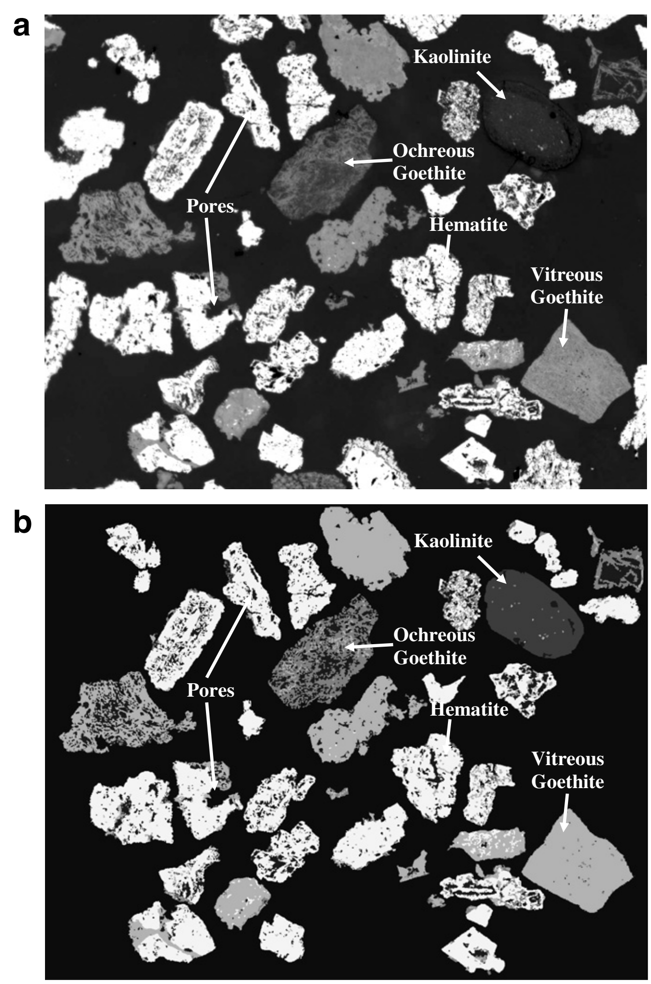

Fig. 1. (a) Original optical image of the −106/+75 μm size fraction of an iron ore sample, (b) mineral map of the image.