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Using mineralogical characterisation and process modelling to simulate the gravity recovery of ferrochrome fines

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ABSTRACT

The recovery of ferrochrome (FeCr) alloy from fine (<600 μm) ferrochrome slag typically involves the use of gravity concentration, amongst other physical separation techniques. This study demonstrates the value of utilising mineralogical methods both to determine alloy composition and liberation and to assist in setting up partition surface models for a shaking table. A Mineral Liberation Analyser (MLA) was used to measure size, density, shape and liberation data of each alloy and mineral in a set of shaking table products. The amount of detailed data gathered by the MLA was sufficient to generate particle tracking analysis (PTA) data in order to simulate the recovery of alloy and mineral phases. Two flowsheet configurations were evaluated to ascertain the possibility of producing a high grade product (>97.5% metal content) comparing shaking table and Reflux Classifier performance. The results of this study show that an approach of using particle characterisation by MLA, coupled with surface partition modelling, may be a useful technique to model gravity separation of fine particles, especially where both valuable and gangue phases contain common elements in their composition.

1. Introduction

In many instances chemical assays per size fraction together with mass flowrate data may be sufficient to model mineral deportment around a minerals processing flowsheet. However, in this instance of evaluating the recovery of variable composition metallics from FeCr slag, both the alloy phases and slag phases present contain common elements. This implies that assays alone are insufficient to distinguish alloy phases either from each other or from the gangue (slag) phases present. This paper demonstrates the use of various forms of mineralogical characterisation data to model individual physical separation processes followed by simulation of an integrated flowsheet.

Chromite (Fe, Mg) (Cr, Al, Fe)$_2O_4$, is the economic mineral of the element chromium (Cr), and is part of the spinel group of minerals. The chromite mineral is theoretically composed of 32.1% FeO and 67.9% Cr_2O_3 and its composition varies with substitution of Mg^{2+} for Fe^{2+} and Al^{3+} and Fe^{3+} for Cr^{3+} content as shown in the chemical formula above. South African chromite mainly occurs in the large layered Bushveld Complex (BC) and is present as a dominant mineral in beds of varying thickness and grades (Mondal and Mathez, 2007). The UG2 chromitite seam and the Merensky Reef are the main platiniferous horizons of the BC and are situated towards the top of the Upper Critical Zone of the Rustenburg Layered Suite (Viljoen and Schürmann, 1998). Chromite is used in the production of ferrochrome as either a lumpy material or a fine concentrate and it is this fine concentrate that is preferentially agglomerated prior to electric arc smelting to produce smelted ferrochrome and slag products (Niemelä and Kauppi, 2007). The chromite content of an ore can be upgraded by employing gravity separation techniques prior to the pelletisation of the feed material to the electric arc furnace (Niemelä and Kauppi, 2007).

The slag sample used for this study is typical of the South African ferrochrome industry, which treats very high proportions of agglomerated fine chromite ores by conventional AC furnace smelting (Niemelä and Kauppi, 2007). Slag is the vitreous mass left as a residue by the smelting of the ore to produce alloy. The main chemical components of the ferrochrome slag are MgO, Al_2O_3, and SiO_2, with smaller amounts of chromium, iron oxides and calcium oxide. Significant quantities of chromium in partially altered chromite (PAC) and entrained alloys can also occur within the ferrochrome slag (Hayes, 2004). Common phases in slag are glass, spinel and olivine. One negative feature of the older design of these furnaces is poor mixing and poor energy dispersion throughout the furnace bath. This results in non-uniform conversion of chromite to FeCr alloy, producing zones containing partially altered chromite grains and a variety of alloy compositions. In essence, therefore, there are two forms of value loss to the slag during tapping:

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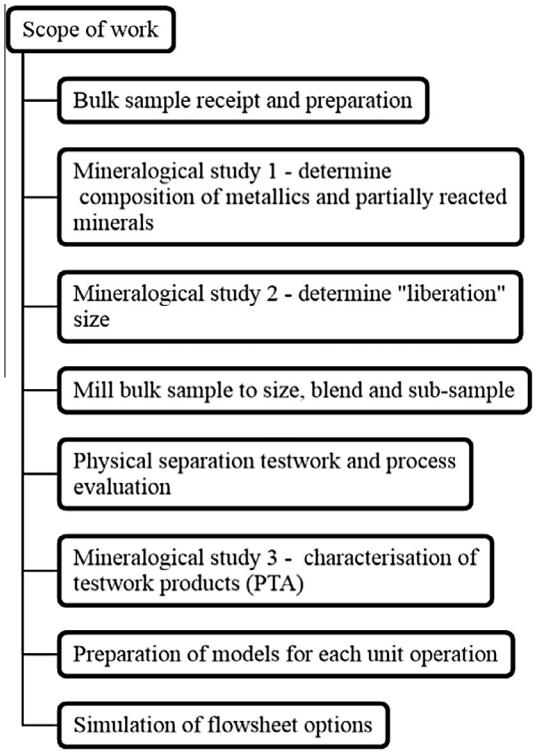

Fig. 1. Scope of work.

Table 1
Counting parameters and detection limits.

	Mg	Al	Si	Ca	Cr	Ti	Fe
Detection limit (wt%)	0.03	0.03	0.03	0.02	0.06	0.03	0.05
Counting time - peak (s)	15	15	20	30	15	20	15
Counting time - background (s)	5	5	5	10	5	5	5

1. alloy lost as entrained droplets in the slag
2. partially converted chromite lost to the slag

For this paper the discussion will be focussed on only the alloy phases, noting that recovery of PAC may also be a value driver. A saleable target product containing >97.5% metal content was required as one part of the over-arching objective of maximising the economic Cr unit recovery from all minerals and phases remaining in the FeCr slag sample.

2. Method

The scope of work for this study is depicted in Fig. 1 below. A 2t bulk sample of FeCr slag was collected from a South African operation, sub-sampled and crushed to <2 mm, blended and split into portions for subsequent evaluation. The first two stages of mineralogical characterisation were conducted on the sample in order to determine the chemistry of each phase present and to determine an appropriate liberation size for milling prior to physical separation testwork. For this paper, only the results of shaking table tests are discussed in some detail and compared to the performance of a Reflux Classifier. Other unit processes such as magnetic separators, flotation, spirals and teeter-classifiers could also be considered. The third stage of mineralogical characterisation was done on the products of the shaking table in order to provide information to construct fairly detailed partition surfaces and thereby model separation efficiency. Finally, these models were linked together into simple flowsheets to determine an appropriate process for the recovery of the alloys.

2.1. Bulk sample collection and preparation

The bulk sample collected was 100% finer than 20 mm as it had already been processed by the mine through a metal recovery plant (MRP) consisting of crushing and screening followed by jigging and low intensity magnetic separation. The remaining metallics in the sample were therefore expected to be predominantly in the <2 mm fraction (which by-passed the MPR) or locked in coarser slag

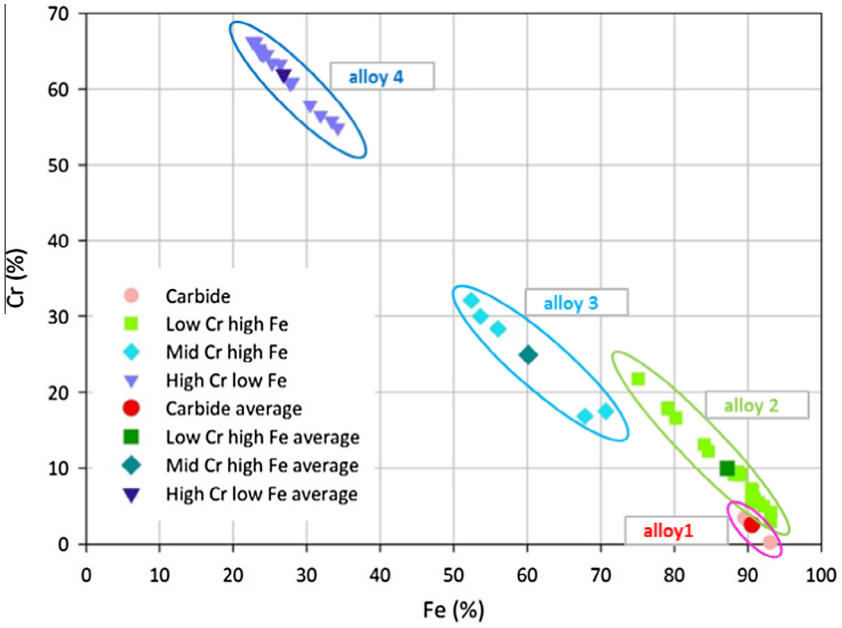

Fig. 2. EMPA: Cr versus Fe compositional data.