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Physicochemical factors affecting flocculation of pre-reduced nickeliferous laterite suspension

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Abstract

This paper deals with the effect of some physicochemical factors on flocculation of fine particle suspension produced during pyrometallurgical processing of nickeliferous laterite. Off-gases dust from the pre-reduction step and flocculants of various ionic characters were used in this study. The effect of suspension pH and temperature as well as of polymer dosage and concentration of polymer solution added on settling rate and supernatant concentration in solids was examined. The results show that the increase of temperature and pH establish a more negative charge on the particles mixture, so rendering the cationic flocculants more effective. On the other hand, both polymer dosage and concentration (or dilution) of the added polymer solution affect significantly the settling rate of the suspension as well as the clarity of the supernatant.

Keywords: Flocculation; Flocculants; Nickeliferous laterite; Physical chemistry of flocculation; Temperature effect on flocculation

1. Introduction

Solid–liquid separation is an essential process in many mining and metallurgical industries, when dewatering of mineral slurries and wastewater treatment are involved. In case of fine particle size, flocculation of the suspension is necessary or else particle settling rate is very slow.

In the present study, solid–liquid separation is related to a fine particle suspension derived after pyrometallurgical treatment of nickeliferous laterites in the plant of G.M.M. S.A. LARCO, cited at Larymna area (Greece). The treatment of nickeliferous laterites includes the following steps: (a) mixing of laterite and coal; (b) pre-reduction (600–800 °C) of the ore in four rotary kilns; (c) completion of the reduction, smelting and FeNi separation from slag in electric arc furnaces; (d) FeNi refining in Oxygen Bottom Maxhütte (O.B.M.) converters.

During the pre-reduction step a significant percentage of fine particles (−1 mm) is produced, which are removed along with the off-gases. The off-gases of the three rotary kilns are de-dusted in a poly-cyclone (radially mounted group of cyclones). About 70% of the solids are recovered in the underflow while the overflow, which contains the very fine particles (−45 μm), is washed in a Venturi tower and a dilute suspension of elevated temperature is formed. The solids are separated from the liquid by thickening and filtration, pelletized and recycled in the rotary kilns. The off-gases of the fourth rotary kiln are dry de-dusted successively in filter-bag and electrostatic precipitator. Then, the recovered fine particles are aggregated and recycled in the rotary kilns as pellets.

Although there is not complete agreement as regards terminology, flocculation may be defined as the aggregation of particle by using synthetic polymers [1,2]. Natural compounds (e.g. starches) also bring about flocculation, although this kind of particle aggregation is generally considered as coagulation. Flocculants based on natural compounds are mainly used in food industry applications (such as brewery, etc.) while those based on synthetic compounds are used in mining, metallurgical and chemical industries.

Extended fundamental work has been carried out by various researchers mainly on mono-mineral systems as regards polymer dissolution and thermodynamics [3–7]. Other re-

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searchers studied flocculation kinetics [8–11] and agglomerate structure [12–14]. Based on the behavior of various minerals, the mechanisms of flocculation have been established and their role on floc structure has been proposed [15–20]. On the other hand, the effect of solid characteristics on flocculation process has been recognized [21,22]. Also, the combined effect of polymer and surfactant on flocculation and dewatering has been examined [23–26].

This paper deals with some of the physicochemical factors affecting the flocculation performance of a relatively dilute multi-mineral suspension derived from the pre-reduction process of nickeliferous laterite. The factors studied were polymer dosage and polymer solution concentration, suspension pH and temperature. Based on the experimental results and the electrokinetic study of the pre-reduced material, it is attempted to elucidate the physicochemical behavior and the adsorption mechanism of the system.

2. Experimental

2.1. Materials

The material to be flocculated was a dilute suspension with solids derived from the pre-reduction stage of nickeliferous laterite. A typical chemical analysis of the solids, which are fed into the thickener, is presented in Table 1.

Table 1
Chemical analysis of the solids

Element/compound	%
C	4.40
FeO	4.80
Fe_2O_3	26.60
Ni	1.35
Co	0.07
SiO_2	34.40
CaO	3.80
MgO	4.85
Al_2O_3	11.50
Cr_2O_3	1.90
Mn_3O_4	0.50
S	0.20

XRD analysis (Fig. 1) shows that the crystalline phases of the solid material consist mainly of quartz, maghemite and hematite. Mposkos et al. showed that chlorite is also present in the raw laterite material as a main mineralogical phase [27]. Based on microprobe analyses, they showed that about 80% of the nickel contained in laterite is bound in the crystal lattice of chlorite, having the following mean chemical composition: 29% SiO_2, 20.5% Al_2O_3, 19% FeO_{tot}, 10% MgO, 2% Cr_2O_3 and 5.15% NiO. Hematite contains about 3% Al_2O_3 and 1.5% Cr_2O_3. Using these data, the following mineralogical composition of the solid material is calculated on the basis of the XRD analysis and chemical composition given in Table 1: chlorite 34%, quartz 25%, maghemite–hematite 30% and chromite 2%. Lignite is also present in the solids of the pre-reduced material.

Since chlorite is not determined by XRD analysis, it is assumed that it is decomposed during calcination, indicating that the pre-reduced laterite is heated above 500–600 °C. The pre-reduced laterite contains 3.8% CaO. Calcium-bearing mineral phases are not determined by XRD analysis. The CaO content of the pre-reduced material could be attributed to the decomposition of calcite that was probably present in the laterite ore and/or in the lignite mixed with the laterite.

The following flocculants of different ionic character were used: the cationic NALCO 603, the anionic NALCO 623SC and the non-ionic SUPERFLOC 16. The first two flocculants

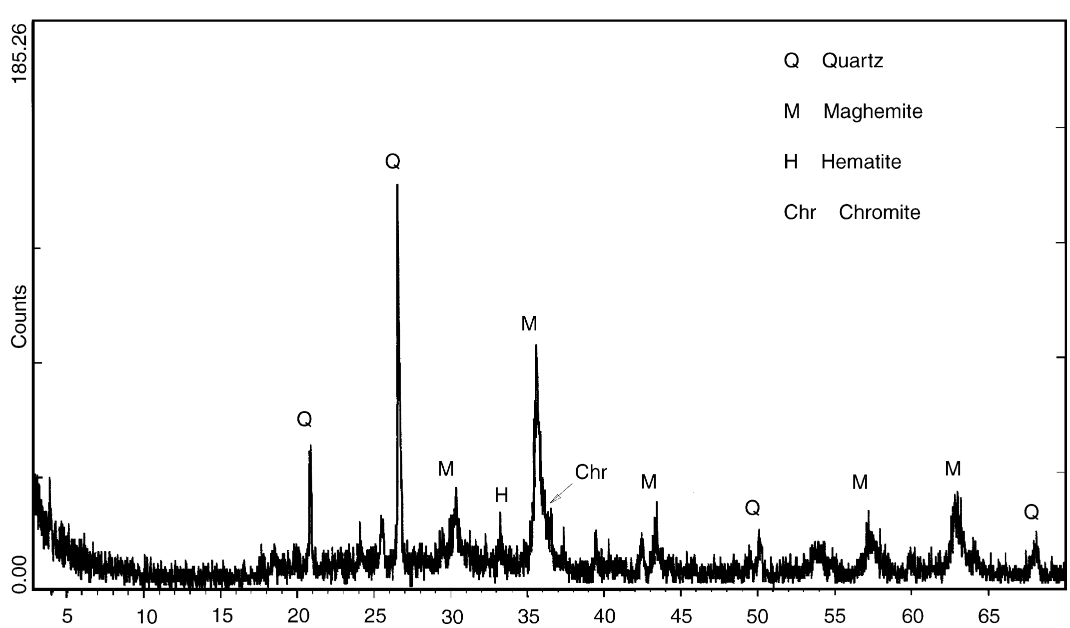

Fig. 1. XRD analysis of the pre-reduced material.