



Dual polymer flocculation approach to overcome activation of gangue minerals during beneficiation of complex iron ore



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ABSTRACT

This paper reports potato and corn starch based dual polymer flocculation of partially liberated complex ooidic iron ore. Corn starch selectivity for hematite, lost due to incomplete liberation of hematite and the presence of 16 ppm Ca^{2+} , 3 ppm Fe^{3+} , and 1 ppm Mg^{2+} polyvalent metal ions, was improved by dual polymer flocculation when the induction order of potato starch followed by corn starch was used. The initial feed grade of 41% Fe was improved to 46.2% with a recovery of 49.3% Fe after the addition of 40 ppm potato starch and 30 ppm corn starch to the iron ore slurry. In our case, potato starch has been found to behave mainly as a selective polymeric dispersant rather than as a flocculant. The paper also discusses the possible occurrence of all the adsorption mechanisms involved in the flocculation of quartz and gangue minerals in the presence of polyvalent metal ions.

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1. Introduction

Selective flocculation has been known as one of the beneficiation techniques applicable to the concentration of finely disseminated iron ores and tailings. Tilden Mines USA and Wadi Sawawin Mines Saudi Arabia [1,2], Camdag Mines Turkey [3], Goldsworthy Mining Ltd Finucane Island, Port Hedland [4] and Kudremukh Iron Ore Mines, Karnataka, India [5] are the mine examples where selective flocculation has been successfully employed to concentrate finely disseminated iron ores. The success of flocculation technique is based upon adequate liberation, selective dispersion and adsorption of an organic polymer on the mineral surfaces [1–6].

Starch based polymers have been successfully used for the last 80 years as selective depressants and flocculants for hematite in the field of flotation and flocculation, respectively. Variety of opinions exist in the literature as regards to the mechanism involved in selective adsorption of polysaccharides on hematite that convey the message that the particular nature of adsorption mechanism is still debatable [2,4,7,8]. Various selective adsorption mechanisms on hematite reported in the literature include electrostatic interaction and hydrogen bonding [9–11], acid–base interactions [12–14], hydrophobic interaction [15–18], chemical complexation [19,20], hydrogen bonding and chemical interactive forces [2] surface complex [4] difference in the concentration of hydroxylated sites on particles [10]

and structural compatibility between starch molecules and metal ion site distribution on the mineral surface [8]. However, most of the researchers favor hydrogen bonding mechanism despite the lack of evidence in their reporting. In addition, those suggesting chemical interaction could not specify the characteristic nature of chemical interaction in terms of either being ionic or covalent [4]. In order to understand the selectivity of starch for hematite, it is important to consider the interaction of two main components of starch i.e. amylose and amylopectin with hematite, quartz and clay minerals. Iwasaki and Lai [21] observed decreasing trend of starches' adsorption density on hematite with the decreasing amount of amylopectin. In contrast, Khosla et al. [20] noted greater adsorption density of amylose for hematite. Weissenborn [22] using amylopectin and amylose individually observed that amylopectin is a bulk flocculant for hematite, goethite, and kaolinite minerals, whereas amylose did not account for a flocculant at all. He further noted that amylopectin preferentially adsorbs on hematite and goethite in the presence of amylose. However, Pavlovic and Brandao [23] found that adsorption density of amylose and amylopectin for hematite was equivalent, whereas for quartz the adsorption density of amylose was noted significantly higher than hematite with amylopectin being completely unabstracted. Increased adsorption density of amylose is attributed to its flexibility displaying random coil behavior in alkaline solution, thus when adsorbed it may be coiled leading to higher adsorption densities [23].

Literature pertaining to selective flocculation process uncovers the fact that selective adsorption of starch on hematite in natural ore systems often gets affected due to either the presence of polyvalent

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metal ions, complex ore mineralogy, poor mesh of liberation or smearing effect during grinding [4,6,11,24–28]. Drzymala and Fuerstenau [24] observed quartz activation and thereby adsorption of polyacrylamide polymer in the presence of polyvalent metal ions. Laskowski et al. [25] observed quartz activation via lead coating of quartz surface resulting in the provision of hydrolyzable metal sites. Arol [11] found that selective adsorption of starch on hematite was not possible when concentration of calcium ions was more than 10 ppm in hematite–quartz slurry. Gururaj et al. [7], Arol [11] and Abro et al. [29] are in agreement that possibilities of preferential adsorption of starch on hematite decrease due to the presence of wide variety of gangue minerals and polyvalent metal ions. Huge literature body suggests that for the last 30 years or so, considerable amount of relevant research has been carried out to enhance the selectivity of corn starch for ultrafine hematite particles present in natural iron ore system containing higher concentration of polyvalent metal ions [4,6,11,24,29]. In this regard, various remedial measures such as judicious adjustment of slurry pH, proper selection of dispersants and optimization of their doses, addition of natural and synthetic polymers with and without agitation and sonication have been attempted. However, to the best of our knowledge application of dual polymer flocculation to mitigate detrimental role of polyvalent metal ions has not been attempted yet. It has been 40 years since dual polymer flocculation is used in many industrial processes for water treatment, papermaking and sludge dewatering. Literature pertaining to dual polymer flocculation reveals that for the first time it was attempted by Brittl (1973) to enhance the flocculation efficiency of pigment filler [30]. Thereafter, enhancement in the flocculation efficiency of alumina particles was attempted using non ionic and ionic polyacrylamide polymers [30–34]. However, most of the research concerned with dual polymer flocculation only addresses a slurry system containing single mineral component; whereas, the information related with dual polymer flocculation of natural ore is not suffice. Broad understanding of the application of dual polymer flocculation transpires into two important mechanisms of dual polymers. 1) Adsorption of first polymer leads to the modification in the characteristics of mineral surface sites resulting in the provision of selective adsorption sites for second polymer; 2) Adsorption of first polymer leads to the blocking of surface active sites of one mineral resulting in the adsorption of second polymer on the surface of the other mineral. The phenomenon described in the latter case is widely acknowledged as side blocking action. The main objective of this paper was thus aimed at investigating the potential of dual polymer flocculation technique to selectively flocculate the partially liberated hematite grains. We used severely intergrown complex iron ore, whose mesh of

liberation exist down to 5 μm , containing 16 ppm Ca^{2+} , 3 ppm Fe^{3+} , and 1 ppm Mg^{2+} polyvalent metal ions [6].

2. Experimental work

2.1. Mineralogy and mesh of liberation

For mineralogical and liberation study 100 kg ore sample, received from Pakistan Steel Mills Ltd., with a size fraction of +1 mm was first crushed in roll crusher. Particles of <1 mm mesh size were further ground in the ball mill to obtain sample size of –38 μm using a close circuit wet grinding scheme. In each batch of grinding test, 1 kg sample was pulped with Reverse Osmosis (RO) water to have the pulp of 50% solids by weight. The particle size distribution of the ground products was determined by a Horiba Laser Scattering Particle Size Analyzer (LA-300). The particle size distribution shown in Fig. 1 indicates that feed sample at P80 of 2000 μm was ground to P80 of 12.5 μm through closed grinding circuit. The principal minerals present in the ore sample were studied using a Bruker X-ray diffractometer (XRD), Model AXS: D-8. Diffraction data was obtained for 2θ angle from 5° to 70° using $\text{CuK}\alpha$ radiation source at 40 kV voltage and 40 mA current with scanning speed $0.02^\circ/\text{s}$. For qualitative and quantitative analysis, Eva and Topas softwares were used, respectively. The petrographic study was conducted using thin section and a JEOL scanning electron microscope (SEM), Model JSM-6380LV. SEM observations were carried out using secondary electron detector at low vacuum mode operated at 10 to 20 kV, whereas X-ray mapping was carried out using energy dispersive spectrometry (EDS), attached with SEM, at 30 keV. Back scattered electron detector was used for X-ray mapping.

The elemental analysis of –1000 μm down to +38 μm size fractions was carried out by a PANalytical X-ray fluorescence spectrometer (XRF), Model AXIOX was operated at 40 kV tube voltage and 60 mA current. For the preparation of sample beads, the ignition percent loss was determined first before their fusion in Lithium tetraborate ($\text{Li}_2\text{B}_4\text{O}_7$) for a sample to $\text{Li}_2\text{B}_4\text{O}_7$ ratio of 1:8.

2.2. Dispersion test

The dispersion tests were carried out in 2 L separating flask, with desired amount of –38 μm ore slurry prepared in RO water in the absence and presence of dispersants at specified pH value. For dispersion analysis, ore sample was diluted with RO water in 2 L beaker

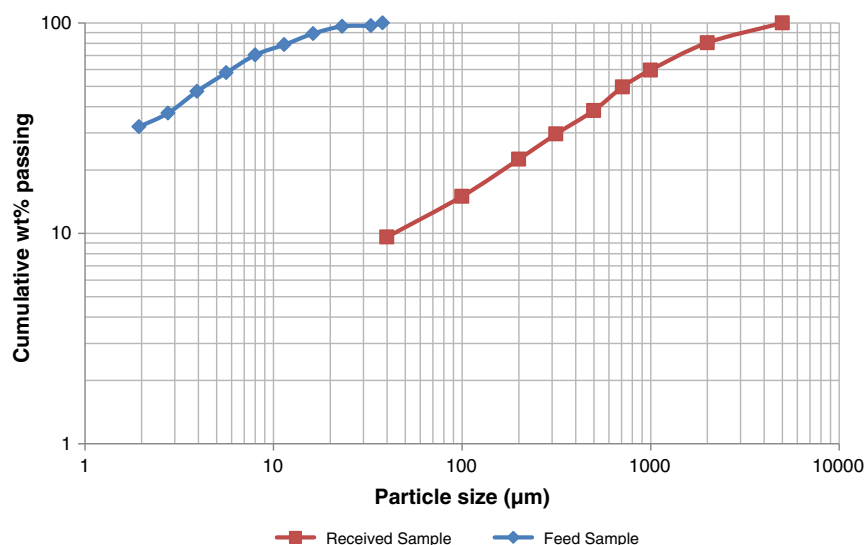


Fig. 1. Particle size distribution of received and feed samples.

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