ISSN-1996-918X

Pak. J. Anal. Environ. Chem. Vol. 10, No. 1 & 2 (2009) 34-38

Effect of Various Parameters on the Dispersion of Ultra Fine Iron Ore Slurry. Part-1.

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Abstract

The effect of various dispersion parameters; such as slurry pH, solid concentration, stirring speed and time, and water quality has been extensively studied for stabilization the ultra fine iron ore slurry prior to selective flocculation. The PZC of Dilband iron ore system was found by using the Zetaphormeter III (CAD E400) at pH value of 4.25. The set of dispersion parameters was optimized on the basis of weight percent and the percent entrapment of fine particles (10µm) sedimented in 2.5min settling time. Finally the selectivity of the optimal dispersion parameters was evaluated on the basis of elemental analysis of the sediment. The optimal conditions for 38µm ultra fine iron ore slurry in double distilled water were found at concentration of 7.5%solid, pH10.5, stirring speed 2000rpm, and stirring time 5min.

Keywords: Dilband iron ore, dispersion, zeta potential, polyvalent cations**.**

Introduction

In Stable dispersion of fine particles is the pre-requisite for the selective flocculation technique involving separation of ultra fine valuable particles from the gangue. Among mineral processing techniques selective flocculation technique is known to have outstanding potential of capturing the particles of particular mineral in slurry of mixed mineral system by selective adsorption of water soluble polymers known as flocculants [1-5]. The critical barrier to success of selective flocculation is the design and optimization of dispersion parameters to obtain the stable dispersion of slurry prior to addition of flocculant.

Some of the earlier success achieved in stablization of slurry of mixed mineral system is based on the judicial adjustment of pH and control of ionic strength, solid concentration, stirring speed, stirring time and selection of most selective dispersant [1, 2, 4, 7-11]. Manipulation of surface charge and surface hydroxyl groups with maneuvering the pH and polymeric dispersants content are the key parameters that govern stability of slurry and minimize the tendency of hetracoagulation [4, 6, 7].

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In present study the effect of different dispersion parameters on stabilization of Dilband iron ore slurry has been evaluated so that selective flocculation technique can be applied. Dilband iron ore is generally considered as the best of iron ore deposits discovered so far in Balochistan Pakistan. Based on the mineralogical, chemical and physical attributes of the Dilband iron ore [12], selective flocculation technique has been envisaged to up-grade it. Therefore main objective of the research work presented in this paper, is to optimize the various governing parameters to achieve the stabilized dispersion of Dilband iron ore slurry.

Materials and Methods

Chemicals

1M NaOH, and 1M HNO_3 solutions were prepared in double distilled water. These solutions were used for pH adjustment.

Material

Dilband iron ore sample received from Pakistan Steel Mills, Karachi was wet grinded and sample of 38µm size fractions was used in present study. Particle size distribution of feed sample was determined by Horiba Laser Scattering Particle Size Distribution Analyzer (LA-300).

Particle size analysis

Particle size distribution of feed ore and sediment of dispersion tests was determined using Horiba Laser Scattering Particle Size Distribution Analyzer (LA-300). The samples were sonicated for 2 minutes in a sample chamber and circulation speed was set to 9. The rare refractive index (R. Refractive) used was 2.000.

Zeta potential measurement

For measuring the zeta potential Dilband iron ore sample was prepared by diluting the ore in double distilled water and agitating at stirring speed of 1500 rpm for five minutes. Dispersant and pH modifier, whenever required, were added and conditioned for 5 minutes before filling the sample in the chamber of Zeta phormeter. For all zeta potential measurements the content of ore in suspension was less than 0.1 mass %. Zeta potential measurements were made by using a Zeta phormeter III (CAD E400). The Smoluchowski's equation was used to calculate the zeta potential.

Determination of polyvalent metal ions

Slurry for analysis of polyvalent metal ions was prepared in double distilled water and agitated for 5 minutes. After agitation the slurry was transferred to a cylinder and its volume was adjusted to have a concentration of 7.5% solid. Finally the supernatant was siphoned after 30 minutes when almost sedimentation process ended and then supernatant filtered from 2.75µm filter paper. To remove the particles finer than 2.75µm the supernatant was centrifuged at 5000rpm for 10minutes. Then Fe^{3+}, Ca^{2+}, and Mg^{2+} were analyzed on Atomic Adsorption Spectrometer.

Dispersion tests

In order to evaluate the effect of dispersion parameters on the stabilization of iron ore slurry, the dispersion tests were conducted in 2000 ml separating flask. The effect of all dispersion parameters were assessed on the basis of wt% of settled material and percent entrapment of fine particles. The slurry of desired percent solids was prepared in 2000ml beaker by diluting the ore with water purified by Reverse Osmosis (RO) principle, hereinafter referred as RO water, and agitating mechanically at different impellor speed for desired time intervals. Thereafter slurry was immediately transferred to separating flask, where it was re-agitated for 1min and then left for the desired settling interval. Sedimented material collected in subsequent time intervals was dried at about 100ºC in oven, cooled to room temperature, weighed and analyzed for particle size distribution.

Results and Discussion

Effect of solid concentration and pH

Results of effect of solid concentration on sediment wt% and % entrapment of fine particles are plotted in Fig. 1 and Fig. 2 respectively. The data very clearly depict that settling rate of the 38µm slurry decreases with increasing the solid concentration and increases with the pH values. On the other hand decreasing trend in % entrapment of fine particles (10µm) is observed with increasing the solid concentration as well as the pH values.

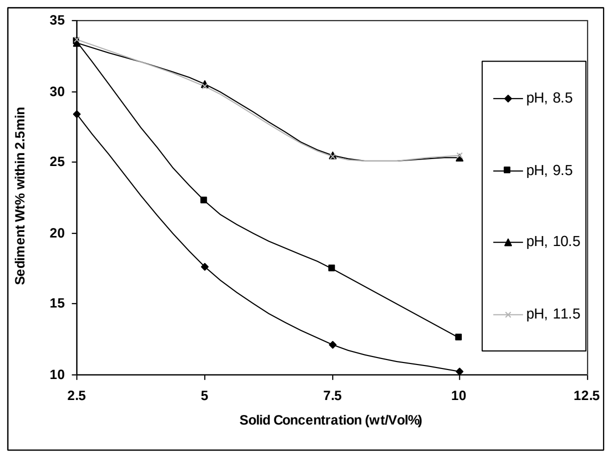

Figure 1. **Effect of pH and solid concentration on stabilization of -38 µm Dilband Iron ore slurry without dispersant addition.**

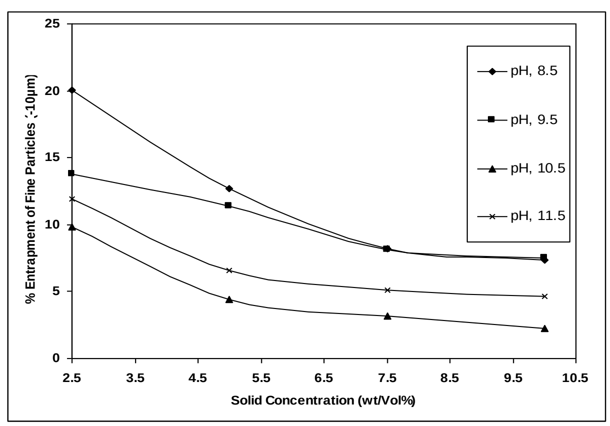

Figure 2. **Effect of pH and solid concentration on stabilization of -38 µm Dilband iron without dispersant.**

The difficulty of quantitative correlation of the experimental results with the hetrocoagulation theory is widely acknowledged even for the simplest system [13, 14]. The complexity of the present system is obvious not only due to particles of wide size range, but also due to heterogeneity in surface potentials, and presence of 16.58ppm Ca^{2+} and 0.8ppm Mg^{2+} ions. Occurrence of hetrocoagulation between dissimilar particles below pH, 10.5 is straightforward where particles of different minerals possesses opposite sign.

Hetrocoagulation at pH, 10.5 and pH, 11.5 where the mineral, present in the Dilband iron ore system, possesses similar charge can not be avoided specially due to presence of polyvalent metal ions. Therefore in the light of theories and investigations pertaining to hetrocoagulation, increasing trend in sediment wt% at pH, 10.5 and pH, 11.5 could be attributed with occurrence of hetrocoagulation.

On the other hand decreasing trend in % entrapment of fine particles (-10µm) with increasing pH Fig. 2 does not attest the occurrence of hetrocoagulation hypothesis, but indicates that jostling interaction would have been taken at low pH values. Therefore with increasing the pH the rejection of fine particles from the vicinity of falling solids taken place thereby jostling interaction is reduced and increase in settling rate resulted. The decrease in % entrapment of fine particles at higher pH values is an evidence of gel formation at lower pH values. Zeta potential of Dilband iron ore slurry measured at different pH values Fig. 3 further confirms the gel formation assumption at low pH values. On the basis of zeta potential values hetrocoagulation/ coagulation could be attributed the cause of gel formation at low pH values. Therefore increase in zeta potential with increasing pH results in hindrance of the fine particles to hetrocoagulate, and hence reduced gel formation and jostling interaction of the particles. Thus increase in settling rate concomitantly resulted.

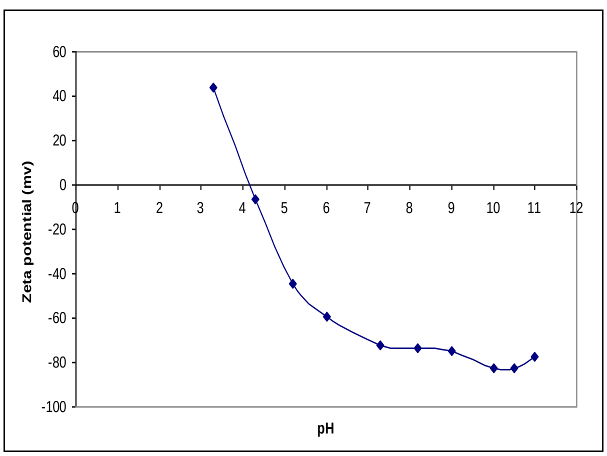

Figure 3. **Effect of pH on zeta potential of Dilband iron ore.**

Besides this the cumulative wt% of material settled in 7.5 min at pH, 8.5 and pH, 9.5 indicated almost similar decreasing trend in settling with increasing solid concentration Fig. 4. However at pH, 10.5 and pH, 11.5 values almost equivalent wt% of settled material at all solid concentrations is observed. This plateau in sediment wt% in 7.5min interval indicate that jostling interaction and gel formation due to high solid concentration is greatly overcame by increasing the pH values to 10.5 and above. Therefore sedimentation at pH, 10.5 and above is increased as compared to pH, 8.5 and pH, 9.5.

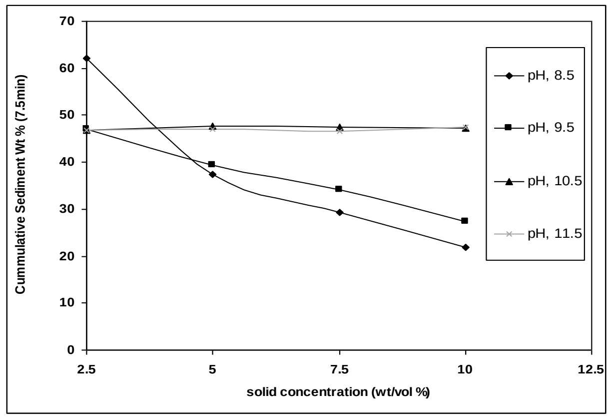

Figure 4. **Effect of pH and solid concentration on settling rate after 7.5 min interval at 2500 rpm stirring speed, 5 min stirring time, and without dispersant.**

On the basis of maximum zeta potential value observed and minimum % entrapment of fine particles pH, 10.5 was supposed to be optimal. While comparing the effect of solid concentration at pH, 10.5 a plateau in sediment wt% at 7.5% and 10% solid concentration was observed.

Effect of stirring speed

In order to quantify the effect of stirring speed on the disperse ability of -38µm slurry four dispersion tests at 1000 rpm, 1500 rpm, 2000 rpm, and 2500 rpm were conducted, at constant values of 5min stirring time, 7.5% solid concentration, and pH, 10.5. Results are plotted in Fig. 5. With increasing stirring speed, decrease in sediment % as well as in % entrapment of fine particles is observed. Since the sediment wt% and % entrapment of fine particles (10µm) at 2000 rpm is almost equivalent to 2500 rpm, therefore 2000 rpm stirring speed seems to be optimal.

In present work the effect of stirring speed on stabilization of 38µm particles indicated that about 2000 rpm stirring speed is sufficient to minimize the settling rate and % entrapment of fine particles (10µm) within the 2.5min settling interval. The possible reason could be the disintegration of the coarser particles that might have been formed during the drying of the wet sieved samples at 100ºC. Similarly with increasing the stirring speed increase in stabilization of BHP iron ore slurry was noted by Weissenborn [15] and had been attributed it with fragmentation of coarse particles.

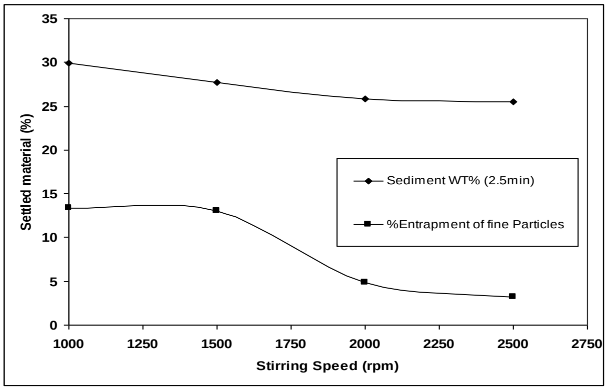

Figure 5. **Effect of stirring speed on settling rate and % entrapment of fine particles (<10 µm) at 7.5 % Solids, 10.5pH, 5 min stirring time without dispersant.**

Effect of stirring time

Effect of 5min, 10min and 15min stirring time on the sediment wt% and % entrapment of fine particles at 2000 rpm stirring speed, pH, 10.5, 7.5% solid concentration, and without dispersant addition is shown in Fig. 6. Results indicate that sediment wt% and % entrapment of fine particles almost remained unaffected by the stirring time. No significant change in sediment wt% and % entrapment of fine particles suggested that 5min stirring time could be optimal stirring time. Although significant efforts have been made so far in exploring the colloidal stability parameters specially for ore slurry, effect of stirring time is rarely studied and the literature pertaining to this issue is not suffice. Therefore it is very hard to support the findings of the present work with published data

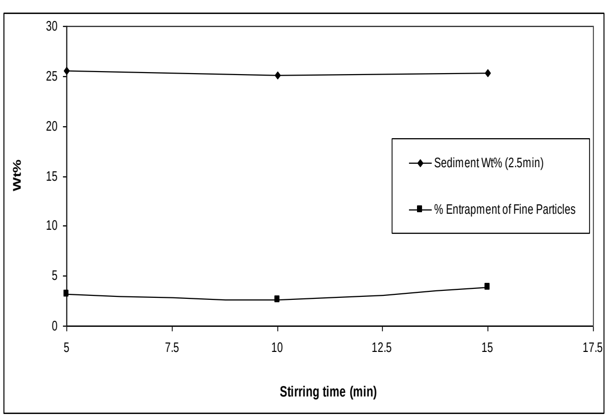

Figure 6. **Effect of stirring time on stabilization of <38 µm Dilband iron slurry without dispersant.**

Effect of water quality

To investigate the effect of water quality, a dispersion test in double distilled (DD) water was conducted at 7.5% solid concentration, 10.5pH, 2000 rpm stirring speed, and 5min stirring time. Results indicated that in case of DD water, stability in sediment wt% increased with decrease in % entrapment of fine particles. The improvement in material stabilization in DD water as compared to RO water was hardly 1.5%, from which detrimental effect of calcium and magnesium ions present in the RO water can be anticipated. The water analysis results of RO and DD water indicated that RO water contains 1.36ppm Ca^{2+} and 0.4ppm Mg^{2+} ions, whereas DD water has 0.07ppm Ca^{2+} ion. Therefore improvement in stabilization in DD water can be attributed with decrease in Ca^{2+} and Mg^{2+} ion concentration.

Effect of water quality on the stabilization of organic and inorganic particles has been studied extensively. Polyvalent metal ions like Mg^{2+}, Ca^{2+}, Fe^{3+}, and Al^{3+} present in the water are observed to play significant role in the colloidal stability [1, 8, 9, 13, 15, and 16]. Generally the decrease in zeta potential, thereby compression in double layer is argued the cause of suspension destabilization. The effectiveness of theses metal ions in reducing the zeta potential increased with decrease in their hydrated radius. Mg^{2+} hydrated radius (0.47 nm) is grater than that of Ca^{2+} (0.42nm) therefore adsorption of Mg^{2+} moieties on clay surface keeps the layers away to coagulate as compared to Ca^{2+} moieties [16]. In addition to causing double layer compression the polyvalent metal ions, known as hydrolyzed species, are highly surface active and can cause the zeta potential reversal [16].

Conclusion

The general conclusions drawn from dispersion tests are that:

- Slurry stabilization increases with increasing solid concentration and pH.
- Presence of polyvalent metal ions played detrimental effect in destabilization via hetracoagulation mechanism.
- Agitation at high stirring speed improved the slurry stability via particle disintegration mechanism.

Maximum stability of about 80% was achieved at 7.5% solid concentration, 2000 rpm stirring speed, 5min stirring time, and slurry pH of 10.5 in DD water.

Acknowledgments

The authors wish to thank the Mehran University of Engineering and Technology (MUET) and Higher Education Commission (HEC), Pakistan for financial support.

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