

Effects of Process Parameters on Selective Flotation of Lead-Zinc Ore

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Abstract

The present paper deals with the results of the characterisation and flotation studies carried out on a typical lead-zinc ore sample under varying process conditions. A detailed characterisation was carried out by chemical analysis, X-ray, optical microscopic and electron probe microanalysis techniques. The sample assayed 2.47% Pb with 13.6% Zn. The ore was predominantly made up of sphalerite and pyrite in association with subordinate amounts of galena, minor amounts of pyrrhotite and chalcopyrite. Dolomite was the main gangue. The modal analysis showed the probability of fair liberation of sulphides from gangues around 60 mesh but the locking of galena with sphalerite and other sulphides continued to finer sizes. The effects of various parameters like granulometry for rougher and cleaner flotation, pH of the pulp, dosage of collector, depressant and activator were studied in detail. The flotation performance was assessed in terms of yield, recovery and grade of the concentrates and the results were analysed graphically to establish the trend.

Keywords: Selective flotation, Lead-zinc ore, Process parameters, Characterisation.

Introduction

Bulk of the world's lead and zinc is supplied from their sulphide deposits which generally occur as finely disseminated bands of galena and sphalerite with varying amounts of pyrite. Froth flotation is widely used for concentration of low grade lead-zinc ores for meeting the required specifications of the concentrates for extraction of metals (Wills 1988). The recovery of lead and zinc bearing minerals as well as the selectivity of separation are greatly influenced by the mineralogical characteristics of the ore and the various process parameters. Selective flotation of lead-zinc ore depends on a number of parameters like particle size distribution of the feed, collector, frother, depressant, activator, pH of the pulp, regrinding and multi-stage cleaning of the rougher concentrates etc. While designing the process flow-sheet for a given ore sample it is necessary to examine the effects of different variables on the process performance (Pradip, Das and Singh 1995).

The present work was undertaken to study the effects of various process parameters on concentration of a typical lead-zinc ore sample by froth flotation. Prior to flotation studies, the sample was characterised with respect to chemical and mineralogical characteristics. The basic flotation scheme adopted for concentration of the lead-zinc ore sample consisted of differential flotation separation by depression of zinc bearing minerals using a combination of sodium cyanide and zinc sulphate as depressant and flotation of lead minerals using potassium ethyl xanthate as collector and methyl iso-butyl carbinol (MIBC) as frother. Lime was used as pH regulator and this also helped in depression of pyrite. Subsequently zinc was floated using copper

sulphate as activator and xanthate and MIBC as collector and frother respectively at a higher pH. These studies were found quite useful for developing flotation based technology for beneficiation of the ore to individual lead and zinc sulphide concentrates. This paper presents the results of characterisation and flotation studies carried out on the lead-zinc ore sample with a particular reference to the effects of various process parameters.

Experimental

Materials

The lead-zinc ore sample used for this study analysed 2.47% Pb and 13.63% Zn with 16.64% CaO and 11.89% MgO. The silica and alumina contents of the sample were low i.e. 0.56% and 0.97% respectively. The mineralogical and liberation characteristics of the sample were determined and are discussed in the subsequent paragraph.

A combination of laboratory grade sodium cyanide and zinc sulphate from M/s BDH India Ltd., Bombay was used as depressant and copper sulphate as activator for zinc bearing minerals. Commercial grade potassium ethyl xanthate (KEX) from M/s Suyog Chemical Pvt. Ltd., Nagpur was used as collector and laboratory grade methyl iso-butyl carbinol as frother for lead and zinc minerals. Commercial grade lime was used as pH regulator and depressant for pyrite.

Methods

Bench scale flotation experiments were carried out in standard Wemco Fagergren Laboratory Flotation Cell. For this purpose 0.5 kg -1.68 mm sample, crushed in stages in jaw and roll crushers, was wet ground in laboratory rod mill at 66% pulp density and floated, after conditioning, at a pulp density of 22%. All the products from the flotation experiments were assayed for % Pb and % Zn by standard wet chemical method and material balance was computed.

Results and Discussion

A detailed characterisation and froth flotation studies were carried out on the sample. The salient results are discussed below :

Mineralogical Characteristics of the Sample

Mineralogical characterisation of the sample indicated that the ore was predominantly made up of sphalerite and pyrite in association with subordinate amounts of galena, minor amounts of pyrrhotite and chalcopyrite. Dolomite was the main gangue. The other accessory minerals and mineral impurities namely, mica, cerussite, smithsonite, quartz, garnet, rutile, magnetite, goethite/limonite were in minor to trace amounts. The ore minerals were widely varying in size from 1.4 cm to less than 5 micron but the bulk of sulphide mineral was 148 micron and above in size. Pyrites were mostly euhedral while other sulphides were anhedral to subhedral in shape. The sulphide minerals showed replacement, exsolution textures and triple junction points. Typical photomicrographs are shown in Figs. 1 and 2.

Table – 1 : Analysis of sphalerite

Elements	Weight (%)			
Zn	60.529	60.062	59.997	62.35
S	32.901	33.328	33.484	32.931
Fe	3.491	6.032	5.920	3.771
Cu	-	-	-	-
Pb	-	0.048	0.054	0.058
Cd	0.063	0.078	0.034	0.087
Co	0.021	-	-	-
Ni	0.018	-	-	-
Mn	-	0.011	0.005	-
Total	97.022	99.556	99.495	99.204

Table – 2 : Analysis of galena

Elements	Weight (%)		
Pb	86.104	87.618	87.145
S	13.088	13.020	13.102
Fe	0.097	0.020	0.001
Zn	1.626	-	-
Cu	0.036	-	-
Cd	-	-	-
Co	-	0.014	-
Ni	-	-	-
Mn	0.024	0.017	-
Total	100.974	100.689	100.248

“ - ” indicates not detected

As it can be observed from the electron probe microanalysis (EPMA) results (Table- 1), the constant presence of iron in all grains of sphalerite could be due to structural substitution while out of the three grains of galena analysed only one grain showed the presence of zinc (Table-2). X-ray diffraction study (Fig. 3) carried out on the sample also corroborated the petrographic findings (Singh et al 1998).

The modal analysis showed the probability of fair liberation of sulphides from gangue around 0.250 mm but the locking of galena with sphalerite and other sulphides continued to finer sizes. This indicated the need of fine grinding below 0.105 mm for liberation of galena and sphalerite from rest of the sulphides.

Flotation Studies

As mentioned in the previous section the basic flotation scheme consisted of differential flotation separation by depression of zinc bearing minerals using a combination of sodium cyanide and zinc sulphate as depressant and flotation of lead minerals using potassium ethyl xanthate (KEX) as collector and methyl iso-butyl carbinol (MIBC) as frother. Lime was used as pH regulator and

this also helped in depression of pyrite. Subsequently, zinc was floated using copper sulphate as activator and xanthate and MIBC as collector and frother respectively at a higher pH. The results on the studies of the effects of various process parameters on flotation performance are discussed below :

Effects of Granulometry of the Flotation Feed

Flotation experiments were carried out to study the effects of granulometry on flotation behaviour of lead and zinc bearing minerals. For this purpose, -10 mesh ore sample, wet ground for different length of time in laboratory rod mill was floated under fixed process conditions as pre-determined

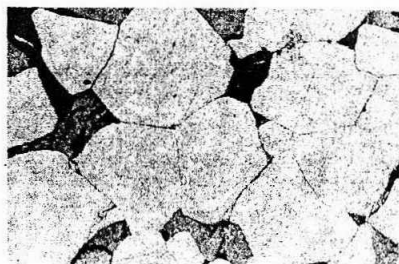


Fig.1: Polished specimen showing triple junction and assemblage of pyrite X 160 Parallel light, Reflected Light Microscopy.



Fig.2 Polished specimen showing gangue containing sphalerite (Sp) and their locking with galena (Ga) and chalcopyrite (Cp) X 160 Parallel light, Reflected Light Microscopy.

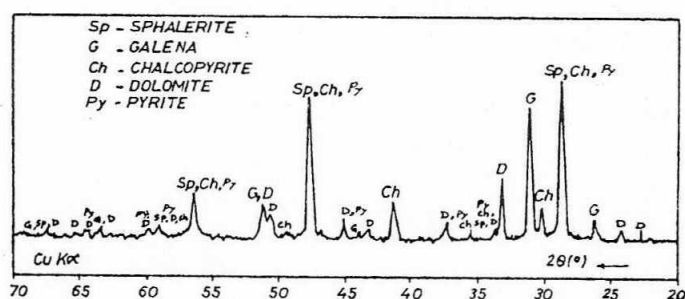


Fig. 3 : X-ray powder diffraction spectrum of lead-zinc ore sample

by trial experimentation. The flotation results are shown in Fig. 4. We can see from this figure due to better liberation an increase in -74 micron particles in flotation feed from 21.5% to 38.5% showed an improvement in lead and zinc recovery. It was also observed that overall flotation kinetics was better. But a further increase in fineness of feed to 57% -74 micron did not show any favourable results rather it caused a loss in lead and zinc recovery. So a flotation feed consisting of 38.5% particles passing below 74 micron was considered suitable for rougher flotation of lead and zinc bearing minerals from the ore.

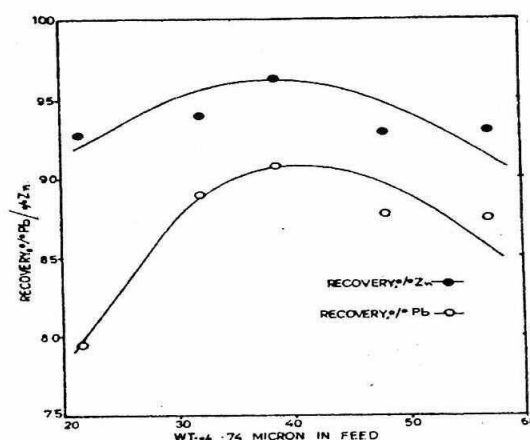


Fig. 4 : Effects of granulometry on recovery of lead and zinc bearing minerals

Depression of Zinc Bearing Minerals

As mentioned earlier, a combination of sodium cyanide and zinc sulphate (1:2.4) was used as depressant for zinc and selective flotation of lead minerals. The dosage of the depressant was varied from 0.215 kg/t. to 1.7 kg/t. The flotation results are graphically shown in Fig. 5. It is evident from the data shown in Fig. 5 that an increase in dosage of depressant from 0.215 kg/t. to 0.425 kg/t. resulted in improvement in recovery as well as grade of lead concentrate to 95.3% and 30.82% respectively. But a further increase in depressant dosage also caused depression of lead as shown by a sharp fall in grade and recovery of lead.

Variation of Collector Dosage

The effects of variation of collector dosage (potassium ethyl xanthate in this case) was studied on flotation of lead and zinc bearing minerals. For flotation of zinc the xanthate dosage was varied from 0.094 kg/t to 0.752 kg/t. The results are shown in Fig. 6. These experiments were carried out using feed with 38.5% -0.074 mm at pH 8.5. As it is evident an increase in xanthate dosage from 0.094 kg/t to 0.350 kg/t there is an improvement in zinc recovery but as expected concentrate grade shows a decline. An increase in xanthate dosage beyond 0.350 kg/t although leads to a sharp deterioration in recovery as well as concentrate grade. For lead collector dosage was varied from 0.125 kg/t to 1.0 kg/t. Like zinc, in this case also it was observed that an increase in dosage from 0.125 kg/t to 0.250 kg/t resulted in improvement in metallurgical performance but a further rise in xanthate dosage affected recovery of lead (Singh et al 2000).

Effects of Activator for Zinc Bearing Minerals

Copper sulphate is widely used as activator for zinc bearing minerals. Experiments were conducted varying dosage of copper sulphate from 0.25 kg/t to 1.0 kg/t. It was found that an increase in activator dosage from 0.25 kg/t to 0.5 kg/t resulted in decrease in zinc loss in the tailings from 65.5% to 1.8%. But a further increase in the activator dosage to 1.0 kg/t affected the flotation selectivity due to undesirable activation at higher dosage (Singh et al 1998).

Influence of pH of Flotation Pulp

pH of the pulp governs the charge on the mineral surface and plays an important role in the adsorption of the reagents and hence separation of minerals. For the flotation of zinc bearing minerals, pH was maintained using lime and was varied from 9.5 to 11.5. The results are shown in

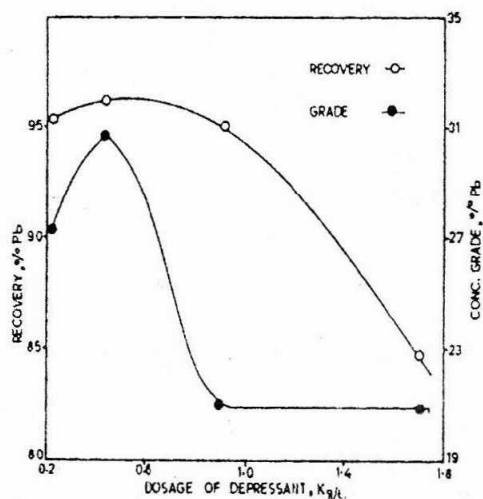


Fig. 5 : Effects of dosage of depressant on flotation of lead minerals

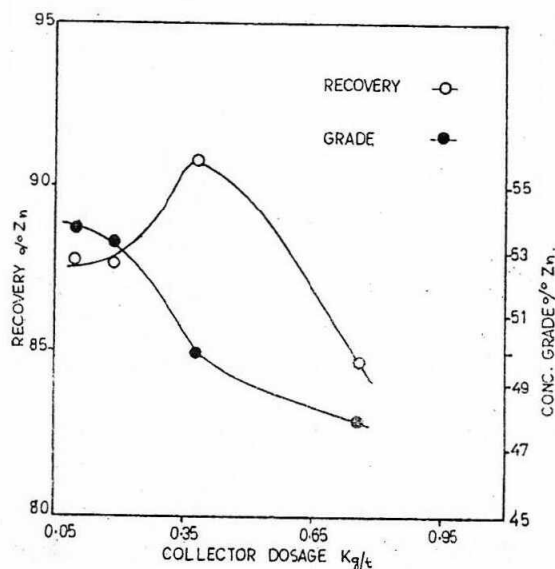


Fig. 6 : Zinc flotation results with varying dosage of collector

Fig. 7. The results indicated that an increase in pH from 9.5 to 10.5 leads to higher zinc recovery with faster kinetics and results in slight loss in concentrate grade. But a further increase in pulp pH to 11.5 caused a sharp decline in both grade as well as recovery. The effect of pH was also studied for flotation of lead minerals. A pH of 8.5 was considered suitable for effective flotation of lead minerals.

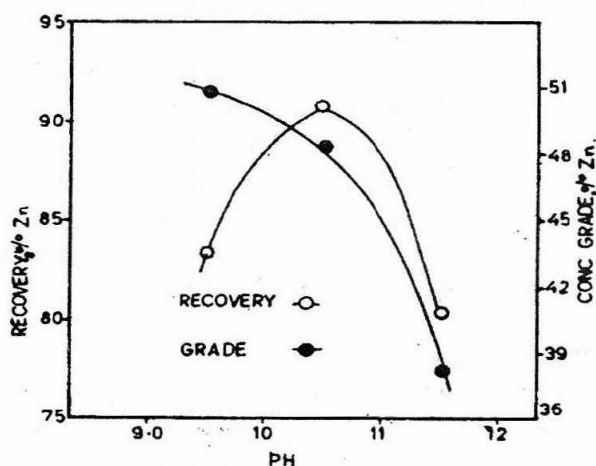


Fig. 7 : Influence of pH on flotation of zinc minerals

Fineness of Rougher Concentrate for Subsequent Cleaning Flotation

As indicated by liberation data and microscopic observation, in particular the high zinc content of the lead rougher concentrate was mainly due to locking problem. Hence experiments were carried out to improve the flotation selectivity by grinding rougher concentrate followed by cleaning flotation of the ground product. The fineness of the lead rougher concentrate was varied from 33% 44 micron to 89.4% 44 micron. For flotation of lead the results are shown in Fig. 8. As we can observe from the data shown in Fig. 8 that two cleaning of the lead rougher concentrate resulted in cleaner concentrate with 63.32% Pb and 1.01% Zn. Grinding the lead rougher concentrate to 85.2% 44 micron improved the concentrate grade to 65.42% Pb with 5.26% Zn. The improvement in grade was mainly due to enhanced liberation of sulphides at finer particle sizes. However, with further grinding of lead rougher concentrate to 89.6% -44 micron, there was increase in lead content of the concentrate but zinc assay was slightly higher (6.24%). This may be attributed to the flotation of the finely ground zinc minerals due to entrainment and entrapment phenomena. Thus a regrinding size with 85% particles passing below 44 micron was considered suitable for cleaning flotation of lead rougher concentrate.

For zinc rougher concentrate although the lead content was low but in order to study the effects of grinding for improving overall grade, regrinding flotation experiments were carried out. But in this case regrinding of the rougher concentrate adversely affected the flotation performance. It seems due to undesirable activation of pyrite during regrinding, it floated along with zinc minerals. So, these results indicated that for zinc circuit regrinding was not necessary.

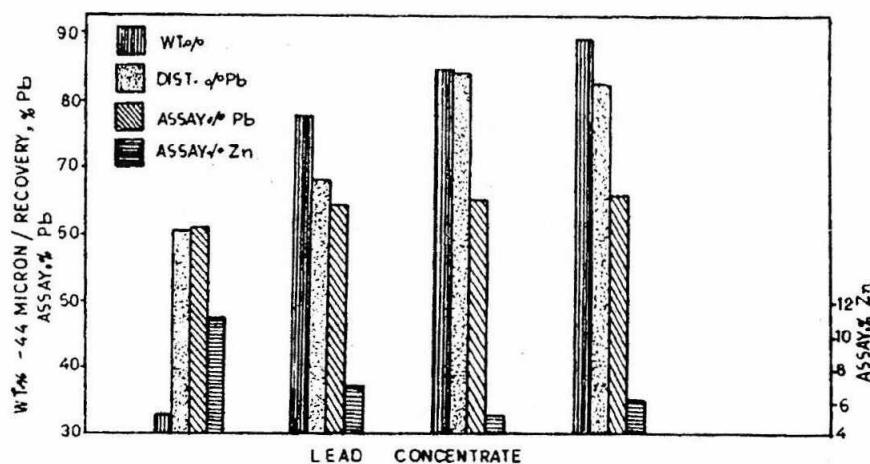


Fig. 8 : Effects of granulometry on cleaning flotation performance of lead minerals

Multi-stage cleaning flotation and process flow-sheet

Above studies on the influence of different process variables helped in establishing trends and conditions for rougher flotation and the granulometry for cleaning flotation. The lead rougher and zinc recovery were observed to be 96.3% and 90% respectively. The next task was to study the improvement in the grade of the individual lead and zinc concentrates by multi-stage cleaning

flotation. For this purpose three stages of cleaning were performed for lead rougher concentrate ground to 85% -44 micron. The final lead concentrate assayed 79.11% Pb with 4.23% Zn and with a lead recovery of 83.4%. The zinc rougher concentrate was subjected to two cleanings resulting in zinc cleaner concentrate analysing 60.08% Zn with 0.12% Pb with a zinc recovery of 80.4%. Based upon the studies undertaken a flotation based process was recommended for the concentration of lead-zinc ore sample under consideration.

Conclusions

Characterisation and flotation studies were carried out on a lead-zinc ore sample assaying 2.47% Pb and 13.6% Zn. The effects of various process parameters like particle size for rougher and cleaner flotation, pH of the pulp, dosage of collector, depressant and activator were studied on the selective flotation of lead and zinc bearing minerals. The studies proved quite helpful in establishing the trends on the effects of these variables on the metallurgical performance and also in designing flotation based process for concentration of the ore to individual lead and zinc sulphide concentrates.

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