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MGS Studies for Recovering Iron and Silver Values from Lead - Zinc Tailings

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Abstract

In mineral processing plants valuable minerals are recovered by rejecting gangue materials through various physical processing techniques to produce high-grade concentrate. However, after processing these ores, the tailings generated contain considerable amount of valuables because of inefficient of process plant or due to fluctuations in the mineralogical composition of the ore. Therefore, recovery of these valuable minerals is prerequisite from environmental and mineral conservation point of views.

In the present test, an attempt is made to conduct experiments on Multi-gravity separator to recover iron and silver metal values from tailings generated in base metal industry. The test results indicate that it is possible to recover 52.19% iron and 57.67% silver with 22.08% iron grade and 40.0 ppm silver grade form the tailings feed containing 9.07% iron and 26.02 ppm silver respectively. Among the MGS variables, it is found that drum rotation has significant effect on the recovery of iron and silver values.

INTRODUCTION

In mineral processing plants valuable minerals are recovered by rejecting gangue materials through various physical processing techniques to produce high grade concentrate. However,. due to frequent fluctuation in the mineralogical composition of the ore and also due to limitation of the operational systems, considerable amount of valuables are lost in the tailings streams. The tailings of base metal industry apart from containing some amount of lead and zinc remnants, they also contain some portion of iron and silver.

It is estimated that for every 141, 373 tons of zinc and 45,655 tons of lea metals recovery tailings generated would be of the magnitude of 6, 935 million tons contains substantial amount of iron and silver. The iron is in the form of pyrite content and is susceptible for acid generation in and around the industry creating environmental problems. Silver is considered as one of the important precious metals. Therefore, recovery of these minerals is prerequisite for mineral conservation and also for environmental benefits.

It is reported in the literature that Multi-gravity separator (MGS) has the potential to treat mineral fines and ultrafines like tin, chromium and other heavy minerals [Chan et.al., (1989, 1981); Tucker et. a1., (1991); Turner et.al., (1993); Clemete et. al., (1993); Burt et. al., (1995); Udaya Bhaskar et. al., (2001); Wills (1997)]. The schematic diagram of MGS is shown in Figure 1. The details of MGS application and principles are given elsewhere[(Chan et. al., 1989); (Udaya Bhaskaret. al., (2001)]. Having identified the potential of the unit, in the present study, an attempt is made to recover iron and silver values from lead-zinc process tailings using MGS.

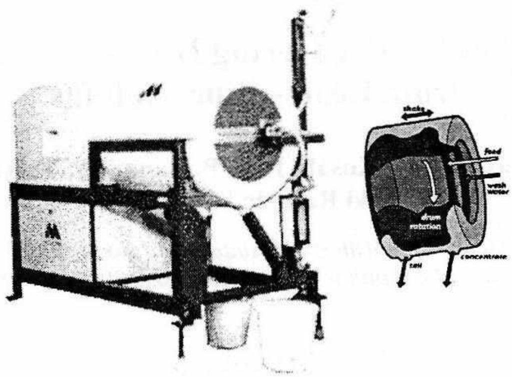

Fig. 1: Schematic Diagram of Multi-Gravity Separator

MATERIALS AND METHOD

The lead-zinc tailings sample from operating plant was collected in slurry form. The sample was dried in the laboratory electric oven at 100 ^{0} centigrade. The dried sample was mixed thoroughly for homogeneity and representative samples were drawn for feed characterization and experimental purpose.

The experimental set up used for the present test work is presented in Figure 2. The set up consists of a slurry tank with a stirrer, peristaltic pump for supplying feed to the MGS at consistent rates, a pilot scale MGS unit and sample containers for collecting the concentrate and tailing samples. For maintaining a required solid consistency in the MGS feed, measured quantities of solids and water were mixed in the slurry tank. The MGS variables were adjusted at the required levels as per the experimental design. The feed slurry was pumped into the MGS drum at the required flow rate using the peristaltic pump while the MGS was in operation. Samples from concentrate and tailing streams were collected at steady state condition which in general was achieved after 5 minutes of processing. The same procedure was adopted for all experiments and sample were collected for sufficient time to a obtain a minimum 100 grams of dry sample. The samples were filtered, dried, weighed and analyzed for pyrite and silver contents.

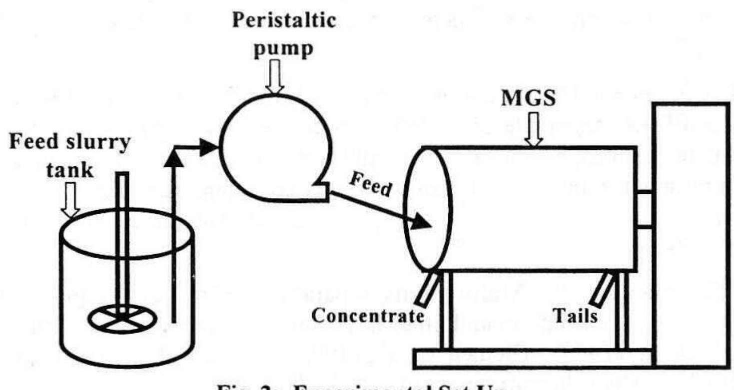

Fig. 2: Experimental Set Up

From the results on the weight recovery and metal contents in the concentrate and tailing products, the iron and silver recovery values are generated using the suitable mass balance equations [Wills (1997)].

DESIGN OF EXPERIMENTS

The preliminary test work carried out on MGS treating lead-zinc tailings revealed that among MGS variables, drum inclination, drum rotation and wash water are having significant influence on metal grades and recoveries. Therefore, in the present test, a full factorial design of experiments of P^n, where 'P' is the levels of variables and 'n' is the number of variables were conducted on laboratory model MGS. The design matrix of levels of variables is given in Table 1.

Table 1: Design Matrix of Levels of Variables

Factor	Lower lever (-1)	Upper level (+)
Wash Water (X1)	3	5
Drum Inclination (X2)	3	5
Drum Rotation (X3)	160	200

RESULTS AND DISCUSSION

Feed Characterization

Feed material characterization provides a very crucial information necessary for planning of experimental work to achieve desired results. Therefore, the feed tailing sample used in the test work is characterized for particle size distribution, size by size iron and silver content distribution.

Size by size particle weight distribution in the representative sample for Multi-Gravity Separator is shown in Table 2. The data indicates that 93.3 % of the material passes through 212 micron opening sieve and 10.2 % of the material passes through 25 micron opening sieve.

Table 2: Feed Size Analysis of Lead Zinc Tailings

Sieve size in microns	weight % retained	Iron (Fe) grade %	Silver (Ag) (ppm)
212	6.70	4.00	18.3
150	28.85	3.70	17.5
106	47.90	4.60	22.5
75	65.90	6.60	25.3
45	84.15	13.30	32
38	86.35	19.00	37.3
25	89.80	21.00	41.3
-25	100	16.90	39.1

The size by size iron and silver contents are also presented in Table 2. The data indicates an increasing trend of iron content from 3.7% to 21.00% with decreasing particle size down to 25 microns. However, a decrease in the iron content value to 16.90% at fines below 25 microns is observed. Similarly, size by size silver content in the representative feed sample is found to distributed from 17.5 ppm to 41.3 ppm. However, below 25 micron size silver content is observed to decrease to 39.1 ppm. As the iron and silver contents are concentrated in finer sizes, optimum recovery of finer material is expected to be the aim of the present study. The overall feed tailing sample contains 8.41 % iron and 26.02 ppm silver.

Effect of MGS Variables

The experimental conditions and results are shown in Table. 3 and detailed discussion on the effect of MGS variables on responses such as iron grade / recovery and silver grade / recovery is presented below.

Table 3: Experimental Condition and Results

Ex.No	Experimental conditions			Iron		Silver	
	WW (X1)	DI (X2)	DR (X3)	Grade (%)	Recovery (%)	Grade (%)	Recovery (%)
1	-1	-1	-1	22.8	52.19	52.50	30.96
2	1	-1	-1	22.8	30.26	60.00	20.07
3	-1	1	-1	34.4	37.66	61.30	19.52
4	1	1	-1	36.2	22.83	65.70	12.71
5	-1	-1	1	12.8	75.04	35.00	70.14
6	1	-1	1	15.6	73.16	36.10	63.84
7	-1	1	1	13.2	71.99	35.00	65.61
8	1	1	1	18.1	69.21	40.00	57.67

WW - Wash water in lpm, DI - Drum inclination in degrees, DR - Drum rotation in rpm

Effect of Variables on Iron Grade Recovery

Effect of Wash Water

An increase in wash water from 3 lpm to 5 lpm has increased the iron grade in all combinations of other variables. For instance, an increase in wash water from 3 lpm to 5 lpm, keeping drum inclination and drum rotation constant at 5 ^{0} and 160 rpm respectively, there is an increase of iron grade from 34.4 % to 36.2% (Experiments 3 & 4) . The similar observation is made in all other combinations of variable. The wash water effect is to have pronounced effect at lower drum rotation. At lower drum rotation, formation of loosely packed bed of particles is influenced greatly by the wash water to improve the iron grade.

The recovery of iron is observed a decreasing trend when the wash water level is increased from 3 lpm to 5 lpm, keeping other two variables kept constant. However, the effect of wash water is more pronounced in decreasing the iron recovery at lower drum revolution. For instance, an increase in wash water, keeping drum inclination at 3 degrees and drum rotation at 160 rpm, there is a decrease of 22% iron recovery (Experiments 1 & 2). But at higher drum rotation, the effect of wash water on iron recovery is minimum (Experiments 5 & 6). This can be observed by the minimum reduction of iron recovery less than 2%. This explains the predominance nature of washing effects at lower drum rotations.

Effect Drum Inclination

The drum inclinations studied in the present test work are 3 an 5 degrees. An increase in drum inclination from lower level to higher level, there is always an improvement in iron grade. As in the case of wash water effect, drum inclination is more effective at lower drum rotation (Experiments 1 & 3 and 2 &4). For example, an increase in drum inclination from 3 to 5, the iron grade is improved by more than 12% at 160 rpm, whereas, at 200 rpm the effect of drum inclination not effective to achieve higher iron grades. At increased drum inclination lighter gangue particles which are comparatively in coarser sizes (Table .1) in the feed are more influenced by the wash water to report to tailings end, thereby increasing the iron grade. At higher drum rotation, centrifugal forces created are forcing the more amount of material towards concentrate discharge end and hence the effect of drum inclination is neutralized causing a inferior iron grade.

The iron recoveries are in decreasing trend in all combinations of variables, whenever the drum inclination is increased from lower level to higher level. For example, at 160 rpm (drum rotation)and 3 lpm wash water an increase in drum inclination has decreased the iron recovery from 52.19% to 30.26% (Experiments). However, the effect of drum inclination influence on iron recoveries is perceived at lower levels of other two variables. At drum rotation 160 rpm, the formation loosely packed bed is more influenced by the addition of wash water than an increase in drum inclination. The same level of wash water is not effective at higher drum rotations, whenever the drum inclination is increased from lower level to higher level, because of compact bed of mineral particles layer formation. Hence the iron recoveries are not effected by the increase of drum inclination.

Effect of Drum Rotation

The iron grade is increased from 13.2% to 34.4% by decreasing drum rotation from 200 rpm to 160 rpm keeping all other two variables constant (Experiments 3 & 7). Similar trend is observed in all combinations of drum rotation. At higher drum rotations higher centrifugal forces are generated on heavier and fine iron particles. These heavier and finer particles are having high iron grade (Table.1). These fine particles compact bed is difficult to be influenced by wash water effects or drum inclinations. This in turn increases the iron grade.

The Drum rotation is found to have more influence on the iron recovery in comparison to wash water and drum inclination. For example at constant drum inclination (3^0) and wash water (3 lpm), an increase in drum rotation from 160 rpm to 200 rpm has increased the iron recovery from 52.18% to 75.05% (Experiments 1 & 5). Similar observations are noticed even at higher level of drum inclination and wash water. An increase in drum rotation might have increased the centrifugal force on heavier and fine iron particles along with coarse lighter particles. Thereby increasing the recovery of iron.

Effect of Variables on Silver Grade and Recovery

Effect of Wash Water

The increase in wash water in general has increased the silver grade . For example, all other variables being constant, an increase in wash water from 3 lpm to 5 lpm has increased the silver grade from 52.5 ppm to 60.0 ppm (Experiments 1 & 2). Further, the effect of wash water is found to be more influenced by drum rotations also. A similar increase in wash water from 3 lpm to 5 lpm has increased the silver grade from 35.0 ppm to 36.1 ppm. An increase in silver grade may be attributed to increased washing effects by the wash water. Relatively coarser gangue particles might have been rejected to a greater extent at higher rates of water than at lower flow rates of water. The pronounced effect of wash water rate, at 160 drum rotations than at 200 drum rotations, may be explained due to the formation of loosely packed at low drum rotations causing more effect of push of fluid on the settled layers of particle bed.

The effect of wash water on silver recovery is presented in Table 3. It is evident from the table that recovery of silver values are reduced by increasing wash water flow rate at all the combinations of the present study. For example, an increase in the wash water from 3 lpm to 5 lpm decreased the silver recovery from 30.96 % to 20.08 % (Experiments 1 & 2), at 160 drum rotation and 3 ° drum inclination.. Similarly, at 200 drum rotation and 3 ° drum inclination also an increase in wash water decreased the silver recovery from 65.82 % to 57.67 %. This indicates that at increased drum rotations, wash water flow rate is not sufficient to push the material towards rejects end. Similar observation can be deduced from other levels of variable of the study.

Effect of Drum Inclination

In the present study experiments were conducted at 3° and 5°. At any combination of variables, an increase in drum inclination increases the silver grade. For example, an increase in drum inclination from 3° to 5° at 3 lpm wash water and 160 drum rotations, increased the silver grade from 52.5 ppm to 61.30ppm (Experiments 1 & 3). Similarly, at 5 lpm wash water and 200 drum rotations, an increase in drum inclination has increased the silver grade from 36.1 ppm to 40.0 ppm (Experiments 6 & 8). It also can be noticed from experiments 4 & 8, that the effect of inclination is dominant at lower drum rotations. An increase in drum inclination might have increased the velocity of the water inside the drum surface. This creates more push on the lighter particles present on the upper layers of the settled bed resulting the washing of these particles towards tailings end. The effect of drum inclination is found to have significant effect on the silver grades also at higher wash water flow rate level (Experiments 2 & 4).

An increase in drum inclination from 3° to 5°, at 160 drum rotation and wash water at 5 lpm, reduced the silver recoveries from 20.08 % to 12.72 % (Experiments 2 & 4). Similarly, at 200 drum rotation and 5 lpm wash water flow rate, also decreased the silver recovery from 63.83 % to 57.67 % (Experiments 6 & 8). The difference in recovery values of this set of results indicate the dominating nature of drum rotation over the wash water. An increased drum inclination increases the water velocity inside the drum forcing some portion of the silver bearing mineral particles to report into tailings stream resulting in silver metal losses.

Effect of Drum Rotation

The two levels of drum rotation studied in the present test are 160 and 200 rpm. At any combination of variables, increase in the drum rotations from 160 to 200 decreased the silver grades. For example, an increase in drum rotations from 160 to 240, at 3° drum inclination and 3 lpm wash water flow rate, decreased the silver grade from 52.5 ppm to 35.0 ppm (Experiments 1 & 5). Similarly at 5° drum inclination and 5 lpm wash water flow rate, a change in drum rotations from 160 to 240 also decreased the silver grade from 65.7 ppm to 40.0 ppm (Experiments 4 & 8). At higher drum rotations, higher centrifugal forces are generated on mineral particles forcing the lighter gangue particles to report to concentrate and form more compact layers which are difficult to be effected by the washing effects of wash water and drum inclination. This in turn reduces the silver grade of the concentrate product.

From the experimental results shown in Table 3, it can be observed that drum rotation has pronounced effect on silver recovery in all experimental conditions of the present study. For example, at constant levels of drum inclination of 3° and 3 lpm wash water flow rate, an increase in drum rotation from 160 rpm to 240 rpm increased the silver recovery from 30.96 % to 70.15% (Experiments 1 & 5). Similar observation can also be made even at higher levels of drum inclination and wash water flow rate. The difference in recoveries explains the dominating effect of drum rotation on silver recovery. An increase in the drum rotation might have increased the centrifugal forces on mineral particles to form compact layers on the drum walls. This results in higher metal recoveries as the fine particles of lighter minerals also have a chance to report along with heavier fractions.

STATISTICAL ANALYSIS

Statistical analysis is an effective tool to analyze the experimental data. Therefore, statistical analysis is performed on MGS experimental data to corroborate experimental observations. The regression coefficients are estimated for main MGS variables such as wash water, drum inclination and drum rotation are presented in Table 4.

From Table 4, it is inferred that experimental observations are matching with the statistically generated data. The table indicates that drum rotation has highest significance on either grade or recovery of iron and silver. Drum inclination and wash water have shown positive influence on Iron and silver grades., whereas drum rotation has negative effect on iron and silver grades. However, drum rotation has shown positive significance on iron and silver recoveries and other two variables have shown negative significance on iron and silver recoveries.

Table 4: Estimated Regression Coefficients for Responses

Response	Experimental factor		
	Wash Water (X1)	Drum inclination (X2)	Drum rotation (X3)
Iron grade	1.19	3.49	- 7.06
Iron recovery	- 5.18	- 3.62	18.31
Silver grade	2.25	2.30	- 11.68
Silver recovery	- 3.39	- 3.69	21.75

CONCLUSIONS

The following inferences ae made based on the test work carried our on MGS using lead-zinc process tailings :

1. Tailings of lead - zinc processing industry contain considerable amounts of iron and silver values
2. The overall feed tailing sample contains 8.41 % iron and 26.02 ppm silver.
3. Recovery of iron and silver is essential from environmental and mineral conservation point of view.
4. The experimental results on MGS indicated that a recovery of 52.19% iron value can be maintained with 22.08% iron grade.
5. Also silver grade of 40.ppm with 57.67% recovery can be achieved.
6. Among the MGS variables studied, drum rotation has the significant effect on pyrite grade followed by drum inclination and wash water. The drum rotation has the maximum effect to recover pyrite values followed by wash water and drum inclination.

REFERENCES

[1] Chan, B.S.K., Mozley, R.H., and Chids , G.J.C The multi-gravity separator (MGS) - A mine scale machine, Symposium, Mineral processing in the UK, Leeds (1989)

[2] Chan, B.S.K., Mozley, R.H. ., and Chids , G.J.C Extended trials with the high tonnage multi-gravity separtor, Mineral Enginering,Vol. 4, No 3/4, 489-496 (1991)

[3] Tucker, P.,.Chan, B.S.K.,.Mozley, R.H and Chids, G.J.C Modeling the multi-gravity separator, XVII International Mineral Processing Congress (1991)

[4] Turner, J.W.G., and Hallewell, M.P Process improvements for fine cassiterite recovery at Wheal Jane, Mineral Engineering, Vol.6 , 817-829 (1993)

[5] .Clemete, D., .Newling,, P., Botelho de Sousa., Lejeune, G., .Barber, S.P and Tucker, P Reprocessing slime tailings from a tungsten mine, Mineral Engineering, Vol.6, 831-839 (1993)

[6] Burt, R.O., Kornik, G., .Young , S.R and .Deveay., C Ultrafine tantalum recovery strategies, Mineral Engineering, Vol.8, 859-870 (1995)

[7] Udaya Bhaskar, K., Govindarajan, B., Rao, K.K.., Barnwal, J.P., Venugopal, R., Jhaku, MR and Rao, T.C Graphite rejection in lead concentrae using graivty concentrate technique. Journal o Metallurgy and Materials Science, Vol.43, Jan- March 2001

[8] Wills, B.A Mineral Processing Technology, 6th Edition. (1997)