REDUCTION OF PHOSPHOROUS CONTENT IN LD SLAG THROUGH SPIRAL CONCENTRATOR FOR INDUSTRIAL UTILIZATION

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Abstract

Slag generated from basic oxygen converter (LD slag) is one of the recyclable wastes in integrated steel plants. LD slag may be used in refining of steel or in iron-making due to its high metal value and lime content. Presently, it is neither used in steel making nor in iron making. However the steel slag rejects cannot be utilized as such since these contains 1.2–1.5% P which is not acceptable for iron ore sintering. In the current study, the efficacy of 7-turn coarse spiral followed by 8-turn fine spiral concentrator was evaluated to process fine (–0.5 mm) LD slag for lowering Phosphorus (P) content to the desired level for its application in iron ore sintering. The effect of varying operating parameters on the performance of spiral has been studied through optimization experiments at different feed flow rates ranging from 18–22.2 Kg/min and altering the splitter positions for varying the density of feed pulp from 18–20%. Under optimized conditions, the results indicate that the concentrate product with low phosphorous content of about 0.76% is achieved, which is far too less from industry requirement perspective of <0.90% phosphorous content with a yield of 31%, and this can be effectively utilized for iron ore sintering. However, the yield of concentrate in the experiments undertaken varied proportionally from 31–57%, depending upon the level of phosphorus content desired in the concentrate i.e 0.76–0.90%. The main mineral phases contained in the slag were identified using X-ray diffraction (XRD) and complementary analysis were undertaken using scanning electron microscopy (SEM) coupled with energy dispersive spectrometer (EDS). The results were discussed in the light of our experimental results.

Keywords: LD slag, Spiral concentrator, Beneficiation, XRD, SEM-EDS

1. Introduction

The basic oxygen furnace process of steel making produces steel slag at the rate of about 125 kg/t which is highly basic and contains free lime, metallic and non-metallic iron and calcium silicates. The steel slag also known as LD slag is water quenched, solidified and processed through a series of magnetic separators to recover metallic iron. The stage wise magnetic separation involves crushing to –300mm, –80mm and –6mm followed by roll magnetic separation. The LD slag processing conducted in waste recycling plant recovers about 20–25% of the total weight of LD slag. The non-magnetic fraction which is –6mm in size is either discarded and dumped or is utilized as aggregate for road making. The reject of waste recycling plant after metal recovery though does not contain much of metallic iron, but this contains substantial quantity of calcium bearing mineral phases like mono, di and tri calcium silicates. These calcium silicates have a good fluxing value, which can be utilized as flux in iron ore sintering. Additionally the rejects also contain iron values which are mostly in oxide form. However the steel slag rejects cannot be utilized as such since these contains 1.2–1.5% P which is not acceptable for iron ore sintering. The objective of the present investigation is to reduce the phosphorous content to the desired level for its utilization in iron ore sintering.

2. Sample preparation

About of 3 tons of LD slag material (–6 mm) was obtained from M/s Tata Steel Ltd, Jamshedpur. Initially, as received sample was screened at 0.5 mm. It was observed that as received sample contains about 40% of the material was below 0.5 mm. The feed sample was prepared by stage wise crushing to prevent generation of ultra fines which involves particle size < 3 mm and < 0.5 mm. Thereafter, the coarser size fraction was ground in a batch-type ball mill of capacity 10 Kg for about 10 minutes in several batches and screened at continuous vibrating screen of 0.5 mm size. The + 0.5 mm size fraction was further ground in the same ball mill by increasing the grinding interval time 5 to 10 minutes at each step, suspending the ball mill operation for drawing the fines through screening and terminating the grinding process after reduction of the material size to – 0.5 mm. The pulverized LD slag material was used as the feed material for further characterization and spiral concentration studies.

3. Characterization of LD slag

A representative sample of Linz-Donawitz steel slag was drawn initially. The chemical composition of the representative sample was determined by ICP and X-ray fluorescence spectroscopy. The mineralogical characterization studies of the LD slag sample were carried out by identifying major mineral phases contained in the slag using X-ray diffraction (XRD) and its complementary analyses were made using scanning electron microscopy (SEM) coupled with energy dispersive spectrometer (EDS). XRD analysis was performed on pulverized material using Bruker AXS D8 diffractometer with a step and continuous scanning device. Diffraction patterns were measured in a 2θ range 10 - 90° at 0.2 sec / step speed using (Cu- Kα) radiation of 50 kV and 30 mA. The chemical analysis of as received sample and feed sample are shown in the Table 1. The size analysis and size wise chemical analysis of the feed sample was shown in Table 2.

Table 1. Chemical analysis data of LD Slag

Radicals (%)	**As received sample (Head)**	**Feed sample (Head)**
Fe (T)	19.10	18.33
FeO	13.52	8.77
CaO	43.58	44.31
SiO_2	13.18	12.79
P	1.17	1.04
Al_2O_3	0.63	1.23
LOI	5.80	7.08

Table 2. Size analysis and size wise chemical analysis of feed sample

Size (mm)	**Wt (%)**	**Radicals (%)**						
		Fe (T)	**FeO**	**CaO**	**SiO_2**	**P**	**Al_2O_3**	**LOI**
– 0.5 + 0.3	12.93	21.56	12.23	39.98	13.63	1.15	1.34	1.13
– 0.3 + 0.21	19.99	19.12	11.42	40.44	13.92	1.16	1.48	3.24
– 0.21 + 0.15	22.04	16.46	11.45	38.97	13.31	1.10	1.22	5.49
– 0.15 + 0.10	12.06	15.68	10.50	39.69	13.30	1.10	1.19	6.34
– 0.10 + 0.075	8.89	15.78	7.67	39.39	12.86	1.10	1.21	7.30
– 0.075 + 0.045	10.00	16.07	9.45	41.22	13.14	1.12	1.33	6.00
– 0.045	14.09	15.31	6.84	41.72	11.42	0.91	1.40	9.34

4. Beneficiation studies through spiral concentrator

In the present study, approximately about 1.5 ton of –0.5 mm LD slag material was processed through spiral concentration. Two full-scale spirals were tested in this study. Spiral 1 was a 7-turn Carpco, USA mineral spiral and spiral 2 was an 8-turn Roche Mining, Australia mineral spiral. Both spirals were operated using the same test circuit, which consisted of a sump, a centrifugal pump with a variable-speed drive and a 5 HP motor and a mixer. The effect of different operating parameters on the performance of spiral has been studied through optimization experiments at different feed flow rates 18–22.2 Kg/min. and splitter positions for different feed pulp densities ranging from 18–20%.

The required amount of water (based on the desired concentration) was added to the sump and allowed to circulate through the system. The required quantity of the LD slag was added to the sump, and the mixer was started to ensure the solids did not settle. The quantities of LD slag and water were varied to achieve the desired solid concentration. The slurry was circulated through the spiral at least for 10 minutes to ensure steady-state operation. For the Carpco spiral, the two discharge splitters were adjusted to partition the products into three streams (heavy i.e concentrate-1, middling, and light). The middling and light products from 7-turn coarse spiral were under recirculation in 8-turn fine spiral. The two discharge splitters were adjusted to partition the products into three streams (heavy i.e concentrate-2, middling and light). All the samples were suitably timed and taken simultaneously.

The results for the Carpco spiral followed by Roche mining spiral concentration of LD slag are shown in the following table 3. The tailings product including the middlings has been back calculated. Feed pulp density 18 Wt% and feed rate 18 kg/min were maintained for the spiral test. The splitter positions for the concentrate-1 of the 7-turn spiral were maintained at 42 mm. The middlings and tailing products of 7-turn spiral were re-circulated in the 8-turn fine spiral. The splitter positions for the concentrate-2 (75 mm), middling's (68 mm) and tailings (50 mm) of 8-turn spiral was maintained. The concentrate-1 product showed that a metal product with 35.61% Fe content with a yield of 8.00% with 0.68% phosphorous content and the concentrate-2 product contain 16.28% Fe content with a yield of 23.00% with phosphorous content 0.79%. The overall concentrate product from spiral test having low phosphorous content about 0.76% with a yield of 31% which can be utilized for iron ore sintering.

Table 3. LD slag spiral concentration test results

Product	**Wt %**	**Fe**	**CaO**	**SiO_2**	**Al_2O_3**	**P**
Concentrate -1	8.00	35.61	33.37	9.62	1.14	0.68
Concentrate-2	23.00	16.28	43.60	21.58	0.90	0.79
Tailings	69.00	18.13	44.76	10.79	1.35	1.35
Total (Calculated)	100.00	19.10	43.58	13.18	1.23	1.17

5. XRD analysis of LD slag processing products

Fig. 1 represents the XRD peaks of the concentrate-1 product of LD slag pilot scale spiral test (Table 3) which mainly contain major peaks of oxides of Fe, Ca and C such as FeO, Fe_2O_3, $FeO.Fe_2O_3$, etc. However, it also indicates the presence of silicate compounds viz. $CaSi_2$, SiO_2, Fe_5Si_3 as minor phases.

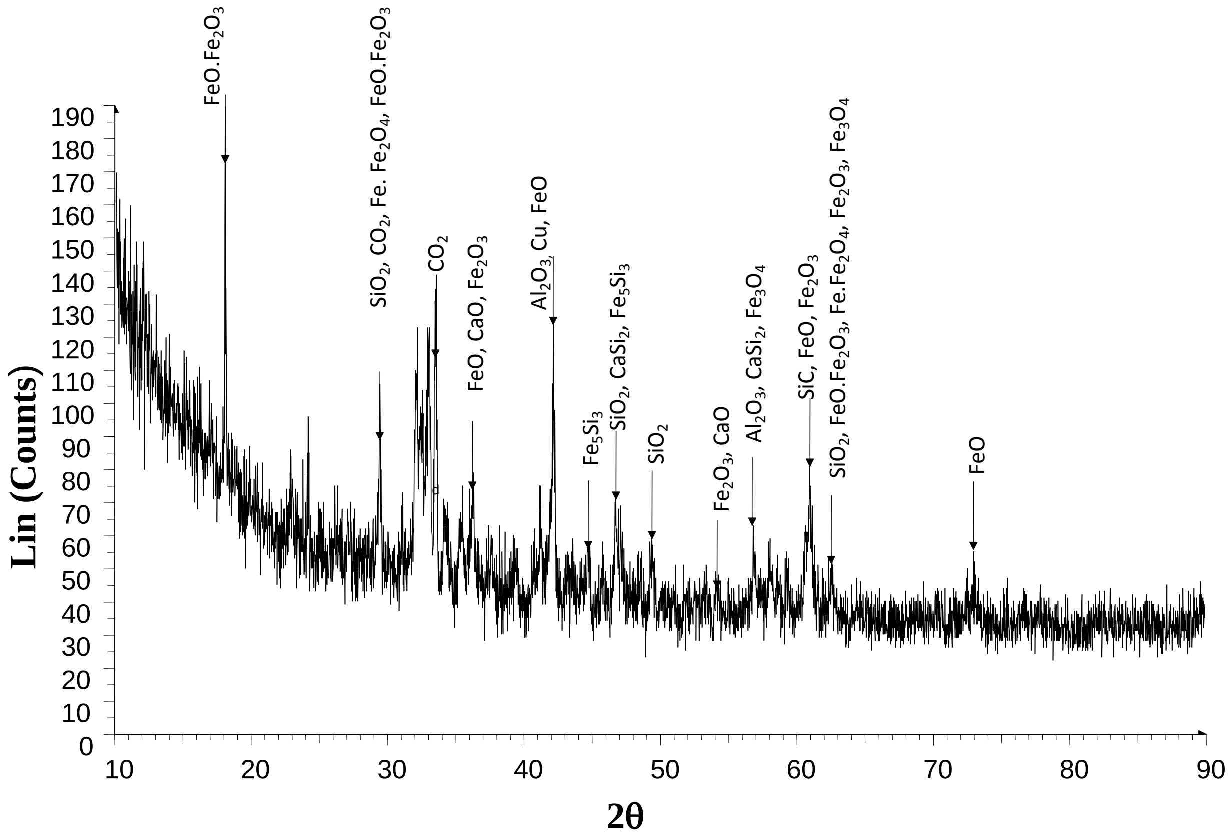

Figure 1: XRD analysis of concentrate-1 product of LD slag pilot scale spiral concentration test

6. SEM-EDS analysis of LD slag processing products

The presence of these metals was also confirmed by the SEM-EDS analysis. Fig. 2(a) below shows the bulk analysis of the concentrate-1 product sample. The EDS graph [Fig. 2(b)] confirms the presence of Ca and Fe, Al, Si, etc. metals in the sample.

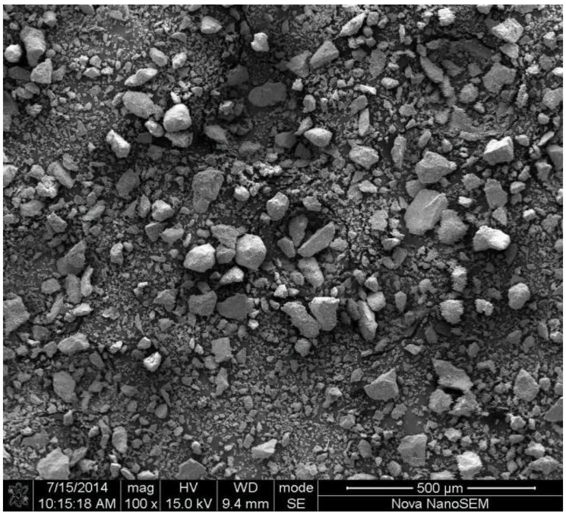

Fig. 2(a): SEM analysis of concentrate-1 product

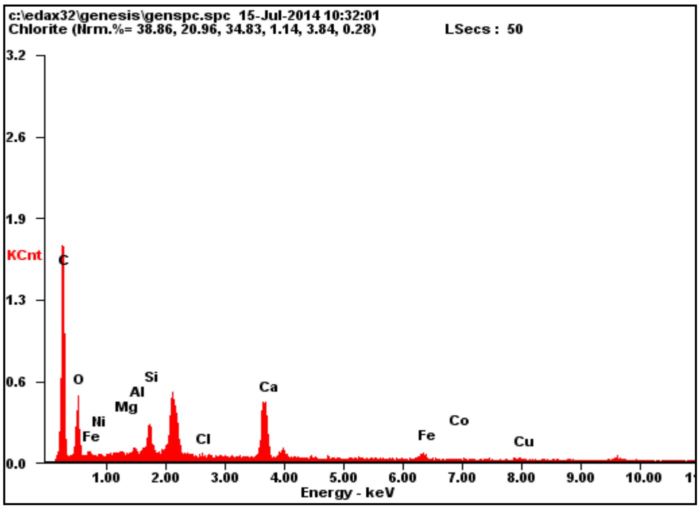

Fig. 2(b): EDS analysis of concentrate-1 product

Conclusions

The effectiveness of 7-turn coarse spiral followed by 8-turn fine spiral concentration was evaluated to process fine (–0.5 mm) LD slag for lowering Phosphorus (P) to the desired level for utilization in iron ore sintering. The impact of different operating parameters on the performance of spiral has been studied through optimization experiments at different feed flow rates, splitter positions and different feed pulp densities. The results indicated that under optimized conditions, concentrate product with low phosphorous content of around 0.76% is achieved, which however, is far below the applicable industry practice, with yield of 31%, which has utilization potential for iron ore sintering. However, the yield of concentrate in the experiments undertaken varied proportionally from 31–57%, depending upon the level of phosphorus content desired in the concentrate i.e 0.76–0.90%.

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