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Dry Magnetic Separation of Bauxite Ore

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Abstract

The paper describes the beneficiation results of the bauxite ore from Durgamanwadi mines to achieve a grade of the products conforming to refractory specification. Mineralogically, the bauxite was predominantly gibbsitic in nature with titanium and iron bearing minerals as main impurities which were intimately and intricately associated with gibbistie. The sample was crushed to –2 mm and classified into 4 size fractions. Each were subjected to the dry magnetic separation using 'Permrol' supplied by the Ore Sorter, USA. The study indicated that the best separation result could be achieved at the optimum belt speed of 3 rpm on the –690+350 micron size fraction in respect of cleanliness of the product when compared to other two size fractions. $Fe2O_3$ and TiO_2 contents could be reduced to 1.52 % and 5.16 % in the concentrate from their respective values of 3.31 % and 7.31% in the feed.

INTRODUCTION

Bauxite is the principal source of aluminium. About 90% of the bauxite mind are utilised for the metal extraction while the rest is consumed in the chemical, refractory, abrasion etc. The refractory grade bauxite finds wide application as primary feed stock for the 60% to 90% alumina content category of refractory shapes and specialities. Indian bauxite ores are generally rich in goethite, hematite and titanium oxide. Bauxite deposits in different places have different mineralogy (IBM 1999). The main problems with bauxite ores are high iron and titanium contents. So, the removal of iron and titanium oxide is required in order to meet refractory specification. Use of gravity and magnetic separations in order to enrich Al_2O_3 content in bauxite has been reported in the past (Nandi 1996, Bhimarao 1997, Kasai 1993). Murray and Lannicelli (Loc. Cit : Nandi 1996) showed that Arkansans bauxite containing 11.3% Fe_2O_3 and upto 2% TiO_2 could be beneficiated to less than 1.2% Fe_2O_3 and less than 0.7% TiO_2 by wet high intensity magnetic separation. It is reported that bauxite could be upgraded by selective crushing, scrubbing and attrition, flotation and wet high magnetic separation (Balkany 1982). Indian Bureau of Mines (IBM) has applied various beneficiation techniques such as, tabling, magnetic separation, acid leaching, reduction roasting and high intensity magnetic separation on Indian bauxite ores mainly to reduce iron and silica content (Nandi 1996).

A typical bauxite deposit available in Maharashtra State, India contains Fe_2O_3 and TiO_2, however, can fulfil the refractory specification when these impurities are removed. An attempt has been made to beneficiate the bauxite sample following dry magnetic separations which is reported in the present paper.

EXPERIMENTAL

Sample and Its Mineralogy

The bauxite sample was received from the Mines of Maharashtra state, India. The ore was buff to pinkish brown in colour with cavernous texture. Specific gravity of the samples varies from 2.05 to 3.11 with an average of 2.50. The sample was stage crushed and appropriately ground to 100 % -2 mm. Table 1 shows the sieve vis- a vis chemical analysis of the crushed sample. It is apparent from

the Table that higher quantity of impurities report to the finer fractions which indicate that the gangue minerals are finely disseminated in the ore body.

Table 1: Sieve and Chemical Analyses of –2 Mm Crushed Bauxite Sample

Size (micron)	Weight %	Assay %		
		Al_2O_3	Fe_2O_3	TiO_2
-2000 + 690	34.0	59.55	3.10	6.20
-690 + 350	15.2	58.81	3.34	7.33
-350 + 150	14.5	58.76	3.47	8.31
-150	36.3	54.26	4.78	9.55
Total	100.0	57.40	3.80	7.89

The identified mineral phases observed at different 'd' values in X-ray diffractogram of the bauxite ore sample are mentioned in Table 2. The sample was predominantly gibbsitic in nature with titanium and iron minerals as main impurities. Table 3 shows mineralogy, texture and the relative abundance of the mineral constituents of ore.

Table 2: XRD Pattern of the Bauxite Sample

Identified mineral phase	d- value with % of highest peak in bracket ( )
Gibbsite	4.857 (100), 4.381 (12), 4.33 (6.2), 2.39 (6.4)
Antase	3.526 (3.7), 1.897 (1.6), 1.70 (1.7)
Hematite	2.707 (1.9), 2.515 (1.6), 1.685 (3.9)
Goethite	2.455 (5.0),
Rutile	3.251 (1.9), 1.698 (1.7), 2.191 (1.6)
Magnetite	1.484 (1.4),
Mica	3.188 (3.6), 1.918 (2.8) 2.514 (1.6)
Pyrite	1.753 (4.2)

Table 3: Mineralogy and Texture of the Bauxite Samples

Phases/Texture	Characteristics
Alumina minerals	Major phase: Gibbsite
Iron minerals	Minor phases: Goethite and Limonite Trace phases : Hematite and Magnetite
Other opaque	Minor phases: Rutile and Anatase Trace phase: Pyrite
Silicates	Very minor / Trace : Mica, Quartz and Amphibole
Texture	(1) Colloform , interstitial and vug filling of goethite and limonite (2) Gangue and iron minerals are intimately and intricately associated with bauxite. (3) Titanium minerals are finely disseminated

Optical microscopic studies (Dana 1984, Paul 1969) revealed that the iron minerals occupied the interstices and vug filling of the ore and also present as intercalation. The titanium minerals were present as fine disseminated grains 0.08 to 0.01 mm in size . The liberation of titanium minerals could occur in fractions below 0.208 mm while the silicate as well as the iron mineral's fair liberation was noticed below 0.15mm. From the above mineralogical and textural features it is inferred that the mineralogy is very complex and iron minerals present very intricately and their removal by physical means of beneficiation is very difficult.

Heavy Liquid and Iso-Dynamic Separation Tests

For above studies the ore was ground to 100 % -212 micron and splitted into –212 + 74 micron (μ) and –74 micron (μ) size fractions. Bromoform (sp.gr. 2.86), methylene iodide (sp.gr. 3.0) and aqueous solution of thalium malonate formate (sp.gr.4.05) were used as heavy liquids for sink and float study. Figure 1 shows the scheme of the heavy liquid test adopted along with the results. The bromoform light (sp.gr. –2.86) fraction of –212+74 micron (μ) fraction was treated in Frantz isodynamic separator (model L-1). Figure 2 shows the scheme of isodynamic separation test adopted along with the results. The above studies indicated that a yield of 36.5% of values with minimum impurities could be obtained when the ore was ground to –212 μ with a pre-separation of –74 μ size fraction. Chemical composition of the non-magnetic fraction is also reported in the figure.

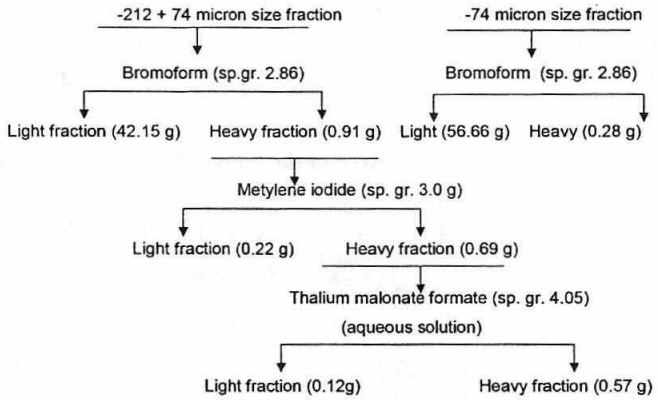


Fig. 1: Scheme and Results of Heavy Liquid Test of Bauxite Sample

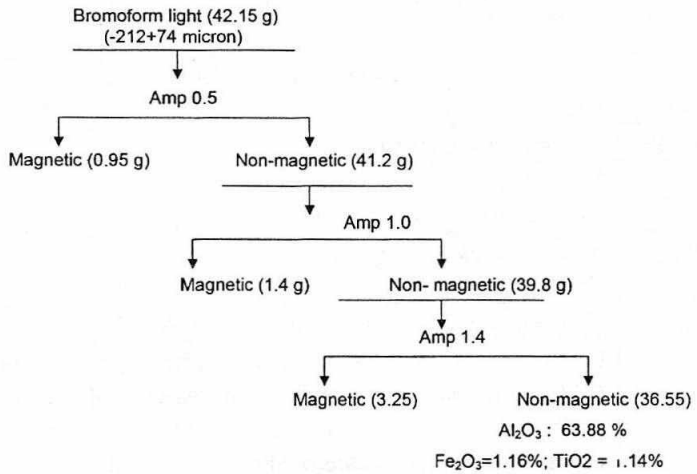


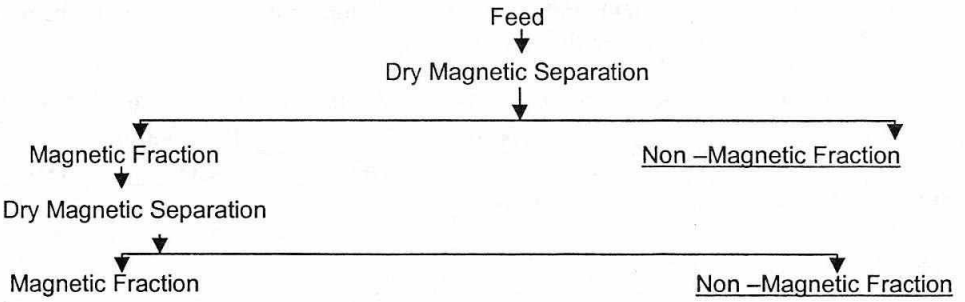
Fig. 2: Result of Isodynamic Test on –212+74 Micron Size Fraction

Preparation of the Sample

The ore sample was crushed to –2 mm size and then classified into –2 mm +690 micron, -690 +350 micron, -350 + 210 micron, -210 +150 micron and –150 micron size fractions. It was noticed that the latter two size fractions were too fine to be treated by the dry beneficiation route and possibly need wet magnetic separation route to be adopted.

Magnetic Separation

The former three size fractions were individually subjected to dry beneficiation using the batch pilot scale permanent magnetic separator 'Permroll' supplied by the Ore Sorter, USA. Vibration of the feeder was fixed at a level so that a continuous mono-layer was built on the machine belt. The cutter position of the machine was set at a level where we focused for the maximum cleanliness of the product (non-magnetic I). The intermediate magnetic fraction was further passed through the separator in order to retrieve additional material from it as schematically shown below.



RESULTS & DISCUSSION

Effect of Belt Speed

Table 4 shows results of the separation of the –690+350 micron size fraction bauxite ore sample at different belt speed. The study indicated that a moderate throughput of the feed material (belt speed 6 rpm) resulted in the better grade of the non-magnetic fractions with higher yield compared to lower (belt speed 3 rpm) higher (belt speed 9 rpm) ones. A clearer separation could not be obtained at 9 rpm belt speed. A marginal difference in Fe_2O_3 content of the non- magnetic fraction and magnetic one was observed in this case. This was due to the fact that an adequate retention time is required for the effective magnetic separation.

Table 4 : Effect of Belt Speed on Dry Magnetic Separation Tests of –690+350 μ Sized Fraction Bauxite Ore

Product	Weight, %	Assay , Wt. %		Distribution , Wt.%	
		Fe_2O_3	TiO_2	Fe_2O_3	TiO_2
(A) Test I : Belt Speed = 3 rpm					
Non- Magnetic I	42.0	2.65	4.96	33.5	28.5
Non-Magnetic II	12.0	3.01	6.35	10.9	10.4
Magnetic	46.0	4.02	9.68	55.6	61.1
Head (calc.)	100.0	3.32	7.30	100.0	100.0
(B) Test II : Belt Speed = 6 rpm					
Non- Magnetic I	50.5	1.52	5.16	23.3	35.7
Non-Magnetic II	9.5	3.75	5.16	10.7	6.7
Magnetic	40.0	5.46	10.55	66.0	57.6
Head (calc.)	100.0	3.31	7.31	100.0	100.0
(C) Test III : Belt Speed = 9 rpm					
Non- Magnetic I	43.4	2.29	4.50	37.7	30.4
Non-Magnetic II	14.6	2.56	5.09	14.2	11.5
Magnetic	42.0	3.02	8.90	48.1	58.1
Head (calc.)	100.0	3.34	7.35	100.0	100.0

Effect of Feed Size

Table 5 shows the results of the magnetic separation of different sized fraction bauxite sample at 6 rpm belt speed which was found optimum (ref. Table 4). From the Table it is apparent that the best separation result could be achieved on the –690+350 micron sized fraction in respect of cleanliness of the product when compared to other two size fractions. $Fe2O_3$ and TiO_2 contents could be reduced to 1.52 wt.% and 5.16 wt.% in the concentrate from their respective values of 3.31 wt.% and 7.31 wt.% in the feed. Comparatively lesser grades of the concentrate after the beneficiation of the coarser as well as finer size fractions other than –690+350 micron size fraction could be attributed to the poorer liberation and 'sticking effect' of the fine particles respectively.

Table 5: Effect of Grain Size of Bauxite Ore on Dry Magnetic Separation Tests at 6 Rpm Belt Speed

Product	Weight ,%	Assay , Wt. %		Distribution , Wt. %	
		Fe_2O_3	TiO_2	Fe_2O_3	TiO_2
(A) Test I : Size Fraction = -2 mm + 690 micron					
Non- Magnetic I	78.2	2.15	6.03	54.7	73.7
Non-Magnetic II	9.4	3.45	7.13	10.5	10.5
Magnetic	12.4	8.62	8.18	34.8	15.8
Head (calc.)	100.0	3.08	6.40	100.0	100.0
(B) Test II : Size fraction –690 + 350 micron					
Non- Magnetic I	50.5	1.52	5.16	23.3	35.7
Non-Magnetic II	9.5	3.75	5.16	10.7	6.7
Magnetic	40.0	5.46	10.55	66.0	57.6
Head (calc.)	100.0	3.31	7.31	100.0	100.0
(C) Test III : Size Fraction –350 + 210 micron					
Non- Magnetic I	20.5	1.62	6.04	9.0	14.5
Non-Magnetic II	41.6	3.58	8.03	40.4	39.4
Magnetic	37.9	4.91	10.37	50.6	46.2
Head (calc.)	100.0	3.68	8.51	100.0	100.0

The Best Result

The best result that could be obtained (i.e. magnetic separation of the –690 + 350 micron size fraction at belt speed 6 rpm) are as follows:

Product	Weight, %	Assay, %		Distribution , %	
		Fe_2O_3	TiO_2	Fe_2O_3	TiO_2
Non-magnetic-I	50.50	1.52	5.16	23.3	35.7
Non-magnetic-II	9.5	3.75	5.16	10.7	6.7
Magnetic	40.0	5.46	10.55	66.0	57.6
Head (calculated)	100.0	3.31	7.33	100.0	100.0

The study could result in partial success in the beneficiation of the bauxite sample through dry magnetic separation for its refractory application. While Fe_2O_3 content could be reduced significantly in the case of individual size fractions of the bauxite sample, TiO_2 could not be reduced significantly. Besides, overall yield of the non-magnetic product was about 25 wt.% of the feed material taking into account the yield of the medium sized fraction bauxite ore (-2000+350 micron) as 50 wt.% of the total bauxite ore sample. By this way one–fourth of the total ore treated could be obtained as a value added product for refractory application, whereas the rest three fourth could be used in the extraction of alumina /aluminium along with normal bauxite. Alternatively, the rest 75 wt.% of the material may be treated through wet circuit route. The earlier results of wet beneficiation using gravity and

magnetic separators indicated that Fe_2O_3 and TiO_2 could be reduced to 1.58 wt.% and 1.95 wt.% respectively , from their levels at 3.80 wt.% and 5.68 wt.% in the feed with 57 wt.% yield when the de-slimed sample was stage ground and classified into coarse and fine fractions and treated separately through wet high intensity magnetic separation route (Bhagat 2001).

CONCLUSIONS

- Mineralogical investigation reveals that the gangue minerals are fine grained and intimately locked with the gibbsite making the separation difficult. A concentrate which can fulfil the desired chemical specification of the bauxite sample pertaining to refractory grade (1.1-1.2%, Fe_2O_3/TiO_2) can be obtained when the ore is ground to -212 micron size with pre-separation of –74 micron size fraction.
- We could achieve partial success in the magnetic separation of bauxite ore through dry circuit route as it was effective for the medium sized bauxite ore fraction which constituted of 50 wt.% of the total bauxite ore sample. The yield of the concentrate was approximately 50 wt.%. his indicates that only one-fourth of the (total) feed material is recovered as concentrate through dry magnetic separation route for its refractory application while rest 75 wt.% of the material need treatment either through wet circuit route or could be utilised in the metallurgical industries. Besides, while Fe_2O_3 content could be reduced significantly in the case of individual size fractions of the bauxite sample, TiO_2 could not be reduced significantly.

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REFERENCES

[1] Balkany A , 1982, Mintek Report No. M19 (pamphlet)
[2] Bhagat, R . P. Banerjee B., Kunwar R. K and Dey S, 2001 Trans. Inst. Mining & Metallurgy, Mineral Processing & Extractive Metallurgy, 110, pp. c165-c168.
[3] Bhima Rao, R., Besra, L, Banerjee, G. N. and Reddy, ˜. S. R. -1997, Jour. Magnetic and Electric Separation, 8(2), pp. 115-123
[4] Dana, E. S., 1984, Text Book of Mineralogy, Fourth Edition, Published by John Wiley & Sons, Inc. London.
[5] I BM, 1999, Indian Mineral Year Book, Vol. 2, Published by Indian Bureau of Mines, Nagpur, India, pp. 224-230.
[6] Kasai, E., Maneenuse, M., Tanjo, M. and Saito, F. 1993, Jour. Miner. Mater. Process. Inst. Japan. 109(10), pp. 817-822
[7] Nandi, A. K. Minerals and Metals, (January) 1996, 31-39.
[8] Paul Ramdohr, 1969, The Ore Minerals and their Inter-growths, Published by Pergamon Press, London, 1969