

Beneficiation of low grade Aluminous Mn- ore from Bonai- Keonjhar belt, Odisha, India

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Abstract Three types of low-grade manganese ores belonging to the Pre-Cambrian age are found in the Bonai-Keonjhar belt of Odisha. Out of the siliceous, ferruginous and aluminous Mn-ores the later type was characterised mineralogically and subjected to different physical beneficiation methods such as gravity (heavy media separation, mineral separation and tabling) and magnetic separation. The results obtained for gravity separation was not very encouraging and the grade of Mn could not be improved beyond 30%. The magnetic separation method was quite useful and a product having only 23% Mn in the feed could be up-graded to more than 32% Mn. However, the increase in Mn-value is accompanied by concomitant rise in Fe value, which inhibits the direct use of the processed product but it can be suitably blended with low iron Mn-ores and finds good market value.

Keywords: *aluminous Mn-ore, magnetic separation, Bonai-Keonjhar belt*

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1. Introduction

The manganese mineralisation associated with the Banded Iron Formation belonging to the Pre-Cambrian age in the Bonai- Keonjhar belt bears a significant position in the mineral map of India. The Mn deposits are usually low to medium grade with small pockets rich in high grade ores. The low grade ores are classified into 3 broad categories depending upon their major matrix, such as i) siliceous, ii) ferruginous, and iii) aluminous (Mishra, 2005). Out of the three low grade ore types, the aluminous Mn ore is of stratiform type i.e. concordant to country rock and exhibits alternate laminae of Mn minerals and clay minerals. A typical deposit of the above type is the Maidan quarry of OMDC lease hold in the north-eastern part of the Bonai- Keonjhar belt. The suitability of dry magnetic separation method to upgrade low-grade siliceous Mn-ore from the Bonai-Keonjhar belt was reported by Mishra et. al, (2009), Mishra et. al, (2013). Several authors have also reported the possible upgradation potential of low-grade Mn-ores through magnetic separation method (Rao et. al 1988, Mohapatra et. al 1995, Mishra et. al 2011). Thus, the low grade aluminium type Mn-ore from Maidan quarry was processed through different physical beneficiation techniques (gravity and magnetic) and the present paper reports the result obtained from the above study.

2. Materials and Methods

Representative samples of low-grade aluminous manganese ore was collected from the Maidan quarry of OMDC lease hold from the Bonai-Keonjhar belt. Optical microscopy (Leica, DM2500), and XRD (Rigaku Ultima IV) were used for mineralogical study. Selective elements like Mn, Fe, SiO₂ and Al₂O₃ were analyzed by XRF Spectrometry on Philips (PW-1400) X-ray spectrometer with scandium and Rhodium targets using Pentaerythritol (Al, Si), Thallium Acid Pathalate (Na, Mg), Germanium (P) and Lithium Fluoride (LIF, for heavier elements) as analyzing crystals in vacuum medium.

The bulk samples were crushed to below 1000 micron size by Jaw crusher followed by Roll crusher. These crushed bulk samples were classified into different close sized fractions using standard test sieves of opening grid 1000 µm, 500 µm, 250 µm, 150 µm and 75 µm. Sink and float studies were carried out using bromoform having specific gravity of 2.85. About 50 gms of the close sized fraction was taken and separated using bromoform. The heavies and lights were collected separately, washed, dried, weighed and analysed for Mn, Fe, SiO₂ and Al₂O₃. In view of the density difference between manganese and clay minerals beneficiation studies were carried out using Mozley mineral separator. About 50 gms of each close sized fraction was taken separately and subjected to mineral separator for 15 minutes at 2.0 liter/minute wash water rate. Both the heavies and lights were collected separately, dried, weighed and analysed. Tabling studies were taken up for the low-grade aluminous Mn-ore samples using 1016x457 mm Denver Wilfley Laboratory table supplied by M/s Denver, USA. For tabling studies samples were classified in to two fractions -500+250 µm and -250 µm. About 10 kg of sample was mixed with 20

liter water and made into uniform slurry. This slurry was pumped to the table feed box at uniform rate. The wash water was maintained at 6 liter per minute and stroke length was kept at 10 mm. Different products obtained were collected, dried, weighed and analysed.

For beneficiation of the close sized fractions of manganese ore, high intensity dry belt magnetic separator of type LOG 1.4 SEP operated at 50 DC Volt and 4.17 DC A current, suitable for fine particle separation, (supplied by Boxmag Rapid Ltd., Birmingham, England) was employed. The magnetic intensity was varied between 0.73 and 1.23 tesla. Dry samples of closed size fractions were continuously fed to the belt magnetic separator by vibrating feeder at controlled rate. Magnetic products were separated by moving disc at required speed and intensity. Based on the requirement, the intensity, feed rate, and gap between the belt and disc in the magnetic separator were varied.

3. Mineralogical Characteristics

Detailed characterisation of the low grade ores from Maidan quarry revealed five morphological types of Mn ores such as a) laminated, b) banded, c) massive nodular, d) massive compact, e) powdery. Out of the five types of ores the powdery ores is the dominant ore followed by banded and laminated types. The ore broadly contains three mineral phases such as manganese, iron and alumina. The manganese phase is represented by cryptomelane and pyrolusite, iron phase by hematite and alumina phase by kaolinite and illite. Quartz is only recorded in powdery type ores. Microscopic study of the above ore types also revealed the occurrence of the above mineral phases.

4. Beneficiation Characteristics

4.1. Size Classification

The marginal to low-grade ROM samples were crushed and subjected to size classification by using standard test sieves of 1000, 500, 250, 150 and 75 μm sizes. Each classified fraction was weighed and analysed for Mn, Fe and selected samples for SiO_2 and Al_2O_3 . The results of the size and chemical analysis of bulk and fractionated materials of low-grade aluminous Mn-ore is shown in Table 1. It is clear from the table that both iron and manganese are almost uniformly distributed in all the size-fractions. However, the respective contents of the SiO_2 and Al_2O_3 go up in aluminous Mn-ores when ground to below the 75 μm size fraction.

4.2. Heavy Media Separation

Sink and float studies were carried out in close sized fraction using bromoform as medium (specific gravity 2.85). The results are presented in table 2. The results indicate that most of the manganese could be recovered in the sink, so it is possible to reject most of the lighter material by this method. The grade of Mn could not be improved beyond 30% because of the presence of iron minerals.

4.3. Mineral Separator

The result obtained on Mozley mineral separator presented in table 3 indicates that no clear separation could be achieved above 75 μm size fraction. Further due to the presence of high iron values in the heavies the grade is reduced, manganese and iron having almost similar densities. A product with 28% Mn having 55% recovery could be obtained at -150+75 μm size fraction.

4.4. Tabling

For tabling studies the samples were crushed below 500 μm and classified in to -500+250 μm and -250 μm size fractions and processed through Denver Wilfley table. The results obtained and presented in Table 4 show more or less identical values when compared with that of the mineral separator. A product with 28.4% Mn could be obtained at 33.2% recovery. The quality of the product could not be improved due to the presence of iron bearing minerals.

4.5. Dry Magnetic Separation

The magnetic separation of aluminous Mn-ore revealed nearly similar results as that of the ferruginous Mn-ore. The bulk considered as feed contained about 23% Mn and 16% Fe. When different size fractions were processed at different magnetic intensities the results obtained at 1.0 tesla represented the best results. The results presented in Table 5 show that though there is a significant rise in Mn-content in the magnetic product at 1.0 tesla for -150+75 size fraction, the Fe content also increases to around 22%. This is because the bulk itself contained some Fe minerals like goethite and haematite which are attracted by the magnet and report to the magnetic fraction. The silica and alumina are significantly less in the magnetic product being only 3.8% and 3.6% respectively.

Table 1. Size and chemical analysis of low-grade Aluminous Mn-ore

Size in μm	Wt %	Mn %	Fe%	SiO_2 %	Al_2O_3
Bulk	-	23.3	16.4	21.7	11.9
-1000+500	22.3	20.4	14.4	25.2	11.1
-500+250	16.7	23.1	17.4	26.2	10.9
-250+150	13.9	24.7	17.3	21.4	8.9
-150+75	14.3	25.9	16.7	14.2	5.9
-75	32.8	24.3	16.2	21.8	22.5
Head	100	23.7	16.4	21.8	11.8

Table 2. Sink and float studies for different size fractions

Size in μm	Sink			Float		
	Wt. %	Mn %	Fe %	Wt. %	Mn %	Fe %
-1000+500	74.6	26.29	26.93	25.4	3.46	2.29
-500+250	76.0	29.75	28.36	24.0	2.07	1.43
-250+150	81.5	30.44	27.79	18.5	103	1.71
-150+75	85.6	29.75	28.36	13.4	1.38	1.71

Table 3. Mineral separator studies on different size fractions

Details	Wt. %	Mn %	Fe %	Mn % Rec.
-1000+500 μm				
Heavies	10.4	22.10	38.55	10.7
Light	89.6	21.42	23.01	89.3
-500+250 μm				
Heavies	33.3	26.52	33.66	40.6
Light	66.7	19.38	19.85	59.4
-250+150 μm				
Heavies	42.1	27.88	33.08	49.4
Light	57.9	20.74	18.98	50.6
-150+75 μm				
Heavies	50.0	28.22	30.49	55.3
Light	50.0	22.78	19.27	44.7
-75 μm				
Heavies	13.3	26.52	31.64	36.3
Light	86.7	7.14	22.15	63.7

Table 4A. Tabling of -500+250 μm size fraction

Details	Wt. %	Mn %	Fe %	SiO ₂ %	Al ₂ O ₃ %	Mn Rec. %
Concentrate	24.9	28.37	25.50	11.27	6.3	33.2
Middling	23.8	24.56	20.34	25.9	4.6	27.5
Tailing	51.3	16.26	20.62	31.8	8.8	39.3

Table 4B. Tabling of -250 μm size fraction

Details	Wt. %	Mn %	Fe %	SiO ₂ %	Al ₂ O ₃ %	Mn Rec. %
Concentrate	15.3	28.7	29.8	6.8	3.26	23.1
Middling	18.9	21.9	19.2	28.1	4.1	21.8
Tailing	65.8	15.9	14.0	26.9	14.9	55.1

Table 5. The magnetic product of dry magnetic separation for aluminous Mn-ore

	0.73 Tesla					1.0 Tesla					1.23 Tesla				
	Wt %	Mn %	Fe%	SiO ₂ %	Al ₂ O ₃ %	Wt %	Mn%	Fe%	SiO ₂ %	Al ₂ O ₃ %	Wt %	Mn %	Fe%	SiO ₂ %	Al ₂ O ₃ %
+500	42.9	26.1	18.5	8.4	9.2	41.4	24.1	17.8	10.	9.9	44.7	27.4	22.2	9.6	9.4
+250	23.0	27.2	20.9	5.6	7.1	25.7	26.8	18.9	8.6	9.1	26.3	28.7	20.6	7.2	8.6
+150	18.2	28.4	22.8	4.2	5.2	17.4	28.2	21.2	7.3	8.2	15.7	29.2	21.8	6.4	7.1
+75	15.9	29.1	24.5	3.0	4.8	15.5	32.8	22.6	3.8	3.6	13.3	31.4	21.4	4.9	5.8
Total	100	27.7	21.6	5.3	6.6	100	28.0	20.1	7.4	7.7	100	29.2	21.5	7.0	7.7

product restricts the direct use of the magnetic product but it can be suitably blended with low iron containing Mn-ores in different proportion to get a marketable Mn-ore.

5. Conclusion

The low-grade aluminous Mn-ore from the Maidan quarry of Bonai-Keonjhar belt, Odisha, India was characterised mineralogically. The study revealed that cryptomelane and pyrolusite are the dominant manganese minerals. Appreciable volume of iron minerals in the form of hematite and goethite are also present. Kaolinite with minor quartz is present in the gangue phase. The size classified samples were subjected to gravity and magnetic separation methods to assess their amenability to physical up-gradation. The gravity separation results showed that significant improvement in the quality of Mn product is not achievable beyond 30%. The dry magnetic separation responded well and a product having 32.8% Mn and 22.6% Fe is obtained at 1.0 tesla magnetic intensity and -150+75 μm size fraction. The increased Fe content in the

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