FEASIBILITY OF PRODUCING SINTER FINES FROM A LOW GRADE AND FINE GRAINED HEMATITE-GOETHITIC ORE

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Abstract

Iron ore quality in India is deteriorating due to continual increase in consumption of good grade ores. It is imperative to use low grade iron ores to meet the current demand. In the Jharkhand-Odisha belt hematite ore containing significant amount of goethite material have difficulty in processing. In the present paper, response of a low grade hematite-goethitic iron ore to beneficiation for the production of sinter and pellet feed material has been investigated. The ore sample contained hematite as the major iron bearing mineral with considerable amount of goethitic material. The major impurities present were quartz and clay. The sample contained reasonable amount of hematitic with relatively coarse liberation, however, overall the sample was poorly liberated. This posed difficulty in producing concentrate with desired metallurgical performance. The modified strategy involved selectively recovering sinter fines with possible recovery of pellet grade material. Hence, the top size of the ore was kept at 5 mm and ore was subjected to scrubbing and washing, followed by classification. Beneficiation studies such as jigging, tabling and WHIMS were carried out on different washed products and results are discussed. A total of 32% with Fe 63.8% sinter material and a varied amount of pellet material could be achieved from low grade iron ore.

Keywords: Low grade iron ore, beneficiation, gravity, magnetic, sinter, pellet.

1. Introduction

India is one of the leading producers and exporters of iron ore in the world with over 28 billion tonnes of iron ore reserves[1]. Processing of low grade iron ore is inevitable as a result of increase in production and consumption of high grade ores . Though Indian iron ore is rich in iron but it contains high alumina, which is not favorable for efficient operation of blast furnace [2]. Indian iron ore mine have been operated by selective mining to maintain the high grade iron ore (Fe>60%), however, it is extremely difficult to practice the same because of two reasons. The first is the huge quantity of material that is needed to cater the demand of Iron & Steel industry (India's steel capacity would be nearly 300 million tonnes by 2025) which is not possible by selective mining alone and secondly, in the process of selective mining, large amount of overburdens (low grades) and fines are generated and dumped near the mine site which subsequently creates environmental hazard to the nearby residents.

Generally, the beneficiation of high/medium grade hematite iron ores in India includes dry circuit covering crushing, screening or wet circuit consisting of crushing, scrubbing, washing and classification[3-4]. This kind of simple approach of washing and scrubbing is not sufficient enough to produce iron concentrate with desirable quality from low grade iron ores. In recent times, several development in the mineral processing in the area of gravity, magnetic separation and flotation namely column has taken place globally. However, there is need to design newer flowsheet involving advanced techniques for low grade Indian iron ores. In the present investigation, an attempt made to produce sinter grade fines and also the pellet-feed material from a low grade iron ore sourced from eastern region of India by using various beneficiation techniques.

2. Experimental

Iron ore sample

The low grade iron ore sample obtained from Eastern region of India was thoroughly homogenized and subjected to stage crushing to produce -5mm material with a view to target feed size for sinter . Head sample was prepared by reducing the size and followed by coning and quartering. The chemical analysis of the sample was given below in Table-1. It is indicated that the sample contains 56.29 % Fe with 4.3 % silica,5.88 % alumina and 8.25% LOI indicating goethitic mineral content of the ore.

Table1: Chemical analysis of low grade iron ore sample

Assay	Fe(T)	SiO_2	Al_2O_3	LOI
%	56.29	4.3	5.88	8.25

Methods

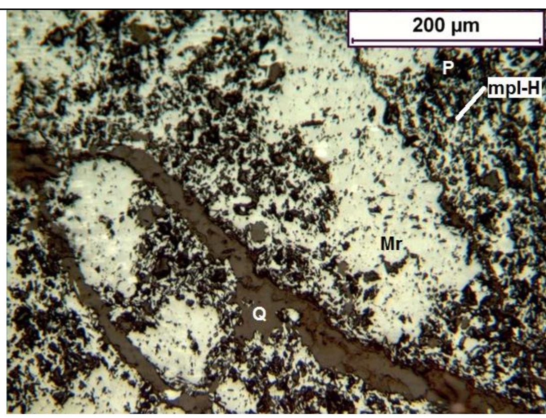
Mineralogical characterization of the iron ore sample was carried out by megascopic and microscopic techniques. For optical microscopic studies polished sections were prepared and studied under a Leitz (Leica)-orthoplan universal research microscope. Liberation characteristics of the samples were determined using a Leitz/Leica-Zoom stereomicroscope.

Bench scale beneficiation study was undertaken on the iron ore sample crushed to -5mm. The crushed material (-5mm) was subjected to scrubbing in a concrete mixer for 4 minutes and wet screened at two different screens i.e.1 and 0.1mm. The three fractions i.e. -5+1, -1+0.1 and -0.1mm were treated separately in different units such as air pulsated jig, Humboltz Wedag make, Wilfley table and Mozleys 2” hydrocyclone respectively. The underflow material from hydrocyclone was treated in a wet high intensity magnetic separator (WHIMS), Allmineral to enrich the cyclone underflow.

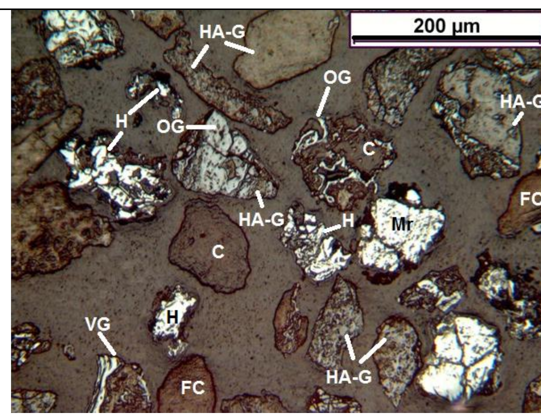
3. Results and Discussion

Mineralogical characteristics of the sample

The iron ore is comprised of goethite (vitreous goethite, ochreous goethite, microplaty ochreous goethite, high-alumina goethite, colloform goethite), hematite (martite, microplaty hematite) and gangue comprising of kaolinite, gibbsite, quartz as revealed from petrological and XRD study. martite, microplaty hematite with porosity in hematitic fragments are associated with interlocked quartz either dispersed or as vein (Fig.-1a). Goethitic fragments are associated with interlocked hematite and clay. Some of the interlocked microplaty hematite of <10 micron size cannot be liberated or processed. Colloform goethite exhibits interlocking of clay at a scale as low as <10 micron. Vitreous goethite, ochreous goethite, high alumina goethite and clay exhibit complex texture with interlocking in varied scale even at a size smaller than 10 micron (Fig.-1b). The granulometric observations under scanning electron microscope indicates microplaty hematite fines of about 1- 2 micron size are interlocked in clay and goethite particle of 5-10 micron size and cannot be liberated. The high-Al goethite contains 4-18% alumina and 2-26% silica and qualify as gangue for the present industrial requirement. The liberation study carried out by optical microscopy under zoom stereo microscope reveals a poor liberation of 82% in a size class -63+45 micron. As the high-Al goethite is equivalent to a gangue mineral but cannot be discriminated by optical microscopy, the liberation data may be an over estimate.



a) Martite (Mr), microplaty hematite (mpl-H), quartz (Q) and pore space (P) in a hematitic fragment in the iron ore



b) photomicrograph of grains under polarising microscope indicating mineralogical variation and interlocking attributes. OG- ochreous goethite, VG- vitreous goethite, HA-G - high-Al goethite, FC- Ferrugenous clay, C- Clay (Kaolinite/gibbsite), Mr- martite, H- hematite.

Figure 1: Various structures and complex textures of low grade iron ore.

Laboratory beneficiation studies

The laboratory beneficiation study results are presented in this section. The results of scrubbing, washing, and wet screening is shown in Table-2. Scrubbing of the crushed sample produced 86.7% of -5+0.1mm materials with 57.77% Fe and ~13% of -0.1mm slime with 44.89% Fe. The slime fraction contains substantial amount of alumina and silica indicating that clayey component are concentrated in this fraction and can be rejected.

Table 2: Results of scrubbing, washing and wet screening of sample crushed to -5 mm

Size, mm	Wt%	Fe, %	Al_2O_3, %	SiO_2, %	LOI, %
-5+1	68.0	58.3	5.13	2.75	6.8
-1+0.1	18.7	55.84	5.91	4.41	9.09
-0.1	13.3	44.89	11.1	11.3	13.1
Feed(Calc.)	100.0	56.06	6.08	4.19	8.06

Jigging of -5+1 mm fraction

Jigging of -5+1mm fraction was carried out and the result is portrayed in Fig 2. Jigging was done at a frequency of 70 strokes per minute with 600 l/min of water flow rate to the jig. Jigging could improve the iron content in the bottom layer from 58.3 % to 66.34% with a yield of 23.6% (16% WRO). However, yield can be improved to46.7% (~32% WRO) if bottom two layers are considered as concentrate with a grade of 63.74% Fe.

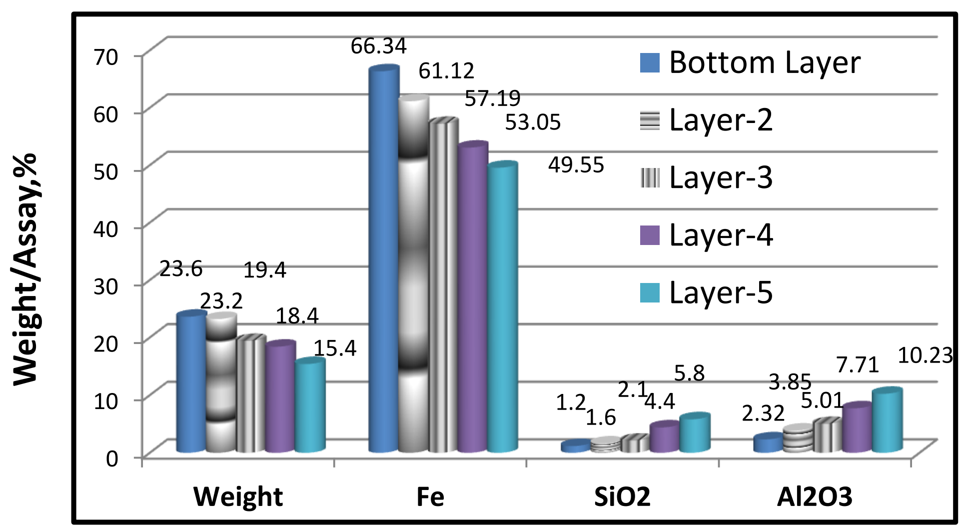


Figure 2: Results of jigging of (-5+1mm) fraction of low grade iron ore sample.

Tabling of -1+0.1mm fraction

The (-1+0.1mm) fraction so obtained from scrubbing and wet screening operation was treated in a sand deck Wilfley Table. The results are given in Fig.3. The concentrate obtained from tabling shows Fe enrichment to 59.68% with a yield of 32% (6 % WRO) with respect to the table feed with 55.84% Fe.

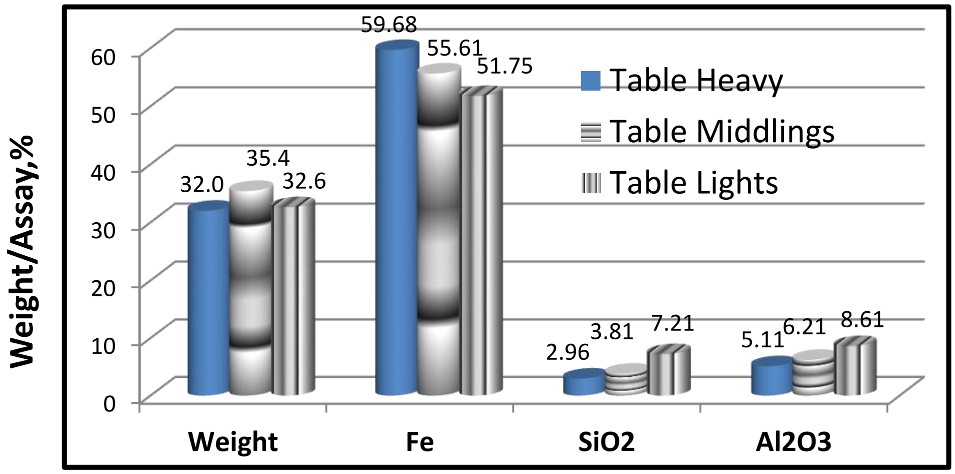


Figure 3: Results of Tabling of (-1+0.1mm) fraction of low grade iron ore sample.

As tabling didn't yield good grade indicating locking of iron bearing minerals with gangue at 1mm size. The (-1+0.1mm) fraction and the jig rejects (layers 3-5) were ground to -150 µm with a view to enhance liberation of valuable mineral.

Hydrocycloning of Ground material of (-1+0.1 mm) and jig rejects

The sample was first deslimed to remove the ultrafine particles using a hydrocyclone under given condition.

Table 3: Results of Hydro cycloning of ground material.

Condition	Product	Wt,% wro	Assay, %		
			Fe	SiO_2	Al_2O_3
Apex dia:5mm Pressure: 10psi Vortex Finder: 14.3mm Solid Conc: 10%	Underflow	44.2	55.19	3.9	6.5
	Overflow	10.7	50.35	5.04	9.51
	Head (Calc)	54.9	54.25	4.12	7.08

Wet High Intensity Magnetic Separation of cyclone underflow

The cyclone under-flow obtained from hydrocycloning condition was further treated in wet high intensity magnetic separator at current of 0.6Amp. The results obtained are presented in Fig.4. Magnetic fraction from WHIMS could produce 4.4 % yield WRO assaying 63.13% Fe.

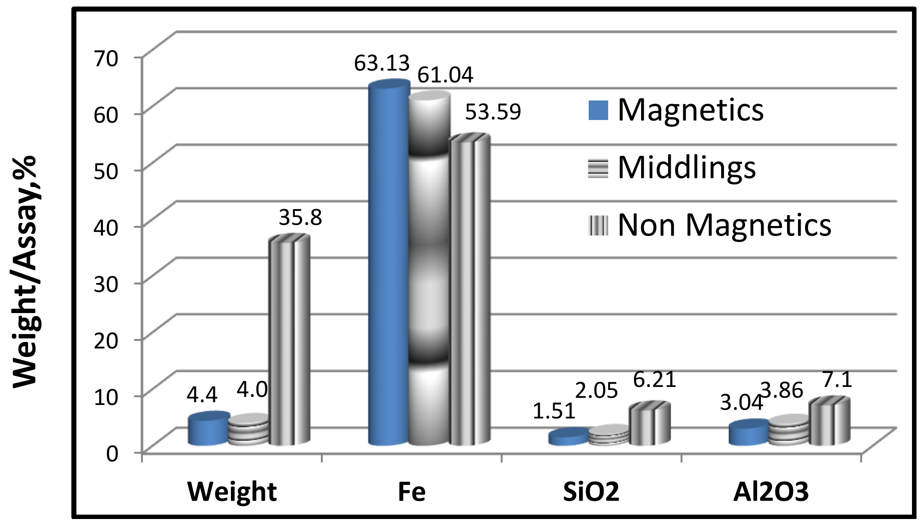


Figure 4: Results of WHIMS of hydro cyclone under-flow.

It was observed that sinter fines are possible by fine jigging (-5+1mm) with a grade of ~63.74% Fe. Similarly, 4.4 % by weight of pellet feed concentrate with Fe content of 63.13% is possible from the ground product (-150 µm) of fraction (-1+0.1mm) and jig rejects using desliming in hydrocyclone followed by concentration by WHIMS.

The low yield in beneficiation may be due to poor liberation. As hematite fines interlocked in goethite report to tailings, and high-Al goethite is equivalent to a ferrugenous gangue they report to a high grade tailing which could not be processed.

4. Conclusions

From the above studies, the following conclusions can be drawn.

- The low grade iron ore sample contains hematite and goethitic/limonitic content as major iron minerals and quartz and clay as the major gangues mineral. High goethitic/limonitic content and the fine size liberation pose problem in achieving desired metallurgical performance.

- It was observed that sinter fines 46.8% yield (~32% WRO) are possible in jigging (-5+1mm) with a grade of ~63.74% Fe.
- 4.4 % by weight of pellet feed is possible to produce from ground product of (-1+0.1mm) and jig reject upon desliming using hydrocyclone followed by WHIMS.

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