Development of Processing Technology for Beneficiation of Lean Iron Ore fines from GOA

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Abstract

Because of the fast depletion of high grade iron ores and increased industrial demand, low grade iron ores which have hither to been unused, have become a focus of interest in recent years. Thus, the objective of the present study is to beneficiate lean iron ore fines from Goa for utilization in metallurgical plants. The feed sample assayed 44.25% Fe, 29.42% silica and 2.81% alumina. It is apparent from the petrographic observations that the primary ore consisted mostly of magnetite with goethite and quartz; both mineral occurring in granular form and in alternate bands. It was observed from the liberation data that reasonable degree of liberation is achieved only below 210 micron size. Several beneficiation techniques such as scrubbing, jigging, spiralling, hydrocycloning, and magnetic separation are being employed to develop a suitable process flowsheet as a step to enhance the quality of the iron ore and to reduce the gangue content. The developed process flowsheet gives the desired enrichment of the lean iron ore fines to a grade suitable for sinter feed and pellet feed at reasonable yield and discussed in the light of our experimental results.

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1. Introduction

India is one of the richest sources of iron ore deposits in the world. The Indian iron ore industry is expected to be a key player in the country's endeavour to rapidly expand the domestic steel industry. With an annual production in the region of 65 million tons, India is currently the fifth largest steel producer in the world [1]. The Steel Ministry has been targeting a production level of almost 200 million tons by 2020, and various leading steel strategists of the country are hopeful that 300 million tons should be achievable in the foreseeable future [2]. There has been a tremendous increase in demand for iron ore with the rise in industrial applications in the global scenario for industrial development. The fast depletion of the high grade iron ores and the increased demands of the industry puts a strong focus on assessing the exploitation of lean ores. The objective of the present study is to develop the processing technology for low grade iron ore with several techniques such as washing, jigging, spiralling, hydrocycloning, and magnetic separation are being employed to enhance the quality of the Iron ore for utilization in metallurgical plants.

2. Experimental

2.1. Raw Material

About 9 tons of the low-grade iron ore was collected from southern Goa. The ore sample was collected from the mine in form of run-off mine ore (ROM). However, the ore was friable and therefore, yielded mostly fines.

The colour of the bulk sample was brownish to reddish-brown indicating its grade to be low. Chemical analysis of the head sample indicated a grade of 43% total Fe. From surface properties and morphological characters it was apparent that the lumps in the sample are partially lateritized and of lower grade. The head sample was crushed to -30 mm and screened with a standard set of screens. It was found that only about 13 wt% material are above 10 mm; 33 wt% was in the sinter feed size between 10 mm and 0.15 mm; and 54 wt% ultra-fines below 0.15 mm. Therefore, taking into consideration the lower grade and less wt.% of the lumps, it is inferred that this ore is unlikely to yield quality lumps for use in the blast furnace. However, if processed the ore may yield sinter feeds or quality pellet feeds.

2.2. Mineralogical Studies

Polished mounts studied under optical petrological microscope reveals that the ore consists of a mixture of magnetite, hematite and goethite with variable amounts of quartz, amorphous silica and clay. Manganese minerals such as psilomelane and cryptomelane are also recorded although there abundance is very low.

From detailed petrographic observations it is apparent that the primary ore consisted mostly of magnetite and quartz; both mineral occurring in granular form and in alternate bands. However, in due course of weathering, the magnetites oxidized giving rise to what is known as martite. Most hematites in this ore are really martites. Lateritization has affected the ore to a significant extent.

The other general feature in the ore is scattered distribution of fine quartz grains (< 100µm) in a matrix of goethite of variable iron content which are traversed by secondary veins of goethite.

It is clear from the petrographic observations that magnetite and martite grain-size (max.) is about 350 µm and majority of the grains are around 200 µm. Therefore, the liberation of these grains can be expected below 48 # and maximum liberation might occur below 65#. Majority of the quartz grains are also expected to be liberated at and around these size fractions. However, the finer size fractions are expected to contain much silica and alumina as because the sample contains lots of amorphous silica and clays that are softer than the ore minerals. The characters of the ore are presented in the Figs. 1 & 2.

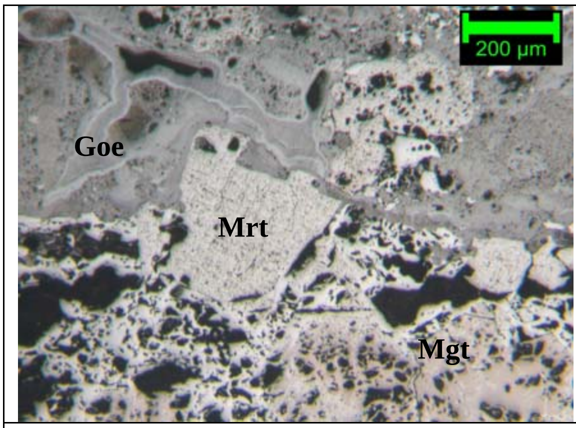

Fig. 1. Photograph showing association of magnetite (Mgt), martite (Mrt) and goethite (Goe)

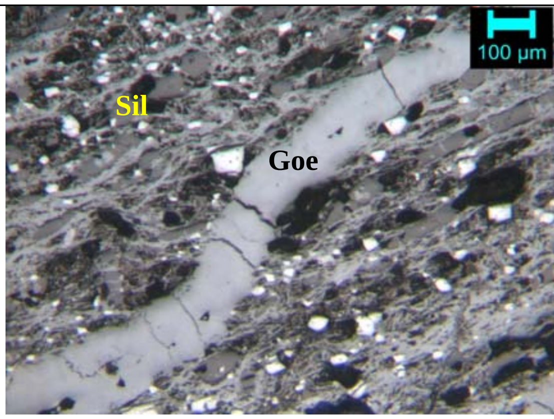

Fig. 2. A supergene vein and other ramifying micro-veins of goethite (Goe) traversing an altered ore with plenty of quartz (Qtz).

2.3. Liberation Studies

To study the liberation characteristics a representative head sample was crushed to -10# and wet-screened to generate various size fractions. The different size fractions were studied under a zoom stereo-microscope and modal distribution of ore and gangue minerals were found out by manual grain counting method. The data are presented in the Fig. 3. It is observed that more than 20% grains remain interlocked at the -10+28# size fraction which decreases slowly in the finer size-fractions and about 90% liberation is achieved below 48#. It is also observed that because of the narrow size range of the iron bearing mineral (martite), a higher percentage of liberated iron-minerals are found between 48 to 100# size ranges. Below 150# the gangue mineral proportion significantly increased because of the gangues especially the clayey matter being concentrating in these finer fractions. Therefore, it is recommended that if the ore is ground to -48#, a good separation of ore and gangue can be achieved.

2.4. Physical and chemical characterization studies

The size analysis of as received low-grade iron ore from GOA was carried out by wet sieving techniques to know the distribution of Fe, SiO_2 and Al_2O_3 at various size fractions. The different size fractions thus obtained were subjected to chemical analysis to ascertain the different quantitative elemental composition of the sample. The complete chemical analysis of the ROM ore and different size fractions were carried out by X-ray fluorescence technique and wet chemical analysis. The chemical analysis of head sample is shown in Table 1 and size wise chemical analysis (wet) of as received sample is shown in Table 2.

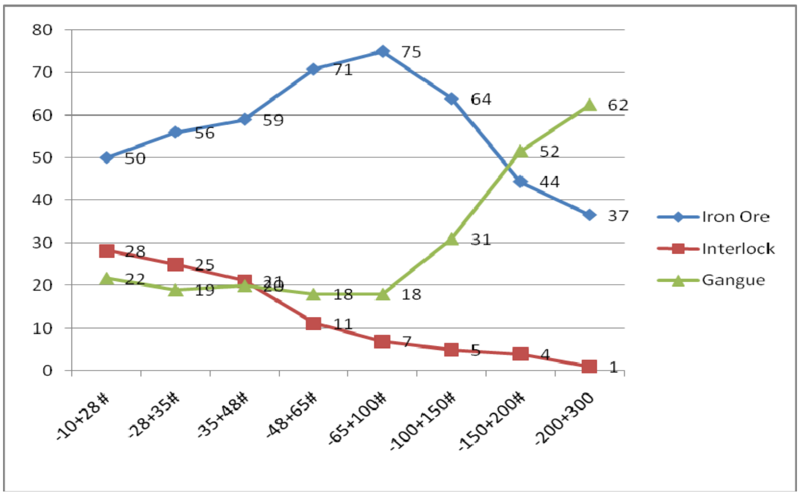

Fig. 3. Liberation characteristics of low-grade ore of Goa

Table 1. Chemical analysis of the Head sample

Fe	SiO_2	Al_2O_3	CaO	MgO	P	S	FeO	Mn	LOI
44.25%	29.42%	2.81%	0.20%	0.12%	0.015%	%	5.03%	0.75%	3.58%

Table 2. Size wise chemical analysis (wet) of as received sample

Size, mm	Wt%	Fe%	SiO_2%	Al_2O_3%	LOI
+25	1.13	57.48	4.01	0.81	8.54
-25 + 20	1.33	51.53	22.6	0.69	1.13
-20 +15	3.85	54.43	10.48	3.87	4.63
-15 +10	6.54	50.78	19.16	1.82	3.6
-10 +8	3.12	56.93	7.51	2.26	4.42
-8 +6.3	4.21	55.68	8.18	3.13	5.63
-6.3 +3.360	4.21	56.32	9.38	2.85	5.24
-3.36 +1.680	3.10	53.99	11.94	2.42	5.78
-1.68 +0.590	6.39	52.92	15.99	2.11	4.21
-0.590 +0.420	1.92	55.86	13.91	1.58	2.63
-0.42 +0.300	2.61	58.19	11.91	1.23	2.03
-0.30 +0.210	4.33	59.36	10.28	1.04	1.79
-0.21 +0.150	3.24	60.2	10.34	0.88	1.69
-0.15 +0.105	6.3	57.47	14.4	0.68	0.97
-0.105 +0.075	6.56	42.87	35.4	0.58	0.85
-0.075 +0.050	10.49	24.92	62.35	0.44	0.96
-0.050	30.67	30.18	45.61	4.91	4.79
	100	43.71	29.45	2.59	3.49

3. Beneficiation Studies

As the aim of the studies was to study feasibility of obtaining different products like calibrated lump, sinter fines and pellet fines, experiments were carefully planned to achieve the same with maximum yield. Beneficiation studies using various routes involving washing, jigging, spiralling, hydrocycloning, and magnetic separation were carried out to up-grade the iron values and to reduce the gangue content. The required separation technique was selected based on particle size and the properties for effective separation. The initial experimentation indicated that lump of +6.3 mm could not be achieved as indicated from size analysis due to it intermix of magnetite and quartz in coarser sizes. Subsequently the whole lump size was reduced to -6.3 mm and subjected to jigging. The jig concentrate was found to be reasonable grade for sintering. The finer fraction generated from this was mixed with earlier fines and subjected processing. The -1 + 0.15 mm fraction was subjected to spiralling and the concentrate was found to be suitable for sintering. The -0.15 mm fraction was processed through hydrocyclone followed by WHIMS. . The beneficiation scheme for -6.3 + 1 mm size fraction involving jigging yielded a concentrate of 8.38 % by wt with about 62 % Fe. The beneficiation scheme for -1 + 0.15 mm size fraction involving spiralling resulted a final concentrate of 63.4% Fe, 2.79% SiO_2 and 1.26% $Al_2O_3$with a yield of 19.7%. The beneficiation scheme for -0.15 mm fraction involving hydrocycloning followed by Wet High Intensity Magnetic Separation (WHIMS) resulted a final concentrate of 62.7% Fe, 5.97% SiO_2 and 1.01% $Al_2O_3$with a yield of 25.3%. The complete beneficiation processing flowsheet is shown in Fig. 4.

4. Results and Discussion

Petrographic studies indicate that the primary ore consisted mostly of magnetite and quartz with some amount of goethite. Although liberation data shows that reasonable degree of liberation is achieved below 210 micron size more than 50 % liberation is achieved in coarser sizes. Keeping this in view studies were aimed to generate concentrate at coarser sizes initially through jigging and spiralling followed by hydrocycloning and WHIMS for finer sizes. It is always useful to study if adequate enrichment may be obtained at a coarser size range to reduce the cost of crushing and grinding.

The crushed lump of +6.3 mm indicated intimate association of magnetite with quartz thereby resulting in poor lump quality. The lumps were crushed to below -6.3 mm. The fraction of -6.3 mm was subjected to jigging. The jig concentrate of 61.93% Fe is obtained with a yield of 8.4%.The jig middling was further crushed, classified and -1 + 0.15 mm fraction was mixed with original fraction before spirlling. The spiral concentrate is obtained with 63.4% Fe with a yield of 19.7% which can be utilized for sinter feed.

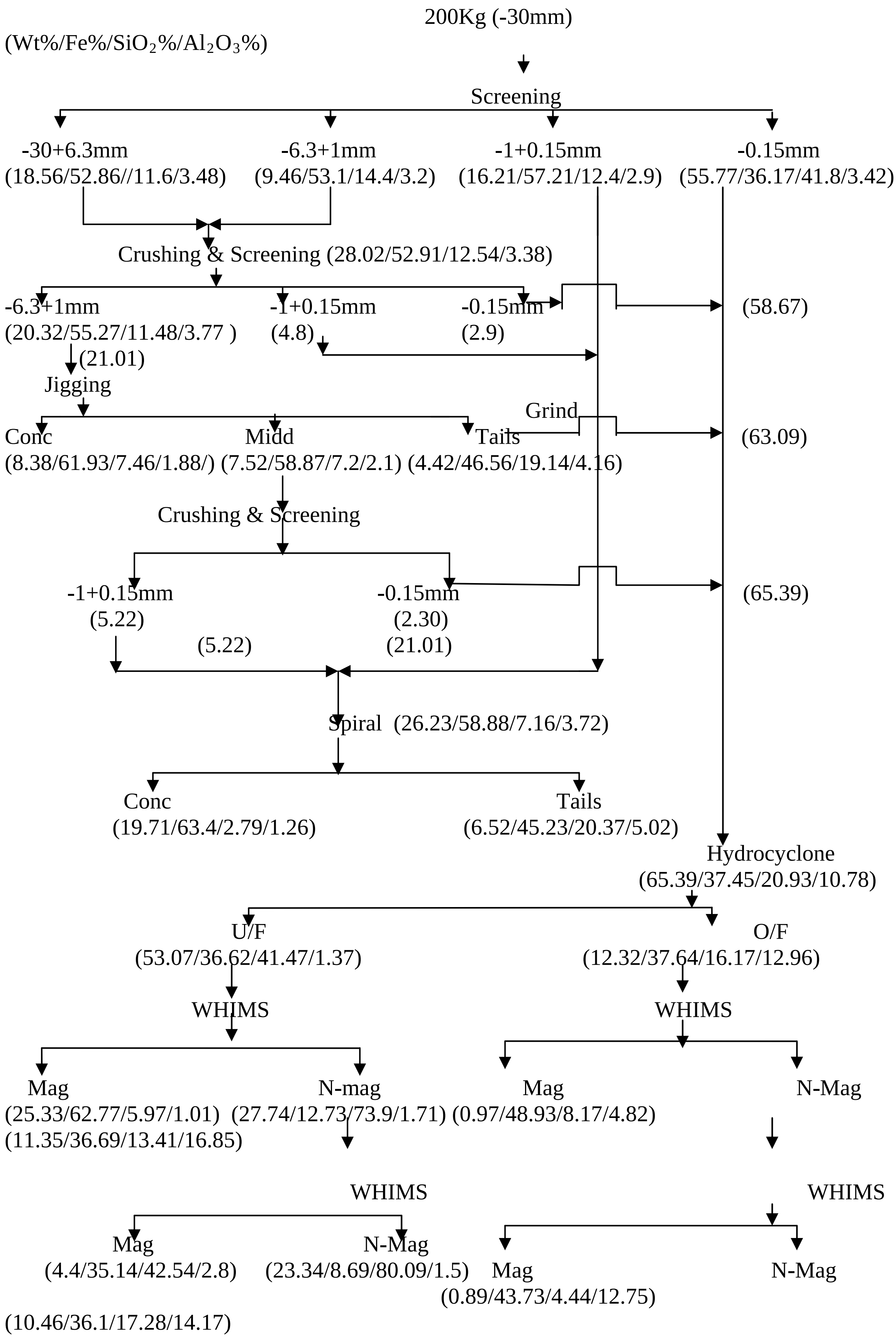

Fig. 4. Processing flowsheet for GOA fines

All the -0.15 mm size fraction generated at different stages of crushing was mixed together and processed through hydrocyclone for removal of ultrafines. The hydrocycloning generated an underflow product with 36.62% Fe with a yield of 53% and overflow product with 37.64% Fe with a yield of 12.3%.The underflow and overflow products from hydrocyclone was treated in WHIMS. The obtained concentrate product shows the improvement in Fe content from 36.6% to 62.7% with a yield of 25.3% for underflow. This can be directly utilized for pellet feed. However, as the overflow contained goethitic material the grade of concentrate was not upto the mark.

To minimise the losses attempts were made to recover from non-mag fractions using second stage of WHIMS at higher intensities. A medium grade concentrate of 45-53 % Fe could be obtained which can be re-circulated for improving further recovery. The overall rejects consists of iron values about 23% Fe with 45% wt.

5. Conclusions

The beneficiation flowsheet has been established involving scrubbing jigging, spiralling, hydrocycloning, and magnetic separation showed significant enrichment in Fe values. The final concentrate of about 63% Fe, 4.18% SiO_2 and 1.44% Al_2O_3 with a yield of 28.09% was achieved using the developed flowsheet for sinter feed and the concentrate of about 62.77% Fe, 5.97% SiO_2 and 1.01% Al_2O_3 with a yield of 25.3% can be used for pellet feed. Further studies are in progress to improve the recovery from fines and slimes.

6. Acknowledgement

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7. References

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