ISSUES RELATING TO CHARACTERIZATION AND BENEFICIATION OF LOW GRADE IRON ORE FINES

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Since a decade the Institute of Minerals and Materials Technology has been engaged in Iron ore research to enhance raw material quality for Iron and Steel industry. Consequently, from our experience we discuss the characterization and beneficiation aspects of five different types of Iron ore samples—Barbil, Bailladilla, Goa, Barajamda and Hospet (Banded Hematite Quartzite, BHQ).

The characterization studies in general indicate that hematite and goethite are the major Iron bearing minerals, where as kaolinite, gibbsite and quartz are present as the gangue minerals. Particle counts of the close sized fractions indicate that the degree of liberation of hematite is about 87% at 53 micron size. The chemical analysis of the hematite ores on an average conform to 57.8 to 64.5% Fe, 1.56 to 6.5% SiO_2 and 1.3 to 6% Al_2O_3. These ores subject to beneficiation yield a concentrate containing 61.5 to 66% Fe at 62 to 86% yield. In case of BHQ ore, column flotation technique has been adopted to obtain a concentrate of 66% Fe at 44.7% yield. It has been observed that beneficiation of low grade ores invariably pose specific challenge due to the presence of clayey/earthy materials rich in aluminum. For both hematite as well as BHQ ores proven flow-sheet with material balance has been developed and satisfactorily implemented through our clients. The processes that have been developed are ideal for pellet making where the future of Steel industry rests.

1. Introduction

India occupies sixth position in the world's Iron-ore reserves and is one of the major Iron-ore producer and exporter due to availability of quality ore and skilled mining personnel. India's Iron ore reserve is around 25,249 million tonnes (MT) apart from Banded Hematite-Quartzite (BHQ) and Banded Hematite Jasper (BHJ). Although India is blessed with large reserves of Iron ore containing average grade around 58% Fe, the performance of blast furnaces has been at lower levels in comparison with the developing countries. This has been mainly due to the presence of high levels of impurities such as silica and Alumina in the raw material contradicting to the blast furnace chemistry.

In order to increase the efficiency of blast furnace, some of the issues relating to Iron ores include chemical composition of Iron ore with low Fe content and high Al:Si ratio, low strength, high temperature break down, lower reducibility, low temperature softening and melting behavior of the Iron ores, etc. Normally Iron ores with Fe content above 65% are desirable to achieve better productivity either in blast furnace or direct reduction. The other impurities level such as Na, K, S and P should be as low as possible. Alumina and Silica content should be within permissible limit for better fluidity of slag. Due to non availability of quality Iron ore, the run-off-mne (rom) needed to be beneficiated to lower the impurities to improve the strength of sinter and pellet quality. The physical, chemical and metallurgical properties of lumps, sinters and pellets are important as they have a significant impact on furnace performance.

For economics reasons, quality raw material is not only required for blast furnace operation but also for the emerging technologies such as smelting reduction and direct reduction route. Beside that, India has set itself a target of achieving production capacity of 110 MT of Steel by 2020 and the required quantity of Iron ore is projected at 190 MT. Over the next few years, demand for Indian Iron ore is expected to rise by more than 200 million tonnes per year to meet the internal demand and export. Two major shifts in Iron ore supply for the Indian Iron and Steel industry have occurred. First the export to foreign market owing to liberalization in the economy and second the adaptation of beneficiation and pelletization practices to utilize low-grade ores and fines. In India for economic and industrial growth, a number of Steel plants have been planed in the states of Orissa, Jharkhand, Chhattisgarh, Karnataka and Maharastra. As the quality of raw materials declines, the impact of Iron making processes on pollution control and energy required will worsen in days to come. Most of the rom Iron ore contains lot of impurities that needs beneficiation prior to use. Therefore research on utilization of low grade Iron ore to produce quality raw material would play a key role in future which is a fact acknowledged by the Iron and Steel industry.

Iron ore is being beneficiated all round the world to meet the quality requirement of Iron and Steel industries. However, each source of Iron ore has its own peculiar mineralogical characteristics and requires the specific beneficiation and metallurgical treatment to get the best product out of it. The choice of the beneficiation treatment depends on the nature of the gangue present and its association with the ore structure. Several techniques such as washing, jigging, magnetic separation, advanced gravity separation and flotation are being employed to enhance the quality of the Iron ore. Washing, jigging and classification are being carried out for the beneficiation of Iron ores in India. During washing and sizing of the ore, slimes with less than 0.21 mm size are generated and discarded into the tailing pond. It is estimated that around 10 million tonnes of slimes are being generated in every year during the processing of hematite ore and lost as tailings containing around 48-62% of Fe. However beneficiation and utilization of these slimes still remains as a challenging task.

The ever increasing need to utilize the slimes is being reflected in the shift in Steel production from basic blast furnaces to electric arc furnace technology. In the USA, around 40% of Steel is produced in electric arc furnaces by using Iron ore pellets. Pellets are also used in traditional blast furnaces in some parts of the world. Pellets are ideal material as a feed to direct-reduction Iron plants. However the use of pellet in our Steel plant is very limited. Lot of low grade Iron ore fines are generated during preparation of lumps, calibrated ores and sinter-fines. In addition to these fines, 10-15% of ore mined is generated as slimes and are discarded as tailings. These fines and tailings are potential sources to produce pellet grade concentrate after suitable beneficiation. Another source of pellet feed concentrate is from low and off grade ores such BHQ & BHJ. All these materials can be beneficiated to yield quality pellet feed. Keeping this in observation, detailed studies have been carried out on different source of materials to produce quality concentrates for pellet feed. The results of four different types of hematite ore fines covering from Barbil, Balladilla, Goa, Barjamada have been discussed in this paper. Increasing worldwide demand for Iron ore triggering the development of India's magnetite and BHQ ores of Karnataka for effective utilization is also highlighted.

2. MATERIALS AND METHODS

2.1 Ore samples

Five different types of representative Iron ore samples from Iron ore mines of India through Barbil, Balladilla, Goa, Barjamada and Hospet area were collected and brought to the laboratory for the detail investigation studies. The as received hematite samples which are either fines or slimes were thoroughly mixed and representative sample of each was drawn by conning and quartering method for different characterization, mineralogical and beneficiation studies. The BHQ sample was lumpy variety with little amount of fines. The sample is very hard in nature and compact. The sample colour is grayish black. Similar coning and quartering method was applied to draw a representative sample from the bulk sample for different investigations.

2.2 Experimental

2.2.1 Physical and Chemical Characterization Studies:

The size analysis of the received Iron ore sample, were carried out by wet sieving techniques to know the average particle size of the sample. 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 florescence technique and wet chemical analysis. The XRF analyses were carried out against the standard calibrated samples of similar values. The loss on ignition (LOI) of Iron ore samples was determined by igniting around 2.0 gm of sample at about 1000^0 C for four hours in a muffle furnace in silica crucible.

2.2.2 Mineralogical Studies:

Closed sized classified samples were examined under stereomicroscope by preparing the corresponding grain slides for identification of different minerals. The X-ray diffraction studies of selected samples were also carried out using a Philips model diffractmeter with CuK radiation. The bulk sample was crushed to below 1 mm size and wet sieved into different size fractions. The size fractions were mounted in resin with hardner and polished following standard procedures. The polished sections were studied under reflected light microscope and the particles of different typologies were counted.

2.2.3 Grinding Studies

In order to increase the grade of Iron ore and for the subsequent liberation of Iron values from the locked particles, the samples were subjected to wet grinding to generate different size particles. A standard ball mill of 12”x12” with required weight of balls as per Bonds formula at 45% filling was used. The grinding was carried out in batch prior to different beneficiation studies. The objective is to achieve the maximum liberation of the Iron particles from the associated gangues due to reduction in size. The large-scale continuous grinding studies were also carried out using 24″x 24″ ball mill to produce samples for further investigations and to establish grinding parameters. All the grinding studies were carried out at 40% solids consistency in the ball mill.

2.2.4 Beneficiation Studies

Beneficiation studies using various techniques such as hydrocyclone, spiral, magnetic separation, flotation etc. were carried out to develop a suitable process flowsheet as a step towards the up-gradation of Iron values and to reduce the gangue content. The required separation technique was selected based on particle size and the properties for effective separation. Initially, the hematite ore fines were ground to required size and then subjected to separation. The sample was ground to below 1.0 mm size for hematite ore fines and less than 100 microns for BHQ ore. However, the tailing samples from Goa ore have been treated without further grinding.

2.2.4.1 Hydrocyclone

Hydrocyclone was used as a step towards the up-gradation of Iron values as well as for de-sliming of slime particles present in the sample. Since the ground samples contained large amount of slime materials comprising of particles down to sub micron size, de-sliming was also thought of prior to flotation. The effect of some of the variables namely apex diameter, vortex finder diameter, operating pressure, solids concentration etc. were optimized. The throughput of hydrocyclone during the experiments was 240 to 780 kg/hr solids and the solid concentrations of ~10-20 % by weight were maintained during the course of the experiments. The underflow and overflow materials were collected at a steady state for a fixed time, dried, weighed and analyzed for the desired Iron and other constituents. The overflow & underflow samples collected at optimum operating conditions were used for further studies.

2.2.4.2 Spiral

The spiral concentrator of 100 mm dia. was used to enrich the Iron content of the classified sample (hydrocyclone underflow). The spiral is an energy saving gravity equipment where large quantities of sample can be fed for pre-concentrations. In the spiral study, the Iron ore sample was fed to the centrifugal pump at the required solids consistency and the slurry was kept re-circulating for a predetermined time. The entire concentrate and tailings were collected after attaining the steady state. The concentrates in some cases were cleaned to improve the grade of products. All the products thus obtained were dried, weighed and analyzed.

2.2.4.3 Wet High Intensity Magnetic Separation

The wet high intensity magnetic separator (WHIMS) and high gradient magnetic separator (HGMS) were used at different magnetic field intensities to recover the fine Iron values from the hydrocyclone over flow or spiral tailings. Both the separators have provision for different magnetic groves of width and matrix with variable currents to provide different magnetic intensities. A desired concentration of solids was passed through the magnetic separator. In some cases the magnetic products were cleaned in second stage to enhance the quality of the product from first stage separation.

2.2.4.4 Flotation

Batch flotation studies were carried out to select either direct or reverse flotation technique to optimize reagent combination and to establish the number of stages of operations. Denver D-12 sub-aeration flotation machine was used for the batch flotation studies. Both cationic (dodecylamine) and anionic (oleic acid) reagents were used as collectors while MIBC was used as the frother. The flotation conditions were optimized to get good grade concentrate with high recoveries. The column flotation studies were carried out by using 100 mm diameter glass column designed and fabricated at our laboratory. The column was operated at nominal capacity of 20 kg of Iron ore fines per hour with the help of a peristaltic pump. Both the concentrate and tailings were collected separately after attaining the steady state and analyzed for Iron content.

(The ramaining presentation would be continued in the December issue of Steelworld.)

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