Beneficiation of goethite iron ore through magnetizing roasting followed by magnetic separation

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Abstract. The present study is carried out to recover iron value from low grade goethite iron ore. The method is based on coal based magnetization roasting followed by magnetic separation. The effect of temperature, residence time and magnetic field intensity on grade and recovery of iron ore have been studied. The magnetizing roasting was carried out at 700°C, 800°C and 900°C for different residual time viz., 10, 20, 30, 40, 50 and 60 minutes. The production obtained from magnetizing roasting was then separated in wet high intensity magnetic separator (WHIMS) at different magnetic field of 2000 gauss, 4000 gauss and 6000 gauss. The result obtained at 900°C roasting temperature for 50 minute followed by magnetic separation at 2000 gauss shows optimum Fe grade of 59.20% and recovery is 68.23%, this grade and recovery of iron ore increases with increase of temperature and time. However, the grade and recovery of iron ore decreases during prolonged roasting at 900°C. The recovery increases with increasing in magnetic field but the grade is decreasing. In the present study, the as received goethite iron ore and concentrate ore have been examined using optical microscopy to know the phases present and change of phase during processing.

Keywords: Goethite ore, magnetized roasting, WHIMS, microscopic

1. Introduction

Goethite (α-FeOOH) ore is formed in terrestrial environment, as a result of oxidative weathering and due to formation of acid soil. It is one of the most common and abundant iron oxide and oxyhydroxide minerals present in the soil [4]. Moreover, goethite constitutes the main component of the reject streams in many iron ore plant. This makes the processing of goethite ores almost inevitable [3]. The overwhelming part of these ores is represented by low-grade varieties which cannot be used in iron and steel industry without preliminary beneficiation. Although various techniques are available to improve lower grade iron ores in various part of the world, the objective of this research work focused on the mineral transformation and chemical of goethite ores from Langalota region of Odisha India by reduction roasting and magnetic separation.

The goethite iron ore which comprises of hematite, goethite, kaolinite and quartz also contains high levels of silicon and aluminum. Vitreous goethite which is rich in iron is hard and crystalline whereas Ochreous goethite is mixed with aluminum through clayed and grained particles. Thus, the prime objective is to investigate how to reduce the impurities such as Al and Si. The existence of iron in ferromagnetic form, such as magnetite, could induce paramagnetic properties in the material, and this paramagnetic material could be attracted along the magnetic field towards the points of higher magnetic field intensity. Magnetite shows the strongest ferromagnetic properties although hematite and siderite can be transformed into magnetite using reduction roasting which can enhance their
separation through the magnetic separation method [2]. The sample fed in the magnetic separation consists of two products (i) the magnetic products (ii) the non-magnetic products; consequently, the magnetic separation was used to separate both products – the magnetic (iron ores) from the non-magnetic (rejects).

A number of researchers have described the techniques of magnetizing processes by roasting-reduction in the range of temperature 700-900°C but several of them were unsatisfied with the recovering rate and cost balance. In this paper, an experiment was performed, to develop a technique of “reduction and magnetic separation” and showing the difference of feed sample and roasted sample of optical microscopy [2].

2. Experimental
The sample of goethite iron ore was taken from an iron ore tailing from the Langalota, Odisha in India. In the sample bigger size of particles was 12.5 mm. The sample divided into different size ranges by screening, mineralogy was characterized by optical microscopy and the chemical composition of the sample. And the coal is collected from Garokhasi, Jharkhand, India the sample is characterized by proximate analysis, ultimate analysis, gross calorific value.

In this process coal and iron ore ratio is constant (1:9) and temperature varies from 700°C to 900°C and time varies from 10 minute to 60 minute. After roasting the roasted product is separated in a magnetic separator at 2000 gauss, 4000 gauss and 6000 gauss.

The mixed sample of iron ore and coal is roasted at three different temperature 700°C, 800°C and 900°C for 10, 20, 30, 40, 50, 60 minutes and then separate in Wet High Intensity Magnetic Separator (WHIMS) magnetic field of 2000 gauss, 4000 gauss, 6000 gauss. The optical microscopy was utilized in order to analyze the phase transformation of goethite after the beneficiation of roasted ore samples by WHIMS (Wet High Intensity Magnetic Separation). This analysis was carried on to determine the iron ore recovery after treating it through dehydroxylation and magnetic separation.

3. Results and Discussion
3.1. Sample characterization
3.2. There is 40.212% Fe, and 19.04% SiO2 and 8.83% Al2O3 in the head sample. The chemical analysis of the main samples are shown in table 1.

| Constituents | Fe  | SiO2 | Al2O3 | LOI  |
|--------------|-----|------|-------|------|
| Assay %      | 40.212 | 19.04 | 8.83  | 10.46 |

The sample was also screening into 4 different sizes, from +12.5 mm to 1 mm, (12.5mm, 6mm, 3mm, and 1 mm) for size by size analysis. The particle size distribution curves are presented in Fig. 1. Nearly 50% of sample contains coarser than 3 mm. And the d80 is calculated as 8.9 mm.

The optical microscopic analysis report the main mineral components of the samples are shown in Fig. 2. The iron ore sample was then taken for microscopic study under reflected light. The study showing iron ore and gangue are very finely interlocked. Due to its poor liberation characteristic it is very difficult to upgrade it by using physical beneficiation process.
Table 2. Size distribution of feed

| mesh size (mm) | Nominal size (mm) | wt. (g) | wt.% | Cum wt.% Retain | cum wt.% Passing |
|----------------|-------------------|---------|------|-----------------|-----------------|
| +12.5          | 12.5              | 375     | 3.57 | 3.57            | 96.42           |
| -12.5 +6       | 6                 | 3971    | 37.86| 41.44           | 58.56           |
| --6 +3         | 3                 | 2572    | 24.52| 65.96           | 34.03           |
| -3 +1          | 1                 | 1434    | 13.67| 79.64           | 20.36           |
| -1 +0          | 0                 | 2135    | 20.35| 100             | 0.00            |
|                |                   | 10487   | 100  |                 |                 |

![Figure 1. Size distribution curve](image)

It required very fine grinding for liberation. The sample is then grinded to -75 micron by using jaw crusher, roll crusher and ball mill. The fine ore was again taken for microscopic study. The sample was then observed under both plain polarized and cross polarized light to know the different phase of iron present in it. The ore contain very less amount of Magnetite and high amount of hematite and goethite. As the sample contain high amount of goethite and hematite reduction roasting is used to convert these phases to magnetite. So that the sample can be easily upgraded by using magnetic separation.

Table 3. Proximate analysis of coal sample (-75 micron)

| Constituents | Moisture | Volatile Matter | Ash     | Fixed Carbon |
|--------------|----------|-----------------|---------|--------------|
| %            | 1.03     | 18.51           | 16.37   | 64.09        |
3.2.1. Gross calorific value  The ground coal was then subjected to Bomb Calorimeter
GCV = 7683 Kcal/kg.

3.2.2. Ultimate Analysis  The sample was subjected for ultimate analyses to know the C, H, N, O, S %

| constituents | C   | H   | N   | S   | O   |
|--------------|-----|-----|-----|-----|-----|
| %            | 68.74 | 4.16 | 1.42 | 0.67 | 25.01 |

Table 4 Ultimate analysis of coal

3.3. Magnetizing roasting and magnetic separation
The main factor affecting the quality of roasting process are coal and iron ore ratio, time temperature, and in magnetic separation main factor affecting grade and recovery is magnetic field intensity.

In this process coal and iron ore ratio is constant (1:9) and temperature varies from 700°C to 1000°C and time varies from 10 minute to 60 minute. After roasting the roasted product is separated in magnetic separator at 2000 gauss, 4000 gauss and 6000 gauss.
3.4. Roasting at 700°C
The mixed sample of iron ore and coal is roasted at 700°C for 10, 20, 30, 40, 50, 60 minutes and then separated in magnetic field of 2000 gauss, 4000 gauss, 6000 gauss. With increase in time the grade and recovery both increases because with increase in time more iron ore phases converted to magnetite and recovery increases. With increase in magnetic field the recovery increases and grade decreases. In 700°C when sample is roasted for 60 minute and separated in 2000 gauss highest grade of 52.49 % obtained with a recovery of 70.3%.

3.5. Roasting at 800°C
The mixed sample of iron ore and coal is roasted at 800°C for 10, 20, 30, 40, 50, 60 minutes and then separated in magnetic field of 2000 gauss, 4000 gauss, 6000 gauss. With increase in time the grade and recovery both increases because with increase in time more iron ore phases converted to magnetite and recovery increases. With increase in magnetic field the recovery increases and grade decreases. In 800°C when sample is roasted for 60 minute and separated in 2000 gauss highest grade of 55.73 % obtained with a recovery of 73.97 %.

3.6. Roasting at 900°C
The mixed sample of iron ore and coal was roasted at 900°C for10, 20, 30, 40, 50, 60 minutes and then separated in magnetic field of 2000 gauss, 4000 gauss, 6000 gauss in WHIMS by using ball matrix. With increase in time both grade and recovery increases up to 50 minute but in 60 minute it decreases. Here up to 50 minute when temperature increases the grade and recovery decrease because different iron ore phases like goethite hematite are converted to magnetite but in 60-minute grade decreases because here some FeO produce which is less magnetic in nature. When the separation was at 2000 gauss the grade was high because the magnetic field-attract high magnetic particles like magnetite and less hematite, goethite.

Figure 3: (a) Roasting for different time at 700°C and separation at magnetic field (2000 gauss). (b) Roasting for different time at 800°C and separation at magnetic field (2000 gauss) (c) Roasting for different time at 900°C and separation at magnetic field (2000 gauss)
When the separation was at 4000 gauss the magnetic field attract some amount of hematite and goethite also with magnetite so the recovery increases but the grade was decreased. During separation at 6000 gauss grade was very low and recovery was very high because at this magnetic field the magnetic field attract high amount of goethite and hematite with magnetite.

After magnetic separation microscopic study for magnetic part was performed. After roasting and magnetic separation iron ore phases changes to magnetite but silica amount was not reduced significantly.

![Microscopic study of product after roasting and magnetic separation in plane polarized light.](image)

**Figure 4**: (a) Microscopic study of product after roasting and magnetic separation in plane polarized light. (b) Microscopic study of product after roasting and magnetic separation in plane polarized light.

4. **Conclusions**

In this article, the mineral transformation and chemical of goethite done by roasting and magnetic separation. The iron ore (goethite) sample of 12.5 mm head size was taken from an iron ore tailing from the Langalota, Odisha region in India. The size analysis carried out a essential amount of fine particles: 30 wt% < 1 mm. Mineralogical and Chemical analysis was conducted using optical microscope and volumetric analysis. The chemical analysis of the sample had 40.212% Fe, 19.04% silica and 8.83% alumina. Optical microscope analysis had the iron ore and gangue are very finely interlocked and magnetite particles shows bright colour in plane polarized light and black color in cross polarized light because it is isotropic in nature. The content of aluminium and silicon in the mineral phases was of the reverse (increasing) order. The laterite iron ore which contain 40.12 % Fe can be upgraded to 59.20 % with 68.23 % Recovery by reduction roasting at 9000C for 50 minute and magnetic separation at 2000 gauss. In reflected light microscope the changes in phase of iron ore was also studied and found that after roasting higher amount of magnetite was found in product. In this Experiment Fe % is increasing from 40.21 to 59.20 % but silica and alumina % is not changing significantly so this can’t be useful for pellet making. So This process can be combined with flotation or gravity separation to decrease the silica and alumina % and its product can be used in pellet making. The product of this process can be used in pellet making blending with high grade iron ore with less alumina and silica.

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