Effects of Fine Iron Ore on Sinter Resistance and Permeability

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Abstract

Segregations of materials exist more or less in iron ore sintering beds and they are essential for the sintering process. Therefore, control of particle size can be a key technology to improve the performance of the process. This study is researched the effect of concentrate iron ore (50%) and pellet dust (50%) additions on the sinter quality parameters and this mixture was called ultra fine iron ore (UFIO). The effect of UFIO addition on cold (Tumbler index-TI) and hot (Reduction and degradation index-RDI) strength, sintering time and permeability etc. were investigated. The results confirmed that the fan pressure increased due to the use of UFIO in the sinter blend. No significant change was observed in other parameters that would affect sinter quality. Parallel to the increase of the UFIO grade of Fe utilization ratio increased in sinter material. As the UFIO ratio increases in the sinter blend, the sintering efficiency and the sintering speed decrease. A change in ratio between UFIO has been experimentally studied. An influence of sintering mixture particle size composition, a charge particle shape on quality and phase composition on quality of the produced iron sinter has been studied.

1. Introduction

One of the major problems in the use of iron ore in integrated iron and steel plants; high-grade, direct feedable iron ore reserves are limited. The recent years development has however shown a decreasing availability of high quality sinter feed [1]. Granulation of iron ore fines into strong and highly porous granules is critical to successful sintering/pelletising and blast furnace operations in iron and steelmaking. Iron and steel makers desire iron ore granules with high compressive strength, porosity and permeability, reducibility, uniform size distribution and low energy consumption to enhance smooth blast furnace operations [2]. The trend has shown increasing gangue contents, leading to lower iron content and as a consequence, higher slag volumes in the blast furnace. In order to maintain iron content and gangue levels of sinter feed, the sinter ores became finer due to an increased necessity of beneficiation at the mining site [3]. One way to keep sinter amount constant and instead tried to improve the quality of produced sinter by various means. Keeping quality has in most cases meant that fine ores as concentrate or even pellet feed has been added to the sinter mix. The increased usage of these types of ores have resulted in larger focus on agglomeration,

either by the use of intensive mixers, but also usage of various binders [4].

Due to the international consuming of reserves of traditional high grade iron ore, the ore resources available throughout the world, especially in steel works co. In the world, have changed drastically from hematite to magnetite ore types. Finally, the proportion of fine material in the available products has increased considerably for most iron ore fines. This has been found to have significant impacts on sinter quality and sintering performance. Magnetite concentrate is typically high in Fe grade and releases extra heat when oxidised to hematite. The amount of magnetite concentrates is expected to increase due to the recent development of a number of magnetite projects. This will not only improve the sinter quality and but also have beneficial impact on the fuel consumption of the sintering process. However, most of the UFIO available are very fine, which will negatively impact the green bed permeability and consequently productivity of the sintering process [5].

The depletion of high-grade iron ore resources worldwide has led to the situation where finer iron ore products have to be utilized in order to achieve an adequate Fe product grade. In order to utilize this fine material in the blast furnace (which is the ironmaking process used by about 90% of the world’s steelmakers), agglomeration in some form becomes essential. Of the available techniques, sintering is by far the most common and usually the most cost effective process. In recent years, developments in sintering process have made it possible for sinter plants to include up to about 30% iron ore concentrate in the Fe raw material mix. Thus the sintering process seems likely to retain its dominant position in terms of agglomeration of iron ore fines for blast furnace feed [6].

Sintering is a thermal agglomeration process (1100-1300°C), of a mixture of iron ore mineral fines by products of the iron and steelmaking industry, fluxes, slag-forming elements and coke breeze as a particle size of <3 mm [6]. The objective of the process, whereby the mixture of materials charged is partially fused at a high temperature to produce clustered lumps, is obtaining a load (5-50 mm) for the blast furnace with the suitable physical-chemical and
mechanical properties with the lowest price [7]. Iron ore sinters have a mineralogy which is basically composed by iron oxides and hydroxides, ferrites and silicates. Their mineralogical composition constitutes an important parameter that can be specified and controlled [8, 9]. From all characteristics of components of raw materials suitable for sinter production, particle size is one of more important aspects of material suitability [10]. The highest allowable particle size for sintering process may not exceed 10 mm [11]. The most convenient particle size for the raw materials processing by sintering is particle size under 5 or 3 mm [12].

The work deals with examination of the influence of UFIO and commercial sinter fines on quality of produced sinter. X-Ray Diffraction (XRD) analysis was performed on the sintered samples to determine the phases. Scanning Electron Microscopy (SEM) displayed phase structures and element analysis of these phases with energy dispersive (EDS). Tromel, RDI and fan pressure tests were performed on the sinter samples, obtained by using UFIO at different proportions. In this way, the effects of UFIO use on sinter quality and sintering process were investigated.

2. Experimental Procedure

Sinter facilities consist of large stock areas, blending areas, ore crushing and screening units, dosing systems, coke, limestone, crushing-screening units and sintering machines. The sintering process is based on treating a mix (fine iron ore, return fines, fluxes, etc.) layer in presence of coke dust to the action of a burner placed in the surface of the layer. In this way, heating takes place from the upper to the lower sections. The mix layer rests over a strand system and an exhausting system allows to the whole thickness to reach the suitable temperature for the partial melting of the mix, and the subsequent agglomeration. The raw materials were selected on the basis of the study conducted by sinter pot instrument. The sintering tests were conducted at sinter pot test from Republic of South Africa. The sinter pot device has a diameter of 200 mm and a height of 400 mm. Bed height for the tests was 350 mm, including a hearth layer of 15 mm. In order to improve sintering performance, a ratio of 1.2 % burnt lime was used during the tests. Representative samples of the raw materials used in the sinter experimental were obtained and prepared for sinter pot test. The sinter tests were conducted for purposes of evaluates the influence of fine iron ore on the formation compositions and the quality of the sinter product. Experimental analyses were carried out by the total of 4 sinter samples from the sintered products. Sinter samples were called as A-1, A-2, A-3 and, A-4. A typical sinter plant flow diagram is demonstrated in figure 1.

The bed top is heated to high temperature by gas burners and air is drawn through the grate. After a short ignition time, heating of the bed top is discontinued and a narrow combustion zone (flame front) moves downwards through the bed, heating each layer successively. In the bed the granules are heated to 1200-1350 °C to achieve their softening and then partial melting [14]. In a series of reactions a semi-molten material is produced which, in subsequent cooling, crystallises into several mineral phases of different chemical and morphological compositions; mainly hematite, magnetite, ferrites and gangue composed mostly of calcium silicates. Their mineralogical composition constitutes an important parameter that can be specified and controlled [15].

3. Raw Material

Sinter plants that use UFIO in sinter plants around the world can use concentrated iron ore in sinter blends of about 60% -90%. The Fe content of concentrate ores generally varies between 16% and 36% [4]. Concentrated ore is generally broken up to 75 μm, which is the free particle size, and can be enriched by magnetic separator and removed to Fe of between 62 and 68%. The pellet material is sieved (-5 mm) to remove dust, before being charged to the blast furnace. UFIO ore consists of 50% of concentrate iron ore and 50% pellet dust. This mixture was added into the sinter blend at the ratio of 10%, 20%, and 30%, respectively. The amount of foreign iron ore is decreased as much as the amount of UFIO added into the sintered blend. Particle size distribution of UFIO is given in table 1. The chemical composition of produced sinter is shown in table 2.

| Table 1. Particle size distribution of UFIO |
| --- | --- | --- | --- | --- | --- |
| Size fraction (mm) | +0.10 | +0.10-0.50 | +0.50-1.00 | +1.00-5.00 | ≥5.00 |
| % | 35.20 | 20.72 | 18.25 | 20.75 | 5.08 |

| Table 2 Chemical Compositions of Produced Sinter (%) |
| --- | --- | --- | --- | --- |
| Fe | SiO₂ | CaO | MgO |
| 55.06 | 6.24 | 11.64 | 1.25 |
| Al₂O₃ | FeO |
| 1.65 | 7.25 |

| Table 3 Iron ore mix in the sinter blend (%) |
| Sinter Sample No | A-1 | A-2 | A-3 | A-4 |
| Foreign iron ore | 55 | 45 | 35 | 25 |
| Domestic iron ore | 35 | 35 | 35 | 35 |
| Return dusts | 10 | 10 | 10 | 10 |
Test studies were carried out at 35% domestic iron ore and 10% iron bearing dust in sinter blends formed with a small basicity value of 1.75. The amount of return dust was kept constant at 10%.

4. Effects of Ultra-Fine Iron Ore on Sinter Quality

The sinter quality parameters obtained from the use of different ratios of ultrafine iron ore at in the sinter blend are compared with each other. Also, comparisons were made with periods in which UFIO is not used.

![Figure 2. The changes of RDI (-3.15 mm) and RDI (-0.5 mm) in sinter, depending on the use of UFIO.](image)

Figure 2 shows that RDI (-3.15 mm) value was 26.05% when UFIO was not used in the sinter blend. When UFIO used with ratio of 10%, 20% and 30% in the sinter blend, RDI (3.15 mm) values were respectively obtained the values of 25.42%, 23.85% and 24.45%. In the sinter blend prepared without UFIO ore, RDI (-0.5 mm) was obtained the value of 5.03%. When UFIO was used with ratio of 10%, 20% and 30% in the sinter blend, RDI (-0.5 mm) values were obtained 4.95, 4.85% and 4.80% individually.

In general, RDI (-3.15 mm) and RDI (-0.5 mm) values are decreased depending on the UFIO utilization ratio in the sinter blend.

![Figure 3. Change of sinter tromel strength (+ 6.35 mm) and dust index values (-5 mm).](image)

Figure 3 is seen 79.55% value of tromel (+6.35 mm) and dust index values (-5 mm). The replacement of fine iron ore by coarse ore particles also worsened the sintering rate. This means that the replacement of fine iron ore by coarse ore results in a decrease in the airflow rate and the slowdown of the flame front speed through the sinter bed. It is said that sinter productivity and sintering rate decrease with a decrease in iron ore mean particle size due to the decrease in the airflow rate. The greater the proportion of coarse ore in the sinter bed, the greater the sintering rate.

![Figure 4. The effect of UFIO on the sintering rate.](image)

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![Figure 5. Fan pressure change in the sinter blend.](image)

Depending on the amount of UFIO usage in the sinter blend, the fan pressure is increased (demonstrated in figure 5). The reason for the increase in pressure is the reduction in the permeability of the sintered coke resulting from the fine particle size from UFIO.
XRD quantification of the different sinter phases were illustrated in figure 6. It can be seen that the variation of UFIO of the sinters influences the amount of the different sinter phases in the sintering process.

By evaluating the sinter in a scanning electron microscope, both the structure and the chemical analysis could be analyzed. For the reference sinter it became clear that the platy and blocky SFCA phase was found to be built from a platy network, as seen in figure 7. In this figure, the same platy structure can also be seen.

5. Conclusion

High quality iron ore improve the possibilities to adjust the chemical composition of sinter in order to achieve desired properties. Production of sinter with high iron content and low silica can significantly improve the possibility to operate the blast furnace in an efficient and cost effective way. The magnetite ores also help to reduce the consumption of coke breeze which from an environmental point of view can be advantageous. The addition of pellet screenings significantly improves the productivity while maintaining metallurgical properties of the produced sinter. The most notable difference is that UFIO has high Fe content and low SiO₂ impurity in its ore. The use of UFIO has increased the Fe content of the product sinter. By using UFIO, optimum RDI and Tromel values have been achieved. Minerology evaluation of all the produced sinters indicate high amounts of calcium ferrite which from a strength and reducibility point of view, is desirable. Hematite, magnetite and needle like etc. structures are observed in the produced sinter samples.

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References


