# The Influence of Raw Material Composition on the Quality of Sinter

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**Abstract:** In this study provides an overview of chemical and physical properties of commercial iron ores as well as their influence on sintering performance. The sinter structure and its characteristics mainly depend on the raw material chemistry, phase body, crack distribution and the sintering process parameters. The aim of the studies is to present a new approach to the characterization of complex macrostructures and microstructures, especially those found in effect of sinter quality and productivity. A number of the commercial iron ores were tested in an industrial sinter plant to study the effect of iron ore composition on the sintering properties. Sintering process was performed for each individual using iron ore as constant basicity, coke dust and flux. The sintering properties of blending ores, including productivity, tumbler index (TI), suitable moisture and coke rate were approximately equal except reduction degradation index (RDI) values, to the weighted means of the individual ores. An important feature of this system is the simultaneous use of X-Ray Diffraction and Scanning Electron Microscope (SEM-EDS) which enables to determine both macro and microstructure of a sinter with high accuracy.

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**Keywords:** Sinter, Iron Ore, Mineralogical Analysis, Tumbler Index

## 1. Introduction

Iron ore sinter is usually the major component of a blast furnace's iron bearing material. Most of impurities and running factors are combined to create molten silicates which called (iron or furnace blast) and floated over the molten iron, so they are separated from the molten iron. The Iron ore is carried then to steel furnace where the content of carbon decreases from 4% to 0.5% and the other impurities are removed. Solid iron slag is added in scrap iron and steel furnaces and iron slag (Zain et al., 2013). There are various types of iron ores traded in the international market. Many researches demonstrated that various types of iron ores affected the mineral structure of sinter and the sintering properties. In industrial sintering applications, the iron ores are blended and composition of the blending ore plays an important role in controlling the sintering properties. The quality properties of sinter are dependent on the mineral structure of sinter (Barnaba, 1985; El-Didamony et al, 2011). Therefore, it is required to understand the fundamental aspects of phase formation during sintering process in order to control and improve the characteristics of sinter. The reaction in sintering and consequently development of phases has been the subject of many studies (Alexander, 1981; Antunes, 1998). All these were basic studies conducted on sinter samples. It has been reported that the metallurgical properties of self-fluxing sinters, such as the mechanical strength, the degradability during reduction at around 1200°C, and the reducibility at high temperatures are greatly dependent on minerals compounds (Barnaba, 1985; Boyd & Ferron, 1995; Brock, 1983). Accordingly, an explanation of the fundamental aspects of the physical and chemical nature of the sintering processes, particularly the mineral formation processes that is required in order to control the qualities of self-fluxing sinters (Camci & Aydın, 2000).

Sinter product consists of various mineral phases produced by sintering of iron ore with fluxes and coke breeze. But yet comprehensive studies have been accomplished, many phenomena in the mineral formation processes have been left unsolved (Chaigneau, 1994; Egundebi, 1989). The problem has been studied through the sintering of very simple mixtures consisting of reagents, and several bits of interesting information have been obtained especially on the formation processes of the secondary or granular hematite, a product detrimental to the degradability (Erünsal, 2000; Fujimori, 1998). But, many complexities can be expected on the mineral formation processes that consist of different points within production process at iron steel plants (Jasienska & Durak, 1999). Because of their complex chemical structure and mineral components, much of solid wastes can be used to utilize in sinter blend (i.e. sludge, flue dust, slag, mill scale). Many investigations on the sinter structure and its qualities have been done. A sufficient clarification has not obtained, however, made on the relationship between the sinter structure and its physical properties. A few research reports have recently been released in an attempt to clarify the relationship between the sinter structure and its physical properties through the quantitative study by image analysis (Hamilton, 1951; Hida et al., 1983).

Several authors were investigated sinter microstructure, which directly influences sinter properties, is largely governed by the type of ore being treated (Hino et al., 2003). And the sinter strength is also a function of original ore properties (Higuchi & Heerema, 2003). Hida et al, concluded that sinter productivity can be influenced by the type of the iron ore used.

In this study, the sinter tests were applied to study the relationship between the sintering mineralogical properties, of the blending and individual iron ores, and attempted to find the way to improve the sintering properties of the blending ore containing with high productivity. Moreover, the effects of different type of iron ores on sinter properties with the basicity of 1.7 were studied. The effect three different types of foreign iron ores and domestic iron ores usage in sinter making processes effects of some sinter properties were examined. For this purpose preparation of sinter mix was done by considering the sintering conditions at an industrial sinter plant. Experiments were carried out in three stages; preparations of the sinter raw mix, baking, followed by the treatment of the burned sinter by some standard tests. Iron ores, coke, limestone and dunite were supplied by an industrial sinter plant for the tests.

## 2. Materials and Methods

Initially; iron ores are crushed to a suitable size (< 8mm) which are stacking on the sinter blend according to their chemical analyses by a stacker. Some flux material, coke and return dust can also be added at proportion unit. Besides, collected dust and mill scale, flue dust and sludge of gas cleaning from steel making can be added to the iron ore blend at the mixing stage. At the start of the sintering operation, the iron ore blend is transferred from the beds to storage bunkers. The ore blend and the coke breeze are weighed on conveyer belts and loaded into a mixing drum (Figure 1). Here, they are blended completely and the mixture is moistening to enhance the agglomerated, which improve the permeability of the sinter bed.

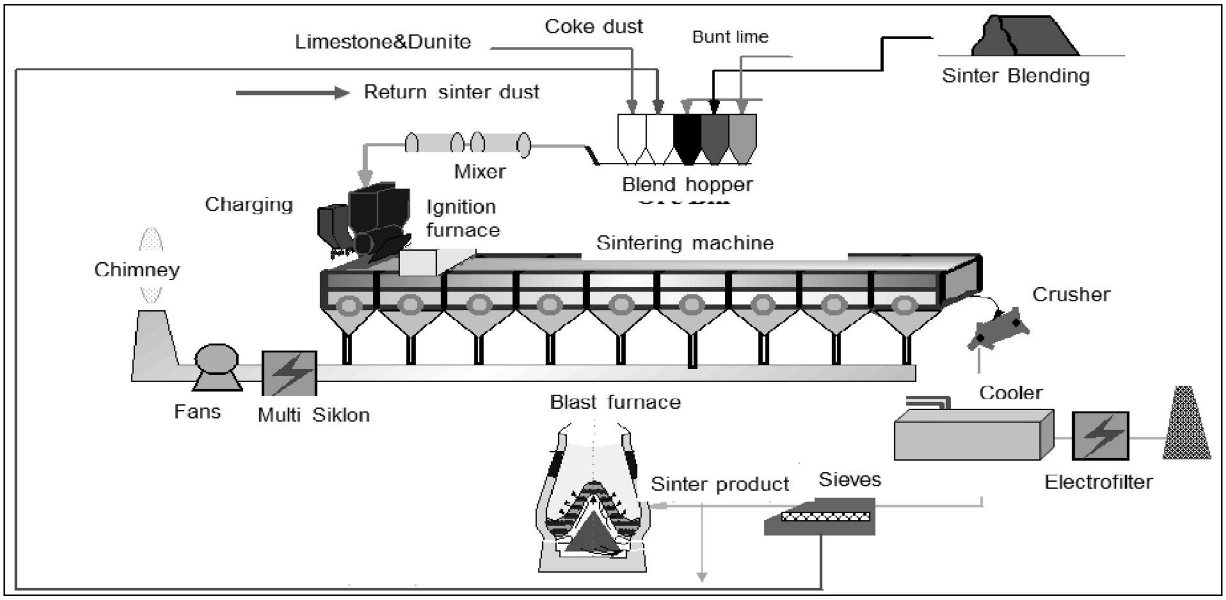


**Figure 1.** Iron Ore Sintering Process Flow Diagram

**Raw materials:** Iron ore X, iron ore Y, iron ore Z were domestic ore, while iron ore K, iron ore L and iron ore M were foreign ore fines mentioned in sinter test program. These iron ores were uniformly mixed respectively to reduce fluctuation of chemical composition and obtain representative sample. Chemical compositions of main iron mineral ores and sintered samples are given in table 1 and 2.

Fixed proportioning ratio among iron ore fines and relevant parameters applied in test program is listed as follows;

- Foreign iron ores (K, L and M): domestic iron ores (X, Y and Z) = 60: 40 (Table 3)

- X: Y: Z: = 10:20:10 (based on weight %)
- BF flue dust and iron bearing sludge account for 1.5 % and 2.4% of raw mix respectively. According to the test program, sintering test was carried out under condition of basicity ($CaO/SiO_2$) 1.7. Moisture in raw mix is fixed at 7.0%.

**Table 1.** Chemical and Mineral Composition of Main Minerals for Iron Ores

| **Raw materials** | **Chemical Composition (%)** | | | | | | | **Size Distribution (mass%)** | | | | **Mineral Composition (%)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***Fe*** | $SiO_2$ | $Al_2O_3$ | ***CaO*** | ***MgO*** | ***Zn*** | ***Ni*** | ***+6.35 mm*** | ***+1 mm*** | ***+0,15 mm*** | ***-0,15 mm*** | |
| **Ore K** | 63.86 | 3.73 | 0.89 | 0.11 | 0.04 | 0.002 | 0.001 | 14.3 | 34.8 | 22.7 | 28.2 | *Hematite* |
| **Ore L** | 62.25 | 3.65 | 1.12 | 0.03 | 0.05 | 0.006 | 0.002 | 17.3 | 26.7 | 24.4 | 31.6 | *Hematite* |
| **Ore M** | 61.88 | 3.18 | 2.09 | 0.02 | 0.03 | 0.005 | 0.001 | 23.5 | 20.9 | 18.2 | 37.4 | *Hematite, Limonite* |
| **OreX** | 55.68 | 6.27 | 0.59 | 1.30 | 0.78 | 0.002 | 0.002 | 15.5 | 35.8 | 23.3 | 25.4 | *Hematite, Geothite* |
| **Ore Y** | 53.38 | 6.47 | 1.41 | 1.29 | 0.86 | 0.038 | 0.003 | 13.5 | 33.9 | 23.4 | 29.2 | *Hematite, Limonite* |
| **Ore Z** | 58.72 | 6.78 | 1.64 | 0.48 | 1.48 | 0.016 | 0.180 | 14.4 | 27.2 | 19.8 | 38.6 | *Hematite, Magnetite* |
| **Limestone** | 0.36 | 1.30 | 0.27 | 53.45 | 1.24 | 0.000 | 0.000 | 1.2 | 42.7 | 33.4 | 22.7 | |
| **Dunite** | 3.39 | 38,42 | 1.17 | 4.68 | 36.5 | 0.04 | 0.240 | 2.2 | 34.2 | 36.5 | 27.1 | |
| **Coke dust** | 1.20 | 51.76 | 25.65 | 2.69 | 1.26 | 0.00 | 0.014 | 4.3 | 35.05 | 31.1 | 29.5 | |

**Table 2.** Chemical Analysis of Sinter Samples

| **Sample** | ***Fe*** | $Al_2O_3$ | ***CaO*** | ***Alkaline*** $K_2O.Na_2O$ | ***MgO*** | $SiO_2$ | ***Ni*** | ***MnO*** | ***Zn*** |
|---|---|---|---|---|---|---|---|---|---|
| **Sinter 1** | 56.94 | 1.68 | 9.56 | 0.04 | 1.15 | 4.89 | 0.01 | 0.48 | 0.02 |
| **Sinter 2** | 53.72 | 1.25 | 11.63 | 0.15 | 1.64 | 6.78 | 0.03 | 0.64 | 0.03 |
| **Sinter 3** | 54.65 | 1.54 | 9.58 | 0.09 | 1.35 | 5.68 | 0.02 | 0.72 | 0.02 |
| **Sinter 4** | 53.07 | 0.92 | 8.04 | 0.26 | 1.52 | 9.95 | 0.05 | 0.93 | 0.03 |
| **Sinter 5** | 52.85 | 1.45 | 12.65 | 0.14 | 1.42 | 7.67 | 0.02 | 0.92 | 0.04 |

**Table 3.** The Sintering Properties of Blending Ores.

| **Sample No** | **Blending of iron ores (mass %)** | | | | **Productivity** | | **RDI(-3.15) (%)** | **Machine Productivity (t/ m$^2$.24h)** |
|---|---|---|---|---|---|---|---|---|
| | ***Total domestic iron ore (X, Y, Z)*** | ***K*** | ***L*** | ***M*** | ***Moisture (Mass %)*** | ***Coke Breeze (kg/t sinter)*** | | |
| **Sinter 1** | - | 33.3 | 33.3 | 33.3 | 6.8 | 76.27 | 24.85 | 40.45 |
| **Sinter 2** | 40 | 60 | - | - | 5.5 | 78.02 | 32.58 | 32.68 |
| **Sinter 3** | 40 | - | - | 60 | 8.4 | 75.38 | 27.41 | 38.78 |
| **Sinter 4** | 100 | - | - | - | 8.9 | 79.95 | 36.02 | 29.89 |
| **Sinter 5** | 40 | - | 60 | - | 6.4 | 77.45 | 30.35 | 36.42 |

Table 3 shows the sintering properties varied with iron ore type. The productivity of the sinter ranged from 29.89 to 40.45 t/m$^2$.24h; the RDI ranged from 24.85 to 36.02 %; the proper moisture of raw mix, 5.5-8.9 mass % (Table 3). The sinters made from the low alumina commercial iron ores (S3, S1, S5) presented the lower coke rate (75.38-77.45 kg/t sinter) and required the lower moisture (6.4-8.4 mass %).

Later dry mixing of the blend, sufficient amount of water was added, and wet mixing was done to obtain adequate ball. Then, sinter mix was placed in the sinter strand in which all sintering experiments were done during with this study. The baking of the sinter mix was done in a plant scale sinter .The baked sinter, called the sinter cake was then subjected to tumbling and abrasion test in sequence. Test results were explained depending on sinter qualities such as sinter strength, return fine balance, sinter mineralogy. Tumbler index test was made to final product using 1/5 ISO standard method. Tumbler drum is of 1000 mm in diameter and 100 mm in width with rotation speed of 25 rpm (Int. Org and Stand., 2007). One batch of 11,3 kg sinter with grain size of 10-50 mm was put into tumbler drum rotating at 200 rpm and screen analysis was applied. The weight percentage of +6.35 mm fraction was taken as tumbler index as the weight percentage of -0.5 mm was taken as abrasion index (Figure 2). The final size was minus 100 microns and 100 gr of the sample was taken for chemical analysis (Table 2).

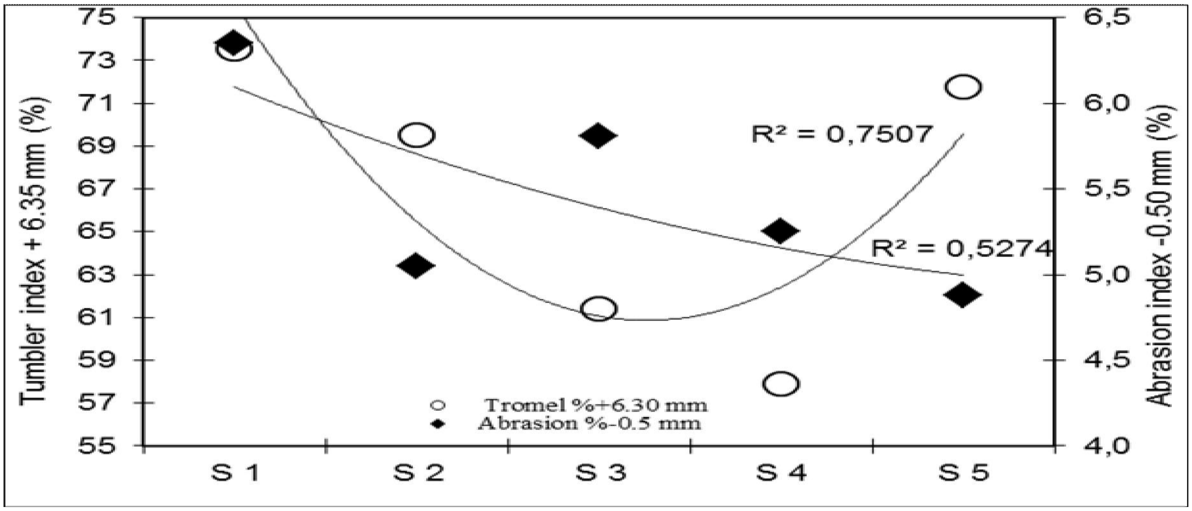


**Figure 2.** Changes of Tromel and Abrasion Index Depend on Iron Ore Types.

## 3. Results

### *3.1. Macrostructure Analyses of the Sinter Samples*

The sintered samples were collected from an industrial sintering plant. Various defects existing on the surface and inside of the sintered ore made easy to form crack propagates under the action of external forces and ambient media, which would finally lead to the breaking and cracking of the sintered ore. The distribution of crack formation in various sintered ore structures are shown in figure 3. The lengths of the indentation and cracks were measured by a microscope of 30 times magnification. The aim of the present work is to provide some reference rules for the macrostructure designing of the sintered ore so as to meet the requirement of BF production. Results of examinations, it is observed that calcium ferrite is a major factor influencing crack resistance of sintered ore. The finer the grain size of calcium ferrite, the greater is the crack resistance of sintered ore.

Porosity is an important parameter that has to be measured to comment on strength and reduction properties of a blast furnace burden. The production of sinter was required an optimum pore size and the strength for used in Blast Furnace (Kawaguchi & Usui, 2005).The results of the distribution of crack lengths in various sintered ore structures are shown in figure 4. It is believed that the strength, reducibility and size distribution of sinter particles and the yield from a sinter strand are determined by the inherent strength of the bonding phases present and the structure of the pores (Hsieh & Whiteman, 1993).

Additionally, different pore sizes seem to have different effects on sinter strength, reducibility and other properties; the high temperature reducing property is controlled by the micro pore sinter structure, while the sinter strength is determined by the macro pore sinter structure (Tsukihashi, Kimura, & Yazawa, 2003). It is therefore important to optimize the pore structure in sinter to improve its reducibility, while maintaining the cold strength, reduction degradation and load softening properties.

Moreover, a number of other researchers suggested that the cracks resulting from a volumetric change accompanying the phase transformation of crystalline hematite to magnetite is mainly responsible for the reduction degradation of sinter (Jasienska & Durak, 1999; Kawaguchi & Usui, 2005).

Recent results suggested that it is possible to further improve the permeability of a sinter blend, and therefore control the pore size distribution of the sinter product, by adjusting the particle sizes of both limestone and coke breeze simultaneously (Kawaguchi & Usui, 2005). S1 and S3 are a sample of the homogeneous a size distribution (average 149.8µm and 141.9µm). Pore size distribution required by the blast furnace is observed in the sample. S2 sample indicates the distribution of heterogeneous porosity (average 161.3µm.) (Figures 4).

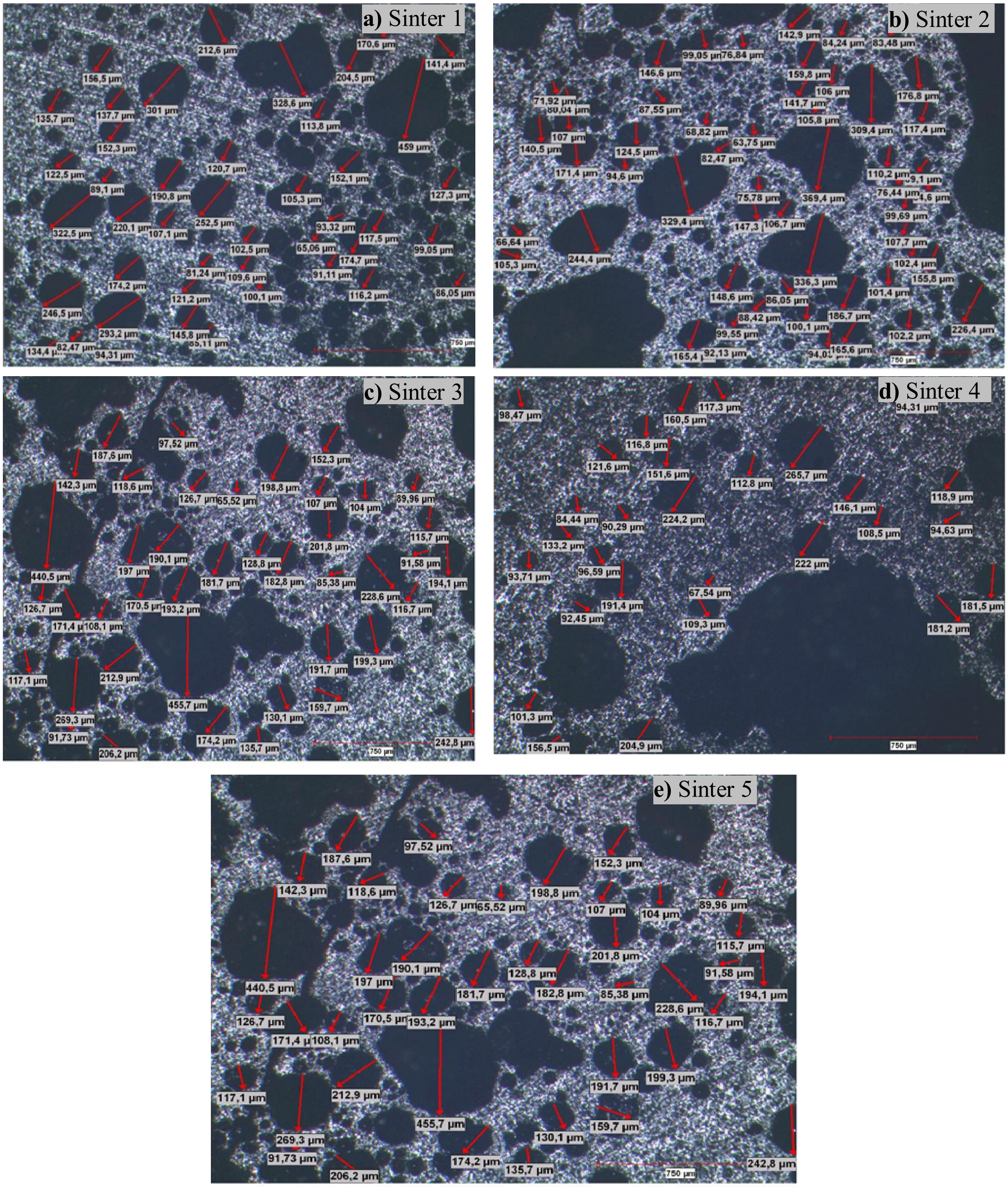


**Figure 3.** The Crack Formation of Sintered Granules with Different Iron Ores. a)Sinter1, b)Sinter2, c)Sinter3, d)Sinter4, e)Sinter5

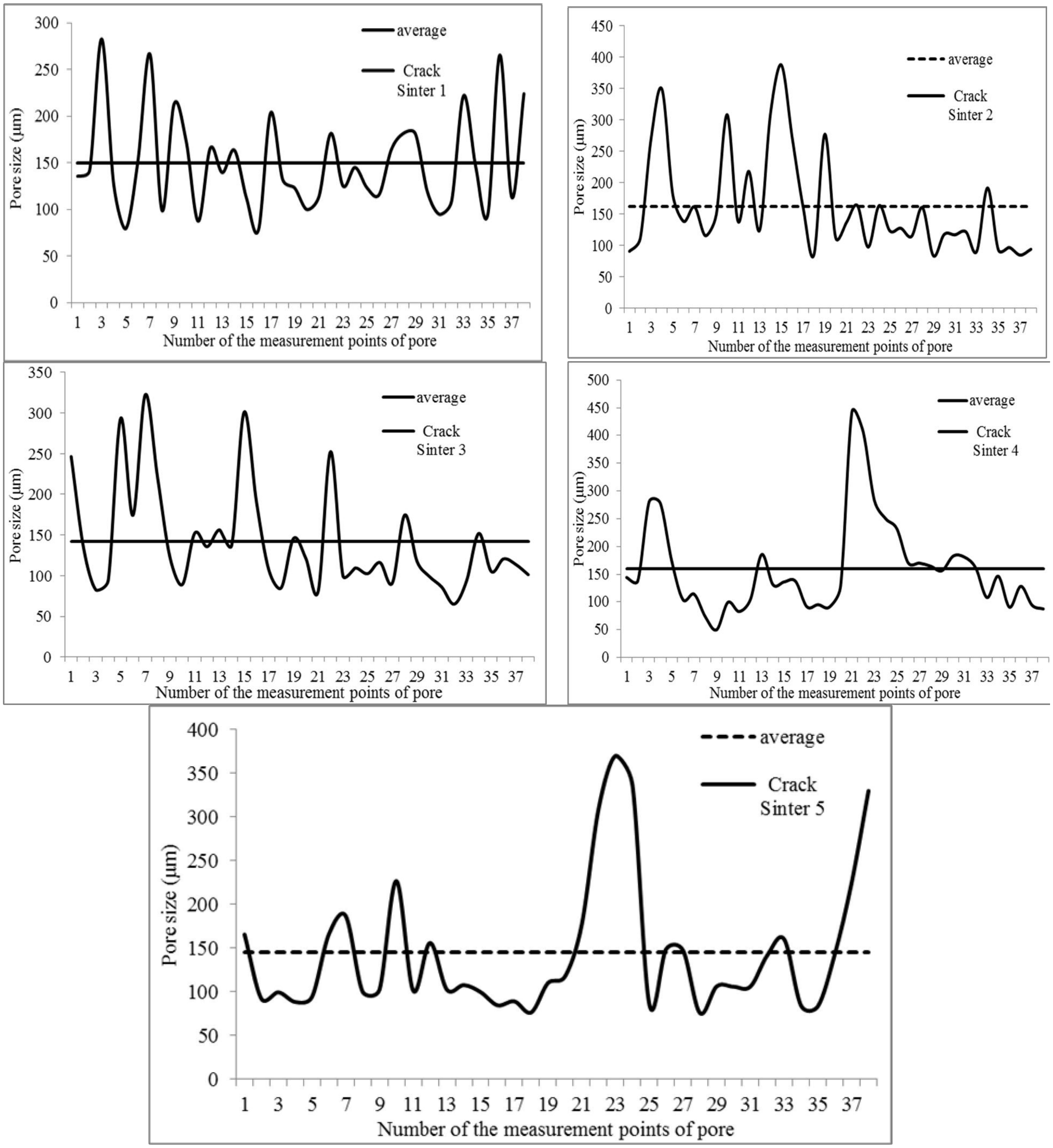


**Figure 4.** Crack Distribution in Various Sintered Ore Structures

### *3.2. Microstructure Analyses of the Sinter Samples*

Sinter products of all experiments were collected for microstructural examination. After sintering, the specimens were mounted in epoxy resin and then vacuum impregnated. The sinter grains of ~1 to 3 mm size were mounted in epoxy resin and vacuum impregnated. When a large ore particle was present, the specimens were polished to expose a plane section vertical to the top surface on a diameter of the specimen so that a cross section of the ore particle could be seen. These sections were polished by using silicon carbide paper to 1000 grit employing ethanol as a lubricant, and finally to 0.3 micron by using diamond paste. The specimens were examined using a light microscope in reflection.

The mineralogical content and microscopic texture of sinter was analyzed using optical microscope. The microcosmic textures of sinter are demonstrated on the micrographics a, b, c, d and e.

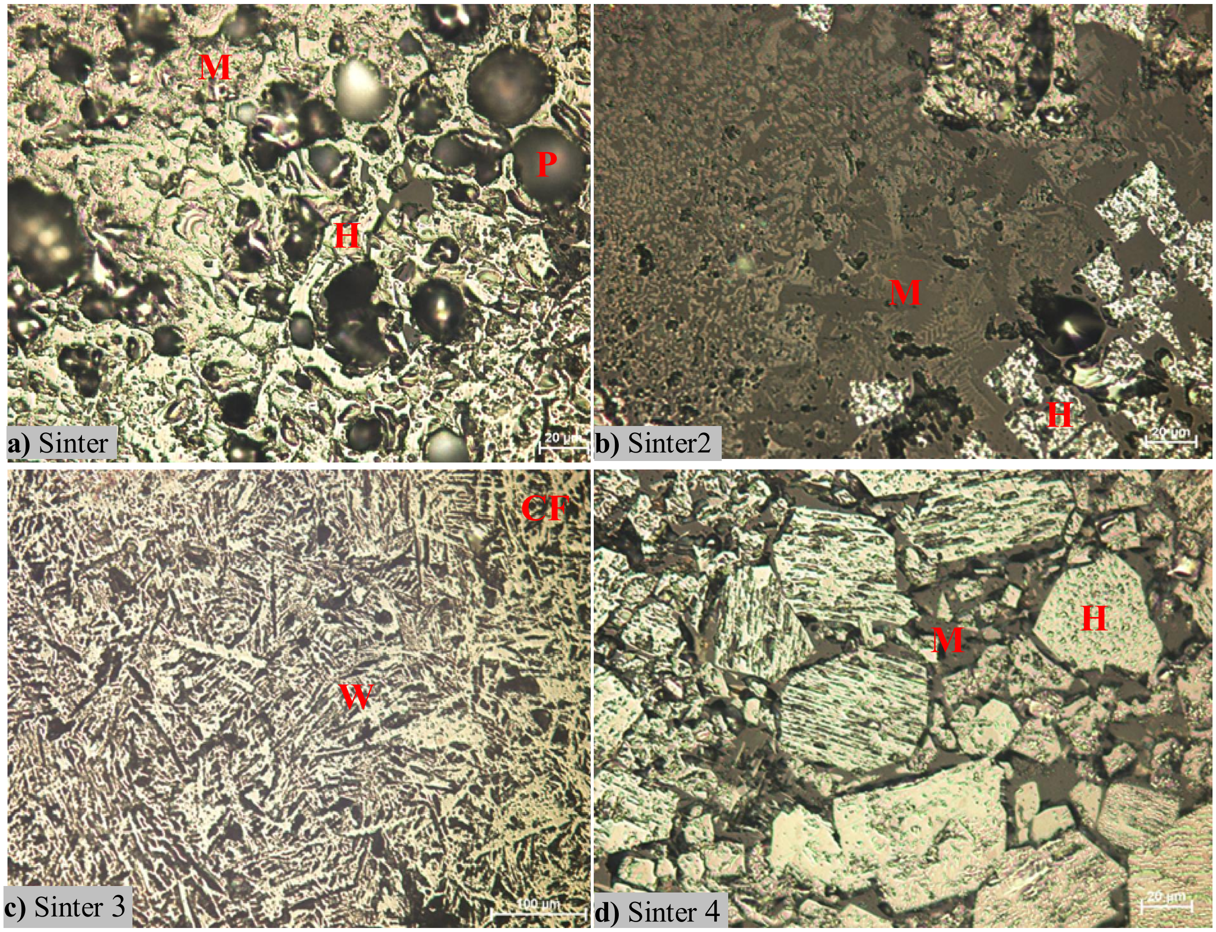
Figure 5a observes typical appearance of sinter structure for iron ore M mix, at 1250°C sinter consists of fine texture of needle like calcium ferrites and hematite, porosity is irregular and disrupted; at 1320°C hematite and magnetite crystals precipitate from slag; calcium ferrites are less abundant but are forming plates. There are a few intergrowths of fine magnetite crystal grains and hematite.

In the event of iron ore L mix (Figure 5b) the same general trends are observed. In addition, typical figures are obtained at low temperature: some kinds of quasi particles are formed; large amounts of needle like calcium ferrites are present at their periphery. The glass phases between hematite together with hematite form eutectic texture. Along edges of some hematite crystal grains, there is oxidation occurrence.

In the case of sinter, made from domestic ore mix to contain high gangue ores (Figure 5c), the same general trends apply. However, the reactions involving slag are promoted, due to the amount of gangue. The amount of calcium ferrites is rather high. At high temperatures, large plates are formed. Their chemistry is quite complex, with remarkable substitutions, involving silica, alumina, lime an even magnesium oxide.

In the event of sinter made a foreign iron ore mix (Figure 5d) consists mainly of molten texture formed by magnetite and calcium ferrite. A few needle shaped or branch shaped calcium ferrite and magnetite form interlacing textures, which occur along caverns holes. Magnetite amount is increased and also intergrowth of magnetite and hematite can be observed. Oxidation occurs at the edges or along caverns holes. At some places in the glass phase, separation out of magnetite fine crystal grains is investigated.

In point of iron ore K mix (Figure 5e) consists mainly of molten texture formed by magnetite and calcium ferrite or second birth hematite that are liquid phase filled by calcium ferrite. The crystal grains of some fine grain magnetite and hematite form interlacing texture, and the crystal grains of some magnetite are filled with calcium silicate. Few gangues are visible. There are a few intergrowths of fine magnetite crystal grains and hematite.



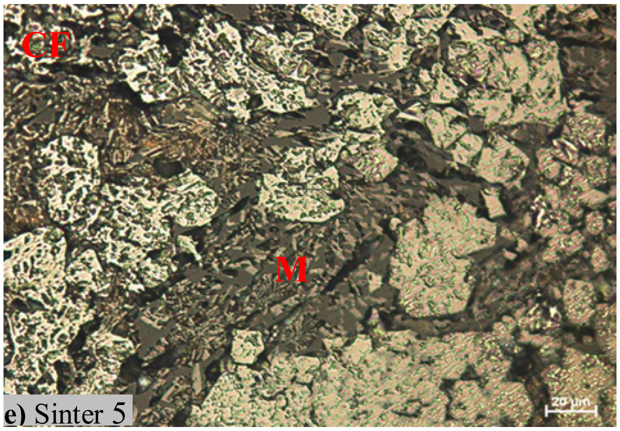


**Figure 5.** Microstructures of Sinter Samples. a) Sinter1, b) Sinter2, c) Sinter3, d) Sinter4, e) Sinter5 (H:Hematite, M:Magnetite, P: Pore, CF: Calcium Ferrite, W: Widmanstaaten (x500)

SEM analysis was performed in all of the samples, but only Sinter2 and Sinter4 were results shown here. SEM analysis was examined by D.E.U. Metallurgy and Materials Eng. Brand in the laboratories of the Department Jeol JSM-6060 model scanning electron microscope. As seen in figure 6 that demonstrates comparison of SEM images of sinter surfaces. There are a few interlacing existences of crystal grains of magnetite, hematite and a few coarse grain porous hematite (Figure 6a). Thus, high capacity of water absorption of S2 was caused by readily intrusion of water thorough open pores from the ore surface. Granulation in high moisture content is necessary to enhance granulation ability. It was clearly shown that each ore had individual surface morphology. In particular, S2 sample consists mainly of molten texture formed by magnetite and calcium ferrite (Figure 6b).

Calcium ferrite melt was found to form within residual ores of Sinter4 (Figure 6b). There is intergrowth of magnetite and hematite. Oxidation is seen at edges or along caverns and holes. At some places between coarse grain hematite, there is glass phase and much separation out of magnetite fine crystal grains (Figure 6b).

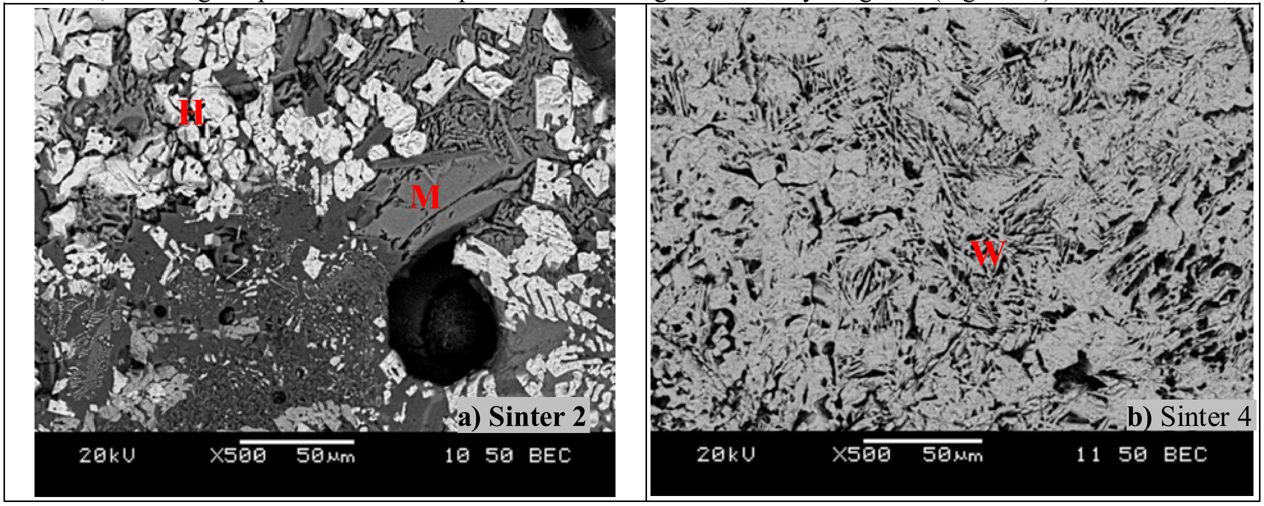


**Figure 6.** SEM Images of Sinter Surfaces. a) S2, b) S4. (H:Hematite, M:Magnetite, W:Widmanstaaten (X500)

### *3.3. X-Ray diffraction studies*

Sinter samples were examined by Rigaku D/Max-2200 model X-ray diffraction and results was given in figure 7. The aim of investigating the sinter samples under a microscopy was to find out the morphologies of phases. As a result of the mineralogical research, the samles were found to be rich in hematite ($Fe_2O_3$), magnetite ($Fe_3O_4$) and wustite (FeO), calcium ferrite ($CaO.Fe_2O_3$ or $CaFe_2O_4$), SFCA (silico-ferrites of calcium and aluminium), wollastonite ($CaSiO_2$), and various CaO-FeO-$SiO_2$ solid solutions like ferro-monticellite ($CaFeSiO_4$). Also $Mn_3O_4$ (Manganese Oxide), $Ca_2SiO_4$ (dicalcium silicate) $K_2S_2O_4$ (Potassium Sulfate) $Na_3PO_4$ (Sodium Phosphate) and amorphous glassy phase were observed. The sinters were very heterogeneous, due to the limited diffusion possible during the short period at melt conditions and variations at the peak temperature reached. Secondary hematite known as skeletal rhombohedra hematite is the major cause of poor reduction degradation resistance of sinter (Jasienska & Durak, 1999 & Larrca, 1992). This is based on frequent observations of cracks around the narrow neck regions of such hematite.

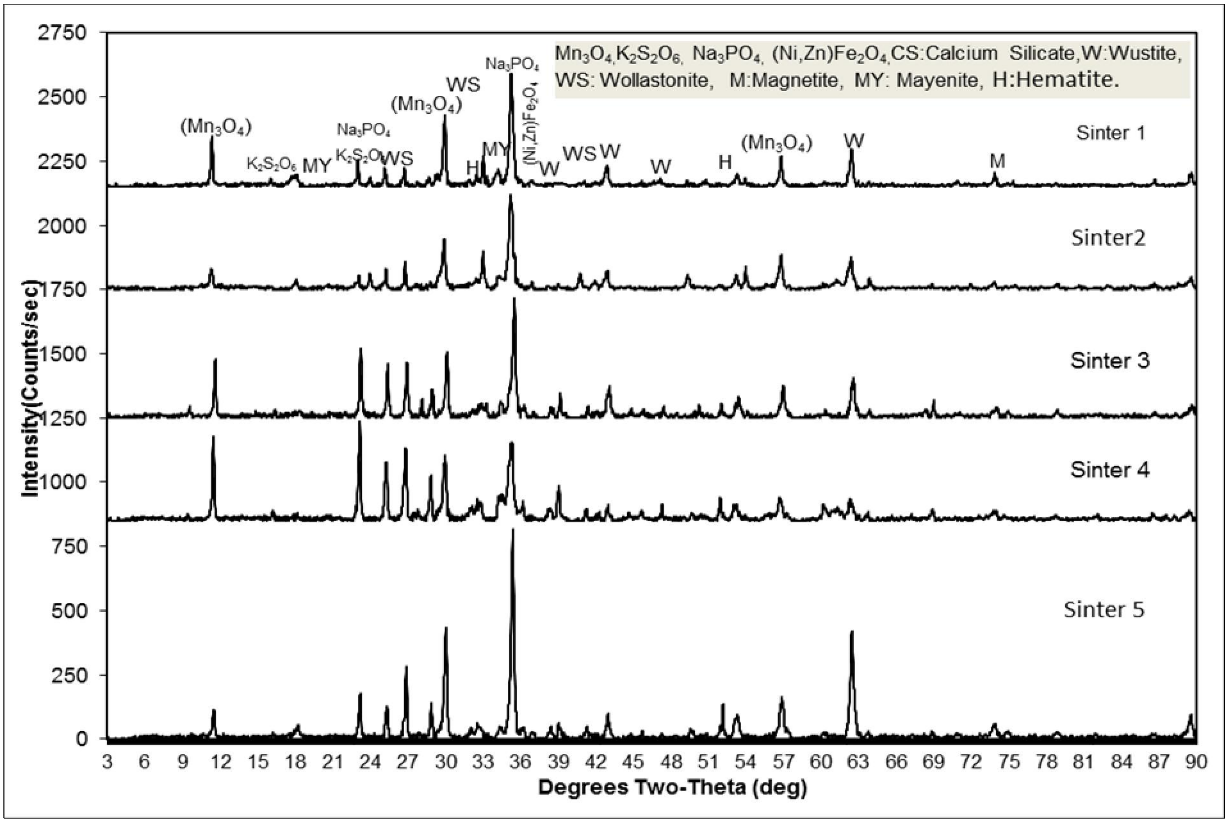


**Figure 7.** X-Ray Diffraction Studies of Sinter Samples

## 4. Discussion

Current literatures have not clearly established the relationship between the sintering properties of blending and individual iron ores. The small particles of blending ore were coated on the large particles to form the quasi particles in the granulation of industrial sintering.

The studies indicated that a little change raw material composition of sinter blends can have a significant adverse impact on the strength and reduction degradation characteristics of final sinter leading to deterioration in gas permeability in the upper part of the blast furnace (Lu, Holmes & Manuel, 2007). The trends of total hematite, reoxidized hematite, calcium ferrite and tumble strength which might affect the RDI were identical for all iron ores, but the trend of porosity varied with iron ore type (Kawaguchi & Usui, 2005; Meyer, 1980). In this study, Sinter3 consisted of with the lowest coke rate showed the largest increase in porosity; Sinter1 was less marked. For Sinter4 comprises with a high coke rate, the porosity was lowest and the porosity was reduced slightly as the alumina content increased. Probably because a high porosity in sinter promoted the transformation of hematite to magnetite during reduction, the RDI would seem to be related to the change in porosity in the same ore sinters that had a variation in alumina. Thus, the slope of the trend in RDI varied with iron ore type (Morrissey, 1953).

Prior work indicated that the high ratio of the pisolitic ore deteriorated the productivity of sinter (Nosovitskii & Zhilin, 1980; Pammer et al., 1980). In the experiments X and Y iron ore of this study, the pisolitic ore also showed the lowest relatively productivity index and increasing the ratio of the pisolitic ore decreased the productivity of sinter. Decreasing the SiO$_2$ content to raise the basicity and decreasing the MgO content may improve the sintering properties the productivity and RDI. This improvement may be related to the phenomena of which the increase in CaO or basicity and the decrease in MgO are able to decrease the porosity in sintering.

If the sinters have a low Al$_2$O$_3$ content (1.0–1.6%), it can be beneficial. The most harmful effect of alumina is to worsen the sinter's RDI, which increases as the alumina content rises. Industrial experience with the blast furnace shows that a sinter within a 10–10.5 % CaO content range an increase of 0.1% in the alumina content raises the RDI by 2 points (Inazumi, Nagano & Kojima, 1970). Sinter with good strength and reducibility, which is able to maintain these properties as long as possible in the blast furnace that is desirable.

The tumbler index of sinter is dependent on critical flaws in the sinter and the propagation of these flaws through a sinter particle. Cold mechanical strength is directly related with the tendency to form fines during transportation and handling from the sinter machine to the blast furnace throat. The best sinters, from the point of view of strength, were achieved with mixtures Sinter1 and Sinter3, with a tumbler index of more than 70%.

Calcium ferrite is the main bonding phase in sinter. It increases with an increase of basicity (Sasaki & Wan, 2001). Generally, the high content of calcium ferrite favors the tumbler strength of sinter, but probably not for the RDI. The hematite includes the unreacted and the secondary hematite and most of the secondary hematite is reoxidized hematite. With an increase in basicity, the reoxidized hematite decreased in sinter (Figures 5a&e). An increase in magnesia can slow the formation of reoxidized hematite during the cooling stage of sintering. The secondary hematite is the most disadvantage phase to the RDI of sinter.

During the cooling stage, the calcium ferrite has previously been supposed to form the solidification of the melt (Scarlett et al., 2004; Sevinç & Topkaya, 2001). However, in this study it has been clearly shown that a large amount of calcium ferrite also may be generated by the reaction of magnetite with silicate melt and oxygen (Figures 6a&b) The analysed ferrites are SFCA type (silico ferrites of calcium and aluminium) and form by solid liquid reaction between the hematite and the $Fe_2O_3$ CaO melt, with the subsequent assimilation of $SiO_2$ and $Al_2O_3$ in this melt. The chemical formula of SFCA can be written as $5CaO.2SiO_2.9(Fe,Al)_2O_3$. These ferrites are beneficial for the sinter structure because they improve its strength and reducibility.

These approaches will contribute to understand more deeply the actual mechanisms of sintering, allowing thus the production of a sinter meeting closely the requirements for efficient blast furnace operation.

## 5. Conclusions

Different ore mixtures have been tested in an industrial plant using various operating parameters to establish the best sinter manufacturing conditions. The structure and composition of a series of sinter samples has been studied by electron microscopy, SEM and XRD. The presence of hematite, secondary hematite, primary magnetite, secondary magnetite, and ferrites has been detected as majority phases, along with a smaller amount of gangue. There is sufficient porosity, with micropores in many cases, to favour the reducibility of the sinter. The structure is always highly heterogeneous with the phases considerably mixed up. The results obtained are summarized as follows:

- In general the structure of the sinters includes the presence of ferrites with beneficial properties for sinter strength and reducibility. The optimum structure, formed by a hematite nucleus surrounded by an acicular ferrite lattice, has been detected. This structure is favoured when working with a higher basicity.
- The size of iron ore also affected the sintering properties. An increase in the size of iron ore promoted the productivity of sinter, but may reduce the tumbler strength slightly and save a little coke.
- The MgO content of the sinters is between 1.2–1.7%. The addition of MgO to the ore mixtures used to manufacture the sinters improves the RDI, because MgO stabilizes magnetite and thus decreases the hematite content, causing a lower stress in the sinter during the hematite to magnetite reduction in the blast furnace.
- The sinters present a low FeO content (<8%), which favours their reducibility. When the chemical composition of an ore mixture is fixed, FeO can provide an indication of sintering conditions, in particular the coke rate. It has been found that increase in the FeO content in the sinter lowers (improves) the RDI index. However, when the FeO content increases, reducibility decreases. It is important to find an optimum FeO content in order to improve the RDI without altering other sinter properties.
- Because of various chemical compositions and heterogeneous particle size distributions from raw materials are blending in industrial iron ore sintering. Thus, a microscopic point of view and the reactions of sintering are heterogeneous. Therefore, done experiments which can only closely simulate the typical microstructure of industrial sinter.
- The information reported in the present work, on the basis of the results obtained on the composition of ore mixtures, will be useful to the operators of the industrial sinter plant to allow improve the sinter manufacturing.
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