Introduction of Pisolitic Goethite Ore into a Chinese Ore Blend

L. X. YANG, D. WITCHARD and Z. N. YU

BHP Minerals Development, PO Box 188, Wallsend 2287, Australia. 1) Laiwu Iron & Steel Company, Shandong Province, China.

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Research has been carried out to examine the effects of introducing an Australian goethitic ore (i.e., Yandi ore) into a Chinese sintering ore blend. Bench-scale studies show that Yandi ore is easier to be assimilated than hematite ore, which agrees with that observed in blending with hematite ores. Substitution of Yandi ore for an Australian hematite in the blends does not lead to significant changes in sinter mineralogy.

Effects of adding Yandi ore on sintering performance was studied by conducting pot tests under simulated conditions of this Chinese sinter plant. It has been found that when an Australian hematite ore is replaced with Yandi at 10–40% in blends, at slightly increased mix moisture, productivity maintains or increases slightly, coke rate maintains and sinter strength shows a marginal increase with increasing Yandi ore. At Yandi ore levels of 10–40%, the productivity is about 1.47–1.51 t/m² h at mix moistures of 7.2–7.3%, ISO tumble index of the sinters is around 69%, coke rate is about 50 kg/t. The low coke is probably due to the easy-melting property of Yandi ore, possible oxidation of the magnetite concentrates, etc. JIS reducibility of the sinters increases from 60% to 68% when the goethite ore level varies from 10% to 40% in the blends.

This work evidences that Yandi ore can be used successfully to replace hematite ores in Chinese type blends.

KEY WORDS: magnetite concentrate; goethite; iron ore sintering; assimilation.

1. Introduction

Goethitic ores, e.g., Yandi ore, are widely used for sintering in Japan, Korea and Australia, and in many cases, the levels of goethitic ores in ore blends are as high as about 50%. In these sinter plants, the goethite ores are blended mainly with hematite ores. Extensive work has been carried out, primarily in Japan and Australia, on sintering behaviour of the goethite ores in such ore blends. The work has been focused on the ore properties,1) granulation behaviour,1,2) sintering properties1,3–5) and technique development for effective use of the goethite ore.1,6–7) Substantial understanding about goethite ores has been obtained although further work is required in order to use the ores more effectively.

The PRC (People’s Republic of China) imports a large amount of iron ores to meet the shortfall in its iron ore supply. Many Chinese sinter plants use various levels of imported hematite ores to blend with their magnetite concentrates. However, goethitic ores are not so widely blended for sintering in the country. Many Chinese plants are considering to introduce Yandi ore to their blends to explore ways to improve their sintering performance.

Plant A—an example of such plants—has been a long term customer of an Australian hematite ore using around 30% in their blend. Other ores in the blends, magnetite concentrates and a low grade magnetite fines, are chiefly from the local areas. This work studies the effects of replacing the imported hematite ore with Yandi ore on sintering of the blends, i.e., conducting bench scale studies to investigate the sintering reactions, and sinter pot tests to look into the effects on sintering performance under simulated Plant A conditions. The results show that good sintering performance can be obtained at Yandi ore levels of up to 40%.

2. Experimental

Most of the raw materials were supplied by Plant A, and their compositions are listed in Table 1. The two magnetite concentrates are very fine with Ore A being almost 100% minus 1 mm and Ore B being about 95% minus 1 mm. Local sintering fines Ore C is about 85% minus 8 mm. About 83% of the limestone is below 2 mm and 89% of the burnt lime is below 1 mm. Recycled materials, such as steel-making slag (BOS slag), plant dusts and blast furnace (BF) dusts, were also used in the plant. The sinter fines generated in re-screening the sinter product before feeding into blast furnace (BF return fines) was approximately 80% below 5 mm.

Ore D and Yandi ore are hematite and goethite sintering fines respectively, and both are produced in the Pilbara range of the Western Australia. Ore D formed via enriched Banded Iron Formation (BIF) and contains mainly hematite, martite and small amount of goethite, while Yandi is a channel ore and is composed of primarily goethite and some hematite. The gangue minerals in the two ores are...
mainly quartz and clay.

Bench-scale studies were carried out under temperature profile simulating the sintering practice using an Infrared furnace, which has been described in a previous publication.8) Atmosphere in the furnace could also be controlled.

Ore blends for pot tests are given in Table 2. The Base blend contains 30% Ore D. Yandi ore was introduced to the Base Blend to replace Ore D in step to form Blends 2, 3 and 4. Blend 5 contains 40% Yandi ore.

The test conditions are as follows, granulation time - 5 min, bed height - 500 mm including 30 mm hearth layer, ignition time - 1.5 min, ignition suction - 6 kPa and sintering suction - 10 kPa. The product sinter was characterised with ISO strength, JIS reducibility, and JIM RDI. The sinter mineralogy was studied by optical microscopy and the mineral composition was determined by the manual point counting, which was detailed in a previous publication.9)

3. Bench-scale Studies

3.1. Properties of the Main Magnetite Concentrate in the Blends—Ore A

Ore A is from a deposit formed via “Contact-Metasomatic” process.10) In such process, magma invades carbonate type rock, resulting massive interactions between the magma and rock. Under the conditions of such high temperatures and pressures the invaded rocks become unstable, and their constituents recombine to form new minerals that are stable under the changed conditions. Changes occur on the margins of the igneous intrusive body, and chiefly on the invaded rock. What to form depends on original mineral of the rock, magma compositions and other conditions such as temperature and pressure. The resulting mineralogy is thus more varied and complex than that produced by heat metamorphism alone, or via sedimentary process. Generally, there exist the remaining carbonates and silicates, and newly formed varieties of silicates. Ores from such deposits are generally very complex in mineralogy and composition.

Mineralogy of Ore A was examined, and its mineral composition, determined by the point-counting technique, is given in Table 3. SEM-EDS (scanning electronic microscope with energy dispersive system) was adopted to assist in identification of the gangue minerals. The ore contains predominantly magnetite and hematite is less common. Main gangue minerals are carbonates, micas, feldspar and quartz.

As a result of the complex formation process, Ore A contains higher levels of Al, Ca, Mg, alkalis, compared to those formed through BIF, e.g., an ore studied earlier (named Ore Ref in this work) with composition Al_2O_3 5 0.29%, CaO 5 0.44%, MgO 5 0.29%, K_2O 5 0.014% and Fe 5 62.6%, in which the main gangue minerals were quartz and pyroxene.11) The alumina content in Ore A is high compared to other PRC concentrates in which the alumina content is usually below 1%.11) SEM-EDS analyses have found that the alumina bearing minerals are (in decreasing order in quantity) clinochlore [(Mg,Fe)_5Al(Si3Al)O10(OH)8], anorthite [CaAl_2Si_2O_8], microcline [KAlSi_3O_8], augite [(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6] and biotite [K(Mg,Fe)-(Al,Fe)Si_O_3(O,H,F)_2].

Porosity and surface area of Ore A were measured by the BET method, and the results are shown in Table 4, where Ore Ref is also included for comparison. The principle of the method is to measure nitrogen absorption by iron ores under controlled conditions, and the measurements are then converted to surface area and porosity. The results indicate that the surface area of Ore A is much larger, and its porosi-
ty is almost 3 times Ore Ref., which could mean that Ore A would participate in reactions more readily in sintering than Ore Ref.

### 3.2. Oxidation of Ores A & B and Assimilation of Ore D & Yandi Ore

Oxidation of the two magnetite concentrates (Ores A & B) has been studied using the infrared furnace, which can simulate the sintering temperature profile seen in sintering process. The ore samples were placed in the furnace and heated up to a given temperature in flowing air. The samples were cooled by switching the power off. Mineralogy of the samples after the oxidation experiments was examined and the results are presented in Fig. 1, where oxidation degree is defined as (hematite/(hematite+magnetite)) ratio. Ore Ref2 (also a magnetite concentrate)\(^1\) with composition Fe\textsubscript{2}=55.8\%, FeO\textsubscript{2}=25\%, SiO\textsubscript{2}=5.2\%, Al\textsubscript{2}O\textsubscript{3}=0.91\%, CaO=0.31\% and MgO=0.37\% is included to compare with the current results. The oxidation degree for all the ores follows the same trend, i.e., increasing with temperature up to 1 100°C. The oxidation degree of Ore A is high, suggesting that the ore is easy to oxide probably due to its high porosity as shown in Table 4. This means that under favourable conditions, majority of Ore A would be oxidised during sintering before 1 100°C, at which most of the sintering reactions start to occur.

Oxidation has been studied earlier for a number of magnetite concentrates.\(^2\) It was found that the oxidation depended on temperature, oxygen pressure in the atmosphere, ore composition, etc. The exposure of magnetite particles to atmosphere was found to be essential at high temperatures due to melt formation and particle coalescence, therefore, gangue level and fusibility of the ore played an important part in the oxidation process. Therefore, Ore B with high gangue level has lower oxidation degree compared to the other magnetite ores.

In sintering, sinter mix is granulated prior to charging onto a sinter machine. During granulation fine particles adhere onto the surface of large particles with the assistance of water lenses to form granules. It is well established that the initial melt is generated from these adhering fines via reactions between iron ore and fluxes during sintering. This melt then assimilates the nuclei particles to produce more melt. Before complete melting is reached, the sintering temperature drops. The melt solidifies and mineral phases precipitate out of the melt forming bonding phases which cement the unmelted materials and form lumpy sinter. The reaction between melt and the unmelted particles (likely to be iron ores) during sintering is called assimilation.

The chemical reactions resulting in melt formation and assimilation mainly take place in the high temperature zone of the sinter bed over a very short period of time. A method has been developed in BHP\(^3\) to study the complex reactions that occur within granules, i.e., reactions of large ore particles and melts formed from fine particles of ores and fluxes. Assimilation of Yandi ore has been studied using hematite ores and fluxes as adhering fines,\(^1,13\) showing that the degree of assimilation of Yandi ore was greater than hematite ores.

Assimilation of Ore D and Yandi ore was studied in this work using magnetite concentrates (Ores A and B) and fluxes as adhering fines. The blends, similar to the Base blend and Blend 5 listed in Table 2, consisted of 46\% Ore A and 15\% Ore B and 39\% Ore D or 39\% Yandi ore (both in 0.7–1 mm). The mix CaO/SiO\textsubscript{2} ratio was 1.7. The samples were sintered in the infrared furnace under the simulated sintering temperature profile at the maximum sintering temperature of 1 300°C in air. The sintered samples were then studied by optical microscopy and the assimilation was measured as the volume percent of ore particles consumed by the melt. Table 5 presents the assimilation results for Yandi ore compared to the porous hematite ore (Ore D), showing that almost all Yandi ore has reacted while quite amount of Ore B remained after sintering. This suggests that Yandi ore particles would more readily participate in sintering reactions compared to Ore D, which is consistent with that observed when Yandi ore was blended with hematite ores.\(^1\)

Generally, magnetite ores are less reactive than hematite and goethite ores.\(^9\) High sintering temperature is required to generate melt for adequate sinter strength in sintering of magnetite ore blends. When a magnetite concentrate is blended with Yandi ore (goethite), the easy reaction nature of Yandi ore would offset the low reactivity of the magnetite ore. This could mean that low sintering temperatures would be used for magnetite/Yandi ore blends to generate sufficient liquid, i.e., coke rate could drop.

### 3.3. Phase Formation in Sintering of the Plant A Blends

Bench-scale studies were carried out to examine the effect of Yandi ore on sinter mineralogy. The blends studied were modified Blends 3 and 5, and Base blend without the recycled materials, i.e., Base blend - 39\% Ore D, Blend 5 - 39\% Yandi ore, Blend 3 - 13\% Ore D and 26\% Yandi ore, and the rest in these blends were 46\% Ore A and 15\% Ore B. Sinter mix with CaO/SiO\textsubscript{2}=1.7 of these blends was heated in inert atmosphere and cooled in air at maximum sintering temperature of 1 270°C under simulated temperature profile. Mineralogy of the analogue sinters is presented in Fig. 2, showing that the sinters are mainly bonded by SFCA, and the main minerals are hematite, magnetite and SFCA. No significant difference is observed between the three

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**Table 5. Assimilation results for Ore D and Yandi ore.**

| Material                  | Nuclei | Retent ore, vol% |
|---------------------------|--------|------------------|
| Ore D (Ores A & B, flux as adhering fines) | 13.2   |                  |
| Yandi ore (Ores A & B, flux as adhering fines) | 0.2    |                  |

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Fig. 1. Oxidation of the magnetite concentrates.
blends. Only minor difference is the decreasing primary hematite in sinter with increasing Yandi ore, which is in accord with the observations in Table 5. Thus, 30–40% substitution of Yandi for Ore D in this PRC blend does not lead to significant changes in sinter mineral composition.

4. Pilot-scale Studies

4.1. Pot Tests Results

Sinter pot tests were carried out for the 4 potential ore blends and the base case listed in Table 2. Yandi ore was introduced to the Base blend step by step to replace Ore D (hematite) forming Blends 2 (10% Yandi ore), 3 (20% Yandi ore), 4 (30% Yandi ore) and 5 (40% Yandi ore).

The sintering results (average of duplicated tests at each conditions) are summarised in Table 6. For the Base blends at 7% mix moisture, the productivity is 1.46 t/m² h, coke rate is 49 kg/t and the sinter ISO tumble index is 66%, which are very good compared to other mills using magnetite concentrate in their blends.14)

For Blend 2 at slightly higher mix moisture (7.2%) than that for the Base blend, the productivity is increased to about 1.5 t/m² h, and the sinter ISO tumble index is about 69%—slightly higher than the Base. The coke rate is about 49 kg/t, which is similar to the Base blend. At mix moisture of 7.3%, the productivity, coke rate and sinter strength for Blends 3 are comparable to Blend 2, and the Base blend (Blend 3 having higher sinter strength than the Base). For Blends 4 and 5, the performance is comparable to the Base blend in terms of sinter strength, coke rate and productivity. At an increased moisture of 7.6% for Blend 5, the productivity increases to 1.57 t/m² h, and the sinter tumble index is 66%, which is similar to the Base blend and comparable to the sinters produced in Australia and Japan using predominantly hematite ores.

Size distribution of the sinter products shown in Table 6 is fairly comparable for the 25–16 mm and 16–10 mm fractions for these blends, while the 40–25 mm fraction is the lowest and 10–5 mm fraction is the highest for the Base blends. This is only an indication of the trend as the size distribution is also strongly dependent on stabilisation and handling conditions after sintering.

Thus, high productivity can be obtained from blends containing Yandi ore up to 40% at slightly increased mix moisture while sinter strength and coke rate are maintained at the similar levels as for the Base case without Yandi ore. In the range of Yandi ore levels in the blends studied, the yield is maintained also.

Generally, when Yandi ore is introduced into a ore blend more water is required to obtain the same effectiveness in granulation because Yandi ore is a very porous ore and absorbs water during granulation.15) If water addition unaltered, a lower productivity would result but sinter strength could be higher. It should be noticed that only a small increase in mix moisture was required with Yandi ore increasing from 0 to 40% in this work, while a larger increase in mix moisture generally incurs if Yandi ore is added to hematite ore-based blends. For instance, the mix moisture was increased from 5.8% to 6.9% when Yandi ore level increased from 0 to 40% in the BHP Newcastle ore blend, in which the rest of components were mainly hematite fines.15) The difference between the BHP Newcastle case and the current work may be attributed to the presence of the magnetite concentrates in the current blends, interactions between the concentrates and the larger ore particles like Ore D and Yandi ore, properties of the ore being replaced by Yandi ore, etc.

4.2. Characterisation of the Sinters

Chemical compositions of the sinters are given in Table 7. As the level of Yandi ore increases gradually from 0% in the Base blend to 40% in Blend 5, the sinter P and Al₂O₃ contents reduce, which is in line with the low P and Al₂O₃ contents in Yandi ore.

Mineral compositions of the sinters were determined by the manual point-counting technique. The results, given in Fig. 3, show the same trend as that in Fig. 2. “Primary hematite” means the unreacted hematite from the original ore, “secondary hematite” means the hematite formed during sintering, e.g., crystallisation from the melt, and “others” include unreacted fluxes and small amounts of silicates precipitated from melt.

As Ore D is replaced with Yandi ore, the sinter mineralogy does not show significant changes. The sinters are mainly bonded by SFCA and glass bonding is less common. The
blends. As it has been stated before (Fig. 3), no significant
reducing properties are obtained with increasing Yand ore level in
the ore blends. This agrees with the observations in labora-
tories and sinter plants when Yand ore is added to the ore
mineralogy were initiated by the stress and cracks generated in the reduc-
tion of hematite to magnetite at low temperatures. The glass content is about 6 vol%.
For Blend 5 containing 40% Yand ore, the SFCA content is as high as
about 46 vol%. The sinter, therefore, is strongly dominated
with the SFCA and magnetite coexistent structure.

Sinter RDI was determined using the JSM standard
method and sinter reducibility (RI) was determined using
JIS 8713. The average values of duplicated two tests for
RDI and RI are listed in Table 8.

Significant and consistent improvements in sinter reduc-
ibility are obtained with increasing Yand ore level in
the ore blends. This agrees with the observations in labora-
tories and sinter plants when Yand ore is added to the ore
blends. As it has been stated before (Fig. 3), no significant
changes in sinter mineral composition are observed with
the addition of Yand ore. The higher sinter reducibility
associated with increasing Yand ore level would most likely
be a result of increased sinter porosity due to the porous
Yand ore, rather than a change in sinter mineralogy.

RDI index is very low for the sinters from Blends 2–5
and Base blend, i.e., RDI = 13–14%, compared to the sinter-
tudes produced in Japan, Australia and some Chinese
steel mills. The RDI for Blend 5 is about 20%, which is still
low. It is well established that early breakdown of sinter size
is initiated by the stress and cracks generated in the reduc-
tion of hematite to magnetite at low temperatures. The sinters from the current blends are dominated by the coex-
sting texture of magnetite and SFCA, and contain relatively
low levels of hematite. The sinter RDI is, therefore, gen-
erally low.

5. Discussions

5.1. Coke Rate

The coke consumption is very low for all the blends, i.e.,
around 50 kg/t, which is very low compared to typical mag-
netite-based ore blend sintering and even lower than hematite ore sintering. The produced sinters are very strong
with ISO tumble index of around 70% at such low coke rates. The sinter FeO content is in the range of 9–10%,
which is low compared to typical sinters from magnetite
ore blends.

There are probably many reasons why low coke rates en-
able to be obtained for the Plant A blends. For the Base
blend, which does not contain Yand ore, the low coke rate
could be because of high granulation efficiency, oxidation
of the magnetite ores, higher reactivity of these magnetite
ores than magnetite ores in general, etc. When Yand ore is
introduced to replace a hematite ore, general observation is
that coke rate would remain almost unchanged since Yand
ore is easy to melt although the calculation requires energy. Under appropriate conditions, the Yand easy-
melting property can be beneficial. This means that suffi-
cient melt could be able to form during sintering at low
coke rates. Magnetite alone requires high sintering temper-
atures to generate sufficient liquid, and high coke rate is gen-
berly encountered. When magnetite concentrate is mixed
with Yand ore, such as Blends 2–5, the easy-melting Yand
ore would react with fluxes at relatively low temperatures to
form melt. It has been shown in Fig. 3 that for Blends 2–5
containing 10–40% Yand ore, over 40 vol% bonding phases
(SFCA and glass) formed after sintering at low coke
rates of about 50 kg/t.

One of the important conditions to enable above to be re-
alised is good granulation efficiency. It was experienced in
this work that when sinter mix was not well granulated, e.g.,
at insufficient level of burnt lime or inadequate level of
moisture, the low coke rates could not be established. Good
granulation is important for good sintering performance,
and perhaps is essential for magnetite-predominated blends.
This would provide conditions for good productivity due to
high permeability and even sintering, i.e., even formation
and distribution of liquid, which would result in strong sinter.

The magnetite concentrate—Ore A—is more readily to
react compare to Ore Ref. This would also assist sintering
reactions to generate liquid. It is also likely that part of the
magnetite in the Plant A blends would be oxidised during
sintering as Ore A is relatively easy to oxidise (Fig. 1), and
this is even more likely to occur at the low coke rates used
in this work. The heat generated from the oxidation would
be a supplement to the sintering process.

Contribution of magnetite ore to heat generation in sinter-
ing has been observed in laboratory studies. Button and
Lundh studied the sintering of a 100% hematite ore blend
and a blend containing 30% magnetite. It was found that
heat generated from magnetite oxidation was equivalent to
coke breeze combustion and the sintering temperature was
a function of both magnetite ore level and coke breeze
added. Compared to the 100% hematite ore blend, the max-
imum sintering temperature, at a given coke rate, was about
60°C higher for the magnetite containing blend, which was
equivalent to about 0.75 mass% coke breeze. Rigaud et al. studied in pilot scale the effect of different levels of magnetite on sintering by varying Carol Lake concentrate additions, where magnetite levels in hematite based ore blends were 7 mass% and 23 mass%. It was established that the inclusion of magnetite was similar to that of coke breeze, and 10% coke breeze saving was observed for a blend containing 23 mass% magnetite.

Oxidation of magnetite ores has been studied under sintering conditions at BHP. It was found that the oxidation was mainly dependent on ore type, gangue level, gangue type, temperature, atmosphere and granule structure. Reducing coke addition, where possible, is no doubt the most effective way to promote oxidation. For a given ore blend at a given coke rate, the granule structure is important as this determines the degree of exposure of magnetite particles to atmosphere. It was suggested by the study that magnetite concentrate likely acted as adhering fines and coarse ore particles would form the nuclei of granules during granulation (granules are generally regarded to consist of adhering fines and nuclei) when magnetite concentrate was blended with a coarser ore, e.g., Ore D and Yandi ore. The magnetite particles adhering on the coarse particles would have more opportunity to be exposed to air and oxidise.

On the other hand, the oxidation would be inhibited and oxidising atmosphere would be less developing at high coke rates, so the melt formed would be more predominated by silicates. The resulting sinter would contain less SFCA, and such sinter would have lower strength. The results, shown in Fig. 4, indicate that high coke rates gave weak sinters.

5.2. Yandi Ore Level in the Plant A Blends

Goethite ore has been successfully blended with hematite ore in many sinter plants. This work has also demonstrated that the goethite ore—Yandi ore—can be blended with magnetite concentrate at levels up to 40%, and very good sintering performance and sinter quality have been obtained.

Magnetite concentrate is famous as a difficult sintering material due to its fine size and low reactivity although it generally performs well in pelletising. Mixing of such materials with goethite ore would probably give suitable blends for sintering in considering that the low reactivity of magnetite ore could be compensated by the goethite ore, and good granulation efficiency could be attained as the goethite ore is generally large in size and rough surface. In this work, Yandi ore had a top size of 9 mm and Ore D had a top size of 6 mm. From this point of view, Yandi ore could form good blends with magnetite concentrate. This requires further studies. Current work shows (Fig. 5) that granulation efficiency for Blend 4 (30% Yandi ore) and Blend 5 (40% Yandi ore) at slightly increased mix moisture is at least the same as the Base blend (30% hematite and no goethite). It should be noticed that gas velocity through a sinter bed represents bed permeability at given bed height and suction.

When Yandi ore is blended with hematite sintering fines, it has been found that mix moisture needs increasing steadily at a level of about 0.3% increase for every 10% addition of Yandi ore. The increase in mix moisture with increasing Yandi ore level is relatively small, e.g., from about 7% for Base blend containing 30% Ore D and Yandi ore to about 7.2–7.3% for Blend 4 containing 30% Yandi ore, which is, no doubt, beneficial to sintering. This could be due to instant coating of the magnetite ultra fines on Yandi ore particles and inhibiting water absorption by Yandi ore particles. If the 40% Yandi ore in Blend 5 is replaced with 40% Ore D (a hematite ore), the sintering results are presented in Fig. 6 at mix moisture of around 7%. Comparable sintering results have been obtained for Blend 5 with 40% Yandi ore at a mix moisture of about 7.2%, indicating only a 0.2% increase in mix moisture. Further increasing mix moisture level to about 7.6% led to a slight rise in productivity and a drop in sinter strength, so optimum mix moisture is dependent on specific plant requirements of optimum sintering performance and sinter quality.
6. Conclusions
The results have demonstrated that the goethite ore—Yandi ore—can be successfully blended into a PRC ore blend at up to 40% for sintering, and that good sintering performance has been obtained at very low coke rates of about 50 kg/t. The possible reasons for such low rates being established could be due to the easy-melting nature of Yandi ore, possible oxidation of the magnetite concentrates occurred in sintering, higher reactivity of the magnetite concentrate compared to those used by other mills, etc.

The sinter strength is 66% (ISO index, %, 6.3 mm), and productivity is about 1.46 t/m² h for the Base blend containing 30% hematite ore (Ore D). Compared to the Base blend, sinter productivity is increased slightly with the addition of Yandi ore to the blend by slightly raising the mix moisture level, e.g., the productivity is about 1.47–1.51 t/m² h for Blends 2–5 containing 10–40% Yandi ore at mix moistures of 7.2–7.3%. Sinter strength improves slightly or remain the same. The productivity increase is probably caused by the shortened sintering time, which would be a result of the easy-reacting property of Yandi ore and improved granulation efficiency with increasing Yandi ore.

The sinter reducibility is also improved with the addition of Yandi ore. Sinter RDI indices are generally low (below 20%) at all levels of Yandi ore.

No significant changes in sinter mineral composition are observed when Ore D is replaced with Yandi ore. The SFCA content in the sinters is about 36–40 vol%, and the predominant structure is the magnetite and SFCA coexistent structure.

The main magnetite concentrate in Plant A—Ore A—is relatively high in alumina and contains carbonates, quartz and mica as main gangue minerals. The ore is more porous and more reactive than a magnetite concentrate containing low alumina. Assimilation of the hematite ore—Ore D—and the goethite ore—Yandi ore—in mixing with the magnetite concentrates shows the same trend as that found in blending with hematite ores.

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