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THE EFFECT OF HIGH GRADE PELLET FEED ON SINTERING PERFORMANCE

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Abstract

With the progressive deterioration of sinter feed quality worldwide in recent years, steelmakers need to seek alternatives to mitigate the deficiency of this raw material. Alternatives to make up for this deficit are the use of concentrate, pellet feed and application of pre-agglomeration technologies, such as intensive mixers, pelletizing discs and nodulizers. The possibility of using in the sintering mixture a high grade Brazilian pellet feed, designated as HGPF, which presents advantages compared with the natural sinter feed currently available in the market, such as low alumina and silica contents, suitable surface morphology and mineralogical properties, was investigated. Sintering tests were conducted at SGA (Studiengesellschaft für Eisenerzaufbereitung) laboratory in Germany to evaluate the performance of this product when added to typical sintering mixtures used in Western Europe. The results showed gains in the chemical, physical and metallurgical quality of the sinter produced.

Keywords: Sintering; Sinter feed; Pellet feed; Iron ore.

1 INTRODUCTION

1.1 The Use of Intensive Mixers in the Sintering Process

Niwa et al. [1] compared the HPS (Hybrid Pelletized Sinter) with the conventional sintering process at NKK. Productivity increased by 0.05t/m^2.h. Fine ore content under 125 μm in raw materials increased to about 40%. Coke consumption was reduced by 5kg/t, because of the improvement of coke combustion which was attributed to preferential coke addition on green pellets. Increase in coke combustion efficiency was proved by the decreasing CO content in the exhaust gas. The SiO_2 content decreased from 5.15% to 4.61%, tumble index increased from 67.4% to 68% and RDI decreased from 44.5% to 43.5%.

Hseieh [2] performed sintering tests comparing conventional mixing and granulation with a high speed agitating mixer connected to a drum. Such tests improved the granulation of raw material by decreasing the content of <2mm in pseudo-particles. With the raw materials used in China Steel sinter plant, it improved the sintering coke rate and productivity.

Ludivine et al. [3] presented the results of the industrial operation during the commissioning phase of the vertical intensive mixer. The main benefits brought by the intensive mixer were the increase of productivity, more flexibility by increasing fine iron ores in the sinter feed and the granulation capacity enhancement in terms of grain growth and resistance. The tests were conducted with challenging bedding composed of 40% fine ore.

1.2 The Effect of Alumina on the Sintering Process

Lu et al. [4] and Cores et al. [5] demonstrated that the presence of alumina increases the viscosity of the primary melt formed during the sintering process, leading to a weaker sinter structure with more irregular interconnected pores. Therefore, the RDI is reported to deteriorate markedly as the alumina content increases. Industrial tests at Thyssen in 1984 showed that a 1% rise in the sinter alumina content increased RDI by 2 points.

1.3 The Effect of SiO_2 on the Sintering Mixture

High grade iron ore could increase users' flexibility to blend different iron ores grades in order to reduce the production costs and maintain the same %SiO_2 content in the final sinter produced. Other option could be decrease the %SiO_2 content in order to reduce the CaO addition in the sintering process and the slag rate in the blast furnace.

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1.4 The Effect of Surface Morphology and Mineralogical Properties on the Sintering Process

Effective granulation directly affects the permeability of the sintering bed. With improved permeability, there is an increase in gas flow and, consequently, in sintering speed, promoting better gas-solid heat transfer and leading to increased productivity and lower energy consumption.

Mao et al. [6] reported that the mineralogical and textural characteristics of the superfine particles are important factors in the granulation behavior of an ore or a blend of ores. The surface properties of iron ore powders include mainly two aspects: surface morphology and wettability. Surface morphology of iron ore refers to roughness and the shape of the particle.

A comparison between the performances of specular iron ore and HGPF was conducted. Qualitative analysis showed that there is a good correlation between ore texture and granulation. Effective granulation could be reached with a small grain and rougher surface. Figure 1 shows that the surface of HGPF is extremely rough when compared with specular iron ore.

2 METHODOLOGY

2.1 Experimental Procedures

For this study, a typical European sintering mixture was tested with different proportions of the HGPF and other ores. This mixture was composed of a high proportion of Brazilian sinter fines, as well as concentrates and blast furnace screened return fines. The sizing distribution, chemical analyses and ore proportion are listed in Tables 1, 2 and 3.

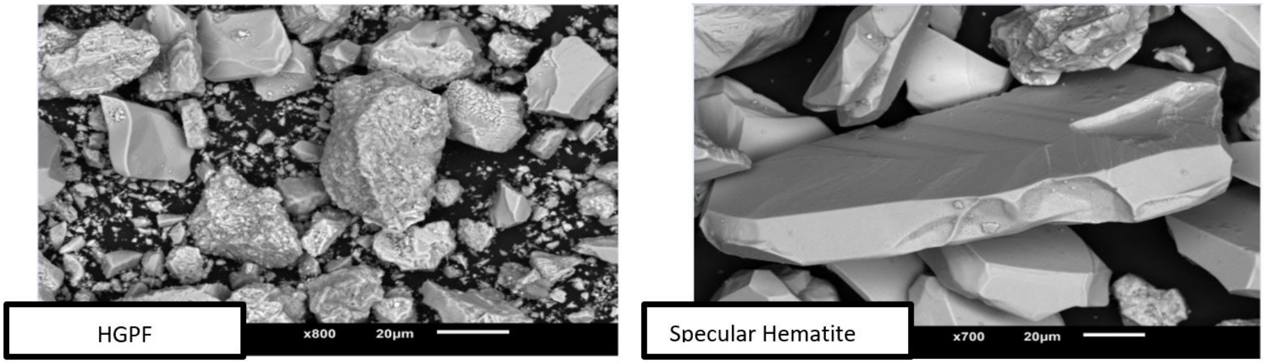

Figure 1. Scanning Electron Microcopy analysis of HGPF and specular hematite iron ore.

Table 1. Sizing distribution of the ores used in the sintering mixture (%)

Sizing distribution	Brazilian Sinter Feed 1	Brazilian Sinter Feed 2	BF Return Fines	Canadian Concentrate	African Concentrate	HGPF
+10 mm	0.6 / 0.6	1.6 / 1.6	0.0 / 0.0	0.0 / 0.0	0.1 / 0.1	0.0 / 0.0
+8 mm	7.6 / 8.2	5.0 / 6.6	0.3 / 0.3	0.0 / 0.0	0.0 / 0.1	0.0 / 0.0
+6.3 mm	3.4 / 11.6	5.9 / 12.5	10.2 / 10.5	0.0 / 0.0	0.1 / 0.2	0.0 / 0.0
+5.0 mm	5.1 / 16.7	6.4 / 19.0	27.4 / 37.8	0.0 / 0.0	0.1 / 0.3	0.0 / 0.0
+4.0 mm	1.1 / 17.8	2.1 / 21.1	13.5 / 51.3	0.0 / 0.0	0.0 / 0.3	0.0 / 0.0
+3.15 mm	7.4 / 25.2	7.0 / 28.1	12.7 / 64.0	0.0 / 0.0	0.1 / 0.4	0.0 / 0.0
+2.5 mm	9.5 / 34.7	8.0 / 36.1	14.6 / 78.6	0.1 / 0.1	1.1 / 1.5	0.0 / 0.0
+1.0 mm	12.3 / 47.0	8.2 / 44.3	9.7 / 88.3	2.1 / 2.2	7.3 / 8.8	0.1 / 0.1
+0.5 mm	7.6 / 54.6	5.2 / 49.5	4.8 / 93.1	5.4 / 7.6	13.6 / 22.4	0.1 / 0.2
+0.315 mm	7.2 / 61.7	3.1 / 52.6	2.2 / 95.3	13.9 / 21.5	14.0 / 36.4	0.1 / 0.2
+0.200 mm	5.9 / 67.6	5.1 / 57.7	1.5 / 96.8	21.9 /43.4	14.8 / 51.2	0.2 / 0.4
+0.160 mm	2.9 / 70.5	3.6 / 61.3	0.0 / 96.8	0.0 / 43.4	0.0 / 51.2	0.1 / 0.5
+0.100 mm	4.6 / 75.1	7.5 / 68.8	1.4 / 98.2	37.1 / 80.5	19.2 / 70.4	0.7 / 1.2
+0.063 mm	3.0 / 78.1	0.6 / 69.4	0.4 / 98.6	14.3 / 94.8	9.4 / 79.8	4.0 / 5.2
+0.040 mm	1.7 / 79.8	16.7 / 86.1	0.3 / 98.9	3.4 / 98.2	6.1 / 85.9	11.0 / 16.2
+0.025 mm	2.5 / 82.3	4.6 / 90.7	0.2 / 99.1	0.6 / 98.8	4.3 / 90.2	19.9 / 36.1
+0 mm	17.7/100.0	9.3 /100.0	0.9 / 100.0	1.2 / 100.0	9.8 / 100.0	63.9 / 100.0
D-80 mm	3.748	4.509	5.848	0.334	0.589	0.037
HS-50 mm	0.800	0.470	4.098	0.149	0.209	0.020

Table 2. Chemical composition of the ores used in the sintering mixture

Chemical Analysis	Brazilian Sinter Feed 1	Brazilian Sinter Feed 2	BF Return Fines	Canadian Concentrate	African Concentrate	HGPF
Fe (%)	65.32	63.79	56.01	65.64	65.36	65.83
FeO (%)	0.20	0.76	7.86	11.26	26.88	0.92
SiO_2 (%)	2.42	5.47	5.33	4.39	7.26	1.65
Al_2O_3 (%)	1.14	0.78	1.44	0.18	0.55	0.38
LOI (%)	1.82	1.69	0.53	1.64	0.38	3.43

Table 3. Iron ore proportion of the sintering mixture (%)

Sinter Series	Brazilian Sinter Feed 1	Brazilian Sinter Feed 2	BF Return Fines	Canadian Concentrate	African Concentrate	HGPF	HGPF*
1	40	35	10	8	7	-	-
2	36	31.5	9	7.2	6.3	10	-
3	32	28	8	6.4	5.6	20	-
4	32	28	8	6.4	5.6	-	20
5	28	24.5	7	5.6	4.9	-	30
6	24	21	6	4.8	4.2	-	40

*Agglomerated HGPF.

2.2 Sintering Conditions and Target Analysis of the Sinters

The sintering tests were performed in the SGA pot grate unit. The following conditions were applied to all sinter tests:

- pot grate Ø 450mm. height 600mm;
- bed height: 520mm. including 20mm hearth layer;
- ignition time: 90 seconds;
- ignition temperature: 1,220°C;
- ignition suction: increasing from 40 to 160mbar;
- sintering suction: 160mbar;
- sinter treatment for return fines generation: tumbling (70 revolutions);
- return fines screening: 6.3mm.

For each series, initial tests were performed to adjust a balanced return fines ratio of 0.95-1.05.

At a balanced return fines ratio and correct FeO-content, the sinter feed moisture and coke breeze consumption were adjusted to achieve optimum productivity.

For the conventional sintering tests the ore blends were prepared as follows:

- mixing of all ores and additives in a cycles mixer for 4 minutes at natural moisture;
- addition of water;
- mixing for another 2 minutes;
- rerolling in a drum for 3 minutes.

For the tests with pre-agglomeration of the pellet feed a special treatment of the pellet feed was performed in an Eirich mixer R05T prior to the mixing with the other ores:

- mixing of pellet feed and binder (10% of hydrated lime) for 60 seconds in counter flow mode of bowl and mixing tool at 600 rpm;
- rolling for 200 seconds at counter flow mode of bowl and mixing tool at 200 rpm;
- micropellets are formed rolling for 60 seconds without mixing tool for further pelletizing (stabilization of micropellets).

After this pre-agglomeration step, the micropellets were treated in the mixing and rolling aggregates as an ore type as described before for the conventional sintering mix preparation.

The chemical target analysis for the final sinter was set as follows (Equation 1):

$$Fe:\ \sim 56.3\%\ FeO:\ 7.5 \pm 0.5\%\ SiO_2:\ 5.9 \pm 0.2\ MgO:\ 1.0 \pm 0.2\%\ CaO\ /\ SiO_2:\ 1.95 \pm 0.1 \tag{1}$$

The sinters produced were tested for the metallurgical and physical properties, including tumble index (TI), low temperature degradation index (RDI), and reducibility index (RI).

3 RESULTS

3.1 Evaluation of Sintering Mixtures

The effect of adding the HGPF to the ore mixture is quite impressive. This addition has a very positive effect on the chemistry, because it increases the Fe content and distinctly decreases the SiO_2 and Al_2O_3 grades. The use of HGPF improves the chemistry of the sinter and can be used to compensate for the disadvantageous chemistry of other fines grades. Table 3 lists the calculated analysis of the European mixture with the addition of the HGPF and proportional dilution of the other ores. For this calculation, only the analyses of the ores were considered; additives were not taken into account.

3.2 Comparison Among Sinter Series

3.2.1 Conventional sintering process

A total of four pot tests were performed for each series. The average sintering productivity distinctly decreased from 34.5 to 32.1t/m^{2}x24h as well as the flame-front speed from 20.3 to 19.3mm/min. when one adds 20% of HGPF in the conventional sintering process. The coke breeze rate increased from 64.4 to 64.8kg/tfinal sinter. These results are graphically displayed in Figures 2 and 3.

3.2.2 With pre-agglomeration

A total of four pot tests were performed for each series. The average sintering productivity distinctly increases from 34.5 to 39.2t/m^{2}x24h as well as the flame-front speed from 20.3 to 24.4mm/min, when one adds up to 30% of HGPF. The coke breeze rate improved from 65.4 to 63.8kg/tfinal sinter. These results are graphically displayed in Figures 4 and 5. These figures clearly demonstrate the very positive effect of the HGPF, both for sintering productivity as well as for coke breeze consumption for the tests with pre agglomeration of the pellet feed.

3.3 Characterization of the Produced Sinters

From each series, the sinter that achieved the optimum productivity was chosen for the chemical, physical and metallurgical tests.

The sinters were controlled at the same levels of basicity, SiO_2, MgO and FeO, but the Al_2O_3 content varied with the mixture of the iron ores, as shown in Table 4. The chemical composition of the sinters produced is presented in Table 5.

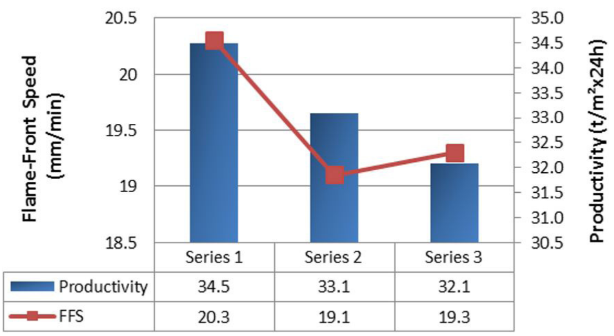

Figure 2. Sinter series productivity and flame-front speed.

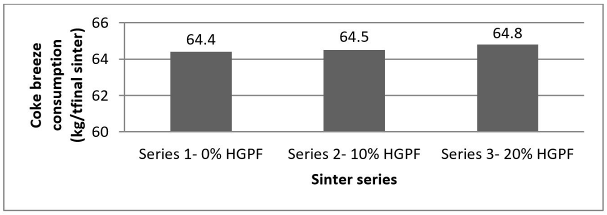

Figure 3. Sinter series coke breeze consumption.

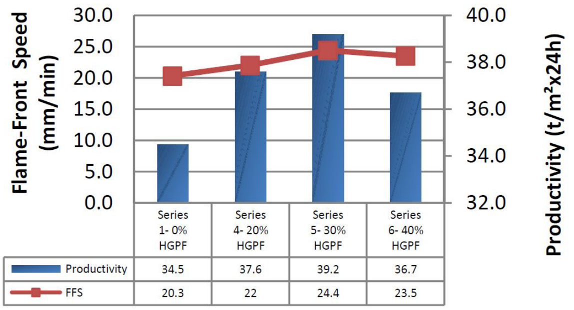

Figure 4. Sinter series productivity and flame-front speed.

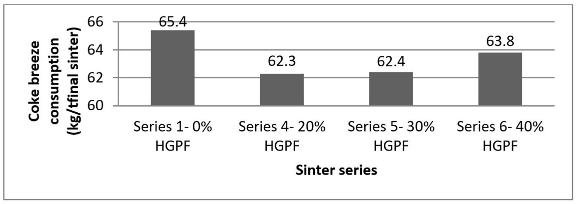

Figure 5. Sinter series coke breeze consumption.

Table 4. Chemical composition of the sintering mixture series

Chemical Analysis	Reference Series	10% HGPF	20% HGPF	30% HGPF	40% HGPF
Fe (%)	63.88	64.08	64.27	64.47	64.66
FeO (%)	3.91	3.61	3.32	3.02	2.72
SiO_2 (%)	4.27	4.01	3.75	3.49	3.22
Al_2O_3 (%)	0.93	0.87	0.82	0.76	0.71
LOI	1.53	1.72	1.91	2.10	2.29

Table 5. Chemical composition of the sinters produced

Chemical Analysis	Series 1	Series 2	Series 3	Series 4	Series 5	Series 6
Fe (%)	56.23	56.30	56.35	56.35	56.42	56.46
FeO (%)	7.30	7.25	7.12	7.34	7.20	7.56
SiO_2 (%)	5.89	5.86	5.87	5.90	5.82	5.90
Al_2O_3 (%)	1.14	1.04	1.00	0.99	0.93	0.89
Basicity	1.97	1.97	1.98	1.96	1.99	1.96

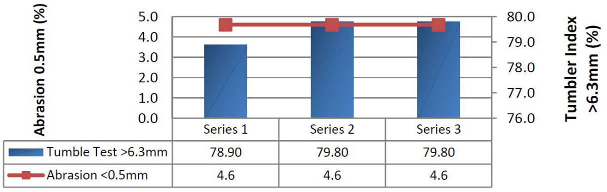

Figure 6. Sinter series tumble strength.

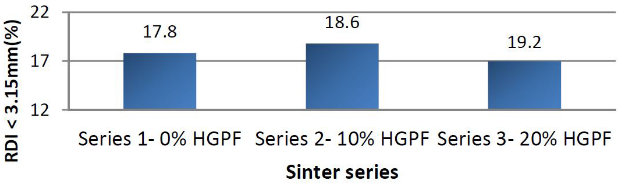

Figure 8. Sinter series RDI <3.15mm.

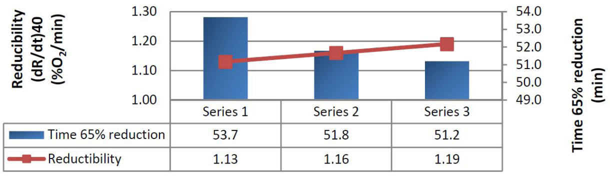

Figure 7. Sinter series reducibility.

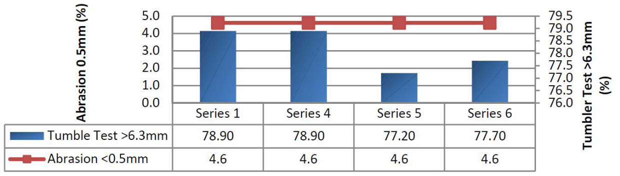

Figure 9. Sinter series tumble strength.

3.3.1 Conventional sintering process

Tumble index, according to ISO 3271 [7], slightly increased by ~ 1.0%, while abrasion was not affected when the HGPF was added to the mixture. This is displayed graphically in Figure 6.

The addition of HGPF increased the reducibility of the sinters from 1.13 to 1.19%O_2/min and reduced the time to achieve 65% of reduction from 53.7 to 51.2min according to ISO 4695 [8], as it can be shown in Figure 7.

All sinters produced reached good RDI results, according to ISO 4696-1[9]. As shown in Figure 8, when up to 20% of HGPF was added the RDI was not affected.

3.3.2 With pre-agglomeration

Tumble strength, according to ISO 3271 [7] slightly decreased by ~ 1.5-2% while abrasion was not affected when the HGPF was added to the mixture. This is displayed graphically in Figure 9.

The addition of HGPF increased the reducibility of the sinters from 1.13 to 1.32%O_2/min and reduced the time to achieve 65% of reduction from 53.7 to 46.0min according to ISO 4695 [8], as it can be shown in Figure 10.

All sinters produced reached good RDI <3.15mm results, according to ISO 4696-1 [9]. As shown in Figure 11, when up to 40% of HGPF was added, these results were slightly improved. Most probably due to the decreased sinter Al_2O_3 content.

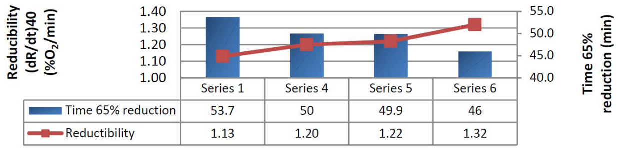

Figure 10. Sinter series reducibility.

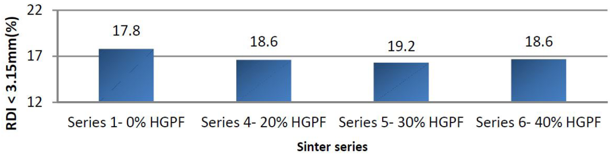

Figure 11. Sinter series RDI <3.15mm.

4 CONCLUSIONS

The tests showed a decrease of sintering productivity from 5.1% to 6.5% when the HGPF was added up to 20% in the conventional process.

However, pre-agglomeration of HGPF, prior to the mixing into the sinter feed, resulted in an increase of sintering productivity from 5.6% to 13.8% and lower coke breeze consumption when HGPF was added up to 40% in the sintering mixture. The chemical analysis of the HGPF is very clean, with high Fe and low gangue contents, which enables mixture users to both improve sinter chemistry and reduce limestone consumption or to compensate for the disadvantage of other fines grades. Slight improvement was observed in the disintegration behavior when the HGPF was added to the mixture, most probably due to its lower alumina content.

Moreover, a remarkable improvement of sinter reducibility was perceived when adding the HGPF to the European blend.

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