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STUDY OF MICROSTRUCTURAL EVOLUTION DURING IRON ORE SINTERING USING NIGERIAN RAW MATERIALS

BY

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ABSTRACT

The suitability of Nigerian iron ore and limestone deposits for production of sinter as a blast furnace feed has been studied. The iron ore used are obtained from Itakpe and Chokochoko while Jakura limestone, Mfamosing limestone and Osara dolomite were employed as the fluxes. The microstructural evolutions of the sinters produced were studied on the basis of the difference in basicity, type of iron ore, effect of limestone/ dolomite and temperature. The results tend to suggest that desirable structures might be obtained in the sinters produced from Nigerian ores when limestone are mixed with them especially the Chokochoko ore which had earlier been reported not to give good structures. This suitability is assessed on the basis of the evolution of microstructure sintering which are known to confer on sinters optimum properties.

Keywords:* *Iron Ore, Sintering, Limestone, Microstructure, Blast furnace.

1.0 INTRODUCTION

For efficient production of iron from the blast furnace, charge materials must be assessed and characterized, either in raw or processed form, to ensure that they have adequate properties. Coke consumption, which is one of the indices for measuring furnace efficiency, apart from depending on the characteristics of the coke itself, depends to a large extent on the characteristics of the burden materials (Biswas, 1991).

To enable smooth and efficient furnace operation of a blast furnace, the burden materials should have as many of the following properties as possible:

a) the correct size range
b) good handling properties
c) adequate bulk reducibility
d) good stability in the furnace upper stack
e) good melting and softening properties in the lower stack
f) bush regions and constant chemical analysis.

The above properties also depend on the following:

i) The properties of the raw materials (chemical analysis, mineralogical composition, e.t.c.) used for burden preparation.
ii) The minerals formed in the burden material during burden preparation. This is further affected by conditions under which the burden is prepared.
iii) The handling of the burden materials after preparation.

Another factor that affects the operation of a blast furnace is the choice of burden materials. The two burden materials that are fed into a modern blast furnace are sinter burden and pellets. The choice as to which burden material to feed into the furnace depends on a number of factors (some furnace operate on 100% sinter burden while some operate on 100% pellet burden, and some operate on the mixture of both). The most important of which is the characteristics of the iron ore which in turn dictates the economics of the sintering or pelletizing process. In a situation where the ore yields very fine particles during crushing or after concentration, pelletizing has been found to be more economical than sintering. Sintering is favoured when the ore is coarse and predominantly hematite (Price, 1996).

Gangue contents, mineralogical complexity, rate of the fusion process, the differences in particle size, and incomplete mixing of the components also have great effect on the sintering process, thus it is unlikely that equilibrium will be attained during fusion. Single ores are unlikely to give better result and blends of as many as three to four ores will be normal, in practice (Linchesky, 1993).

Rich ore sinters are much more homogeneous than lean ore sinters and this suggests that the mineralogical constitution of rich ore sinters is controlled to a major extent by the chemical analysis of the raw mix and the fuel addition used. The quality of sinter is related to its mineralogy which depends on the chemistry of the mix. The quality of sinter also is defined by the chemical composition of the raw mix and the fuel content (William, 1990).

Fluxing agent, e.g. limestone or dolomite of varying basicity may be used for the adjustment of sinter chemistry. A more highly fluxed sinter is desirable since strength and size characteristics improve with increasing basicity. Thus, sinter basicity provides the dominant effect on strength (Bagnall, 1996).

However, sinter is one of the feed materials that are commonly used in the blast furnace. Thus, this research is aimed at assessing the suitability of local iron ores and fluxes for sinter production through their microstructural analysis.

2.0 EXPERIMENTALTECHNIQUES

The already beneficiated iron ore samples, (Itakpe and Chokochoko) are further ground in a micronizer to reduce their sizes into smaller fines. These fine grains are then sieved to separate the very fine powder of -100μm suitable for sintering process. The chemical analysis of the ore concentrates is shown in table 1. The ores consist of hematite, magnetite and silica as shown in table 2.

Table 1:

Chemical analysis of the concentrates of Itakpe and Chokochoko ores (%)

Minerals	Itakpe	Chokochoko
Fe	64.80	64.20
CaO	0.06	0.02
SiO_2	4.65	3.15
MnO	0.07	0.08
Al_2O_3	0.00	0.45

Table 2:

Mineralogical analysis of Itakpe and Chokochoko ores (%)

Minerals	Itakpe	Chokochoko
Fe_2O_3	50.70	39.20
Fe_3O_4	42.50	51.20
SiO_2	4.40	6.60

Similarly, limestone and dolomite are ground and sieved into powdered form of -75μm. These allow for adequate mixing and increase in the surface contact of the mix which eventually led to effective sintering operation and good products.

The iron ore and limestone are mixed together properly in a calculated proportion according to the given basicities. Adequate mixing will enhance good results. Table 3 shows the experimental mixes of ore/limestone ratio.

Table 3:

Experimental mixes (ore/limestone ratio)

Basicity	Itakpe	Chokochoko
1.5	85/15	98/10
2.0	80/20	88/14
3.0	75/25	81/19

Small quantity of each mixture is transferred into an alumina-boat ready for sintering process.

Each of the alumina boat containing a mixture of iron ore and limestone of calculated basicity (Appendix I) is put into the muffle furnace which has been raised to a predetermined temperature (between 1250^{0}c and 1300^{0}c) for 6 minutes. During this period the mixture fuses together and solidifies. The sample is withdrawn and cooled in air before being removed from the boat for microstructural examination.

A total of 54 samples were prepared and sintered at different basicities (1.5, 2.0, & 2.5) and temperatures (1250^{0}C & 1300^{0}C).

These are represented in 8 broad groups as shown in the following results.

3.0 RESULTS

Effect of Basicity

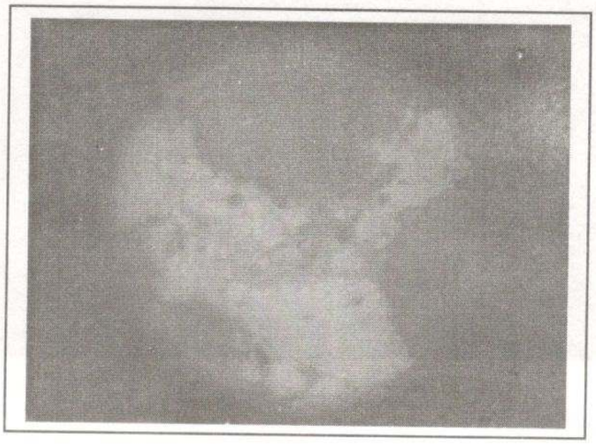


Fig: 1a: **Itakpe + Jakura, Basicity 1.5 at 1250^{0}C x 250**

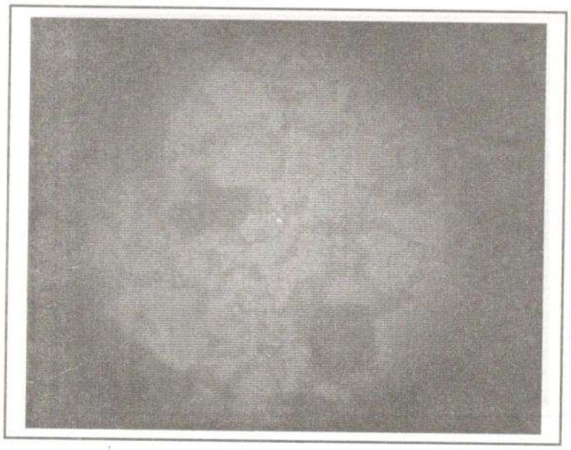


Fig: 1b: **Itakpe + Jakura Basicity 2.0 at 1250^{0}C x 150**

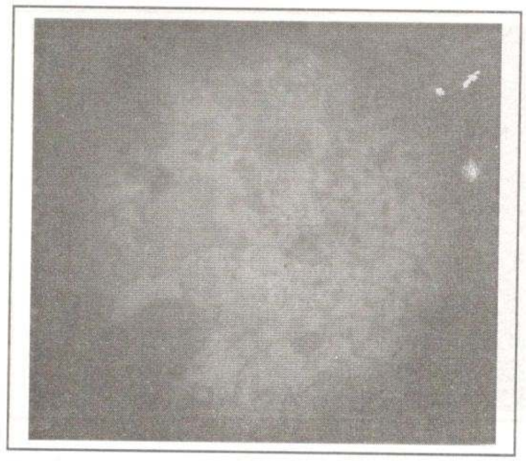


Fig: 1c: **Itakpe + Jakura Basicity 2.5 at 1250^{0}C x 150**

Effect of Temperature

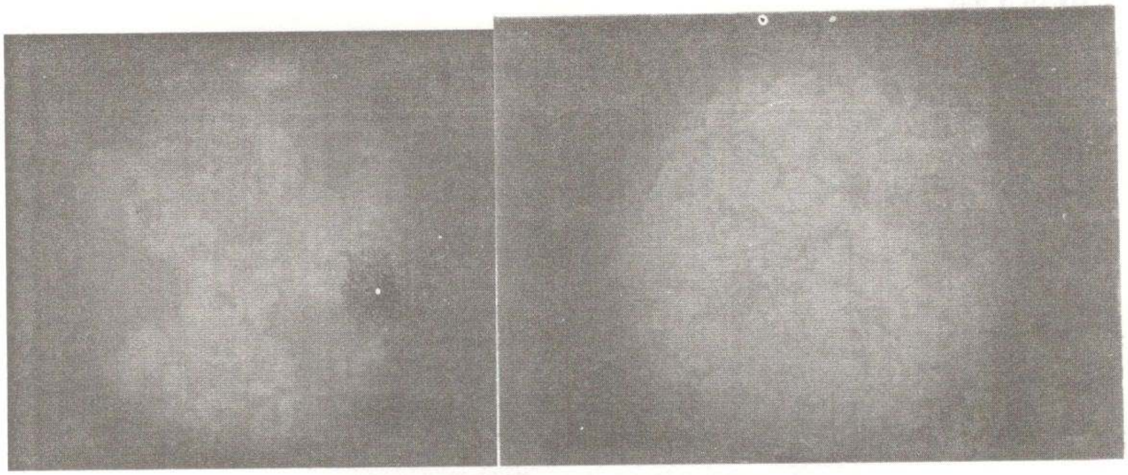


Fig. 2: Itakpe + Jakura
Basicity 2.5 at 1300^0C x 125

Effect of Ore

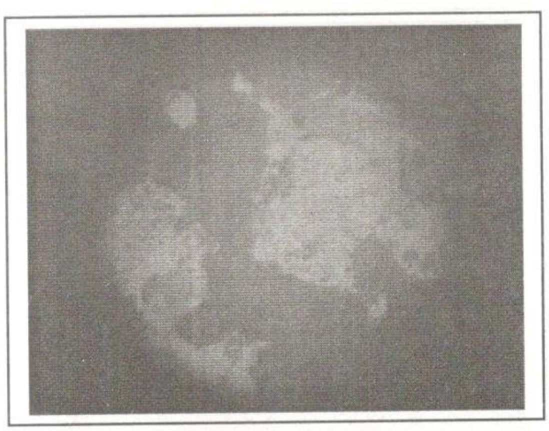


**Fig. 3a: Chokochoko + Mfamosing
Basicity 2.0 at 1250^0C x 200**

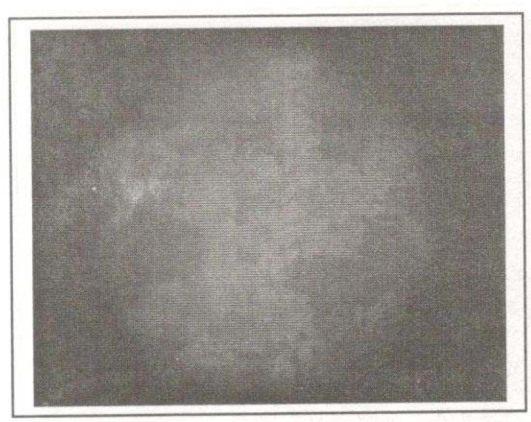
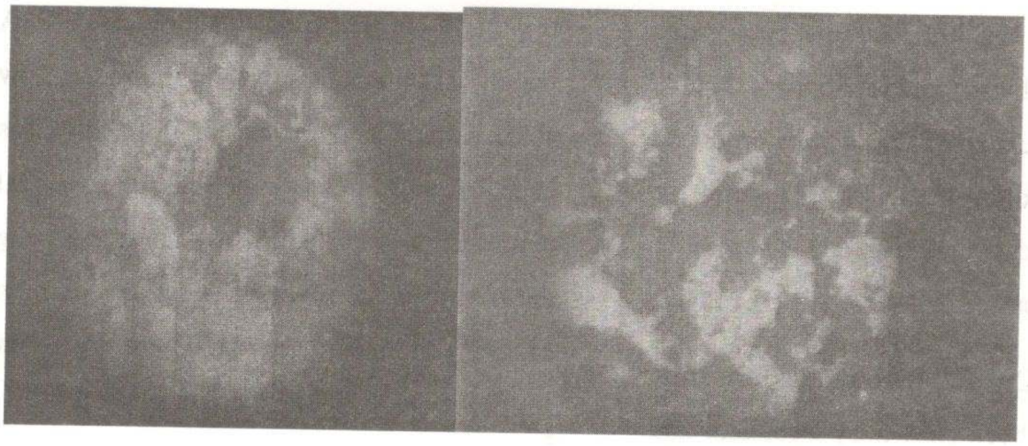


**Fig. 3b: Itakpe + Mfamosing
Basicity 2.0 at 1250^0C x 150**



4.0 DISCUSSION OF RESULTS

In general, all the micrographs show the evidence of the presence of glass and hematite + magnetite phases. The clear grey region is representing the glass + silicate phase, the hematite + magnetite phase is shown in white on the micrograph while the SFCA (Silico-Ferrite of Calcium and Aluminium) region is dark grey (diffused).

Moreover, sintering time was probably too long for SFCA to be observed properly. The size of the composition of iron and limestone must be very fine to get SFCA in a good proportion.

Itakpe ore and Chokochoko ore have been shown to contain hematite + magnetite, hence they are expected to reveal the same phase on the micrographs under similar condition of sintering.

But Chokochoko ore sinter consist more SFCA phase. This is however not consistent with the result of Egundebi (1995) in which Itakpe ore was found to be more suitable for production of good sinter in terms of formation of SFCA.

With increase in basicity, more SFCA is expected to be formed. But there is likelihood of the presence of more SFCA at basicity 2.5 and less in 1.5.

Jakura and Mfamosing limestone have Ca0 which have been reported to favour the formation of SFCA (Oluwadare, 2007).

Osara dolomite contains a mixture of Ca0 and Mg0, and the MgO component is also expected to inhibit the formation of SFCA. It is therefore expected that sinters produced from Osara Dolomite should be inferior to those produced from limestone in terms of good phases formed.

The effect of Ca0 and Mg0 on the formation of SFCA had been shown by Egundebi and Whiteman (1992) to be due to their effect in melt viscosity. Ca0 increases melt viscosity while Mg0 lowers it. SFCA tends to precipitate out of a viscous melt.

The two temperatures employed for the sintering process are 1250ºC and 1300ºC. However, this study has shown that more SFCA phase were formed at 1250ºC than at 1300ºC.

The effect of temperature is also linked with viscosity. The higher the temperature, the lower the viscosity.

5.0 CONCLUSION AND RECOMMENDATIONS

An essential factor in low silica sintering technology is the use of lower sintering temperature and lower sintering time. This has a significant effect on sintering reactions and on sintering mineralogy. The most important product of reaction is SFCA which is the main bonding phase in low silica sinters. The morphology of SFCA has been shown to be dependent on its chemical composition and high $Si0_2$ content favoring the optimum form which is fine production of SFCA both from the view point of ease of formation and also the amount formed.

The assessment of suitability of Nigerian raw materials available for sintering has been studied. It was found that some of them will be good for sintering if certain precautions are taken. Optimal sinter quality can be achieved at high basicity of 2.5, temperature of 1250^0c and with absence of Mg0 in the composition. This result is obtained with Chokochoko ore +Jakura/Mfamosing limestone.

Since sinter of high basicity may lead to blast furnace slag of high basicity, acidic components can be added to the furnace to control the slag basicity to the level required. The ore and limestone/dolomite must be very fine to allow for adequate mixing for proper reaction to occur. Sintering time may also be reduced from 6 minutes to about 4 minutes to give better result.

APPENDIX I

Typical Charge Calculations

Itape Ore + Jakura Limestone @ Basicity 1.5

Description	Itakpe Ore	Jakura Limestone
CaO	0.06	53.00
SiO_2	4.65	1.81

Basicity = CaO/ SiO_2

Let weight of ore = X, weight ratio of ore = X_0,

and weight of limestone = Y, weight ratio of limestone = Y_0

Basicity = (0.06X + 53Y)/(4.65X + 1.81Y)

Thus, for basicity = 1.5 = 3/2

$0.06X + 53Y = 3$

$4.65X + 1.81Y = 2$

$0.279X + 246.45Y = 13.95$

$-0.279X – 0.1086Y = -0.12$

$246.3414Y = 13.83$

$Y = 0.056142$

$X = \{2 – 1.81(0.056142)\}/4.65$

$= 0.408255$

Therefore, weight ratio of ore = 10X/(X + Y)

$X_0 = 10 (0.408255)/(0.408255 + 0.056142)$

$X_0 = 10 (0.408255)/(0.464397)$

$X_0 = 8.7911g$

$Y_0 = 10 – 8.7911$

$Y_0 = 1.2089g$

REFERENCES

1. Bagnall, E.M.J., 2006. "Influence of Feed Material Properties on Sinter for Blast Furnaces Agglomeration''. Vol. 2, pp 587 – 603.

2. Biswas, A.K., 2001. "Principles of Blast Furnace Iron Making", Cootha Publishing House, Brisbane, Australia.

3. Egundebi, G.O.,1995 ."Ph. D. Met. Thesis" University of Sheffied, U.K

4. Egundebi, G. O. & Whiteman E., 1992. ''M. Met. Dessertation'' ,University of Sheffield, U.K.

5. Linchesky, B., Sobolevsty, A. & Kalmenev. A., 2003. ''Iron and Steel Making'', Moscow, USSR.

6. Oluwadare, G.O., 2007. "Trends in Applied Sciences Research 2(6): pp 508-514, Academic Journal Inc.

7. Price, C. & Wasse D., 2006. "Development in Iron Making Practice". London, Iron & Steel Institute, U.K.

8. William, A. & Arthur, S., 2000. "Metal in the Service of Man", Seventh Edition, Hamilton, Canada.