EFFECTS OF ALUMINA AND BAUXITE ON THE PHYSICAL PROPERTIES OF SUPERFLUXED NIGERIA IRON ORE SINTERS

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ABSTRACT

An attempt has been made to examine the effects of alumina and bauxite on the strength characteristics of superfluxed sinters. The results of the experiments indicate that alumina and bauxite superfluxed sinters are stronger than normal iron ore sinter. The strength minimum reportedly experienced at basicity 1.0-1.8 for normal sinter was absent for superfluxed bauxite and alumina sinters. A mixture of alkaline and bauxite gave even stronger sinter.

INTRODUCTION

Modern metallurgy demands the rapid and constant improvement of methods of preparation of raw materials for smelting. Sinter is still the most important and commonly used raw material for the blast furnace smelting. The reason for this is not far fetched. This includes the simplicity in solving its equipment problems, its high productivity and the minimal cost of its equipment.

Today's large blast furnace demand sinter of high quality, which is related mainly to its mechanical strength. Super fluxed sinter is a useful material in this regard, since it possesses good fusibility and is highly oxidized. Usage of super fluxed sinters in blast furnaces eliminates, either partially or totally, the introduction of raw flux into the furnace. Moreover, the production and usage of super fluxed sinters instead of ordinary sinter incurs practically no extra capital expenditure.

The introduction of additional oxides into the components of super fluxed sinter may, under certain conditions, act as stabilizators of the sinter coke. This, on its own, should make it easier to produce such sinters if the temperatures of sintering do not exceed what is technologically possible during sintering. Of special interest in this regards are super fluxed sinters produced either from bauxite, alumina or red mud. This work examines the effects of bauxite and alumina on the physical properties of sinters.

THEORY

The general theory of super fluxed sinters has been discussed elsewhere by this author. From the phase diagram of the system $CaO.SiO_2.Al_2O_3$ it is observed that the least low-temperature liquid phase areas lie at the double and tertiary eutectic, which are situated within the ranges 7-10% SiO_2, 30-40% Al_2O_3, 35-55% CaO.

Raising the basicity of rich alumina sinters should, therefore, lower the temperature level of sintering. However, this temperature level in non-iron system is quite high-more than 1350°C. Iron containing system of the same basicity as that of non-iron containing, melts at 1100-1250°C.

Having Fe_2O_3 as impurity in super fluxed areas (approximately ($2CaOFe_2O_3$) does not reduce, but on the opposite, increases the liquids temperature. In another system, where calcium oxide is contained in four calcium aluminoferrite, tertiary eutectic is found with a melting temperature of 1280°C.

Predicting the effect of other oxides it could be said that magnesium oxide is capable of raising sintering temperature while iron oxide lowers this temperature by 150-200°C. Such systems are characterized by the presence of wide areas of solid solutions of calcium ferrites with alumina.

Complex compounds are successfully formed during solid phase reactions. It is of interest to note that at 1200 – 1300°C the formation of calcium aluminosilicates is more intensive than calcium silicates and calcium aluminates[2].

With increase in the heating temperature the basic crystalline phases are formed in the following sequence: $CaO.Al_2O_3$, $2CaO.SiO_2$, and $2CaO.Fe_2O_3$, $4CaO.Al_2O_3.FeO_3$, $3CaO.Al_2O_3$, $3CaO.SiO_2$.[3]

The strength and reducibility of alumina superfluxed sinters are determined by the calcium ferrites and calcium aluminoferrites present in them. By possessing the lowest melting temperature, they could be the best representatives of the bonding minerals in the sinter. Hence Mazanek and Jasenska.[4], while studying the effect of silica on the strength and reducibility of sinter of basicity 1.3, concluded that it is calcium ferrites and calcium alumino ferrites that improve its physico-chemical properties.

The beginning of the reaction of a mixture of, for example, sinter of composition $4CaO.Al_2O_3.Fe_2O_3$, is 500-600°C. The first products of reaction are $CaOAl_2O_3$ and $CaO.Fe_2O_3$. Above 1000°C 2 CaO. Fe_2O_3 and 5CaO. Al_2O_3 are formed. At 1200°C and above 4CaO Al_2O_3. Fe_2O_3 is formed. The last compound is the result of the reaction of 5CaO. Al_2O_3, 2CaO. Fe_2O_3 with CaO.

The intensity of bonding of CaO during the production of different calcium aluminoferrites were studied by Nikolaev, Butt and Timashev.[5] They concluded that the formation of calcium aluminoferrites proceeds faster than calcium aluminates.

The phase analysis carried out by Ivanor revealed that during addition of alumina to calcium ferrite the refractive index and its micro strength did not change up to 3% Al_2O_3[7]. In difference from calcium (i) ferrite, the strength of calcium (ii) ferrite sharply increase on addition of little amounts of Al_2O_3. Hence, the micro strength of pure calcium (iii) ferrite is about 3.5kN/mm². On addition of 0.5% Al_2O_3 the value became 4.5KN/mm².

This work, therefore, investigates the effects of bauxite and alumina on the physical properties of superfluxed sinters produced from Nigeria iron ore.

EXPERIMENTAL PROCEDURE

Series of experiments were carried out to examine the effects of bauxite and alumina on the physical properties of superfluxed sinters produced from Nigeria Iron Ores.

MATERIALS

The chemical composition of all the raw materials used in this investigation are given in Tables 1 and 2. Before the materials were mixed, a detailed calculation using the method proposed by this author [8] was carried out to determine the quantity of the components necessary for the production of sinters of different basicities (CAO/SiO_2).

Sinters were produced from Nigerian Iron Ore concentrates of sizes 1mm and having an average Fe content of 63%. The flux was a mixture of Jakura limestone and Burum dolomite. The chemical composition of the bauxite and mixture of limestone and dolomite used are shown in table 3.

RESULTS AND DISCUSSIONS

Sinter from sinter mix with increased level of alumina

Initial experiments were carried out to determine the effect of sinter mix containing a high level of alumina on the strength of superfluxed sinters. The results of these experiments are shown in table 4. From the table it is seen that increasing the quantity of alumina in sinter mix improves the strength characteristics of the sintering product.

The difference in strength characteristics is quite impressive for sinters of basicities 1.5-2.5. This is explained by the fact that alumina sinters have aluminic and cordite bonds instead of olivinic aluminuous bonds. Yitkov had earlier reported that for such sinter there is a sharp decline of the quantity of calcium (ii) silicate in its structure.

Sinters from bauxite

The results of these experiments are shown in table 5. As is seen from the table, superfluxed bauxite sinters are considerably stronger than iron ore sinters of basicities 1.2-1.4 but are close to the results obtainable for ordinary superfluxed iron ore sinters. Hence, the 0-5mm fraction sinters obtained after ISO drum test was 10-20% for bauxite sinters and correspondingly 24-30% and 15-19% for Itakpe and Agbaja iron ores. Sinter output of class > 10mm for bauxite sinter BI ranges from 64-73 (basicity 3.5) to 58-68% (basicities 5-5.5). For Itakpe and Agbaja sinters, these values are correspondingly 34-40 and 70-76%. The average chemical composition of the sinters are shown in table 6.

As the raw material is changed to that containing high degree of silica and low level of alumina the strength of the sinter decreases. Hence, sinters from bauxite B2, though not worse than normal sinter, have lower percentage of fraction sizes > 10mm when compared with sinters from bauxite B1. They also have lower dust.

Coke breeze rate required for the production of any given basicity could change with increase in the basicity of sinters of types B1 and B2. This is explained by the many possible compositions of the cementing phase of bauxite superfluxed sinters. The initial bauxite that enters into sinter mix does not completely enter into the melt. Therefore the composition (basicity) of the melt may differ from the composition of the sinter to a considerable extent.

Sinters were also produced from a mixture of bauxite and alkaline. The results are shown in table 7. From the table it is seen that the total iron (Fe_T) in the sinters decreased as the basicity increased. Sulphur and carbon both increased with increase in basicity. This is expected because it had been earlier reported by this author that increase in basicity negatively affects desulphurization and the ability of the mix to assimilate carbon.[8]

Table 8 shows the strength characteristics of sinters produced from a mixture of bauxite and alkaline. From the Table it is seen that the strength of this sinter practically does not change with increase of basicity up to 1.44. The output of marketable sinter, (sinters of sizes > 10mm after shatter test) lies within 87.5 and 89.3%. On increasing the basicity up to 1.8 - 2.2. marketable sinter output increases up to 90.20% at the same vertical sintering speed.

Sinter outputs of the classes 0-5 and 10mm after ISO drum test are, for basicity 1.05, correspondingly 14.7 and 70.1% and for basicity 1.84 correspondingly 12.4 and 78.7%.

Further increase of calcium oxide in the sinter results in a somewhat decrease of the parameters of sintering. Hence, for CaO/SiO_2 = 0.6 at sintering speed = 16.1mm/min. marketable sinter was 87.3%, while the class of sinters of sizes 0-5 and >10mm after ISO drum test were correspondingly 16.4 and 60.4%. However, in difference from normal iron ore sinters which have minimum sinter strength at the interval 1.0 to 1.8, bauxite sinters have high strength parameters at such intervals. This could be explained by the stabilizatory effect of Al_2O_3 on sinter coke of the system $2CaO.SiO_2$ – calcium ferrite. It is of interest to note that decreasing the basicity of sinter as a means of decreasing the quantity of calcium oxide in the raw mix does not help to strength sinter. This could be explained by the increase of the viscosity of the melt of the sintering mix [9].

CONCLUSION

1. Addition of alumina and bauxite to sinter mix stabilizes calcium (ii) silicate in the sinter.
2. Increasing the alumina content in iron ore sinter mix improves the strength characteristics of the sinters produced.
3. Superfluxed bauxite sinter is considerably stronger than iron ore sinter at basicities 1.2-1.4.
4. Sinters produced from a mixture of bauxite and alkaline show that with increase in basicity sulphur and carbon in the sinters increase.
5. The strength of bauxite sinter practically does not change as the basicity rises up to 1.44.
6. Superfluxed bauxite sinter does not show a minimum strength at 1.0-1.8 basicity as in the case for normal superfluxed sinters.

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Table 1 **Chemical Analysis of Sinter Mix Components Wt %**

Composition	Fe_{tot}	Fe_2O_3	FeO	SiO_2	Al_2O_3	CaO	Mg0	S	P	Mn_{ToT}	TiO_2	Na_2O	K_2O	P_2O_5		
Itakpe Hill Concentrate	63.0	88.90	1.00	8.80	0.80	0.20	0.28	0.005	0.03	-	0.05	0.11	0.002	0.085		
Agbada-Okudu Iron Ore	62.82	88.65	0.99	5.45	2.24	0.97	0.30	0.007	0.05	-	0.08	0.09	0.04	0.13		
Jakura Limestone	0.20	0.50	13.43	1.70	0.30	58.4	18.8	-	0.013	-	1.31	2.05	3.21	9.09		
Burum Dolomite	0.15	0.20	18.20	1.40	7.90	36.859	34.71	0.002	0.03	0.7	-	-	-	-		
Sinter Returns	52.86	59.30	16.30	7.50	0.90	10.10	1.70	0.11	0.03	-	-	-	-	-		
Table 2										MnO	S_{org}	FeS	SO_3	P_2O_5	C_m	C_v
Coke breeze	2.119	0.21	-	6.01	3.20	1.36	0.64	0.40	0.004	0.21	0.31	0.25	0.211	0.02	83.89	1.10

Table 3

Chemical Composition of the bauxite and flux used, %

Type of Bauxite	Composition			
	Al_2O_3	SiO_2	CaO	Fe_{Tot}
B1 (0-5mm)	58.3	6.3	1.7	18.5
B2 (0-3mm)	43.4	10.7	5.2	19.8
Flux	2.1	3.6	55.1	3.7

Table 4
Comparative Sinter Strength Characteristics

Type of sinter	Basicity CaO/SiO_2	n	M	B	L
Itakpe iron ore sinter	1.5	62	31	21	25.3
	2.5	64	22	30	26.1
	3.5	70	16	45	27.3
Itakpe iron ore sinter	1.5'	62	26	31	25.8
Increased amount of	2.5	68	17	45	26.7
Alumina (10% Al_2O_3)	3.5	72	13	47	27.3

Note: n-sinter output of + 10mm after shatter test, % m and B- output of sinter fractions 0-5mm and +10mm after ISO drum test, %; L-vertical sintering speed, mm/min.

Table 5

Comparative sinter strength characteristics

Type of Sinter	CaO: SiO_2	K*, %	1**, %	M, %	B, %
Iron Ore	1.2-1.4	4-4.5	14	27-30	32-40
Itakpe iron ore	4.0-5.5	5.0-6.0	30	12-18	72-78
Agbaje iron ore	3.5	8.5-10	24	12-18	70-75
Bauxite sinter from ore B1	5-5.5	6-6.5	31	17-20	64-73
Bauxite sinter from ore B2	4-4.5	9.5-10	36	10-14	48-73

- Optimum content of coke breeze in sinter mix

** Average content of limestone in sinter mix.

Table 6
Average Chemical Compositions of Bauxite Sinters

Bauxite	CaO/SiO_2	Composition			
		Al_2O_3	CaO	SiO_2	Fe_2O_3
B_1	3.5	45.6	22.4	6.4	19.5
	5.0	37.4	31.5	6.3	16.9
B_2	2.0	36.8	24.2	11.5	25.5
	3.0	33.4	31.4	10.5	22.9
	4.0	28.7	39.0	20.9	

Table 7

Chemical Composition of Bauxite/Alkaline Sinters

CaO/SiO_2	Fe_T	Fe_2O_3	FeO	CaO	SiO_2	Al_2O_3	S	C	CaO_2
1.05	25.70	23.00	12.30	7.25	6.90	44.90	0.027	0.082	0.07
1.20	25.17	24.22	10.61	7.97	6.50	43.00	0.027	0.083	0.08
1.25	25.17	21.07	13.50	8.93	7.11	42.00	0.065	0.084	0.08
1.45	25.12	20.90	13.35	10.85	7.59	41.80	0.096	0.084	0.11
1.80	24.00	18.00	14.56	12.12	6.62	41.20	0.10	0.074	0.12
2.25	24.50	17.20	16.16	15.65	6.97	40.10	0.16	0.17	0.15
5.00	20.20	14.40	13.03	27.90	5.52	35.00	0.27	0.43	1.80
6.00	17.61	13.00	10.96	32.50	5.47	32.40	0.29	0.43	3.50

Table 8
Sintering Parameters of Bauxite Sinter

CaO/SiO_2	L	H_B	T_{max}	N	M	B	Q
1.05	20.4	360	860	87.5	14.7	70.1	1.15
1.23	18.7	380	840	90.7	16.7	68.3	1.21
1.26	20.4	370	820	91.8	13.6	69.8	1.26
1.44	20.4	370	730	89.3	13.3	68.6	1.25
1.84	20.4	410	720	89.1	12.4	76.7	1.25
2.24	20.4	400	560	90.2	13.4	72.4	1.24
5.00	16.1	420	600	89.2	14.1	66.7	0.765
6.00	16.1	410	520	87.3	16.4	60.3	0.715

Note:

L – vertical sintering speed, mm/min
H_B – initial vacuum (mm, water guage);
t_{max} – maximum sintering temperature ^0C
n-sinter output of sizes > 10mm after snatter test;
B-sinter output of sizes 0-5mm and > 10mm after ISO drum test, %;
And Q – sinter box productivity, Tonne/(m^2 hour).
At 15% alkaline, 30% sinter returns and 9% coke breeze in the sinter mix