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Sintering of Highly Rich Iron Oxide Wastes from Integrated Direct Reduced Steel Companies

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Abstract

There are five integrated iron and steel companies in Egypt. Egyptian Iron and Steel Company in El-Tebbin (EISC) is the largest iron and steel company in Egypt and the first company in the Middle East. EISC adopts the sintering blast-furnace route and is using local El-Bahareya iron ore. This ore after 40 years of exploitation does not meet any more the required specifications for neither the sintering nor the pig iron production in the blast furnaces. Its iron content became less than 50% while its Cl and MnO contents became far beyond their upper limits. At the meantime, the other four integrated companies which adopt the direct reduced route (DR) use imported iron oxide pellets with iron content more than 67% to produce sponge iron, are producing wastes as by-products with iron content about 67% and with almost zero percent Cl and MnO. A representative sample (about 20tons) of these wastes was transported by trucks from Al Ezz Dekheila Steel Company (EZDK) in Alexandria to the sintering plant of EISC in El-Tebbin. Several experiments in the sintering pilot plant were performed to investigate the sinter-ability of these waste. The sinter produced was found to meet both the requirements of sintering and blast furnace plants. As a matter of fact, during the production of sponge iron, two important waste by-products, oxide fines and sludge with an iron content more than 67% are formed. It is expected that the annual production of such waste by-products from the four DR integrated steel companies will be about one million tons. This means that as long as the four companies are producing sponge iron according to their designed capacities and so far as natural gas is available, about one million tons of highly rich iron oxide wastes almost free from Cl and MnO will be annually available as well.

Keywords: Waste material; Oxide fines; Sludge; Blast furnace route; DR Route

Introduction

There are five integrated steel companies in Egypt; the EISC in El-Tebbin, EZDK company in Alexandria, Bishay steel company in El-Sadat city, EZZ steel company in Suez and Suez company for steel production (El-Garhi MF) in El-Ain El-Sokhna. Among these five integrated companies the EISC is the only one who adopts the blast furnace route. It is also the only company in Egypt, which has a sintering plant and uses local iron ores to produce pig iron. The other four integrated companies adopt the DR route and use highly rich imported iron oxide pellets to produce sponge iron. In the late march of 1977 the head of the EISC, had submitted a memorandum [1] in which he stated:

- The contract no. 7700 signed in 22nd of Sep. 1964 between the Soviets and the Egyptians aimed to increase the company's production of steel to reach 1,500,000 tons per year; i.e. to raise its production of pig iron to be 1,750,000 tons.
- In 25th of Oct. 1965 the Soviets had submitted a techno-economic report in which they stated that El-Bahareya iron ore deposits contain some threatening impurities such as Cl and high MnO and the use of such ores require special treatment in order to get rid partially if not completely of such threatening impurities before using it in the sintering plant.
- The results of the experiments performed in the first stage of operation which took place in the 15th of Dec., 1973 proved that EISC will never achieve its designed capacity stated in the previously signed contract in 1964, unless the company will find a way to get rid of the threatening impurities, such as Cl and high MnO contained in El-Bahareya iron ores.

Meanwhile, these four integrated companies produce highly rich iron oxide with almost 0.0% Cl and MnO.

Main Characteristics of Blast Furnace Route

The EISC was established in 1954 and was based on the exploitation of the iron ore deposits nearby Aswan. It started its production in 1958, but it did not take long time – less than ten years- to find out that Aswan iron ores does not any longer meet the blast furnace requirements and this was because of the selective mining techniques used in mining operation. EISC needed a miracle to face this catastrophic situation and to find within a short period of time another iron ore with the same quality and price. The discovery of El-Bahareya iron ore deposits in El-Gedida region in the early sixties was that miracle and since then it became the only iron ore used in EISC. As a matter of fact, the iron deposits in El-Gedida region is distributed among three locations plateau (39.6 mt~58% Fe), west valley (60 mt~50% Fe) and N.E valley (12mt~48% Fe). The detailed composition of the iron ores in the three locations of El-Gedida region is given in Table 1. In order to avoid (the previously mentioned) selective mining mistakes committed in Aswan, a predetermined program for ore extraction from the three locations was established [2-4]. This program is supposed to guarantee the constancy of the chemical composition of the blend and the maximum utilization of the reverses in the three locations, blending of ores from the three locations, should lead to the specifications previously agreed upon in which Fe% should be > 51%, Cl% should be < 0.6% and MnO% should be < 2.4%. However, after 40 years of exploitation, El-Bahareya mines became unable to fulfill such obligations. The iron content now is < 50% and the Cl % > 0.6 % and MnO % > 2.4%. Nowadays EISC is seriously looking for a solution taking into consideration the detrimental effect of alkalies in the sintering plant and the blast furnace beside the effect of high percentage of MnO in the converter process [5-7].

Table 1: Chemical Composition of El-Gedida Iron Ores [2].

Region	Fe%	Cl%	MnO%	SiO%	CaO%	Al_2O_3%	Reserves Million Tons
Plateau	50.2	0.74	1.4	11.2	1	0.36	39.6
West Valley	50.2	0.47	3.76	8.1	1.2	0.37	60
North East and East Valley	48.82	0.22	1.54	12.2	1.4	0.37	11.98
Total Reserves							111.58

El-Bahareya oasis is about 350 km far from the EISC stockyard and thus the iron ore after extraction is transported by trucks and then by train to EISC in El-Tebbin for further preparation steps for agglomeration in the sintering plant. In EISC sintering is considered to be an essential step in ore preparation for the blast furnace operation [8-11]. Sintering may be defined as the agglomeration of fine particles into strong porous mass. The sintering process is carried out by heating a mixture consists beside the iron ore the required quantities of coke and moisture and limestone or any other useful additive to obtain sinter of a specific composition and quality. The temperature during the sintering process may reach the fusion temperature of the mixture. It approaches ~ 1350°.

Main Characteristics of the DR Route

The four previously mentioned DR companies in Egypt are importing highly rich iron oxide pellets to produce sponge iron and produce as well as by-product oxide fines and sludge in which the iron content is almost the same as in the iron oxide pellets, i.e. between 67 & 68%. The total amount of these highly rich iron oxide wastes produced as a by-product from the four previously mentioned companies is supposed to be in the range of one million tons per year. This highly rich in iron oxide wastes is almost free from alkalies and MnO. These two compounds are threatening EISC from utilizing El-Bahareya iron ores, beside this amount of wastes which is estimated to be in the range of one million tons per year can be considered as an iron ore mine whose reserves are existing as long as these four Companies Are Producing Sponge Iron [12].

Material and Experiments

The reuse of the highly rich iron oxide wastes of EZDK (oxide and sludge fines) became in 2015 one of the promising if not the best alternative in front of EISC who is searching for another iron bearing material almost free from Cl and MnO to be used in the sintering and the blast furnaces charge. Several meetings were held in this respect to negotiate signing a protocol between the EISC and EZDK through which EZDK, the owner of the wastes gives these wastes to EISC and gets instead the equivalent weight of pig iron from EISC, and thus both sides agreed upon the necessity of performing a set of experiments on the suitability of such highly rich iron oxide wastes for sintering, since the blast furnaces in EISC use only sintered iron ores in the charge. Accordingly, EZDK took the initiative and had send by trucks a representative sample of its highly rich iron oxide wastes. This representative sample (20 tons) was delivered to the sintering plant of EISC in El-Tebbin.

Material

As mentioned above the material used in this investigation is composed of the highly rich iron oxide wastes produced as by-products in EZDK Company in Alexandria. The chemical composition and the annual production of these wastes are given in Table 2. From Table 2 it is clear that the contents of the two components MnO and Cl in these wastes are almost either traces or nil while in El-Bahareya ore their contents are far beyond the allowable limits previously stated by EISC.

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Table 2: Chemical Composition of the Highly Rich Iron Oxide By-products and their Annual Production in EZDK Company.

Material	Annual Production	Chemical Composition					
		Fe %	CaO %	SiO_2%	Al_2O_3%	MnO%	Cl %
Oxide fines	200	67.8	0.8	1.1	0.36	0.1	niL
Sludge	150	68.1	1.2	1.8	1.16	0.2	niL

Experimental Work

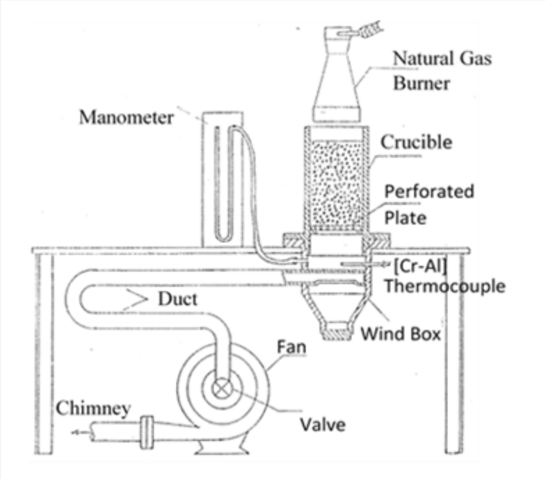

Figure 1: Pilot Scale Sintering Unit.

EISC is the only company in Egypt, which has sintering plant. In this plant the iron bearing material goes through its final step of preparation since the blast furnaces, are fed by the iron bearing material in the form of sinter. In accordance with this, the sinterability of the highly rich iron oxide wastes was the target of this investigation in order to decide the possibility of using it in EISC. Several experiments using a blend of these wastes were performed in the sintering pilot plant in EISC as shown in Figure 1. The chemical composition for six of these experiments is given in Table 3. The sintering process requires Coke, Limestone and Moisture beside the iron bearing material. Six sintering experiments for different burdens as given in Table 3 were performed in the sintering pilot plant of EISC. The chemical analysis of the produced sinter is given in Table 4. Physical analysis and mechanical properties of the six sinters produced, expressed in terms of sieve analysis and drum test were performed. The results of these tests are given in Table 5.

Table 3: Charge Composition of the Six Sintering Experiments.

Exp. No	Oxide fine		Sludge		Coke Breeze	Limestone	Sinter return	Total [Kg]
	kg	%	Kg	%				
1	8	5 0	8	50	2.5	3	6.2	27.7
2	11	52	10	48	0.8	1	5	27.8
3	12	64	7	36	0.6	0.7	5	25.3
4	12	55	10	45	0.6	0.7	5	28.3
5	8	50	8	50	0.7	1	5	22.7
6	9	60	6	40	0.7	1	5	21.7

Table 4: Chemical Analysis of the Produced Sinter.

Exp. No	Chemical analysis %								
	T.Fe	FeO	SiO_2	Al_2O_3	MgO	MnO	CaO	Cl	Basicity
1	57.56	28.3	5.22	2.18	1.7	0.94	9.46	0.02	1.8
2	63.1	15.69	2.7	1.55	1.78	0.32	4.73	0.01	1.8
3	63.6	15.4	2.95	1.46	1.67	0.27	4.73	0.04	1.6
4	62.95	15.47	2.87	1.27	1.72	0.35	5.3	0.04	1.8
5	63.9	17.5	2.52	1.23	1.3	0.33	4.72	0.01	1.9
6	63.6	23.68	3.58	1.09	1.28	0.31	4.95	0.01	1.4

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Table 5: Physical and Mechanical properties of the produced sinters.

Exp. No.	Weight % of different size fractions (mm)									Mech. Prop.	
	40	20	15	10	8	6.8	5	-5	Max 20%	Drum Test	Max 13%
1	58.35	9.61	3.43	8.47	2.75	3.89	2.95	10.53	Accepted	7	Accepted
2	31.63	14.23	5.1	19.53	7.43	6.37	2.97	12.71	Accepted	8.5	Accepted
3	29.41	10.51	5.31	17.65	5.67	8.19	7.14	15.13	Accepted	9.5	Accepted
4	41.49	11.49	5.53	15.53	4.04	8.51	2.77	10.84	Accepted	8	Accepted
5	30.99	12.09	6.37	25.49	2.86	5.93	3.08	13.19	Accepted	11.5	Accepted
6	42.38	14.13	3.81	16.82	3.36	5.83	1.35	12.32	Accepted	12	Accepted

Discussion

The previously mentioned four DR companies are producing highly rich iron oxide wastes (oxide fines and sludge (as by-products during the production of sponge iron. The annual production of such wastes from these companies is expected to be about one million tons per year. Nowadays EZDK is selling these by-products in either the local market or exporting it abroad. On the other hand, and at the mean time the EISC in El-Tebbin is searching for another iron bearing material with higher iron and lower Cl, MnO content than that in El-Bahareya iron ores. The illustrated results shown in Tables 3-5 proved that the highly rich iron oxide wastes generated as by-products during the production of sponge iron are sinterable. In addition, judging by the results of their sieve analysis and the drum test, it maybe confirmed that the sinter produced based on such waste materials can successfully be used in the blast furnaces of EISC and thus, based on the results given in these tables, the following can be concluded:

➢ Judging by the drum test results, sinter no 1 has the best mechanical properties (-5mm and 7%), at the same time the highest percentage of the large size fraction +40 is 56%, besides it has the highest percentage of FeO (~28%). This indicates that the coke consumption will increase if such sinter is going to be used for pig iron production in the blast furnace.

➢ Sinters no. 2, 3 and 4 Judging by the results of the sieve analysis are having the best size distribution beside acceptable values for the drum test which lies between (8.0 & 9.5). At the same time, they have the lowest FeO content, thus the coke consumption in the blast furnaces is expected to be the lowest, in case if one of these sinters will be used for the pig iron production.

➢ Sinters no. 5 and 6 compared with the above, have the highest values for the drum test i.e. the lowest index of the mechanical properties and relatively high FeO% (17.5 and 24%) and thus is not recommended for the blast furnaces operation.

Conclusion and Recommendations

a. The performed experiments in the sintering pilot plant of EISC company proved that the highly rich iron oxide waste produced as by-products during the production of sponge iron in EZDK company in Alexandria are sinterable, and the produced sinter meet the required specifications agreed upon for pig iron production in the blast furnaces in EISC.

b. El-Bahareya iron ore mines will be sustained as long as the four integrated DR companies are producing sponge iron.

c. Further experiments should be made to achieve the minimum consumption of coke in the sintering process

d. Further experiments in which different ratios of El-Bahareya ores together with the highly rich iron oxide wastes should be performed.

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