USE OF SINTERED PELLETS IN PRODUCTION OF HIGH CARBON FERRO CHROME

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ABSTRACT

Production of Ferro-alloys through submerged electric arc furnace involves use of electric power as one of the major inputs. Hence the production by this power intensive process can be made economically more competitive if the specific power requirement for smelting each ton of the product is brought down. This becomes all the more necessary where the power cost is comparatively high, like in India.

Since the day FACOR started production of Ferro Chrome in 1968, briquetted chromite fines along with lumpy ores were used as feed. Subsequently the increase in the proportion of briquettes and reduction in lumpy ore helped in increasing the use of chromite fines and also brought down the specific power requirement.

Meantime FACOR had been closely watching the technical development of use of sintered pellets in Outokumpu and SRC Processes which need still lower specific power. But the high capital requirement for a pelletisation plant kept FACOR from introducing pellets feed to their Ferro chrome furnaces. So this was postponed to be adopted in future.

In February 2004 in the "1st Ferro-Alloys India", a paper [1] was presented by Dr. Amit Chatterjee. In the questions period after the presentation of the paper there came up a discussion in which it was revealed that with the Indian high grade chrome ores it was not possible to make sufficiently strong pellets, unless a larger percentage of bentonite is used as binder. This is because the Indian high grade Chrome ores have different mineralogy of gangue content compared to low grade ores in Finland and South Africa. Higher usage of bentonite gives rise to higher slag volume and this would result in increased specific power. Since FACOR had plans to go in future for sintered pellets feed, this gave rise to a doubt on success of pelletisation for Indian high-grade chrome ores. This prompted FACOR to take up experimental production of sintered chromite pellets and use of the same in one of their existing furnaces for production of high carbon Ferro chrome. The results are encouraging and are summarized in the paper.

1. INTRODUCTION

FACOR made a beginning in 1950s by producing Manganese & Silicon alloys on a large scale. During the last 5 decades the Ferro Alloys Industry has grown vastly to meet the requirement of the domestic steel industry and also to remain as a potential exporter in the International Market.

Manufacturing ferro-alloys by electrothermic process is highly power intensive since all the heat required for the endothermic reduction reactions and to achieve thermodynamic equilibrium in the furnace, is supplied through electrical energy only. Thus electrical energy is the most vital input. To make the ferro alloy industry cost-effective, it is imperative that measures for energy conservation are taken by improving operational efficiency and adopting processes which utilize the energy in the exhaust gases.

FACOR, started working for energy conservation by improving the charge porosity to have maximum possible heat exchange between the upcoming gases from the reaction zone and the descending charge material by agglomerating chrome ore fines by briquetting , since the day of commercial production of High Carbon

Ferro Chrome in 1968. In the process of constant pursuit of energy conservation, FACOR came across several Research & Development works in the direction of pelletisation of chromite fines in the country and abroad. All those experiments, were carried out on low grade ores and later their application on industrial scale was made for production of metal with 50-55% chromium content. However, doubts were expressed about making pellets with requisite physical strength from high grade Indian ores having different mineralogy of the gangue constituents. FACOR had decided to try on their own pelletilisation studies on high grade Indian ores. They could locate a small scale cement plant where the vertical shaft kiln is being used for clinker making. This appeared ideal to produce sintered pellets. After a study of the published literature on pelletisation of chromite and conducting of lab. scale tests, experimental production was carried out in this cement plant and pellets produced were used in one of the furnaces for production of high carbon ferro chrome with 60-63% Cr content successfully.

2. PRODUCTION OF CHROME ORE SINTERED PELLETS

A study was made of the available literature and some published papers on chromite pelletisation [2] to [7]. After this laboratory scale experiments were carried out on pelletisation. Past experience of the authors helped and production of chrome ore green pellets with requisite strength was easily achieved. With these results production of pellets was taken up in the mini cement plant.

The effect of various variables namely moisture in green pellets, size of pellets, green strength, length of the green pellet column above the burning zone of the kiln, air quantity for combustion, additions of reductant in the pellets for sintering and surface heating were adjusted in the initial runs and optimized during the production of sintered pellets with desired physical characteristics.

For production of these sintered pellets TISCO friable ore fines of 50-52% Cr_2O_3 grade, screened fines of coke/coal obtained during screening while feeding to furnace day bins were used. Chemical and sieve analysis of ore fines and coke/coal fines is given in Table-1. Coke/coal fines are used in the pellet mix as the energy source for sintering as well as for ignition.

The production was conducted in the available vertical shaft kiln which does not have the instrumentation to record temperatures in different zones but control was exercised by observation. The objective was to establish that without use of excessive binder Indian high grade chrome fines can be pelletised and sintered pellets with required strength can be produced.

3. PROCESS DESCRIPTION

The process flow sheet is presented in figure 1.

Drying of ore fines & Coke/coal fines

For effective grinding of sinter mix to minus 200 mesh (75 microns) the ore fines & coke fines are dried in a double drum drier and the dried fines are taken for grinding.

Weighing & Grinding of Raw-Materials

Minus 6mm dried ore fines, 6% coke/coal fines, 2% quartz fines and 0.5% bentonite are weighed from individual bins, in a single hopper and conveyed to the ball mill for grinding. Fineness of the ground mix is maintained at minimum 80% of minus 200 mesh (75 microns). After grinding, the mix is blended in a bin provided with aeration pads and then stored in another bin.

After producing initial 500 MT of pellets, the bentonite addition was gradually reduced and then totally stopped considering high ash contents in the coke/coal fines, which we expected would provide the required binding. It was seen that even without bentonite the green pellets strength could be maintained at 2 kg.

Table 1: (a) Ore Fines; (b) Coke/Coal Fines

(a) Ore Fines

Moisture Content 6% Chemical Composition On Dry Basis	
	%
Cr_2O_3	50.68
FeO	16.17
SiO_2	4.28
MgO	11.2
Al_2O_3	10.71
CaO	0.56
LOI	6.2
Cr	34.67
Fe	12.56
Cr/Fe	2.76

Sieve Analysis	
	%
-6 +3 mm	10.64
-3 +1 mm	28.16
-1 +60 mesh	33.97
-60 +100 mesh	13.56
-100 +200 mesh	8.83
-200 mesh	4.84

(b) Coke/Coal Fines

Moisture Content 8% Chemical Composition On Dry Basis	
	%
Ash	30.2
Vol.	23.85
FC	45.95

Ash Analysis	
	%
SiO_2	42.16
Fe_2O_3	15.19
CaO	3.36
MgO	6.86
Al_2O_3	15.3
Cr_2O_3	15.35
P_2O_5	0.037

Moisture & Pelletising

The ground material is then conveyed to a 1.5 meters diameter disc pelletizer. Water spray is matched with material flow and the mix is pelletized. Moisture content in the mix is maintained around 12% and pellets size is optimized to 12 - 15 mm by adjusting the angle of the pelleltizer disc. The green strength of the pellets is 2 to 2.5 kg.

Pre-Heating & Sintering of Pellets

The green pellets from the disc pelletizer are fed into the vertical shaft kiln through a rotary and revolving chute fixed at the top of the kiln. Prior to the feeding of pellets, the burning zone of the kiln is thoroughly ignited with 3 to 6 mm coke/coal fines. The height of the column of the mix normally called the bed height is around 400 mm. Air is introduced in small quantities initially to promote pellet ignition and after the lower layer of the pellets are ignited air quantity is increased for proper combustion of coke/coal and to maintain burning zone temperature over 1000^0C. After ensuring sintering of the top layer of the batch, fresh batch is taken and the same process is continued

In the vertical shaft kiln, the moist pellets are initially dried by upcoming hot gases and subsequently sintered. During the descent from the burning zone the pellets are passed through the cooling zone of the kiln as cold air is being blown from below. In the vertical shaft kiln process coke/coal additions are made in be-

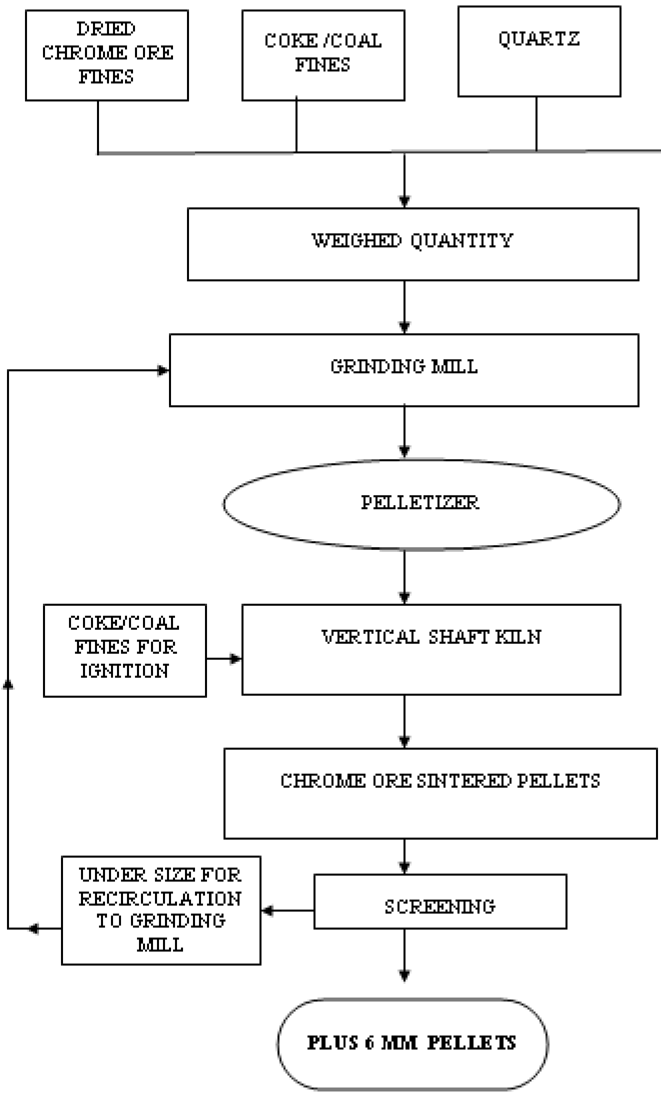


Figure 1: Process Flow Sheet for Pelletising

tween the pellet layers for surface heating of the pellets to maintain the required temperature to promote the sintering of pellets. The quantity of pellets per batch for 400 mm layer is around 500 kg and the retention time of the batch is 15-20 min in the burning zone. The retention time of the pellets in cooling zone is around 12 hrs and they are finally discharged through kiln grate after they are cooled down to below 100^{o}C.

After cooling, the sintered pellets are screened on a rotary screen and the under sized pellets below 6 mm are recycled to the grinding mill. Sintered pellets of +6 mm size are transported and stored in a shed for smelting trials.

The chemical composition of sintered pellets and their crushing strength is given in Table-2.

4. ELECTRIC FURNACE SMELTING STUDIES

After accumulating a quantity of about 1500 tonnes smelting trials were conducted.

Table 2: Chemical Composition of Pellets

Ash Analysis	
	%
SiO_2	42.16
Fe_2O_3	15.19
CaO	3.36
MgO	6.86
Al_2O_3	15.3
Cr_2O_3	15.35
P_2O_5	0.037

Screen Analysis	
	%
+20 mm	Nil
-20 +15 mm-15	16.04
+10 mm	60.19
-10 +6 mm	21.42
-6 mm	2.35

Crushing Strength: >200 Kgs.

The furnace used for the study is an open furnace with, secondary voltage ranging from 100 – 200 Volts and operating on 8.5 MW load. Daily power consumption on this furnace was 200 – 205 MWH. The average production of High-carbon Ferro-chrome is 55 – 56 MT a day with standard charge pattern consisting of 20% hard lump, 15% friable lump 65% briquettes. The specific power consumption with the standard charge is about 3650 KWH/MT.

The trial smelting with pellets replacing briquettes was made for 15 days in a phased manner. For about one week even the friable lump is also substituted with pellets thus the charge mix consisted of 80% pellets and 20% hard lump. Similarly the reverse study replacing the pellets with briquettes was also made and the observations are given in Table 3 and Figure 2. From this data it can be observed that with 75% to 80% pellets in the charge mix, the specific power consumption is reduced to 3250 KWH from 3650 KWH.

The reduction in specific power consumption with 80% pellets in the charge is attributed to,

(i) Higher porosity if the sintered pellets which retain their form deeper in the smelting zone and higher proximity of ore to reductant and flux because of smaller size of pellets compared to briquettes.
(ii) Finer size of the ore particles in pellet give higher surface area for reduction reaction
(iii) Finer particles of ore got totally reduced during smelting thus there is no loss of partially reduced ore particles in slag.
(iv) Constant and consistent pellet size leads to better porosity of charge giving better heat exchange between descending charge and upcoming hot gases giving a cooler furnace top with uniform flame distribution showing optimum utilization of thermal energy in the gases from the reaction zone.

It is observed that the specific power is not the same while having same quantity of pellets in the mix while replacing briquettes in the mix with pellets and while replacing pellets with briquettes. This appears to be because while briquettes are replaced with pellets, when the pellets which are more reactive, reach the smelting zone, the layer of the charge above the pellets consists of the pellets only which are more reactive compared to briquettes. Whereas while replacing pellets with briquettes, when briquettes reach down to the reaction zone the layers of the charge above are having briquettes which have a lower reactivity. This difference clearly indicates the difference between the reactivity of pellets and briquettes.

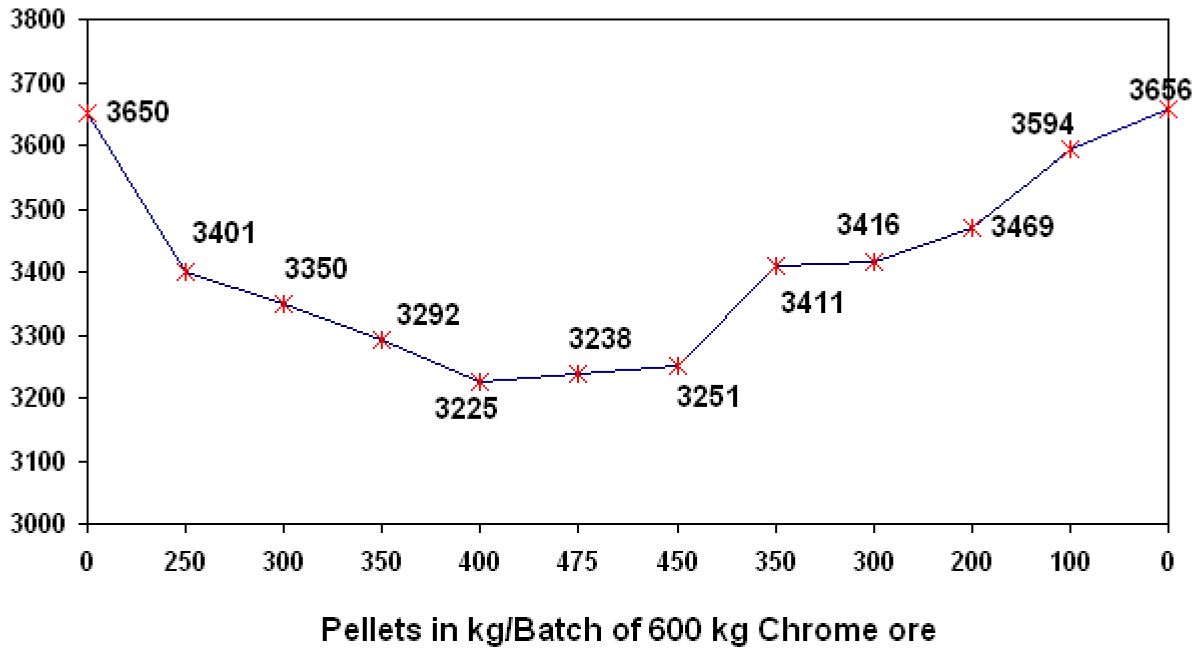
The other advantages observed on using pellets in place of briquettes are

(i) Operation of furnace is possible at higher secondary voltages with optimum electrodes penetration i.e. secondary voltage is kept at 175 volts compared to 161 volts with briquettes, thus giving a higher furnace power factor and lower reactive power losses.
(ii) Total chromium in slag is 5.5% with pellets while it is 8.2% in slag with briquettes. This proves lower chromium losses in slag.

Table 3: Data on Experimental Trial with Chrome Ore Sintered Pellets and Briquettes

Trial period in Days	Cr Ore Pel-lets kg.	Cr Ore Briqu-ettes kg	Fri-able Cr Ore Lumps kg	Hard Cr Ore Lumps kg	Low Ash Met. Coke kg	Gas Coke kg	Quartz kg	No.of Mixes Cons-umed	Metal Vol. Per Mix kg	Slag Vol. Per Mix kg	Estd Prod in MT	Power Consm MWH/ day	Specific Power in KWH
1	-	375	100	125	85	55	40	228	264	260	60.19	220.2	3658
2	-	375	100	125	87	55	41	215	264	260	56.76	206.8	3643
3	-	375	100	125	86	55	41	188	264	260	49.63	181.2	3651
4	-	375	100	125	86	55	40	211	264	260	55.70	203.8	3659
5	-	375	100	125	85	55	41	224	264	260	59.14	215.4	3642
6	250	150	75	125	92	70	24	225	270	264	60.75	206.6	3401
7	300	100	75	125	95	70	23	224	270	264	60.48	205.9	3404
8	300	100	125	125	99	70	25	230	272	266	62.56	206.2	3296
9	350	50	75	125	101	70	25	230	272	272	62.56	206.6	3302
10	350	50	75	125	105	70	25	233	271	275	63.38	208.0	3282
11	475	-	-	125	108	70	25	233	274	272	63.38	204.4	3225
12	475	-	-	125	158	-	29	219	274	272	60.00	194.5	3242
13	475	-	-	125	165	-	29	230	271	274	63.02	204.7	3248
14	450	-	-	150	165	-	28	230	271	274	62.33	203.1	3258
15	450	-	-	150	167	-	25	220	271	274	59.62	194.2	3257
16	450	-	-	150	167	-	23	228	271	274	62.24	201.9	3244
17	450	125	-	150	165	-	22	229	268	268	62.52	203.0	3247
18	350	175	-	125	160	-	20	224	267	265	61.15	208.6	3411
19	300	275	-	125	160	-	23	233	262	262	62.21	212.5	3416
20	200	375	-	125	147	-	32	225	262	262	58.95	204.5	3469
21	100	475	-	125	141	-	37	227	258	258	58.57	210.5	3594
22	-	475	-	125	132	-	42	223	254	254	56.64	207.0	3655
23	-	475	-	125	129	-	42	215	254	254	54.61	199.5	3653
24	-		-	125	130	-	43	217	254	254	55.12	201.8	3661

Figure 2: Effect on Specific Power During Usage of Chrome Ore Sintered Pellets



Pellets Kg/Batch	0	250	300	300	350	350	400	475	475	475	450	450	450	450	350	300	200	100	0
Specific Power (KWH)	3650	3401	3404	3296	3302	3282	3225	3225	3242	3248	3258	3257	3244	3247	3411	3416	3469	3594	3656
Average	3650	3401	3350		3292		3225	3238			3251				3411	3416	3469	3594	3656

(iii) Uniform flame distribution indicating even distribution of heat and optimized conditions for utilisation of energy.

(iv) With usage of pellets, the furnace could be operated with higher secondary voltage giving wider craters and tap hole could be opened with only two lancing pipes against 4-5 during briquettes usage. During tapping flow of metal and slag from the furnace is uniform with no ejection of charge fines from the tap hole.

(v) Above all, cleaner atmosphere prevailed throughout the trial run since particulate matter in the fumes is negligible because of better strength of sintered pellets at higher temperatures compared to briquettes.

5. CONCLUSION

The following conclusions have been drawn from the trial conducted :

The production of High Carbon Ferro Chrome in submerged arc furnace using sintered pellets in place of briquettes is comparatively better in all respects viz., specific power, smooth operation of the furnace thus increased operational efficiency, with increased "utility quotient" of equipment, leading to higher production.

The trial conducted has proved that Indian high grade chrome ores can be successfully pelletised without excessive use of binder and used for smelting to produce high carbon ferro chrome with 60-63% Cr content.

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