Sintering characteristics of manganese ore fines from Balaghat and Ukwa mines of Manganese Ore (India) Limited

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ABSTRACT

Indian manganese ore reserves are depleting very fast and Manganese Ore (India) Ltd. realised that utilisation of Manganese ore fines will pave the way for conservation of lumpy high grade manganese ore.

Manganese ore fines generated at Balaghat and Ukwa mines of MOIL were subjected to sintering studies at the R&D Centre of Paramount Sinters Pvt. Ltd.

The studies indicated that fluxed sinter with very good strength and porosity could be produced. The sinters showed a high degree of reduction and even metalization was noticed. The chemical and physical characteristics indicated that sinters can be used in ferro manganese furnaces.

Advantages of using sinter in the ferro alloy manufacture has been highlighted in this report. The authors have concluded that from the point of view of conservation and reduction of manufacturing cost, sintering has a vital role to play in ferro alloy industries.

Introduction

The recoverable reserves of manganese ore in India according to inventory prepared by IBM in collaboration with GSI (as on 1-1-80) are placed at 116.63 million tonnes. These reserves include measured indicated and inferred reserves. Out of 116 63 million tonnes, the reserve under measured category is 21.99 million tonnes only. The reserves of manganese ore in the lease-hold of Manganese Ore India Limited (MOIL) are 32 million tonnes. MOIL is operating 13 mines all over India. It produces nearly 25% of India's production of manganese ore. 75% of the high grade manganese ore requirement of the country is met by MOIL.

Demand

Manganese is essential for production of all types of steel. Manganese in one or other form is used for desulphurisation, deoxidisation, conditioning, alloying of steel etc Manganese is also used for production of copper and aluminium alloys. Manganese imparts toughness

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and hardenability to metals. Manganese dioxide is also used as depolariser in dry cells. However, 95% of the domestic consumption of manganese is in the iron and steel industry.

As per Planning Commission, the estimated requirement of low grade manganese ore and high grade manganese ore during 1987-88 will be as follows :

Domestic Consumption

		Lakh tonnes
i)	Low grade manganese ore (Blast Furnace)	8.8
ii)	High grade manganese ore (Ferro Manganese)	7.1
iii)	Other Industries	0.84
iv)	For export	4.5
	Grand Total	21.24

The demand is not increasing as per projected demand by planning commission due to recession. However, in coming years the demand will pick up.

Considering the projected demand, the reserve of manganese ore in measured category is very less.

Utilisation of manganese ore

During the course of mining of ores, lumps and fines are produced. Lumpy manganese ore is used in blast furnace as well as in ferro manganese plant leaving a large quantity of manganese ore fines un-utilised. About 20 to 40% fines are generated during mining of manganese ore depending upon the physical characteristics of ore. These fines are of varying grades. To conserve our natural resources it is necessary that the fines produced in different mines should also be used in the industry. The fines produced can be utilised after agglomeration.

Low grade fines produced can be beneficiated by gravity methods for utilisation. High grade manganese ore fines are generated at Balaghat, Ukwa and Dongri Buzurg mines of MOIL. MOIL was keen to conserve high grade fines by suitable agglomeration process and had explored the various agglomeration techniques such as pelletisation, sintering and briquetting. Due to steep increase in oil price, the pelletisation process has become un-economical for manganese ore agglomeration. Several briquetting techniques were tried. However, briquetts with sufficient high temperature strength could be produced only by employing sodium silicate as binder. Since sodium will have detrimental effect on ferro-manganese furnace refractory, briquetting has been abandoned leaving sintering as the only alternative.

For production of high grade ferro manganese, phosphorous content of the ore should be less and manganese iron ratio should be high. But it has been observed that the phos content in the ore mined is steadily showing an upward trend and manganese iron ratio is also decreasing Phos. content of the ore can be decreased and manganese iron ratio increased by beneficiating manganese ore. However, if beneficiation techniques are employed, the concentrates produced will be in fine form which will again necessitate agglomeration.

Therefore, the agglomeration process has to play a vital role in utilisation of standard grade manganese ore fines and off grade manganese ore lump and fines. As pelletisation and briquetting cannot be employed due to techno-eco nomic reason, the only alternative left is sintering.

R&D Centre of Paramount Sinters Pvt. Ltd.

MOIL sponsored experimental work for agglomeration of Mn ore fines produced at their Balaghat and Ukwa Mines at the R&D Centre of M/s. Paramount Sinters Pvt. Ltd., (PSL). The latter has pioneered the manganese ore sintering in India and has been successfully operating a sintering plant as ancillary to Ferro Manganese plant of Maharashtra Electrosmelt Ltd , at Chandrapur. The sinter pot of the PSL has been fabricated out of heavy MS Plate. The four vertical sides are bolted together to form the pot. Two sides are supported on swinging arms such that after sintering, two sides of the pot can be opened and swung away, thus exposing the sinter cake for visual examination. The bed depth of the pot can be adjusted from 150 mm to 400 mm. The grate area is 0.135 sq. meter. The grate plates are of cast alloy and are provided with 6 mm slots for passage of air. The wind box has a bottom gate for removal of material that passes through the grates. The sinter suction fan is rated for 20 M^3/mt. of air at 800 mm water guage vacuum and is connected through a 150 mm pipe to the wind box. The ignition hood running on rails can be moved over the sinter pot for quick ignition. The oil burner on the top of the hood can be used on furnace oil/ L.D.O. A separate blower supplies air for atomisation and combustion. A chromel / Alumel thermocouple is provided below the grate to measure the temp. and the vacuum below the grate is measured by a well type manometer. A manually operated hand mixing drum and a motorised pelletizing drum with variable speed, slope and length is utilised for mixing the charge. An Avery beam scale is used for weighing. A Tumbling Index drum, set of 200 mm dia and 400 mm dia, test screens. double pan balance and AMIL make rapid moisture meter are some of the other facilities available with PSL.

Test Procedure

10 Kg. lots of the raw mix consisting of fines of manganese coke flux and return fines in a predetermined proportion are introduced into the mixing drum, which is rotated initially for one minute without addition of water and subsequently for 4 minutes with addition of water. The wet mix is then discharged to a pan and transferred to the sinter pot. Before transferring the wet charge to the pot, the grate is covered by a 25 mm thick layer of return sinter of 8 mm —16 mm size so as to protect the grate. Sufficient wet mix is charged to the pot so as to maintain the bed height to 300 mm. The burner hood is positioned over a refractory lined fire box which is connected to a chimney through which the hot gases are exhausted. The burner used to stabilize within 10 minutes time. The sinter fan is started with air inlet valve in closed position. The valve is then slowly opened and the suction below the grate is adjusted by bleeding air and manipulating the inlet valve. The burner hood is then rolled above the sinter pot and kept for 1.5 minutes so as to bring the surface to incandescence. At the end of the period, the burner is shut off and the hood is moved out. The vacuum and temperature are recorded at regular intervals As sintering progresses the temperature rises gradually. The rise in temperature of out going gases continues till the flame front reaches the bottom. The temperature then starts dropping — which indicates that the sintering process is complete.

The two sides of the sinter pot are opened and the sinter cake exposed. The cake is visually examined and pushed to the floor (drop of 1.5 metre). If sintering is complete the cake breaks into few big lumps with little fines. The lumps of +25 mm size are separated by screening and weighed. The weight of the lumps is used as an indicator of effective sintering.

The sinter cake is crushed to minus 50 mm size. The crushed sinters are sieved on 6 mm screen and weight of - 6 mm fraction recorded. This fraction represents the sinter fines available for recirculation.

During the investigation tests were conducted by varying the mix composition and the sinter properties were evaluated to find out the effect of mix composition on sinter quality.

Experimental Work

Characteristics of the raw materials.

MOIL transported 2 M. T. of Balaghat and 1 M. T. of Ukwa manganese ore fines to R&D Centre of PSL. The screen and chemical analysis of these materials are given below :—

TABLE — 1

Screen Analysis of manganese ore fines

Size range	Weight % Balaghat	Ukwa
−6 mm + 3 mm	40.0	26.5
−3 mm + 1.65 mm	28.5	9.0
−1.65 mm + 0.70 mm	11.0	20.0
−0 7 mm + 0.50 mm	1.5	7.5
−0.50 mm + 0.150 mm	15.0	28.7
−0.150 mm	4.0	8.3
	100.0	100.0

TABLE — 2

Chemical analysis of manganese ore fines

Radical	Assay % Balaghat	Ukwa
Mn.	48.9	46.8
SiO_2	5.87	8.98
Fe	5.90	6.10
P	0.086	0.17
Insolubles	6.51	10.23

Mineralogy of ore fines

Mineral	*Approximate content* %
Braunite	10
Psilomelane & Pyrolusite	60
Hollandite	20
Sitaparite	5
Garnet	3
Feldspar	2

Psilomelane is mostly cryptocrystalline in nature. Pyrolusite occurs as coarse prismatic aggregates. Some of the pyrolusite occur as long and coarse prismatic crystals along with psilomelane. Fine scaly pyrolusite occurs as coarse prismatic aggregates. At places, psilomelane contain unaltered remnants of braunite or sitaparite. Braunite and sitaparite occur as interlocked grains with each other. Hollandite occurs as coarse and slightly elongated granular aggregates. Gangue minerals contain inclusions of ore minerals and some of them are interlocked with ore minerals.

Coke fines used by PSL sinter plant was employed for studies on MOIL samples. The size composition and chemical analysis (proximate) are given in table 3 & 4. Tables 5 & 6 record screen analysis and chemical composition of flux utilised.

TABLE — 3

Screen anaiysis of coke fines

Size range	Wt. %
−6 mm + 3 mm	00.5
−3 mm + 1.65 mm	12.2
−1.65 mm + 0.7 mm	27.0
−0.7 mm + 0.5 mm	10.3
−0.5 mm + 0.15 mm	38.8
−0.15 mm	11.2
Total	100 0

TABLE — 4

Chemical analysis of coke fines

	Assay %
Fixed Carbon	65
Ash	32
Volatile matter	3.0
P	0.15

TABLE — 5

Screen Analysis of flux fines

Size range	Weight % Limestone	Dolomite
−3 mm + 1.65 mm	15.2	17.9
— 1.65 mm + 0.7 mm	20.8	11.3
— 0.7 mm + 0.5 mm	6.8	6.7
— 0.5 mm + 0.15 mm	47.6	52.8
— 0.15 mm	9,6	11.3
Total	100.0	100.0

TABLE — 6

Chemical Analysis of Limestone and Dolomite

Radical	Assay %	
	Limestone	Dolomite
CaO	32.25	27.32
MgO	8.80	15.76
Al_2O_3	3.13	2.21
SiO_2	14.52	9.28
Mn	2.80	2.80
Fe	2.70	2.50

Sinter pot tests

The initial tests were conducted for determining the optimum coke necessary for proper sintering. Partial sintering starts as the coke content approaches the correct value. At the optimum coke content entire mix sinters into a cake. If coke content exceeds the critical value, the sintering becomes partial due to fusion of top layer. The first few tests were conducted with addition of 5% coke fines and keeping the other constituents at the levels recommended by the consultants. This was done for generating return fines of —6 mm for the actual tests.

Effect of Coke content in the mix

Balaghat and Ukwa ore fines were mixed in the proportion of 55:45 to simulate the blended concentrates likely to be used in the MOIL sinter plant and the proportions of the various constituents in the sinter mix were as follows. (Table - 7).

TABLE — 7

Mix Composition

Sinter mix	Test-1	Test-2	Test-3	Test-4
Mn. Ore fines	41.5	41.0	40.5	40.0
Return Sinter	35.0	35.0	35.0	35.0
Limestone	7.8	7.8	7.8	7.8
Dolomite	4.7	4.7	4.7	4.7
Coke	4.0	4.5	5.0	5.5
Water	7.0	7.0	7.0	7.0
Total	100.0	100.0	100.0	100.0

Sintering tests were conducted under the following conditions :

Ignition time	1.5 mts.
Suction	350 mm water gauge
Bed height	300 mm

The sinter cakes were visually examined in situ In test 1 sintering was partial. In the case of tests 2,3 & 4 sinter cakes were good.

After visual examination the sinter cake was dropped from a height of 1.5 M. Lumps bigger than 25 mm were separated and weighed. Weight percentage of +25 mm lumps with respect to the total weight of sinter (i.e. inclusive of —25 mm material) was taken as lump yield (Table - 8).

TABLE — 8

Lump yield at various coke levels

Test	Coke in the Mix %	Lump Yield
1.	4.0	56.2
2.	4.5	86.7
3.	5.0	88.2
4.	5.5	87.1

It can be seen that coke level of 5% would be optimum for sintering of Balaghat / Ukwa manganese ore fines.

Effect of circulating load

A series of tests were conducted to find out the level of return fines addition at which the sinter stabilizes i.e. the return fines generated during crushing the sinter cake to minus 50 mm balance with the return fines added to the mix.

The following conditions were maintained during these tests. (Table - 9).

TABLE — 9

Mix Composition

Sinter Mix	Test-5	Test-6	Test-7	Test-8
Mn. Ore fines %	50.5	45.5	40.5	35.5
Return fines %	25.0	30.0	35.0	40.0
Limestone %	7.8	7.8	7.8	7.8
Dolomite %	4.7	4.7	4.7	4.7
Coke %	5.0	5.0	5.0	5.0
Moisture %	7.0	7.0	7.0	7.0

An ignition time of 1.5 mts. and suction of 350 mm was maintained for bed height of 300 mm. The sintering time ranged from 12 mts. to 13 mts. The sinter cake was crushed to —50 mm size in the hot condition to simulate the plant conditions. The crushed product was screened on 6 mm screen and the weight of — 50 + 6 mm fractions was recorded. The results are shown in Table - 10.

TABLE — 10

Return fines generation

	Test-5	Test-6	Test-7	Test-8
Sinter (—50+6 mm) %	46.5	50.5	47.0	50.0
Return sinter (—6 mm) %	36.5	32.5	36.0	33.0
Loss %	17.0	17.0	17.0	17.0
Total	100.0	100.0	100.0	100.0

Comparing Table 9 & 10 it may be seen that for test-7, 35% return sinter was added while 36% generated.

Tumbling and Abrasion Indices

The —50 mm + 6 mm sinter fraction from Test-7 was subjected to tumbling in the standard I.S.I. drum. The results are given in Table - 11.

TABLE — 11

Tumble and Abrasion Indices of Mn. Ore sinters of M/s. MOIL

Tumble Index	—	84.5
Abrasion Index	—	2.2

Chemical Analysis of Sinters

The fluxed manganese ore sinter was handed over to MOIL for chemical analysis. The results are shown in Table - 12.

TABLE — 12

Chemical analysis of sinter

Radical	Assay %
Mn	40.4
P	0.14
SiO_2	10.48
Fe	7.80
CaO	10.28
MgO	2.03
Al_2O_3	3.17
Insolubles	11.44
$\frac{CaO}{SiO_2}=1$	

Porosity

The porosity determinations were made on sinters of —50 mm + 6 mm size. The results are shown in Table - 13.

Mineralogy of Sinter

The microscopic observation reveals that there are three distinct phases present :—

Metallic Manganese - like phase

Metallic manganese like phase occurs as tabular to triangular grains and at places as laths of fine aggregates; associated with hausmanite and gangue like phases. It is fine to coarse grained. Fine inclusions of metallic manganese like phase are noticed within the groundmass of hausmanite and gangue like phases.

Hausmanite like phase

This is the predominate phase in the sample. Hausmanite like phase is greyish white in colour, showing weak bireflectance, anisotropy and lamellar twining. It occurs as medium

TABLE — 13

Porosity of Mn-Ore and sinter

	Sr. No.	Apparent Volume V2 cc	Apparent Volume (After coating) V1 cc	True Volume V3 cc	Porosity (V1-V3)/V1 %	Average porosity
Mn. Ore (Balaghat)	1.	2.66	3.82	2.60	32	24.2
	2.	2.90	3.55	2.82	21	
	3.	3.66	4.65	3.55	24	
	4.	4.07	4.95	4.01	19	
	5.	3.75	4.88	3.68	25	
Mn. Ore sinter	1.	2.1	4.85	1.78	63.29	52.22
	2.	2.7	5.40	2.40	55.55	
	3.	3.06	4.78	2.80	41.42	
	4.	3.12	5.37	2.76	48.60	

sized angular to sub-rounded grains, associated with metallic manganese and gangue like phases.

Gangue like phase

It is fine to medium grained, dark grey in celour containing lamellar inclusions of hausmanite like phase and isotopic in nature. Fine inclusions of this grey colour minerals are present within the groundmass of hausmanite like phase.

X-Ray Analysis of the sinter confirmed that the sinter consists of mainly hausmanite phase.

Summary

Results of the sintering studies conducted at R&D centre of PSL on manganese ore fines from Balaghat and Ukwa mines are summarised;

Fluxed sinter of basicity 1.0 could be produced by employing the following conditions :

Raw Mix.	*Wt. %*
Mn Ore fines	40.5
Return Sinters	35.0
Limestone	7.8
Dolomite	4.7
Coke	5.0
Moisture	7.0

Sintering conditions :—

ignition time	1.5 mts
Suction below the grate	350 mm WG
Sintering time	12-13 mts
Bed height	300 mm

Return sinter level stabilized around 35%. The sinter had tumbling and Abrasion index of 84.5 and 2.2 respectively with manganese content of 40.4%, and average porosity of 52.22%. The mineralogical studies on the sinter and ore reveals that ore is predominantly MnO_2 while sinter is mostly in Mn_3O_4 form. The metallic manganese in the microphotographs shows that high degree of reduction is taking place during sintering.

Conclusions

A good quality fluxed sinter could be produced from manganese ore fines of Balaghat / Ukwa. Tumbling and Abrasion indices of the sinter were very good.

The high degree of reduction achieved during sintering indicate that a substantial reduction of power, reductant, flux and electrode paste etc. per ton of ferro-manganese produced would be possible compared to direct smelting of the ore.

The pot sinter studies have established beyond doubt that manganese ore fines likely to be generated at Balaghat/Ukwa mines of MOIL can be conserved and utilised for ferro manganese manufacture successfully.

The sinters had very high porosity (50%) compared to the lumpy ore from Balaghat/Ukwa (24%). The high porosity indicates very high surface area and hence much better reducibility. Thus during smelting, sinters shall reduce to the metal at a faster rate compared to the lumpy ores. The ferro manganese furnace productivity is bound to go up when sinters are used in the furnace burden.

Mineralogical and X-ray studies have indicated that the sinters are predominantly as Mn_3O_4 compared to MnO_2 in the case of feed ore. Even metalization has been noticed in the sinters. Thus part of the reduction of the ore has been achieved during sintering itself, expending little power and rejected coke fines. When such a sinter is used in the furnace burden, there will be appreciable saving in the coke and electric power per ton of ferro manganese.

Every ton of sinter used brings about saving of one ton of lumpy ore. In India ferro manganese plants alone generates 1 lakh M. T./year of fines. If the entire fines are sintered and utilized we can conserve 1 lakh M. T/year of high grade ore.

Accumulation of unutilized Mn-Ore fines at the plants pose pollution as well as storage space problems. Both these can be solved if Mn Ore fines are utilized through sintering.

Normally, fluxing materials in the lumpy form alone are utilized by ferro-manganese manufacturers. As flux fines are not acceptable, these are screened out and rejected By introducing these flux fines into the sinter, conservation of fluxing material as well as financial savings can be achieved.

Paramount Sinters have been successfully operating a Manganese Ore sinter plant for the last 3 years. More than 30,000 M.T. of Mn-Ore sinters have been produced and used in ferromanganese production and most of the technical advantages listed out earlier have been confirmed during smelting operations. The economic benefits derived from the use of sinters in ferro-manganese production also have been confirmed beyond doubt.

All the existing ferro alloy plants should consider incorporation of sinter plant in their works in order to fully utilize the manganese ores purchased by them. The future ferro alloy plants should be planned with an integrated sinter plant and charging of hot sinters should also be considered. By utilising the sensible heat of the sinter further saving of electric power can be achieved.

At the present rate of depletion of our manganese ore deposits, before the end of this century India may become an importer of Manganese ores. The only way to avert such a tragedy seems to be sintering.

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Discussion

P. K. Chakravarty, TISCO, Jamshedpur.

Sintering is a means to convert fines in 'lump' with the addition of gangue material (coke ash). All fines are poor in Mn ratio. Do you know of any fines satisfying in large quantities. Or do you suggest beneficiation to prescribe sintering ?

Answer

i) Certain fines available from MOIL and few private parties have a better Mn/Fe ratio which certainly can be sintered.

ii) Beneficiation will definitely help in better feed to sintering. But economics has also to be considered simultaneously.

iii) Yes, we recommend beneficiation and agglomeration of concentrates for conservation.

Dr. A. S. Venkatadri, RDCIS, SAIL, Ranchi.

Have you tried Fe - Mn slags in sinter making ?

Answer

No, we have not tried.