IOP Conf. Series: Materials Science and Engineering **285** (2018) 012033 doi:10.1088/1757-899X/285/1/012033

Beneficiation and agglomeration of manganese ore fines (an area so important and yet so ignored)

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Abstract. Unpredictable changes in demand and prices varying from very attractive to depressing levels have thrown all Manganese ore mines out of normal operating gear. The supply has to be in time-bound fashion, of dependable quality and continuous. With setting-up of numerous small units and with existing ferro-alloy units, ore supply has become extremely sensitive issue. Due to unpredictable swing in price of Mn ore lumps , furnace operators found it economic and convenient to use fines, even at great risks to furnace equipment and operating persons and therefore risks & damages were conveniently & comfortably ignored. Beneficiation Cost(Operating) approx. – (ferruginous ore) – Roast reduction followed by magnetic separation route-particulars – Water 20/-, Power 490/-,Coal fines-675/-,OH-250/- totaling to Rs.1435/T.(Figures are based on actual data from investigations on Orissa & Karnataka sector ores).Feed Grade Mn- 28 to 32 %, Fe – 14 to 25 %, Concentrate (Beneficiated ore fines)- - Mn- 45 to 48 %, Fe – 6 to 8 %.,Recovery - 35 % , Price of 28-30 % Mn ore fines = Rs. 2400 /T, Cost of Concentrated fines (45/ 48% Mn grade) = Rs. 8300 /T, Price of 47-48 % Mn Lumpy ore = Rs.11,000 /T. Sintering Cost (Operating) – Approx-Rs.1195=00 / T Sinter. Therefore cost of Sinter produced from beneficiated concentrate is 9130+1195 = Rs. 10325. The difference in cost of 48%Mn ore Lumps & 48%Mn sintered concentrate = 11000-10325 = Rs.675/T. The main purpose of this paper is to show that establishment of beneficiation unit & Sintering unit is economically feasible. There are many misconcepts, still prevailing, about use of Mn ore sinters. Few of the main misconcepts are-1)Sinters bring no benefit – technical or economical.2) Sinters are very friable and disintegrate easily into high fines during handling/transportation. 3) Fines below 100 mesh cannot be sintered. 4) Silica increases to high level during sintering, resulting in to high slag volume thereby higher power consumption. All are false. Sinters have already been proved to bring enormous technical benefits in smelting operation. However small mine owners find it practically impossible to set up a small beneficiation and/or sintering unit at mine site. Recent advances in dry or pneumatic separation which depends on density difference between valuable mineral and gangue/waste rock, are proving to be advantageous & effective because of its small capacity. Capacity is 5 T/hr or 10 T/hr . When applied to low grade high silica Iron ores Iron content has been found to be enhanced by 8 to 10 % from 48% to 58 % , with overall wt. recovery of 60 to 70 %. Recently this technique was applied to low grade siliceous Mn ore with very encouraging results. Mn content has been found to be enhanced from 25 +/- 2 % to 37 +/- 2 % and with 50 to 65% wt. recovery. Size of feed is restricted to (i) 6 to 25 mm and (ii) 2 to 6 mm. Due to Modular design it is possible to put up units from 50 TPD to 800 TPD capacity.

1. Introduction

Unpredictable changes in demand and prices, varying from very attractive to depressing levels have practically thrown all the Manganese ore mines out of normal operating gear. Although efforts are intensified in all the mines to cope up with the erratic demand, alternatives to supplement existing facilities have gained tremendous importance. The end users of Manganese ores are also experiencing the impact of such erratic & unpredictable changes which have ignited a competition in cost-effective measures to draw maximum benefit in present global market of Manganese based ferro alloys.

The ore consuming industry is exerting tremendous pressure on mining industry for supply of all grades of ores. The supply has to be in time-bound fashion, of dependable quality and continuous. With setting-up of numerous small smelting furnaces (capacity varying from 2.5 MVA to 5 MVA) and already existing ferro-alloy units, ore supply has become extremely difficult and very sensitive issue.
With such situation, setting up of beneficiation unit for lean ores and otherwise unsuitable ores has to be considered very seriously. Details of almost every known manganese ore deposit in India are studied and published, encompassing a wide range of its geological formations, mineral compositions, nature of ore bodies and chemical analysis with advantages & disadvantages. It is seen that, by and large, most of the Ferro-Alloy Producers are suffering due to one or more of the following technological gaps-

1) Existing technology unable to cope up with deterioration in Raw Material quality
2) Coupled with rising cost of power and its availability.
3) Continued use of outdated and inefficient Plant & Machinery.
4) Lack of automation and / or modernization in fairly old plants.

In fact end-users of manganese ores, prominently ferro-alloy units are required to put up intensive efforts in following areas for proper use and pragmatic conservation of this strategically important mineral-

1) Up gradation of lean ores by appropriate beneficiation methods.
2) Use of fines in Briquettes or Sintered or Pellet form
3) Charging of pre-heated and pre-reduced raw material in the furnace.
4) Installation of Gas Cleaning Plant and Waste Heat Recovery system.
5) Use of computer aided operations in optimization of process parameters.

If proper & consistent supply of our own resources is not ensured, end user is bound to embrace imported ore even if it turns out to be more expensive. He would not hesitate to make few business compromises even with his competitors because his shear existence would be at stake if proper raw material is not available within country.

Studies on utilization Of Indigenous Lean Grade Manganese Ores – India has done massive work on manganese ore beneficiation and agglomeration. The research work conducted in reputed laboratories like IBM, NML, NMDC, RRLS, CSIR labs and various engineering colleges is highly significant. In fact there is hardly any manganese ore deposit in India, which has not been investigated. Volumes and volumes of data / information is available on characteristics of various Mn ore deposits, different techniques applied in beneficiation, various parameters in briquetting /sintering / pelletization process, material balance and energy balance and other related technological data, and yet, beneficiation and sintering of manganese ores remained a grossly ignored area in India.

2. What could have gone wrong?

After beneficiation & sintering / pelletization of iron ore, beneficiation and sintering of manganese ore fines attracted technology experts due to massive expansion in manganese based ferro-alloys. Fast depleting high grade lumpy manganese ore deposits made the beneficiation and sintering all the more wanted solution. But the real problem started when price of lumpy ore was compared with beneficiated and/or sintered equivalent grade of fines. As the difference in prices of lumps and fines started fluctuating unpredictably with an element of uncertainty, chances of installing beneficiation

and sintering plant were dimmed. Rising power tariff in India, over-production in other countries, export-import restrictions in India complicated the matter further. Investors went in defensive shell and Ferro Alloy industry went on back-foot. Mining industry was not prepared for such situation and looked confused.

When situation started looking gloomy and immediate relief/solution was not in sight, many furnace operators opted to use fines without any treatment, due to probably following reasons -

1) Non-availability of economically viable lumpy ore.
2) To reduce cost of production even at the risk of equipment & human health, just to earn marginal profit or even just to cover fixed expenses to sustain the existence.(Few operators even had to bear losses just to keep the unit running and avoid retrenchment of people)

It was made amply clear by most of the furnace operators that fines were charged because there was no other option. So with all the risks of explosions, gas eruptions, slag boil, higher power, more slag and grade deterioration, fines continued to find its way to smelting furnaces. Due to unpredictable swing in price of lumpy Mn ore , furnace operators found it economic and convenient to use fines, even at great risks to furnace equipment and operating people. And that was how, unfortunately, a technological abuse or violation got glorified.

The population of manganese based ferro alloy units having furnace capacities up to 9MVA or less, is very large compared to big units with furnace capacity of 12MVA and above. Use of fines in small furnaces (2.5 MVA to 9 MVA) spread like a wild fire which is still continuing. Net result was a grossly wrong concept that fines work wonderfully in small furnace and lumps can be easily restricted to 10-15 %. Unfortunately small & medium sized private producers picked up wrong message– "Fines need not be beneficiated or sintered ". The apparent difference in prices of lumps & fines was too lucrative, the temptation was huge and therefore risks & damages were conveniently & comfortably ignored. The net outcome was that once again the proposals for Beneficiation and / or Sinter Plants received a massive set back .

Table 1. An illustration to indicate the viability of beneficiation and sintering process.

PARTICULARS	**QTY**	**RATE Rs/T**	**TOTAL-Rs**
Water	2 Cu M/T	10	20
Power	70kwh/T	7	490
Coal Fines	150 Kg/ T	4.5	675
Salary + Maintenance + other overheads			250
TOTAL			1435

(Figures are based on actual data from investigations on Orissa & Karnataka sector ores of India)

Feed Grade of ferruginous Manganese ore - - - - - - Mn- 28 to 32 %, Fe – 14 to 25 %

Grade of Concentrate (Beneficiated ore fines)- - Mn- 45 to 48 %, Fe – 6 to 8 %.

Recovery of concentrate by weight – (approx) - - - - - - - - - - - - - - - - - - - 35 %

Price of 28-30 % Mn ore fines = Rs. 2400 /T

Cost of Concentrated fines (45 to 48% Mn grade) = Rs. 8300 /T

Price of 47-48 % Mn Lumpy ore = Rs.11,000 /T

Another barrier in establishment of a beneficiation plant is its size. Even a small capacity crushing-washing-screening-wet jigging circuit becomes uneconomical. Unlike Iron ore mines, manganese ore mines have small production capacity and have, many times, heterogeous nature of ore, making common beneficiation technique quite difficult. Therefore small mine owners find it practically impossible to set up a small beneficiation plant at mine site. Moreover any beneficiation technique

which requires water becomes cumbersome due to expensive water recovery and recirculation system, apart from requirement of additional land for slurry pond.

Recent advances in gravity separation which depends on density difference between valuable mineral and gangue/waste rock by dry or pneumatic Jigging, are proving to be advantageous & effective. Presently small Iron ore mine owners are using this technique specially in size range of 6 to 25 mm as it is feed size for DRI units. The size is limited to due restriction caused by liberation of minerals at quite coarse size. Iron content has been found to be enhanced by 8 to 10 % from 48% to 58 % Fe with overall wt. recovery of 60 to 70 %. It has been proved to be economical. Recently this technique has been applied on low grade siliceous Mn ore with very encouraging results. Mn content has been found to be enhanced from 25 +/- 2% to 37 +/- 2% and with 50 % wt. recovery. Silica was reduced from 50 +/- 2 % to 18 +/- 2 %. Present price difference between 25 % Mn grade and 38 % Mn grade chips ore (i.e. size between 6 to 25 mm) justifies installation of this DRY or PNEUMATIC way of separation.

Table 2. Another ignored area is sintering of Mn ore fines sintering Cost (Operating) – Approx

PARTICULARS	QTY / T	RATE (Rs/ unit)	Rs/ T
Coke Fines	70 Kg	6.5	455
Water	100 Liters	L.S	10
Fuel (FO/LDO)	5 Liters	45	225
Power	65 Kw	7	455
Maintenance			50
TOTAL			1195

Therefore cost of Sinter produced from beneficiated concentrate is 8715+1195 = Rs. 9910. The difference in cost of 48%Mn ore Lumps & 48%Mn sintered concentrate = (11000-9910) = Rs.1090/T. A simple illustrative example to indicate possibility of sintering low grade fines and blending with high grade ore to arrive at economical blend, when compared with price of equivalent grade lumpy ore –(Based on data collected from various resources)) –

Hutch – 30 % Mn --Rs 2500 +/- 5%
Fines – 32 % Mn – Rs 2800 +/- 5%
Fines - 35% Mn – Rs 3300 +/- 5%
Ave. - 33 % Mn Rs 2850 +/- 5%

If these fines are sintered, then with requirement of 1.05 T of average grade fines and Rs.1195/T cost of Sintering, cost of 1 T of sintered fines will be Rs.4138 /T and grade will be approx. - 35% Mn. If Sinters are blended with high grade Mn ore (47% Mn) in ratio of 85:15, average grade will be 36.40 % Mn, with a cost of (0.85 x 4138 + 0.15 x 11000) = Rs 5167 /T of blend. Say – Rs 5170 / T. If prices of other grades of lumpy ore are compared to sintered ore, following picture would emerge -

Average cost of 30 % Mn lumpy ore ----- Rs 4750 +/--5%
Average cost of 32 % Mn Lumpy ore - - -Rs 5100 +/-- 5%
Average cost of 34 % Mn Lumpy ore - - -Rs 6000 +/-- 5%
Average cost of 37 % Mn Lumpy ore -- - Rs 7000 +/-- 5%
Average cost of 35/36 % Mn grade Lumpy ore - - - (approx) Rs.6200 / T +/-- 5%
(prices based on data from various resources)

The difference in Lumpy ore & sintered fines of 35%Mn grade = 6200-5170 = Rs. 1030 +/-- 5%. The purpose is indicate possibility of establishing a viable sinter plant unit. We need to work seriously in this direction.

3. MSP – (Mini Sinter Plant) – A New Concept in Sinter Plant Design.

The need for establishing manganese ore sintering units was realized long back but one of the major constraints was sizing of the plant. Most of the Iron ore sintering plants, as a part of integrated steel

plant had large capacities ranging from 10,000 TPD upwards. Attempts to miniaturize the conventional sinter plant did not prove to be a viable proposition in view of high capital investment and high cost of production. In India only 3 companies ventured into establishment of small capacity(100 TPD or less) Manganese ore sinter plants -1) Khandelwal Ferro Alloys Ltd , 2) Chandrapur Ferro Alloy Plant of SAIL (earlier known as Maharashtra Elektrosmelt Ltd) and 3) Navbharat Ferro Alloys Ltd. There were no known efforts since last 30 – 35 yrs. Successful establishment of MBFs (Mini Blast Furnaces) to cater to the MINI and MIDI steel plants necessitated production of Iron ore sinter on smaller scale. Mini Sinter Plant was conceived and established. In place of heavy, cumbersome and expensive conventional straight line travelling grate type sinter machine, a simple circular sinter machine comprising of number of small pots/pans or continuous bed type was designed successfully. MSPs gained enormous importance since last 10 to 15 years as MBFs were proving to be economic in steel industry. However unfortunately such efforts were missing in Ferro Alloy industry.
These modifications will help Manganese ore sintering to be less expensive due to reduced capital expenditure and ease to operate.

There are many misconcepts, still prevailing, about use of Mn ore sinters. Few of the main misconcepts & facts are as follows –

Misconcept 1	Fines cause no harm to furnace or process
Fact	Fines cause formation of crust, reduce gas permeability, choke the passage, increased dust losses in flue gas, which ultimately result in higher specific power consumption
Misconcept 2	Sinters bring no benefit – technical or economical
Fact	Sinters ensure higher permeability, higher resistivity of charge, higher power factor, more thermal stability, lesser flue dust losses, lesser power consumption- resulting into reduced cost of production
Misconcept 3	Sinters are very friable and disintegrate easily into high fines during handling/transportation
Fact	Sinters are as strong as Iron ore sinters and have T.I of +75 % and A.I. of less than 5 % . As Iron ore sinters pose no problems in Blast furnace charging or operation, Mn ore sinters are equally beneficial in Sub merged Arc Furnace operation
Misconcept 4	Fines below 100 mesh can not be sintered.
Fact	Fines up to 80 % below 1 mm and overall up to 50 % of fraction in fines below 100 mesh can be sintered without any problem, with special Intensive Mixers
Misconcept 5	Silica increases to high level during sintering, resulting in to high slag volume thereby higher power consumption
Fact	With addition of coke to max 8 % of sinter mix, silica increase in finished sinter is to the tune of 0.5 to 0.75 % only. This drawback is more than compensated by other major technical advantages by use of sinter.

End users of manganese ores, mostly ferro-alloy smelting units, are also required to put up intensive efforts in following areas for proper use and pragmatic conservation of this strategically important mineral, to ease pressure on Mining sector.

1) Use of Briquettes / Sinters / Pellets from fines – natural or beneficiated.
2) Charging of pre-heated and pre-reduced raw material in the furnace.
3) Replacement of coke by other carbonaceous reductants.
4) Installation of Waste Heat Recovery system.
5) Use of computer aided operations in optimization of process parameters.

The reserves of Manganese ore are limited, the constraints are well known, the demands are fairly well projected and there is a continuous pressure from consumer sector to provide better and

consistent quality products which are not expensive. Global markets are opening to Indian end users with a wide variety of ore choice. The prices may not be very economic but availability and consistent supply are of prime importance which bring solace & consolation to Ferro Alloy smelting units. It is now entirely left to the Mining Engineers, Mineral Processing Engineers and Metallurgical Engineers to come together for a national cause, to sharpen their skills and rise to the revival of Mineral Industry in general and Manganese Ore Industry in particular, towards a promising future.

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