Fines generation in kiln process of direct reduction

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INTRODUCTION :

The growth of iron and steel making through conventional BF-BOF route is restricted due to depleting reserves of coking coal. Direct reduction (DR) processes, which eliminate the use of coke, have become technologically and economically viable alternative for iron ore reduction.

Direct reduction is a solid state process of reducing iron ore lumps, fines or pellets using a solid reductant such as non-coking coal or a gaseous reductant such as reformed natural gas.

The limited reserves of natural gas available in India may have to cater to various critical industrial needs. As such, the process using non-coking coal, which is abundantly available, is of greater significance to Indian conditions.

Among the various processes using solid reductant, the rotary kiln process has been found commercially successful. However, the efficiency of rotary kiln process depends on the control of uniform temperature, dust generation, accretion formation etc. The dust generation is influenced by the decrepitation characteristics of iron ore.

The present work outlines an attempt made to evaluate the fines generation in kiln process for different ores having different decrepitation characteristics.

Test Samples :

The decrepitation characteristics of iron ore lumps from different mines were evaluated based on their Reduction Degradation Indices (RDI). For this purpose a sample of 500g each of −20 +15mm lumps was reduced for 30 minutes isothermally at 550°C in a vertical tubular furnace using a gas mixture at a flow rate of 15 litres/minute containing nitrogen and carbon monoxide in the ratio of 70:30. The reduced sample was cooled and then tumbled in a drum of size 130 mm dia and 200mm length for 30 minutes at 30 rpm. The tumbled product was screened at 3mm and the weight percent of −3mm product was designated as RDI.

Hematite ores (Fe 63−66%) having different RDI values falling over a wide range were selected for direct reduction studies. The details of the samples thus selected, are given below.

Details of test samples

Sl. No.	Source	RDI % (−3mm)
1.	Bayaram	5.2
2.	Kumarswamy	12.7
3.	Bailadila -14-I	20.2
4.	Bailadila -5	28.8
5.	Donimalai	33.4
6.	Bailadila -14-II	42.2

Direct Reduction Studies :

The rotary kiln process of direct reduction was simulated in the laboratory by conducting batch scale tests using Linder test apparatus. The equipment is an electrically heated horizontal reduction tube of size 160mm dia and 630mm length with a facility for rotation of the reduction tube at different speeds.

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For these studies, a test sample of 1000g each of −15+5mm size was charged into the tube alongwith non-coking coal of −15+3mm size. The amout of coal was adjusted to maintain the ratio of total iron unit to the total carbon unit at 2.0. Also, limestone of −3mm size was added to the extent of 6% of the ore charge for the purpose of desulphurisation. The charge was heated to 1000°C for 3 hours after which the sample was allowed to cool in an inert atmosphere.

The cooled sample was taken out, weighed and subjected to magnetic separation. The magnetic portion formed the directly reduced iron (DRI) and the same was subjected to size and chemical analysis to determine the extent of fines generation and metallisation. The results obtained in the tests with different samples are given in table I.

Discussion :

The studies revealed that all the iron ore samples tested are amenable to direct reduction using noncoking coal.

The DRI product from all samples possessed a high degree of metallisation of over 93%, meeting the requirement for electric steel making. The operation of electric arc smelting requires a feed stock with restricted amount of fines. The presence of significant amount of fines in the charge affects the furnace operation and economy. Considering these aspects, the draft Indian Standard No. SMDC 16/P-7 proposes to limit the −1 mm fines content in DRI product for electric steel making to 2% only. Our test results show that the values of −1mm fines generated range from 8% to 28.5% for different samples. The fines generated will have to be screened out before the use of sponge iron in electric arc furnace. Thus, the profitability of the process is dependant on the extent of fines generation.

Besides affecting the economical viability, the fines also cause operational problems in rotary kiln. Thus, the extent of fines generation during reduction in kiln assumes importance in evaluating the suitability of the ore. The generation of fines is mainly due to the decrepitation characteristics of the ore. Hence, the RDI values, which indicate the degradation tendency of the ores, are compared with the fines generated in the DRI products. The RDI values of different samples and the corresponding fines in DRI products are detailed in table II.

The amount of fines generated during direct reduction studies is more than the corresponding RDI values due to the following reasons.

i) The higher temperature of 1000°C maintained during direct reduction tests

ii) The increased number of revolutions the sample is subjected to in the kiln

It can be seen that increasing amount of fines is generated in case of ores having higher RDI values. Thus, the RDI values could be used as an indication to the extent of fines generation in direct reduction in kiln.

Table I : Size and Chemical analysis of DRI

Sl. No.	Iron ore sample description	Degree of metallisation	Weight percent		
			+3mm	−3+1mm	−1mm
1.	Bayaram	93.4	87.2	4.8	8.0
2.	Kumarswamy	95.6	79.7	11.2	9.1
3.	Bailadila -14-I	97.6	77.6	9.7	12.7
4.	Bailadila -5	94.4	61.3	17.7	21.0
5.	Donimalai	95.2	49.7	21.8	28.5
6.	Bailadila -14-II	96.2	47.4	28.4	24.2

Table II : Comparison of RDI and fines in DRI products

Sl. No.	Iron ore sample designation	RDI % (—3mm)	Weight precent of—3mm fines in DRI product
1.	Bayaram	5.2	12.8
2.	Kumarswamy	12.7	20.3
3.	Bailadila -14-I	20.2	22.4
4.	Bailadila -5	28.8	38.7
5.	Donimalai	33.4	50.3
6.	Bailadila -14-II	42.2	52.6

Conclusion :

Considering the importance of kiln process for direct reduction of iron ores in India, tests were carried out with ores from different mines.

Based on the degree of metallisation, all the ores tested are amenable to direct reduction using noncoking coal.

The extent of fines generated during the process is found to vary for different ores in relationship with their RDI values.

The RDI values of iron ore could be used as a tool in assessing the suitability of the ore for direct reduction in kiln.