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TECHNO ECONOMIC EVALUTION OF COAL AND IRON ORE & REDUCTION KINECTICS IN THE MANUFACTURE OF SPONGE IRON MAKING

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Abstract
The present paper deals with the techno-economic evaluation of coal and iron ore. Also, attempt was made to evaluate reduction kinetics in the manufacture of sponge iron making.

Key-Words: Coal, Iron ore, Sponge

INTRODUCTION

It is well accepted that properties of raw materials for coal based Sponge iron production in rotary kiln, i.e. iron ore and coal, greatly influence the process and product. Iron ore is the basic material to be reduced; hence its chemical and metallurgical properties need close examination. Scheme of reduction is also sensitive to granulometry and degradation characteristics of the ore inside the rotary kiln. As to the reductant, metallurgical property from the ultimate reducing of carbon monoxide comes into picture. Success of the process for production the sponge iron will depend on the suitability of these properties in the particular reactor. In a heterogeneous reaction, reaction rate will dependon:

1. Area available for reaction by physical process in the solid, passage of gas and diffusion rate in solid.
2. Granulometry of ore (optimum surface area exposed).
3. Availbility of CO gas, which in turn depends on reactivity of the reductant.
4. Temperature condition.

In the rotary kiln, iron ore, which, in this particular case is hematite Fe_2O_3 is put to a reducing condition so that metallic iron is obtained in solid state. For reducing the ore, non-coking coal is charged which when combines with oxygen of air blown inside, transforms into CO_2 and further to CO as per Boudouard reaction (CO_2+C = 2CO) and ultimately CO happens to be the reducing agent. During reduction of hematite (Fe_2O_3) to magnetite (Fe_3O_4) the crystal structure changes from hexagonal to cubic[3]. This volume change again influences the breaking of ore particle.

A solid-solid reaction is always slower firstly because the solid-solid contact area is limited (while when a gas reacts with a solid particles) and secondly soild-state diffusion is much slower compared with mass transfer to/from gases. Therefore it was recognized quite early that the overall reaction during the reduction of iron oxide takes place in two stages.

Reduction of Iron oxide:

$$mFe_xO_y\ (s) + pco\ (g) = nfe_zo_w\ (s) + rco\ (g)$$

and

Gasification of carbon:

$$C(s) + CO_2\ (g) = 2CO\ (g)$$

Solid state DR processes generally operate within a narrow temperature range of 900-1100^{0}C (Fastmet and comet operate at = 1200^{0}C) to prevent the formation of any semi-solid phases. In large reactors which treat substantial volumes of material it is not always possible to maintain the operating temperatures within these narrow limits in the entire reactor.

In all coal based DR processes, sized and measured quantities of lump iron ore (or pellets) and a coarse fraction of non-coking coal are fed into a rotary kiln from the inlet end. A finer fraction of coal is also introduced from the discharge end of the kiln to help complete the reduction. The temperature of the charge bed inside the kiln is confined to a maximum of around 950-1050^{0}C depending upon the ash fusion temperature of the coal used so that the entire reduction occurs in the solid state.

EXPERIMENTATIONS

Iron Ore : Tests and experiments were carried out on iron ore from two sources (Ore A & Ore B) Because of considerable difference between two types, and then have been tested separately.

1. Tumbler Index

Tumbler test is carried out basically to see the impact and abrasive strength of the ore.

Parameters are (as per Is)

Drum diameter	1000 mm.
Drum width	500 mm.
Lifters	2 Nos.

RPM	25
No of rotation	200

Test result :

Ore Source	Abrasion Index (- 0.5 mm)	Tumbler Index (+ 3.6 mm)
Ore A	9	83
Ore B	3	88

Low temperature degradation test under reducing condition.

This test has been carried out in a pit furnace a cylindrical chamber having gas inlet at the bottom and gas outlet at top is used as the reaction chamber. In this test sized non- coking coal has been put at the bottom of chamber and over this coal layer sized ore was put. Parameters used are

Coal size	5-10 mm
Coal quantity	300 gm
Iron ore size	5-10 mm
Iron ore quantity	300 gm
Time of reaction	1 Hr.
Temperature	600^0 C

Test result :

Ore Source	Abrasion Index (- 0.5 mm)	Tumbler Index (+6.3 mm)
Ore A	9	83
Ore B	3	88

Test Result:

Ore Source	% Magnetic	Degradation Index - 5mm	Metallic Fe	% Fe_3O_4	Remarks
Ore A	100	3.5%	Nil	31 %	ore particles Fractured Through
Ore B	56	7.0%	Nil	18 %	Clevage
Mode amount					Rate of flaking

Decrepitation inside rotary kiln

Ore charged into the kiln was screened in different size fractions. From the same kiln, size fraction of sponge iron was also determined Results show.

Size Fraction	Ore A % Wt.	Sponge Iron from Ore A % wt	Ore B % wt	Sponge iron from Ore B
+20mm	0.72	0.28	0.42	0.56
- 20 + 16 mm	23.72	2.94	30.13	5.26
-16 + 10mm	36.60	6.00	32.33	16.74
- 10 +5 mm	36.86	49.95	35.97	46.16
- 5 + 3 mm	0.73	11.91	0.39	8.82
- 3 +1 mm	0.55	16.18	0.20	16.6
-1	0.79	12.74	0.53	5.70

The results show for ore A mean size is 12.0 mm sponge iron above 10 mm size is 9.22 % of total quantity against 61.04 % in feed Ore.

In case of Ore B, mean size is 12.4 mm. sponge iron above 10 mm size is 22.56 % of total quantity against 62.88 % in feed ore. These shows higher

Decrepitation in ore A

Chemistry of Iron Ore.

Moisture %	ORE A	ORE B
	1.90	0.96
LOI	3.22	0.90
Fe (T)	64.0	66.50
Sio_2	1.75	1.28
Al_2O_3	1.84	0.97

Coal Quality :

Jindal steel & power Limited has practically stopped purchase of SECL Coal and is using coal from captive mines. Ash of JOCCM Coal is 35 % to make it suitable for for use in rotary kiln this coal is washed. The peculiarty of this coal is high near gravity material (around 1.6 sp. Gr). However, with R & D effort it has become possible to produce clean coal with ash suitable for rotary kiln with a reasonable yield. Also V.M. ash and F.C. is very consistent.

Washability test result of JOCCM Coal:

a) **Washability** test was conducted on JOCCM 9^{th} Seam Coal. Results show high near gravity material as Obtained from a Typical float & sink test :

Size 0.5 – 22 mm

Sp. Gr. Of Washability	% Wt	% Ash	□% Wt	□% Ash	%Ash Distribution	Degree
< 1.3	7.07	10.78	7.07	10	2.17	5
1.3-1.4	21.63	19.15	28.70	17.09	13.97	15
1.4-1.45	14.74	30.27	43.44	21.56	26.68	17
1.5-1.55	16.51	40.49.	74.94	28.21	60.05	15
1.55 – 1.6	1.02	45.24	75.94	28.37	61.36	14
1.6 – 1.65	8.37	49.27	84.31	30.44	73.10	11

1.65 – 1.7	3.35	53.29	87.66	31.31	78.17	9
1.7 – 1.8	6.05	57.96	93.72	33.03	88.16	6
> 1.8	6.29	66.11	100	35.11	100	0

From the above washability index works out to 24 (as show in Graph No. 1) this shows that washability of this coal has medium washability characteristics very near the difficult washability range[4].

b) Proximate analysis of feed & washed coal (Dry Basis)

	% Moisture	% V.M	% Ash	% F.C
Feed Coal	10.8	28.76	34.96	36.28
Washed Coal	17.8	31.83	27.52	40.57

On 60 % RH at 40 deg. C basis ash washed coal works out to 25.5

The graph No. 2 shows consistent Ash in samples of washed coal. Values are within a narrow range of 26.5 to 28.5 (analysis on dry basis) the above figures also show that V.M. is increased in washed coal by more than 3 % and F.C. increased by 4 % Both are beneficial for Rotary kiln. Higher moisture in washed coal is the only demerit of this coal. In view of this practice of drying has been introduced for injection coal.

c) Reactivity

Reactivity of clean coal has shown improvement[5]. From around 1.54 reactivity in as received coal reactivity in clean coal has improved up to 1.94 cu. Cm. of co/gm of C-Sec. Increase in reactivity has shown reduction of average temperature at reduction zone by around 30^0C.

RESULTS & DISCUSSIONS

Results of tests on iron ore from two ores A & B shows that ore A is generally more degradable (as obtained from tumbler index) but having higher reducibility.

On processing of ore A in rotary kiln shows higher decrepitating than that in ore B.However both types of ore are being used in different kilns with different parameter of working to achieve good product with both ores. This brings out the resilience of process ore of different characteristics successfully.

Low temperature degradation test under reducing condition brings out the fact that this degradation is due to volume change with crystallographic transformation from hexagonal (hematite) to cubic (Magnetite). The Ore particles are found to have cleavage fracture and not forming very fine particles. As against this tumbler test shows formation of fine particles due to abrasion. In the low temperature degradation test under reducing condition ore A has shown higher reducibility that Ore B.

Successful washing of JOCCM coal has given rise to consistent quality of coal with increased reactivity suitable for rotary kiln On the above test result we are clearly under stand what are the suitable ore characteristics for minimize the accretionaccusation.It is possible

CONCLUSION

1. India because of certain inherent lavational advantages has always been reckoned as a country holding considerable potential for sponge iron making through coal route.
2. Rotary kiln/ reactor both ported and imported ones are being predominantly used for coal based sponge iron making in India.
3. Although the process can handle a wide variety of raw materials, yet it is very sensitive to raw material characteristics, stringent selection of which is of paramount importance.
4. Although India has large no of deposits of iron ore suitable for sponge iron making, non-coking coal suitable for sponge iron making is difficult to find.
5. New coal-based plants are likely to be based predominantly on rotary kilns. However, some entrepreneurs may also contemplate installation of rotary hearth furnaces (RHF). Installation of such facilities will depend on a number of factors such as proximity to raw material sources (iron ore fines, steel plant wastes, etc.) process capabilities, techno-economics, etc.
6. The last two years have witnessed a mushrooming of mini coal-based rotary kilns with capacities in the range of 50 to 100 TPD It is understood what such units have comparatively lower costs of installation. However, Long term prospects of these plant vis-à-vis existing larger capacity units, in a dynamic and competitive market scenario needs to be critically reviewed.
7. Coal quality is one of the most important factors that determine the operating characteristics and general health of a rotary kiln based plant. Unfortunately, the coal sources and qualities earmarked for use by the coal-based plants do not, in majority, meet the desired specifications, principally with respect to ash content. Moreover, plant operators are piagued by other problems such as variation in quality, extraneous matter in as-received coal, etc. These factors also need to be suitably addressed by the DR industry in order to ensure their Long term survival.

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