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Studies on composite pre-reduced pellets of iron ore fines of Sandur area, Bellary district, Karnataka, India

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ABSTRACT

The paper deals with the study of composite pre-reduced pellets prepared using mixture of iron ore fines and non coking coal with bentonite and cement as binders. The iron ore fines from sandur area analysing 66.80% Fe, 1.72% SiO_2, 1.34% Al_2O_3 and 0.043% P has been used for the purpose. Non-coking coal/ coke has been used as reductant. The iron ore fines and reductants of uniform size were mixed in desired proportions to prepare pre-reduced pellets by using laboratory techniques and the parameters were optimised. After pre-heating the pellets were indurated for three different intervals, i.e., 1250°C, 1300°C and 1350°C non isothermally. The tests on pellets were conducted on degree of reduction, porosity, swelling index, compression strength and metallisation. From the experimental studies, the optimum degree of reduction rate of 63% was obtained at 1350°C of 50 minutes with iron ore to coal ratio 1:2. At this stage, the pellets produced possessed good strength of 204 kgs/pellet with porosity 24.0%, swelling index 16.60% and metallisation 78.5%. The composite pellets produced can be subjected to reduction efficiently which gives many advantages as a blast furnace feed in the steel industry in addition to conservation of mineral resources and effective utilisation of iron ore fines in abating the environmental problems.

***Key words**: Iron ore fines, Non-coking coal, Composite pre reduced pellets, Reduction, Steel industry*

INTRODUCTION

Sandur region is endowed with huge deposits of iron ore of different grades. The fast depletion of high grade ore and the demand for the same in the steel

industry calls for an effective utilisation of low to medium grade ores after beneficiation. During mechanised mining and crushing lot of fines are generated. In addition to this, large quantity of naturally occurring blue dust which is in fine form is available. These fines cannot be used directly in the blast furnace. In view of the fast development of steel industries in the Bellary district, it is imperative to utilise these fines in the blast furnace. Keeping this in view, in the present investigation iron ore fines and non coking coal have been used to produce composite pre-reduced pellets. The use of composite prereduced pellets as a blast furnace feed is increasing rapidly in the production of steel. It has been observed that the use of composite pre-reduced pellets has helped in improving the productivity of the blast furnace and has proved as substitute for steel scraps in electric arc furnaces. Because of these advantages, the present work is aimed at preparing a blast furnace feed using mixture of iron ore fines and coal fines with binders to prepare a pellet of suitable size. This not only helps in utilising natural resources which have been dumped as waste in mining and plant areas but also helps in abating environmental problems. During the study, the effects on variables such as temperature, time, iron oxide to carbon ratio on the degree of reduction, porosity, swelling index, compression strength and metallisation have been studied. Direct reduction of iron ore by using solid reductants has been studied by many workers[1-4].

EXPERIMENTAL WORK

Iron ore fines from Sandur area was collected and subjected to chemical analysis. Non coking coal has been used as reducing agent. The chemical analysis of iron ore and the proximate analysis of non coking coal are given in Table 1. Feed of desired size was prepared and kept separately for the experiments. Limestone of 1% and 0.5% bentonite were used as binders. After mixing the iron ore and the non coking coal in different proportions the pellets were prepared using disc pelletiser. Parameters for the preparation of pellets have been optimised. Iron ore to coal molar ratio has been varied from 1:1, 1:1.5 and 1:2. The size of the pellet prepared is of 13-16 mm. The pellets were dried in oven and rolled on a moistened iron ore fines so as to coat on to each of the pellet. To remove the moisture, the composite pellets thus formed were dried in a oven for 6 hours at 110°C and fired at three temperature intervals i.e 1250°C, 1300°C and 1350°C for 50 minutes non- isothermally in a muffle furnace. The reduction behaviour of composite pellets were studied at 10 minutes interval. The change in the weight of the sample at different temperature intervals was noted. The tests on pellets were conducted on degree of reduction, porosity, swelling index, compression strength and metallisation.

Table 1 : Chemical analysis of iron ore and proximate analysis of coal

Constituents (Iron ore)	*Wt.%*	*Constituents (coal)*	*wt. %*
Fe_2O_3	66.80	Moisture	14.0
SiO_2	1.72	Ash	5.2
Al_2O_3	1.34	Volatile matter	35.12
P	0.043	Fixed carbon	46.73

RESULTS

The composite pre-reduced pellets produced by using iron ore and non coking coal were subjected to reduction tests at three different temperature levels with iron ore to carbon molar ratio 1:1, 1:1.5 and 1:2. The effect of temperature, iron ore to carbon ratio, time and other physical properties have been studied and the results are shown in Table 2. From the table it is evident that as theiron ore to carbon ratio in the mixture increases with temperature, the degree of reduction and the strength of the pellet also increase. The pellets fired at 1250°C with molar ratio of iron to carbon 1:2, the degree of reduction was 48% with compression strength of the pellet 96 kg/pellet. There is an increase in the degree of reduction and the strength of the pellet with increase in the temperature of the pellets. At 1300°C the degree of reduction is 51.5% with strength of the pellet 143 kg/pellet. Further increase in the degree of reduction of 63% and the com-

Table 2 : Effect of iron ore/carbon ratio, temperature and time on degree of reduction and other physical properties using non coking coal at 50 minutes

Temperature 0°C	Iron ore/ C ratio %	Degree of reduction %	Porosity %	Swelling index %	Compression strength kgs/pellet	Metallisation %
1250	1:1	42.0	31.6	22.00	77	61.0
	1:1.5	43.5	27.3	18.40	85	62.2
	1:2	48.0	25.0	14.13	96	66.3
1300	1:1	43.6	32.5	19.6	87	63.1
	1:1.5	49.0	29.0	16.3	131	65.8
	1:2	51.5	26.0	14.0	143	67.3
1350	1:1	45.0	30.2	21.3	128	69.4
	1:1.5	54.0	26.0	17.2	163	73.3
	1:2	63.0	24.0	16.6	204	78.5

pression strength of 204 kg/ pellet was observed when the pellets were fired at 1350°C. In all the experiments the pellets were kept at the desired temperature for 50 minutes. The results are represented graphically in Figs. 1-3 as degree of reduction as a function of time with iron ore to carbon ratio 1:1, 1:1.5 and 1:2 which show that the rate of reduction increases with increasing temperature. But at higher temperatures minor cracks were observed. The results obtained shows that with an increase in the heating time, the degree of reduction increased to certain extent and with further increase of time, the degree of reduction started decreasing. In the experimental work, when the iron ore to carbon ratio was studied at 1:1 there is a low reduction which is mainly due to the shortage of reducing agent as the carbon present in the mixture is less than the stoichiometric carbon requirement. Addition of 1% limestone and 0.5% bentonite to the iron ore and carbonaceous mixture has showed increase in the rate of reduction as compared to those pellets prepared without binders.

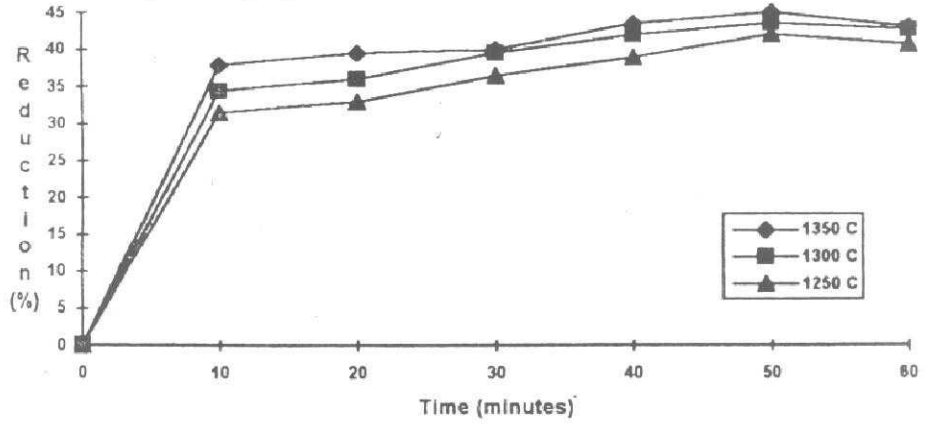

Fig. 1 : Reduction behaviour of iron ore/non-cooking coal composite pellet with Fe_2O_3/C ratio of 1:1

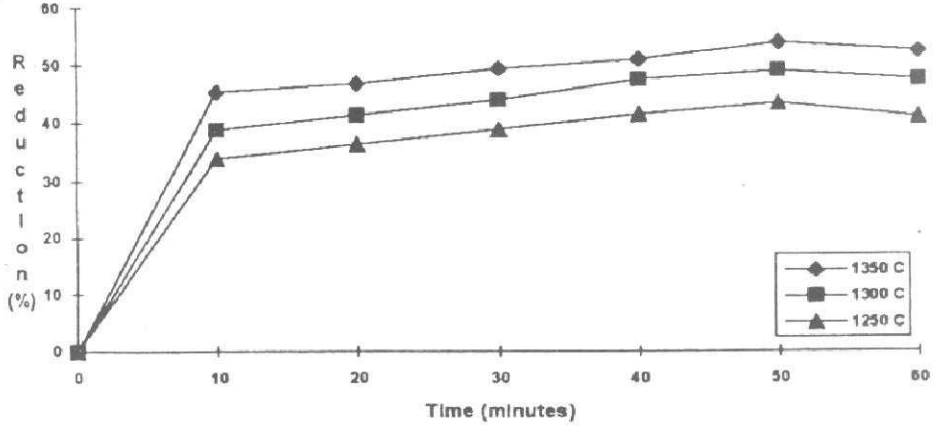

Fig. 2 : Reduction behaviour of iron ore/non-cooking coal composite pellet with Fe_2O_3/C ratio of 1:1.5

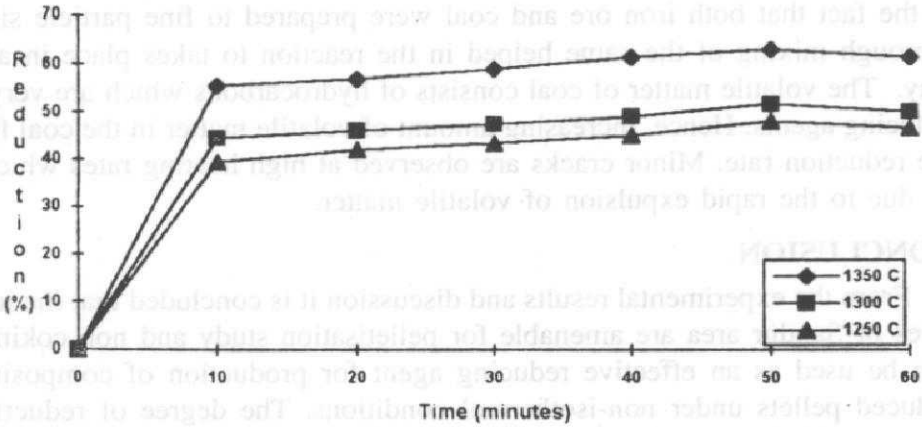

Fig. 3 : Reduction behaviour of iron ore/non-cooking coal composite pellet with Fe_2O_3/C ratio of 1:2

DISCUSSION

From the experimental results it has been observed that the pellets prepared using mixtures of iron ore, non coking coal and binders were subjected to reduction tests by heating under non-isothermal conditions. During the production of composite pre-reduced pellets the initial step is to pelletise with iron and coal fines, then to have a coating with iron ore followed by drying and induration non- isothermally. Iron ore coated on the surface of the pellet acts as a protective coating and it separates iron ore/carbon mixed core from the ambient atmosphere. The reduction of iron ore- coal pellet during heating takes place through reactions in the initial stages and the reductions kinetics equations have been studied by many workers[5,6]. The reduction of iron oxides by carbon occurs through gaseous intermediates Co and CO_2. The reduction of iron oxide commences after pre heating the pellet and continues until all the carbon deplete in the form of CO and CO_2. The sequence of reactions may continue till either of the reactants, i.e., iron ore or coal exhaust in the core while firing a composite prereduced pellet. When firing is continued beyond a stage after exhaustion of the reactants, reduction reaction no longer occur and the surrounding atmospheric oxygen will try to reoxidise the composite pre-reduced pellets. Hence, during the firing of the pellet, it is essential that the pellets be withdrawn from the furnace after achieving maximum reduction. Thus, the freshly reduced iron present in the composite pre-reduced pellet will revert back to its oxide state leading to a decrease in its degree of reduction. Thus, a well fired composite pre-reduced pellet would be composed of metallic iron core surrounded by an annular space due to shrinkage and then the layer of Fe, FeO, Fe_3O_4 and Fe_2O_3 in the shell. Temperature and time have a pronounced effect on the rate of reduction. There is an increase in the rate of reduction of iron ore with increasing temperature and increase in the carbon content of the pellet which is mainly attributed

to the fact that both iron ore and coal were prepared to fine particle size and thorough mixing of the same helped in the reaction to takes place in a faster way. The volatile matter of coal consists of hydrocarbons which are very good reducing agents. Hence, increasing amount of volatile matter in the coal favours the reduction rate. Minor cracks are observed at high heating rates which may be due to the rapid expulsion of volatile matter.

CONCLUSION

From the experimental results and discussion it is concluded that the iron ore fines of Sandur area are amenable for pelletisation study and non coking coal can be used as an effective reducing agent for production of composite pre-reduced pellets under non-isothermal conditions. The degree of reduction increases with increase in temperature and time. Optimum degree of reduction rate of 63% was obtained at 1350°C and firing time of 50 minutes. The degree of reduction increased with increase in carbon proportion of the charge. Optimum degree of reduction is obtained at 1:2 molar ratio. The pellet produced possessed good crushing strength, porosity, swelling index and metallisation. The composite pre-reduced pellets can form a suitable feed for the blast furnace as well as for steel making processes. The principal advantages of the composite pre-reduced pellet route is, in its ability to utilise fines directly without the need of high temperature preparations of raw materials such as sintering. Another advantage is, utilisation of non coking coal because of its projected low cost, good resistance to oxidation during storage, ease of preparation and the effective utilisation of the plant wastes.

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