

Utilisation of iron oxide waste through cold bonded pelletisation

B. B. AGRAWAL¹, K.K. PRASAD¹ and H.S. RAY²

R&D Centre for Iron & Steel, SAIL, Ranchi 834002, India

²Central Glass and Ceramic Research Institute, Calcutta, India

ABSTRACT

India is endowed with large reserves of iron ore. Mechanised mining generates considerable amount of iron ore fines. Additionally, large quantities of slimes are generated from washing of ores at mine-heads. Further, many coal based rotary kiln sponge iron plants are generating huge quantities waste fines within their works. In addition, in integrated steel plants, a lot of iron oxide rich wastes are generated. Some of them are generated mixed with carbon particles or hydrocarbons (oil, etc.). All these pose problems both with respect to economy and ecology.

In RDCIS, work was carried out to pelletise iron ore fines after mixing with up to 10% non-coking coal, and utilise these composite pellets in coal based rotary kiln DR plants. These pellets were cold bonded so that carbon is retained for reduction purpose. After extensive laboratory investigations, these pellets were tested in a rotary kiln DR plant. Composite pellets reduced much faster as compared to lump ore. Metallisation level of over 90% was achieved consistently. Kiln productivity increased and energy consumption decreased substantially. The plant trials established the suitability of composite pellets for DRI production in rotary kilns.

Keywords : Iron ore fines, Iron oxide wastes, Cold bonded pelletisation, Ore-coal composite pellets, Sponge Iron, Rotary kiln.

INTRODUCTION

Iron ore is the basic raw material for iron and steel Industry, and India is one of the few countries in the world endowed with large reserves of good quality iron ore which can meet the growing demand of indigenous iron and steel industry as well as for export. The iron ore in India is within banded iron ore formations, occurring as massive, laminated and friable ore and also in powdery form. Mechanised mining generates considerable amount of iron ore fines. During the

year 1998-99, the total output of iron ore was 70.7 mt¹¹ out of which 34.8 mt (49%) were fines. While majority of these fines are now being utilised for sintering, but the balance is lying unutilised at mine-heads¹². Further, many coal based rotary kiln sponge iron plants are generating high quality waste fines within their works. Another type of fine iron ore is the slime, which is generated from washing of ores and this poses serious environmental problems.

In integrated steel plants, a lot of iron oxide rich wastes are generated. Some of them are mixed with carbon particles or hydrocarbons (oil etc). Efforts are going on to enhance the utilisation of these fines in integrated steel plants, especially in sinter production. Even then, some of the wastes, such as that containing oil, are not finding any use and are being dumped.

NEW IRON MAKING TECHNOLOGIES: NEW REQUIREMENTS

In blast furnace, sized feedstock is needed - iron ore lumps and sinter - but a number of new iron making technologies are being developed as alternate of, and to supplement Blast Furnace technology. These may be grouped under Direct Reduction and Smelting Reduction technologies. In these alternate technologies, iron ore material could be lump ore, pellets or fines depending on the design of the process. For example, in rotary kiln and shaft based DR technologies, conventionally pellets or sized iron ore is needed. There are fluidised bed DR processes where fines are needed. Similarly in smelting Reduction, either sized ore/pellets/sinter are needed (such as Corex), while in others (DIOS, HISMELT) dried fines are used.

Emergence of these alternate technologies and customised reactors thereof has opened up new possibilities to design new feedstock for iron making. Ore-coal composite pellets is one of such possibilities.

COLD BONDED ORE-COAL COMPOSITE PELLETS

While fine iron oxide is difficult to process directly for iron making, once we agglomerate, it becomes suitable for most of the reactors. Mixing the fines with coal before agglomeration has obvious advantages and this aspect is fully utilised in sinter making. However, sinter can be used in very limited number of reactors and bulk usage can only be in blast furnace. Premixing with limited amounts of coal is always an option available in the making of heat hardened pellets, but this option is seldom availed as it hampers the strength of fired pellets which go mainly for use in shaft reactors. Heat hardening adds significantly to the cost of making pellets and consequently only those processes, which can afford such costs, can use these pellets. Attempts with cold bonding have met with partial success in making a suitable shaft furnace feed. While heat-hardening cost is saved, the binders used add to the gangue content and affect the process viability.

Premixing with coal makes the pellets weak and therefore cold bonded ore-coal composite pellets have not proved to be successful shaft furnace feed material.

With regard to sponge iron making, mixing of limited amount of carbonaceous material with iron ore during agglomeration has definite advantages. The reduction kinetics is expected to be enhanced due to the presence of reductants in-situ which causes shortening of diffusion distances of reductant and also because a large number of reaction sites are available simultaneously. These agglomerates have to be necessarily cold bonded since the carbonaceous material is to be retained for reduction. Attempt to heat harden would result in a premature consumption of in-situ reductants.

Cold bonded ore-coal composite pellets have been successfully used in some of the emerging processes which produce sponge iron using rotary hearth furnace (Inmetco, Pelletech, Fastment, DryIron, etc.). In these processes pellets are placed on the hearth of the furnace with minimum of tumbling, as though these are 'flowers.' Pellets are consequently placed either in single layer or in two to three layers. While these processes using rotary hearth reactor have been technically very successful, their commercial viability has remained in question largely due to the following two factors

- a) Very poor utilisation of the volume of reactor, and
- b) Inability or limited ability to use coal as external fuel and reductant.

In a rotary hearth the reducing atmosphere and temperature has to be maintained through partial combustion of costly hydrocarbons (natural gas or fuel oil). Rotary hearth is not easily amenable to using coal for heating and reduction, and hence it was decided to attempt making cold bonded ore-coal composite pellets suitable for reduction in a rotary kiln where coal can be easily used as an external fuel as well as external reductant.

DEVELOPMENT OF COMPOSITE PELLETS

For making the pellets, the effect of granulometry of pellet-mix, type & amount of internal reductants and types and amount of binders were studied in detail. Since it was decided in the beginning itself not to have a heat-hardening step, the strategy was to dry or cure the pellets in ambient atmosphere. These pellets were evaluated with respect to i) dry compression strength for handling purpose and ii) their reduction characteristics for sponge iron making in rotary kiln.

Iron ore from Baitarini (Orissa) and non-coking coal from Haripur (Bihar) were used for making composite pellets. Chemical compositions of these materials are given in Table 1. Pellets of size 10-12 mm were made in a 400-mm dia.

disc pelletiser. Wet pellets were kept for natural curing in ambient atmosphere for 3 to 5 days. The scheme for pellet making is given in Figure 1.

Table 1 : Chemical composition of raw materials

Iron ore	Fe(T)	Fe ₂ O ₃	FeO	SiO ₂	Al ₂ O ₃	CaO	MgO	S	P	(Dry LOI-free basis)
	67.78	91.37	4.90	1.41	2.13	Traces	Traces	0.018	0.07	
Coal	VM = 33.21		Ash = 29.45		FC = 47.34		(Dry basis)			

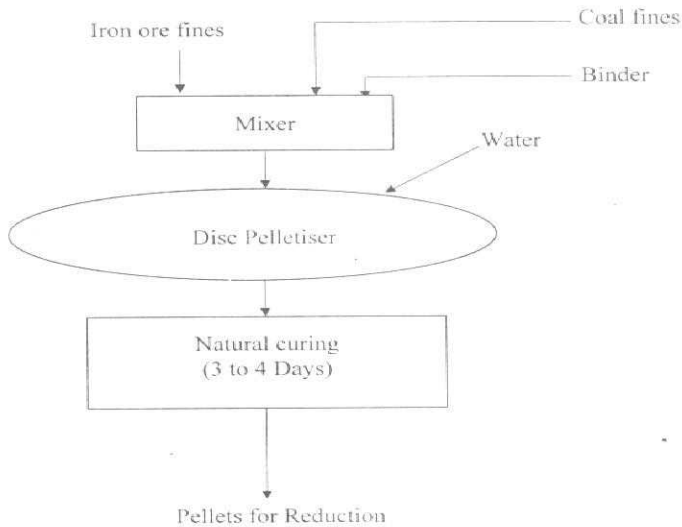


Fig. 1 : Schedule for making cold bonded composite pellets

DRY COMPRESSION STRENGTH CONSIDERATION

Preliminary experience indicated that dry compression strength of around 30 kg/pellet is good enough for handling the pellets in a commercial plant. It was decided to select the binder, granulometry and percentage internal coal to produce pellets of strength not less than 30 kg/pellet. Various binders like bentonite, molasses, dextrine were tried. The granulometry of ore-coal mix was -100 mesh; out of which -325 mesh fraction was varied to see the effect of granulometry. Amount of internal coal was varied from 5% to 15% of the pellet-mix. The pellets were tested for their dry compression strength. The details of these are given elsewhere¹³⁻⁵¹.

Reduction Behaviour Consideration

Dry pellets were reduced in an electrically heated laboratory tube reactor in presence of external non-coking coal under isothermal conditions (1050°C, 15 minutes). The reduction tests were carried out to study the extent of reduction (metallisation) possible, decrepitation level and strength of sponge iron produced. The reduction kinetics of the pellets were also studied separately^[6].

RESULTS OF LABORATORY TESTS

Ore-coal composite pellets were made through a simple cold bonded pelletising process obviating the need for heat hardening step for curing. Aerial curing of 3 to 4 days in ambient atmosphere was adequate to impart dry strength of around 30 kg/pellet. To achieve this, dextrine (4%) was found to be the most appropriate binder. -325 mesh fraction was found critical as it had considerable effect on the strength of dry pellets. Tests during reduction in laboratory rotary tube indicated that 40% -325 mesh fraction in the overall -100 mesh ore-coal mixture was the most suitable granulometry.

Composite pellets with 10% internal coal reduced very fast to reach a metallisation level of about 90% within 15 minutes at 1050°C. This feature of composite pellets is expected to enhance the otherwise low productivity of rotary kiln process. Increased carbon content in the sponge iron, which is produced through composite pellets route, is an additional advantage.

USE OF COMPOSITE PELLETS IN ROTARY KILN PLANT

To verify the laboratory findings, and to test these pellets under industrial process conditions, large-scale trials were conducted in a rotary kiln sponge iron plant. Pellets (6 to 12 mm) were made in a disc pelletiser of 2.35 metre diameter. The granulometry of pellet-mix is given in Table 2.

Table 2 : Granulometry of pellet-mix

Mesh size	+100	-100+200	-200+325	-325
Percentage	8.78%	15.40%	30.25%	45.60%

A simplified flow sheet of plant is given in Fig. 2. Performance of these pellets was evaluated in terms of degree of metalisation of product (sponge iron). Any iron oxide feedstock, which can be metallised up to and above 90% is considered suitable feedstock for rotary kiln. Plant trials were conducted varying the feed rate of pellets and external coal, ratio of pellets and coal and rpm and inclination of the kiln (residence time).

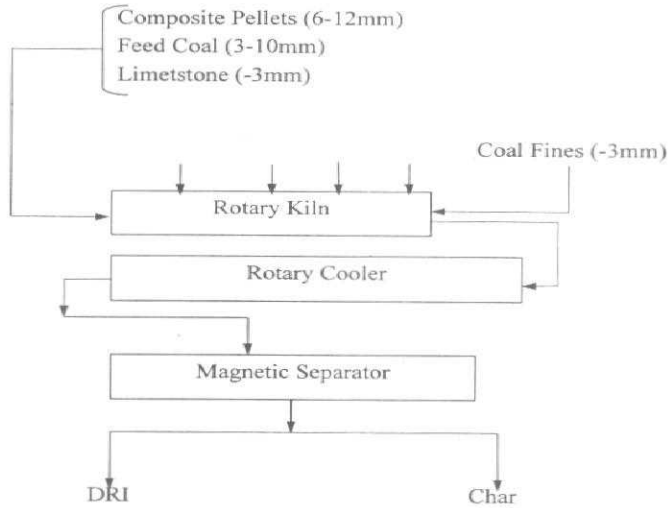


Fig. 2 : Simplified flow sheet of the rotary kiln plant

RESULTS OF PLANT TRIALS

Important observation of plant studies can be summarised as below:

- i) To achieve 90% metallisation, the required residence time in the kiln was found to be only 60 minutes as compared to 200 to 240 minutes for conventional iron ore.
- ii) Requirement of total coal decreased by about 20%.
- iii) Kiln productivity increased almost two-fold.
- iv) Carbon content of sponge iron was in the range of 0.9% to 1.7% as compared to 0.2% in case of lump iron ore.
- v) Careful control of temperature profile in the kiln was necessary to sustain productivity and the quality of product.

Table 3 gives summary of comparison of kiln performance with lump iron ore and with composite pellets.

Table 3 : Comparison of rotary kiln plant performance with iron ore and composite pellets

Sl.No.	Parameter	Lump ore feed	Composite pellet feed
1.	Iron oxide feed	Lump ore (6-20mm)	Composite pellets (8-12mm)
2.	Residence time in kiln and cooler	330 minutes	60-80 minutes
3.	Time in reduction zone	240 minutes	40-60 minutes
4.	Throughput in kiln	300 Kg/hr	600 kg/hr
5.	Carbon in sponge iron	0.2%	0.9-1.7%
6.	Cfix/Fetotal ratio	0.45	0.38-0.41
7.	Ability to accept iron oxide fines	No	Yes (after pelletisation but without any heat induration)

DISCUSSION

Both laboratory and plant trials confirmed the fast reduction nature of pellets. This may be due to the start of reduction-reaction simultaneously at all sites within the composite pellets where coal is present, in addition to the reduction through diffusion of reducing gases from the surface to the core of pellet. Faster rate of reduction facilitated enhancement of throughput in the kiln, which resulted in higher productivity. Higher throughput resulted in elongation of pre-heating zone of kiln and shrinkage of reduction zone. This aspect permitted the charging of most of the coal as injection coal from discharge end of the kiln. This way most of the volatile matter from coal was better utilised within the kiln, thus saving in the energy consumption.

Preparation of pellets, especially the binder, adds to the cost of operation. But there was considerable saving in the cost of coal. Further, the substantial increase in productivity, which was observed, would save fixed costs and thus would make the process viable. Reduction of composite pellets in rotary hearth has so far not been as economical, since it has to use a minimum amount of costly fuel oil, both as fuel and for maintaining reducing atmosphere. Rotary hearths have so far not been found amenable to use coal to fullest extent, which the rotary kiln can do.

CONCLUSION

Cold bonded ore-coal composite pellets were developed using dextrine as a binder. Both laboratory and plant trials showed fast reduction nature of the pellets as compared to lump iron ore. The plant trials established the suitability of composite pellets for sponge iron making in rotary kiln with enhanced kiln productivity and reduced energy consumption. Efficient use of coal as fuel as well as reductant was possible for heating and reducing composite pellets in the rotary reactor and no assistance from hydrocarbon gas or fuel oil was needed.

REFERENCES

1. Chauhan, S.B.S., (April 2000) "Status of iron ores and mines for steel industry", *Iron and Steel Review*, 43(11), p. 8.
2. Sutaone, A.T. Ghosh, S.K. and Raju, K.S., (Sept. 1997), Need and scope for new beneficiation processes in the preparation of raw materials for iron and steel industry, *Proc. Intl. Conf. Raw Materials and Sintering*, Ranchi, India, Vol. I, p. 44.
3. Agrawal B.B., (1996), Ph.D. Thesis, "Development of ore-coal composite pellets and investigations on their reduction behaviour", I.I.T. Kharagpur.
4. Agrawal, B. B. et. al., "Cold bonded ore-coal composite pellets for sponge ironmaking", part 1 - Laboratory scale development, *Ironmaking and Steelmaking* (in press).
5. Agrawal, B.B.et. al., "Cold bonded ore-coal composite pellets for sponge ironmaking", part 2 - Plant trials in rotary kiln, *Ironmaking and Steelmaking* (in press).
6. Agrawal B. B.et. al., (1991), In *Proc. 3rd Intl. Symp. 'Beneficiation and Agglomeration'*, Bhubaneshwar, India, p. 560 .