Study on the Induration Cycle During Pelletization of Goethitic Iron Ore

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Abstract

In the present study an effort has been made to enhance the strength of the roasted iron ore pellets. Concentrates have been generated through beneficiation of slime ores of Bolani, Gua and Dalli mines of SAIL. Preliminary experiments carried out with these concentrates. The DTA/TG analyses of these ores shows the presence of significant amount of goethite. Green pellets of size 9-16 mm were prepared in a laboratory disc pelletiser of 1m diameter with 0.6% bentonite as binder. Thereafter, drying, pre-heating and firing stages of induration have been carried out in a tailor made horizontal zone furnace by varying the process parameters such as temperature and duration of soaking. A strength level of 180 kg/pellet has been achieved by optimizing the process parameters (drying: 250°C / 20 min, pre-heating 900-1100°C / 20 min, firing: 1200-1300°C/ 20 min), which is not satisfying the desired strength value. Some more tests have been conducted with optimizing the drying stage and about 240 kg/pellet strength has been achieved.

Keywords: Goethite Ore, Disc Pelletizer, Iron Ore Pellet, Induration, Cold Compressive Strength

Introduction

Indian blast furnaces are fed with lump iron ore (10 - 40 mm) and sinter as burden. Sinter is a prepared burden, where iron ore fines of size -10 + 0.15 mm are agglomerated using mainly flux and coke. Iron ore fines of less than 0.15 mm are not utilized in sintering technology and hence are mostly discarded at mines during processing as slime. To utilize such very rich quality of iron ore mineral particles, pelletization technology has been developed and commercialized in many places. In line of the use of such technology, SAIL (Steel Authority of India Limited) also has planned to adopt in near future. For green pellet, grinding of ore fines need to be studied; whereas, induration requires a study of high temperature oxidation, grain growth and cementation. Central of preheating and firing cycle are supposed to be the main variable parameters to prepare the quality heat harden pellet, suited to use as BF burden.

A significant step has already been contemplated in SAIL for increasing the proportion of prepared burden in blast furnaces through the introduction of iron ore pellets in BF charge. Various SAIL mines have about 100 Mt of dumped fines and slimes as waste. These are generally low grade iron ores. SAIL Corporate plan envisages the utilization of these low grade iron ores and waste dumps in future by making pellets. These ores should be ground up to micron level for their effective beneficiation. But utilization of these micro-fines is limited in sintering process. Pelletization is the only established route for its effective utilization.

On the other hand, goethite ore (FeO(OH)) contains a significant amount of chemically bonded water (approx. 6%). During pellet induration this water suddenly gets evolved out at a temperature range 350ºC to 450ºC. Some pellets get cracked and some of them gets disintegrated during induration. It significantly affects the strength of the cooked pellet and also the process yield.

Iron oxide pellets are one of the main feed sources for blast furnaces or direct reduction processes of the iron and steel making industry. Pelletizing is the first step in the production of these pellets. The process basically consists of mixing finely ground iron ore concentrate with several additives and water in pelletizing disks or drums until balls of a specific size are obtained (called green pellets). Prior to shipment to steel plants, green pellets need to be fired in order to increase their mechanical strength for transportation and handling considerations. Pellet induration is typically performed in moving grate or grate kiln furnaces[1], through which pellets are sequentially dried, fired and cooled by direct contact with hot gases of varying flow rates and temperatures. Pellets quality (i.e. mechanical strength) strongly depends on their residence time and temperature profile within the firing zone as well as their residual moisture content at the time pellets reach the firing zone, since induration reactions only begin when drying is completed. Pellet drying is therefore a bottleneck for increasing production rate and pellet quality and also is a major energy consumer[2-3] . Patisson *et al* [4-5] reported that about 25 % of the total amount of energy required for pellet induration is used for drying. Thus, any small improvement in the drying performance of sintering furnaces can result in considerable savings for the pellet producer, both in capital and operating costs [2].

Several investigations[1-7] were carried out to study the induration of iron ore green pellets. However, most of such studies have been based on either with total induration process or modelling on the induration process. Relatively few studies[6] have been reported on the drying stage of the induration process. In the present study, an attempt has been made to improve the strength of the roasted iron ore pellets by optimizing the drying stage of induration process.

Constraints with Goethite Ore

Goethite ore (FeO(OH)) contains a significant amount of chemically bonded water (approx. 6%). Extra heat is required for pellet induration to remove this water. This water suddenly gets evolved out at temperature from 350ºC to 450ºC. Some pellets get cracked/disintegrated during induration as shown in **Figure 1**. It significantly affects the strength of pellet and also the process yield.

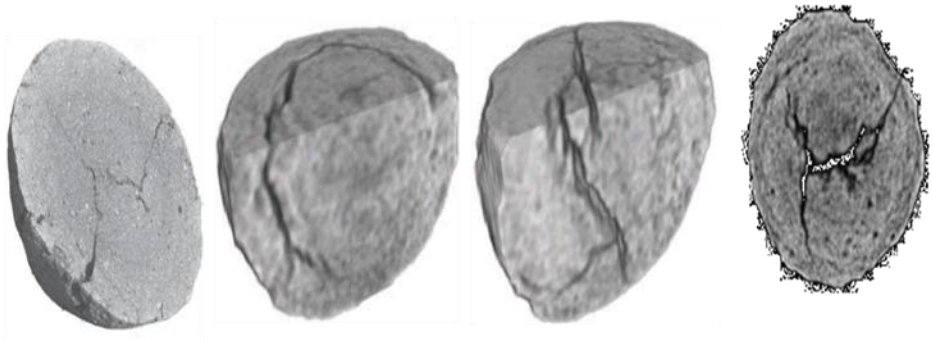


Figure 1: Different Types of Cracks Formed during Induration of Goethite Ores

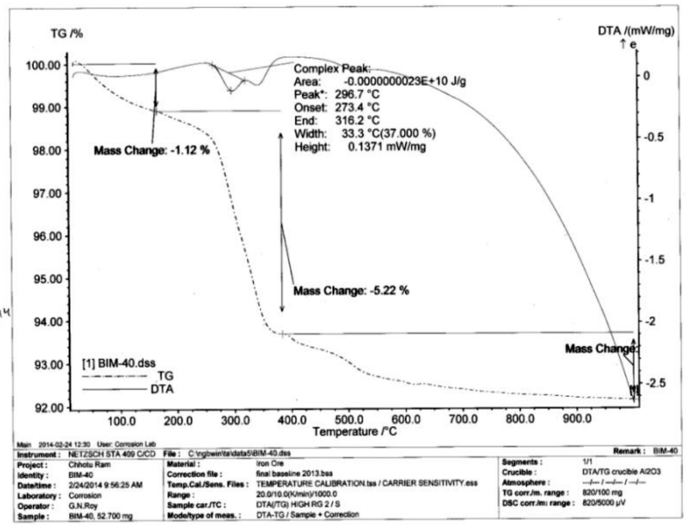
Experimental

Iron ore concentrates of average size less than 100 µm have been generated through beneficiation of slime ore of Bolani, Gua and Dalli mines of SAIL. The chemical analyses of the beneficiated ores are given in Tables 1.

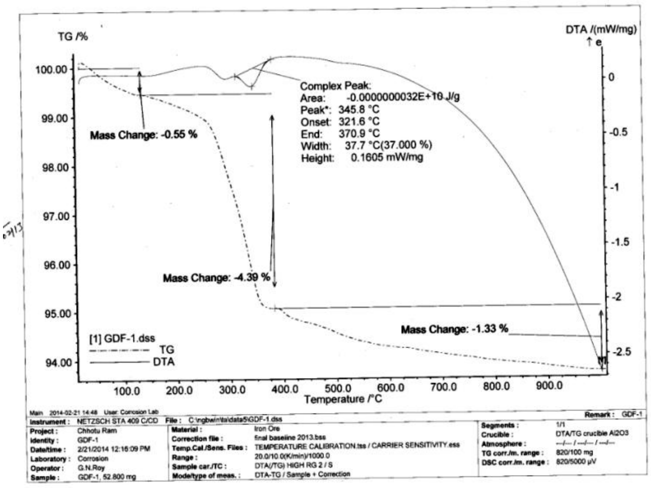
Table 1: Chemical Analyses of Dalli, Gua and Bolani Beneficiated Concentrates

Source of Ore Concentrate	Fe, %	SiO_2, %	Al_2O_3, %	LoI, %
Dalli	63.5	1.5	2.0	4.7
Gua	63.2	1.3	2.2	5.1
Bolani	62.8	1.2	2.1	7.1

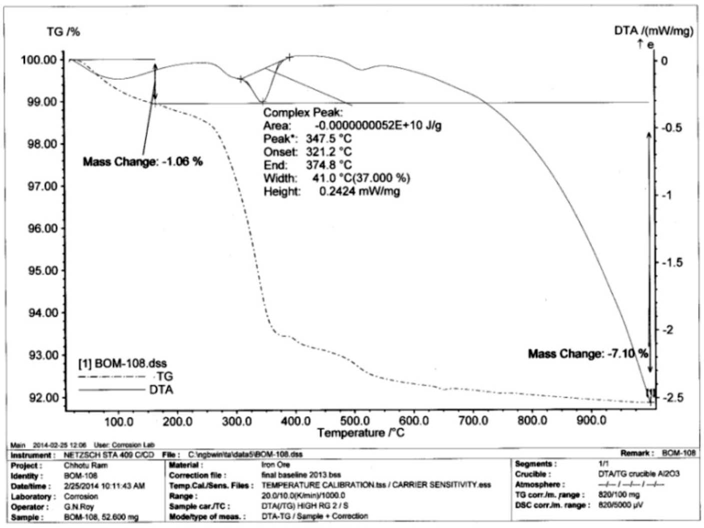
The DTA / TG analyses of these ores are depicted in Figures 2 (a) - (c). Green pellets of size 9 - 16 mm were prepared by a laboratory disc pelletiser of 1m diameter using the ore fines of minimum blaine value of 2,000 cm^2/g with 0.6% bentonite as binder.



(a) Dalli Concentrate



(b) Gua Concentrate



(c) Bolani Concentrate

Figure 2 (a) - (c): DTA/TG Analyses of Different Iron Ores

A schematic of the experimental setup used to study the induration of the green pellets is shown in **Figure 3**. This is a specially designed tailor made horizontal zone furnace.

The Furnace has different Heating Zones (isothermal zones) of 200°C, 1,000°C & 1,400°C designated as drying zone, pre-heating zone and firing zone, respectively. There is a separation between each zone. Separate control system as per required temperature zone with temperature & time variation has been maintained in the furnace. Furnace has rectangular c/s of 120 mm x 150 mm and a depth of 1,600 mm. The maximum temperature of the drying zone has been maintained up to 200°C, but the working temperature is 120°C. Therefore, the temperature of this zone can be varied at any temperature between 50°C and 200°C with ±10°C accuracy. The maximum temperature of the preheating zone has been maintained up to 1000°C, but the working temperature is 900°C. Therefore, the temperature of this zone can be varied at any temperature between 50°C and 1000°C with ±10°C accuracy. The maximum temperature of the firing zone has been maintained up to 1400°C, but the working temperature is 1350°C. Therefore, the temperature of this zone can be settable at any temperature between 50°C and 1400°C with ±10°C accuracy. Thermocouples in different zones are placed at the centre of each zone. Heating element used as Kanthal Tubular for drying zone, Kanthal Globar SD elements (silicon carbide) for pre heating zone and Kanthal Super for firing zone. (*Kanthal is a heating element of Fe-Cr-Al alloy (Fe - 73 wt%, Cr - 2wt% and Al - 6 wt%)*).

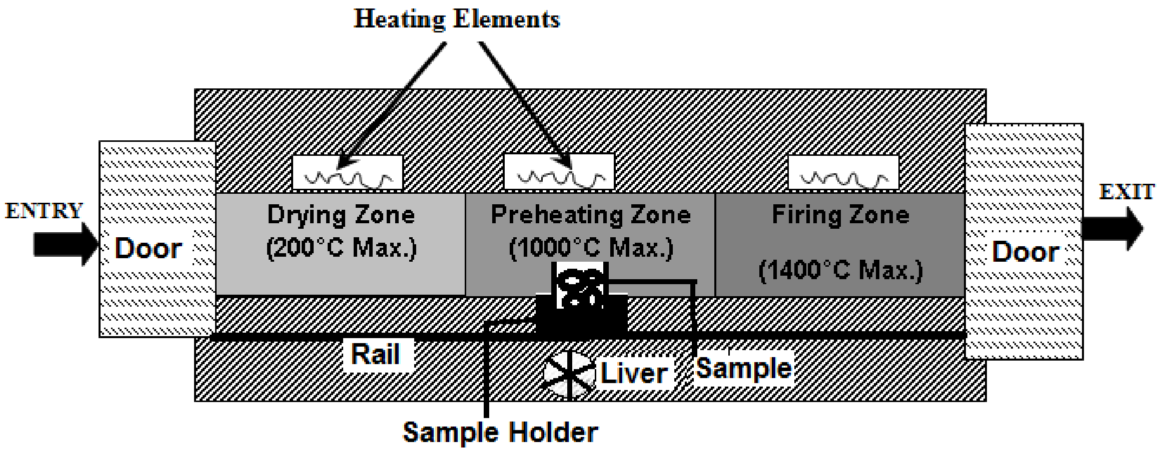


Figure 3: Schematic Representation of the Horizontal Zone Furnace

The doors are front opening type, insert-type, swing-aside, facing away from the operator in any position. There is an arrangement of pushing the trolley which moves on silicon carbide embossed rail by a lever. It carries, keeps and also transfers the special designed ceramic tray with materials of 0.5 to 1.5 kg between the different temperature zones. One scale type zone indicator has been introduced to know the exact work zone of the material. The Cold

Crushing Strength (CCS), porosity, Reduction Degradation Index (RDI) , Reducibility Index (RI) of the roasted pellets were also measured in the laboratory.

Methodology and Results

Two types of indurations have been planned. One type of experiments were conducted through traditional hardening process i.e. Drying at 250°C for 15 min, Preheating at 1000°C for 20 min and Firing at 1350°C for 15 min. The other type of experiments were conducted through special hardening process i.e. Drying at 250°C for 15 min, After Drying at 400°C for 15 min, Preheating at 1000°C for 20 min and Firing at 1350°C for 15 min. In the second case an extra hardening treatment i.e. after drying treatment was given at 400°C for 15 min. The experimental methodology is given in **Table 2**.

Table 2: Different methods of Pellet Induration

Pellet Induration	
Traditional Method	**Special Method**
Drying at 250°C for 15 min	Drying at 250°C for 15 min
	After drying at 400°C for 15 min
Preheating at 1000°C for 20 min	Preheating at 1000°C for 20 min
Firing at 1350°C for 15 min	Firing at 1350°C for 15 min

The results of different tests conducted after hardening of the pellets i.e. Cold Crushing Strength (CCS), Porosity, Reduction Degradation Index (RDI), Reducibility Index (RI) are given in **Table 3**.

Table 3: Salient Properties of the Roasted Iron Ore Pellets

Properties	Values		
	Traditional Method	**Special Method**	**Commercial Grade**
CCS, kg per Pellet	180	240	230-260
Porosity, %	15	18	18-20
RDI, %	8	7	6-8
RI, %	58	61	58-62

After drying treatment during induration results in higher CCS value[8] and the pellets also exhibit better properties (porosity, RDI, RI, etc) compared to the traditional hardening treatment. This may be due to smooth evolution of chemical water of goethite ores. It can be assumed that constant rate of heat transfer from the pellet surface to interior results in smooth evolution of chemical water which in turns results superior properties of the roasted pellets. **Table 3** also reveals that pellets obtained in special hardening treatment method i.e., after drying treatment exhibit the properties in line with the commercial grade.

To show the effects of blaine numbers of the iron ore fines concentrate, some more tests were also conducted by changing the blaine values. the blaine values were varied from 2000 to 4000 cm^2/g. But no significant change in CCS values were observed as shown in **Figure 4**.

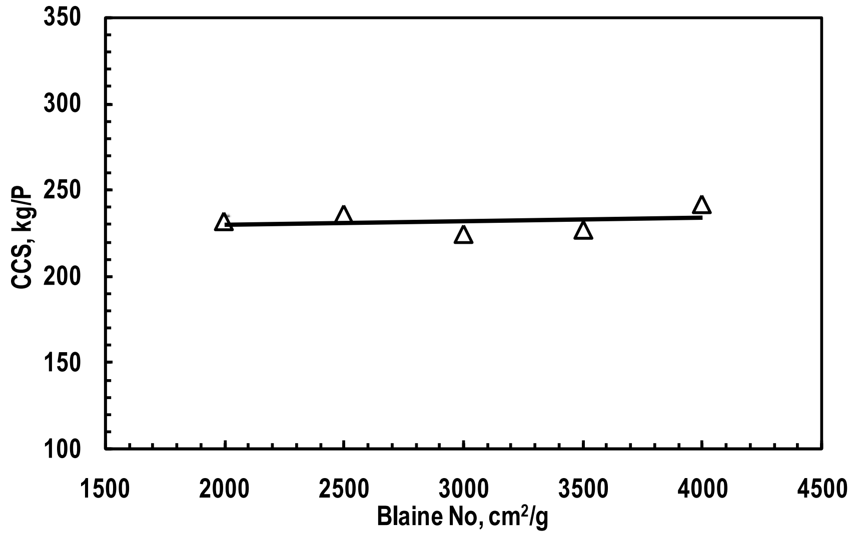


Figure 4: Effect of Blaine no. on CCS Values of the Roasted Pellets

Additional experimentation with more modification of the drying stage is required for the induration to exhibit better properties of the roasted pellets made from goethite ore.

Conclusions

- Green pellets of size 9-16 mm were prepared in a laboratory disc pelletiser of 1m diameter using goethite ore (LoI: 6%) with 0.6% bentonite as binder.
- A tailor made horizontal zone furnace has been designed, developed and installed at RDCIS Complex to simulate the iron ore pellet induration process.
- After drying treatment shows higher CCS value and the pellets also exhibit better properties such as porosity, RDI, RI, etc.
- Pellets obtained in special hardening treatment method i.e., after drying treatment exhibit the properties in line with the commercial grade
- Variation of Blaine Number has no significant effect on the CCS value of the roasted .

Acknowledgement

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References

1. K. Meyer, Pelletizing of Iron Ores, Springer-Verlag, Berlin, 1980
2. K.N. Clark, Trans. Inst. Min. Metall. C. Vol. 90C (1981), pp. C66–C72.
3. J.A. Thurlby and R.J. Batterham, Trans. Inst. Min. Metall. C. Vol. 89C (1980), pp. C66–C72.
4. F. Patisson, J. P. Bellot, D. Ablitzer, Metall. Trans. B, Vol 21 B(1990), pp. 37–47.
5. F. Patisson, J. P. Bellot, D. Ablitzer, E. Marli, C. Dulcy and J. M. Steiler: *Ironmaking Steelmaking*, 18 (1991), 89.
6. D.F. Ball, J. Dartnell, J. Davison, A. Grieve, R. Wild, Agglomeration in iron ores, Heinemann Educational Books Ltd., London, 1973.
7. T. Tsukerman, C. Duchesne, D. Hodouin, Int. J. Miner. Process, vol. 83 Z2007), pp. 99–115.
8. International Standard ISO4700:1996(E). ‘Iron ore pellets - determination of crushing strength’, 1996.