International Journal of Mineral Processing 126 (2014) 76–89

Contents lists available at ScienceDirect

International Journal of Mineral Processing

journal homepage: www.elsevier.com/locate/ijminpro

Effect of fluxing agents on the swelling behavior of hematite pellets

Srinivas Dwarapudi [a,*], P.K. Banerjee [a], Pradeep Chaudhary [a], Surajit Sinha [a], Ujjal Chakraborty [a], Chandra Sekhar [a], T. Venugopalan [a], R. Venugopal [b]

[a] Tata Steel Ltd, Jamshedpur, India
[b] FME, ISM University, Dhanbad, India

ARTICLE INFO

Article history:
Received 7 September 2013
Received in revised form 26 November 2013
Accepted 29 November 2013
Available online 5 December 2013

Keywords:
Limestone
Magnesite
swelling
pyroxenite
MgO pellets

ABSTRACT

Pellet properties are largely governed by the form and degree of bonding achieved between ore particles during induration and the stability of these bonding phases during reduction. Fluxing agents play an important role in forming these bonds by forming different phases depending on the type of flux. In the present study, effect of different fluxing agents, viz., limestone, magnesite and pyroxenite, on melt formation & microstructure during the induration and on swelling behavior during reduction, was examined. Optical microstructural studies with image analysis were carried out to estimate the amount of different phases. SEM-EDS analysis was done to measure the chemical analysis of oxide and slag phases. X-ray mapping was also carried out to understand the distribution of CaO, MgO, SiO_2 and Al_2O_3 in different phases. From the results, it was observed that limestone addition decreased the swelling at lower basicity but exhibited highest swelling at 0.6 basicity and decreased thereafter. Formation of low melting point calcium olivines between Fe_2SiO_4 and Ca_2SiO_4 can be attributed to the highest swelling at 0.6 basicity. With increasing addition of magnesite and pyroxenite, pellet swelling found to be decreased considerably. Formation of magnesioferrite phase and high melting point slag formed during induration could be attributed to the improved swelling of magnesite and pyroxenite fluxed pellets. Limestone fluxed pellets at 0.8 basicity, pyroxenite fluxed pellets at 1.5% MgO and magnesite fluxed pellets at 1.0% MgO exhibited low swelling behavior among all the pellets studied.

1. Introduction

Quality of agglomerates plays a vital role in decreasing the fuel rate and increasing the productivity of blast furnace. Modern blast furnaces essentially need most of the iron bearing burden in the form agglomerates, viz., sinter or pellets. Pellets usage has been increased now-a-days due to their advantages like uniform size and shape, high strength and low disintegration during handling and reduction. But during reduction, pellets expand or swell, thereby crack and disintegrate in to fines leading to lower gas permeability and low productivity of blast furnace. In the earlier studies, it was observed that pellet swelling can be reduced by controlling their chemical composition and pelletizing & reduction parameters (Sharma et al., 1990; Sharma et al., 1992; Frazer et al., 1975).

Chemical composition of pellets can be varied by varying the type and amount of the fluxing agents. In fluxed pellets, the bonding is achieved through silicate melt formation during induration. The amount of gangue in the concentrate, CaO & MgO in the fluxes and the binder influence the amount and chemistry of oxide and melt phases. CaO fluxes silicate melt as well as reacts with iron oxide to form different calcium ferrites. MgO either enters the magnetite lattice to form magnesioferrite or dissolves in the slag phase (Frill et al., 1980). These melting phases interact with each other and dissolve a variable amount of iron oxides. As the formation of phases and microstructure during induration depends on the type and amount of fluxes added, there is a need to study the effect of these fluxing agents on pellet quality, especially on swelling behavior.

It is important to note that conditions and parameters of pelletizing are specific to given ore or concentrate; the present study is undertaken for friable high alumina hematite iron ore fines from Noamundi region in Singhbhum craton of eastern India. These friable iron ore fines contain hematite, goethite, quartz and weathered shale as primary minerals. The alumina is mainly contributed from the shale bands in the form of kaolinitic saprolite (Beukes et al., 2008). Hematite from such fines shows variable quantities of impurities like Al and Si which amount up to 3.0 to 5.0% within the hematite mineral structure (Roy and Das, 2008).

In the present study, effect of different fluxing agents, viz., limestone, pyroxenite and magnesite, on melt formation & microstructure during the induration and on swelling behavior during reduction, was examined. Optical microstructural studies with image analysis were carried out to estimate the amount of different phases. SEM-EDS analysis was done to measure the chemical analysis of oxide and slag phases. X-ray mapping was also carried out to understand the distribution of CaO,

* Corresponding author at: R&D, Tata Steel Ltd, Burma mines post, Jamshedpur-831007, Jharkhand, India. Tel.: +91 6572648928 (Office), +91 7763807389 (mobile), fax: +91 65722717.
E-mail address: srinivasd@tatasteel.com (S. Dwarapudi).

0301-7516/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.minpro.2013.11.012

Table 1
Chemical composition of materials used for pelletizing.

Constituents, wt.%	Iron ore	Bentonite	Limestone	Magnesite	Pyroxenite	Coal
Fe(t)	66.6	14.2	1.0	1.0	11.0	0.5
SiO_2	1.5	55.5	1.7	4.3	52.2	8.0
Al_2O_3	2.1	17.6	0.1	0.4	0.9	3.9
CaO	0.2	1.5	51.2	6.0	0.8	0.2
MgO	0.1	2.9	4.4	45.0	29.5	0.2
LOI	1.1	3.1	40.2	49.1	–	6.7
Fixed carbon	–		–	–	–	77.0

Table 2
Particle size distribution of the ground materials used for pelletizing.

Size range (μm)	Iron ore	Bentonite	Limestone	Magnesite	Pyroxenite	Coal
+150	10.8	0.0	15.4	12.8	29.3	7.7
−150 + 75	13.3	2.2	14.8	11.1	27.2	28.8
−75 + 63	5.9	97.8	5.8	4.9	8.2	12.1
−63 + 45	4.1	–	3.6	5.9	2.9	15.0
−45 + 37	11.0	–	5.7	8.8	4.1	3.0
−37 + 25	4.0	–	5.3	8.3	6.4	4.5
−25	50.9	–	49.4	48.4	21.9	28.9

MgO, SiO_2 and Al_2O_3 in different phases. It was attempted to establish correlation between pellet chemistry (in terms of CaO and MgO) and its swelling behavior.

2. Experimental

The following materials were used for preparing the green pellets: iron ore fines, bentonite, anthracite coal, limestone, pyroxenite and magnesite. All these raw materials were ground separately in laboratory ball mill to get the required fineness for pelletizing. The chemistry and particle size distribution of the all the materials are given in Table 1 and Table 2 respectively. Bentonite is hydrous alumino-silicate, largely composed of montmorillonite clay mineral. Coal used was anthracite with medium volatile matter. Magnesite is a naturally occurring magnesium carbonate mineral ($MgCO_3$), found in two different forms, crystalline and cryptocrystalline. The magnesite used in the present work is of cryptocrystalline with off-white color due to the presence of silica. Pyroxenite is a magnesium silicate rock composed largely of pyroxene with small amounts of olivine and serpentine. Table 3 shows the chemical formula and theoretical MgO content of these minerals (Lonial and Verma, 1997).

Green pellets were prepared using a laboratory balling disc with a diameter of 600 mm, an edge height of 200 mm and a tilting angle of 45° at 27 rpm. During balling, green pellets were screened with 10 mm and 12.5 mm screens to get 10–12.5 mm pellets. The amount of ingredients added for preparing green pellets with varying limestone, pyroxenite and magnesite is shown in Tables 4, 5 and 6 respectively.

Table 3
Chemical formula and theoretical MgO content of magnesium silicate minerals.

Mineral	Chemical composition	Theoretical values of MgO%
Pyroxene	$MgSiO_3$	40
Olivine	Mg_2SiO_4	57
Serpentine	$3MgO{\cdot}2SiO_2{\cdot}2H_2O$	43

Table 4
Ingredients of green pellets with varying amount of limestone and their quality.

	Pellet L1	Pellet L2	Pellet L3	Pellet L4	Pellet L5
Iron ore, wt.%	97.8	97.3	96.6	95.9	95.1
Bentonite, wt.%	0.8	0.8	0.8	0.8	0.8
Limestone, wt.%	0.0	0.5	1.3	2.0	2.8
Coal, wt.%	1.4	1.4	1.4	1.3	1.3
Green pellet quality					
Drop number	4.6	3.9	3.7	4.3	4.4
Green crushing strength, kg/pellet	1.6	1.8	1.8	1.9	1.8
Green pellet moisture,%	7.9	7.6	7.4	6.9	7.6

Table 5
Ingredients of green pellets with varying amount of pyroxenite.

	Pellet P1	Pellet P2	Pellet P3	Pellet P4	Pellet P5	Pellet P6
Iron ore, wt.%	96.7	95.1	93.3	91.6	89.9	88.3
Bentonite, wt.%	0.8	0.8	0.7	0.7	0.7	0.7
Pyroxenite, wt.%	1.2	2.9	4.7	6.3	8.0	9.7
Coal, wt.%	1.4	1.3	1.3	1.4	1.3	1.3
Green pellet quality						
Drop number	4.3	4.4	4.3	4.4	5.1	4.9
Green crushing strength, kg/pellet	1.7	1.6	1.7	1.6	1.6	1.62
Green pellet moisture,%	7.1	6.7	7.9	7.5	7.9	7.8

Table 6
Ingredients of green pellets with varying amount of magnesite.

	Pellet M1	Pellet M2	Pellet M3	Pellet M4	Pellet M5	Pellet M6
Iron ore, wt.%	96.9	95.8	94.7	93.5	92.4	91.3
Bentonite, wt.%	0.8	0.8	0.8	0.7	0.7	0.7
Magnesite, wt.%	1.0	2.1	3.2	4.4	5.5	6.6
Coal, wt.%	1.4	1.3	1.3	1.4	1.4	1.4
Green pellet quality						
Drop number	3.8	4.4	4.4	4.0	2.8	4.6
Green crushing strength, kg/pellet	1.8	1.9	1.7	1.5	1.9	1.9
Green pellet moisture,%	7.4	7.0	8.2	7.6	7.2	7.2

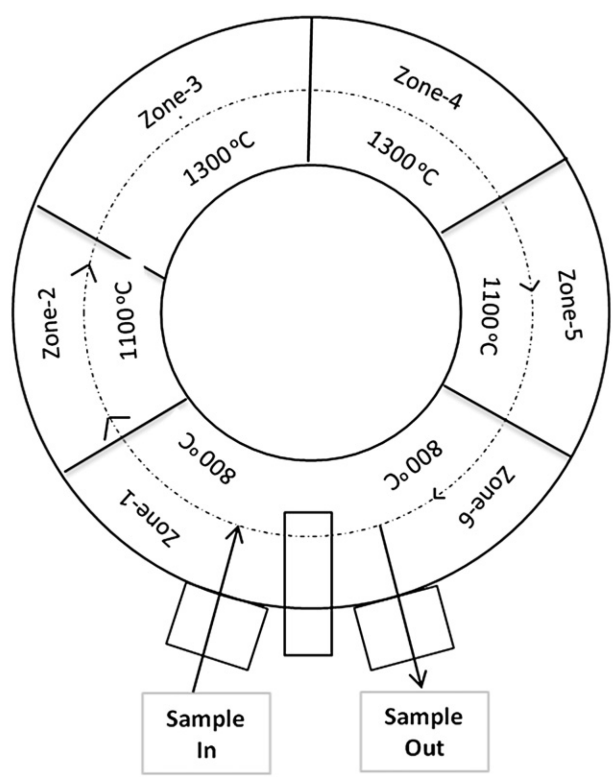

Fig. 1. Schematic diagram of rotary hearth furnace used for firing the pellet samples.