

# Abstract

## BACKGROUND

Iron making furnaces like the blast furnace or shaft furnace need burden that form a permeable bed, permitting the reducing gases to flow through it uniformly at a high rate. Powdered iron ore fines or concentrates are not suitable in their as-produced form because they tend to pack into voids, permeable areas and thus make the bed non-permeable. With the adoption of the mechanized mining and close sizing of the iron ore, the quantity of fines generated has increased. For economic reasons, optimum utilization of these fines is essential. The most common agglomeration techniques in industrial practice are sintering and pelletizing. While the sintering process utilizes ore fines in the size range of minus 10mm to 0.15 mm, ore fines less than 0.15mm size can only be utilized through the pelletizing process.

Pellet quality plays a vital role in decreasing the reducing agent consumption and increasing the productivity of the blast furnace. More attention has been given in recent years to the use of fluxed pellets in the blast furnace due to their good strength and improved reducibility, swelling and softening melting characteristics.

Generally, the quality of pellets is influenced by the nature of ore or concentrate, associated gangue, type and amount of fluxes added and their subsequent treatment to produce pellets. These factors, in turn, result in the variation of physicochemical properties of the coexisting phases and their distribution during pellet induration. Hence properties of the pellets are largely governed by the form and degree of bonding achieved between the ore particles and the stability of these bonding phases during the reduction of iron oxides. As the formation of phases and microstructure during induration

predominantly depends on the type and amount of the fluxes added, there is a need to study the effect of these fluxing agents on pellet quality.

It is important to note that conditions and parameters of pelletizing are specific to a given ore or concentrate; the present study is undertaken for hematite ore fines from Noamundi region of the eastern India. This necessitates detailed study on the characterization of the iron ore fines, different fluxes and their behaviour during pellet making and pellet induration. Physical and metallurgical properties of the pellets made out of different fluxes need to be tested and correlated with the pellet chemistry. The main objectives of the present study are;

- I. Establishing green pelletizing characteristics of the iron ore fines from Noamundi region
- II. Carryout detailed pelletizing and induration studies with different fluxes like limestone, dolomite, pyroxenite and magnesite
- III. Establishing correlation between the pellet quality and its chemistry in terms of  $\text{CaO/SiO}_2$  ratio and MgO content using different fluxes mentioned above.

The objective also includes establishing an optimum pellet chemistry for Tata Steel's 6 MTPA pelletizing plant at Jamshedpur. Optimum pellet chemistry with superior physical and metallurgical properties will

- reduce the specific energy consumption of the pelletizing
- increase the productivity of the blast furnace
- decrease the fuel rate of the blast furnace

## PLAN OF WORK

- Detailed characterization of Noamundi iron ore fines and the fluxes by QEMSCAN microscope, XRF, XRD and TGA.
- Grinding and granulometry studies to find out the effect of grinding time on particle size distribution (PSD) and mean particle size of the ground ore.
- Green pelletizing trials with the Noamundi iron ore fines to understand the effect of fineness of pelletizing feed on the drop number, green crushing strength and moisture content of the green pellets.
- Green pellet growth studies to establish correlation between the feed fineness and  $D_{50}$  of green pellets. Considering the green pellet quality and growth characteristics, an optimum feed fineness to be established.
- Pellet firing tests to establish the right firing temperature for a given feed fineness and targeted cold crushing strength of the pellets.
- Detailed laboratory tests to prepare the pellets with varying CaO and MgO contents using different fluxes like limestone, dolomite, magnesite and pyroxenite.
- Detailed metallurgical testing of the pellets, viz., swelling, reducibility, reduction degradation, cold crushing strength and softening-melting characteristics to establish correlation between the pellet chemistry (in terms of CaO/SiO<sub>2</sub> & MgO) and quality.
- Optical microscope with image analysis and electron microscopic studies with EDS analysis to quantify the formation of different phases, their chemistry and microstructure in the fired pellets.
- Structure-property correlation between the pellet chemistry, microstructure and their metallurgical properties.

## MAJOR FINDINGS

- Primary iron minerals in the Noamundi iron ore fines are hematite and goethite. Kaolinite, limonite, gibbsite and quartz are present as gangue minerals. Hematite and goethite are present in the proportion of 68% and 30% respectively. 90% of the alumina in the sample is associated with goethite, gibbsite and kaolinite.
- Liberation analysis revealed that goethite is more liberated in the finer fractions and hematite in the coarser fractions.  $\text{Al}_2\text{O}_3$  is predominantly contributed by goethite and the average  $\text{Al}_2\text{O}_3$  content in the goethite is around 3%.
- Pelletizing feed with mean particle size of 55 microns exhibited optimum green pellet properties viz., drop number, green compression strength and moisture content.
- Pellets need to be fired up to  $1300^\circ\text{C}$  to obtain cold crushing strength desired for blast furnace.
- Acid pellets exhibited highest swelling during reduction, whereas maximum swelling in the limestone fluxed pellets was observed at 0.6 basicity ( $\text{CaO}/\text{SiO}_2$ ). Addition of MgO to both acid and limestone-fluxed pellets at all basicity levels considerably reduced the swelling tendency and improved reducibility of pellets due to the formation of high melting point slag that gives sufficient bond strength to withstand the reduction stresses and retains the porosity.
- Limestone fluxed pellets at 0.8 basicity and dolomite fluxed pellets at 0.4 basicity & 1.5% MgO exhibited optimum metallurgical quality parameters.
- In magnesite pellets, MgO resulted in the formation of magnesioferrite in the fired pellets. FeO content of the silicate melt/slag phase in the pellets decreased from 30% in the acid pellets to around 5% in the magnesite fluxed MgO pellets. Lower FeO in the melt increases its melting point.

- Magnesite fluxed pellets decreased reduction degradation and improved the reducibility in the range of 1.0 to 1.5%MgO.
- For the first time, pyroxenite (magnesium silicate mineral) was established as suitable flux for the pelletizing. Unlike carbonate fluxes like limestone or dolomite, pyroxenite does not undergo any endothermic reaction for its dissociation.
- Addition of pyroxenite up to 5% to get 1.5% MgO in the pellets was found to be an optimum flux dosage for the blast furnace grade hematite pellets. Pyroxenite addition beyond 5% showed its poor assimilation in the pellet matrix and increased the amount of relict magnesium silicate phase resulting in no further drop in the slag FeO.
- RDI of the pyroxenite pellets was found to be superior, compared to the acid pellets, due to the formation of magnesioferrite and more amount of silicate melt, which are more stable under the reducing conditions in the blast furnace.
- Advanced metallurgical tests indicated that a minimum of 0.9% MgO is required in the pellets to obtain the desired metallurgical properties.
- A new dimensionless index called “composite quality index” (also called ‘p-index’) has been formulated for the pellets. This index can be used as a tool to relatively compare quality of different pellets based on vital metallurgical quality parameters.
- Based on the resultant pellet quality observed during this entire test work and availability of fluxes at the captive mines, pyroxenite fluxed pellets were suggested as suitable burden material for the blast furnaces at Tata Steel.
- A patent was also filed on the use of magnesium silicate (pyroxenite) as flux in the pelletizing for improved metallurgical properties.
- Use of pyroxenite flux for pelletizing the Noamundi iron ore fines, as suggested, resulted in improved metallurgical properties of the pellets, especially swelling index and reducibility, at the 6 MTPA capacity iron ore pelletizing plant of Tata Steel at Jamshedpur.