Characterization And Processing Of Low Grade Iron Rich Manganese Ore

U.M Reddy, S.J Gopalkrishna, P.S Kumar, Basavaraj Hatti.

Abstract: Manganese consumption in steel and alloy making has increased rapidly because of the important role of manganese in carbon steel production. The increasing need for good grades of manganese ore makes steel and alloy makers to think on the beneficiation of low-grade manganese ores more economical usage. In the current study, the characterization and beneficiation studies of low grade iron rich manganese ores of Sandur area, India were carried out to propose a flow sheet for typical low-grade manganese ores. For this aim, different gravity separation methods were applied. According to the mineralogical analysis, the major mineral phases are pyrolusite (MnO2) and psilomelane (MnO2) while the major gangue mineral is hematite and limonite Gravity separation tests were accomplished by using jigs, in order to obtain products with high Mn ratio, high intensity magnetic separation was also performed after the reduction roasting. As a result, flow sheet is proposed based on the laboratory studies to obtain a concentrate 40.2% Mn, 20.1% Fe, 6.24% acid insoluble, 0.85% LOI and Mn/Fe ratio >2 could be obtained with Overall % Mn distribution of 63.3 at overall wt.% yield of 49% meeting the local and ferromanganese and steel industry specifications and may be used after sintering..

Key words: Jigging, Magnetic separation, Manganese, Reduction roasting

1. INTRODUCTION

The depletion of high grade ores, closure of mines due to governing regulations, environmental reasons and exponential demand for clean products mostly by iron and steel industry and utilization of low grade ores, mine wastes for economic, mineral and environmental conservation, warrants the evolution of low grade and problematic/ refractory ores, processing for yielding saleable products. In view of this, recovery of manganese values from iron rich low grade manganese ores of Sandur area has a vital significance (Acharya et al, 2003; U.M Reddy and SJG Krishna, 2018). In total production of steel making in the world, approximately 95 % of manganese is used to form ferro-manganese-alloys which intern act as a deoxidizing and desulfidizing agent (Acharya et al, 2003). From many years Manganese ores have been undergone various types of beneficiation techniques for effective separation of iron inclusions. The processing of manganese ores is dependent upon the Mn content of the ore where high grade manganese ores are processed into suitable metallic alloy formed by pyrometallurgical processes, the hydrometallurgical processing of low grade manganese ores is performed after conventional pyrometallurgical reductive roasting for the manufacturing of chemical manganese dioxide (CMD) or electrolytic manganesedioxide (EMD) (Zhang, 2007). Manganese ore is typically classified into three grades based on the manganese content of the ore. High grade ores contain 44–48% and above while medium and low grade ores contain 35–44% and 25–35% and lower Mn respectively (Acharya et al, 2004). For beneficiation of manganese ore, gravity separation techniques can be used to remove ferrous gangue minerals but additionally high intensity magnetic separation is required to obtain products with high Mn ratio in the non magnetic concentrate (Huaming and Guanzhou, 1998; Singh et al, 2011). In this study, the characterization and beneficiation studies have been carried out for increasing the Mn/Fe ratio in concentrate and Flowsheet is proposed for the utilization of low grade iron rich manganese ores of Sandur area based on the laboratory beneficiation studies.

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2 CHARACTERIZATION

2.1 Raw materials

Manganese ore samples were collected from Sandur area India contains -10mm size fractions of flaky manganese mineral and also needles shape. Specific gravity of 4.1, bulk density 2.8t/m^3 and angle of repose 33°. The chemical analysis of the samples is given in Table 1. The results indicated that Mn+Fe value was 55.11%, Mn/Fe ratio was 1.2 with 6.94% of silica+alumina and low Phosphorous. The table 2 shows the size analysis of the received sample

Table 1: *Chemical composition of low grade Mn ore sample*

Radical	Assay %
Mn	30.83
Fe	24.28
SiO_2	3.86
P	0.03
Al_2O_3	3.08
LOI	7.89
Mn/Fe	1.2

2.2 Mineralogy

The mineralogical data is given in Table 2 and shown in Fig 1 (A-D). The sample consists of hematite and manganese minerals (pyrolusite, psilomelane as major along with goethite/ limonite and martitised magnetite of the sub-ordinate amount). Clay, quartz+ feldspar, gibbsite, pyroxene/ amphibole, mica and jacobsite are found in minor to trace amount. and liberation data and found that gravity method of separation is not possible to these type of ores because of presence of hematite inclusion in the manganese lattice. And requires reduction roasting to convert the hematite in to magnetite for effective separation at fine sizes.

Table 2: *Mineralogy of ferruginous manganese samples collected from the study area*

Mineral	Description
Pyrolusite Psilomelane	Manganese minerals such as pyrolusite, psilomelane/ cryptomelane, occur as fine to medium-sized grain at minus 72 mesh size. Most of the manganese minerals are interlocked at minus 72 mesh size fig 5.16 (A&B)
Hematite	Hematite occurs as fine-sized grain at minus 72 mesh size. Most of the hematite grains are free from interlocking at minus 72 mesh size Fig.5.16 (C&D)
Goethite and Limonite	Goethite/ limonite occur as fine to medium-sized grain at minus 72 mesh size. Most of the goethite/ limonite grains are interlocked with hematite, martitized magnetite, clay and manganese minerals. Fig 5.16 (D)
Martitized magnetite	Martitised magnetite occurs as fine to medium-sized grained at minus 72 mesh size.
Quartz	Quartz+ feldspar occur as fine and medium-sized grained at minus 72 mesh size. Most of the quartz+ feldspar grains are containing opaque particles as inclusion
Ferruginous clay+ Gibbisitic clay	Clay occurs in fine-sized grain and almost all the grains are interlocked with iron and manganese minerals

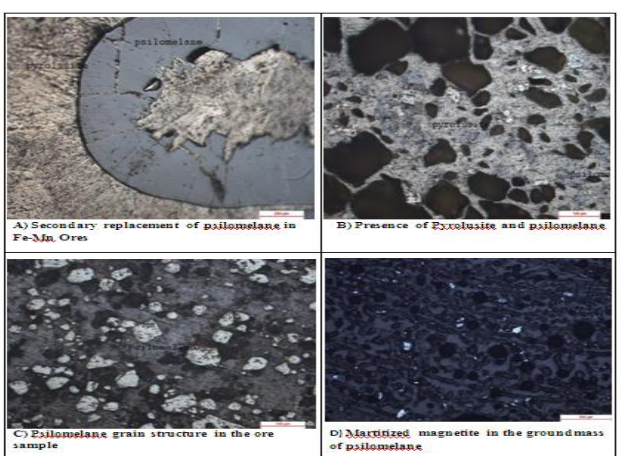

Figure 1 (A-D): Photomicrographs of ferruginous manganese ore samples

2.3 X-Ray Diffraction Studies:

The X-Ray diffraction study was carried out for the feed sample to confirm the different mineral phases present in the ore samples and results are shown in Figure 2. From Figure 2, it was found that the pyrolusite, psilomelane, are the major Mn ore minerals and hematite and goethite as the major gangue minerals in the ore sample confirming the mineralogical findings.

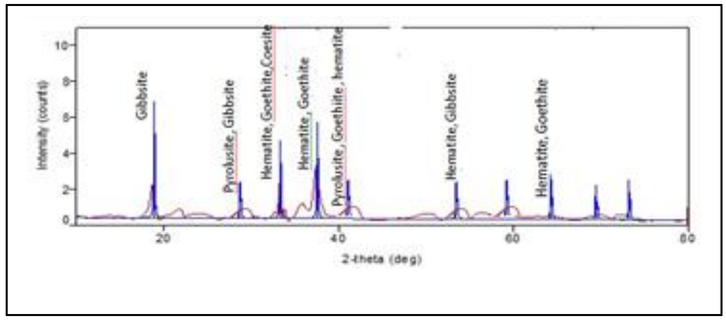

Figure 2: *TGA analysis of feed sample*

2.4 Electron Probe Microscopic Studies:

Electron probe microscopic (Bruker) studies were carried out on ferruginous manganese ore sample. The EPMA picture and EDS (Energy Dispersive X-Ray Spectroscopy) of the sample are shown in fig 3. From the fig 3, it was clear that the sample shows manganesemineralssuch as pyrolusite, psilomelane/cryptomelane as major minerals and hematite and goethite as minor minerals

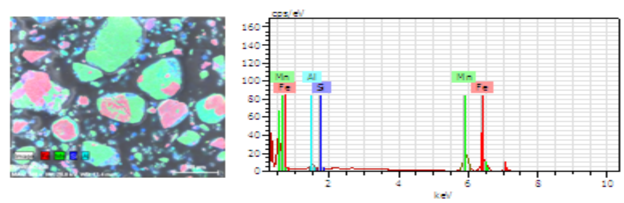

Figure 3: *EPMA Studies on ferruginous manganese ore feed sample*

3 BENEFICIATION

3.1 Gravity separation studies

Enriching the Manganese content in concentrate is the most challenging aspect of beneficiation studies. Therefore gravity method of separation, jigging is applied for beneficiation of iron rich low grade manganese ore. The samples of -40+20mm fractions and -20+5mm fractions were treated separately in to lab mineral jig. The schematic diagram of lab mineral jig is shown in Fig 4. as it is established that split sized concentrations yields better performance with selectivity. The results indicate that a jig composite heavy fraction assaying 34.87% Mn , 20.90 % Fe, 1.7 Mn/Fe ratio with 37.1 % Mn distribution at wt. % yield of 33.0 was obtained, just meeting the metallurgical grade specifications. a composite heavy and middling of jig concentrate assaying 32.79% Mn, 22.02% Fe with75.4 % Mn distribution at wt% yield of 71.3 is obtained which . The test was confirmed and recommends that the further enrichment of Mn values in the concentrate requires the roasting of the ore sample for effective removal of iron content. Hence, for producing concentrates by reduction roasting followed by low intensity magnetic separation is chosen to improve further Mn/Fe ratio on jig concentrate and jig pre-concentrate.

Fig 4: *Lab set up of jigging of M/s. Insmart systems, Hyderabad*

3.2 Reduction roasting studies

A plethora of literature is available on roasting followed by magnetic separation on iron rich manganese ores of India in general and the study area, in particular, indicates that concentrates with the Mn/Fe ratio depend on feed Mn/Fe ratio. Hence, in order to obtain high Mn values with Mn/Fe >2 reduction roasting followed by magnetic separation method was to improve the Mn values of jig concentrates. The jig concentrates of size -40 +5mm assaying 36.34% Mn, 20.90% Fe, Mn/Fe 1.74 is subjected to stage crushing to obtain -8+1mm and subjected for reduction roasting. For each roasting experiment, 200 g of the sized manganese fines along with the coal sample from South Africa RB-2 having GCV 4967Kcal/Kg , NCV 4700Kcal/Kg assaying 46% fixed carbon (FC), 25% ash, 21% volatile matter, and 8% moisture was used as the solid reductant. The 40% coal by weight was thoroughly mixed, put in a refractory crucible and placed inside the furnace set at the desired temperature. The sample after being roasted for a pre-determined time was taken out and immediately quenched with water bath in order to prevent oxidation of the reduced products. The subsequently obtained roasted products of each size class were ground to below 75 microns size so as to allow maximum liberation of the mineral phases and then subjected to low intensity magnetic separator (LIMS) using laboratory model low intensity magnetic separator (Insmart Systems, Hyderabad) at a magnetic intensity of 1500 G shown in fig 5. The magnetic and nonmagnetic fractions were collected separately filtered and dried. The non-magnetic concentrate fraction is analyzed for Mn and Fe [T] by the standard chemical procedures.

Fig 5: *Low Intensity magnetic Separator. Insmart systems, Hyderabad*

4 RESULTS AND DISCUSSIONS

The jigging studies of the lumpy iron rich low grade manganese ore samples shows the no appreciable improvement in the Mn/Fe ratio for the jig concentrates. It can be understood that the liberation size of this ore sample is under -0.075 mm jigging would not be efficient for beneficiation and therefore the jig products are subjected to reduction roasting to convert the paramagnetic hematite phase in to ferromagnetic magnetite phase for easy recovery of Mn values as non magnetic fractions in the magnetic separations. The reduction roasting process parameters like temperature and time was studied and the results are explained in the further discussions.

4.1 Effect of reduction temperature:

The reduction roasting experiments were carried out by varying the roasting temperature from 500^{o} C, 600^{o} C and 700^{o} C. The results are shown in figure 6 and 7. The results shows that

(1) With an increase in temperature Mn/Fe ratio, %Mn grade increases significantly more with a significant decrease in % Mn distn., at temperature >600°C was observed fig6.

(2) With an increase in time % Mn grade, Mn/Fe ratio increases and %Mn recovery decreases in general and more significantly at 700°C

(3) The best result were obtained at 700oC, 90' producing a concentrate assaying 51.89% Mn, 14.79% Fe, Mn/Fe 3.5 with 52.2% Mn distribution at wt.% yield of 36.6 (overall wt. % yield of 15%) meeting closely the ferromanganese grade specifications

(4) Alternatively, A-grade concentrate assaying ~ 48% Mn, ~18% Fe and Mn/Fe>2.5 was produced with 74% Mn distribution at 56% yield (overall wt. % yield of 23%). Narayanan et.al., (1957), Hiremath (2003 and 2013) and Kevinen et.al., (2010) obtained similar results for ferruginous Mn ores from Sandur region. Kevinen opined maximum Mn grade that was obtained was 54%, irrespective of feed grade under intensive reduction roasting similar to a maximum value of 52% Mn obtained in the present investigation. Based on the experimental results the conceptual Flowsheet is drawn shown in fig 8.

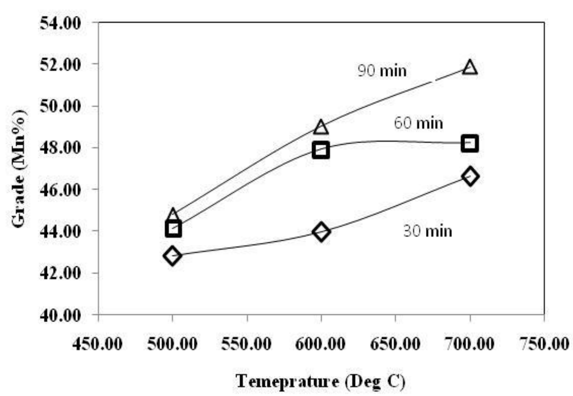

Figure 6: *Effect of time and temperature on Mn grade of jig concentrate reduction*

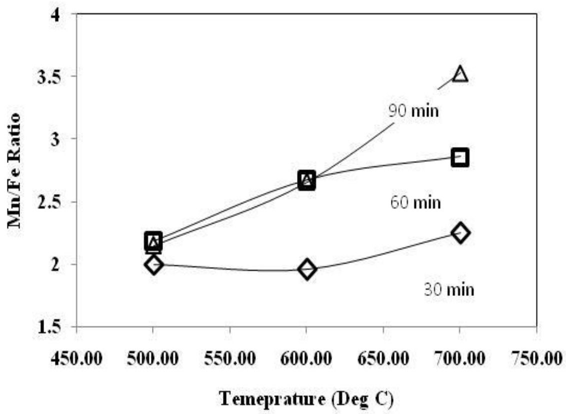

Figure 7: *Effect of time and temperature on Mn grade of jig concentrate reduction*

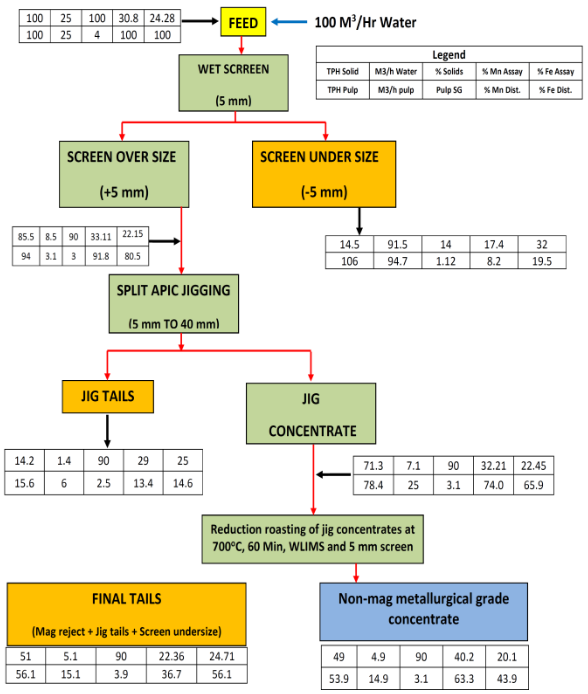

Figure 8: *Conceptual Design of processing Fe-Mn ores*

CONCLUSIONS

The iron rich low grade Manganese sample from sandur area is amenable to processing. The test comprising jig pre-concentrate (Concentrate and Middling) assaying 32.21% Mn, 22.45% Fe at 700°C for 1 hour, -40mm size followed by water quenching and crushing to -8mm subjected to WLIMS, a concentrate 40.2% Mn, 20.1% Fe, 6.24% acid insoluble, 0.85% LOI and Mn/Fe ratio >2 could be obtained with Overall % Mn distribution of 63.3 at overall wt.% yield of 49% meeting the local and ferromanganese and steel industry specifications and may be used after sintering coping the way for their utilization in the local steel hub. The flowsheet for processing ferruginous manganese ore is shown in Fig.6.2.and table 6.8.

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