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Pelletization Studies of Pre Concentrated Magnetite

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ABSTRACT

Pelletization studies were conducted on dry ground beneficiated magnetite concentrates from Belagal Range, Sandur Schist belt varying disc inclination, disc rpm, moisture%, and MOG and Bentonite % initially. The optimum conditions were 45o inclination, 22.5 rpm, 9.4% moisture, 89% -0.045 mm / 1576 cm2/gm., 0.9% Bentonite. Increase in Magnesite-CaO dosage to 1.45% increased the yield, drop number and CCS under above optimum conditions to 72.5%, 8.2,1040 gms. respectively The above green pellets were dried, pre heated, fired and cooled in Pot grate furnace 4-6' Ramp and 2' hold time at 350oC, 500oC, 700oC, 1000oC, 1175oC, 1310oC each respectively for drying, preheating and firing zones.BF grade pellets assaying 63.7% Fe,7.42% silica, 0.21% alumina, 0.36% CaO, 0.71% MgO, 0.01% each P and Sat, 0.13 basicity, 71% green pellet yield, 4 drop No., 640gms CCS, 2.09 g/cc bulk density, 95.4% Tumbler index, 4.5% Abrasion index, 223 kg crushing strength,31% porosity, 6% reduction degradation index, 14.5% thermal degradation index, 65% relative reducibility were produced under optimum conditions. The beneficiated magnetite concentrate was found amenable to pelletization.

Keywords: Pelletization, Agglomeration, Beneficiation, Magnetite Concentrates

I. INTRODUCTION

The Banded Magnetite Quartzite BMQ deposits of Belagal range of Sandur Schist belt extends from Haraginadoni, Sanjeevarayanakote of Ballari district, Karnataka state and extends to Obalapuram, D Hirehalmandal, Anantpur District, Andhra Pradesh The beneficiation and pelletization was chosen as it was reported to pose challenge for conventional processing owing to high silica and marginally high amounts of S and P. necessitating the process evolution followed by pelletization. The deposit is near to the steel hub of Ballari. The medium size reserves, demand for alumina/ silica ratio pellets by small – medium scale DR plants and Mini Blast Furnace (MBF). The plethora of literature on beneficiation of Indian BMQ are enormous mostly comprising of DLIMS Cobbing, Gravity concentration, WLIMS for beneficiation and flotation for refining(IBM (2006 and 2011)) but the literature on pelletization of concentrates obtained by beneficiation of BMQ are little except the works of Banerjee and Narayanan (1958), Sinha et.al. (1974 and 75), IBM (2011) and JSL (2017). The specification for BF pellets is Fe>63%, $SiO_2+Al_2O_3$ <8%, Al_2O_3/ SiO_2 <0.5, P<0.05%, S<0.05%, TI>95%, AI<5%, crushing strength >200 kg/pellet.

II. MATERIAL AND METHODS

2.1 Materials:

About a ton of concentrate was produced in pilot scale beneficiation plant comprising of Crushing and grinding the sample in ball mill in closed circuit to -0.1mm followed by gravity concentration using FM1 spirals followed by Wet low intensity of spiral tails in a counter current Rougher and Cleaner circuits in concentration. The composite concentrate was dewatered. The as received representative concentrate was subjected to standard feed preparation, sampling, physical, chemical and mineralogical studies. The feed consisted of mostly black coloured fine powder. The sample analyzed 65.65% Fe (T), 6.65% SiO_2, 0.07 %Al_2O_3 0.05% P, 0.05%. Na_2O <0.05%, K_2O <0.05%, 0.31% CaO and 0.03% MgO. The binder bentonite was pale yellow coloured powder assaying 9.2% Fe (T), 54.00% SiO_2, 13.07 %Al_2O_3 0.05% P, 0.05%. 6.56 % Na_2O, 0.95%, K_2O, CaO 0.31%, MgO 0.03%. and 7.76% LOI. The burnt lime powder assayed 9.65% SiO_2, 1.31 %Al_2O, 81.75% CaO and 9.31% MgO. The magnesite concentrate powder assayed 0.25% SiO_2, 0.05 %Al_2O, 1.75% CaO, 43.31% MgO and 52%LOI

2.2 Methods

2.2.1 Size reduction of concentrates:

20 kg batches of dry concentrate was dry ground in a batch ball mill of 750 mm dia x 1000 mm long rotating at 21 rpm with 1;1 mix of 25 and 20 mm steel balls charge weighing 200 kg. The variable grinding time of 1, 2 and 4 hours yielded a powder with D_{80} of 53, 40 and 25 microns with specific surface of 1,193, 1,576 and 2,147 cm^2/gm respectively.

2.2.2 Disc pelletizer;

the standard disc pelletizer of 1m dia x 0.2 m lip height. The disc had a variable rpm of 20 to 30. The slope of disc pelletizer can be varied from 35 to 55 degrees. The charge to pelletizer consisted of 20 kg of iron ore concentrate ground for 2 hours with 85% passing 45 microns, 180 gms of bentonite, 20 gms of quick lime were mixed in a Muller for 30 minutes. The material is slowly charged to rotating pelletizer and noted quantum of water of 1900 cc for 8.5% moisture. Once pellets are formed and they are rolled for some more time. The contents are discharged and screened over 8 mm round holed screen. The % +8mm pellet formed are noted. The mean drop number and compression strength of green pellets are recorded. The pellets are dried and physical strengths are determined.

2.2.3 Pot Furnace:

A 300 mm die pot grate with turn table facility for down and up draft suction of hot air, oil fired main burner, gas based pilot burner and thermo couples were used for pot grate tests. The prescribed procedure as per the operating manuals was adopted for the studies. The physical and metallurgical properties of fired pellets were evaluated by cold crushing universal testing machine, Tumbler drum and Linde test.

III. RESULTS AND DISCUSSION

3.1 Optimization of green pellet production

3.1.1 Effect of disc rpm;

Tests were done on a mix of 1 hr ground 20kg concentrate (68% - 45 microns, 1193 cm^2/gm specific surface), 180 gms of bentonite, 20 gms of lime 1900 cc water 45degree inclination varying disc rpm from 20, 22.5,25. The test results are presented in Table 1. The results indicate that increase in rpm increases % yield of +8mm pellets and Green pellet crushing strength marginally reaching an optimum at 22.5 rpm and subsequently drops. The drop number of pellets drops with an increase in rpm significantly at rpm more than 22.5 rpm. Klatt thumb rule indicated 22.5 rpm to be optimum. (Kurt Mayer (1980))

Table 1. Effect of disc rpm on green pellet

rpm	% Yield	Drop No.	CCS gms
20.0	60	2.7	399
22.5	62.5	2.69	402
25.0	61.2	2.52	380

3.1.2 Effect of angle of inclination;

Tests were done on a mix of 1 hr ground 20kg concentrate (68% - 45 microns, 1193 cm^2/gm specific surface), 180 gms of bentonite, 20 gms of lime 1900 cc water at 22.5 rpm with varying amount of water 1700 cc (7.8), 1900 (8.6% moisture) and 2100 (9.4% moisture)The results are shown in Table 2 The results indicate that with increase in angle of inclination, cold crushing strength increases, while the yield increases initially reaching a saturation at 45 degrees significantly drops and drop number decreases. It is observed that steep angle led formation small dia compact pellets. The tilt angle shall be more than dynamic angle of repose of charge. The rim height is also determined by the tilt angle (Kurt Mayer (1980) and Pandey et.al. (2012)) for all practical purposes the tilt angle will be 45 degrees and is normally adopted in Indian pellet plants. (IBM (2011)).

Table 2. Effect of disc inclination on green pellet

Angle °	% Yield	Drop No.	CCS gms
40	65.0	2.73	399
45	62.5	2.69	402
50	67.2	2.42	410

3.1.3 Effect of moisture; Tests were done on a mix of 1 hr ground 20kg concentrate (68% - 45 microns, 1193 cm^2/gm specific surface), 180 gms of bentonite, 20 gms of lime at 22.5 rpm, with water varying from1700 cc (7.8 % moisture), 1900cc (8.6% moisture) and 2100 cc (9.4% moisture). The results are given in Table 3. The test indicates that increase in moisture increased the % yield, drop number significantly and compression strength less significantly. The pellets of 9.4% moisture appeared to be slightly plastic. Kurt Mayer (1980) reported that the drop number increased with the moisture and specific surface of feed and compression strength increased with % moisture and then dropped significantly after saturation moisture%. Further it was stated that the % moisture in pellets and % yield increases with % moisture in feed. It was reported that the moisture content varies from 7% to 15% depending upon on crystalline magnetite, hematite/ martitized magnetite, synthetic magnetite. The moisture content for magnetite and hematite mixtures was 7 to 10.5%. Nanda (2015) obtained similar results while pelletizing the ground iron ore concentrate by beneficiation of BHQ-J from Donimalai, Sandur schist belt and optimum moisture content was found to be 9.25% for 1570 cm^2/gm hematite concentrate. Kurt Meyer (op.cit) reported that % moisture content increases with increase in specific surface of pellets.

Table 3. Effect of % moisture on green pellet

% Moisture	% Yield	Drop No.	CCS gms
7.8	55.0	2.53	370
8.6	62.5	2.69	402
9.4	67.2	3.42	400

3.1.4 Effect of specific surface of feed;

Tests were done on a mix of ground 20kg concentrate for different time of 1, 2 and 4 hours, 180 gms of bentonite, 20 gms of lime at 22.5 rpm, with water 2100 cc (9.4% moisture). The results are shown in Table 4. The results indicate that % yield, drop number and CCS increases with specific surface. Since generally for increase in 40 Cm^2/gm or 1% increase in % -325 mesh. The grinding cost will be 1kw/t for an increase in 100 Cm^2/gm or 2.5% increase in -0.045mm size. Very fine pellets produce very compact pellets with little porosity affecting subsequent thermal treatment and reducibility, through the mechanical properties increase. Though very finely ground feed of 2147 Cm^2/gm specific surface, -0.045 mm by 4 hours grinding yielded the best results, the optimum values were fixed at 2 hour grinding, 89% -0.045mm, 1576cm^2/g has been chosen. Kurt Meyer (1980) reported that specific surface and % -0.045 mm for magnetite pelletization varies from 1500 to 2000 with a mean value of 1700 cm^2/g and 70-100% -0.045mm with a mean value of 85% The granulometry also depends on surface rugosity and mineral nature. Incidentally, Nanda (2015). obtained similar results while pelletizing the ground iron ore concentrate by beneficiation of BHQ-J from Donimalai, Sandur schist belt and optimum specific surface was 1500 cm^2/g by dry grinding beneficiated concentrate for 2 hours in a similar ball mill. Umadeviet.al. (2009) varied the % -0.045 from 55 to 75% and found that the drop number and green compressive strength increased by 4 and 500 Gms for an increase in 25% -0.045mm size for different iron ore poweders of Sandur schist belt.

Table 4. Effect MOG/ Specific surface on green pellet

Sp Su Cm^2/g ,%-0.045mm, Hr Gr.	% Yield	Drop No.	CCS gms
1193 cm^2/g,, 68%-0.045mm,1h	67.2	3.42	400
1576 cm^2/g, 89%-0.045mm,2h	72.0	3.67	510
2147 cm^2/g,100%-0.045mm,4h	77.5	8.20	1040

3.1.5 Effect of Binder Bentonite concentration;

Pelletization studies were conducted at 89%-0.045 mm, 9.4% moisture, varying the bentonite dosage from 0.7.0.9 and 1.1% (140, 180,220 gms of bentonite). The results are shown in Table 6.. The % yield, drop number and CCS increased with increase in Bentonite concentration similar to earlier works on pelletization. A similar result was obtained by Nanda et.al. (2015) while pelletizing iron concentrates and obtained an optimum value of 0.9% bentonite. Since the acid constituent silica in concentrate and silica-alumina in bentonite needs to be neutralized, basic constituent needs to be added. This may dilute the grade of pellet though it is magnetite in composition. Normally the% binder concentration is fixed less than 1% preferably 0.5-0.7 %.(Kurt Meyer (1980)). Addition of 0.5,1 and 2% Bentonite for 1.7, 4.7 and 7.4 silica + alumina bearing iron ore concentrates like Magnetite during pelletization, increases the total acidic gangue content by 100% for very low gangue high iron concentrate and 22% for high gangue bearing iron concentrate. Metallurgically bentonite is a detrimental constituent incurring scorification costs.

Table 5. Effect of % Bentonite on green pellet

% Bentonite	% Yield	Drop No.	CCS gms
0.7	67.0	2.53	370
0.9	72	3.67	510
1.1	71.8	4.50	870

3.1.6 Effect of fluxing additives;

Basic Fluxes like CaO, $MgCO_3$ are added to, to reduce indurating temperature and time, improve the mechanical and metallurgical properties of pellet, by reacting with acid gangue constituents of concentrate and bentonite binder. Tests have been carried out varying the Magnesite concentration from 0.75,1% and 1.25% at 150,200 and 250 gms / 20kg iron ore concentrate. The green pellet properties are indicated in Table 6. Increase in magnesite content (flux/bentonite ratio from 0.9, 1.2 to 1.5) increased the % yield, drop number and CCS significantly up to 1% and subsequently with marginal improvement.

Table 6. Effect of % Magnesite on green pellet

% Magnesite	Flux/Bentonite	% Yield	Drop No.	CCS gms
0.75	0.9	72	3.67	510
1.00	1.2	72	3.87	580
1.25	1.5	72.5	4.00	640

3.1.7 Green pellets production under optimum conditions:

The optimum conditions were 45° inclination, 22.5 rpm, 9.4% moisture, 89% -0.045 mm / 1576 cm^2/gm, 0.9% Bentonite. And Magnesite-CaO dosage to 1.45% produced pellets with yield, drop number and CCS of 72.5%, 8.2, 1040 gms respectively

3.2 Drying of green pellets

The green pellets produced after roll screening over 8 mm were dried in trays for 1 hour and 3 hours at 150 and 300° C in drying oven. The dried pellets were then subjected to firing.

3.3 Firing of pellets

Pelletization studies were conducted at 89%-0.045 mm, 9.4% moisture, 45° tilt, 22.5 rpm, and 0.9% bentonite varying Flux/Bentonite ratio from 0, 0.9, 1.2 and 1.5. The green pellets were evaluated and reported to have Yield>70% and then subsequently subjected to drying in oven followed by preheating, indurating and cooling in the pot furnace. The temperature profile of pot grate furnace is given in

Table 7. The fired cooled pellets are subjected to chemical analysis, physical- mechanical properties and metallurgical properties. The results are given in Table 8. The results indicate that the BF grade pellets can be obtained by pelletizing gravity- WMIMS concentrates. Similar results were obtained by Nanda (2015) while pelletizing concentrates from Donimalai BIO. Similar BF grade concentrates are industrially produced from S-P rich BMQ, Rajasthan by JSL (2017) by WLIMS – pelletization for own use.

Table 7. Temperature profile of pot grate furnace during firing

Sl. No.	Ramp (Min)	Temp. (°C)	Hold (Min)	Zone
1	5	350	2	Drying
2	4	500	2	
3	4	700	2	Pre - heating
4	6	1000	2	Firing
5	4	1175	2	
6	6	1310	7	
7	20	350	15	Cooling

Table 8. Physico-chemical and metallurgical properties of pellets produced varying bascicity

Particulars	Blaine No. and Grade %Fe		
	1576cm²/g 65.65% Fe		
	Basicity		
	0.06	0.11	0.13
Properties of Green Pellets			
Recovery (-20+10 mm) (%)	72	72	71
Drop Number (1.5')	3.67	3.87	4
Green Crushing Strength (Grams)	510	580	640
Dry Crushing Strength (Grams)			
Physical Properties			
Bulk Density [T/m³]	2.10	2.09	2.09
Tumbler Index [%+6.3mm]	93	94.3	95.4
Abrasion Index [%-0.5mm]	6	5.5	4.55
Crushing Strength (Kg)	153	213	223
Apparent Porosity (%)	24.97	28.14	31.2
Metallurgical Properties			
Reduction Degradation Index [%-2.8mm]	25.2	16.7	14.54
Thermal Degradation Index [%-6.3mm]	4.5	6.2	6.0
Relative Reducibility [%]	58.00	62.31	65.22
Swelling Index			16.25
Chemical Analysis of Fired Pellet			
Fe [Total]	63.84	64.00	63.70

SiO_2	7.65	7.00	7.42
Al_2O_3	0.26	0.35	0.21
FeO	0.42	0.10	0.10
LOI	0.31	0.09	0.06
CaO	0.16	0.34	0.36
MgO	0.32	0.50	0.71
P	0.02	0.01	0.01
S	0.01	0.01	0.01

IV. CONCLUSION

Pelletization studies were conducted on dry ground beneficiated magnetite concentrates from Belagal Range, Sandur Schist belt assaying 65.65% Fe(T), 6.65% SiO2,0.07 %Al2O3 0.05% P, 0.05%. Na2O <0.05%, K2O <0.05%, 0.31% CaO and 0.03% MgO, varying disc inclination, disc rpm, moisture%, MOG and Bentonite % initially. The optimum conditions were 45o inclination, 22.5 rpm, 9.4% moisture, 89% -0.045 mm / 1576 cm2/gm, 0.9% Bentonite. Increase in Magnesite-CaO dosage to 1.45% increased the yield, drop number and CCS under above optimum conditions to 72.5%, 8.2,1040 gms. respectively The above green pellets were dried, pre heated, fired and cooled in Pot grate furnace 4-6' Ramp and 2' hold time at 350oC, 500oC, 700oC, 1000oC, 1175oC, 1310oC each respectively for drying, preheating and firing zones produced.BF grade pellets assaying 63.7% Fe,7.42% silica, 0.21% alumina, 0.36% CaO, 0.71% MgO, 0.01% each P and Sat, 0.13 basicity, 71% green pellet yield, 4 drop No., 640 gms CCS, 2.09 g/cc bulk density, 95.4% Tumbler index, 4.5% Abrasion index, 223 kg crushing strength,31% porosity, 6% reduction degradation index, 14.5% thermal degradation index, 65% relative reducibility under optimum conditions. The beneficiated magnetite concentrate was found amenable to pelletization.

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