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Grinding, Filtration and Beneficiation studies of iron ore fines of Hospet-Sandur-Bellary Sector, Karnataka, India

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Abstract-- Mechanisation in mining and material handling systems has resulted in the production of large amount of iron ore fines. These generated fines are slightly poorer in Fe content and are richer in alumina and silica. In view of this, an attempt has been made to beneficiate, grind and filter, to make them suitable for use as pellet feed. In order to arrive at optimum processes to improve their quality, studies were carried out for utilisation in agglomeration processes in the iron and steel industry, thereby increasing the economic value of these bye-products.

Index Terms- Beneficiation, Agglomeration, Pelletisation, Sintering, granulation, Hydrocyclone

1. INTRODUCTION

This paper is focused on the characterization studies of generated iron ore fines including morphological features, constituting the results of various beneficiation/grinding and filtration studies, utilizing the iron ore fines of Hospet-Sandur-Bellary sector. The process of beneficiation helps in upgradation of quality by Scrubbing, Wet screening, Classification and Cycloning. Further, grinding and filtration of fine particles derived from iron ore processing is a topic of increasing importance to mineral industries. In iron ore agglomeration, a range of process parameters such as particle size distribution and specific surface area must be controlled to achieve optimized operation conditions, through appropriate grinding and filtration operations. Thus, filtration tests were performed and the relationship between the moisture of the cake and the productivity was determined. Upgradation in quality and sizing is critical for successful sintering/pelletising and blast furnace operations in iron and steelmaking, to achieve high compressive strength, porosity and permeability, reducibility, uniform size distribution and low energy consumption to enhance smooth blast furnace operations.

2. STUDY AREA

The Sandur schist belt has rich iron ore and manganese deposits in the Bellary district, Karnataka, India. The Schist belt trends North North West-South South East, with a length of about 53 kilometres spreading over an area of 930 square kilometres. . The hills of schist belt are "Canoe" shaped, due to the valley on either side of the hill ranges, which extends towards each other with diminishing width, in an attempt to close up at both ends, resulting in the formation of a boat shaped structure. The iron ore deposits of the area fall within "Survey of India" topo-sheet number 57/8 and 57/12, falling between the longitude 76.5436 to 76.66840 E and latitude 14.9832 to 15.08810 N.

3. EXPERIMENTAL WORK

3.1 Beneficiation Studies

Samples of iron ore fines which were subjected for beneficiation studies belong to four mining blocks of following hill ranges of Sandur schist belt. (a) North Eastern Block range (Iron ore mines of M/S R. Pampapathy)–sample No 1. (b) Kumaraswamy range (Iron ore mines of M/s Deccan mining syndicate)-Sample No 2. (c) Donimalai range (Iron ore mines M/S H.R.Gaviappa)- Sample No.3 (d) Devadari Range (iron ore mines of M/s V.S.Lad)-sample No.4.

The samples ranging between 50 to 100 kg, were drawn from the bunkers of respective crushing and screening plants. Different types of ores present in those ore samples were physically separated and their proportions estimated. The details are given in Table1.

Table 1.Compositon of iron ores

Sa No	Location (Range andMines)	Description of material	Propo-rtion
1	NEB Range C&S Plant of M/s R.Pampapathy	i) Medium Hard massive Ore	31.0
		ii) Soft Laminated Ore	12.0
		iii) Friable Ore	38.0
		iv) Blue Dust	19.0
2	K S range C & S plant of M/s DMS	i)Medium Hard Laminated ore	22.7
		ii) Soft Laminated Ore	16.0
		iii) Friable Ore	49.0
		iv) Blue Dust	12.3

3	Donimalai Range-C&S Plant of M/s HRG	i)Medium Hard Laminated Ore ii) Soft massive Ore iii) Friable Ore	22.4 50.0 27.6
4	Devadari Range-C&S Plant of M/s V.S.L	i) Medium Hard Laminated Ore ii) Soft Laminated Ore iii) Friable Ore iv) Blue Dust	0.3 33.8 46.5 19.4

Table.2. Properties of iron ore fines samples collected for Beneficiation studies.

Constituet	Donimalai Range	Devadari Range	K S Range	NEB Range
Physical	HRG	VSL	DMS	RPP
Sp.Gravity	4.22	4.34	4.58	4.31
BulkDensy	2.11T/M^3	2.56T/M^3	2.39T/M^3	2.27T/M^3
AngleofRep	39^0 00’	34^0 30’	37^0 57’	38^0 40’
Chemistry				
Fe	64.40	64.60	65.38	64.80
SiO_2	2.70	2.80	2.39	3.27
Al_2O_3	2.60	2.75	2.45	2.18
LOI	1.87	1.96	1.55	1.60

The iron ore fines samples obtained after crushing /screening were subjected to homogenous mixing individually. Representative samples were drawn by standard sampling techniques for characterization studies and beneficiation studies. Characterisation studies include determination of bulk density, angle of repose, chemical composition and screen-assay-analysis. The data obtained are presented in Table 2 and 3 a, b, c and d.

Table.3a.Screen-Assay values of iron ore fines of NEB Range (M/s. R.Pampapathy Iron Ore Mines)

Size in mm/mes-Tyler	Wt %	Fe	Assay Percent		
			SiO_2	Al_2O_3	LOI
+10 mm	0.7	66.80	1.88	1.00	1.07
+6 mm	9.7	66.88	1.50	1.32	0.097
+3 mm	18.3	67.00	1.42	1.33	0.91
+10 mesh	14.7	66.80	1.78	1.37	0.97
+20 mesh	10.7	65.72	2.68	1.38	1.23
+35 mesh	6.4	65.53	3.30	1.29	1.10
+48 mesh	3.7	65.60	3.33	1.48	1.18
+65 mesh	2.3	65.40	3.64	1.57	1.17
+100 mesh	2.6	65.40	3.39	1.72	1.32
+150 mesh	2.8	65.20	3.04	1.94	1.40
+200 mesh	2.2	64.70	2.87	2.20	1.89
+325 mesh	2.9	64.80	2.97	2.42	1.75
-325 mesh	23.0	58.90	6.65	5.40	3.40
Head (Calc)	100	64.57	3.24	2.36	1.65

Table.3b.Screen-Assay values of iron ore fines of Kumaraswamy Range (M/s. Deccan Mining Syndicate Iron Ore Mines)

Size in mm/mesh Tyler	Wt %	Fe	Assay Percent		
			SiO_2	Al_2O_3	LOI
+10 mm	1.2	66.00	2.73	1.50	0.86
+6 mm	5.6	65.80	1.00	2.21	1.25
+3 mm	16.7	67.80	1.06	1.08	0.59
+10 mesh	14.5	66.80	1.76	1.58	0.86
+20 mesh	12.6	66.70	1.90	1.35	0.97
+35 mesh	8.1	66.00	2.60	1.68	1.07
+48 mesh	4.1	65.90	2.62	1.71	1.12
+65 mesh	2.4	65.80	2.50	2.00	1.20
+100 mesh	3.4	65.40	2.60	2.05	1.55
+150 mesh	3.5	65.00	2.38	2.74	1.76
+200 mesh	2.7	64.20	2.32	3.26	2.20
+325 mesh	3.4	63.10	2.62	4.16	2.58
-325 mesh	21.8	59.80	5.84	5.12	3.02
Head (Calc)	100.0	64.93	2.73	2.53	1.51

Table.3c.Screen-Assay values of iron ore fines of Donimalai Range (M/s. H.R. Gaviappa iron ore Mines)

Size in mm/mesh Tyler	Wt %	Fe	Assay Percent		
			SiO_2	Al_2O_3	LOI
+10 mm	1.6	67.80	1.12	0.81	0.50
+6 mm	11.8	67.60	1.04	1.02	1.12
+3 mm	17.8	67.00	1.45	1.30	1.31
+10 mesh	13.4	66.80	1.84	1.46	1.17
+20 mesh	10.1	66.20	2.32	1.43	1.24
+35 mesh	6.7	66.00	2.48	1.49	1.43
+48 mesh	3.1	65.80	2.38	1.83	1.20
+65 mesh	2.6	65.20	2.64	1.98	1.40

+100 mesh	2.4	65.00	2.56	2.35	1.85
+150 mesh	2.8	65.10	2.24	2.47	1.70
+200 mesh	2.3	64.20	2.30	3.22	2.10
+325 mesh	1.4	63.00	2.82	4.67	2.37
-325 mesh	24.0	60.20	5.30	4.80	3.20
Head (Calc)	100.0	64.97	2.67	2.33	1.77

Table.3d.Screen-Assay values of iron ore fines of Devadari Range (M/s. V S Lad iron ore Mines)

Size in mm/mesh Tyler	Wt %	Fe	Assay Percent		
			SiO_2	Al_2O_3	LOI
+10 mm	-	-	-	-	-
+6 mm	10.0	66.0	1.16	2.50	1.84
+3 mm	16.1	66.0	1.48	1,81	1,69
+10 mesh	10.6	66.6	1.76	1.41	0.99
+20 mesh	10.3	66.4	2.0	1.17	1.21
+35 mesh	7.0	66.8	2.20	1.0	1.24
+48 mesh	3.7	65.6	2.82	1.31	1.53
+65 mesh	3.3	65.60	2.56	1.71	1.20
+100 mesh	3.1	65.6	2.60	1.71	1.66
+150 mesh	3.4	65.2	2.10	2.05	1.95
+200 mesh	2.4	64.80	2.20	2.53	2.00
+325 mesh	5.6	63.00	3.00	3.87	2.53
-325 mesh	24.5	60.00	5.44	5.00	3.28
Head (Calc)	100.0	64.43	2.80	2.61	1.98

The test samples drawn were fed to the Rotary Scrubber through Vibratory Feeder. The scrubbed material was wet screened using a double deck vibrating screen having apertures of 10 mm (top deck) and 3 mm (bottom deck). Material of -3 mm was fed to a screw classifier. The Classified sand was collected separately while the slimes were treated in a hydrocyclone.

Table.4a.Results of Scrubbing, Wet Screening, Classification and Cycloning of Sample Collected from NEB Range (Iron ore Mines of M/s R.Pampapathy)

Product	Wt %	Assay Percent			
		Fe	SiO_2	Al_2O_3	LOI
+10 mm	1.4	67.20	1.32	1.26	0.82
-10 mm +3 mm	31.8	67.20	1.40	1.35	0.95
Cl Sand	39.2	66.50	2.47	1.18	1.11
Combined Fines	72.4	66.82	1.98	1.26	1.03
Cy.U/F (-100+325)	14.00	64.40	3.66	2.42	1.65
Cy.O/F(-325)	13.6	54.60	10.64	5.08	5.60
Head (Calc)	100.0	64.82	3.39	1.94	1.74

Table.4b.Results of Scrubbing, Wet Screening, Classification and Cycloning of Samples collected from Kumaraswamy Range (Iron ore Mines of M/s Deccan Mining Syndicate)

Product	Wt %	Assay Percent			
		Fe	SiO_2	Al_2O_3	LOI
+10 mm	1.7	66.55	1.02	2.06	1.21
-10mm+3 mm	32.4	66.72	1.24	1.67	1.12
Cl Sand	42.7	66.32	1.88	1.62	1.10
Combined Fines	76.8	66.49	1.59	1.65	1.11
Cy.U/F (-100+325)	11.5	64.04	2.28	3.19	2.29
Cy.O/F(-325)	11.7	55.00	10.08	7.05	3.70
Head (Calc)	100.0	65.10	2.66	2.46	1.55

Table.4c.Results of Scrubbing, Wet Screening, Classification and Cycloning of Samples collected from Donimalai Range (Iron ore Mines of M/s HRG)

Product	Wt %	Assay Percent			
		Fe	SiO_2	Al_2O_3	LOI
+10 mm	1.4	67.00	1.10	1.59	0.86
-10mm +3 mm	28.5	66.30	1.40	1.73	1.30
Cl Sand	37.8	66.30	1.80	1.59	1.11
Combined Fines	67.7	66.31	1.62	1.62	1.18
Cy.U/F (-100+325)	18.1	64.00	2.44	2.61	2.85
Cy.O/F(-325)	14.2	54.60	9.50	7.10	4.96
Head (Calc)	100.00	64.23	2.74	2.60	2.02

Table.4d.Results of Scrubbing, Wet Screening, Classification and Cycloning of Samples Collected from Devadari Range (Iron ore Mines of M/s V.S.Lad)

Product	Wt %	Assay Percent			
		Fe	SiO_2	Al_2O_3	LOI
+10 mm	1.9	67.80	1.00	0.95	1.05
-10 mm +3 mm	23.2	66.60	1.36	1.73	1.20
Cl Sand	44.4	66.20	1.76	1.70	1.30
Combined Fines	69.5	66.38	1.61	1.69	1.27
Cy.U/F (-100+325)	15.1	63.60	2.90	3.66	2.20
Cy.O/F(-325)	15.4	56.80	7.32	7.30	3.96
Head (Calc)	100.0	64.48	2.68	2.85	1.82

Table.5. Consolidated Values of Results of Beneficiation.

Sample No	Product	Wt %	Assay Percent			
			Wt %	Fe	SiO_2	Al_2O_3
1-RPP	Comb. Fines	72.4	66.82	1.98	1.26	1.03
	Cy/U/F	14.0	64.40	3.66	2.42	1.65
	Cy.O/F	13.6	54.60	10.4	5.08	5.60
	Head (Calc)	100.0	64.82	3.39	1.94	1.74
2 DMS	Comb. Fines	76.8	66.49	1.59	1.65	1.11
	Cy/U/F	11.5	64.04	2.28	3.19	2.29
	Cy.O/F	11.7	55.00	10.8	7.05	3.70
	Head (Calc)	100.0	65.10	2.66	2.46	1.55
3-HRG	Comb Fines	67.7	66.31	1.62	1.62	1.18
	Cy/U/F	18.1	64.00	2.44	2.61	2.85
	Cy.O/F	14.2	54.60	9.50	7.10	4.96
	Head (Calc)	100.0	64.23	2.74	2.60	2.02
4-VSL	Comb. Fines	69.5	66.38	1.61	1.69	1.27
	Cy/U/F	15.1	63.30	2.90	3.66	2.20
	Cy.O/F	15.4	56.80	7.32	7.30	3.96
	Head (Calc)	100.0	64.48	2.68	2.85	1.82

The products of hydrocyclone were collected separately. The results of these operations are given in Table 4 a, b, c and d. Overall results of beneficiation processes are given in Table 5. Flow sheet of the process is presented in Fig 1.

3.2 Grinding and Filtration studies

The sample collected from M/s ZTC crushing /screening plant of Ramghad range was found to be -10mm size. The physical parameters and characters of the samples like Size analysis, Specific Gravity, Bulk Density and Chemistry are given in Table 6.

Table.6.Characters of Sample from M/s ZTC Crushing and Screening plant of Ramghad area.

1.Size Analysis			
Size	Wt%	Cumulative Wt% Retained	Cumulative Wt% Passing
-10 mm to +9.423 mm	2.3	4.3	98.0
-9.423 mm to +2.5Mesh	2.3	4.3	98.0
-2.5 # to +3 #	5.7	10.0	95.7
-3 # to +4 #	11.2	21.2	90.0
-4 # to +6 #	12.2	33.4	78.8
-6 # to +8 #	9.7	43.1	66.6
-8 # to +10 #	8.3	51.4	56.9
-10 # to +14 #	8.3	59.7	48.6
-14 # to +20 #	7.1	66.8	40.3
-20 # to +28 #	6.1	72.9	33.2
-28 # to +35 #	4.6	77.5	27.5
-35 # to +48 #	3.9	81.4	22.5
-48 # to +65 #	3.0	84.4	18.6
-65 # to +100 #	2.9	87.3	15.6
-100 # to +150 #	3.2	90.5	12.7
-150 # to +200 #	3.0	93.5	9.5
-200 # to +250 #	1.0	94.5	6.5
-250 # to +325 #	3.2	97.7	5.5
-325	2.3	100	2.3
Total	100.00		
2.Specific Gravity	4.76		
3.Bulk Density	2.89 t/m^3		
4.Chemistry	Constituents	Assay %	
	Fe	67.14	
	SiO2	1.38	
	Al2O3	1.08	
	LOI	0.98	
	P	0.04	
	S	Traces	

Open circuit wet grinding studies were carried out in a 0.4 m X 0.8 m ball mill with a steel ball charge of 200 kg. Composition of the steel ball charge is given in Table7a.

Table.7a.Details of Steel Balls

Size	Wt	Wt%
40 mm dia	20 kg	10
30 mm dia	100 kg	50
25 mm dia	60 kg	30
20 mm dia	20 kg	10
Total	200 kg	100

Table.7b. Equipments and Instruments

Ball Mill	Size	0.4m X0.8 m
	Mill Volume	0.105 cu-m
	H.P.of the Mill	5
	Critical speed of the Mill	67 r.p.m
	% volume of feed in mill	20.8
Conditioner	Size	0.45 m X 0.60m
Filter	Type/Size	0.45 m dia 4 discs filter
	No of Discs employed	1
	Area of Disc	0.3028 sq-m
	Suction Area	0.23 sq-m

Table.8.Grinding Test data

Feed rate to Mill(in kg/hr)	80Kg/hr	100Kg/hr	120Kg/hr
% Solids in the mill discharge	71	71	71
% Solids in the filter feed	60	58	59
-325 mesh in the ground product	66.7	64.1	60.9
Specific surface Area (Cm3/gm)/Blaine no	1972	1776	1547

Table.9.Filtration characters of Ground samples

Test sample (ground product obtained at different feed rate to the mill	80 Kg/hr	100 Kg/hr	120 Kg/hr
% Solid in the slurry	60	60	60
Speed of the filter disc (rev/hr)	43.4	43.4	43.4
Rate of filtration (Kg/sq-m suction area/hr)	492	471	436
% Moisture in the filter cake	6.97	7.63	8.46
Thickness of the filter cake	4 mm	4 mm	4mm

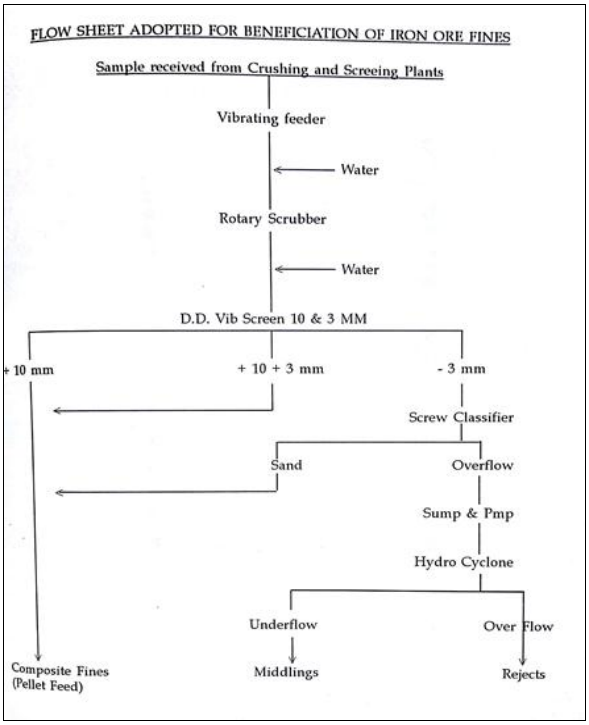

Fig 1. Flowsheet adopted for Beneficiation studies

4. RESULTS

4.1 Beneficiation Studies

The iron ores collected from crushing and screening plants from four different regions subjected to beneficiation processes were containing medium hard laminated ore, soft massive ore, friable ore and blue dust in different proportions. Screen analysis data given in Table 3a, b, c and d, indicate that the values of alumina and silica increase and the values of Fe decrease with decreasing size, in all the four samples. Though there was a considerable variations in the composition of different iron ore types in the four samples taken for beneficiation, the quality of the beneficiated fines is more of less uniform. Through simple beneficiation, it was possible to increase the Fe content from 64% to 67%, silica content is reduced from more than 2.5% to less than 2% .Recovery of fines is to the extent of 70% with Fe content of about 67%. Slimes which constitute about 30% were further subjected to hydrocycloning. The underflow which constitutes about 11 to 15% contains about 64% Fe and more than 5% of total alumina and silica. Overflow samples are still poorer in Fe content and richer in alumina and silica. Thus it can be concluded that, these minus 10 mm fines are amenable for beneficiation by relatively simple processes involving Scrubbing, Wet Screening and Classification.

4,2 Grinding and Filtration Studies

From the Table 6.1 it is seen that, fines obtained from crushing and screening plant of Ramgad area contain less than 2.5% of -325 mesh. Grinding studies have shown that (Table 8) with open wet grinding, it is possible to obtain 60.9 to 66.7% of -325 mesh ground product. At a feed rate of 80 Kg/hour, the ground product was found to contain 66.7% by weight of -325 mesh. Though this is little on the lower side of specification of 70-75%, specific surface area of the product is 1972, which is well within the value of specific limits (1750-2000) .Even the product obtained at a feed rate of 100 kg/hour is acceptable. It is seen from the Table 9 that moisture content increases with feed rate. A feed rate of 80 kg/hour gives a moisture content 6.97% which is within the permissible limit of 7%.

5. CONCLUSIONS

The following conclusions were drawn after the Beneficiation / Grinding and Filtration studies conducted on samples collected from different crushing and screening plants of iron ore mines of Hospet-Sandur-Bellary sector : (a) Fe content of the ROM can be increased by 2%. (b) Alumina content could be decreased by at least 1%. (c) Silica also could be decreased at least by 1%. (d) Hydrocyclone underflow, which is about 15% contains about 64% Fe, and little over 6% of Al_2O_3+SiO_2. (e) Fe content of Hydrocyclone over flow is only 54% and Al_2O_3+SiO_2 combined constitute more than 15%. This product also can be used or preserved for future use (f) Iron ore fines of Hospet-Sandur-Bellary sector are amenable for beneficiation. (g) Grinding at the feed rate of 80 to 100 kg/hour and filtration, it is possible to get the product of suitable size (blaine No >1700) and cake moisture (7%) for pelletisation.

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(A.1)

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