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AMENABILITY TESTS FOR CONCENTRATION OF LOW GRADE MAGNETITE ORE

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Abstract:

Magnetite is one of the prime mineral for the production of iron. Due to the increase in the demand and the depletion of the high grade ores, benevolent attention is given in recent times for processing low grade iron ores like banded magnetite quartzite BMQ. The major gangue mineral was identified in such ores are quartz. BMQ ore sample was received from the study area and was visibly greyish to black and attracted to a bar magnet containing hard and compact flaky lumps of max size of 50 mm with considerable amount of fines. The sample was subjected to characterization studies which include particle size analysis, chemical analysis, X-Ray Diffraction studies of feed sample, density measurement, and mineralogical studies. The lean grade BMQ sample from the Sanjeevarayankote area assaying 42.7% Fe(T), 6.07 % FeO, 36.3% SiO_2, 0.4% Al_2O_3, 1.44% MgO, 0.119%P and 0. 14%S and containing mainly fine grained magnetite and hematite intimately associated with major amounts of quartz with minor to trace amounts of fine grained amphibole, apatite, pyrite and goethite, liberating at size finer than -0.1mm The present study aims to conduct the amenability studies for process evolution. The amenability studies comprise of effect of MOG on heavy liquid test, Dry low intensity magnetic separation, Wet low intensity magnetic separation, Davis tube studies and combination of gravity followed by magnetic concentration techniques with varying mesh of grind. , produced concentrates assaying 62%, 61.5%, 63%, 68.9%, 69% Fe respectively with the variation in wt. % yield and % Fe recovery values. It was observed from the magnetic amenability tests that, the sample is amenable to magnetic separation. However, when the sample is subjected to Heavy liquid separation studies for amenability to gravity separation, producing concentrate assaying 62% Fe with 55 wt.% yield, at very fine mesh size of -200#, showing that, the sample is also amenable to gravity technique at very fine sizes. The BMQ sample is amenable to both gravity and magnetic separation at size finer than 0.1mm producing pellet grade concentrates and media grade concentrates at -0.07mm.

Key Words: Magnetite, Amenability, Gravity Concentration & Magnetic Concentration

1. Introduction:

Banded magnetite quartzite (BMQ) ore magnetic in nature contains very fine grained magnetite generally interlocked with the quartz grains. The BMQ deposits are occurs as small deposits and usually neglected because of their low Fe content. In India, such ores are considered as low grade iron ores with Fe content of 25–45%, SiO_2 30–60% and Al_2O_3 1–5%. Enormous research has been done on utilization of lean ores but, till now no commercial plant has been set up so far to recover the iron values from such lean ores by mineral processing techniques. The recent times benevolent attention has been given to address the issues with the processing of such lean grade deposits to meet the increasing demand of quality iron ore for iron and steel industries. Recovery of iron values from such low-grade ores is generally attempted by gravity concentration, magnetic separation and flotation techniques [1–6]. The mineral processing activities involving beneficiation of such lean grade ores is dependent on the dissimilarity in physical, chemical and mineralogical properties between constituent minerals and their grain sizes (7). Therefore a scientific and research assisted selection of unit operations is required to optimize iron grade and recovery. The gangue and ore minerals contained in Banded Magnetite Quartzite is vary significantly in their physical properties i.e magnetic and gravity properties. Therefore gravity and magnetic separation techniques are the potential low cost techniques that can be applied to pre-concentrate or beneficiate such ores. The fine size of the ore, gangue minerals and poor liberation is however, one of the constraints that limit its beneficiation at coarser sizes. This paper details out the attempts made to laboratory amenability studies for concentrating BMQ ore and compares the performance of gravity, Magnetic and gravity-magnetic amenability tests.

2. Experimental:

2.1 Materials and Methods: The lean grade magnetite (BMQ) sample was collected from Sanjeevrayanakote Area of Belagal range, Ballari Dist. Karnataka State, India. The sample is subjected to detailed laboratory amenability tests. Laboratory grade bromoform is used for heavy liquid separation studies and the dual intensity hand magnet is used for both wet and dry magnetic separation studies.

2.2 Mineralogical Studies: The representative sample was subjected to transmitted and reflected light microscopic studies to study the type of gannge minerals and their interlocking with the iron ore minerals using Leica M-26 stereo microscope and Leitz orthoplan optical microscopes.

2.3 X Ray Diffraction Studies: X-ray diffraction studies were made on a Siemens D-500 Diffractometer using Cu-Ka radiation (k=1.79026 A) at a scan rate of 18/min,

2.4 Amenability to Gravity Separation Test: Heavy liquid separation study was carried out by using organic liquids to analyse the liberation of mineral grains in ground sample. The ground samples were subjected to Sink and Float analysis using heavy liquid Bromoform supplied by laboratory (Rasayan chemicals ltd.,) of density 2.81g/cc. The products of sink and float were dried separately and weighed for chemical analysis.

2.5 Amenability to Dry/Wet Bar Magnetic Separation Test: A representative sample of feed with varying MOG is subjected to Dry/ Wet Magnetic separation studies using Bi-Pole Hand magnet to analyse the percentage of magnetic content in the feed. Similarly, low grade magnetite samples of study area of varying MOG (-0.125mm, -0.150mm and -0.105mm) diluted with 30% solids and introduced in 250ml beaker. The low intensity cylindrical bar magnet of 0.1T covered with thin plastic cover is introduced in to the pulp and manual rotation is adjusted to achieve 30rpm in anticlockwise direction. The bar magnet was washed with the clean water and the magnetic fractions were collected separately after the 10sec of pulp-magnet interaction time which is kept constant for all the MOG of the sample.

2.6 Amenability of Sample to Davis tube Test: The Ferro- magnetic content in the sample is determined by Davis tube test. It consists of glass tube which is agitated in an electromagnetic field. The water wash is used to remove the non-magnetic material. The important variables studied are sample weight , magnetic field , wash water flow rate , agitation rate, agitation time and slope feed sample weight vary from 10 to 30 grams per test and small weights is used for more magnetic content based material. The MOG was varied (-60, -150 and -270 mesh). The water flow rate is maintained to maintain the pulp level in the tube and near the poles. The agitation rates vary from 30 to 90 RPM with mean of 60/minute. The agitation time is dependent on material and varies from 5 to 30 minutes. The angle varies from 30 to 60 degree but 45 degree slope is selected for the study.

3. Results and Discussions:

3.1 Lean Grade Magnetite Sample: The lean grade magnetite (BMQ) sample is obtained from Sanjeevrayanakote Area of Belagal range, Ballari Dist. Karnataka State, India. The sample was visibly greyish to black and attracted to a bar magnet containing hard and compact flaky lumps of max size of 50 mm with considerable amount of fines. The portion of head sample was initially crushed in laboratory roll crusher to obtain the size fractions of -1mm, -0.6mm,-0.250mm. Further the sample was ground to laboratory rod mill to obtain -0.150, -0.1 and -0.075mm to study the effect of size on amenability concentration studies.

3.2 Characterization Studies: Physical examination reveals that, the sample mainly consisting of Brown fines containing compact hard lumps showing alternate bands attracted to hand magnet figure1. The sample was free flowing in nature. Preliminary studies on the samples shows angle of repose 38° and specific gravity nearly 3.2 and bulk density 1.9 T/m^{3}. Chemical analysis indicated that the BMQ ore fines assayed 42.7% Fe(T), 6.07 % FeO, 36.3% SiO_2, 0.4% Al_2O_3, 1.44%MgO, 0.119%P and 0. 14%S. The X-ray Diffraction (XRD) study was carried out to identify the different mineral phases present in the size fractions of -75µ, -150µ and -300µ ore sample and the resulting XRD peaks of the respective size class of ore sample shown that, magnetite and hematite are the main iron bearing minerals whereas quartz is the major gangue mineral as shown in figure 2.

Figure 1: Low grade BMQ ore sample of study area

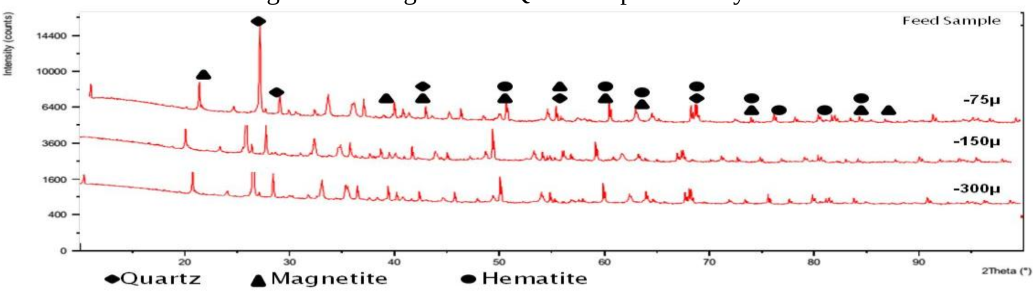

Figure 2: XRD of Feed Sample

3.3 Mineralogical Studies: Representative sample thoroughly subjected to transmitted and reflected Ore Microscope. Microscopic studies reveal that the samples do contain simple mineralogy with considerable gangue mineral content. Magnetite (Mag) is the major ore mineral followed by Hematite (Hem). The sample is confirmed to Banded Magnetite Quartzite with few deformed structures and few martitic structures also observed major gangue mineral is Quartz (figure.3). The brownish dark grey coloured sample contained mainly fine grained magnetite and hematite associated with quartz with minor to trace amounts of fine grained amphibole, apatite, pyrite and goethite, liberation finer than -0.1mm size.

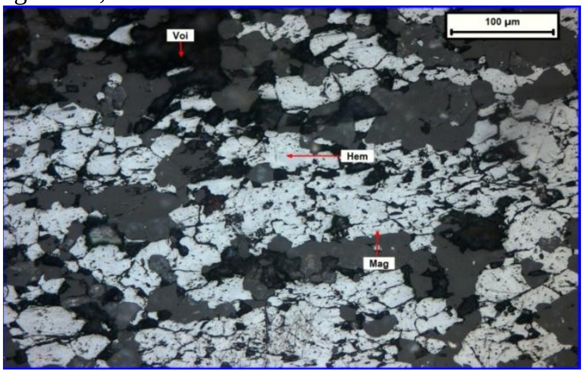

Figure.2: Micro-photograph of BMQ sample displaying complex association of irregular shaped Hematite (Hem) and Magnetite (Mag). Few Voids (Voi) also present. [X- 200].

3.4 Effect of Size on Heavy Liquid Separation Studies: Heavy liquid separation study was carried out as amenability to gravity separation. The ground samples were subjected to Sink and Float analysis using heavy liquid Bromoform supplied by laboratory (Rasayan chemicals ltd.,) of density 2.81g/cc varying the mesh of grind from 50, 100, 200 mesh. The products of sink and float were dried separately and weighed for chemical analysis. The table 1 shows the results of the HLS studies.

Table 1: Results of HLS Studies

MOG Mesh	Products	Wt%	Fe% Assay	%Fe Distn
-50 #	Float	31.3	11	8
	Sink	68.7	57.8	92
	Head Cal	100	43	100
-100#	Float	33.9	12.68	10
	Sink	66.1	58.51	90
	Head Cal	100	43	100
-200#	Float	44.6	19.28	20
	Sink	55.4	62	80
	Head Cal	100	43	100

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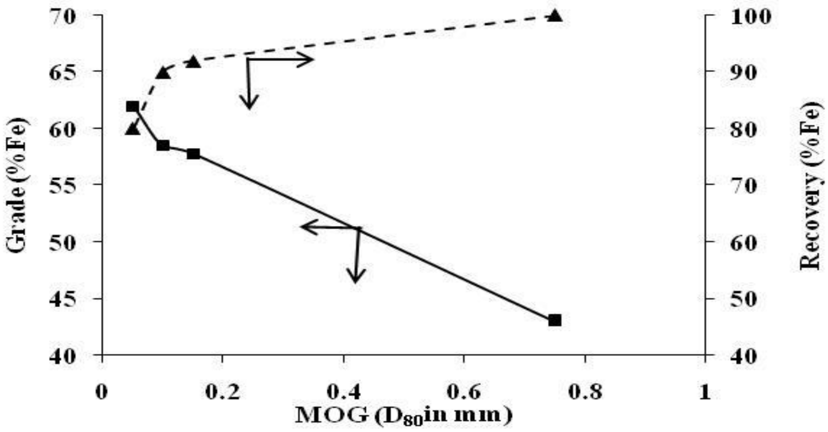

Figure 3: Grade recovery curve for HLS Studies

The table 1 and figure 3 shows the results of HLS amenability tests. The above test indicates that, the feed samples are amenable gravity separation at sizes finer than 200 mesh. The MOG finer than -0.1mm is essential for separating iron oxides from associated silicates for processing BMQ from Ballari and Ananthpur areas [8-11] . The grade of concentrate increases with increase in fineness of MOG.

3.5 Amenability of Feed Sample to Magnetic Separation:

3.5.1 Effect of Size on Dry Low Intensity Magnetic Separation: A representative sample of feed is accurately weighed 100gms and subjected to dry and dry low intensity magnetic separation varying the MOG -50#/-100#/-200#. The results are shown in Table 2.and Fig 4. The bar magnet amenability studies results that, at finer fraction of MOG -200# grade of the feed was reached to maximum of 61.5%Fe with a 78% distribution and wt% yield of 55 which shows the separation efficiency of 63.55%.

Table 2: Amenability of sample to dry low intensity bar magnetic separation

MOG Mesh	Products	Wt%	Fe% Assay	%Fe Distn
-50 #	Mag	62.5	45.05	65
	Non mag	37.5	39.95	35
	Head Cal	100	43.14	100
-100#	Mag	65	55.03	82
	Non mag	35	22.36	18
	Head Cal	100	43.6	100
-200#	Mag	55	61.5	78
	Non mag	45	20.8	22
	Head Cal	100	43.19	100

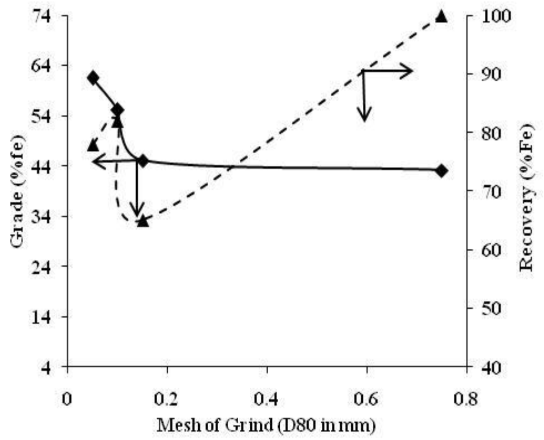

Figure 4: Grade and recovery curves of DLIMS by bar magnet

3.5.2 Effect of Size on Wet Low Intensity Bar Magnetic Separation: A representative sample of feed is accurately weighed 100gms and subjected to dry and wet low intensity magnetic separation varying the MOG -50#/-100#/-200#. The results are shown in Table 3.and Fig 5. The bar magnet amenability studies results that, at finer fraction of MOG -200# grade of the feed was reached to maximum of 63.63%Fe with a 67.5% distribution and wt.% yield of 50 which shows that, the loss of Fe distribution compared to dry separation is attributed to slime generation and the grade of the feed was marginally increased to 63.3% which results the increase in separation efficiency of 73.54%.

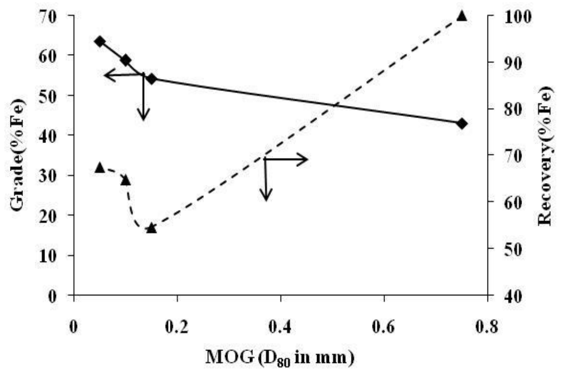

Figure 5: Grade and Recovery curve of WLIMS

Table 3: Results of Wet Bar Magnetic Separation Studies

MOG Mesh	Products	Wt%	Fe% Assay	%Fe Distn
-50#	Mag	42.1	54.30	54.6
	Non-Mag	57.9	32.80	45.4
	Head	100.0	43.06	100.0
-100#	Mag	47.36	58.86	64.9

	Non-Mag	52.64	28.67	35.1
	Head	100.0	43.06	100.0
-200#	Mag	50.0	63.63	67.5
	Non-Mag	50.0	30.62	32.5
	Head	100.0	43.06	100.0

3.6 Effect of Size on Davis Tube Ferromagnetic Separation:

Tests were carried out to study the amenability of sample to Davis tube ferromagnetic separation varying the MOG (-60#/-150#/-270#) to determine the magnetite content as per the standard procedures at 500 gauss intensity. The test results are given in Table 4 and shown in Fig.6. The results indicate that the feed grade of concentrate increases with fineness of MOG. 68.9%Fe concentrate was obtained at the -270# with 53.7 Fe Distribution. The product meets the specification of heavy media for coal washeries. The separation efficiency was 71.07.

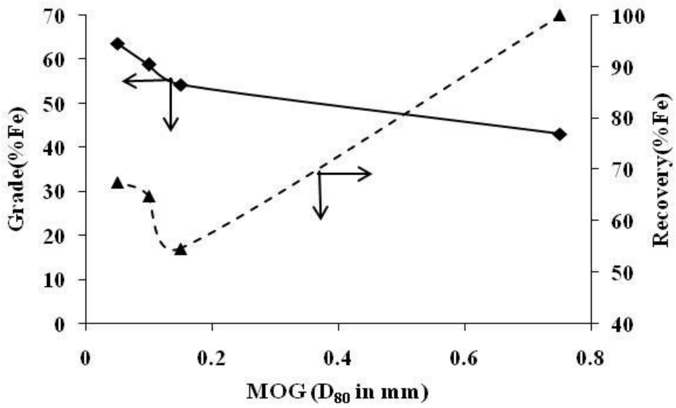

Figure 5: Grade and Recovery curve of WLIMS

Table 4: Results of the Davis Tube Test

MOG Mesh	Products	Wt%	Fe% Assay	%Fe Distn	Sep. Efficiency
-60 #	Mag	25.0	57.10	33.2	38.8
	Non mag	75.0	38.30	66.8	
	Head Cal	100.0	43.00	100.0	
-150#	Mag	37.5	63.41	55.3	54.49
	Non mag	62.5	30.75	44.7	
	Head Cal	100.0	43.00	100.0	
-270#	Mag	33.5	68.93	53.7	71.07
	Non mag	56.5	35.16	46.2	
	Head Cal	100.0	43.00	100.00	

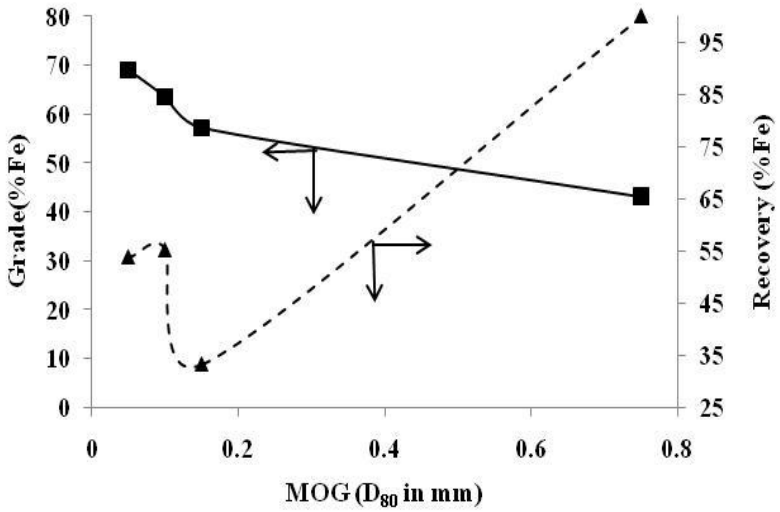

Figure 6: Grade and recovery Curve of Davis Tube Test

3.7 Effect of Size on Gravity Followed by Magnetic Separation: The feed sample was subject to heavy liquid separation and the wet bar magnetic combined gravity and magnetic separation studies to know the performance of the sample to the gravity and the magnetic separation techniques. The sink products of the heavy liquid test of varying MOG were subjected to wet low intensity bar magnetic separation. The results were tabulated in the table 5. The results shows that, gravity separation followed by magnetic separation technique produces the super grade magnetite concentrate of 69% Fe with 30% weight % yield which is useful for heavy media for coal industries and other application of magnetite. The non mag product assayed 60% Fe which can be used as a metallurgical grade for a pellet making application.

Table 5: Effect of size on amenability of sample to gravity followed by magnetic separation

MOG Mesh	Products	Wt%	Fe% Assay	%Fe Distn
-50 #	Float	31.3	11.00	8.0
	Sink Mag	46.9	51.53	56.2
	Sink Non mag	21.8	50.98	25.8
	Head Cal	100.0	43.00	100.0
	Sink Cal	68.7	57.80	92.0
-100#	Float	33.9	12.68	10.0
	Sink Mag	43.5	59.31	60.0
	Sink Non mag	22.6	57.10	30.0
	Head Cal	100.0	43.00	100.0
	Sink Cal	66.1	58.51	90.0
-200#	Float	44.6	19.28	20.0
	Sink Mag	33.9	69.76	55.0
	Sink Non mag	21.5	60.05	30.0
	Head Cal	100.0	43.00	100.0
	Sink Cal	55.4	62.0	80.0

4. Conclusions:

The lean grade BMQ sample from the Sanjeevarayanakote area assaying 42.7% Fe(T), 6.07 % FeO, 36.3% SiO_2, 0.4% Al_2O_3, 1.44%MgO, 0.119%P and 0. 14%S and containing mainly fine grained magnetite and hematite intimately associated with major amounts of quartz with minor to trace amounts of fine grained amphibole, apatite, pyrite and goethite, liberating at size finer than -0.1mm was subjected to various magnetic amenability tests and gravity followed by magnetic amenability tests varying MOG in the present investigation. It was found that, the sample is amenable to wet low intensity magnetic concentration producing pellet grade > 63 Fe% concentrate. WLIMS yielded higher grade concentrate as compared to dry low intensity magnetic separation. The Davis tube test was produced super grade of 69% Fe at very fine size i.e -270# with 33 Wt.% yield. The magnetic amenability tests indicated that grade of concentrate increased significantly when the MOG was finer than -0.1mm. The combination of gravity followed by the magnetic amenability test produced the concentrate as same as Davis tube test i.e. 69% Fe with 33 wt% yield at -200# and the concentrate appears to meet the requirement of heavy media specifications for deshaling of coal. The BMQ is amenable to magnetic and gravity separation. The detailed test work is recommended for the evolution of the complete flow sheet confirming and improving the amenability test findings

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