Journal of Mines, Metals and Fuels, *70(5) : 233-241; 2022. DOI: 10.18311/jmmf/2022/29942*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: www.informaticsjournals.com/index.php/jmmf

Resource Management and Utilization of Lean Grade Iron Ore Resources of Karnataka, India

Kumara Swamy[1*], N. Suresh[1] and P. Sharath Kumar[2]

[1]Department of Fuel, Minerals and Metallurgical Engineering, IIT (ISM), Dhanbad – 836206, Jharkhand, India; aspariaks@gmail.com

[2]Department of Mineral Processing, Vijayanagara Sri Krishnadevaraya University, Ballari – 583105, Karnataka, India

Abstract

As per the National Steel Policy 2017, more than 300 million tons of steel needs to be produced by 2030, to meet the increased demand due to the tripling of per capita consumption of steel in India. Accordingly, the local steel production from the Ballari steel hub of Sandur schist belt is expected to be raised from present 25 million tons per year to 60 million tons per year by 2030, thus necessitating 150 million tons of high grade hard lumpy/pellets for domestic Ballari steel hub alone excluding long term export commitments. Hence, a strategy for processing lean grade iron ores to augment the demand of high-grade iron ores for metallurgical applications is studied. A composite mixed Banded Hematite Quartzite (BHQ) from different ranges of Sandur schist belt, Ballari district, Karnataka, India was subjected to characterization, mineral processing and palletization studies to produce pellets Fe > 62.5 %, (SiO_2+ Al_2O_3)<9 %. The BHQ sample analyzing 41.44% Fe, 36.00% SiO_2, 1.00 % $Al_2O_3$and 1.06%LOI, comprising fine grained (<70 μ) mainly hematite [55–60%], very fine grained (<40 μ) quartz [35- 40%] and fine grained (<70 μ) minor amounts of martitized magnetite [1–5%], which are mutually intimately intermixed and intergrown, was subjected to beneficiation. The BHQ is amenable to gravity concentration by tabling reverse flotation, and WHIMS produces pellet grade concentrates. The final conventional process comprising gravity concentration, followed by magnetic separation of gravity tails and refining of magnetic fractions by reverse flotation. The final concentrate has produced assaying 64.5%Fe, 6.32% SiO_2, 0.29% $Al_2O_3$and 0.63% LOI, with 73% Fe distribution, has met the pellet grade specification. The pellets produced from beneficiated iron ore concentrate is assayed 64.10 %Fe, 6.85%SiO_2, 0.42 Al_2O_3%. DRI could be produced from the pellets from which steel is produced paving the way for conservation, sustenance, and sustainable development with the viability of using BHQ of the Sandur schist belt.

Keywords: *BHQ, Reverse Flotation, WHIMS, Gravity Concentration and Pelletization of Concentrates*

1. Introduction

India has a sizable amount of iron ore resources of about 31,213 million tons, of which about 10,747 million tons (34%) is of magnetite and the rest (66%) belongs to hematite type, which is the primary source of supply of iron. The iron ore deposits are located in well-defined belts in Odissa, Jharkhand, Chhattisgarh, Maharashtra, Goa, and Karnataka. The un-utilization of the rich magnetite deposits are due to their occurrence in eco sensitive forest areas and sanctuaries where mining is banned. Increasing per capita consumption of steel from present 60kg to 180 kg demands, the higher steel production rates (Figure 1. (IBM, 2011)). The domestic steel production, commen-

**Author for correspondence*

surable with consumption, is expected to rise annually by ~10 %, thereby increasing the steel production to 300 MTPA and iron ore requirement to 500 million tons annually by 2030. On the other hand, the fast depletion of high-grade iron ore deposits, closure of some of the high-grade iron ore mines due to stringent environmental regulations, increased demand for quality iron ores-agglomerates have forced the mineral engineers to look into the processing of low-grade iron ores as an alternative. This has eventually resulted in the processing of iron ore wash-plant tails and the banded hematite quartzite/jasper (BHQ/J) to produce quality grade agglomerates as input to the existing steel making technologies like Blast Furnace (BF) and Direct Reduction of Iron (DRI). It is known that 1% decrease in alumina content of iron ore leads to a 2.5% decrease in coke rate with an increase of 4% in blast furnace productivity and a reduction in flux consumption of 30kg per ton of hot metal. An increase in 2% Fe increases productivity by 2%. An increase in the BF productivity by 40% is reported when charged fully with pellets (IBM, 2005). The problem of Indian iron ores is their high Al_2O_3 content and $Al_2O_3/SiO_2>1$, which needs to be addressed also.

The Sandur schist belt is a lens of about 60 km in length, with a maximum width of 28 km in the central part (Figure 2) Sandur schist belt of Karnataka has a vital iron ore reserve of 811 million tons in 8 ranges, producing 50 million tons of iron ore per year mainly for local Ballari steel hub requirement and long term export commitments. About 20% of iron ore production comprises BHQ/J which are dumped separately amounting to 10 million tons per year occupying space in mines, increasing the foot print and land degradation ecological problems. The schist belts of Ramgad range (213 million tons), Kumarswamy range (253 million tons), Donimalai range (156 million tons), Thimmppanagudi range (27 million tons), NEB range (82 million tons), Devadari range (26 million tons) Ettinahati range (37 million tons) and Belagal range (20 million tons) shows the mineralization occurs as banded hematite quartzite (BHQ)/Banded Hematite Jasper (BHJ). The intercalation of ferruginous shale, long, narrow and scattered patches of hematite with intervening shale bands containing 58-64% Fe also observed. The BHQ/J resources of the Sandur schist belt are estimated to be 160 million tons of which 100 million tons is of BHQ type. About 20 million tons of BHQ are untouched and stacked as dumps separately. The steel production is expected to be raised from the present 25 million tons per year to 60 million tons per year by 2030. Thus, necessitating 150 million tons of high grade hard lumpy/pellets for domestic Ballari steel hub alone excluding long term export commitments. Hence, beneficiation, pelletization, and utilization of BHQ is of paramount importance for the sustenance of industry in future.

Work on beneficiation of BHQ has been conducted by Raj *et al.*, (2007) Anupam *et al.*, (2010), Das *et al.*, (2012), Rao *et al.*, (2012), Gurulakshmi *et al.* (2010 and 2012), Nanda and Gopalkrisha, (2014). But the work pelletization of concentrates from beneficiation of BHQ/J is limited except the works of Sinha *et al.*, (1974), Nanda (2016) and Sharath Kumar (2018) for the utilization Therefore, the present paper's objective has been to conduct beneficiation studies on BHQ sample from Sandur schist belt producing pellet grade concentrate, pelletization of concentrate yielding pellets of Fe>62.5%, $(SiO_2+Al_2O_3)<9\%$, $Al_2O_3/SiO_2<1$, P<0.05%, S<0.05%, Tumbler index >90%, Abrasion index <10%, Crushabiity>200kgs. size -20+6.25mm and 20–30% porosity

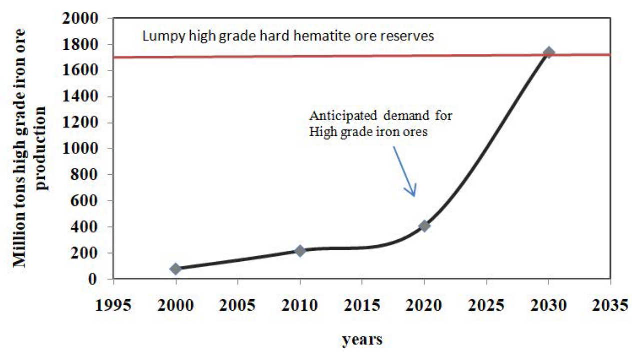

Figure 1. Production of iron ore since millennium and anticipated production in 2030 (IBM, 2011).

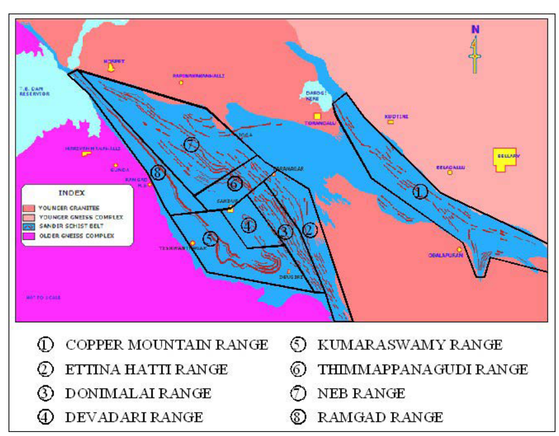

Figure 2. Iron ore resources in Sandur schist belt (Roy and Biswas, 2008).

2. Material and Methods

2.1 Beneficiation Studies

The BHQ samples weighing about 5 tons from different BHQ dumps are collected from different mines of Sandur Schist belt as shown in Figure 3. For testing its feasibility for concentration, shaking table (MPE Mumbai) was used. The amenability and the magnetic separation tests were carried out by using wet high intensity magnetic separator (Star Trace Ltd., Chennai). A self-aerated Denver D-12 SA type laboratory flotation machine (MPE, Mumbai) was used for laboratory flotation tests for recovery of Fe values from gravity and magnetic separation tailings. Cleaning of gravity and magnetic separation tailing is further processed by reverse flotation for recovery of Fe values. The chemical analysis of the feed sample analysis showed silica is major gangue mineral, The commercial grade Dodecylamine (DDA) (Hi-Media Laboratories Pvt. Ltd) was used as a cationic collector for silica removal. The cornstarch and NaOH was used as an iron oxides depressant. The feed sample was stage crushed in a laboratory jaw crusher of 150 mm wide X 250 mm followed by a secondary crushing in rolls crusher of 200 mm X150 mm. Nearly 256 No's of ~16 kilos sacks of stock ore samples are prepared by using riffles. 1 kg stock sample was stage ground in laboratory rod mill in wet condition at 67% solids to produce minus 300 µm (D_{80} 205 µm), minus 150 µm (D_{80} 106 µm), minus 106 µm (D_{80} 82 µm), minus 74-µm (D_{80} 50 µm) size maintaining 5 minutes stage grinding time. The size distribution of ground products are shown in Figure 3. The experimental test procedures and analysis were conducted as enumerated by the handbook (SME, 1980; IBM, 2012).

2.2 Agglomeration Studies

The disc Pelletiser of 0.9 m diameter is used to study the agglomeration of concentrate-produced from beneficiation plans. The fired pellet quality is assessed after the firing of pellets by using pot grate furnace of 300 mm diameter. Appropriate propositions of the binder bentonite, magnesite (flux) and lime was used after screening it to minus 53 µm. The pelletiser disc is fitted with variable frequency drive to vary the disc rpm. The angle of the disc is set to 45 degrees. 20 kg of iron ore concentrate of size D_{80} 45µ, and 180 gm binder, 25 gms magnesite and 10 gms lime were mixed in a sand Muller for 30 minutes. After homogenization the mixture is slowly introduced in to disc pelletiser with addition of moisture to attain 10% moisture. The pellets discharged from disc are introduced to 6.25 mm round holed screen. The mean drop number and compression strength of green pellets are recorded. The pellets are dried and physical strengths are determined. A 450 mm dia pot grate with turn table facility for down and up draft suction of hot air is used for firing the green pellets. The prescribed procedure as per the operating manuals was adopted for the conduction of experiments. The quality analysis of fired pellets like crushing strength and tumbler index and linder test is conducted using Universal testing machine, Tumbler drum and Linde test (Meyer, 1980) respectively.

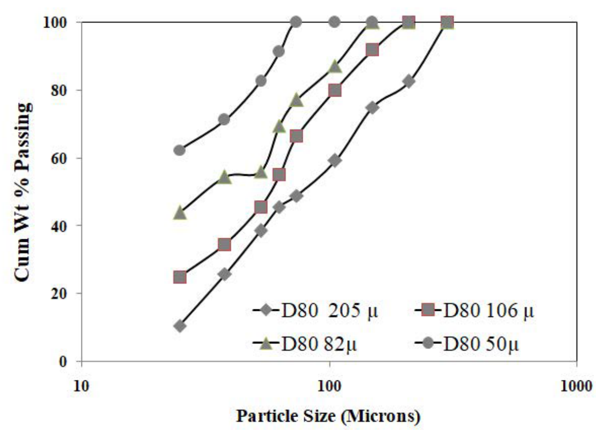

Figure 3. Size distribution of ground products.

3. Results and Discussion

3.1 Feed Material Characterization

The as received sample consisted exhibiting banding 32° angle of repose, bulk density of 2.0t/m^3, specific gravity of 3.3. The feed sample and pre concentrate sample was analyzed for Bond's ball millwork index and shown 10 kWh/short ton and 15 kWh/short ton. The mineralogical characteristics of the sample indicated that the feed is fine-grained. It comprises, of fine grained (<70 µ) mainly hematite [55–60%], very fine grained (<40 µ) quartz [35–40%] and fine grained (<70 µ) minor amounts of martitized magnetite [1–5%], which are mutually intimately intermixed and inter-grown. A fair degree of liberation of hematite is observed at minus 74 µ size (Figure 4 (a–c)). The X-Ray diffraction studies of the feed is shown in Figure 5 and confirmed that presence of silica as a major gangue mineral and hematite and magnetite are minor valuable minerals. The association of gangue mineral with valuables is understood by mineralogical characterization. The mineralogical characterization showed that, silica is distributed as very fine-grained and is associated with hematite are shown in Figure 4 (a–c). Since, the association of the fine quartz within the matrix of hematite necessitates fine grinding for better liberation.

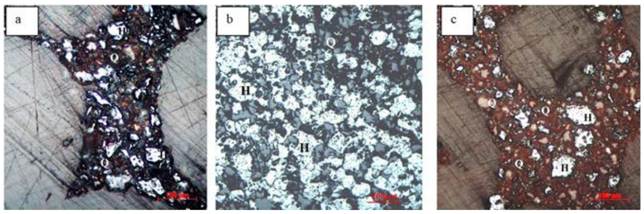

Figure 4. Microscopic images of low grade iron ores of Sandur area (a) Finely disseminated quartz phase (b) distribution of quarts in hematite matrix (c) Fine grains of hematite [H] dispersed in extreme fine grains of quartz [Q].

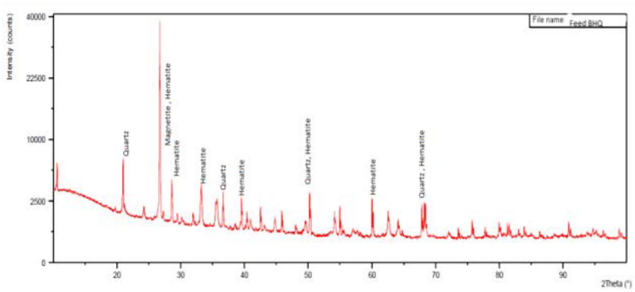

Figure 5. X-Ray diffraction of composite banded hematite quartzite sample of Sandur schist belt.

3.2 Sink and Float Test

Many researchers have tested heavy liquids separation test in the laboratory for the appraisal of gravity separation techniques for iron ores Anupam *et al.*, (2010), Das *et al.,* (2012), Rao *et al.*, (2012), Krishna *et al.,* (2013), Nanda (2016) and Nanda *et al.*, (2020). Sodium Poly-Tungstate (SPT) with densities of up to 3.1 g/cm^3 is non-volatile and non-toxic has certain advantages over organic liquids. Some researchers have used finely ground Tungsten Carbide (TC) suspension in SPT to obtain densities up to 4 g/cm^3 (Koroznikova *et al.*, 2007). In this study, a Tetra-Bromo-Ethane (TBE) and acetone mixture was used to prepare the heavy liquids with density of 2.9 g/cm^3. From the mineralogical inferences, the sample was subjected satge grinding to obtain -74μm and de-slimed sample of size -0.074+0.025 mm is subjected for heavy liquid separation studies using TBE. The results showed that, a sink product (concentrate) assaying 62%Fe with 66% Fe recovery at 43.3- wt% yield. The results indicated that the grind size of -74μm will be the optimum size at which better liberation and separation takes place.

3.3 Bench Scale Beneficiation Studies

Bench scale beneficiation studies are carried out for the low-grade iron ore sample of study area. The beneficiation test comprising gravity separation by tabling, magnetic separation and reverse flotation for varying Mesh of Grind (MOG). The stage grinding of the sample produced varying MOG; minus 0.30 mm, minus 0.15 mm, minus 0.106 mm and minus 0.074 mm. The influence of MOG on the separation is studied by analyzing the % Fe grade and recovery of each unit operations varying MOG is shown in Figure 6 (a–d). The results shown in Figure 6(d) that, the iron ore concentrate of >62% was obtained by tabling with 40% Fe recovery at minus 0.074 mm. The decrease in % Fe recovery in gravity concentration is attributed to bypass of Fe values in tailings. The microscopic observation of tailings shows that embedment of quartz in hematite grains at finer size as shown in Figure 7. Wet High Intensity Magnetic Separation (WHIMS) could produce concentrate with marginal pellet grade of 62.5 % Fe but with minimum recovery. The poor recovery probably due to enhanced interstitial matrix pore volume avoiding concentration of slimy iron minerals, though theoretically, the concentration criteria of magnetic separation is higher than that of gravity concentration. Tang *et al.* (2010), recommended vertical pulsating wet high gradient magnetic separators to avert this problem with high recoveries. Flotation at a very coarse MOG of minus 0.30 mm could not be done due to faster settling of particles in cells and poor dispersion. However, the MOG coarser than 74 μm did not produce favorable results due to lack of liberation and fine interlocking as shown in Figure 6c and 6d.

The results of gravity and magnetic separation studies results in poor recovery of Fe values. Performance of reverse flotation for recovery of Fe values from finer grind size is well established. Vijayakumar *et al.* (2015) indicated that flotation by column cells would avert the slime entrapment problem and prevent the loss due to Fe slimes. Recovery of finely distributed Fe values is studied by reverse flotation. The feed sample at minus 0.074mm size to reduce the siliceous gangue is done by conditioning the pulp for 10 minutes with caustic starch (depressant) dosage of 1.5kg/t and with dodcylamine (collector) dosage of 0.15 kg/t for 1 minutes. Flotation results the concentrates with high %Fe recovery and observed slight fall in the grade of concentrate Figure 6(c and d). Metchem (2006) recommended flotation of gravity concentrate to obtain pellet grade. The beneficiation studies of processing of low grade iron ores shows magnetic separation followed by flotation yielded better results, indicating flotation is a better refining concentration process Raj *et al*. (2007).

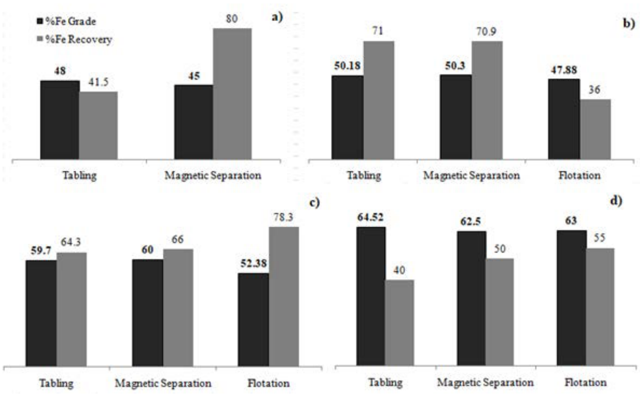

Figure 6. Effect of MOG on Grade and Recovery of unit operations (a) at MOG of minus 0.30 mm (b) at MOG of 0.15 mm (c) at MOG of minus 0.106 mm (d) at MOG of 0.074 mm.

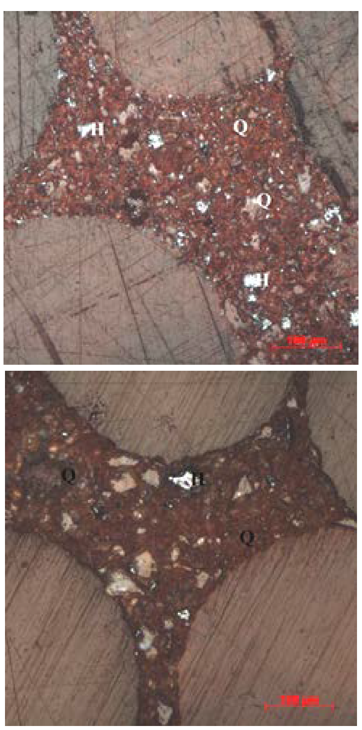

Figure 7. Microscopic images of tailings of low grade iron ores.

3.4 Final Test

Based on the results of bench scale studies, the final conventional process is designed. The final process flow sheet for processing of lean grade resources consisted of the tabling of stage ground product MOG of minus 74 µm and tabling tailings are introduced to wet high intensity magnetic separation at 30% solids, at 10000 gauss intensity, 3 mm ball matrix. For further cleaning of magnetic fractions, the pulp is treated for Inverse flotation after conditioning the pulp for 10 minutes with 1.5kg/t caustic starch, and with dodecylamine (collector) dosage of 0.15kg/t for 1 minute. The flow sheet is shown in Figure 8. The results are given in Table 1. The final test yielded a pellet grade concentrate assaying, 64.5% Fe, 6.42% SiO_2, 0.29% Al_2O_3 and 0.63% LOI, with 73% Fe recovery. The process eliminates the energy intensive concentrate grinding stage since the final product has nearly 80% passing 45 µm helpful for pellet making. For pilot test, comprising of minus 1mm stock sample was pulverized in an IC pulverizer–air classifier to get dry powder of -74 µ, D_{80} 53 µ. The dry ground product was subjected to continuous tabling at 0.25 tph and table rejects are introduced to vertical pulsating high gradient magnetic separator (LGS 500 VPWHIMS) and cleaning of concentrate by flotation. The table concentrate and non-float are thickened in 1.2m dia thickener and filtered in 1 m^2 vacuum pan filters. The air dried concentrate cake assaying ~64.5%Fe, D_{80} ~45 µ, ~1750 cm^2/g could produce direct to use pellet grade concentrate.

Table 1. Conditions and results of Final conventional process flow sheet

Product	Wt%	%Fe	
		Grade	Dist.
Table concentrate	32.2	64.52	50.0
Flotation concentrate	14.8	64.49	23.0
WHIMS tails	40.4	16.46	17.0
Flotation float rejects	12.6	32.93	10.0
Feed Cal	100.0	41.50	100.0
Final concentrate	47.0	64.50	73.0
Final tails {WHIMS-non mag+flotation rejects}	53.0	21.14	27.0

Conditions: at-74µ, D_{80}50µ, WHIMS of thickened table rejects at 10,000Gauss, 30%Solids, 3mm ball matrix, Flotation of WHIMS magnetic with 1.5kg/t of caustic starch depressant, 0.15kg/ton of dodecylamine collector

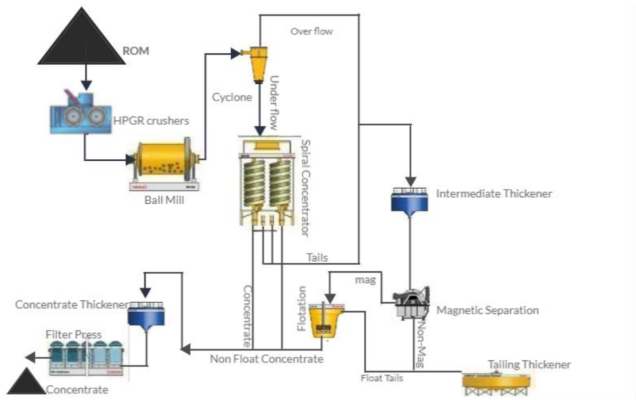

Figure 7. Process flowsheet for beneficiation of BHQ from Sandur schist belt, Karnataka. (Icon Source: https://www.at-minerals.com).

3.5 Agglomeration Studies

An agglomeration study of final concentrate is carried out for further utilization by pellet and DRI making. Figure 8 shows the flow sheet for the pelletization process flow diagram. The 20 kg beneficiated concentrate analyzing 64.50% Fe showed a size distribution of 80% passing 45µm. The optimum balling conditions were found at 45° angle of inclination, 22.5 rpm, 9.4% moisture. The binder (bentonite) and flux (lime) is added at the rate of 0.9% and 1.25% respectively during pelletization. Green pellets of size range -25+6.25mm were dried for 1 hour at 150°C and 300° C for 3 hours in a drying oven. The pre heating, firing and cooling cycle were adjusted as per the Table 2. The fired pellets are subjected to physical, chemical, mechanical, and metallurgical analysis. The chemical analysis of showed 64.10 %Fe, 6.85% SiO_2, 0.42 % Al_2O_3, 0.10% CaO, 0.63% MgO, 0.18% Na_2O, 0.05% K_2O, 0.01%P, 0.01%S, 0.06 Al_2O_3/ SiO_2, 7.27%(SiO_2+Al_2O_3) and traces LOI. The sized pellets of minus 20+6.25 mm has shown bulk density of 2.1 t/m^3, 94% Tumbler index, 5% abrasion index, 260 kgf/pellet cold crushing strength, 25% apparent porosity, 7% Reduction degradation index, 2.5% Thermal degradation index, 65% Relative Reducibility and 16% swelling index, meeting the specifications of the blast furnace iron making. The low grade iron resource of study area has confirmed it's amenability to beneficiation and pelletization as pellets meeting the specifications of the iron and steel industry was produced not only conserve the high grade resources also solves the sustainability issues in utilization of such low grade iron ore resources.

Table 2. Temperature profile of pot grate furnace during induration

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	4	Firing
5	4	1175	4	
6	6	1310	6	
7	20	350	15	Cooling

3.6 Evaluation of Pellets for Sponge Iron

The growth of Indian DRI industry is very critical in secondary steel segment to achieve the Governments ambitious target for 2025. Innovative approach is required to counter the shortages of key inputs and logistics challenges for DRI industry. Continuous exploration of new avenues to reduce cost of production and to maximize the use-installed capacity is necessary. The fired pellets of size -12.5+6.25mm were subjected to an open cycle sponge iron making. The sponge iron manufacturing facility consisted of 0.76 m dia x 10.67 m long rotary kiln of capacity 100 kg/h pellets with a fuel rate of 100 kg/h non-coking coal fines (ash<25%) is used for making sponge iron from fired pellets. The facility has produced sponge iron assaying 92% Fe, 85% Fe (M), with 90% metallization.

3.6.1 Economics of Beneficiation and Utilization of Low-grade Resources

The proposed process flow diagram of the project comprises:

1. Estimated low grade iron ore resources of study area 1.8 million tons per year of ore at a rate of 250 tons per day considering three shifts per day.
2. Fine crushing to minus 3mm, followed by grinding to -0.074 mm concentration by gravity and WHIMS and refining of gravity and WHIMS concentrate by reverse flotation. Thickening and filtration to produce pellet grade concentrate at the rate of 200 tons per hour operating in three shifts.
3. Mini pellet plants of capacity 0.6 million tons per annam using grate kiln technology at 100 tons per hour in three shifts.

4. Sponge iron production at 0.4 million tons per year from 0.6 million tons of pellets.

The study reveals that, the low grade resources like Banded Hematite Quartzite's (BHQ) will fulfill the major raw material needs of DRI units of the regions. The project proposes crushing in mobile crushers with screening plant of 250 Tons Per Hour (TPH) to minus 3 mm. The fines are then ground to minus 0.074 mm in closed circuit with 250 dia cyclone cluster at 250 tph. The ground product of minus 0.075 mm fed to 5 x 10 m long screen. The deslimed ground minus 0.074+0.025 mm size fractions are subjected to gravity concentration in spiral concentrators. The middling and tailings of gravity separators is introduced to 30 m dia thickener. The thickened pulp is introduced counter current vertical pulsating high gradient magnetic separator (1.2 Tesla) of 3 m dia with rougher-scavenger and cleaner counter current configuration. The magnetic fractions are subjected to reverse flotation. The gravity and flotation concentrates meets the pellet specification.

It is proposed to have one grate-kiln technology of 0.6 MTPA iron ore pelletization plant adopting dual firing system utilizing producer gas and heavy furnace oil in the ratio of 70:30% in both the pelletizing plants.

DRI process based on coal which is a simple process with a single-step furnace operation is being preferred. The DRI unit consists of 3 kilns with 500 TPD capacities each. Iron ore is reduced in solid state at 800 to 1,050°C (1,472 to 1,922°F) either by reducing gas (H_2+CO) or by coal. The specific investment and operating costs of direct reduction plants are low compared to integrated steel plants and are more suitable for many developing countries where supplies of coking coal are limited. The capital cost of the proposed conceptual project is given under Table 3 and order of magnitude operating costs are given in Table 4.

Table 3. Capital costs involved in project

Particulars	**Million USD**
Capital Cost for mineral processing for 1.8 MTPY at 7200 hours per year	20.0
Capital cost for pelletization for 0.6 MTPY at 7200 hours per year	20.0
Capital cost for 0.45 MTPY DRI plant of 500x3 kiln	20.0
Waste hear recovery and power generation plant1	12.5
Gross capital	72.5

Table 4. Operating costs of each units

Particulars	**USD/t of ore**
Processing cost	10.0
Pelletisation cost	40.0
DRI Manufacturing for 0.45 MTPY	40.0
Gross operating cost	90.0

3.6.2 Viability Studies

The viability of the project based on cash flow is given in Table 5 with a 10-year period for 18 Million reserves. The revenue for 0.5 MTPY steel at 175USD/ t of ore at the present rate of steel after deducting operating expense of 125 USD/t of ore is 50 million USD/year and the capital of 100 million USD is paid back in 2 years with an NPV of 313.1 MUSD at 5% inflation. The conceptual project is attractive from an economic, conservation point of view and is dependent on the price of steel and coal.

Table 5. Viability of the project

Years	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Expense including capital and supplies MUSD	90	115	115	115	115	115	115	115	115	115	115
Revenues in MUSD	-	175	175	175	175	175	175	175	175	175	175
Income inn MUSD	-	60	60	60	60	60	60	60	60	60	60
Net revenue in MUSD	-90	-30	30	90	150	210	270	330	390	450	510
NPV MUSD	313.1										
%IRR	19%										
Payback period	2 years										

4. Conclusions

The iron ore production in Sandur schit belt of Karnataka is expected to be raised from present 25 million tons per year to 60 million tons per year by 2030, thus necessitating 150 million tons of high grade hard lumpy/pellets for domestic use excluding long term export commitments. Hence, a strategy of processing low grade resources like BHQ which are untouched in mines to augment the demand and reduce the foot print of mine. A banded hematite quartzite from Sandur schist belt, observes a fair degree of liberation at minus 74 μm size. The BHQ was amenable to gravity concentration by tabling, reverse flotation and magnetic separation. The final conventional process comprising of gravity concentration by tabling followed by WHIMS of table rejects (slimes, tails and middling). Refining of WHIMS concentrate by flotation could produce a composite pellet grade concentrate with 73% Fe recovery. Thus, obtained concentrate was subjected to pelletization studies. The beneficiation and pelletization produced pellets has met the DRI grade pellets. The concept appears viable as break-even point is less than 2 years, 18% Internal Rate of Return. The concept not only utilize the lean grade iron ores of the study area also enhance the sustainability of the mines by conserving the high grade ores.

5. References

1. IBM. (2011). Iron and steel vision 2020.
2. Raj, B., Rae, B.S.S., & Mathur, S. (2007). Development of a process floweret for beneficiation of Indian Banded Hematite Quartz (BHQ) iron ore, *Proceedings of Iron Ore 2007 Conference*, Perth:Assam.
3. Das, B., Rath, SS., Reddy, PS., Das, SK. and Mishra, BK. (2012). The flotation response of banded iron ore of Karnataka Region, India, *XXVI International Mineral Processing Congress Conference. (IMPC2012)*, New Delhi.
4. Rao, A., Rudramuniyappa, M.V., Hiremath, M.S., & Naganoor, P.C. (2012). Flotation studies on banded hematite quartzite from Sandur schist belt, Bellary district, Karnataka *XXVI International Mineral Processing Congress Conference. IMPC-2012*, New Delhi.
5. Gurulaxmi, S.N., Ghosh, T.K., & Mukherjee, AK. (2010). State of art characterization study of Banded Hematite Jasper for the purpose of beneficiation, *Int. Sem. on Min. Pro. Tech.*
6. Nanda, N.K., & Gopalkrishna, S.J. (2014). Beneficiation studies on Banded Hematite Jasper (BHJ) of Donimalaiarea, Indian Mining & Engineering Journal, 53(02): 15-20.
7. Sinha, P.K., Sharma, V.K., Sengupta, B.L., & Mathur, G.P. (1974). *Pelletization of Donimalai iron ore fines and production of pellets for MECON to be tested at Hyland Midrex Laboratories*, NML-IRNo.802/74.
8. Nanda, N.K. (2016). Beneficiation and utilization of BHJ, Donimalai, Ballari, Ph.D. Thesis, VSK University Ballari.
9. Kumar, P.S. (2018). Process amenability studies on BHQ from Belagal range, Karnataka and Andhra Pradesh states, India. Ph.D. Thesis, VSK University Ballari.
10. Roy, & Biswas. (2008). Iron ore resources of Sandur schist belt GSI.
11. IBM. (2012). Manual of classical and instrumental analysis of ores, mineral and environmental samples.
12. Meyer. (1980). Pelletizing of Iron Ores, Springer Verlag, Berlin.
13. Krishna, S.J.G., Patil, M.R., Rudrappa, C., Kumar, S.P., & Ravi, B.P. (2013). Characterization and processing of some iron ores of India. *Journal of The Institution of Engineers, Sec D*, 113-120 p.
14. Nanda, S.K., Pani, S., & Beura, D. (2020). Recovery of iron values through conventional beneficiation techniques from BHJ of eastern India with reference to mineralogical and chemical characterization. *Indian Journal of Science and Technology,* 13(38): 3960-69.
15. Koroznikova, L., Klutke, C., Knight, S.M.C., Hall, S. (2007) The use of low-toxic heavy suspensions in mineral sands evaluation and zircon fractionation, *6th International Heavy Minerals Conference "Back to Basics", The Southern African Institute of Mining and Metallurgy*.
16. Tang, Y., Zhang, J., & Wernham, J. (2010). The research on the application of new technologies in High Gradient Magnetic Separator with horizontal magnetic line. *Int. Min. Pro. Cong. IMPC2010*. Brisbane:AusIMM
17. Vijayakumar, T.V., Prabhakar, S., & Gopalkrishna, S.J. (2013). Selection of cationic collector for reduction of alumina and silica in iron ore slimes of an operating plant by flotation. *International Journal of Engineering, Science and Technology*, pp. 3295-3302.
18. Metchem. (2006). Conceptual beneficiation of BHQ from Thimppanagudi, Ballari, Project No. 24039
19. Mishra, BK., Reddy, P.S., Das, Biswal, S.K., Prakash, S., & Das, S.K. (2007). Issues relating to characterization and beneficiation of low grade Iron ore fines. Available from: www.worldsteel.org.
20. Nayak, N., Das, A., & Paul, B.K. (2012). Feasibility of beneficiation of BHJ of eastern India, *International Journal of Engineering, Science and Technology*, 1(9): 1-6.

21. NMDC. (2020). Int. communication of BHQ pellets NML (2016) - Sponge iron technology VAA73 PP 29-36

Available from: www.censusindia.gov.in

Available from: www.ibm.nic.in

Available from: www.intierraRMG.com

Available from: www.steel.gov.in

Available from: www.indsteel.org.

Available from: www.worldsteel.org

Available from: www.ibef.org

Available from: https://www.at-minerals.com for flow sheet icons