AMENABILITY TEST AND ANALYSIS OF PROCESSING OF LOWGRADE IRON ORE

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Abstract:

The study on the amenability and processing of low-grade iron ore focused on evaluating the potential of magnetic separation techniques for upgrading the ore. A Banded Magnetite Quartzite (BMQ) sample from Taranagar village, Bellary, was subjected to pre-concentration and various beneficiation tests. The results revealed that the ore had a high silica content, and magnetic separation techniques, such as Davis Tube and LIMS, were effective in concentrating the iron-bearing minerals. The study found that a finer particle size than -100# was crucial for effective separation, and the magnetic fraction yielded a higher Fe grade. Further, the VPHGMS test showed that the magnetic fractions recovered from the tails contained approximately 49% Fe. The findings suggest that MOG plays a vital role in producing the desired grade concentrate, and MOG-200# separation is necessary to enhance the ore's value. The results demonstrate the feasibility of upgrading low-grade iron ore for efficient mineral processing.

Keywords: Amenability test, low-grade iron ore, magnetic separation, Davis Tube, LIMS, VPHGMS, beneficiation.

1.Introduction

The extraction and processing of low-grade iron ore have become increasingly important as higher-grade reserves continue to deplete. Iron ore, primarily composed of magnetite and hematite, is a vital resource for steel production. However, the low-grade ores, often rich in silica and other impurities, present significant challenges in terms of beneficiation and efficient processing. Traditional methods, such as gravity separation and flotation, have limitations in handling such ores, prompting the exploration of advanced techniques like magnetic separation. Several studies have focused on improving the beneficiation of low-grade iron ores using these methods. Amin and Goktan (2006) explored the use of magnetic separation for improving the grade of iron ore, emphasizing the importance of particle size and separation efficiency. Similarly, Singh and Gupta (2012) investigated the impact of different magnetic forces on the separation of iron-bearing minerals from gangue. Further studies, such as those by Sharma and Meena (2017), have shown that techniques like Vertical Pulsating High Gradient Magnetic Separation (VPHGMS) and Davis Tube Tests can efficiently recover iron from low-grade ores, improving the overall grade of the material. The current study aims to assess the effectiveness of these methods in upgrading low-grade iron ore, focusing on particle size distribution and magnetic separation efficiency. The amenability of low-grade iron ore to magnetic separation has been the focus of various studies, particularly with the aim of reducing silica content and enhancing iron concentration. Kumar and Reddy (2015) demonstrated that finer particle sizes allow for more efficient separation in magnetic separators, as smaller particles have better interaction with the magnetic field, resulting in higher recovery rates. Lee and Kang (2012) conducted similar research and found that the separation efficiency significantly improved when the ore was ground to a finer mesh, highlighting the need for optimal particle size control in beneficiation processes. Furthermore, Mishra and Srivastava (2019) discussed the role of LIMS (Low-Intensity Magnetic Separation) in improving the concentration of iron ore, emphasizing that the technique effectively separates magnetic minerals from non-magnetic gangue, leading to an enriched product. In their study, they confirmed that using a combination of magnetic and non-magnetic fractions could improve the overall iron recovery rate. Similarly, Pandey and Kumar (2018) explored the application of the Davis Tube Test for evaluating the magnetic characteristics of low-grade ore, concluding that this method helps to precisely determine the recovery efficiency and separation limits of different mineral fractions.

2. METHODOLOGY

The methodology for this study focuses on the beneficiation of low-grade iron ore using magnetic separation techniques, specifically examining the Davis Tube Test and Low-Intensity Magnetic Separation (LIMS) for improving the ore quality. The first step involved the collection of approximately 500 kg of low-grade iron ore from the Taranagar village in Bellary, Karnataka. This ore was then pre-treated by grinding to different particle sizes to assess the impact of particle size on magnetic separation efficiency. The sample was carefully mixed to ensure uniformity, and a sub-sample was taken for analysis. The Davis Tube Test was conducted using a laboratory-scale model to determine the magnetic susceptibility and liberation characteristics of the ore. The ore was subjected to grinding for varying times (5 to 20 minutes), and after each grinding stage, it was passed through the Davis Tube to measure the magnetic content of the sample. The magnetic products were analyzed for Fe content, and the non-magnetic fractions were also examined. Following the Davis Tube tests, the sample was processed using Low-Intensity Magnetic Separation (LIMS) to separate the magnetic and non-magnetic fractions. The effectiveness of LIMS was evaluated by varying the particle size and analyzing the resulting concentrates for their Fe content. The analysis also involved assessing the grade and recovery rates of both magnetic and non-magnetic products.

Raw Materials

The low-grade iron ore sample used in this study was collected from Taranagar village in Bellary, Karnataka. It was selected for this investigation because of its availability. As shown in Figure 10, the deposit is part of the Fe Banded Iron Ore formation.

Fig 1: iron ore sample case study area

Physical Examination:

According to the physical examination findings, the majority of the sample consisted of brown fines, with only a trace amount of hard, compact chips measuring less than one millimeter in size. The sample demonstrated a specific gravity of approximately 4.8 and an angle of repose of 42 degrees.

Feed Preparation and Sampling

For the purpose of this investigation, an approximately 500-kilogram sample of the low-grade iron ore found in the study region was collected. As shown in **Figure**, a representative sub-sample was taken from the bulk sample using riffle sampling as well as coning and quartering. A subsample was then taken for the experiment, and it was sieved to determine what percentage of particles were larger than 100 mesh (150 microns). Following that, the sample was used for characterization studies, which included particle size analysis (dry and wet), chemical analysis, and amenability studies. The remaining sample was put to use for beneficiation research.

A comprehensive chemical investigation was carried out on the first sample. Without any fine grinding, a sample that was almost 250 grams in size and the representative fraction of the as-received sample were subjected to the Davis Tube Test. The sample was wet ground for a total of five, ten, fifteen, and twenty minutes to determine the percentage of magnetic permeability. The resulting products were re-examined using a Davis tube to determine the degree of release. The grinding times varied from five to twenty minutes.

The remaining fractions were passed through a magnetic separator called a drum magnetic separator, which enabled the production of magnetic and non-magnetic goods. Both chemical and microscopic examinations were conducted on the products. Based on the results from the characterization and diagnostic amenability tests, the ores were classified. After determining the ore type, a mineral processing test was carried out using the general process designed for the liberation size.

Fig 2: Feed sample

Sieve Analysis Test Procedure

The sieve analysis test is a common laboratory procedure used to determine the particle size distribution of granular materials, such as sand, gravel, and ore products. The test involves passing a sample through a series of sieves with varying mesh sizes to separate the material into different size fractions. The following steps outline the typical sieve analysis procedure:

1. **Sample Preparation**: The sample to be tested is first weighed accurately. The sample size is typically between 100 to 200 grams, depending on the material and desired precision.
2. **Sieving**: The sample is placed in the top sieve of a stacked sieve column. The sieves are arranged in descending order with the coarsest mesh at the top and the finest mesh at the bottom. The stack of sieves is placed in a mechanical shaker that vibrates the sieves for a predetermined

time, typically between 10 to 15 minutes, depending on the material and the desired level of separation.

3. **Separation**: During the sieving process, the material passes through the mesh openings of each sieve. The coarser particles are retained on the upper sieves, while the finer particles pass through to the lower sieves. The collected material on each sieve is carefully weighed after the sieving process.
4. **Calculation of Results**: The weight of material retained on each sieve is recorded, and the cumulative percentage of material passing through each sieve is calculated. The results are typically presented as a **cumulative weight percentage passing** through each sieve, providing insight into the particle size distribution of the sample.

Table 1: Sieve Analysis of Product

Mesh	Size in Microns	Wt %	Cumulative Wt % Passing
-50+72#	210	24.00	76.00
-72+120#	125	19.2	56.80
-120+140#	106	7.2	49.60
-140+200#	75	10.4	39.20
-200+240#	63	4.0	35.20
-240+272#	55	8.0	27.20
-272#	-55	27.20	0.00
Head	100.00		

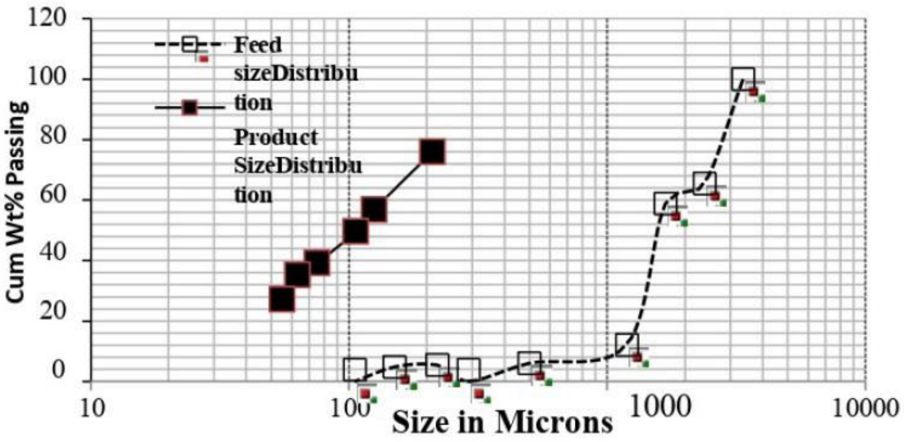

Fig 3: Graphical representation of feed and product sieve analysis

Vertical Pulsating High Gradient Magnetic Separation Studies

Magnetic Jigging Principles were instrumental in the development of the Vertical Ring and Pulsating High Gradient Magnetic Separator (VPHGMS), which employs pulsation mechanisms designed to improve the separation efficiency of magnetic minerals from non-magnetic ones. This process is accomplished by churning the slurry and keeping the particles in motion to prevent particle entrapment within the matrix, which, in turn, creates additional surfaces for the collection of particles inside the matrix. When used theoretically, this technique enables the separation of mixtures with very minor differences in density and magnetic susceptibility.

The research was conducted using a laboratory model of the VPHGMS with a field intensity of 11,000 gauss, a rotational speed of 2.5 RPM, and a pulsation rate of 75 strokes per minute, as shown in Figure

20. The purpose of the study was to determine whether it was possible to recover the magnetic fraction from the medium-intensity magnetic separator tails, also known as the non-magnetic fraction. The findings indicated that there was no increase in Fe values or recovery, suggesting that the entire magnetic fraction was successfully isolated from the feed sample.

The results revealed no increase in Fe values. Additionally, it was discovered that the percentage of SiO2 in the non-magnetic fraction increased to 67.28%, with a high recovery of 74.4%. The detailed outcome can be found in Table.

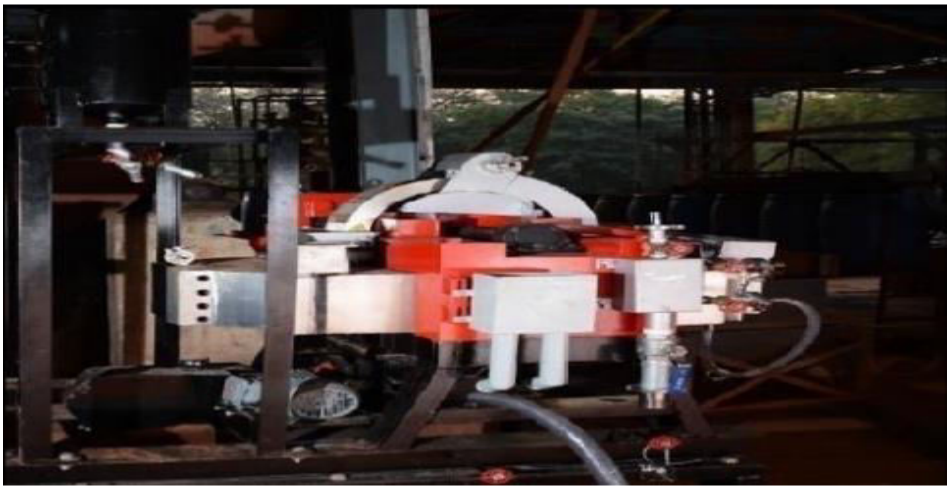

Fig 4: VPHGMS Test

Table: Results of VPHGMS Test

Product	Wt	Wt. %	Fe %	FeO	Al2O3	SiO2	LOI
Mag.	9.05	24.00	49.09	1.25	0.19	25.29	1.44
Middling	0.60	1.59	40.75	1.67	0.24	34.03	1.59
Non-Mag.	28.05	74.40	15.16	1.23	0.30	67.28	2.21
Head	37.7	100.0	23.70	1.24	0.27	56.66	2.015

4. Results and Discussions

Drum Magnetic Separation Studies

The received sample, weighing approximately 600 kg, was carefully mixed before being fed into the drum magnetic separation device. This process aimed to separate the magnetic fraction from the non-magnetic fraction within the feed material. Based on the findings, about thirty percent of the total volume was identified as the non-magnetic fraction. Representative samples of the magnetic (Mag) products, totaling 250 grams, were analyzed using a wet sieve for detailed examination. The precise size distribution and the amount of Fe present in each Mag product fraction are shown in Table 8. Additionally, it was found that nearly 33% of the Drum magnetic product consists of +100 Mesh (150 Microns). It was observed that the grade of the drum product is at its highest point at a finer size, specifically at -200 mesh, where it contains 62% iron.

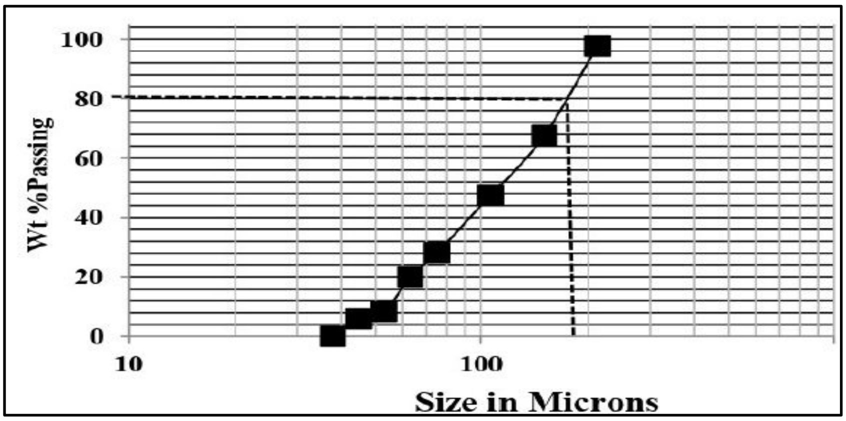

Fig 5: sieve analysis of received sample

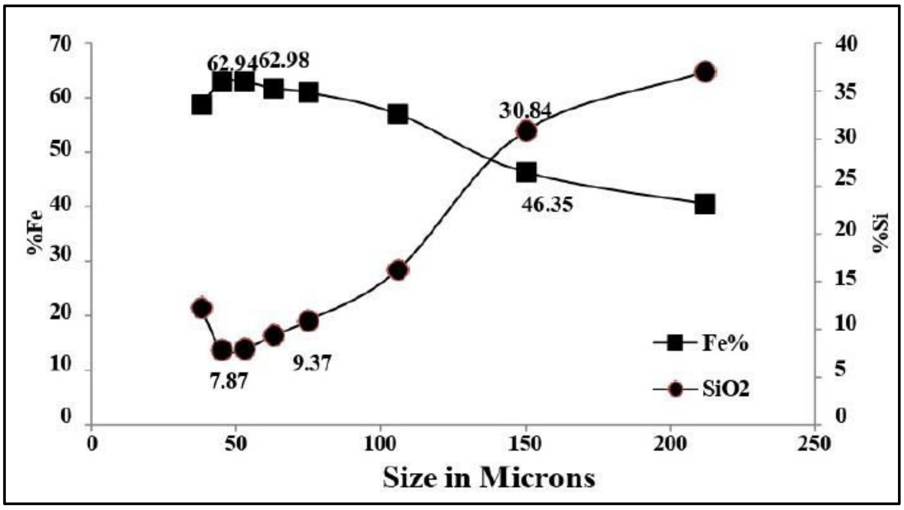

Fig 6: Effect of Size on %Fe and %Si Values of Feed Sample

Effect of MOG on Davis Tube Test

Wet grinding was performed on a representative sample weighing approximately 200 grams of feed for a period ranging from 5 to 20 minutes. The ground material was then subjected to the Davis Tube Test, which operates at a water flow rate of 650 cc/min and is designed to maintain the pulp level in the tube and poles at a constant level. The agitation rate was set to 30 revolutions per minute (RPM), and the agitation time was allotted for 10 minutes. A slope angle of 45 degrees was chosen for the test, which was deemed ideal for this investigation.

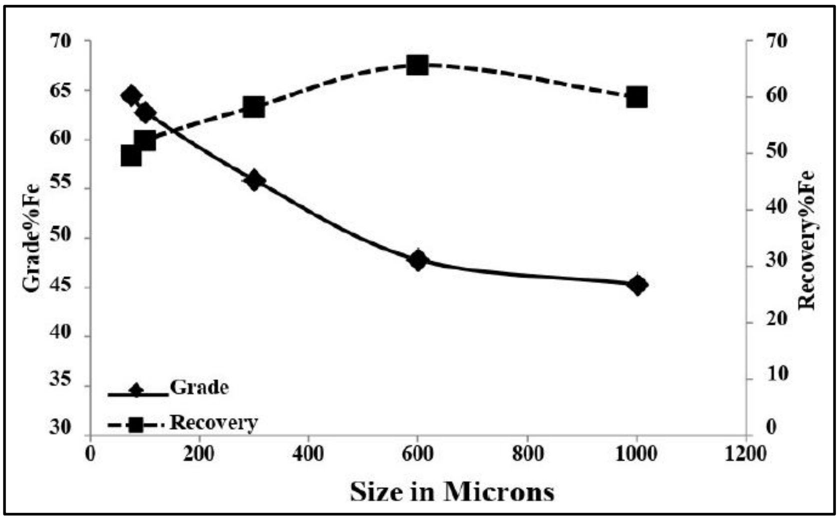

Fig 7: Grade and recovery curve Davis Tube Test

Model Analysis of LIMS Test Products

(a) +100# of LIMS Mag

The LIMS on Products of the LIMS test Mag sample at **+100#** size comprises four primary groups of mineral grains, as follows: **Free iron-bearing minerals** (Hematite / Magnetite) 74%, **Free Quartz** 11%, **Interlocked particles** 7%, and **Other (iron ore coated gangue)** 8%. The iron-bearing minerals have sizes ranging from around 550 microns on the larger end to less than 30 microns on the smaller end. The coarsest size is approximately 550 microns. When they are around 70 microns in size, particles that are trapped together may be released.

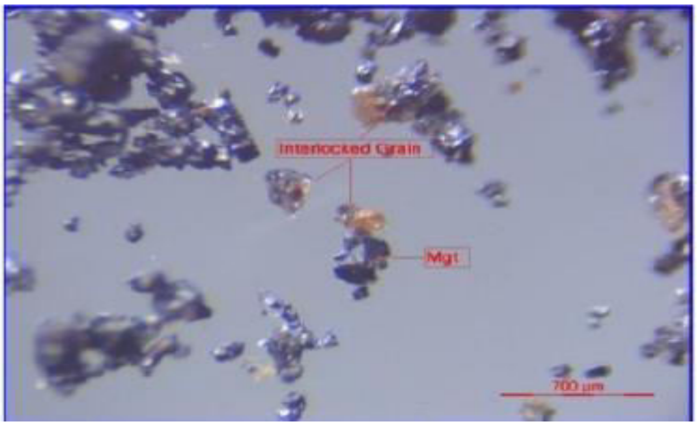

Fig 8. Stereo Microscopic Photograph displays Free Magnetite (Mgt) and Magnetite and Hematite interlocked grains in **'LIMS MAG +100#** sample. (X-45).

(b) +100# of LIMS Non-Mag

The results of the **LIMS examination** show that **free iron-bearing minerals** (Hematite/Magnetite) make up 25% of the non-mag sample at the **+100#** size. **Free Quartz** makes up 60% of the sample, **interlocked particles** make up 10%, and other (iron ore coated gangue) accounts for 5%. The iron-bearing minerals have sizes ranging from less than 30 microns to as large as 150 microns at the coarsest point. The average size of an iron-bearing mineral is about 150 microns. When they are around 50 microns in size, particles that are trapped together may be released

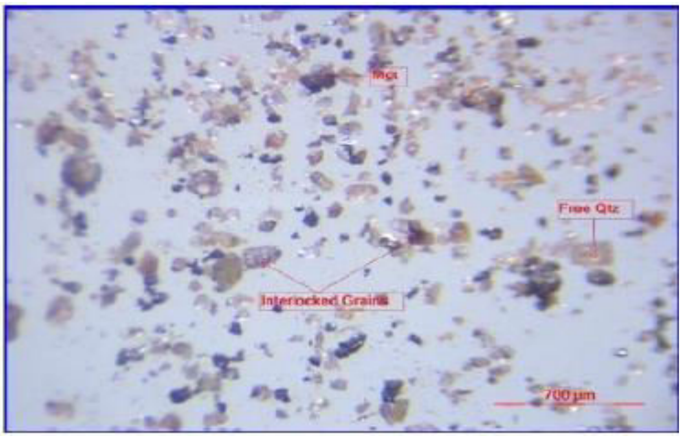

Fig 9. Stereo Microscopic Photograph displays Free Magnetite (Mgt), Free Quartz (Qtz), and Magnetite and Hematite interlocked grains in **'LIMS NON-MAG +100#** sample. (X-60)

(c) -100# of LIMS Mag

The results of the **LIMS examination** of the mag sample show four primary types of mineral grains, including **free iron-bearing minerals** (Hematite and Magnetite) making up 97% of the sample, **free quartz** making up 2%, and **interlocked particles** making up 1%. The iron-bearing minerals have sizes ranging from less than 30 microns to as large as 150 microns at their coarsest point. The average size of an iron-bearing mineral is about 150 microns. When they are around 50 microns in size, particles that are trapped together may be released

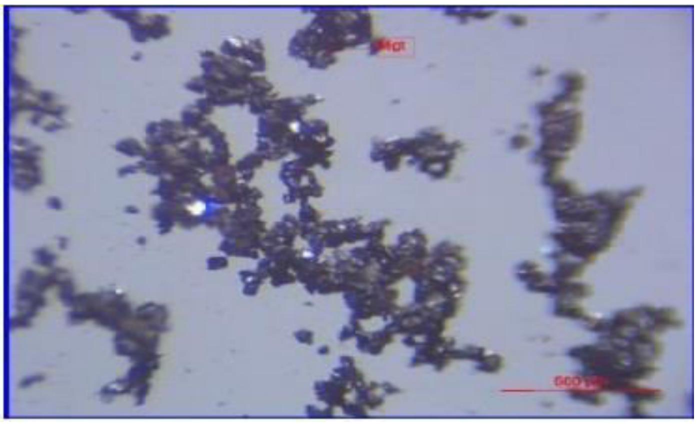

Fig 10.: Stereo Microscopic Photograph displays Free Magnetite (Mgt) grains in **'LIMS MAG -100#** sample. (X-60).

(d) -100# of LIMS Non-Mag

The results of the **LIMS examination** of the non-mag sample at **-100#** size consist of four major categories of mineral grains, namely **free iron-bearing minerals** (Hematite/Magnetite) 5%, **free quartz** 60%, **interlocked particles** 5%, and other (iron ore coated gangue) 10%. Free iron-bearing minerals make up 5% of the sample, while the free quartz makes up 60%.

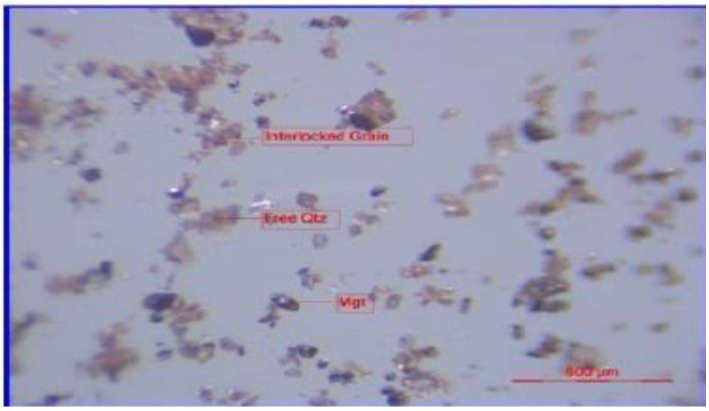

Fig 11: Stereo Microscopic Photograph displays Free Magnetite (Mgt), Free Quartz (Qtz), and Magnetite and Hematite.

Conclusion:

A Banded Magnetite Quartzite (BMQ) sample with a number of -150# was obtained from the Taranagar hamlet in the Bellary area. This sample was used in a process evolution to get concentrate with an assay of Fe > 65%. The pre-concentrated sample had an analysis of 37% Fe (T) and 42% silica content, with the majority of the silica coming from fine-grained Magnetite and fine-grind quartz. The process amenability test suggested that a MOG with a finer particle size than -100# should be separated using magnetic forces in order to create the concentrate of the required grade. The exploratory Davis tube test provided confirmation of the result of the amenability test in relation to MOG. The results of the tabling test on extremely MOG revealed that the necessary grade concentrate could only be generated at MOG finer than -150 mesh, despite the fact that recovery was low. In a similar manner, LIMS confirming -100# MOG results in 66.6% Fe with 74.6% Distribution. According to the findings of the research relevant to LIMS non-mag, that was submitted to WMMIS validating MOG -200#, MOG is necessary for the production of the required grade concentrate. The VPHGMS test is carried out with the goal of recovering the tiny Magnetic fractions from the tails of the whole process, which gives a total of 49 percent Fe with 23% dispersion. The final flow sheet is illustrated in the figure, and it produces a concentrate that has a Fe content of 64.67 percent, with a Fe distribution of roughly 70 percent at a Wt percent yield of 74. The product satisfies the requirements of the given standard in addition to those of the metallurgical industry (with reference to Fe) and the heavy metal specification. It is advised that a detailed investigation on a continuous pilot scale test be performed for the future development of this process, enhancing it, and collecting engineering data for the implementation of this process as the target for mineral investigation and recovery.

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