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Research Paper

Investigation of the Effect of Various Parameters on the Ore Hardness of Gole-Gohar's No. 1 Mine

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Abstract: Attention to the hardness of ores and their grindability is increasing due to the importance of energy consumption. In this study, 73 samples of iron ore were prepared from Gole-Gohar's No. 1 mine, and the SAG power index test was performed to measure hardness. The distribution of the hardness values of these samples and its comparison with the results of the last five years showed a significant increase in the hardness of the mine so that the average hardness increased from 32.1 minutes to 65.6 minutes. In addition, the hardness distribution of Gole-Gohar mine demonstrated that 52%, 26%, and 22% of the ore were obtained with a hardness of less than 50 minutes (soft materials), 50-100 minutes (medium), and more than 100 minutes (hard), respectively. Among the hardness-related parameters, the total Fe, S, Fe/FeO ratio, density, and magnetite recovery in the Davis tube test had no significant relationship with hardness, indicating the special importance of homogenizing the feed to the processing plant based on ore hardness in addition to grade homogenization. However, mineralogical factors such as texture, the composition of the constituent minerals, and the type and frequency of the constituent minerals have a significant effect on the hardness of the samples.

Keywords: Iron Ore, Hardness, SPI Test, Gole-gohar.

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INTRODUCTION

With the advancement in the science of grinding and thus autogenous and semiautogenous (SAG) mills, the mining industry has always been associated with the problem of preparing representative samples for the design, sizing, and experiments related to mill grinding. Apart from providing such a sample, performing such tests was costly. Accordingly, some plants and companies were seeking to find methods to solve these problems. MinnovEX (1993) developed a SAG power index (SPI) test that was proper according to less representation sample and cost [1,2]. With the advent of the SPI method, various mining companies can easily and quickly measure the hardness of the ore. If the test is accurate, the grindability of the ore in different areas is obtained by the extensive sampling of the mine and testing on these samples, and the distribution of the special energy of the mill in the entire deposit can be calculated accordingly. Design and processing engineers can design and select equipment based on hardness-related fluctuations and changes by determining the distribution of specific power and energy throughout the deposit. Therefore, using the SPI test and SAG mill power, it is possible to prevent the reduction of plant throughput and instability caused by changes related to crushing capacity in the plant [3,4]. Various studies have recently focused on investigating the hardness of the ore entering the AG mill and its performance in the Gole-Gohar Mining and Industrial Complex [5-7].

Considering the previous research and the necessity of updating the hardness information of Gole-Gohar's No. 1 mine and observing the fluctuations in the performance of the plant equipment, especially the AG mill, the current study evaluated the hardness of the feed of Gole-Gohar's Plant. Fluctuations related to the AG mill can be reduced by examining and determining the hardness of different areas of the mine pit and its blocking, along with determining the relationship between the hardness of feed and the specific power of the AG mill, ultimately leading to improved mill performance. Previous evidence has shown what factors affect the change in hardness and how to act to control the hardness and proper feeding to the plant. Thus, the hardness of different samples, which were prepared from exploration cores in different parts of the mine, was determined by the SPI test, and then the hardness number for each sample with specific coordinates was computed as well. Next, the hardness distribution of the samples was compared with related data of previous research in this regard. Eventually, the relationship between different factors related to the hardness of the ore was evaluated, including Fe, FeO, S, density, Davis tube test results, and optical and electron microscope studies.

METHODS

In this research, 73 different samples were used to perform SPI tests, which were prepared from exploration cores in various parts of the Gole-Gohar Iron Ore Mine located in Mine-1 in Sirjan-Kerman. These samples were moved to the pilot plant of Gole-Gohar Complex for testing. After crushing the samples, they were homogenized using a chute sample splitter and reduced to the subsamples of 2 kg for the SPI test.

SPI standard for the SPI:

The SPI test is the commercial name given to a laboratory ore-hardness characterization test by the MinnovEX Technology Company, and its procedure was originally developed by John Starkey [3]. The procedure involves the use of a 300 mm diameter, 100 mm long laboratory mill loaded with 25 mm steel balls. In addition, 2 kg of the feed material is crushed to -19 mm (F80 is approximately 12.5 mm) and ground in the mill until obtaining a product P80 of 1.7 mm. The time in minutes to reach this point is the SPI. The SPI parameter is applied in conjunction with the following equation to predict the specific energy of SAG mills [4,5].

$$P_{SAG} = \left(P_{80}{}^{-0.33}\right)(2.2 + 0.1t) \quad (1)$$

Where:

P80 and t: denote the d80 of the SPI test product and the total time consumption of the test, respectively.

To study the grade of different elements of the samples, the iron titration method and the X-ray fluorescence method, Davis tube test, and specific gravity determination were used from the pycnometer in the central laboratory of Gole-Gohar Complex. Moreover, the samples were sent to the Laboratory of Iran Mineral Processing Research Center located in Karaj for microscopic studies of thin and polished sections, XRD, and SEM, and the results were evaluated accordingly.

FINDINGS AND ARGUMENT

The hardness study of 73 samples from various parts of the mine with the SPI test is graphically illustrated in Figure 1-2018. The hardness range of the ore is divided into five categories of highly soft, soft, medium, hard, and extremely hard based on the test results. Accordingly, 27% and 25%, of the mine have soft and highly soft ores with a hardness between 20-50 minutes and extremely low and less than 20 minutes, respectively. Further, 26% of the ore has an average hardness range of 50-100, and a small percentage of the mine generally covering 22% of the ore has a hardness of more than 100 minutes.In the hardness evaluation of Gole-Gohar No. 1 mine (2013), the average hardness of the studied samples and their standard deviations were 32.1 minutes and 20.8, respectively. Furthermore, the softest sample had a hardness of one minute while the hardest sample represented a hardness of 103 minutes. The following results can be obtained by comparing the hardness results of Gole-Gohar No. 1 mine in 2013 and 2018. As the mine progresses, the hardness of the ore indicates an increase. The hardest sample in 2013 had a hardness of 103 minutes. However, the hardness of the ore reached 324 minutes in the current study. The relation between ore hardness and Fe, S, and Davis tube recovery is depicted in Figure 2. As shown, there is no correlation between the hardness parameter and the values of Fe and S, and predicting the ore hardness based on the grade of Fe and S is impossible. Therefore, these parameters are completely independent.

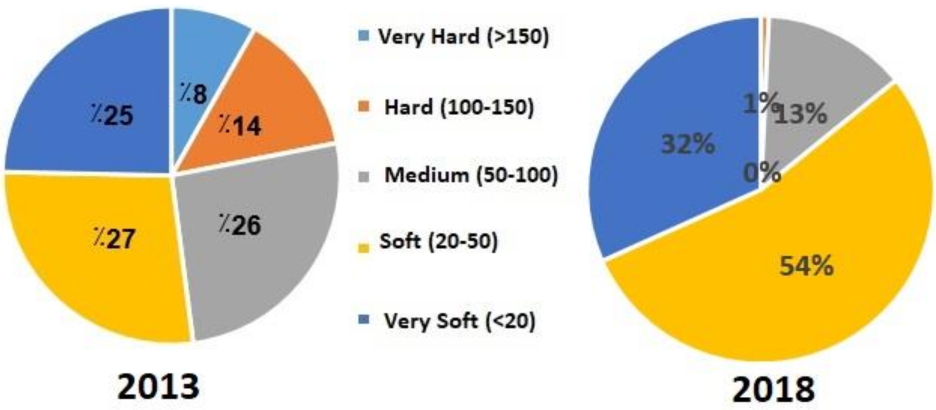

Figure 1. Comparison of the distribution of ore hardness of Gole-gohar No. 1 mine's

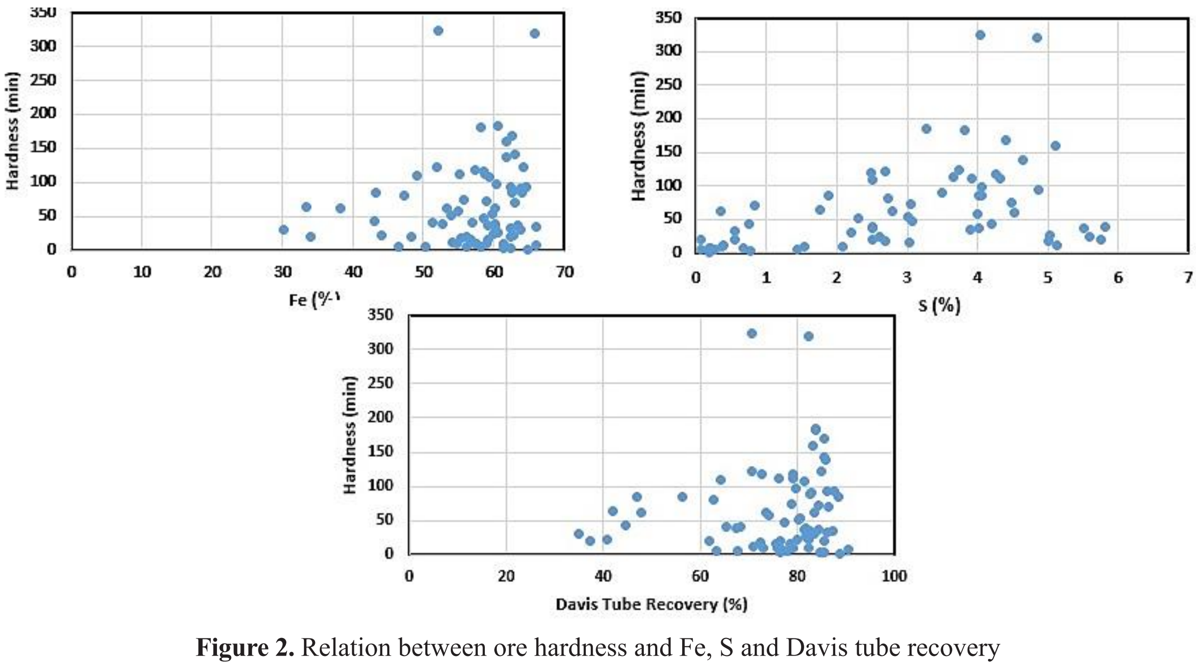

Figure 2. Relation between ore hardness and Fe, S and Davis tube recovery

Mineralogical studies performed on samples with different hardness showed that the difference in the hardness of the samples depends on many factors. The most important and effective reasons for the change in hardness in different samples included the texture of the sample, the minerals in the sample, the frequency of each mineral, the degree of alterations, porosity and weathering, the involvement of different minerals, and the degree of mineral oxidation. According to Figure 3-A, the space between the magnetite cavities is included by talc, chlorite, biotite, and dolomite minerals, leading to a reduction in the hardness of the sample. However, the inclusion of cavities and vessels and veins between the magnetite by pyrite and chalcopyrite sulfide minerals is observed (Figure 3-B), increasing the hardness of the sample.

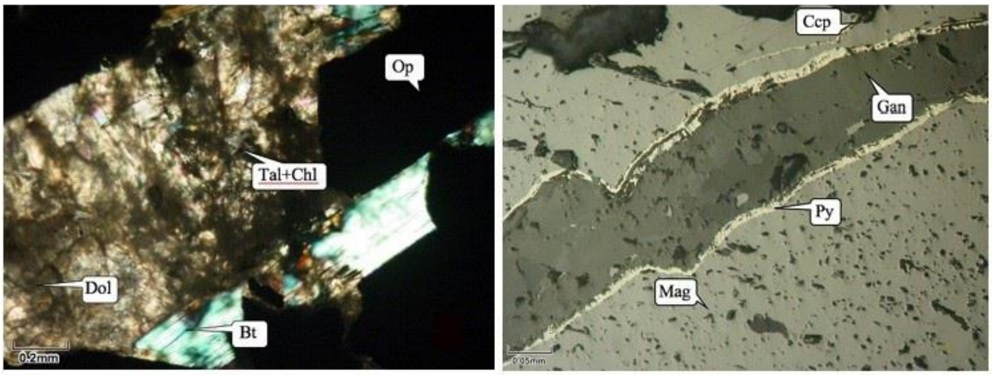

Figure 3. A: Soft minerals inclusion (dolomite, biotite, talc, chlorite), **B:** Hard mineral inclusion (pyrite)

CONCLUSIONS

The distribution of the hardness values of 73 representative samples of Gole-Gohar No. 1 mine and its comparison with the results of the last 5 years demonstrated a significant increase in the hardness of the mine so that the average hardness increased from 32.1 minutes to 65.6 minutes. Additionally, the hardness distribution of the Gole-Gohar mine showed that 52% of the ore resulted with a hardness of less than 50 minutes (soft materials). Further, 26% and 22% of materials were obtained with a hardness of 50-100 minutes (medium) and more than 100 minutes (hard), respectively. Among the parameters related to hardness, the total Fe, S, Fe/FeO ratio, density, and magnetite recovery in the Davis tube test exerted no significant relationship with hardness, implying the special importance of homogenizing the feed to the processing plant based on ore hardness in addition to grade homogenization. However, mineralogical factors such as texture, the composition of the constituent minerals, and the type and frequency of the constituent minerals had a significant effect on the hardness of the samples.

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