Effect of Feed Size on Fine Grinding of Dolomite from Naulla Deposit, Sri Lanka

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Abstract

This study examines the crucial role that feed size plays in the fine grinding of dolomite obtained from Sri Lanka's Naulla deposit. The study is carried out at Metal Mix Pvt. Ltd. Galpatha site, a commercial facility that prepares dolomite for use in a variety of industries. By identifying the most efficient feed size range that improves comminution efficiency while attaining the desired particle size distribution, the main goal is to optimise the dolomite crushing unit, in particular the autogenous mill. The research process includes in-depth field tests and laboratory examinations. The effect of different feed size ranges on the grinding process is assessed by on-site studies. Analyses of the particle size distribution are performed based on the output of the autogenous mill to evaluate how well it performs with various feed sizes. The outcomes show that there is a distinct relationship between feed size and the effectiveness of fine grinding. According to the study, limiting feed size ranges from 1.5 to 4 inches which greatly raises crushability, cuts down on energy waste, and optimizes the grindability. The dolomite processing industry, where energy-efficient comminution is of utmost importance will be benefitted out of the findings of this study.

Keywords: Autogenous mill, Comminution efficiency, Dolomite, Feed size, Fine grinding, Particle size distribution

1 Introduction

Dolomite is a vastly abundant mineral with wide and complex industrial applications. In Sri Lanka, crystalline dolomitic rocks are often found in metamorphic terrains which are mainly applied as raw material in the ceramic industry, fertilizer industry, and local lime manufacturing plants. Dolomite is usually a sedimentary rock-forming mineral with the chemical composition of $CaMg(CO_3)_2$.

The Metal Mix Pvt. Ltd. Galpatha site, Sri Lanka is an industrial establishment that has been involved in aggregate quarrying, and quarry dust production over the past sixteen years, whereas tile mortar production, and processing of dolomite for the glass manufacturing industry over the past twelve months. The engineers on site needed optimisation of the dolomite crushing unit available on their site which includes an autogenous (AG) mill. The industrial requirement of the output of the crushing unit below 700 µm particle size produced on this site also includes 20% of the particles below 100 µm. Since the crushing equipment is fixed, the only variation that can be made is changing the feeding size [1]. The site is equipped with another primary crushing equipment (cone crusher) which can give the required size to the AG mill. The existing feed size is 6 inches by 10 inches. However, the output contains about 10% passing (from 700µm) which is significantly low, hence the system required feed size optimisation.

The comminution energy consumption is strongly related to the type of ore and the particle size of the grinding product. Crushing produces particles of coarse sizes (typically ф≥ 5 mm) and consumes relatively low energy, whereas milling produces particles of fine sizes and is highly energy intensive [2]. Furthermore, [3] indicated that 97% of the energy consumed in comminution is related to the milling circuits. According to [2], the power consumption of a semi-autogenous (SAG) mill is between 12 and 23MW and its performance (or energy-efficiency) is strongly influenced by the operating conditions of the mill and the ore characteristics, [4] i.e., in the milling process, the involved variables present uncertainty, which implies that the responses of the milling process (performance or energy efficiency) also present uncertainty. Therefore, the research has been addressing the scientific gap where there is no research done to investigate the optimum feed size of dolomite for AG mills. Moreover, the findings of the research will be highly valuable for both relevant scientific and industrial communities as it fills a major research gap and gives a highly valuable set of information on particle size analysis of dolomite which directly reflects its future industrial applications.

AG mills are tumbling mills that employ the ore itself as the grinding media. Jones and Fresko [5] explain that this type of mill combines the size reduction steps of crushing, coarse grinding, and fine grinding. The capability of AG grinding depends on the ore's amenability to this process, which necessitates the presence of sufficient competent pieces within the ore to act as grinding media. Due to the varied nature of the grinding process, AG mills are employed for fine grinding. Many small particles are produced as a result of impact and abrasion. The grinding material is left in the mill for a considerable amount of time, which frequently results in the over-grinding of ore particles, which are typically more brittle than gangue particles [6]. Three lithological types of copper ore were the subject of comparative analyses for strength distribution by Nad [7]. Rod mills were used since it was necessary to crush the large dolomite and shale particles. Simultaneously, any worries about the excessive grinding of ore minerals that had previously been liberated from sandstone ore were dispelled. The factors of the mill's operation, such as rotational speed, load, filling with grinding medium, and size, determine how effectively it operates. The particle size distribution, which includes the largest particle size subject to grinding and susceptibility to grinding, is the most crucial feed parameter.

The most important common technological challenge related to the grinding of dolomite is choosing the right mill or grinding media type and size to ensure the proper performance of the entire grinding stage, classification circuit, and regrinding of the feed properties subjected to this procedure [8].

2 Aim and objectives

2.1 Aim

To determine the optimum feed size for the dolomite crushing plant at Metal Mix Pvt Ltd. - Galpatha quarry site to optimise the crushability of dolomite.

2.2 Objectives

1. To investigate of the dolomite feed given to the existing plant to understand the requirements for the highest crushability and feed size related to the same.
2. To identify the existing crushing plant mechanisms, equipment, and variables of the grinding operations.

3 Methodology

Since the optimisation was recommended for a fully operational plant now, a current situation analysis was necessary including a particle size analysis for the current output of the plant [9]. For that purpose, a comprehensive study was done to identify the mechanism, type, and working principle of the equipment and preliminary sieve analysis for the plant output for their current feed range of 0-6 inches.

The plant comprises of several parts as shown in Fig. 1, in which the upper and lower images illustrate the end view and the plan view of the same, respectively. As mentioned under the research objectives, the AG Mill has been the focal point for the optimisation of the grinding mechanism in this entire plant. The AG mill maintains a consistent milling capacity of 8 tons per hour and a power rate of 90 kWh, throughout the experimental process. In the plant itself, the observed parameters affecting the grinding are:

1. Feed size
2. Moisture content
3. Mill specifications

Out of these parameters, the feed size was recognised as the only viable parameter that could be changed for these trials as per the plant requirements.

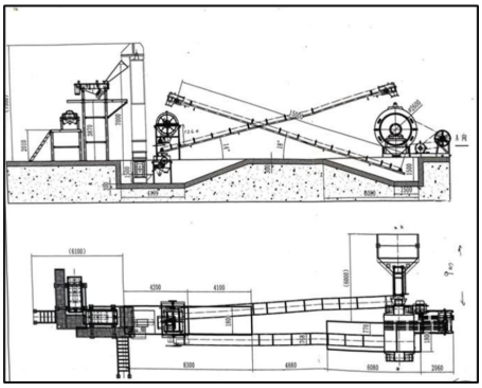

Figure 1: End view and plan view of the plant [Chinese manufacturers catalogue]

Accordingly, the optimum feeding size for the plant was investigated, and a series of trials were designed as per Table 1. The existing feed range was split into three groups and three specific trials were made accordingly.

Table1: Feed range selection for trials

Trail number	Feed range (in)
Current Situation	0-6
1	0-1.5
2	1.5-4
3	4-6

The first feed range of 0- 1.5 inches was neglected without testing since the practical input of that range is economically not viable at any circumstance. The second range from 1.5- 4 inches was tested using 1084 kg of feed sample and the results were gained in different time intervals. In the initial time intervals, the fine content was not high (below 40%) as the system was not stabilised and residues of previous material inside the AG mill were present.

However, after stabilising (in sample sets 4 and 5 given in Table 3) the results show above 50% passing and highest of 65% in this range.

Therefore, it can be understood that this range has a better fine content than the existing range. As the (0-1.5) inch feed range is technically not harmful, the summation of two ranges is more effective than the current range itself.

4 Results

Two hundred and seventy sieve analysis tests including three trail tests were carried out as per ASTMD4222-63. Table 2 gives the particle size distribution of the AG Mill output of the existing plant.

Based on the above five sieve test results, the average particle size distribution curve derived is presented in Fig. 2.

Table 2: Particle size distribution of AG Mill output of the existing plant

	Retained in each Text				
Sieve	**1**	**2**	**3**	**4**	**5**
850.0	309.5	364.5	359.5	325.0	330.5
600.0	120.5	95.5	95.0	114.5	110.0
500.0	21.5	15.0	16.5	20.0	19.5
212.0	26.0	15.0	15.5	22.0	21.5
90.0	18.5	7.0	6.5	11.0	11.0
53.0	0.5	1.0	0.5	3.5	3.5
Pan	0.5	0.5	0.5	1.0	0.5
Total	496.5	498.0	493.5	496.5	496.0
Loss	3.5	2.0	6.5	3.5	4.0

Figure 2: Average particle size distribution of AG Mill output of the existing plant

Three numbers of field trials were done as per Table 1. The average particle size distribution of AG mill output as per these trials is given in Fig.3.

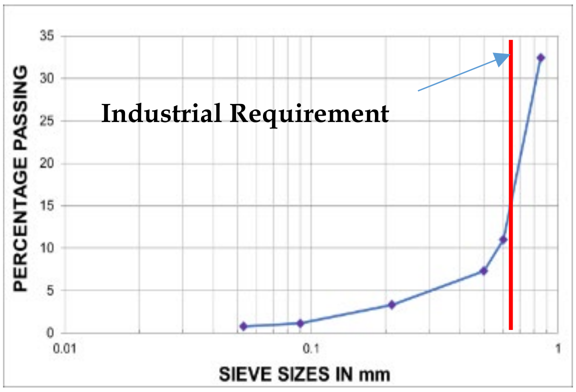

Figure 3: Average particle size distribution of AG Mill output of the existing plant as per field trials.

5 Discussion

The requirement by the glass manufacturing industry is an output below 700 µm particle size from the crushing unit, however, which is currently at 20% on average of the particles below 100 µm of the existing plant. According to the analysis of the current situation, the existing output (from 0-6 in the feed) has a range of (40-45)% passing (from 700 µm) which records more than a 50% of particle returning rate of the plant back to comminution unit. Therefore, the current operation can be considered significantly ineffective as almost half of the feed is recirculated in the system.

The findings of this study indicate that achieving of higher efficiencies in the crushing process of dolomite involves narrowing down the particle size range rather than crushing a larger range, such as (0-6) inches, all at once. By narrowing down the particle size range, the feed material becomes more homogeneous, resulting in improved crushability, although achieving complete homogeneity is not practically feasible. Based on the experimental results, it was observed that a particle size range of (1.5- 4) inches exhibited a 10% increase in fines compared to the normal range of (0-6) inches. However, considering the impracticality of excluding fines in the (0-1.5) inch range, a practical solution would be to demarcate the particle size range of (0-4) inch for optimal crushing performance.

The major objective of this research was to find out the optimum feed size that is applicable for the Galpatha dolomite plant to increase the efficiency of the grinding unit. As per the trial runs the best size was determined as (1.5-4) inch range. Hence, primary comminution equipment could be applied to grind particles to that level before feeding them to the AG mill.

The knowledge about the nature of Sri Lankan dolomite and its properties (At least the site specifics) are rather vital although the existing scientific publications and research material on the topic is low and the importance of the information is high as it applies to the existing dolomite processing operations and value addition. Moreover, Metalmix Pvt Ltd, Galpatha quarry site needed to optimise their grinding operations using the knowledge gained based on this research to cut down the energy waste for grinding of dolomite.

Therefore, the research goals were to determine the optimum feed size for the dolomite crushing plant at the Metal Mix Galpatha quarry site optimise the crushability of dolomite and investigate the physical and chemical properties of dolomite which is being used in the plant to give a complete picture about dolomite feed and provide information regarding physical and chemical properties of dolomite from Matale, Naulla area as a secondary objective. In the research itself a series of trial runs were made onsite to achieve the primary objective and laboratory physical and chemical tests were performed to achieve the secondary objective.

6 Recommendation

According to the outcome of this study, a (1.5-4) inch feed range can be recommended as the best range of feed which gives the optimum crushability of the AG Mill.

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