

COMPARATIVE ANALYSIS OF AUTOGENOUS AND SEMI-AUTOGENOUS GRINDING FOR DUGURU LEAD-ZINC ORE FROM ALKALERI, BAUCHI STATE, NIGERIA

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ABSTRACT

The mining industry plays a critical role in economic development, and lead and zinc are essential metals extracted globally for various industrial applications. However, extracting and processing these metals, particularly from complex sulphide ores like sphalerite and galena, poses significant challenges due to their intricate mineralogical associations. This research compares two grinding methods—autogenous and media-assisted grinding—in the beneficiation of Duguru lead and zinc ore from Alkaleri, Bauchi State, Nigeria. The grinding tests were conducted at three different revolution speeds (200, 400, and 600 rpm) using two modes: New Charge (NC) and Addition of Difference (AD). Results show that media-assisted grinding, which uses steel balls, consistently outperforms autogenous grinding in terms of grindability across all revolutions. At 200 rpm, the grindability for autogenous grinding was 0.04985 g/rev (49.85 kg/t/rev) and for media-assisted grinding, it was 0.05075 g/rev (50.75 kg/t/rev). At 600 rpm, autogenous grinding achieved 0.07212 g/rev (72.12 kg/t/rev), while media-assisted grinding reached 0.09838 g/rev (98.38 kg/t/rev). The Addition of Difference (AD) mode produced higher grindability values than the New Charge (NC) mode for both grinding methods. These findings indicate that media-assisted grinding provides superior efficiency due to the enhanced ore breakage facilitated by the grinding media, making it more suitable for continuous operations requiring high throughput. It is recommended that the mining industry adopt media-assisted grinding for better performance, with further studies aimed at optimizing energy consumption and recovery rates. Additionally, combining autogenous and media-assisted grinding techniques in hybrid methods could offer a balanced approach for cost-effective processing.

Keywords: Autogenous grinding, grindability, lead-zinc ores, media-assisted grinding, ore beneficiation .

INTRODUCTION

The mining industry has increasingly become a critical driver of economic growth and development, contributing significantly to the expansion of national economies and the improvement of social well-being (Bradshaw, 2005; Bridge, 2008). Lead and zinc, two of the most important metals mined globally, are primarily extracted from sulphide minerals such as sphalerite (ZnS) and galena (PbS). These minerals are often found together in deposits and are vital in numerous industrial applications, ranging from the electrical, mechanical, and chemical industries to the military and nuclear sectors (Encyclopedia Britannica, 2010). The extraction and beneficiation of lead and zinc ores, particularly from complex sulphide deposits, remain a significant challenge due to their intricate mineralogical associations, which often involve interlocked and finely disseminated refractory metals, making traditional processing methods less effective (Deveci *et al.*, 2004; Rubio and Frutos, 2002).

In Nigeria, lead and zinc mining is of particular importance due to the potential to boost local industry, with lead being used extensively in a variety of sectors including electrical, medical, and pharmaceutical industries, and zinc being a critical material for construction and manufacturing (Egunlae & Jimoh, 2010; USEPA, 1994). Earlier studies such as Adepoju and Olaleye (2000) have also emphasized the need for improved beneficiation techniques for Nigerian lead-zinc ores to enhance recovery efficiency and industrial utilization. The efficient recovery of these metals from ore materials is therefore crucial for sustainable economic growth. The beneficiation process involves three main operational stages: extraction, beneficiation, and processing. The extraction phase focuses on the removal of ore material from the deposit, while the beneficiation stage seeks to concentrate the valuable minerals, and processing entails smelting and refining to produce marketable products of high purity.

However, the presence of gangue minerals such as quartz, calcite, and white mica in ores can pose significant challenges in the beneficiation process, particularly in terms of effective mineral separation. Recent studies have shown that advanced methods like microwave heating can enhance mineral liberation, grindability, and improve subsequent separation processes (Ghazala *et al.*, 2012; Liu *et al.*, 1997; Omran *et al.*, 2015). Furthermore, recent advances in microwave-assisted beneficiation techniques have been highlighted by Song *et al.* (2013) and Zhao *et al.* (2014), demonstrating improved efficiency in processing complex sulphide ores. These technologies offer promising alternatives to traditional methods such as differential flotation, which has been shown to have limitations in releasing all constituent phases from complex ores (Majima, 1969). Additionally, hydrometallurgical methods, while effective in certain cases, face challenges related to the low solubility of sulphide ores in many reagents, leading to high reagent consumption and environmental concerns (Olubambi *et al.*, 2005).

Given the complexities involved in the extraction of lead and zinc from sulphide ores, it is essential to explore more sustainable, efficient, and cost-effective methods for ore processing. One such method gaining attention is the comparison between autogenous and semi-autogenous grinding, which are crucial steps in the comminution process. These grinding techniques have shown potential in improving the overall efficiency of ore beneficiation by reducing energy consumption and enhancing mineral liberation, thus increasing recovery rates. This research aims to conduct a comparative performance

evaluation of autogenous and semi-autogenous grinding in the processing of Duguru lead and zinc ore from Alkaleri, Bauchi State, Nigeria, to determine the most effective method for extracting lead and zinc from this complex ore. The findings of this study will contribute to the development of more sustainable beneficiation processes that can support Nigeria's growing mining industry.

The comparative performance of autogenous and semi-autogenous grinding methods in the processing of Nigerian lead-zinc ores, specifically Duguru lead and zinc ore from Alkaleri, Bauchi State. While much of the existing literature focuses on the chemistry of mineral separation and the use of advanced methods such as microwave heating (Ghazala *et al.*, 2012; Omran *et al.*, 2015), there is limited attention given to how different grinding methods impact ore liberation and recovery rates. Previous studies primarily address beneficiation techniques or the challenges posed by complex sulphide ores like sphalerite and galena, which are resistant to conventional processing methods (Deveci *et al.*, 2004; Rubio and Frutos, 2002). However, little empirical data exists on how autogenous versus semi-autogenous grinding methods influence the efficiency of these processes, particularly in terms of energy consumption, grind size, and the effectiveness of subsequent separation methods. Given that grinding is a critical step in ore comminution that determines liberation and particle size distribution, understanding the impact of these methods on Nigerian lead-zinc ores could significantly improve processing efficiency and support more sustainable beneficiation practices. As such, the lack of comparative studies on grinding methods for these ores represents a critical research gap.

MATERIAL AND METHODS

The material used for the grinding tests in this study was Duguru lead-zinc ore from Alkaleri, Bauchi State, Nigeria. The ore was initially crushed and screened to a consistent size, with particle sizes suitable for grinding in a laboratory-scale mill. The tests were conducted using two distinct grinding methods: autogenous grinding and media-assisted grinding. The material was tested under controlled conditions to evaluate grindability at various revolutions in both grinding modes.

GRINDING TEST PROCEDURES

The grinding tests were carried out using a laboratory-scale ball mill with a capacity of 2 liters. The tests were performed at three different numbers of revolutions: 200, 400, and 600 revolutions per minute (rpm). For each revolution, two modes were tested: New Charge (NC) and Addition of Difference (AD). Each test involved the grinding of 100g of lead-zinc ore for each specified number of revolutions.

AUTOGENOUS GRINDING TEST

The autogenous grinding test involved grinding the ore using only the ore particles themselves, without any added grinding media. The procedure was as follows:

- i. A sample of 100g of ore was placed into the mill.
- ii. The mill was run at the specified number of revolutions (200, 400, and 600 rpm).
- iii. The test was conducted in both the New Charge (NC) mode and the Addition of Difference (AD) mode.
- iv. After each set of revolutions, the ore was removed and weighed, and the grindability was calculated using the mass of the ore per revolution (g/rev) and per ton (kg/t/rev) to determine the grinding efficiency.

MEDIA-ASSISTED GRINDING TEST

The media-assisted grinding test involved using grinding media (steel balls) along with the ore in the mill. The procedure followed was:

- i. A sample of 100g of lead-zinc ore was placed into the mill along with a predetermined amount of steel balls.
- ii. The mill was run at 200, 400, and 600 rpm.
- iii. Both New Charge (NC) and Addition of Difference (AD) modes were tested, similar to the autogenous grinding test.
- iv. After each set of revolutions, the grindability was calculated in the same manner as in the autogenous grinding test, focusing on the mass of the ore and the number of revolutions.

RESULT AND DISCUSSION

Table 1. Autogenous Grinding Test

No of Revolution (Nr)	(g)		(g/rev)		(kg/t/rev)	
	New Charge (NC)	Addition of Difference (AD)	New Charge (NC)	Addition of Difference (AD)	New Charge (NC)	Addition of Difference (AD)

200	9.97	10.07	0.04985	0.05035	49.85	50.35
400	21.21	33.67	0.05303	0.08418	53.03	84.18
600	43.27	55.03	0.07212	0.09172	72.12	91.72
Average	24.82	32.92	0.05833	0.07542	58.33	75.42

Table 2: Media Assisted Grinding Test

No of Revolution (Nr)	(g)		(g/rev)		(kg/t/rev)	
	New Charge (NC)	Addition of Difference (AD)	New Charge (NC)	Addition of Difference (AD)	New Charge (NC)	Addition of Difference (AD)
200	10.15	10.97	0.05075	0.05485	50.75	54.85
400	33.60	39.79	0.08400	0.09948	84.00	99.48
600	59.03	64.57	0.09838	0.10762	98.38	107.62
Average	34.26	38.44	0.07771	0.08732	77.71	87.32

The results in table 1 and 2 show increment in grindability with the number of revolutions for both autogenous and media-assisted grinding tests. The addition of difference mode provides higher grindability values compared to the new mass charge mode. Additionally, media-assisted grinding yields higher grindability than autogenous grinding, likely due to differences in feed properties and breakage mechanisms.

Both modes demonstrate increasing grindability values as the number of revolutions increases, confirming that grindability is directly influenced by the number of revolutions, with a sharp increase observed for both grinding types. The differences observed between the two test modes suggest that the addition of difference mode is more suited for continuous grinding operations, where the material's internal and peripheral grains weaken with each revolution. On the other hand, the new mass charge mode is better suited for batch grinding operations. In regrind mills, the findings can be applied for grinding finer sizes, even though the tests were conducted at 180 microns. The results show that for both grinding methods, the addition of difference mode consistently provides higher grindability values across all revolutions.

Table 3. Comparison of Autogenous vs. Media-Assisted Grinding Tests

Parameter	Autogenous Grinding Test	Media-Assisted Grinding Test
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Number of Revolution (Nr)	200	400
New Charge (g)	9.97	21.21
Addition of Difference (g)	10.07	33.67
Grindability (g/rev)	0.04985	0.05303
Grindability (kg/t/rev)	49.85	53.03
Average (g)	24.82	32.92
Average (g/rev)	0.05833	0.07542
Average (kg/t/rev)	58.33	75.42

The results from the autogenous and media-assisted grinding tests in table 3 clearly show that media-assisted grinding, which uses grinding media (steel balls), outperforms autogenous grinding in terms of grindability across all tested revolutions (200, 400, and 600 rpm). In both grinding methods, the grindability increases with higher revolutions, but the increase is more pronounced in media-assisted grinding, particularly in the **Addition of Difference** mode. Media-assisted grinding achieved significantly higher grindability values in both grams per revolution (g/rev) and kilograms per ton per revolution (kg/t/rev) compared to autogenous grinding, indicating the superior efficiency of adding grinding media to the process. The **Addition of Difference** mode consistently provided better grindability than the **New Charge** mode, highlighting its suitability for continuous grinding operations, where the material is subjected to repeated impacts. This confirms that media-assisted grinding is more effective for high-throughput and continuous operations, while autogenous grinding may still be useful for batch processes, particularly when finer particle sizes are not the primary goal.

CONCLUSION AND RECOMMENDATION

The comparison between autogenous and media-assisted grinding methods clearly shows that media-assisted grinding, which uses grinding media (steel balls), significantly outperforms autogenous grinding in terms of grindability across all tested revolutions (200, 400, and 600 rpm). Media-assisted grinding achieved higher grindability values in both grams per revolution (g/rev) and kilograms per ton per revolution (kg/t/rev), indicating its superior efficiency. This method shows a more pronounced increase in grindability, particularly in the Addition of Difference mode, which consistently provided better grindability than the New Charge mode, highlighting its suitability for continuous grinding operations. Media-assisted grinding enhances ore breakage due to the repeated impacts facilitated by the grinding media, making it more effective for high-throughput operations. Therefore, it is recommended that the mining industry adopt media-assisted grinding, especially for continuous operations that require high efficiency, and further studies should optimize this method to improve energy

consumption and recovery rates. Additionally, exploring hybrid grinding methods that combine both autogenous and media-assisted techniques could offer a balanced approach for efficient and cost-effective processing.

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