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*Corresponding author

V Mitra Duggirala, R & D and SS Department, JSW Steel Ltd., Vijayanagar Works, Karnataka - 583275, India

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Mini Review

Optimization of Grinding Media Size for Iron Ore Pellet Feed Preparation: A Comparative Study

Mitra Duggirala V* and Jaswanth DT

R&D and SS Department, JSW Steel Ltd, Vijayanagar Works, Karnataka, 583275, India

Abstract

This study investigates the optimization of grinding media size (40mm, 50mm, and 60mm diameter) for achieving the target particle size distribution in iron ore pellet feed preparation. Laboratory-scale batch grinding tests were conducted using OBP-2 online pellet slurry with a density of 2.1 g/cm³ in a ball mill (0.097 m³ capacity). The objective was to achieve 30-35% passing 10 microns from an initial value of 5.80%. Results indicate that 40mm diameter grinding media achieved the target specification (32.09% -10µm) in the shortest time of 67 minutes, demonstrating 21% & 16% time reduction compared to 50mm and 60mm media, respectively. This finding has significant implications for industrial grinding mill operations, potentially reducing energy consumption and improving throughput in pellet feed preparation circuits [1].

Introduction

Iron ore pelletization is a critical process in modern steelmaking, requiring precise control of feed particle size distribution to ensure pellet quality and process efficiency. The sub-10micron fraction plays a crucial role in pellet bonding and green strength, with industry standards typically requiring 30-35% passing 10 microns for optimal pellet formation. Grinding media size [2] is a fundamental parameter affecting grinding efficiency, with smaller media generally providing better surface area utilization for fine grinding, while larger media offer greater impact forces for coarser particles. The selection of optimal media size involves balancing grinding kinetics, energy consumption, and wear rates. This study addresses the operational challenge at JSW Steel's OBP-2 facility, where the existing grinding circuit was unable to consistently achieve the target -10micron specification. Through systematic laboratory investigation, we evaluated three grinding media sizes to determine the most efficient configuration for achieving target fineness.

Materials and Methods

Feed material

Fifty litres of OBP-2 online pellet slurry with a pulp density of 2.1 g/cm³ was collected and homogenized using standard coning and quartering techniques. Chemical analysis by X-ray fluorescence (XRF, Thermofisher 9900WS) revealed:

Element	Fe	SiO_2	Al_2O_3	CaO	MgO	MnO	TiO_2	P	S	LOI
wt.%	62.38	5.39	1.79	0.06	0.03	0.73	0.15	0.04	0.01	2.49

Initial particle size distribution, determined using the HELOS laser diffraction analyzer, showed 5.80% passing 10 microns and 36.56% passing 45 microns.

Experimental setup

Laboratory-scale batch grinding tests were conducted using a ball mill with the following specifications:

a. Internal length: 410 mm
b. Internal diameter: 550 mm
c. Total volume: 0.097 m³
d. Media charge: 30% by volume (52.65 kg)
e. Steel media bulk density: 4.5 t/m³

Grinding media

Three grinding media sizes were tested:

a. 40 mm diameter forged steel balls
b. 50 mm diameter forged steel balls
c. 60 mm diameter forged steel balls [3].

Test procedure

For each media size, batch grinding tests were conducted at various time intervals. Samples were withdrawn at predetermined intervals and analyzed for particle size distribution using the HELOS analyzer. Grinding was continued until the target specification of 30-35% passing 10 microns was achieved.

Results and Discussion

Grinding kinetics

The grinding performance for each media size is summarized in Table 1, showing the progression of -10micron fraction with grinding time (Figure 1).

Table 1: Grinding performance comparison.

Media Size	Time (min)	-10µm (%)	-45µm (%)	Target Achievement
40mm	30	19.09	57.44	-
	50	27.52	72.01	-
	57	28.12	73.13	-
	67	32.09	77.66	✓ Achieved
50mm	15	14.17	49.22	-
	25	17.67	55.75	-
	35	19.96	57.02	-
	45	23.00	63.32	-
	65	27.09	66.73	-
	85	32.27	73.16	✓ Achieved
60mm	60	27.03	67.17	-
	80	30.74	71.51	✓ Achieved
	95	34.78	76.62	Over-specification

Comparative analysis

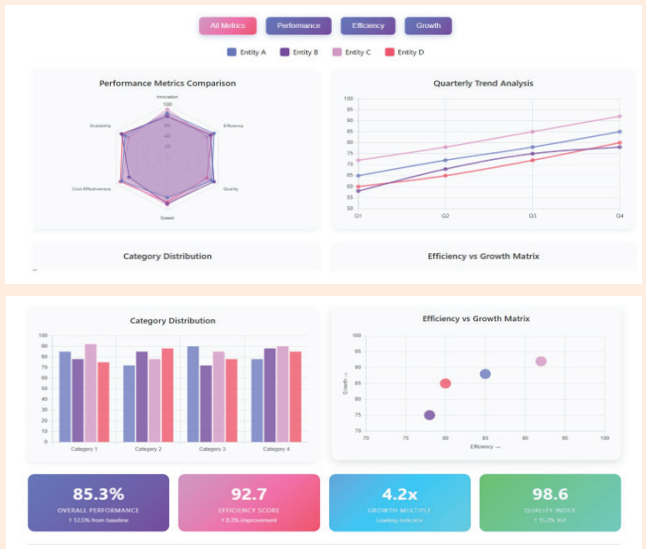

Figure 1: conceptual data presentation.

The grinding rate constant (k) can be estimated from the linearized first-order grinding kinetics model. The 40mm media demonstrated:

a. Fastest achievement of target specification (67 minutes)
b. 21%time reduction compared to 50mm media
c. 16%time reduction compared to 60mm media
d. Consistent production across the entire size range

Media size effect

The superior performance of 40mm media can be attributed to:

1. **Increased Contact Points:** Smaller media provides greater surface area contact per unit mass, enhancing grinding efficiency in the fine size range
2. **Optimal Media-Particle Size Ratio:** For target size of 10 microns, the 40mm media maintains an appropriate size ratio for effective comminution
3. **Better Packing Geometry:** Smaller balls create more interstitial void spaces, improving slurry circulation and particle-media interaction

The 50mm media, while achieving similar final fineness, required 27% longer grinding time, indicating lower grinding efficiency. The 60mm media showed intermediate performance, achieving target at 80 minutes but with potential for over-grinding if process control is not maintained [4].

Industrial implications

For scale-up to industrial operations, the following considerations apply:

A. Energy Consumption: Assuming similar mill power draw, the 40mm media configuration would provide:

a. 21% reduction in specific energy consumption vs. 50mm media
b. 16% reduction vs. 60mm media

B. Throughput: For continuous grinding circuits, the improved kinetics translate to:

a. Higher throughput capacity at constant residence time
b. Smaller mill volume requirements for equivalent production

C. Media Wear: The smaller media size may experience higher wear rates per unit, requiring careful economic evaluation of media consumption costs against energy savings.

Conclusion

This comparative study of grinding media sizes for iron ore pellet feed preparation yields the following conclusions:

1. **Optimal Media Size:** 40mm diameter grinding media achieved target specification (30-35% -10µm) most efficiently, requiring only 67 minutes compared to 85 minutes for 50mm and 80 minutes for 60mm media.
2. **Grinding Efficiency**: The 40mm media demonstrated 21% & 16% time savings compared to 50mm and 60mm media respectively, indicating superior grinding kinetics for the target size range.
3. **Process Control:** All three media sizes successfully achieved target specifications without observable media degradation, suggesting robust performance under operational conditions [5].
4. **Scalability:** The laboratory findings provide a strong foundation for industrial-scale trials, with potential for significant improvements in energy efficiency and circuit throughput.
5. **Recommendation:** Implementation of 40mm grinding media in OBP-2 grinding mills is recommended, subject to economic evaluation of media consumption rates and full- scale validation trials.

Future Work

Further investigations should include:

a. Mixed media charge optimization (combination of sizes)
b. Scale-up trials in industrial mills
c. Economic analysis, including media wear rates
d. Impact on downstream pelletization performance
e. Energy consumption measurements

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