

Improving Gold Ore Classification Efficiency and Flotation Performance Based on Screening Classification Method

Ning Xu ^{1, a}, Tao Guan ^{1, b}, Zhihai Huang ^{1, c}, Hao Guo ^{1, d}, Jian Kang ^{1, e},
Xingwei Song ^{1, f}, Shiming Cao ^{2, g, *}, Yujia Wang ^{2, h}

¹ Shandong Gold Mining (Linglong) Co., Ltd. China;

² School of Resources and Environmental Engineering, Shandong University of Technology, China.

^a jnxuning@163.com, ^b tao5360745@163.com, ^c 646741384@qq.com,

^d guohao1999727@163.com, ^e 18596171718@163.com, ^f songxingwei@sd-gold.com,

^{g,*} ironshark@163.com, ^h jethrowangla@outlook.com

& These authors contributed equally to this work

Abstract. The hydrocyclone is currently the most commonly used classification device in gold ore processing. However, its efficiency is limited by both its operating principles and structural design, making further improvement in classification performance difficult. In recent years, high-frequency vibrating screens—capable of precisely classifying particles based on their geometric size—have played an increasingly important role in efficient classification. Despite these advantages, there is ongoing debate about their application in classifying gold ores, which are often compositionally complex. To address this issue, this study established a pilot-scale experiment platform to assess the classification performance of high-frequency vibrating screens with gold ore. The results were then compared to those obtained using hydrocyclones. In addition, flotation tests were conducted to examine the relationship between the particle size distribution produced by high-frequency screens and flotation performance. This approach provides a comprehensive evaluation of the potential advantages of high-frequency vibrating screens in processing complex gold ores.

Keywords: gold ore; classification; high-frequency vibrating screen; hydrocyclone; flotation.

1. Introduction

Gold is a vital precious metal with indispensable roles in both industry and finance[1]. Gold ore resources are typically classified into two main types: primary gold ores and placer gold ores. These ores have complex mineral compositions and often contain minerals such as pyrite, chalcopyrite, and quartz[2, 3]. During gold ore beneficiation, the grinding and classification stages are critical, as their effectiveness directly affects energy consumption, processing capacity, and the performance of subsequent separation processes[4, 5].

Currently, the most common classification methods in mineral processing are spiral classifiers and hydrocyclones. Spiral classifiers are simple in structure and provide stable operation, but they have relatively low classification efficiency and require a large footprint. In contrast, hydrocyclones are widely used in gold ore processing plants due to their high efficiency, compact design, and large handling capacity[5, 6]. However, their classification efficiency typically does not exceed 60% because of inherent structural limitations. Additionally, the characteristics of gold ores and the classification principles of hydrocyclones give rise to the "dense medium effect." Because of the density differences between gold minerals and gangue, some liberated fine gold particles are incorrectly sent to the underflow and recirculated to the ball mill for further grinding, resulting in overgrinding and the production of excessive fines. At the same time, some coarse composite particles with lower overall density may report to the overflow[7, 8]. These factors collectively limit the classification performance and subsequent recovery efficiency in gold ore processing.

To address these challenges, high-frequency vibrating screens—which classify particles based on size—have demonstrated significant advantages[9]. Operating at high vibration frequencies and utilizing resonance principles, these screens achieve efficient and precise separation by strictly

sorting materials according to geometric size. This approach avoids the particle size misallocation caused by the “dense medium effect” commonly observed in hydrocyclone classification. High-frequency vibrating screens have already been successfully applied in the classification of magnetite ores with simple mineral compositions and coarse mineral grain sizes. However, their use in gold ore classification remains controversial due to the complex mineralogy and variable grain size distribution of gold ores, and there are currently no industrial case studies in this context. To evaluate the potential of high-frequency vibrating screens for gold ore, we established a pilot-scale, continuous experiment system that closely replicates industrial conditions. This platform allowed us to systematically examine the classification performance of high-frequency vibrating screens on gold ores. Additionally, flotation tests were conducted to compare the effects of hydrocyclone and high-frequency screen classification on flotation outcomes.

2. Methods

2.1 Grinding - Classification Experiments Research Method

A pilot-scale experiment approach was used for the grinding-classification process. Crushed ore from the plant was stored in a silo, then fed by conveyor into the ball mill. After grinding, the slurry was pumped to the classification equipment for screening. Oversized material was returned to the ball mill for further grinding, while material of the target particle size was collected as the final product of the grinding-classification stage (see Figure 1). The main equipment used in the study is listed in Table 1.



Fig. 1 Pilot-Scale Experiment System

Table 1. Main Equipment for the Pilot-Scale Experiment

Numble	Equipment	Model	Remarks
1	Ball Mill	MQG0918	Overflow-type Ball Mill
2	High-Frequency Vibrating Screen	FS-AU-4045S	Sieve apertures: 0.25 mm + 0.20 mm
3	Hydrocyclone	FYΦ75mm	

2.2 Flotation Experiment Method

Closed-circuit flotation tests were carried out on products classified by the high-frequency vibrating screen (undersize product) and the hydrocyclone (overflow product) under identical flotation conditions. During pilot-scale experiments, representative samples of the classified slurry were collected and transferred to a mixing tank. The feed for flotation was then delivered from the mixing tank to the flotation cell using a peristaltic pump. In each flotation test, the collector was first added and mixed for three minutes, followed by the addition of the frother and one minute of further mixing. Finally, air was introduced to begin the flotation process.

3. Results and Discussion

3.1 Comparison of Classification Efficiency between Hydrocyclone and High-Frequency Vibrating Screen

The pilot-scale experiments used ore sourced from a gold processing plant in Shandong. According to the plant’s flotation requirements, the feed slurry must have a particle size of -0.074 mm 40.0%-45.0%, and a pulp concentration of 45.0%. The concentration and fineness of the classification products in the pilot-scale experiments were kept consistent with these on-site standards. Since classification efficiency and circulating load can vary with different feed sizes, even under the same equipment and process parameters, comparative tests were designed to ensure a fair evaluation. Therefore, to accurately compare the performance of the hydrocyclone and high-frequency vibrating screen, both devices were tested using classification feed with the same particle size distribution (approximately 25% passing 0.074 mm).

Under the condition that approximately 25% of the ball mill discharge passes 200 mesh, classification was performed using a hydrocyclone. Table 2 presents the particle size distribution of each product at different feed rates, and the test results are illustrated in Figure 2.

Table 2. Particle Size Distribution of Grinding and Hydrocyclone Classified Products

Processing capacity	Particle size / mm	Yield		
		Grinding mill discharge	Oversize product	Undersize product
1.0t/h	+0.25	41.68%	53.00%	12.00%
	-0.25+0.15	13.82%	15.00%	11.00%
	-0.15+0.074	20.00%	17.69%	30.22%
	-0.074+0.038	10.31%	6.25%	16.72%
	-0.038	14.19%	8.06%	30.06%
	Total	100.00%	100.00%	100.00%
1.2t/h	+0.25	44.22%	59.33%	12.85%
	-0.25+0.15	18.81%	16.65%	19.09%
	-0.15+0.074	13.87%	10.52%	21.39%
	-0.074+0.038	8.80%	5.43%	15.67%
	-0.038	14.30%	8.07%	31.00%
	Total	100.00%	100.00%	100.00%

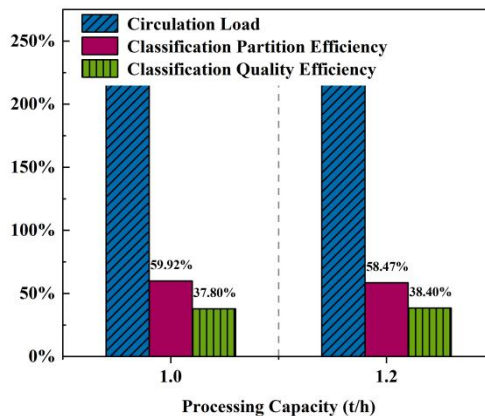


Fig. 2 Grinding - hydrocyclone classification results

Under the same feed particle size conditions, classification tests were conducted using a high-frequency vibrating screen. Table 3 shows the particle size distribution of each product at different ore processing rates, and the test results are illustrated in Figure 3.

Table 3. Particle Size Distribution of Products from Grinding and High-Frequency Vibrating Screen Classification Tests

Processing capacity	Particle size / mm	Yield		
		Grinding mill discharge	Oversize product	Undersize product
1.2t/h	+0.25	39.55%	68.24%	5.48%
	-0.25+0.15	18.05%	16.66%	22.52%
	-0.15+0.074	17.07%	9.30%	28.44%
	-0.074+0.038	10.97%	3.32%	18.00%
	-0.038	14.36%	2.48%	25.56%
	Total	100.00%	100.00%	100.00%
1.4t/h	+0.25	37.63%	65.00%	7.96%
	-0.25+0.15	19.04%	20.55%	18.04%
	-0.15+0.074	17.88%	8.12%	28.52%
	-0.074+0.038	9.87%	2.56%	18.00%
	-0.038	15.58%	3.77%	22.48%
	Total	100.00%	100.00%	100.00%
1.6t/h	+0.25	40.06%	66.76%	4.45%
	-0.25+0.15	20.03%	18.98%	24.52%
	-0.15+0.074	15.93%	9.71%	26.14%
	-0.074+0.038	9.00%	1.55%	20.00%
	-0.038	14.98%	3.00%	24.89%
	Total	100.00%	100.00%	100.00%
1.7t/h	+0.25	50.04%	71.25%	3.63%
	-0.25+0.15	16.84%	14.86%	27.82%
	-0.15+0.074	10.24%	6.78%	21.94%
	-0.074+0.038	11.00%	4.33%	15.34%
	-0.038	11.88%	2.78%	31.27%
	Total	100.00%	100.00%	100.00%

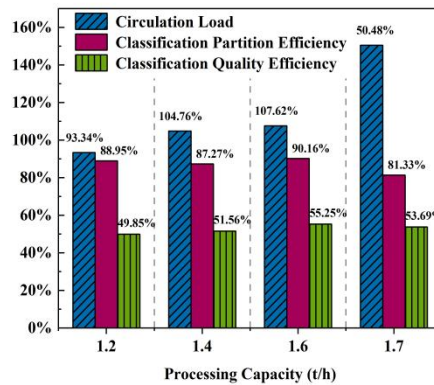


Fig. 3 Grinding-high-frequency vibrating screen classification results

The experimental results indicate the following:

(1) In mineral processing, particle sizes above 0.25 mm and below 0.038 mm are typically considered difficult to float and result in lower flotation efficiency. As shown in Table 2 and Table 4, when using a hydrocyclone for classification, the proportion of particles larger than 0.25 mm ranges from 12.00% to 12.85%. In contrast, with the high-frequency vibrating screen, this proportion falls below 8%. Similarly, the proportion of particles finer than 0.038 mm exceeds 30% with the hydrocyclone, but remains below 26% with the high-frequency screen. These findings suggest that replacing the hydrocyclone with a high-frequency vibrating screen can effectively reduce coarse particles in the overflow and fine particles in the underflow caused by the “dense medium effect,” thereby optimizing the particle size distribution of the classified product.

(2) Within the tested range of ore processing rates, the hydrocyclone achieved a classification efficiency by weight for particles smaller than 0.074 mm of 58.74%–59.92%, while the classification efficiency by quality fell below 39.00%, indicating relatively poor precision. In comparison, the high-frequency vibrating screen maintained a classification efficiency by weight above 87% and by quality at or above 49.85% for the same particle size range (0.074 mm) when processing 1.2 to 1.6 t/h of ore. These results demonstrate that the high-frequency vibrating screen outperforms the hydrocyclone in both classification efficiency and precision.

(3) When classified with a hydrocyclone, the circulating load of the grinding-classification system ranged from 218.65% to 245.52%. In contrast, the circulating load was significantly lower with the high-frequency vibrating screen, at only 93.34% to 107.62%. A lower circulating load with the high-frequency screen indicates a greater ore handling capacity for the grinding-classification system. Under pilot-scale experiment conditions, the maximum ore processing capacity of the grinding-hydrocyclone system was 1.2 t/h, whereas the grinding-high-frequency screen system maintained high classification efficiency and low circulating load at ore processing rates between 1.2 t/h and 1.6 t/h. Therefore, replacing the hydrocyclone with a high-frequency vibrating screen can increase the ore handling capacity of the grinding-classification system by at least 33.33% without modifying the ball mill.

3.2 Effect of Classification Method on Flotation Performance

Considering the high-frequency vibrating screen avoids the “dense medium effect” seen with hydrocyclone classification, there are notable differences in the particle size distribution of their respective products. This inevitably affects the flotation behavior and performance of the classified materials. To assess these impacts, slurry samples were collected from both the hydrocyclone and high-frequency vibrating screen products during pilot-scale experiments, with the ore processing rate set at 1.2 t/h. Flotation tests were then conducted under identical conditions. The test procedure and reagent scheme are shown in Figure 4, and the results are presented in Tables 4 and 5.

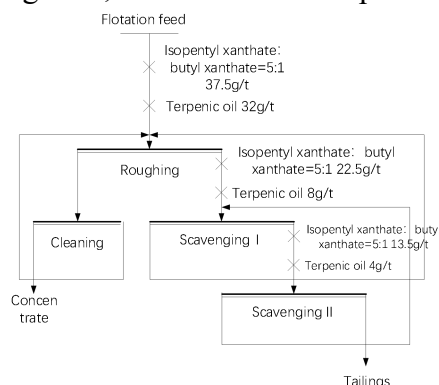


Fig. 4 Flotation process and reagent scheme

Table 4. Flotation results of hydrocyclone classified products

Product	Yield/%	Au Grade (g/t)	Recovery (%)
Concentrate	3.02	41.76	94.90
Tailing	96.98	0.07	5.10
Feed ores	100.00	1.33	100.00

Table 5. Flotation results of high-frequency vibrating screen classified products

Product	Yield/%	Au Grade (g/t)	Recovery (%)
Concentrate	2.79	46.33	95.68
Tailing	97.21	0.06	4.32
Feed ores	100.00	1.35	100.00

The flotation test results show that the tailings grades for the hydrocyclone and high-frequency vibrating screen classification products were 0.07 g/t and 0.06 g/t, respectively, indicating little difference. However, the concentrate grade increased from 41.76 g/t for the hydrocyclone product

to 46.33 g/t for the high-frequency screen product, and the enrichment ratio rose from 31.40 to 34.32. This suggests that using a high-frequency vibrating screen for classification helps improve flotation concentrate quality, likely because of the lower proportion of particles smaller than 0.038 mm, which reduces the non-selective entrainment of fine, muddy particles during flotation [10]. In addition, the flotation recovery rate for the high-frequency screen product was 0.78 percentage points higher than that for the hydrocyclone product, attributable to the reduced proportion of particles larger than 0.25 mm, leading to a higher degree of gold mineral liberation [11]. Overall, these results demonstrate that substituting the hydrocyclone with a high-frequency vibrating screen for classification can improve both the grade and recovery of flotation concentrates.

4. Conclusions

This study compared the performance of hydrocyclones and high-frequency vibrating screens in gold ore classification, using classification efficiency (by quantity and quality) and circulating load as key parameters. The impact of different classification methods on the ore processing capacity of the grinding-classification system was also evaluated. Furthermore, the flotation performance of products obtained from both classification processes was examined. The main conclusions are as follows:

(1) Compared to traditional hydrocyclones used in gold ore classification, high-frequency vibrating screens offer significant advantages in both quantitative and qualitative classification efficiency. Higher classification efficiency results in a lower circulating load for the grinding-classification system. As a result, using high-frequency vibrating screens as the classification equipment can substantially increase the ore processing capacity of the system without requiring changes to the grinding equipment.

(2) High-frequency vibrating screen classification effectively avoids the adverse effects of the “dense medium effect” associated with hydrocyclone classification, reducing the proportion of both coarse particles larger than 0.25 mm and fine particles smaller than 0.038 mm that are difficult to separate.

(3) Owing to the improved particle size distribution achieved with high-frequency vibrating screen classification, both the grade and recovery of flotation products were enhanced compared to those classified by the hydrocyclone. Specifically, the concentrate grade increased from 41.76 g/t to 46.33 g/t, and the recovery rate rose from 94.90% to 95.68%.

Acknowledgment

This research was funded by the Shandong Provincial Natural Science Foundation Youth Fund: (No. ZR2022QE089).

References

- [1] Yin Wanzhong, Gold Ore Dressing Technology. 2016: Gold Ore Dressing Technology.Fangfang. Research on power load forecasting based on Improved BP neural network. Harbin Institute of Technology, 2011.
- [2] Lü Xianjun et al., Study on the Petrological and Mineralogical Characteristics of Jiaodong Altered Rock-type Gold Ores. Rock and Mineral Testing, 2012, 31(1): p. 5.Ma Kunlong. Short term distributed load forecasting method based on big data. Changsha: Hunan University, 2014.
- [3] Zeng Lingxi. Study on the Petrological and Mineralogical Characteristics of a Certain Gold Deposit and Analysis of Its Correlation with Mineral Processing Methods. China Mining, 2008, 17(4): p. 3.
- [4] Miller, P. and A. Brown, Advances in Gold Ore Processing. 2005.
- [5] Malkin, S., Grinding Technology: Theory and Applications of Machining with Abrasives. International Journal of Machine Tools and Manufacture, 1991. 31(3): p. 435-436.

- [6] Duan Xixiang and Xiao Qingfei, *Crushing and Grinding*, 3rd Edition. 2012: Crushing and Grinding, 3rd Edition.
- [7] Nguyen, A.V. and A.H.J. Schulze, Colloidal Science of Flotation. 2004: Colloidal Science of Flotation.
- [8] Sun, Z.M., et al., Optimization and mechanism of gold-bearing sulfide flotation. Rare Metals, 2014(3): p. 6.
- [9] Huanshuai, Z., T. Institute and E. Groupco, Analysis on Dynamic Behavior and Internal Stress Distribution of Large High Frequency Vibrating Screen. Mining Research and Development, 2013.
- [10] Trahar, W.J., A rational interpretation of the role of particle size in flotation. International Journal of Mineral Processing, 1981. 8(4): p. 289-327.
- [11] Grano, S., The critical importance of the grinding environment on fine particle recovery in flotation. Minerals Engineering, 2009. 22(4): p. 386-394.