ISSN : 0974 - 7435 Volume 10 Issue 7

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(7), 2014 [1904-1911]

Experimental study on classification process of fine iron ore tailings using hydrocyclone

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ABSTRACT

Previous work mainly focused on investigations of computational model and using numerical simulation method, this method is limited in study of hydrocyclone due to the impact of simplification of boundary condition and turbulent models. In light of this, this paper designed an experimental strategy for industrial hydrocyclones on classification of fine iron ore tailings. The paper studied the classification efficiency of industrial hydrocyclone for fine iron ore tailings. The study analyzed the effect of hydrocyclone diameter and underflow diameter on the classification efficiency. The analysis primarily focused on the effect of structural variation of underflow in hydrocyclones with different diameters on underflow solid phase productivity, Newton comprehensive classification efficiency, and underflow granularity composition. The experiment results showed that the size of hydrocyclone had great influence on the performance of the hydrocyclone, which provided basis on the selection of hydrocyclone, as well as structural design and optimization.

KEYWORDS

Hydrocyclone; Fine iron ore tailing; Classification efficiency; Experimental study.

INTRODUCTION

Hydrocyclone is a separation device that uses centrifugal sedimentation principle to separate, classify or concentrate sands. It has been widely used in mineral processing, petroleum and chemical engineering, due to its simple structure, high working capacity, high separation efficiency, and low maintenance costs. The structure and size of hydrocyclone are of great importance to the separation efficiency. The diameters of hydrocyclone and the underflow are very important parameters that influence the working capacity and separation efficiency. For a large hydrocyclone diameter, the separation efficiency is low, but the working capacity is high. Therefore, large cyclone diameter is preferred if the separation efficiency is satisfied. For solid-liquid hydrocyclone, increasing the size of underflow can increase the flow rate of the underflow. However, if the size of underflow were too large, large amount of water would flow from the exit of underflow tube, which jeopardized the function of the hydrocyclone. In contrast, if the underflow diameter were too small, blockage of solid particles could occur, especially for relatively large concentration perturbation of the feeding slurry. Therefore, designing appropriate diameters of hydrocyclone and the size of underflow tube is key to the separation efficiency of a hydrocyclone. Chu et al conduced experimental studies on structural parameter effect on separation efficiency of a hydrocyclone, and obtained some universal equations[1-8]. Other oversea researchers mainly focused on investigations of computational model for hydrocyclones. For instance, B.Wang et al[9] used RSM model of Fluent to study the separation efficiency of a hydrocyclone. They compared the simulation results with experimental data, and obtained the distribution of sands[10-12]. The numerical method is limited in study of hydrocyclone due to the impact of simplification of boundary condition and turbulent models, as well as the difficulty of accurate setting of particle distribution at the inlet. In light of this, this paper designed an experimental strategy for industrial hydrocyclone on classification of fine iron ore tailings. This study used laser particle size analyzer to study the effect of underflow diameter on separation efficiency at different hydrocyclone diameters, which highlighted the influence on underflow granularity composition, underflow solid phase productivity and Newton comprehensive classification efficiency.

THE BASIC STRUCTURE OF HYDROCYCLONE AND WORKING PRINCIPLE

The basic structure of hydrocyclone is shown in Figure 1. It consists of upper cylindrical section, lower cone section, inlet tube, overflow tube, and underflow tube. Solid particles enter hydrocyclone with feeding slurry at certain velocity from inlet. The liquid slurry is forced to rotate when it gets close to wall, whereas the solid particles keep their original linear path and move forward due to inertia. Larger particles are under larger centrifugal force, and thus can overcome the resistance of hydraulic force and move closer to the wall. However, smaller centrifugal force is acted to fine particles, such that they would rotate with the slurry before they get close enough to the wall. Under successive feeding, slurries keep moving downwards and rotate. The solid particles are then acted by centrifugal force of inertia. As the result, large particles keep gathering towards outside area, whereas fine particles stay in the center area. Therefore, particles with different sizes form a distribution in the radial direction. The bigger the particles, the larger the radius of gyration. Consequently, the outside bigger particles enter underflow exit with outside helical flow, whereas the central finer particles enter overflow tube with the upward inside helical flow. The working principle is shown in Figure 2.

EXPRIMENTAL IN INVESTIGATIONS

The particle size composition of tailings was carried out with laser particle size analyzer, BT-9300S, shown in TABLE 1.

From TABLE 1, it can be seen that particles with diameter smaller than 74um(-200 mesh)occupied 75.07% of total particles. The particles with diameter smaller than 45um(-325 mesh) and

37um(-400 mesh)were 63.67% and 61.57%, respectively. Therefore, tailings mostly contained fine particles.

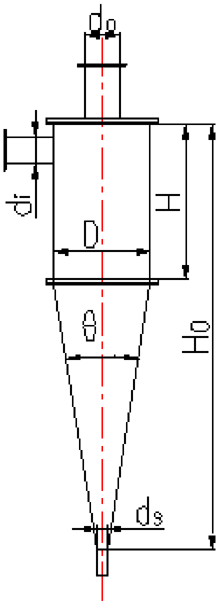

Figure 1 : The basic structure of the hydrocyclone

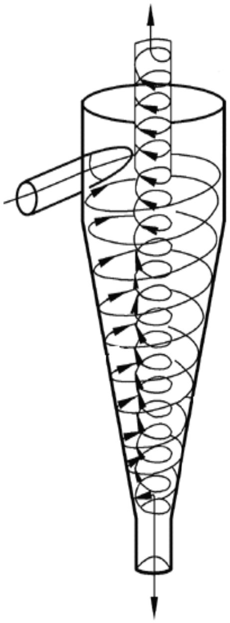

Figure 2 : The working principle of the hydrocyclone

TABLE 1 : Particle size composition

mesh	Particle size, um	rate of gain size, %	Negative cumulative yield, %
-40+50	-450+280	6.50	100.00
-50+100	-280+150	7.60	93.50
-100+200	-150+74	10.83	85.90
-200+325	-74+45	11.40	75.07
-325+400	-45+37	2.10	63.67
-400	-37+0	61.50	61.57

Experimental strategy design The experimental platform is shown in Figure 3. Classification experiments were conduced for specific iron ore tailings in hydrocyclones with different structural parameters.

Figure 3 : Chart of the experimental test

The pre-configured iron ore tailing slurry was pumped from a slurry pool using an output pump. The pressure value was controlled by adjustment of opening range of recirculation valve to be stably at the desired experiment inlet pressure value. After a certain period of stable operation time, the samples were taken from the exits of return flow tube, overflow tube, and underflow tube. Slurry concentration and size distribution at the inlet, overflow exit, and underflow exit were measured with and experiment scale and a laser particle size analyzer.

Measurement data and calculation Three hydrocyclones were selected with the types of 350, 250, and 150mm. Classification experiments were conduced with different working pressures in different underflow diameter conditions. Due to the length constrain, here we only consider one working pressure (0.1Mpa), and the experimental results are shown in TABLE 2, 3 and 4.

TABLE 2 : The experimental results of hydrocyclone with 350mm diameter

Underflow port diameter(mm)	Working pressure (Mpa)	Name of material	Concentration %	underflow solid phase productivity %	-200mesh (-74um)		-325mesh(-45um)	
					Content%	Newton comprehensive classification efficiency %	Content %	Newton comprehensive classification efficiency %
30	0.10	inlet	23.58	100.00	75.07	80.05	63.67	77.64
		overflow	16.62	61.43	98.40		93.10	
		underflow	70.80	38.57	33.20		17.60	
35	0.10	overflow	15.87	57.71	98.40	73.46	95.30	77.90
		underflow	69.94	42.29	41.60		21.80	
40	0.10	overflow	15.34	55.17	97.20	70.93	95.90	77.31
		underflow	69.56	44.83	41.90		23.50	

TABLE 3 : The experimental results of hydrocyclone with 250mm diameter

Underflow port diameter (mm)	Working pressure (Mpa)	Name of material	Concentration %	underflow solid phase productivity %	-200mesh（-74um）		-325mesh(-45um)	
					Content%	Newton comprehensive classification efficiency %	Content %	Newton comprehensive classification efficiency %
16	0.10	inlet	23.58	100.00	75.07	73.55	63.67	75.08
		overflow	15.05	53.77	99.30		95.40	
		underflow	69.19	46.23	43.20		25.30	
20	0.10	overflow	14.98	52.89	98.40	67.41	97.50	73.38
		underflow	66.35	47.11	47.60		29.60	
25	0.10	overflow	12.26	38.83	96.60	63.65	93.50	66.00
		underflow	56.96	61.17	48.40		32.40	

TABLE 4 : The experimental results of hydrocyclone with 150mm diameter

Underflow port diameter (mm)	Working pressure (Mpa)	Name of material	Concentration %	underflow solid phase productivity %	-200mesh(-74um)		-325mesh(-45um)	
					Content%	Newton comprehensive classification efficiency %	Content %	Newton comprehensive classification efficiency %
14	0.10	inlet	23.58	100.00	75.07	72.26	63.67	75.81
		overflow	15.63	56.03	98.90		97.80	
		underflow	67.00	43.97	43.80		27.60	
18	0.10	overflow	13.87	44.85	96.30	60.28	93.10	62.11
		underflow	54.76	55.15	51.00		35.60	
22	0.10	overflow	13.35	36.81	97.00	53.26	92.70	51.75
		underflow	42.59	63.19	56.80		43.30	

Experiment result, discussion, and analysis For 350, 250, and 150mm hydrocyclones, according to the classification experimental result under the working pressure of 0.1Mpa, the influence curves of hydrocyclone diameter on classification efficiency, underflow granularity and underflow solid phase productivity are shown in Figure 4-6.

It can be seen in Figure 4 that, for -45um granularity, the maximum classification efficiency of 350, 250, and 150mm hydrocyclone was 77.90%, 75.08% and 75.81%, respectively. For -74um granularity, the maximum classification efficiency of 350, 250 and 150mm hydrocyclone was 80.05%, 73.55% and 72.26%, respectively. The result showed that the classification efficiency increased with the increase of the hydrocyclone diameter.

It can be seen in Figure 5 that, the maximum concentration of -45um granularity in underflow for 350, 250, and 150mm hydrocyclones was 23.5%, 32.4% and 43.3%, respectively. the maximum concentration of -74 um granularity in underflow for 350, 250 and 150mm hydrocyclones was 41.9%, 48.4% and 56.8%, respectively. This result indicated that with increasing hydrocyclone diameter, underflow granularity become coarse. Therefore, large diameter hydrocyclone is favorable to obtain coarse sands.

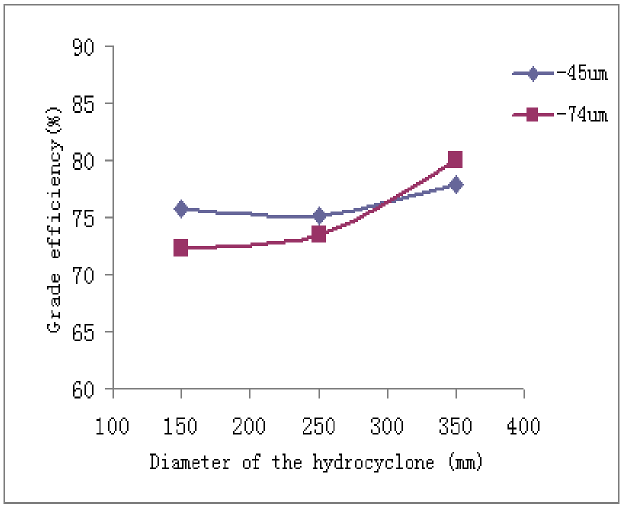

Figure 4 : Influence of diameter of the hydrocyclone on the separation efficiency

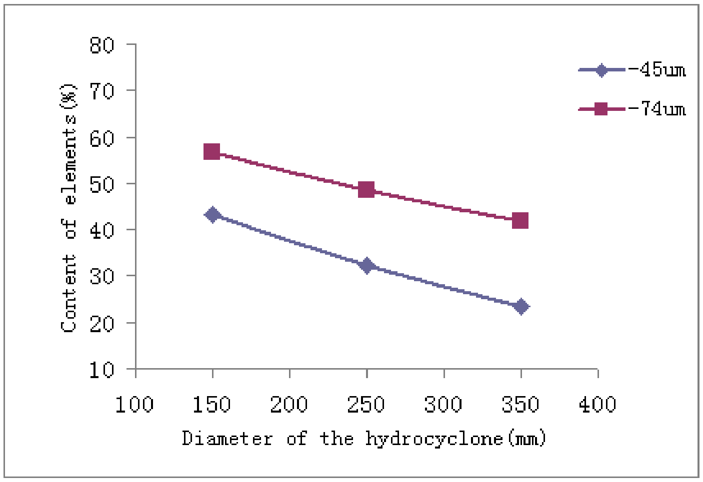

Figure 5 : Influence of diameter of the hydrocyclone on the content of elements of underflow

From Figure 6, the maximum solid phase productivity for 350, 250 and150mm hydrocyclone was 44.83%, 61.17% and 63.19%, respectively. It indicated that the solid phase productivity tended to decrease with the increase of the hydrocyclone diameter.

To investigate the underflow diameter effect on separation efficiency, the experiment was also conduced for the same hydrocyclones diameter but different underflow diameters (due to the length constrain, this paper only discussed the 350mm hydrocyclone, and the other two hydrocyclones gave similar results.)The influence curves of underflow diameter on classification efficiency and underflow granularity and underflow solid phase productivity are shown in Figure 7-9.

For the hydrocyclone with diameter of 350 mm, when underflow diameter was 40, 35 and 30 mm, it can be seen from Figure 7 that the classification efficiency for -45um granularity was 77.31%, 77.90% and 77.64%, respectively. The classification efficiency for -74um granularity was 70.93%, 73.46% and 80.05%, respectively. The result showed that classification efficiency decreased with increase of underflow diameter for -74um granularity, but it was not influenced significantly by underflow diameter for -45um granularity. It can be seen in Figure 8 that for underflow diameter of 40, 35 and 30mm, the concentration of -45um granularity in underflow was 23.5%, 21.8% and 17.6%, respectively. The concentration of -74um granularity in underflow was 41.9%, 41.6% and 33.2%, respectively. This result indicated that with decreasing underflow diameter, the granularity become coarse in underflow. Therefore, for the hydrocyclones with same specification, appropriate decreasing underflow diameter is favorable to produce more coarse granularity sands. From Figure 9, when underflow diameter was 40, 35 and 30mm, underflow solid phase productivity was 44.83%, 42.29% and 38.57%, respectively. It illustrated that with decrease of underflow diameter, the solid phase productivity tended to decrease.

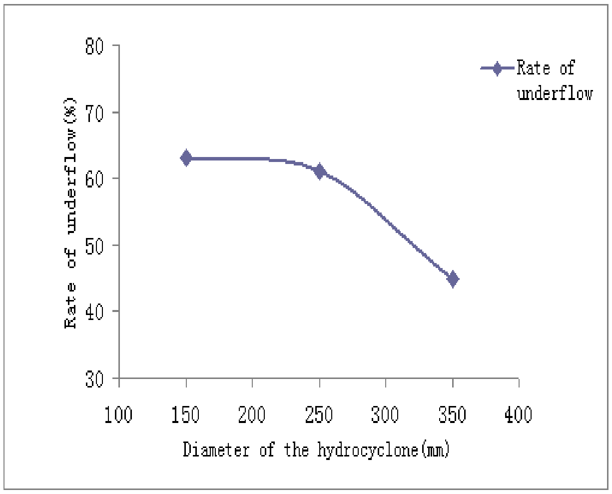

Figure 6 : Influence of diameter of the hydrocyclone on the rate of underflow

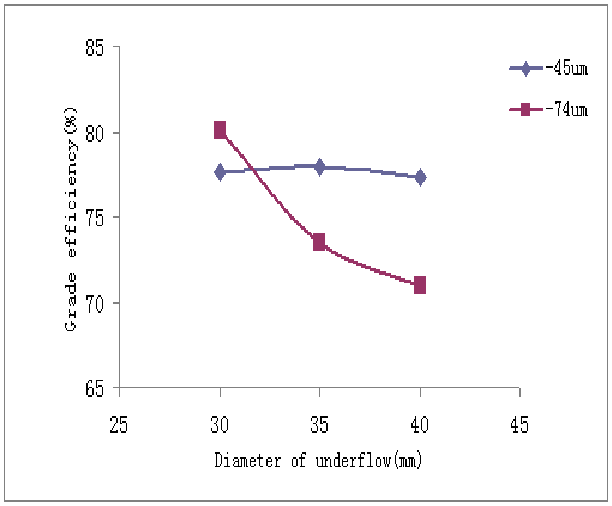

Figure 7 : Influence of diameter of the underflow on the separation efficiency

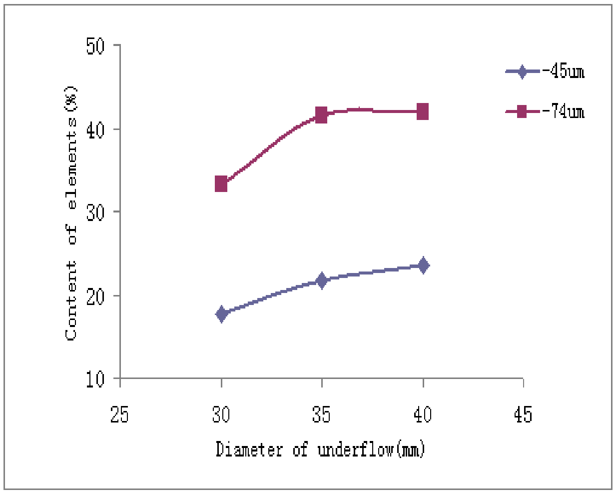

Figure 8 : Influence of diameter of the underflow on the content of elements of underflow

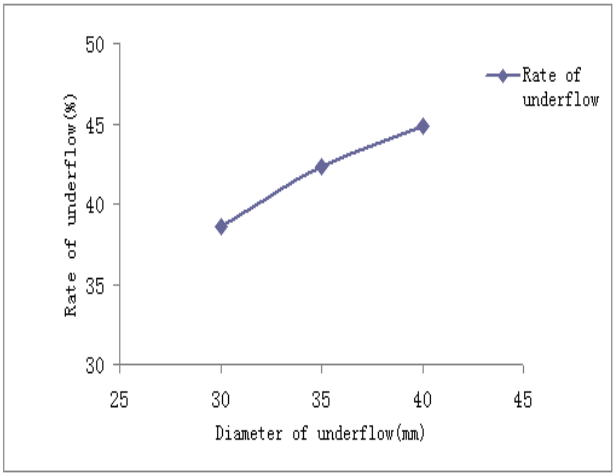

Figure 9 : Influence of diameter of the underflow on the rate of underflow

CONCLUSION

Aiming at the practical production problem, that is, separation of fine iron ore tailings using hydrocyclone, this paper designed multiple hydrocyclone structures, and conducted indoor laboratory study on the separation performance. This study analyzed the effect of hydrocyclone diameter and underflow diameter on the classification performance, and focused on the influence of underflow structure on underflow solid phase productivity, Newton comprehensive classification efficiency, and underflow granularity composition for hydrocyclones with different diameters. Through optimization experiment, this study determined the optimal structural plan and reasonable operating parameters. The conclusions are drawn as follows.

(1) Larger diameter hydrocyclone was favorable to obtain coarse sand with coarser granularity. For hydrocyclones with same specification, appropriate decreasing underflow diameter was also favorable to obtain coarse sand with coarser granularity.

(2) Large diameter hydrocyclone should be selected, with the proper range of underflow granularity composition. Meanwhile, to ensure higher underflow productivity, the underflow diameter could be increased properly.

Therefore, the 350 mm hydrocyclone, with underflow diameter of 30mm and 35mm was optimal to the working condition in this study for separation of iron ore tailings, which can obtain high underflow concentration, and underflow solid phase productivity. In the meantime, higher -45um size fraction could be obtained from overflow.

ACKNOWLEDGES

This work is supported by the National Natural Science Foundation of China (No.21276145) and guiding program for scientific and technological research of China National Coal Association (No. MTKJ2013-365).

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