A study on the mineral dressing test of bauxite ore in Central Guizhou province, China

Guizhou province is one of the major bases of bauxite resource in China; but some of them had a low grade. In this study, couple of tests for the bauxite desliming were carried out to gain the best conditions and controlling parameter. The industrial water in Guizhou province has moderate hard water and so sodium hexametaphosphate not only can eliminate the influence of calcium and magnesium ions, but also acted as dispersant. Sodium silicate had similar disperse effects to sodium hexametaphosphate, and their dosage was similar too. In continuous operation, the hydraulic desliming equipment worked normally and reliably. When treating low grade bauxite with an Al-Si ratio of 4.71, bauxite concentrate with an Al-Si ratio of 6.78 and Al_2O_3 recovery of 85.14% can be obtained by the equipment.

Keywords: *Test, equipment, bauxite, dispersant.*

1. Introduction

The bauxite ores in China are mostly diasporic bauxite, containing limonite, halloysite, illite, pyrophyllite, chlorite and other clay minerals. To achieve monomer dissociation, the grinding fineness should be 80% of particles below 0.074 mm as the minerals are usually finely disseminated. In this case, large amount of slimes inevitably generate during the process. The slimes can seriously deteriorate the flotation process and concentrate quality, resulting in low concentrate grade, low recovery, high reagent consumption, and high concentrate moisture.

The deterioration of flotation process caused by slimes is mainly reflected in:

(1) The low probability of collision adhesion between slimes and air bubbles makes it difficult for the slimes to attach to the bubbles;

(2) The flotation rate of slimes is relatively slow, which causes long flotation time;

(3) Slimes are easily adhered to or covered to the surfaces of coarser particles, which would decrease the floatability of coarser particles and worsen the flotation indexes;

(4) Slimes are easily coagulated with each other to form fine clay aggregates, which causes sorting difficultly;

(5) The surface active sites on slimes (residual bonds and active ions) increase, which would strength the non-selective adsorption of flotation reagents and increase dosage of reagents;

(6) Slimes have strong hydration ability, if the slimes adhere to the bubble surfaces, the bubbles will become stable and sticky and difficult to defoam, thus affecting the beneficiation process. The main problems are the deterioration of inflatable conditions of flotation machine and the difficulties in thickening of the concentrates;

(7) The moisture channels of filter cake and eyelets of filter cloth are clogged by slimes, which can decrease the processing capacity of filter machine;

(8) Slimes can mechanically mix in the flotation froth, which may reduce the concentration quality and cause the metal loss;

(9) Slimes can enable the concentration “inevitable ions” increase because of their high solubility. The inevitable ions interfere with the flotation process, decrease the selective adsorption of flotation separation, and worsen the effect of flotation reagents.

On the basis of the above analysis, slimes have adverse effects on bauxite desilication no matter in direct or reverse flotation process. In order to weaken the adverse effects of slimes, sodium hexametaphosphate is used as dispersant in direct flotation of bauxite to strengthen the dispersion effect of the pulp at present, and controlled dispersion is adopted to achieve selective desliming in reverse flotation. Practices have proven that in order to realize effective desliming, efficient desliming equipment is very important besides proper flocculants and process conditions

2. Experimental

2.1 Samples, reagents and equipment

The bauxite samples used in experiments were collected from Yunfeng deposit in central Guizhou province, China. Sample I was mainly used for the condition tests, and sample II was mainly used for validation tests of desliming equipment system. The chemical analysis results of sample I and II were

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Table 1: Results of chemical analysis of bauxite samples

Sample number	Content (%)		A/S
	Al_2O_3	SiO_2	
I	57.96	11.62	4.86
II	62.88	13.75	4.46

shown in Table 1, the Al-Si ratio of sample I is 4.86, and that of sample II is 4.46, which both belong to low-grade bauxite.

The XRD patterns of the samples I and II are shown in Figs.1 and 2. From the figures, we can conclude that mineral compositions of the two samples are similar, main aluminum mineral was diaspore, siliceous gangue minerals are mainly kaolinite, illite, chlorite and quartz, in addition, the samples also contained a certain amount of hematite.

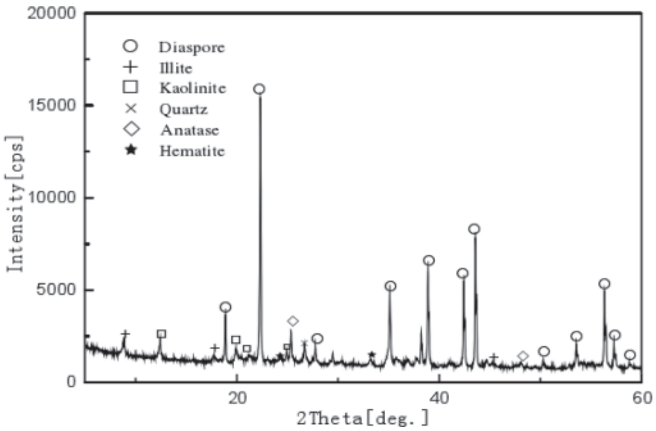

Fig.1 XRD patterns of sample I

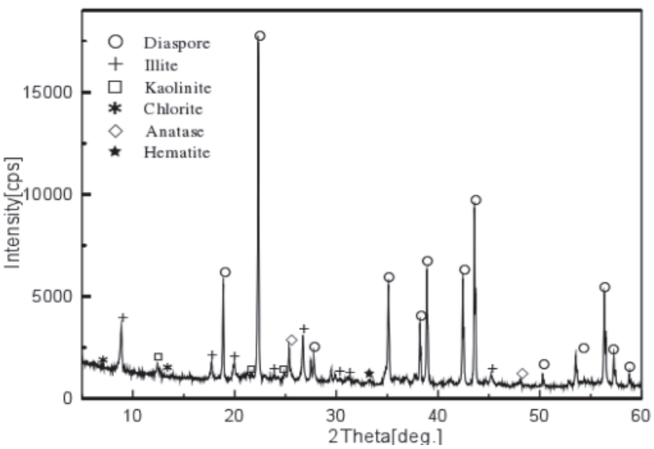

Fig.2 XRD patterns of sample II

Reagents used in the experiment were sodium hexametaphosphate (analytical grade), anhydrous sodium carbonate (analytical grade), water glass (industrial). They were all used as solution of proper concentration in the experiments.The equipment used in the experiments were XMB-70 three-roll four-cylinder rod mill, glass settlement tube, electric mixer, siphon, and electronic balance.

2.2 Test methods

2.2.1 Methods of desliming condition test

Desliming condition test is carried out in the glass settlement tube with 300g ore sample each time. The sample is grounded by rod mill to 90% of the product below 0.074 mm, the desliming settlement concentration was 8%, and the height of the glass settlement tube and pulp settling is 250 mm and 130 mm, respectively.The desliming granularity in the test is 0.01 mm, and settling time can be calculated based on the Stokes formula of interference settlement:

$$d^2 = h/54.5(\rho_s{}^{-1})t \quad \ldots \quad (1)$$

where d is the desliming particle size, p_5 is the density of mineral particle, h is the height of settlement, and t is the settling time. Therefore, when $p_5 = 0.0026$ g/mm^3, $h = 130$ mm, $d = 10$ gym, the settling time $t = 24.85$ min can be obtained. After pulp settling for 24.85 min in the test, the pulp above 130 mm scale line was extracted, and then filtered, dried, and weighed. The slime product is sent for chemical analysis.

3. Bauxite desliming condition tests

3.1 Effect of desliming particle size

In the practice of bauxite desliming, the size of desliming has maximum impact on improving quality of bauxite. Generally speaking, when the grinding fineness is 90% below 0.074 mm, most siliceous gangues are in the state of slimes. If the desliming size is too small, it is difficult to operate and the amount of slimes may be too small to improve the quality of bauxite significantly, while if the desliming size is too big, excessive amount of slimes may cause too much loss of aluminum minerals and thus affect the recovery of aluminum minerals. So it is very important to select a proper desliming particle size. When the pulp concentration is 10%, detailed tests are carried out with sodium hexametaphosphate as dispersant (dosage 9.67 kg/t) in the medium of industrial water to investigate the effect of desliming particle size. The results are shown in Fig.3.

Fig.3 shows that under the conditions above, when the desliming size is 10 gym, about 19% slimes with an Al-Si ratio

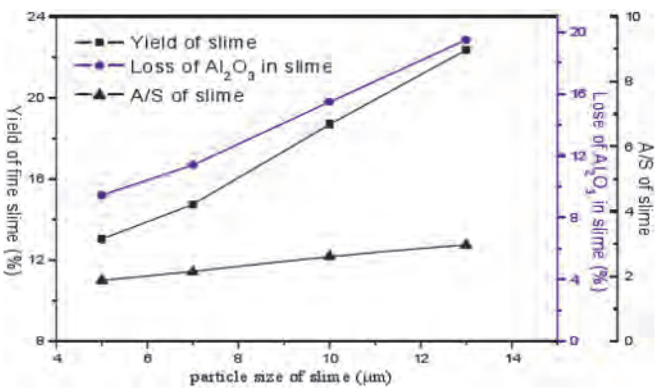

Fig.3 Effect of slime size on desliming

of about 2 can be removed. So in the following tests, desliming granularity is kept at 10μm.

3.2 Effect of pulp concentration

As an operation generally carried out in the aqueousmedia, the pulp concentration is one of the main factors affecting the settlement desliming of bauxite. When pulp concentration is small, solid particles in the suspension can all settle freely without disturbing with each other, but the process capacity is small; when pulp concentration is too large, solid particles in the suspension interfere with each other, affecting the dispersion effect and resulting in a worse effect. To investigate the effect of pulp concentration on desliming, detailed tests were carried out with sodium hexametaphosphate as dispersant (dosage 7 kg/t) in the medium of industrial water when the desliming size was 10μm. The results are shown in Fig.4. Fig.4 shows that under the conditions above, when the pulp concentration is 8%, about 11.19% slimes with an Al-Si ratio of 2.05 can be removed. So in the following tests, pulp concentration of desliming is kept at 8%.

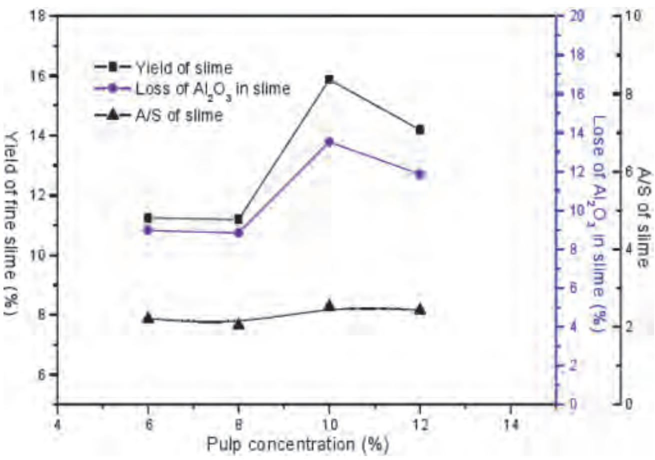

Fig.4 Effect of pulp concentration on desliming

3.3 Effect of dispersant on desliming in deionized water medium

As one of the key factors in bauxite desliming, excellent dispersants can improve desliming effect greatly. Sodium hexametaphosphate and sodium carbonate are commonly used as dispersants in mineral processing. Phosphate anions generated by sodium hexametaphosphate's ionization in the aqueous can react with A13+ ions on bauxite particles' surface to form hydrophilic and stable complexes, which can reduce the surface potential of bauxite and strength the electrostatic repulsion of between mineral surfaces.

Meanwhile some of its hydrolysis components can react with mineral surfaces by electrostatic interaction, hydrogen bonding or complexation to increase steric hindrance between particles, which is beneficial to the pulp dispersion and slime removal. But when the dosage of sodium hexametaphosphate is excessive, a multilayer physical adsorption may occur, impeding particles' dispersion in the pulp. Sodium carbonate can not only adjust the pulp pH, but also can adjust the surface potential of mineral particles, making both diaspore and siliceous mineral negatively charged and eliminating heterogeneous aggregates between the mineral particles.

Thus, the dispersion of pulp is good enough to achieve selective desliming. So sodium carbonate can be used as an effective dispersant for selective desliming of bauxite. However, excessive dosage of sodium carbonate can form multilayer physical adsorption and increase the pulp viscosity, which is harmful for dispersion on the contrary.

In order to investigate the influence of sodium hexametaphosphate and sodium carbonate on desliming and compare the differences between them, a series of tests are carried out in detail. To observe the dispersion effects visually, these desliming tests are carried out in pure water. Figs.5 and 6, respectively, when given sodium hexametaphosphate and sodium carbonate dispersant, pharmaceutical dosage under different conditions, bauxite desliming affect. The results are shown in Figs.5 and 6, respectively.

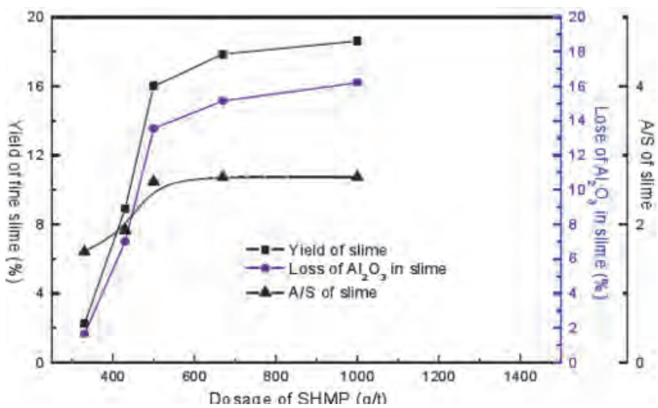

Fig.5 Effect of dosage of sodium hexametaphosphate on desliwing (deionized water)

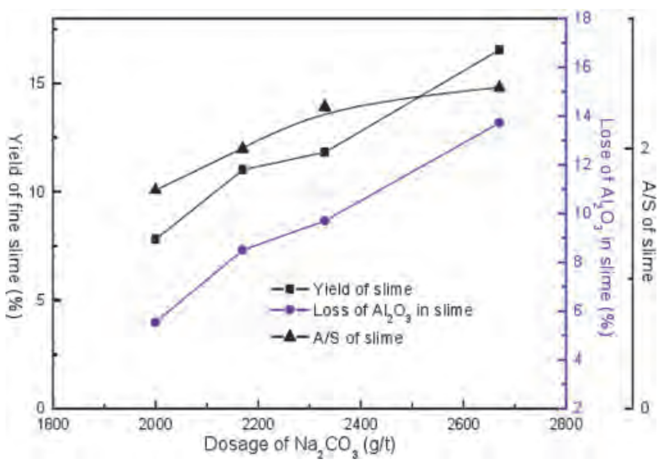

Fig.6 Effect of dosage of sodium carbonate on desliwing (deionized water)

Fig.5 shows that with the dosage of sodium hexametaphosphate increasing, the yield of slimes, loss of $A1_2O_3$ and Al-Si ratio of slimes all increased. When the dosage is 0.43 kg/t, slimes with a yield of 8.93% and Al-Si ratio of 1.92 can be obtained, while the loss of $A1_2O_3$ in slime is only 7.01%, indicating a good desliming effect.

Fig.6 shows that with the dosage of sodium carbonate increasing, the yield of slimes, loss of $A1_2O_3$ and Al-Si ratio also shows a trend of increasing. When the dosage is 2.17 kg/t, slimes with a yield of 11.02% and Al-Si ratio of 2.00 can be obtained, while the loss of $A1_2O_3$ in slime is 8.50%, indicating a good desliming effect.

3.4 Effect of dispersant on desliming in industrial water

Different from deionized water, the desliming operation is usually carried out in industrial water medium in practical production. The water for industrial use in Guizhou province is of high hardness with the total concentration of calcium and magnesium ions at 130mg/L. The existence of calcium and magnesium ions can significantly affect the dispersion of bauxite pulp, thus affecting the desliming effect. In a wide range of pH values, the surfaces of siliceous gangue minerals, like kaolinite and illite, are negatively charged, while calcium and magnesium ions are positively charged.

When the ions are oppositely charged from mineral surfaces, they can be adsorbed on the diffusion layer from the electrical double layer as counter-ions to neutralize the surface potential. At the same time when electrolyte concentration in the solution increases, the thickness of diffusion layer will be compressed, and the surface potential may be reduced, thereby the electrical repulsion between mineral particles is reduced, promoting mineral particles agglomerate to accelerated settlement.

According to the results of previous tests, the effects of desliming with sodium hexametaphosphate and sodium carbonate as dispersants are obvious in deionized water medium. However, in industrial water medium, the effect of the dispersants is likely to be dramatically decreased. For this reason, detailed desliming tests were carried out in industrial water medium with sodium hexametaphosphate, sodium carbonate and sodium silicate as dispersants. The results are shown in Figs.7 to 9.

Fig.7 shows that due to the high content of calcium and magnesium ions in industrial water in Guizhoun province (about 130 mg/L), the effect of selective desliming is badly deteriorated. To eliminate the adverse influence, the consumption of sodium hexametaphosphate must be greatly increased. When the dosage is 7 kg/t, slimes with a yield of 11.19% and Al-Si ratio of 2.05 could be obtained, while the loss of $A1_2O_3$ in slime is 8.84%, indicating a good desliming effect.

Fig.8 shows that even the dosage of sodium carbonate is 10 kg/t in industrial water medium, the dispersibility of pulp

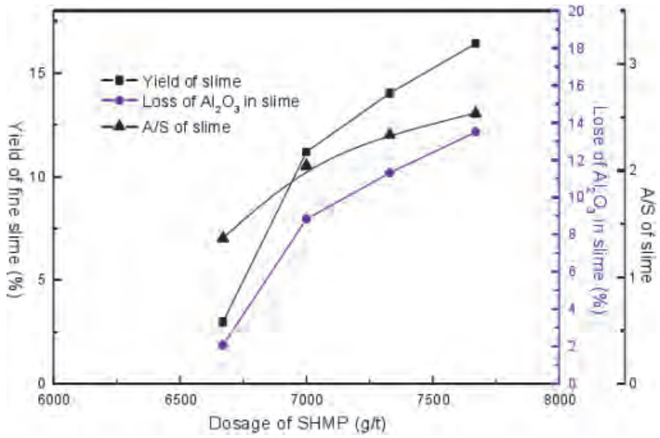

Fig.7 Effect of sodium hexametaphosphate on desliming (industrial water)

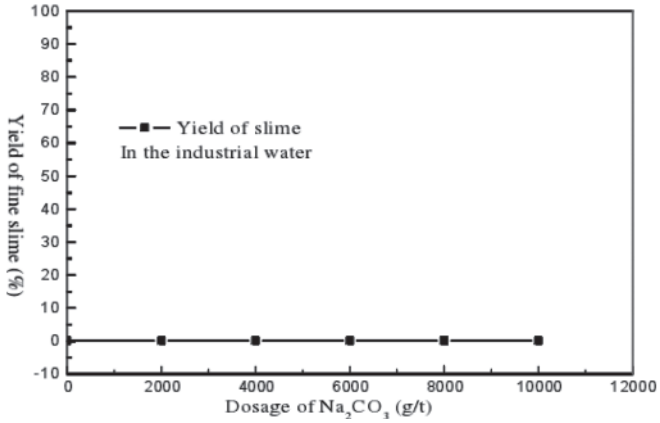

Fig.8 Effect of sodium carbonate on desliming (industrial water)

is still very poor, making the desliming operation unable to be performed. It indicated that sodium carbonate is not suitable for dispersant in bauxite desliming.

Fig.9 shows that with the dosage of sodium silicate increasing, the yield of slimes and Al-Si ratio of slimes both increased. When the dosage is 6.0 kg/t, slimes with a yield of 6.50% and Al-Si ratio of 1.97 can be obtained, indicating a qualified desliming effect.

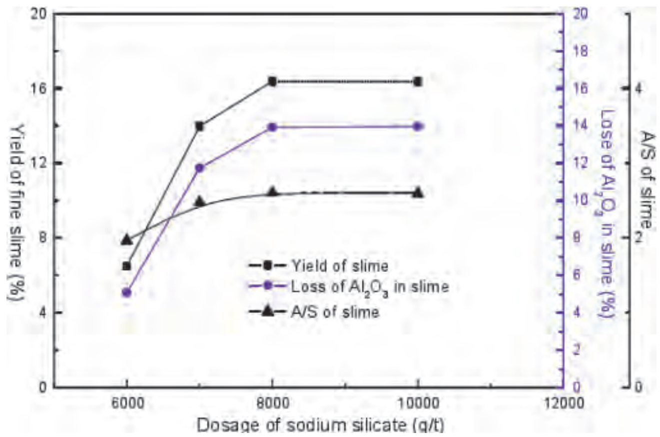

Fig.9 Effect of sodium silicate on desliming (industrial water)

4. Manufacture and practice of hydraulic desliming equipment

4.1 Structure and working principle of the hydraulic desliming equipment

The basic structure of the hydraulic desliming equipment is shown in Fig.10, which was mainly composed of feeding pipe, annular overflow tank, cone body, circular pipe and spigot.

The hydraulic desliming equipment can divide particles in a broad size level into two or more narrow size levels according to their different settling velocity in water based on the theory of hindered settling. Settling velocity of particles in water is related to the particle size, shape and density. In the process of hydraulic classification, particles with the same density can be classified according to the size, but if the particles are of different density, the coarse and light particles will be settling together with heavy and fine particles.

Classification process of the hydraulic desliming equipment contains two parts: settling classification and fluidization classification. Pulp was given into the equipment through the feeding pipe continuously. When the cone body was filled with pulp, it existed horizontal flow and rising flow in the cone. During the process, light and fine particles were brought to the overflow tank on top by the rising flow, meanwhile heavy and large particles (mixed with fine particles) settled down to the fiuidization classification region because of their faster settling velocity than the rising flow.

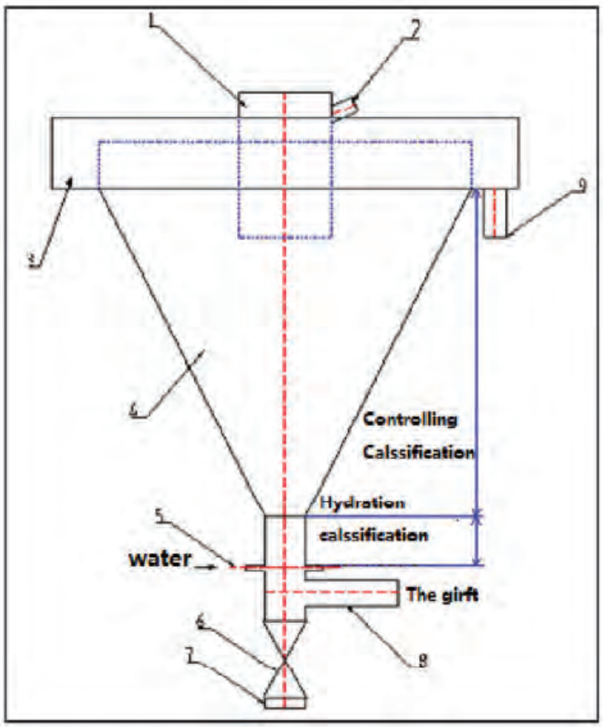

Fig.10 Basic structure of the hydraulic desliming equipment
1. Feeding tube 2. Feeding pipe 3. Annular overflow tank
4. Cone 5. Circular pipes 6. Valve 7. Output 8. Spigot 9. Overflow

In the region of fiuidization classification, several pipes were arranged around to supply water. The upward water flow will wash out the classified solid particles to form an interference fluidization bed. The narrow space made the speed of water flow very fast, thereby preventing the penetration of particles with low settling velocity. The secondary classification effect made the mismatched fine particles to get the motivation to rise again. These fine particles were brought to the top of the equipment and were discharged together with the overflow of settling classification. After classification, the coarse product was discharged by a pneumatic diaphragm pump.

Mineral grains settling down in the equipment, the water flow up against the direction of mineral particle sedimentation, the mineral particles according to the difference between the interference settling velocity, or float upwards, or settling down.

4.2 Pilot plant test of the hydraulic desliming equipment

Test system of the hydraulic desliming equipment is shown in Fig.11. Pulp with a certain concentration was given into the feeding pipe after being stirred uniformly in an agitation barrel. Related operating parameters of the test were controlled by an automatic control system. After the pulp being deslimed by the equipment, base flow and overflow products are returned back to the agitation barrel to form a circulation. After the working state of the equipment is stable, the base flow and overflow products under different working conditions are sampled at the same time. All the samples were dried, weighed, and sent for chemical analysis. The test

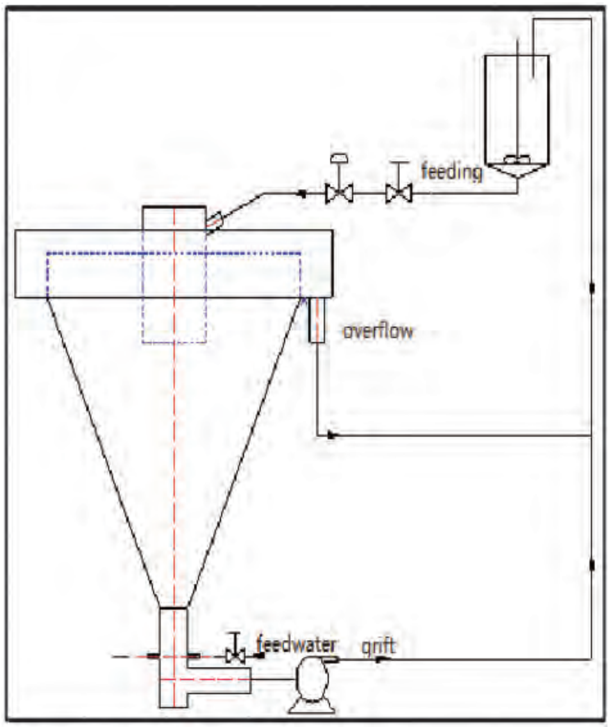

Fig.11 Schematic diagram of the pilot plant test system

system is cleaned by water after each test.

Desliming tests are conducted on sample II by the hydraulic desliming system. Being debugged for two times, processing capacity of test is determined at 233 kg/d (9.744 kg/h). After the system is stable for 1 hour operation, test samples are collected. The test results are shown in Table 2. The results show that, when treating sample II with the desliming system, fine slimes with a yield of 19.95% and Al-Si ratio of 1.71 can be removed, while bauxite concentrate with a yield of 80.05%, Al-Si ratio of 6.78, and $A1_2O_3$ recovery of 85.14% can be obtained.

TABLE 2: PILOT PLANT TEST RESULTS OF THE HYDRAULIC DESLIRNING EQUIPMENT

Product	Yield (%)	Content (%)		A/S	Recovery (%)	
		Al_2O_3	SiO_2		Al_2O_3	SiO_2
Overflow	19.95	46.07	26.94	1.17	14.86	40.91
Baseflow	80.05	65.78	9.7	6.78	85.14	59.09
Total	100	61.85	13.14	4.71	100	100

5. Conclusions

(1) The industrial water in Qingzhen, Guizhou province belonged to moderate hard water, with the content of calcium and magnesium ions in water more than 150mg/L, which affected the pulp dispersion a lot during bauxite desliming process;

(2) With sodium hexametaphosphate as dispersant, the bauxite desliming results of sample I in industrial and deionized water showed that calcium and magnesium ions affected the desliming effect seriously. Sodium hexametaphosphate not only can eliminate the influence of calcium and magnesiumions, but also acted as dispersant;

(3) Dosage tests of sodium carbonate showed that in deionized water, sodium carbonate can disperse bauxite pulp very well, but in industrial water, sodium carbonate cannot disperse bauxite pulp at all;

(4) Sodium silicate had similar disperse effects to sodium hexametaphosphate, and their dosage was similar too;

(5) When the desliming particle size was 10 μm and pulp concentration was 8%, as to bauxite sample I, slimes with a yield of about 10% and can be removed with sodium hexametaphosphate and sodium silicate as dispersant and water softener; about 90% rough concentrate with an Al-Si ratio of 5.60 can be obtained at the same time;

(6) In continuous operation, the hydraulic desliming equipment worked normally and reliably. When treating low grade bauxite with an Al-Si ratio of4.71, bauxite concentrate with an Al-Si ratio of 6.78 and $A1_2O_3$ recovery of 85.14% can be obtained by the equipment.

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