FLOWING FILM JIGGING FUNCTION IN THE NEW "IFFC" PROCESS FOR SEPARATING MINERALS OF ULTRAFINE SIZES①

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ABSTRACT

The concept of the flowing film jigging was first applied to the flowing film concentration area. The flowing film jigging function is an important element of the new process, in jection–flowing film centrifugation(IFFC), for separating and recovering minerals of ultrafine sizes.

Key words: flowing film jigging mineral processing ultrafine sizes IFFC

1 INTRODUCTION

It is well known in the flowing film concentration process the longitudinal conditions of flow must occur at $Re<500$[1], so the longitudinal shear (du_x/dh) from which the Bagnold force is created must be restricted to a low levels in order to recover fine particles effectively. That limitation prevent the development of this technology from progressing further.

Over the past 25 years orbital shear[2, 3]and rocking–shaking action[4] have been essentially aimed at intensifying the Bagnold effect to improve the vertical stratification of particles. According to the experimental results[5], the centrifugal procecs with the additive shaking in an axial direction can only operate in the very low centrifugal strength. When a centrifugal force is applied for separating ultrafines in the above restricted conditions and high field strength, the increase in the Bagnold force can hardly be synchronized with the large–scale increase in the centrifugal force. The latter is much greater than the former. Therefore an additional vertical force must be introduced into the film. In order to resolve this contradiction, a new separation process with the additive utilizing of instantaneous hydraulic impact force of high pressure water jet, injection–flowing film centrifugation (IFFC) is presented by the auther[6, 7].

2 EXPERIMENTAL SAMPLE AND APPARATUS

Ultrafine cassiterite silicate–carbonate slime samples(80～90%–10 μm, grade 0.054% Sn and 0.082% Sn respectively) in the form of old tailings including iron–manganese oxides were obtained from Yunnan, China and are shown in Fig.1. Microscope examination showed that 98% of the cassiterite particles were in a liberated state. Clearly these slimes are too fine to be treated at present.

The schematic arrangement and the specification of the laboratory SL–300 Separator (SL–300S) are shown in Fig. 2 and Table 1 respectively. Slimes were fed at optimum density onto the inner surface of drum 1 by pipe 3 and, as a result of high speed rotation, formed into

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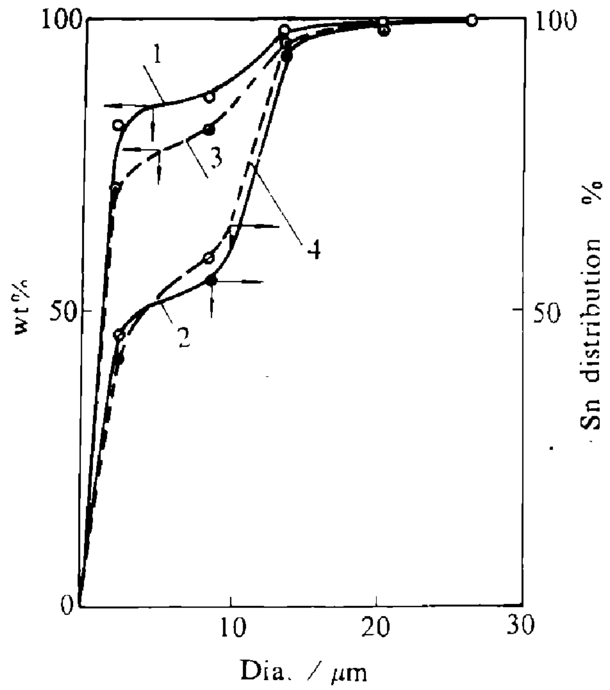

Fig. 1 Size and tin distributions in slimes

1, 2—Slime grade 0. 054%Sn;

3, 4—Slime grade 0. 082%Sn

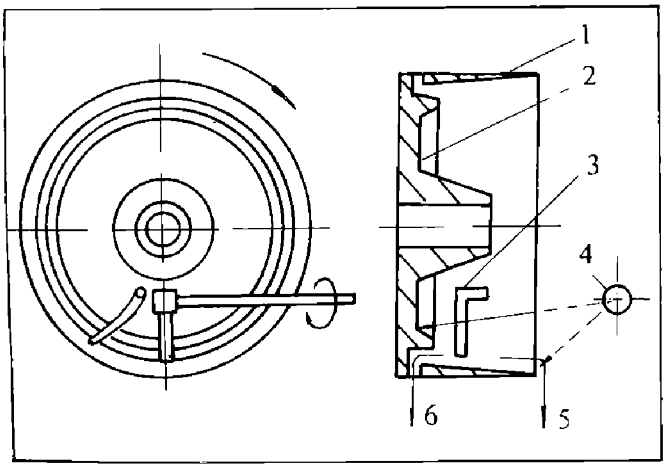

Fig. 2 Schematic arrangement of SL–300S

Table 1 SL–300S *

Drum Diameter × Length / mm	300 × 120
Pressure of Water Jet / MPa	~ 1.5 adjustable
Oscillation Speed of Jet / cps	adjustable
Capacity of −10 μm Slime / kg · h^{-1}	~ 110
Power of 2 motors / kW	1. 5

* Product of BGRIMM

stratified beds of moving particles. The heavy particles were in contact with the surface and transported out as a concentrate via exit 6 by the impact of water jet 4 acting against the longitudinal flow. The light particles, as tailings, overflowed downstream past exit 5. If necessary, cleaning water should be supplied to the disc 2.

3 EXPERIMENTAL RESULTS

Using the SL–300S in an open circuit with a primary roughing and cleaning at a feed rate of 110 kg / h of −10 μm slime, with a grade 0.082%Sn, a tin concentrate suitable for fuming treatment can be obtained at a grade of 2.17%Sn (the total enrichment ratio 26.46)with a recovery of 67.20%.

(1) Size–E. R. –recovery relationship

Based on the test, the size–enrichment ratio(E.R)–recovery relationship is shown in Figs. 3 and 4.

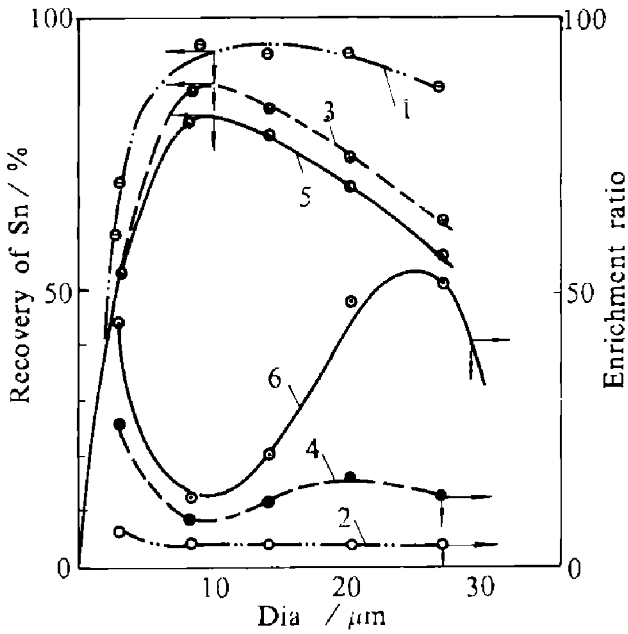

Fig. 3 Size–E. R. –Recovery relationship of SL–300S treating 0. 054%Sn grade slime (Capacity 46. 3kg / h; Feed density 20%)

1, 2—Roughing; 3, 4—First cleaning;

5, 6—Second cleaning

The SL–type separator tends to exhibit a double enrichment ratio peak existing at diameter of 5 and 28 μm, which are clearly related to the presence of two kinds of concentration functions, i. e. the vertical stratification of suspended (−10μm) ultrafine particles and the longitudinal flowing film concentration of unsuspended fine particles. The former peaks are particularly obvious at the cleaning stages.

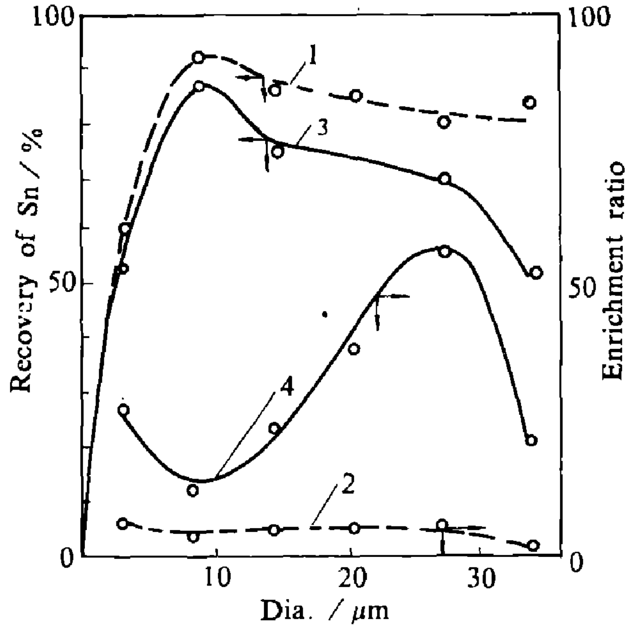

Fig. 4 Size–E.R. –Recovery relationship of SL–300S treating 0.082%Sn grade slime (Capacity 110kg / h; Feed density 20%)

1, 2—Roughing; 3, 4—Cleaning

(2) Characteristic of self–supporting ragging

It is significant that the settled particle bed stayed on the inner surface for separating the cassiterite slime (grade 0.054% Sn).

1) Tin Distribution

After the process was balanced, the tin distributions are shown in Fig. 5. By use of a high pressure water jet acting against the longitudinal flow, a grade in the maximal concentration region (5.63%Sn) 100 times or more greater than that of the feed was obtained, and the average grade of settled particles β_r, which was 35.5 times greater than that of the continuously discharged concentrate β_c, was obtained .

2) Size distribution

The size distributions are shown in Fig. 6. Clearly, the size distribution of settled particles is comparatively coarser than that of the dis- charged concentrate.

3) Ragging distribution

The test results are shown in Table 2. The self–supporting ragging was basically at the region of the inner surface near the feed and the thickness of the cassiterite was approximatively 16.70 μm at 20 mm wide distant feed exit in the slope direction at the roughing stage.

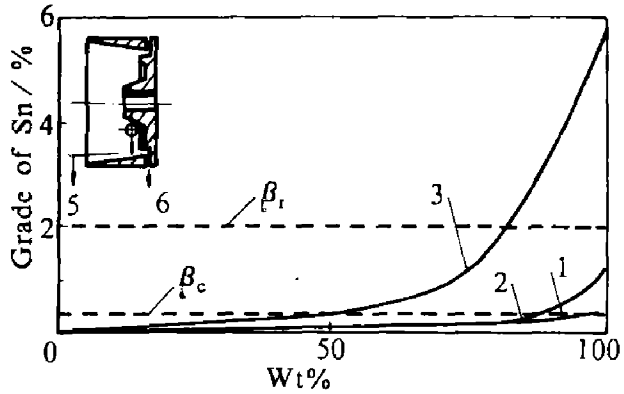

Fig. 5 Tin distribution in the settled particle bed stayed in the drum

1—No cleaning water; 2—Discontinuous cleaning water, 119 cm³ / s; 3—Continuous cleaning water, 119 cm³ / s

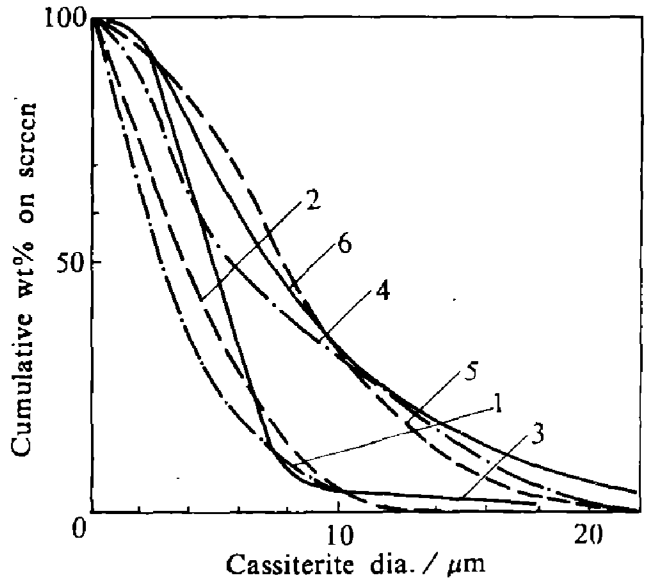

Fig. 6 Size distribution of the settled bed stayed in the drum

1, 2, 3—Roughing and second cleaning concentrate, and settled bed of slime grade 0.054%Sn;

4, 5, 6—Roughing and cleaning concentrate, and settled bed of slime grade 0.082%Sn

As has been indicated above, the coarser and richer in cassiterite grains and associated heavy minerals of the settled bed stayed on the inner surface of the drum acting as a self-supporting artificial ragging for separating suspended ultrafine particles, particularly in the cleaning stages.

Table 2 Ragging distribution of cassiterites

Distance to feed	/ mm	20	40	60	80	100	Sum
Weight(67.8g)	/ %	30.24	23.89	18.58	21.39	5.90	100
Grade(Sn)	/ %	5.63	0.86	0.23	0.33	0.09	
Recovery	/ %	83.99	10.14	2.11	3.48	0.28	100
Calculated[1] thickness	/ μm	16.70	2.02	0.04	0.07	0.01	

4 DISCUSSION

(1) Hydraulic impact of particles

It is clear that IFFC is a new, continuous centrifugal separation process intensified by the hydraulic impact force(P) of a high pressure water jet acting against the longitudinal flow of the film and characterized by a multi–force field. The forces acting on a particle simplified to a sphere at the bottom of the film on the inclined surface in the "IFFC" process are shown in Fig.7.

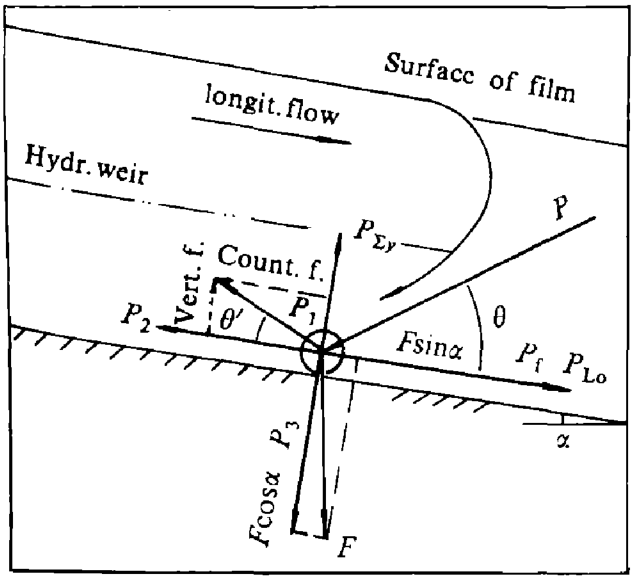

Fig. 7 Forces acting on a particle simplified to a sphere at the bottom

The impact force P could be instantaneously split into three active component force(P_1, P_2 and P_3). When the force P is moving against longitudinal flow, the hydraulic impact zone and non–impact zone are existing simultaneously on the inclined surface. At the same time, the settled particles are loosening (fine particles), suspending(ultrafine particles) in varying degrees and stratified by weight and size. Thus, the two different critical suspended particles in each zone woud appear. If the suspension effect intensified by hydraulic impact could be evaluated the ratio of critical diameter of particles suspended in the impact zone, d'_{cr}, to the non–impact zone, d_{cr}, it may be given by

$$d'_{cr} / d_{cr} = \sqrt[4]{v_1^2 \sin^2 \theta' / m^2 C^2 H i \sin\alpha} \qquad (1)$$

where v_1—Rebounding initial velocity of water jet; θ'—The elevation angle of rebounding flow; i—Centrifugal force strength; α—The slope of inner surface; H— Film thickness; C— Bazin coefficient; m—Hydrodynamic coefficient.

Using the preliminary test results[7], the d'_{cr} / d_{cr}— i relationship shows that the d'_{cr} / d_{cr} must be kept under control in the region of 5~ 6 in order to insure the lower cost and the higher recovery.

(2) Instantaneous pulsating of particles

When the drum was at a high rotation speed, the "hydraulic weir conditions" have turned up in the film by combining adverse action of the rebounding flow(P_1) and the counter flow(P_2). The "hydraulic weir" not only had altered the velocity distribution of longitudinal flow, but also promoted settling of the ultrafine minerals, which are difficult to settle down in general case, in front of the "weir". This"weir effect" would effectually occur when the instantaneous vertical fluid velocity is controlled at a lower values and the loosening ultrafine particles must be constained in the laminar boundary layer which can be easily fulfilled by controlling the parameters of water jet. The unrecoverable mineral particles in the longitudinal fluid above the "weir" would be overflowed downstream as tailings. The maximum diameter of particles lost with the "weir flow" is the minimum diameter of recoverable particles, which can be written as

$$d'_{h.m} = 4.24k_3\sqrt{\mu v_1 \sin\theta' / (\delta - \rho) gi\cos\alpha} \qquad (2)$$

where k_3—Scraping coefficient; μ—Medium dynamic viscosity; δ, ρ—Particle and medium density; g—Gravity acceleration

By the test results, the scraping coefficient equal approximatively to o.1, which means that the $d'_{h.m}$ is equivalent to the diameter of suspended particles, while the $\sin\theta'$ decreases to 1% of its initial value.

When water jet impanges upon prticles, the motion of them is more complex. For simlifying, it may be described by the motion of the $d'_{h.m}$ particles, assuming that there was no relative motion between these particles and rebounding flow before reaching peak. The pulsating curves of the $d'_{h.m}$ particles can be described as follows

$$h_d = F(t) = \begin{cases} (R / k_3^2 k_4)t - git^2 / 2 & 0 < t' \leqslant t'_h \\ (R - H'_{im})(\exp t / k_4 - 1) & t'_h \leqslant t < t_0 \end{cases} \qquad (3)$$

$$v_d = f(t) = \begin{cases} gi(1.098 \times 10^{-4} - t) & 0 < t' \leqslant t'h \\ [(R - H'_{im}) / k_4](\exp t / k_4 - \exp 1.098 \times 10^{-4} / k_4) & t'_h \leqslant t < t_0 \end{cases} \qquad (4)$$

Where R—Average radius of the drum; k_4—Combined parameter; H'_{im}—Maximum rebounding height

According to the above equations (3) and (4), the moving curves of $d'_{h.m}$ particles are illustrated in Fig.8.

Obviously, the h_d—t curve is a typical micro—sawtooth pulsating feature(0—t_0). The pulsating impact acts so quickly during the first half of cycle(0—t'_h) and rather slowly during the other half (t'_h—t_0). That of latter is roughly 50~ 100 times as slow as that of the former. This curve feature renders the injection—flowing film to have better vertical stratification of suspended particles. Thus, one of functional differences between the IFFC and the simple flowing—film centrifugation (FFC)[9] is whether it has possessed of the inherent flowing film jigging funcíion of suspended ultrafine particles[6–8]. After the process was balanced, the settled particle bed stayed on inner surface would spontaneously act as self-supporting artificial ragging.

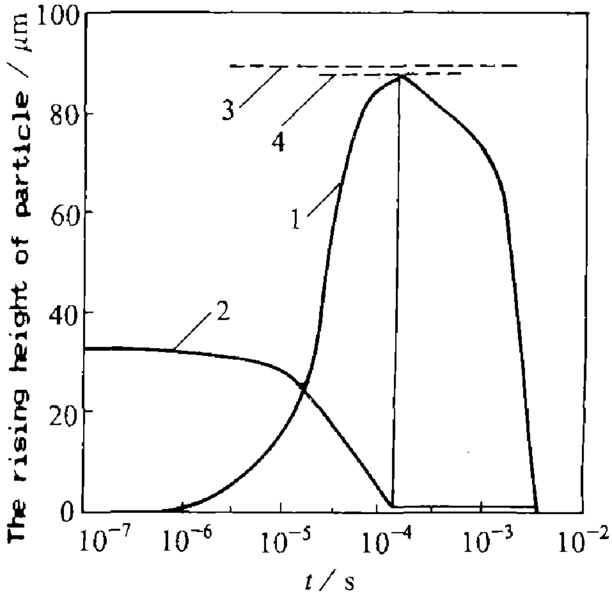

Fig. 8 Moving curves of the $d'_{h.m}$ particle

1—h_d—t; 2—v_d—t; 3—Hydraulic weir; 4—Scraping layer

5 CONCLUSION

By use of a high pressure water jet first introduced as an effective separating force in flowing concentration, the new continuous process "IFFC" has been created. The inherent flowing film jigging function of the pulsating film in the "IFFC" process can significantly improve the performance of the film as a separation medium for separating and recovering minerals of ultrafine(−10μm) sizes, as has been verified by the experimental results.

REFERENCES

1 Burt, R O. Gravity Concentration Technology. Elsevier Science Publishers, B. V. 1984. 89–98.

2 Burt, R O; Ottley, D J. In: Proc Ann Meet, Canadian Mineral processing 5th, Ottawa, 1973. 29.

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$2NiB+12en+6H_2OH_2$

The transportation of electrons suddenly decrease the potential to −1.12 V.

At the moment of inducing the potential of the stainless steel moves suddenly from −0.83 V to −0.72 V and then moves to −1.12 V. Perhaps it is related to the surface reactions. The detailed mechanism should be researched further. Period Ⅳ is the transition stage that has been discussed before. Period Ⅴ is the period when the Ni−B−SiC electroless composite plating occurs continuously.

The experimental results indicate that the passivity of the surface is one of the factors determing the catalytic activity of the substrate metal besides the stationary potential and temperature of the bath.

4 CONCLUSIONS

The obtained results are summarized as follows:

(1) Besides the stationary potential of the substrate metal and temperature of the bath the passivity of the surface of substrate metal determines its catalytic activity;

(2) The transition time and slope of the potential−time curve are useful for judging the catalytic activity of a substrate metal;

(3) The deposition rate of Ni−B−SiC electroless composite plating is almost the same on the catalytic metal.

REFERENCE

1 Jiang, Xiaoxia. In: Proc of the First Conf on Electroless Plating of China. Nanjing.. 1992.
2 Fang, Jingli. Acta Chimica Sinica, 1983, 41(2): 129.
3 Fang, Jingli. Acta Chimica Sinica, 1983, 41(6): 505.
4 Wang, Fengyin; Zhao, Guopeng. Electroplating and Pollution Control, 1986, (3): 1.
5 Bard, Allen J. Faulkner, Larry R. Electrochemistry Methods-fundamentals and Applications. Beiging: The Chemistrial Industry Press, Beijing, 1988.
6 Zhao, Guopeng, Yu, Xinwei. J Finishing Science, 1991, 16: 130.
7 Huang, Zhixiu, Wu, Chunshu. Electroplating Theory. Beijing; The Agrologica Machinery Press, 1982.

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3 Burt, R O. Inter J of Mineral Processing, 1975, 2, 219−234.
4 Chin, P C; Wang, Y T; Sun, Y P. In: proceedings of 13th Mineral Processing Congress, Laskowdki, J (ed.) Warsaw, Elsevier, 1980, 1398−1423.
5 Tucker, P; Chan, S K, Mozley, R H *et al.* Preprints of International Mineral Processing Congress, Dresden 1991, 77−89.
6 Chinese Patent, CN 85 1 02837B, Int. Cl^4. BO3B 5 / 00.
7 Lu, Yongxin. Nonferrous Metals(Quarterly), 1989, 41(1): 35−41 1989 (in Chinese).
8 Lu, Yongxin; Luo, Xingmin and Du, Maode. In:Proceedings of the First Inter Conference On Modern Process Mineralogy and Mineral Processing. Int Academic Publishers of China, Beijing. 1992, 316−321.
9 Sun, Y P. Gravity Concentration. Beijing: Metallurgical Industrial Press, 1982. 256−264 (in Chinese).