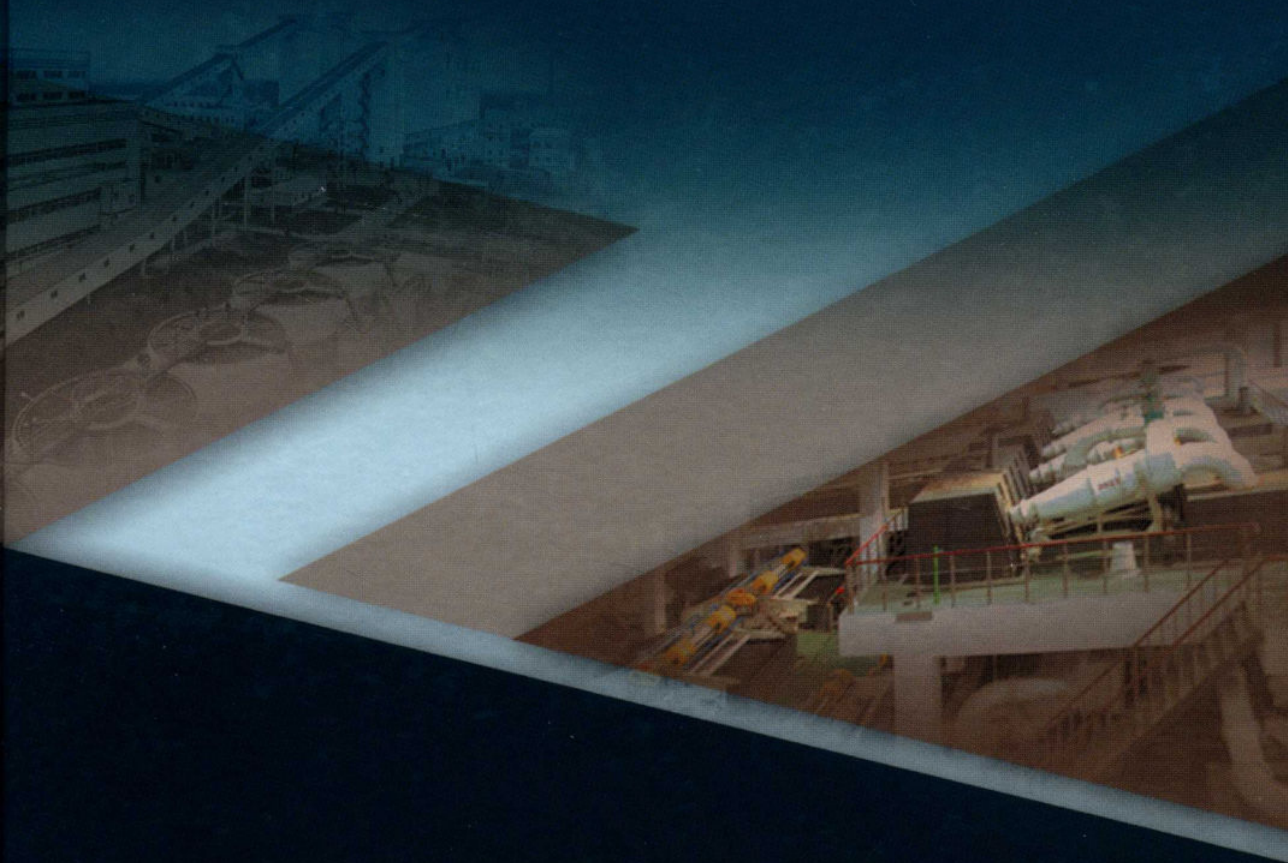


ZHEN LI

Stirred Pulp-mixing in Flotation: Process Characteristics and Mechanism



中国矿业大学出版社

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Summary of the Content

Aiming at the problem that there are only few reports on related basic theory research of stirred pulp-mixing in flotation, this book describes and evaluates the stirred pulp-mixing process and its effect from several different angles; summarize parameters that are used to evaluate power consumption and mixing time, conclude characteristic parameters that represent circulation and shear properties, and come up with the corresponding evaluation standard for mixing efficiency; according to the distribution regularity of material in tank under different stirring mechanisms, parameters and concepts such as cumulative concentration variance, interval concentration variance, just-suspended capability, poor mixing zone and effective range, etc. are summarized to represent the suspension performance of material; use Computational Fluid Dynamics software—FLUENT to correspond to and evaluate typical flow field characteristics, and deepen the research on the function characteristic and regularity of flow field; combining with theoretical discussion in aspects such as flow field characteristic, mixing process, interaction between particles, dispersion of reagents, evaluation parameters of mixing performance of stirring mechanism and solid-liquid mass transfer in agitated tank, and so on, this book lays a theoretical foundation for realizing cognition and control of practical pulp-mixing process.

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Biography of the Author

Zhen Li was born in China in April 1983. He joined the Communist Party of China in December 2003. He got his PhD degree in Mineral Processing Engineering in 2010. His researches cover a wide range of areas from the theory to the process and equipment of mineral processing, and mainly focus on theoretical research and technology development related to pretreatment of pulp, froth flotation, ultrafine grinding-fine grading, and comprehensive utilization of mineral resources. He is now an associate professor and master's supervisor in mineral processing in department of chemistry and chemical engineering in Xi'an University of Science and Technology. Being the young core instructor of provincial predominant discipline of mineral processing, he serves as the dean in his department, and his public positions also include the backbone and visiting researcher in Key Laboratory of Coal Resources Exploration and Comprehensive Utilization, Ministry of Land and Resources. He currently chairs many high-level research projects (contain projects that have been completed), which include one national level project (National Natural Science Foundation of China), two provincial and ministerial level projects (one project is the Specialized Research Fund for the Doctoral Program of Higher Education of China and the other is Natural Science Basic Research Plan in Shaanxi Province of China), four provincial departmental level projects (two Scientific Research Programs Funded by Shaanxi Provincial Education Department, one open project of Key Laboratory of Coal Resources Exploration and Comprehensive Utilization, Ministry of Land and Resources, one open fund of Key Laboratory of Coal Processing and Efficient Utilization of Ministry of Education), and three projects based on the subproject of 973 project, and several science innovation projects based on university-enterprise cooperation. In addition, he serves as the director in many projects related to the discipline construction and talents cultivation. He has published more than thirty papers as the first author, published one academic monograph, obtained thirteen patents as the first inventor and edited four planned textbooks. He won two provincial science and technology awards, three bureau level science and technology progress awards and two teaching achievement awards. He has been awarded the Chinese Government Scholarship to sponsor his study abroad through a "Special Talent Development Project in Western Region of China" and has been a visiting professor at University of Alberta in Canada from 2015 to 2016.

Preface

China is a major consumer of resources. Especially in recent years, the development of economy has had increasing demand for mineral resources, which has led to the prominent characteristics of inferior natural endowment—"poor, fine, mixed" of China's mineral resources; meanwhile, due to the requirements of the development of clean coal technology, the mining industry is also faced with the problem of how to implement quality improvement and high-efficiency usage of fine-particle coal. Because the reclamation of fine and microfine particle mineral is very difficult, enormous loss of resources have been made during the processing process. As the currently most important fine-particle mineral separation method, the research on the development of flotation technology has become the hot spot and difficult point of the research and development of mineral separation technology.

The development of China's mineral processing technology is always in the lead. In recent years, in the areas of intensifying mineralization and separation environment, combining with the mineral separation characteristics, the regulation and control factors for different flotation processes have already been summarized. Great achievements have been made, especially in the researches on flotation reagents and flotation technology & equipment, and systematic and effective researches have been conducted, however, about the initial link of the whole flotation process—pulp-mixing unit, in-depth researches have not yet been made. There is still no clear evaluation standard for current pulp-mixing operation system to evaluate the quality and efficiency of pulp-mixing operation.

The process of flotation stirred pulp-mixing includes the processes of micromixing and mass transfer, which involves particles as the dispersed phase and liquid as the continuous phase, so the movement situation is relatively complicated; in addition with the complexity of operating conditions and boundary conditions, it is hard to detailedly describe the phenomena, such as turbulent characteristics of fluid, transfer process, local mixing, etc. At present, there are still few researches on this aspect, which haven't formed a uniform theoretical system.

The researches on flotation stirred pulp-mixing conducted by the author derive from the "Eleventh Five-Year" Plan Project supported by National Science and Technology (Grant Number: 2008BAB31B01), and National High Technology Research and Development Program of China (863 Program) (Grant Number: 2007AA05Z339), and at present, the in-depth study contents on this aspect have been covered by the relevant research works of National Key Basic Research Program of China (973 Program)—

“Disequilibrium Process and Dynamics of Deep Desulfurization and Deashing of Coal” (Grant Number: 2012CB214905), besides, the research on this area is going to achieve breakthrough on efficient pulp-mixing technology of fine-particle mineral. The major contents of this book are translated from the first part of “Stirred Pulp-mixing in Flotation: Process Intensification and Application” in Chinese version, and the purpose of writing this monograph is to analyze and summarize the basic results and conclusions in the relevant researches of stirred pulp-mixing in flotation, so as to provide theoretical and technical support for the establishment of the evaluation system of stirred pulp-mixing mechanism and the optimization design of efficient pulp-mixing device.

Discussions with Chinese Academy of Engineering academician Jiongtian Liu, Professor Zhenghe Xu, Fellow of Royal Society of Canada and Fellow of Canadian Academy of Engineering, Professor Yijun Cao from China University of Mining and Technology, Professor Anning Zhou from Xi’an University of Science and Technology, Dr. Gen Huang from China University of Mining and Technology (Beijing) have assisted in numerous ways, which provided important advice and suggestions on amendments. The help I received at the beginning of my research from Chinese Academy of Engineering (senior) academician Qingru Chen is gratefully acknowledged. I also thank the support and assistance from Xi’an University of Science and Technology, China University of Mining and Technology, Zhengzhou University, China University of Mining and Technology Press, Key Laboratory of Coal Resources Exploration and Comprehensive Utilization, Ministry of Land and Resources, Key Laboratory of Coal Processing & Efficient Utilization of Ministry of Education, etc.

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During the period of writing, literatures and research results of many domestic and overseas experts were referenced and cited, which were all listed in the references. Here, I offer my sincere thanks and respect. If there is any omission, it is the carelessness of the author, and your criticisms are appreciated.

Author

February, 2017

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Chapter 1 Origin and occurrence

The separation idea of the recently arisen process intensification has come up with higher demand for the development of current mineral processing technology, and its purpose is to emphasize the significance of “process” regulation to mineral processing, and to further promote the popularization and application of new technologies, based on fully identifying the “process industry” property of mineral processing itself.

Through mineral processing workers’ active exploration, in recent years, they have summed up different process regulation factors in the aspects of intensifying mineral and separation environment, coordinated with mineral flotation characteristics. Especially, they have obtained relatively great achievements in researches of mineral processing agents, and separation technology and equipments, which led to the development of flotation industry. But it still couldn’t fully cover the researches of the whole mineral flotation process, most researchers put their concerns on the regulation factors of the main unit of flotation, such as efficient composite agents, reinforcement mineral conditions, composite separation environments, etc. However, there’s no deep research work on the source of the whole flotation process — the pulp-mixing element. The current pulp-mixing operation system hasn’t had a specific evaluation standard to measure the quality and efficiency of pulp-mixing operation. In fact, pulp-mixing is the starting point of the whole flotation operation, especially for the “poor, mixed, difficult” characteristics of minerals. To implement effective dissociation, minerals usually enter into flotation operation section as fine or microfine particles, and the characteristics intensively stand out are: fine particle size, poor selectivity, and adsorption of fine clay on coarse particles, etc. Thus, creating necessary mineral conditions and fine interfacial behaviors are the premise and requirement of fulfilling efficient recovery of fine particle and microfine particle minerals. At the mean time, the urgency of current mineral processing mode to the implementation of compact process separation technology, requires the fulfillment of coupling separation conditions with the separation material properties in the whole separation process, and it also demands the certain operation sections to give full play to its functions and to stay in good condition during the entire process, and thus reducing the impact to other operation sections. Throughout development requirements, pulp-mixing technology will become one of the keys to affect the following separation operation efficiency.

Research on pulp-mixing technology can provide ideal initial conditions to the entire flotation process. Nowadays, during the mineral separation operation procedure, pulp-mixing operation is usually set up before flotation operation section to fully disperse minerals and to let agents completely react with minerals. Pulp-mixing is to use agitated

tank (or other stirring equipments which have similar function) to realize minerals disperse homogenization and to bring about the surface action between minerals and the corresponding agents. Because of the coupling of multiple influence factors, the relation between “force” and “flow” in the actual stirring process is usually non-linear, meanwhile, the purposiveness and efficiency requirements of industrial process determine the non-spontaneity of pulp-mixing process and its characteristic of being able to be artificially intensified.

Currently, previous studies on pulp-mixing mainly focus on circulation efficiency, such as intensifying the design of axial circulation to solve the problems such as easy to pile up, high power consumption, etc., caused by large proportion, high concentration and coarse particle size of pulp, and these studies play an active role in the macromixing of minerals. However, because of China’s “poor, fine, mixed” mineral resources, minerals usually enter into flotation operation section as fine particles or microfine particles to implement effective dissociation. Fine particle size of supplied minerals is easy to cause excessively strong agglomeration in the agitated tank, which is easy to generate the mixing of gangue particles in useful mineral flocs, and then affect the complete surface interaction between agents and minerals. In addition, due to the horizontal circulation phenomenon existed in most stirring processes, the pulp introduced into the agitated tank and the agents are easy to flow out along with the circulation motion, and then cause short circuit since the lack of stirring and mixing process, which can further lead to the decreasing of effective adhesion ability of air bubbles in the following mineralization process, and eventually, affect the separation results, get poor concentrate grade, and reduce the recovery capacity. Therefore, pulp-mixing before flotation is not a negligible but significant operation section, which is the precondition of efficient mineralization and flotation separation.

1.1 Demand of flotation machine system to efficient stirred pulp-mixing

1.1.1 Relation between stirring mechanism of flotation machine and stirred pulp-mixing mechanism

As the main equipment for flotation units in most concentrating plants, conventional flotation machine has certain stirring function due to its own hydrodynamic environment. As shown in Fig. 1-1, agitating component of conventional mechanical agitation flotation machine is similar to centrifugal pump, except from sucking pulp, it can disperse the inhaled air into very small bubbles, and can also keep solid and liquid in suspension and maintain air dispersion in the flotation machine. The function of the stator is to prevent the circulation rotation movement of flotation machine pulp, and to promote the dispersion of air bubbles, which is similar to the countervane of centrifugal pump. The swift jet flow

leaving from stator blades lashes flotation tank wall, and then splits into two jet flows which move upward and downward respectively. The upper wall jet flow mixes with the surrounding flow and becomes upper eddy region, which benefits the suspension and dispersion of solids. The lower wall jet flow usually distributes at the bottom of the flotation machine, forms the lower eddy region, and participates in the circulation of solids. In terms of flow pattern, the stator-rotor stirring mechanism of flotation machine should be defined as similar to the stirring of radial flow impeller^[1]. Because of the diversion effect of the stator part, it weakens the pulp circulation rotation caused by the impact of tangential flow.

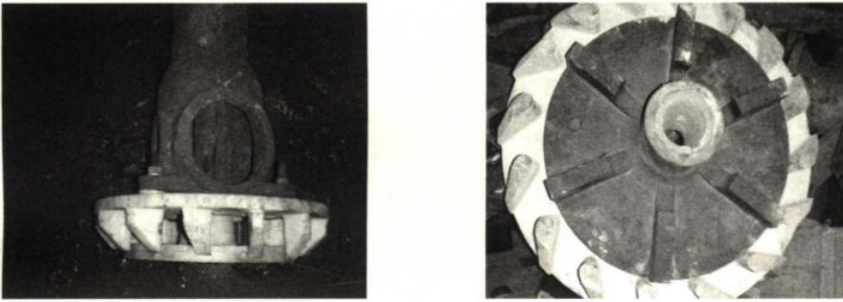


Fig. 1-1 The setup of stator-rotor of flotation machine

Because flotation machine has its own stirring mechanism, and has a long process and relatively ample action time, its requirement for forepart stirred pulp-mixing is not high all along, and it still relies on its own stirring mechanism to make up for the inadequate pulp-mixing operation to some extent. From the point of view of process, the result is using energy from separation process to make up for the insufficient of pulp-mixing process, thus affecting the separation efficiency of flotation machine system on the whole.

On the other hand, too strong turbulent flow of flotation machine unit is bad for flotation process; previous literatures^[2,3] have reported cases that mineralized bubbles detached because of the excessively strong turbulent flow environment in the flotation machine separation process, and thus affecting separation index. However, adequate pulp-mixing of minerals requires a strong turbulent flow environment. Simultaneous realization of the two opposite flow environments requirements cannot rely on the stirring mechanism of flotation machine itself. Therefore, flotation separation system needs to refocus on the process intensification mechanism of the stirred pulp-mixing unit, that is, to emphasize turbulent flow during stirred pulp-mixing operation, and reduce the influence of turbulent flow in flotation separation environment. The higher efficiency of stirred pulp-mixing unit, the lower the overall turbulent degree in the flotation machine tank, and the decreasing of energy consumption in mixing zone is good for the static separation environment of separation zone and foam zone, which also has great significance in lowering energy consumption, reducing wear and tear, and improving separation results.

1.1.2 Impact of stirred pulp-mixing on the development of flotation machine

Along with the increasing demand of separation technology, future flotation machine will tend to be large scale, adopt the aeration mode of mechanical stirring combined with air press-in, and has no agitating components.

(1) Large-scale

Given the large-scale flotation machine has merits such as big processing capacity per single machine, low power consumption, and small occupied area, etc. , in recent years, flotation machines at home and abroad have developed in the direction of larger scale. But during the scale-up, it is difficult to overcome the negative effects such as aggravating mechanical wear, increasing energy consumption, etc. caused by the enhancement of rotor speed. If we primarily concern the separation process mechanism of flotation machine and the control of reducing stirring speed, it will be good for forming relatively stable foam layer, and can create favourable hydrodynamic environment by reducing mineral particles falling off from air bubbles. Thus, it can intensify the stirred pulp-mixing efficiency, provide prerequisite to control the flotation machine stirring speed to a suitable condition, and reduce the mechanical wear, lower the energy consumption, optimize the flotation separation environment of the large-scale flotation machine.

(2) Adopt the aeration mode of mechanical stirring combined with air press-in

Fundamental characteristic of subaeration flotation machine with external blower is: mechanical agitating component is usually just used to stir pulp, scatter and distribute airflow, while air is blown in by force which mainly depends on the external auxiliary fan. Because the rotor-stator system doesn't have air suction function, the rotor speed can be reduced, thus decreasing the wear of rotor-stator system, extending the service life, lowering the corresponding equipment maintenance and management cost, and at the same time, getting a relatively low power consumption per unit mineral processing; the decline of rotor speed can also lead to the reduction of mechanical agitation strength, a relatively stable mineral pulp surface, and coarse mineral being hard to fall off from the bubble, which are beneficial to improve flotation technical index; because aeration is separated from mechanical agitation, aeration volume is easy to be adjusted alone, which can be maintained at a constant volume according to the requirements of production process, or be increased to improve the production capacity of flotation machine. However, on the other hand, due to weaker agitation performance of the aeration flotation machine, the consumption of flotation reagents, especially difficult-soluble reagent is large, meanwhile, the flow field strength which deals with agglomeration phenomenon of fine particle, microfine particle materials is limited. Thus, emphasizing the stirring mixing operation effect can make the reagents work fully and completely before entering the flotation machine, so as to solve the issues such as high reagent consumption, poor selectivity of the reagents caused by relying on its own stirring mechanism of the flotation machine.

(3) No agitating components

No agitating components mainly refers to the applied research of flotation column. Because flotation column cylinder itself has no agitating component, the mechanical power consumption is low, and mechanical wear is relatively small. However, it is due to the lack of complementary effect of stirring mechanism, actual application of flotation column will put more emphasis on the effect of stirring operation. The related content will be elaborated in the following article.

1.2 Demand of flotation column on efficient pulp-mixing

China's mineral resources have complex composition, low grade and high production cost, and flotation process with flotation machine as the main body, often exposed problems of complex process and low separation efficiency. In practical applications, compared with the conventional flotation machine, flotation column shows its characteristics such as high concentrate grade^[4-6], simplified process^[7,8], economical infrastructure investment^[9], and low production energy consumption^[10,11]. In recent years, the revival and development of flotation column has laid a foundation for the realization of compact process configuration and increase of separation efficiency, thus creating a new mineral separation mode established on the characteristic of column structure.

In our country, there are two main types of flotation column in application, one kind is aeration flotation column, representatives are Canada's CPT flotation column (as shown in Fig. 1-2) and China's CCF flotation column of Changsha Engineering & Research Institute of Nonferrous Metallurgy (as shown in Fig. 1-3); the other kind is FCSMC, which is developed by China University of Mining and Technology and has independent property rights (see Fig. 1-4). On the configuration of separation environment, the two kinds of flotation column have their own different separation systems due to their different mineralization mechanisms, but they all have higher requirements for the high efficiency of stirred pulp-mixing operation.

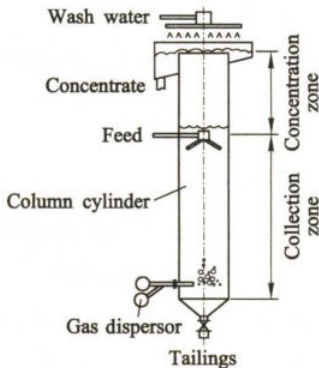


Fig. 1-2 Working principle of CPT flotation column.

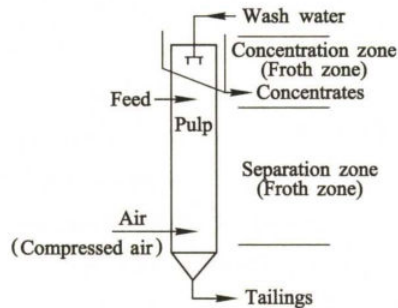


Fig. 1-3 Working principle of CCF flotation column.

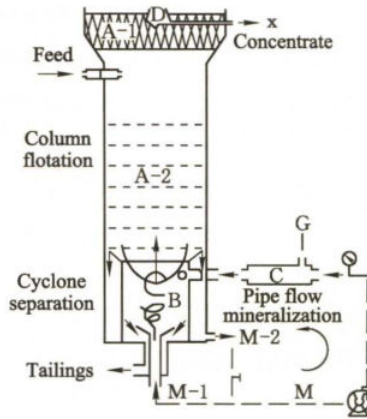


Fig. 1-4 Operating principle of cyclonic-static micro-bubble flotation column.

1.2.1 Aeration flotation column

The CPT flotation column produced by Canadian Process Technologies and the CCF flotation column designed and produced by Changsha Engineering & Research Institute of Nonferrous Metallurgy both adopt traditional countercurrent collision mineralization mode, which belong to typical aeration flotation equipments^[12]. The basic working principle is: micro bubbles produced by the air dispersor which locates at the bottom of the flotation column, freely arises under the effect of buoyancy; while mineral particles entered from the upper cylinder freely fall down due to gravity; rising and falling mineral particles contact and collide in the collection zone; hydrophobic particles are captured, attached to the air bubbles, thus mineralizing the air bubbles, which float up and form the froth layer, and the concentrates are obtained eventually.

In the entire separation system, movement mode of the internal flow field of the aeration flotation column cylinder is mainly convection, and the external aeration system is the main power source for the internal flow field. Pulp starts separation operation as soon as it enters into the flotation column, whose functions are mainly mineralization and separation, and has no further complementary pulp-mixing function. So the initial conditions of pulp before separation are only provided by the front part of stirred pulp-mixing operation. If stirred pulp-mixing efficiency is not high, it will directly affect the flotation column separation precision and ability.

Effective mineralization is the premise of the guarantee of separation effect. Aeration flotation column only has single countercurrent-collision mineralization mode, in order to improve the separation effect, it usually depends on increasing aeration volume and raising cylinder height. Considering from the essential factors of the entire process, the insufficient of mineralization condition caused by low stirred pulp-mixing efficiency also can only depend on intensifying the separation process mode and process determinants, namely, gas holdup and time, to alleviate the problem of low separation efficiency.

What needs to be specially explained is, for the concentration operation of direct

flotation, its flotation feed material is the float-up products of roughing, and most feed minerals react well with the reagents. For obtaining qualified products, generally, concentration does not need or only needs a small amount of reagents to further promote the reaction between minerals and reagents. Speaking from the perspective of pulp-mixing effect, concentration has a low requirement for stirred pulp-mixing operation, and mineralization difficulty during the separation process is small, and also for this reason, this type of flotation column is mainly used in concentration operation at present.

1.2.2 Cyclonic-static microbubble flotation column

FCSMC is invented by China University of Mining and Technology, and is an efficient column flotation equipment with the independent intellectual property rights of our country^[13-20], whose separation principle is illustrated in Fig. 1-4. During the construction of the separation environment, based on traditional countercurrent collision mineralization, it brings in the featured separation modes of countercurrent flow and pipe flow, and forms a separation mechanism which consists of column flotation, multiple cyclone separation and pipe flow mineralization processes^[21]; the whole equipment is a cylinder, and column flotation locates in the upper part of the cylinder, it adopts the flotation theory of countercurrent mineralization, which separates microfine materials under a low-turbulence static separation environment and serves as roughing and concentration in the overall column flotation method; column flotation and cyclone separation are linked together in a up-down structure, which constitute the main body of column separation method; cyclone separation includes gravity concentration based on differences in density and cyclone flotation in centrifugal force field. Cyclone flotation not only offers a high-efficiency mineralization mode, but also greatly reduces the lower particle size limit of flotation and highly increases the flotation speed. Pipe flow mineralization utilizes the jet flow principle, and forms gas-solid-liquid three-phase system for minerals in circulation in the pipe by inhaling and crushing air into bubbles, which leads to high-turbulence mineralization. Pipe flow mineralization is linked with cyclone separation along tangential direction, which forms circular separation for middlings. The separation environment of the whole flotation column is reinforced step by step along the cylinder, which forms the featured separation theory of “multiple flow regimes-step intensification” and has the following characteristics as summarized:

① **Corresponding united mineralization modes of “plug flow-cyclone flow-pipe flow”**: countercurrent collision mineralization happens in plug flow environment, cyclone flotation mineralization occurs in cyclone flow environment, and pipe flow mineralization takes place in pipe flow environment. The step combination and progressive enhancement of three mineralization modes match the characteristic that the mineral floatability is worse and worse along the axial direction of the cylinder, thus obtaining high mineralization efficiency.

② **Two efficient separation processes with respective emphases** : column flotation unit

can obtain high-quality concentrate based on its advantage on selectivity; Cyclone separation unit and pipe flow mineralization unit are combined together to build an intensifying recovery mechanism, which can intensify the materials recovery rate.

③ **A non-linear separation idea** : It offers different flow field environments, adopts different mineralization modes, and inputs different energy to deal with the characteristic that the material's mineralization reactivity becomes worse and worse during the separation process, and achieves optimal mineralization reaction, high-efficiency flotation and adapts energy states to the variation of mineral floatability.

The circulation system consists of its external circulating pump of FCSMC provides the flow field operation energy for the whole equipment. The operation mechanism of the pump part has certain promotion effect for mixing, but because its media are middlings which contain a lot of bubbles, the mixing effect is very limited due to the existence of gas phase interface. Because the internal fluid medium of the cylinder contains a large number of bubbles, the target locates in the gas-solid interface action, therefore, mineralization-separation is still the dominant action. Column flotation separation is a static separation environment, which basically has no effect on mixing. The turbulent flow type in a large range of the flow field within the flotation column is the cyclone flow force field of cyclone separation section, thus, main energy is consumed here. In the three velocity components in cyclone flow zone, the tangential velocity is the largest, which is also the most important velocity component, because tangential velocity determines the centrifugal force, which plays an important role in cyclone separation^[22]. Therefore, the flow field of cyclone separation section is dominated by circulation, and the stirring effect is relatively low^[23]. The action mechanism of the centrifugal force field is to work with buoyancy and together implement bubble dispersion and mineralization. From the implementation of mineralization and separation point of view, the effect of this section is focused on intensifying the recovery of materials, and further increasing the concentrates yield^[20].

The separation unit construction of FCSMC multiple intensification is still for the purpose of efficient mineralization and separation, the separation objects of each separation unit have different features. The whole separation operating mechanism focuses on the reinforcement of separation process, so the demand of pulp-mixing efficiency is similar to it of the aeration flotation column, which is, relying on the high-efficiency and using is as the premise of efficient separation, in order to give full play to the separation accuracy and scale characteristic of each separation unit of the cylinder, reduce the interference of separation objects with different features, and form a real sense of "multiple flow regimes-step intensification" for the process.

In a word, efficient pulp-mixing is also the requirement of efficient column separation equipment and column flotation technology. Because there is no dynamic stirring device inside the flotation column, flow field function of the pulp inside the equipment has limited promotion to the further mixing degree of mineral particles and reagents, therefore, pulp-

mixing effect is particularly important to the subsequent separation process. Unlike flotation machine with agitator, which can buffer and complement the pulp-mixing unit, if pulp-mixing in the pulp pretreatment stage of flotation column is insufficient, it will directly affect the mineralization effect and separation index.

1.3 Demand of fine particle mineral separation on efficient pulp-mixing

After being crushed and ground, the specific surface of the minerals increases, but the formed edges and corners increase even more. Because edges are always the “active center” of adsorbing other substances on the mineral surface (uncompensated bond force has high unsaturation degree around the edges), the more fine the ground minerals, the more intensive the adsorption ability and action activity are^[24].

Definition of different particle sizes is shown in Fig. 1-5. Coarse particles of $+74\ \mu\text{m}$ or $+100\ \mu\text{m}$ are excellent objects for a variety of physical separation methods, while froth flotation is difficult to play a role; $-0.1\ \mu\text{m}$ is the typical colloidal particle size; $-5+0.1\ \mu\text{m}$ size range has some colloid properties, which is difficult to be dealt with conventional froth separation method, however, this particle size range is exactly the particle size of mud containing pulp, which is called microfine particle; optimal particle size range of conventional froth flotation is between $-100+7\ \mu\text{m}$ or $-74+3\ \mu\text{m}$, the so-called fine particle^[25].

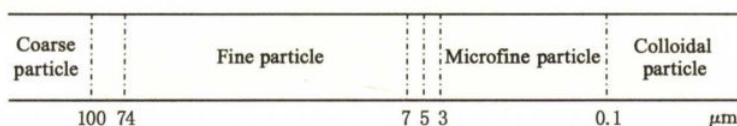


Fig. 1-5 Defined schematic of particle size

For the “poor, mixed, difficult” features of minerals, in order to realize efficient dissociation, minerals always enter the flotation operation section with fine particle or microfine particle size. Fine particle or microfine particle minerals have small mass and small specific surface, which lead to phenomenon which is bad for the reagents function, mineralization, and even the separation between particles, particles and liquid phase in the pulp system (as shown in Fig. 1-6). For example, because of the high activity due to the high specific surface area, particle flocculation easily occurs between fine particle and microfine particle minerals, which is not easy to be rubbed off by other particles. This is not only easy to cause the mixing of gangue particles in useful microfine mineral flocs, but also easy to influence the changing of mineral surface properties at the same time, which is due to the surface interaction between reagents and mineral particles is restricted. So, in order to implement efficient recovery of fine particle and microfine particle minerals, it is