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Study of characteristics of internal solid-liquid two phase flow field of KYF flotation machine

According to the complexity of internal solid-liquid two phase flow field of KYF flotation machine, we determine the boundary condition for the numerical simulation of solid-liquid two phase flow field, use the mathematical model of discrete solid-zero equation, and standard k-epsilon turbulence model for continuous liquid phase, and explore the impact of different mineral particle sizes, densities and viscosities on characteristics of internal solid-liquid two phase flow field of KYF flotation machine. The results of the research are of the guiding significance and practical application value to further improve the separation effect of flotation machine and develop efficient flotation equipment.

Keywords: *Flotation machine, characteristics of flow field, numerical simulation.*

1. Introduction

Flotation is the most important separating method of processing low-grade complex ore in mineral processing, and as the core equipment of flotation process, flotation machine has been highly concerned about by researchers in mineral processing [1-2]. Mineral flotation is carried out in solid-liquid-gas three-phase mixing fluid and its internal flow characteristics are very complex, therefore, it is more difficult to study the characteristics of liquid during the flotation [3-4].

With the continuous improvement of computational fluid dynamics, there is a new research and development direction for studying the characteristics of complex flow field of flotation machine [5-7]. Tiitinen[8] studied the relationship between the fluid state and the structure of flotation machine in OK flotation machine. Xia Jiliang et al., [9] studied the flow mechanism of the flotation tank by single phase flow field simulation. Li et al. [10] conducted numerical simulation of large mechanically stirring air-charging flotation machine and obtained the influence law of impeller structure and internal flow characteristics of flotation machine. Han [11] built mathematical models and methods of conducting numerical simulation on pulp retention time of mechanically stirring air-charging flotation machine. Zeng et al., [12] studied the turbulence intensity of pulp in flotation tank, pointed out that the intense turbulent movement of the pulp in mechanically stirring air-charging flotation machine is the obstruction of the ore may obstruct ore particles, especially coarse ore particles, to fall off from the air bubbles, which are adhered to particles.

Due to the complexity of three-phase flow field in flotation machine, the paper conducts numerical simulation of internal solid-liquid two phase flow field of KYF flotation machine, define the boundary conditions for numerical simulation of internal solid-liquid two phase flow field, use the mathematical model of discrete solid-zero equation, and standard k-epsilon turbulence model for continuous liquid phase, explore the impact of different mineral particle sizes, densities and viscosities on characteristics of internal solid-liquid two phase flow field of KYF flotation machine, and thus lay a foundation for the study on numerical simulation of solid-liquid-gas three-phase flow field of the flotation machine.

2. Computional model and boundary conditions

2.1 Computational model

Taking KYF air-charging flotation machine, which is general, as the subject, the study designs and manufactures the model of mechanically stirring air-charging flotation machine, and based on the modelling structure of solid works as shown in Fig.1 and rotor as Fig.2, adopts backward inclined

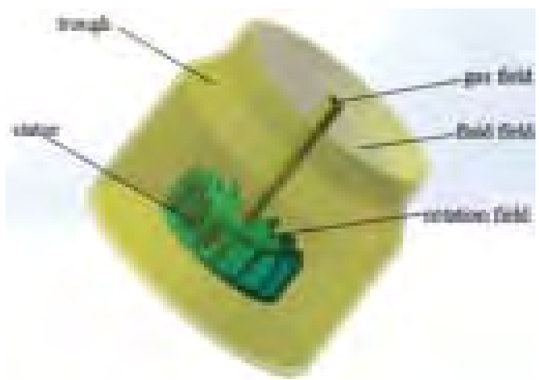

Fig.1 0.03m^3 mechanically stirring air-chargingflotation machine

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Fig.2 Rotor model

Fig.3 Stator model

Fig.4 Air charging system

TABLE 1: GEOMETRIC PARAMETERS OF MAIN PARTS

Rotor diameter / mm	Stator diameter / mm	Leaf angle /°	Groove bottom diameter / mm	Groove top diameter / mm	Groove height / mm
120	180	30	360	300	360

blade and high ratio speed impeller, which have high flow and low pressure head. The air charging system is installed in impeller center with structure shown in Fig.3, and has the ability of pre-dispersing air and raising the impeller to disperse air. The stator structure is shown in Fig.4, and adopts low-damping straight suspension, diagonally installed above the impeller and at the bottom of tank body with support frame. Geometric parameters of main parts of flotation machine are shown in Table 1.

Computational mesh region of numerical simulation of internal flow in flotation machine includes multiple couplings such as impeller flow path, gas domain and fluid domain, and the tetrahedral meshing is carried out with ICEM meshing platform in computational domain of internal flow field of flotation machine. The mean of the mesh quality parameters of the computational domain of the flotation machine is 0.83 and the meshes with quality parameter of above 0.6 accounts for above 96% of the total computational meshes.

2.2 Solid-liquid two-phase numerical simulation strategy

2.2.1 Setting property parameters of mineral particles and process parameters of the flotation machine

Spherical solid particles of CFX are selected as mineral particle medium to simulate mineral particles of different sizes, densities and viscosities, with the average diameters of particles covering 50μm, 74μm and 100μm, mineral densities covering 3.5×10^3kg/m^3, 4.0×10^3kg/m^3, 4.5×10^3kg/m^{3}and 5.0×10^3kg/m^3, mineral dynamic viscosity covering low level of 9.5×10^{-7} Pa·s, middle level of 3.0×10^{-2} Pa·s and high level of 5.5Pa·s.

2.2.2 Setting of buoyancy reference density

As for internal solid-liquid two phase flow field of the flotation machine, since the pulp fluid in the flotation machine is continuous-phase water plus thinner discrete-phase solid mineral particles and the relative density gradient of discrete-phase and continuous-phase is small, the density of continuous-phase water is set as buoyancy reference density and the continuous-phase reference density makes up the total buoyancy and pressure gradient phase of the momentum equation.

2.2.3 Selection of multiphase flow model

In multiphase flow simulation, CFX provides free surface, mixture model and particle model to the transmission of two phases. Since one phase of the solid-liquid two-phase pulp fluid in the flotation machine is continuous-phase water and the other is discrete-phase solid mineral particles, particle model is purposefully selected without considering the impact of flotation agents and temperature fields on the process of flotation, assuming that mineral particles are uniform globules with constant diameters and incompressible.

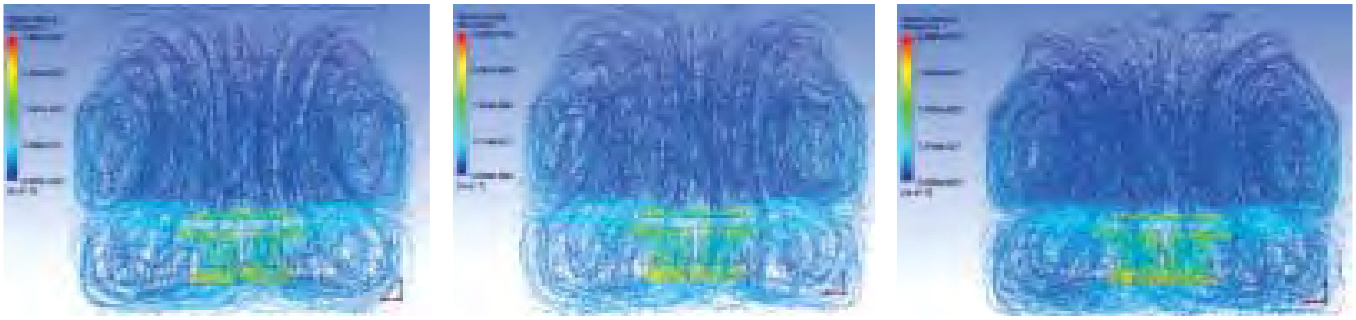
2.2.4 Selection of turbulence model and equation

The mineral flotation process is the movement of pulp with very thin concentration in the flotation machine, so the standard k-ε model is selected as turbulence model in continuous-phase, which is suitable for discrete-phase with very thin concentration, and the turbulence model of discrete-phase solid mineral particles is discrete-phase zero equation model.

3. Study of characteristics of internal solid-liquid two phase flow field of the flotation machine

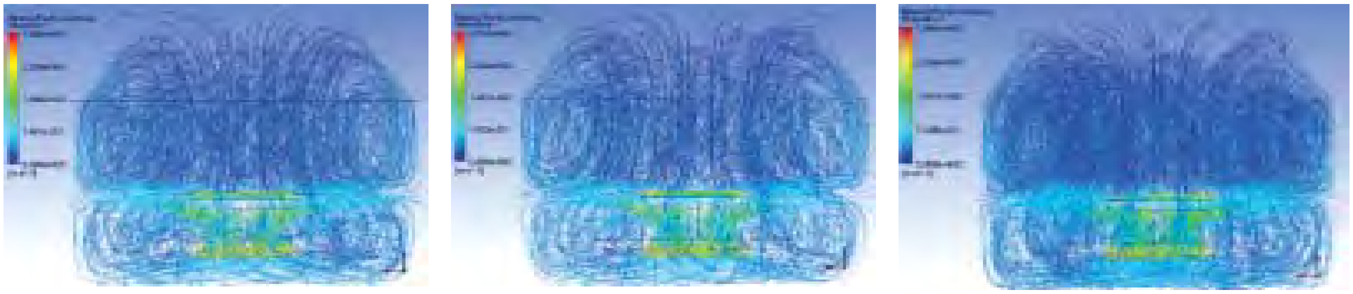
3.1 Study of the impact of mineral size on characteristics of internal solid-liquid two phase flow field

The characteristics of internal solid-liquid two phase flow field is simulated for mineral particles with size of 50μm, 74μm and 100μm respectively during the mineral flotation, the velocity characteristic distribution of liquid-phase water and solid-phase mineral particles is extracted in CFX-post, with the simulation results of characteristic values of liquid-phase



(a) 50μm (b) 74μm (c) 100μm

Fig.5 Trace of liquid-phase velocity at different particle sizes



(a) 50μm (b) 74μm (c) 100μm

Fig.6 Velocity trace of solid-phase at difference sizes

velocity trace distribution as shown in Fig.5 and those of solid-phase velocity trace distribution as shown in Fig.6.

From Fig.5, under the rotor mixing, mineral particles and continuous-phase fluid water, similar to velocity distribution characteristics of a single liquid flow field, present upper and lower cycles of movement in the flotation machine, mineral particles of three sizes have a little impact on the trace of internal liquid movement of the flotation machine and the traces of the solid-phase and liquid-phase movement are basically the same, therefore, the size of fine minerals has a little impact on the liquid movement trace in the solid-phase and liquid-phase flow field of the flotation machine.

From Fig.6, the liquid-phase and solid-phase in the lower cycle region have a higher velocity, with the increase of the distance from the bottom of the trough, the velocity of the liquid decreases, enabling that mineral particles, under the stirring of rotor impeller, can fully contact and collide with air bubbles in the lower cycle region in ensuring the enough stirring strength in the lower cycle region. The liquid in the rising zone has relatively low velocity, which ensures that mineralized bubbles move upward steadily in the rising zone, and the liquid in the zone with stable bubbles has the minimum velocity, which ensure the stableness of bubble layer during the flotation and facilitates to raise mineral flotation recovery and concentrate quality.

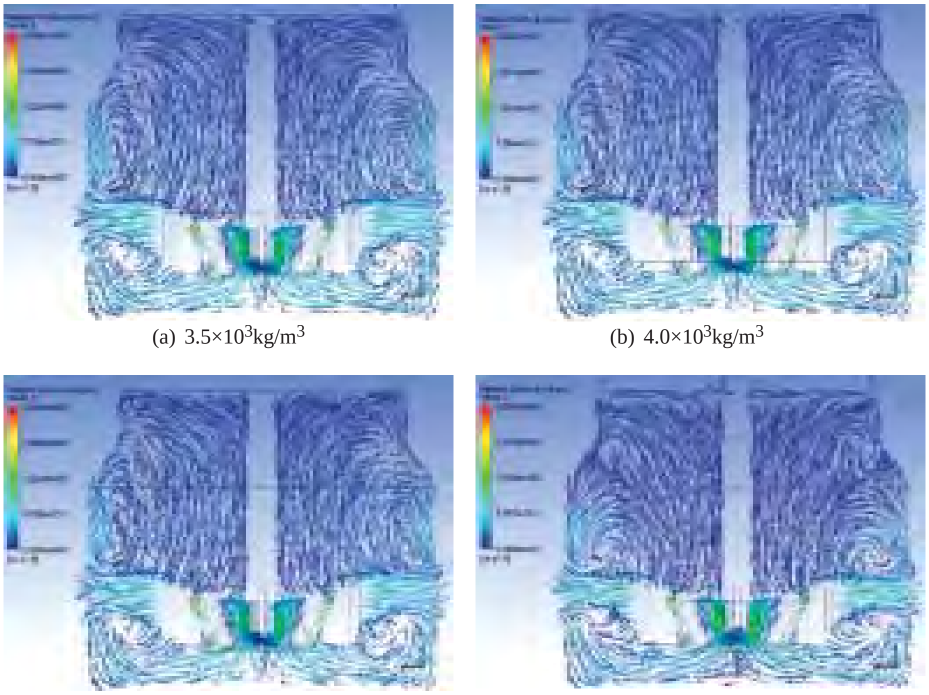
3.2 Study of the impact of mineral density on the characteristics of solid-liquid two-phase fluid

In order to explore the impact of mineral density on the characteristics of solid-liquid two-phase fluid in the flotation machine, under the numerical simulation strategy of solid liquid two-phase fluid, mineral particles with size of 74μm and densities of $3.5\times103kg/m^3$, $4.0\times103kg/m^3$, $4.5\times103kg/m^3$ and $5.0\times103kg/m^3$ are respectively simulated numerically.

Simulation results of flow velocity distribution characteristics are shown in Fig.7 and Fig.8, with Fig.7 as the vector diagram of Y=0 longitudinal velocity at different densities and Fig.8 as the nephogram of Z=5/100/200/295 cross sectional velocity.

Seen from Fig.7 (a), (b) and (c), velocity vector distribution characteristics of mineral particles with the density of $3.5\times10^3kg/m^3$, $4.0\times10^3kg/m^3$ and $4.5\times10^3kg/m^3$ are basically the same. The mineral particles move rapidly under the stirring of rotor impeller and are distributed in the upper and lower cycle zones at the passage of stator blade, which are not greatly different in size.

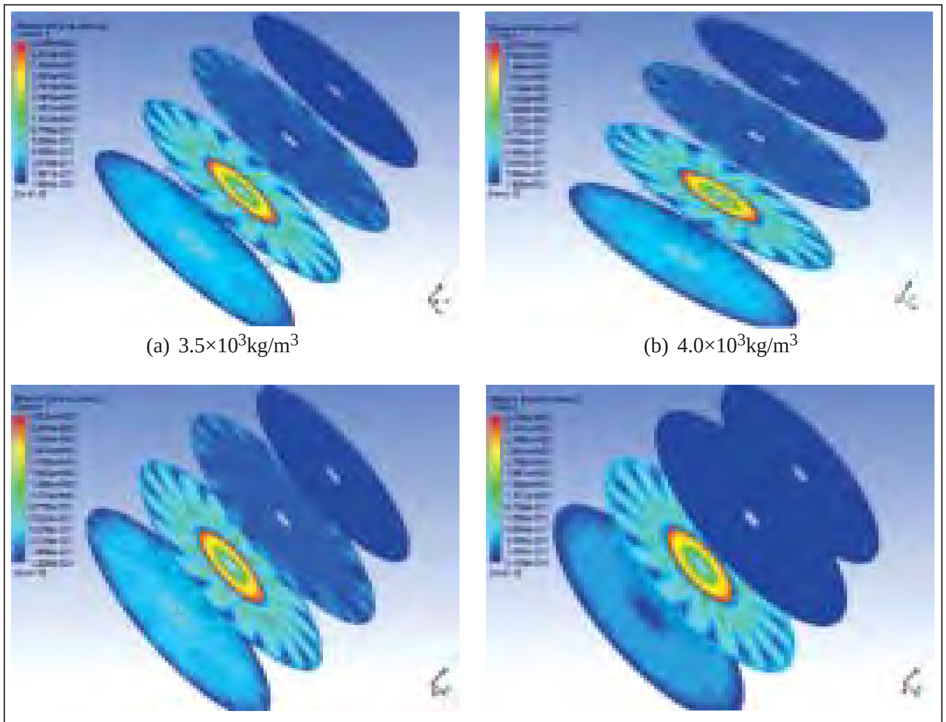
The velocity direction of mineral particles in the rising zone is relatively stable and from Fig.7 (d) that of mineral particles with the density of $5.0\times10^3kg/m^3$ below the upper cycle zone changes and compared to the size of mineral particles with smaller density, the rising height is relatively low, which results from the fact that when the density of minerals is greater, the gravity of itself is greater and the lift action is smaller, so the particles with greater density have a smaller height in the flotation machine. When floating the mineral particles with greater density, the trough of the flotation machine with smaller lift space may be selected or the rotor speed may be increased



(a) 3.5×10^3kg/m^3 (b) 4.0×10^3kg/m^3

(c) 4.5×10^3kg/m^3 (d) 5.0×10^3kg/m^3

Fig.7 Vector diagram of Y=0 solid phase velocity at different densities



(a) 3.5×10^3kg/m^3 (b) 4.0×10^3kg/m^3

(c) 4.5×10^3kg/m^3 (d) 5.0×10^3kg/m^3

Fig.8 Nephogram of cross sectional solid-phase velocity

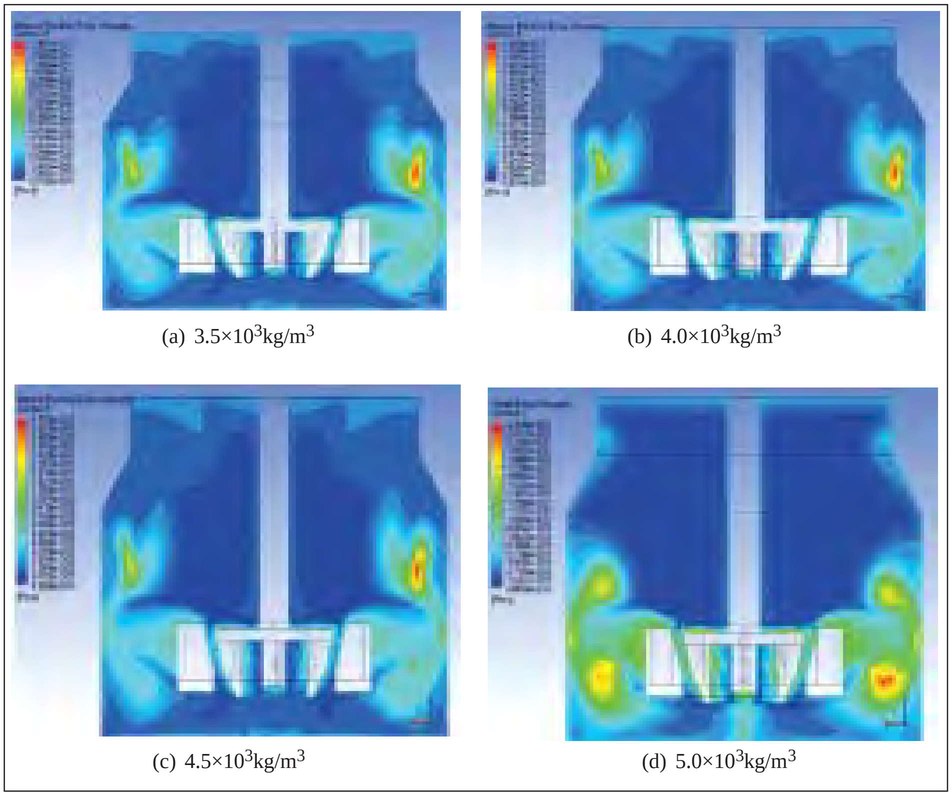
properly without affecting the probability of air bubbles sticking to mineral particles to raise the velocity and lift height of minerals in the flotation machine.

Comparing the nephograms of different cross sectional solid-phase velocities in Fig.8 (a), (b), (c) and (d), it is seen that solid-phase mineral particles in the flotation machine flow the fastest in the rotor-stator zone, with the increase in rising distance of mineral particles, the velocity of mineral particles decreases accordingly and the fluid velocity in the foam zone near the liquid surface is lower, ensuring the stability of foam layer, particularly, the fluid velocity of mineral particles with the density of 5.0×10^3kg/m^3 in the liquid level of flotation tank is the lowest. Therefore, it is concluded that the greater the density of mineral particles is, the lower of the fluid velocity in upper liquid surface and the more stable the foam layer is.

From nephogram of distribution characteristics of solid phase vortex intensity as shown in Fig.9, the distribution characteristics of solid phase vortex intensity of mineral particles with the density of 3.5×10^3kg/m^3, 4.0×10^3kg/m^3 and 4.5×10^3kg/m^3 are basically similar, and the greatest value of vortex intensity is distributed in the bottom of the upper cycle zone and increases as the growth of density of mineral particles. When the density of mineral particles is 5.0×10^3kg/m^3, the distribution characteristics of its vortex intensity significantly change and the highest points of vortex intensity are distributed respectively in the bottom of the upper and lower cycle zone.

3.3 Study of the impact of mineral viscosity on the characteristics of solid-liquid two-phase fluid

Under the numerical simulation strategy of solid-liquid two-phase fluid of internal pulp in the flotation machine, mineral dynamic viscosity is set at the following three levels, that is, the low level of 9.5×10^{-7} Pa·s, the middle level of 3.0×10^{-2}Pa·s and the high level of 5.5Pa·s, for the numerical simulation. Under the full



(a) 3.5×10^3kg/m^3 (b) 4.0×10^3kg/m^3

(c) 4.5×10^3kg/m^3 (d) 5.0×10^3kg/m^3

Fig.9 Nephogram of Y=0 solid phase vortex intensity at different densities

(a) 9.5×10^{-7}Pa·s (b) 3.0×10^{-2}Pa·s (c) 5.5Pa·s

Fig.10 Distribution of Y=0 solid phase velocity vector diagram at different viscosities

stirring of solid-liquid two-phase, the velocity distribution characteristics of flow field is basically the same. The results of simulation for solid-phase mineral particles are as shown in Fig.10.

From the results of the numerical simulation, the viscosity greatly affects characteristics of solid phase velocity flow field and different viscosities have greater impact on the dispersion of solid phase. From the distribution of solid phase velocity vector diagram as shown in Fig.10, mineral particles with higher viscosity have lower height in the rising zone because of viscous action, some mineral particles move to the lower cycle without reaching the relatively stable bubble zone, which results in such issues as poor flotation index and lower recovery rate of mineral particles with higher viscosity. Comparatively, the low viscosity is much more suitable for actual characteristics of flow field during the flotation of minerals. Therefore, for mineral flotation with higher viscosity, it is possible to decrease the density of pulp or choose flotation reagents with lower viscosity, thus indirectly reducing the viscosity of mineral pulp and raising the separation efficiency of mineral flotation.

4. Conclusions

(1) There is less interaction between disperse-phase and continuous-phase mineral particles, and the distribution characteristics of flow field are basically consistent. The size of fine mineral particles has smaller impact on the characteristics of solid-liquid two-phase flow field and compared to the flotation characteristics of fine particles in the mechanically stirring air-charging floatation machine, the coarse minerals have a lower lift height in the rising zone of the flotation tank;

(2) Mineral density has certain impact on the distribution characteristics of internal flow field of the floatation machine. With the increase of mineral density, the pulp decreases in the vortex-distributed regions of the lower cycle zone, and the mineral particles have a higher sink rate. As for mineral particles of greater densities, the rotor speed may be increased properly and the stirring intensity of pulp may be increased to lift the mineral particles to move upwards;

Continued on page 667