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# Liquid-phase Flow Field Characteristics of Mineral Separation Device Based on Hypergravity Stirred Tank

Junke Xie

Sichuan University of Science & Engineering, school of mechanical engineering, Yibin Sichuan 644000，China.

1039106416@qq.com

## Abstract

**In order to improve the efficiency of hypergravity beneficiation and separation, and to obtain the optimal separation parameters of minerals in the fluid, the characteristics of liquid flow fields under different stirring speeds were studied based the ANSYSY-FLUENT in this paper. The results show that: when the stirring speed was 100 r/s, the effect of the agitator on the separation of mineral particles was good, the axial flow velocity was changed the largest along the radial distance, and the liquid phase flow field was better. This research provides theoretical and technical guidance for the design and production of mineral particle agitators.**

## Keywords

**Hypergravity, Stirring, Separation, Theoretical, Mineral particle.**

## 1. Introduction

Nowadays, mechanical agitation tank is widely used in petroleum industry, chemical industry, material processing and other fields with different structure forms. In general, theoretical analysis, numerical simulation and experimental research are used to analyze the flow field characteristics of the flow velocity, turbulence characteristics and the number of blades in the stirred tank. Through the comparative analysis of the central double-layer mixing and the eccentric double shaft mixing, G.H. Zhu[1] et al. concluded that the eccentric mixing can effectively eliminate the isolation zone and improve the speed component. D.M. Mao[2] used numerical methods to study different types of agitating paddles and found that the upper part is the axial flow slurry and the bottom is the radial flow slurry. Scholars[3-6] studied the laminar flow in the eccentric stirring tank, and proposed that the eccentric stirring can improve the mixing efficiency, and the advantage has nothing to do with the geometry of the blade. F.L. Yang[7] et al. used resin simulation method to study the suspension characteristics of solid and liquid in eccentric stirred tank, and analyzed the effect of segregation rate on flow pattern and concentration. J.H. Ji[8] et al. used CFD numerical simulation to study the influence of the new impeller on the uniformity of flow field, turbulence intensity, mixing time and mixing cost. In this paper, the ANSYS-FLUENT software is used to study the flow characteristics of the liquid-phase flow field in the stirred tank at different rotating speeds, and the optimal stirring parameters for the separation of mineral particles are obtained, which provides useful guidance for the follow-up study.

## 2. Numerical simulation

### 2.1 The geometric model

In this study, according to the actual beneficiation device modeling, the SolidWorks is used to build a three-dimensional geometric model of the inverted cone beneficiation device and the schematic

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diagram of the boundary conditions are shown in Figure 1. The geometric dimensions of the agitator are as follows: the diameter of the top of the agitator is 500mm, the diameter of the bottom is 350mm, and the height is 600mm; there are two paddles, the length * width * thickness is 100* 30* 3 mm, and the inclination angle is 25°.

The first phase of the mixing medium is water with a density of 1000kg / m3, accounting for 98% of the total. The second phase is mineral particle copper with a density of 8900kg / m3 and a volume fraction of 2%.

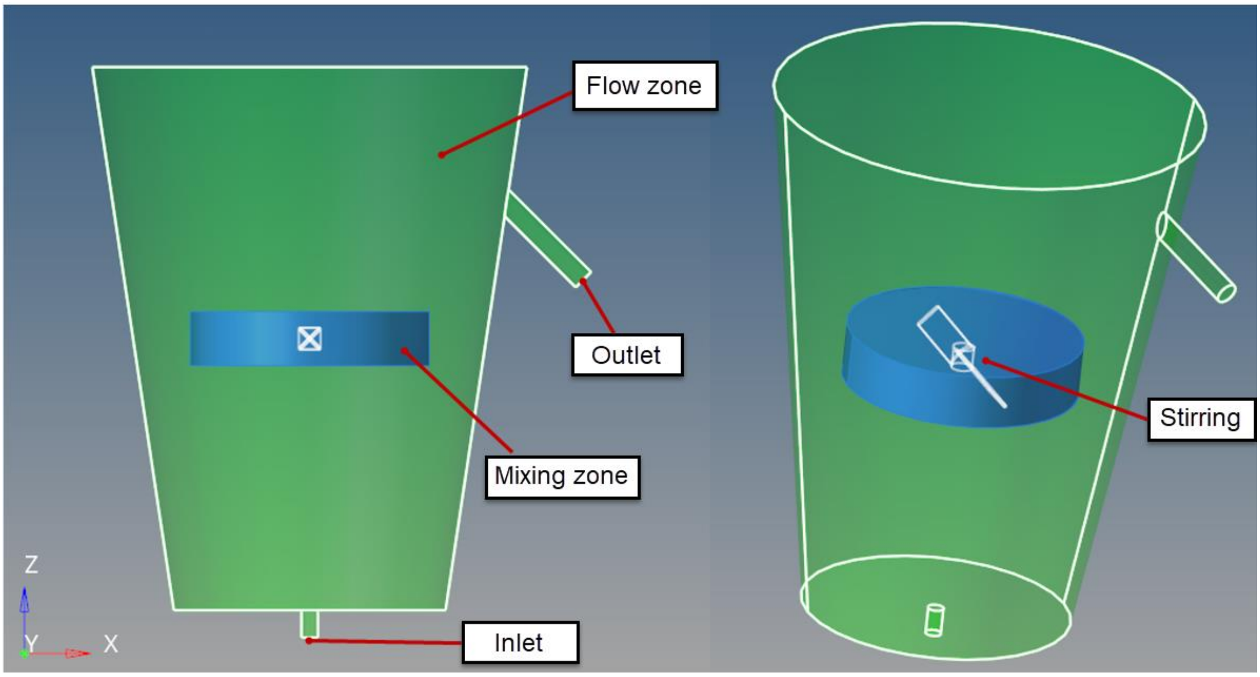


Figure 1. The geometric model of mixing device

### 2.2 The mathematical model

In the mixing device, water and mineral particles are composed of two different components, which interact after mixing. The mass conservation equation of slurry solid-liquid two-phase mixed flow is as follows:

$$\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho \omega)}{\partial z}=0 \tag{1}$$

Where: ρ is the density of the fluid; t is the time; u is the velocity vector; u, v and ω are the components of the velocity vector u in the X, y and Z directions.

The equation of conservation of momentum is the rate of change of total fluid momentum to time, which is equal to the sum of various forces acting on the outside. The conservation equation of momentum is:

$$\frac{\partial(\rho u)}{\partial t}+\frac{\partial(\rho uu)}{\partial x}+\frac{\partial(\rho vu)}{\partial y}+\frac{\partial(\rho \omega u)}{\partial z} = \rho f_x-\frac{\partial p}{\partial x}+\frac{\partial}{\partial x}\left(2\mu\frac{\partial u}{\partial x}+\lambda \mathrm{div} U\right)+\frac{\partial}{\partial y}\left[\mu\left(\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)\right] +\frac{\partial}{\partial z}[\mu\left(\frac{\partial w}{\partial x}+\frac{\partial u}{\partial z}\right)] \tag{2}$$

Where: f is the volume force per unit mass of the fluid; μ is the dynamic viscosity of the fluid; and **λ** is the second molecular viscosity of the fluid.

### 2.3 Finite element modeling

The three-dimensional model established by SolidWorks is saved as the general format of CAE. XT is imported into ICEM for grid division. Tetrahedral grid division is used to divide the calculation

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area in agitator into mixing area and flow area. After grid division, the number of grids in agitator is 1185724. After grid independence verification, increasing the number of grids on this basis does not improve the reliability of the calculation results.

### 2.4 Simulation method

The relative motion of the agitator and the agitator is simulated by multiple reference systems. In the process of the agitator, the agitator and the agitator shaft are set as the rotating wall, the bottom and the circumference of the agitator are the wall boundaries, and the upper surface of the agitator is the free flow surface. The K-epsilon turbulence model is used under steady condition.

## 3. Results and discussion

### 3.1 Analysis of the flow characteristics

In order to study the mixing process in agitator, it is necessary to accurately simulate the flow field in agitator Figure 2 shows the flow field structure of the longitudinal section where the mixing shaft is located. The position of the center of the left and right vortices in the flow field is symmetrical with respect to the mixing tank body, which indicates that there is a stable mixing dead zone in the upper and lower areas of the mixing impeller. The fluctuation of the upper part of the fluid in the whole stirred tank is small, and the stirring range in the upper part is reduced.

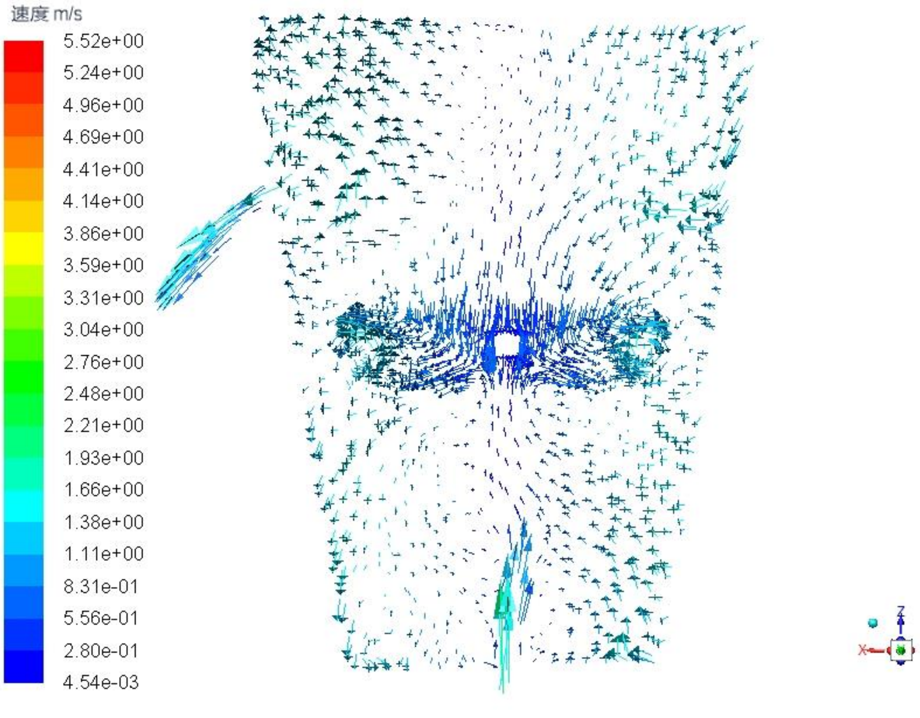


Figure 2. The flow diagram of longitudinal section

### 3.2 Radial velocity distribution at different speeds

Fig. 3 shows the change rule of radial velocity on radial distance at different rotating speeds in the stirred tank. It can be seen from Figure 3 that the direction along the X axis changes in a curve. When the rotating speed is 20 r/s, there are two peaks and valleys, and they are basically symmetrical distribution. The maximum radial speed is 0.24 m/s at 0.17 m of the radial position. When the rotating speed is increased to 50 r/s, the radial speed is significantly increased, and the radial speed is up to 1m/s at 0.2 m of the radial position. When the rotating speed continues to increase to 100 r/s and 120 r/s, it can be seen that when the rotating speed is 100 r/s, they are uniformly symmetrical distribution, but when the rotating speed is 120 r/s, they are in motion The above analysis shows that when the stirring speed is 100 r/s, it has the maximum radial velocity value, which is better than other rotating speeds for the radial mixing and mixing of fluid.

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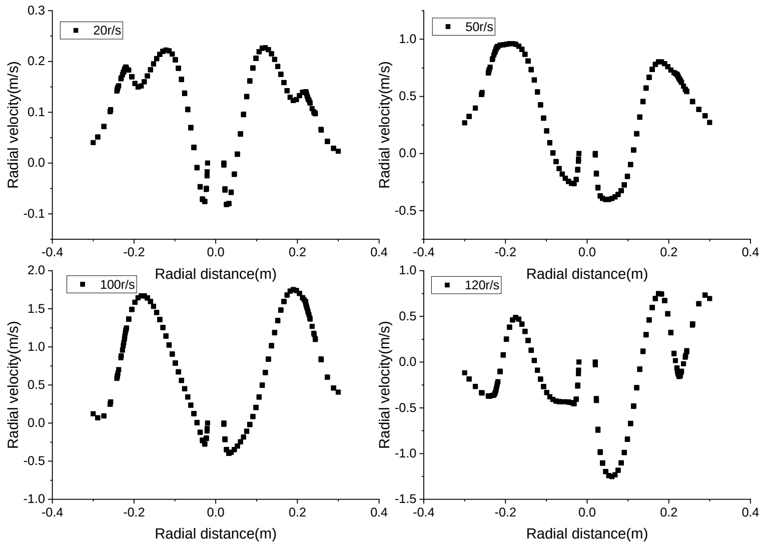


Figure 3. The change of agitator inner diameter velocity along radial direction

## 3.3 Tangential velocity distribution at different speeds

The change curve of tangential speed along radial direction at different speeds is shown in Figure 4. It can be seen that with the increase of the rotating speed, the tangential velocity in the mixing tank increases correspondingly. When the rotating speed is 20 r/s, the radial distance at the center of the mixing shaft, i.e. at the radial distance of 0.2 m, the fluid flow in the mixing tank with the tangential velocity of 1.4 m/s is stable. When the rotating speed increases to 50 r/s, it is obvious that the tangential velocity increases sharply near the agitated slurry; when the rotating speed continues to increase to 100 r/s, the radial distance is symmetrically distributed, and the tangential velocity increases greatly, indicating that the dispersion degree in the liquid phase flow field is the best under this speed, which is conducive to liquid-solid separation; when the rotating speed increases to 120 r/s, the tangential velocity changes irregularly The higher the apparent velocity is, the better. The greater the rotational velocity is, the more turbulent the liquid is.

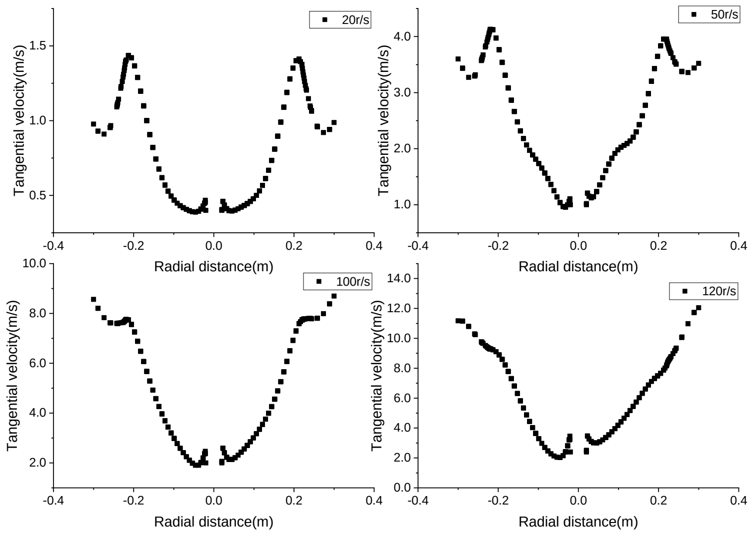


Figure 4. The change of tangential velocity in agitator along radial direction

## 3.4 Axial velocity distribution at different speeds

Fig. 5 shows the change curve of axial velocity of fluid with radial position. It can be seen that when the rotating speed is 20 and 50 r/s, the axial speed fluctuation is small; when the rotating speed is increased to 100 r/s, the change rule from the edge of the mixing tank to the center position is gradually low, which may be caused by the existence of vortex near the wall of the mixing tank; with the increase of the rotating speed in the mixing tank, the volume of water discharged from the mixing

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tank increases in unit time, compared with the low rotating speed. The higher rotational speed increases the flow velocity of the whole liquid phase flow field, increases the flow intensity of the liquid, and provides more favorable conditions for mineral separation.

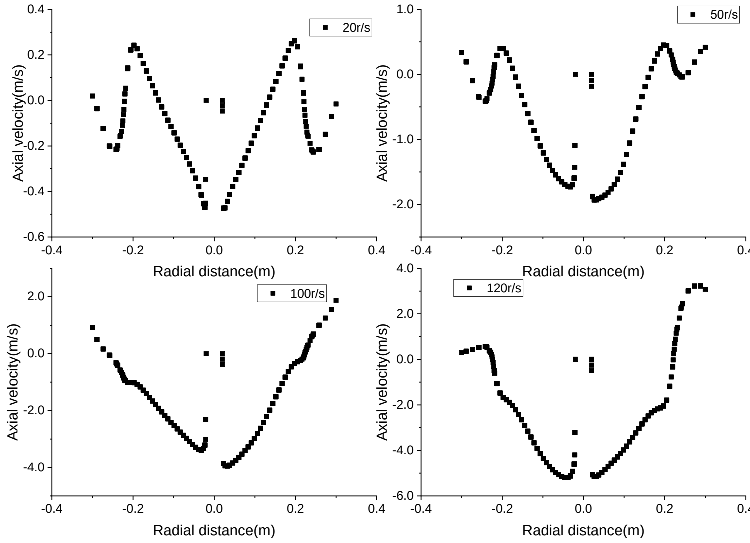


Figure 5. The change of axial velocity in agitator along radial direction

### 3.5 Turbulence characteristics at different speeds

Figure 6 shows the characteristic distribution of turbulence in a stirred tank at different rotating speeds. It can be seen from the figure that the turbulent kinetic energy in the stirred tank increases significantly with the increase of stirring speed. At 20 r/s and 50 r/s, the turbulent kinetic energy will fluctuate obviously. At 100 r/s and 120 r/s, the turbulent kinetic energy will be symmetrical with the radial distance and there is no obvious fluctuation. The turbulence kinetic energy at the center is the largest. With the increase of the radial distance away from the center, the turbulence decreases obviously. The turbulence kinetic energy at the farthest distance away from the radial center is the smallest, which is very conducive to the separation and separation stability of different density mineral particles on the wall.

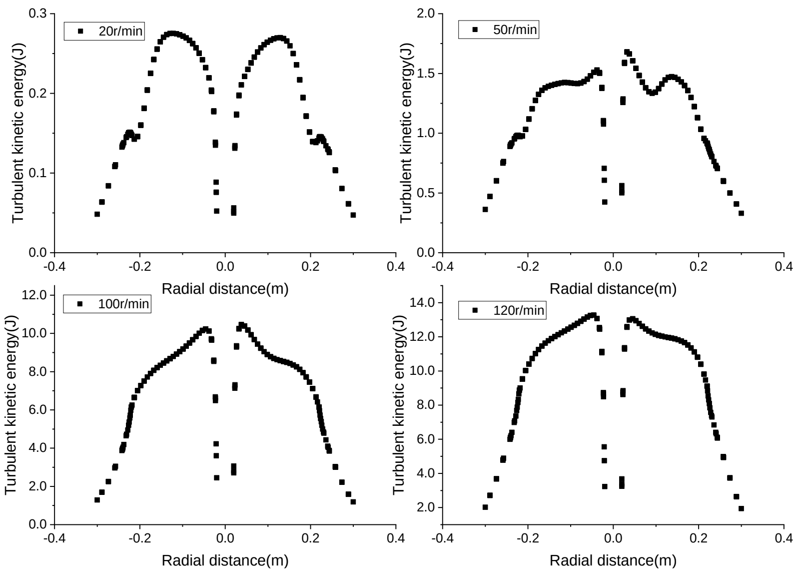


Figure 6. The change of turbulent flow energy in radial distance

## 4. Conclusion

(1) The rotating speed in the stirred tank plays an important role in the dispersion of mineral particles. In a certain range, with the increase of the rotating speed of the agitator, the agitating capacity of the

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agitator will be enhanced, which is helpful for the better dispersion of mineral particles. When the stirring speed reaches 100 r/s, the dispersion effect is the best, which is conducive to the separation of mineral particles.

(2) The change of the axial flow velocity along the radial distance is the largest, which shows that the liquid phase fluid mainly moves along with the impeller in the process of mixing, and the axial movement is the key index to improve the mixing effect.

(3) At 100 r/s, with the increase of the radial distance away from the center, the turbulence obviously decreases, which is conducive to the separation and separation stability of different density mineral particles on the wall.

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