

Improving the parameters affecting the agitator of the copper ore flotation cell of the Daralo copper complex concentration plant

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Abstract

Hydrodynamic components in column flotation have a great impact on the performance and efficiency of the process. Computational fluid dynamics can be used as a powerful numerical method to analyze and predict the components of this process. Therefore, in this research, the flotation process has been modeled using the commercial software ANSYS Fluent. The modeling has been carried out in two phases and using the volume of fluid (VOF) module. In the design step, the independence of the solution from the grid has been examined, and then the calibration of the developed numerical model has been examined. For different methods of using blades inside the flotation cell, the flow field, bubble diameter, and gas retention have been investigated. The results showed that horizontal blade placement has the best performance in reducing axial mixing in the column, and using this blade placement method, the axial velocity can be reduced by up to 75%. The results also showed that increasing the speed of the agitator from 700 rpm leads to an increase in the separation forces, and as a result, the recovery of copper particles inside the flotation cell decreases. On the other hand, increasing the speed of the agitator leads to an increase in the instability of the foam phase.

Keywords: flotation, copper concentration, computational fluid dynamics, Daralo copper complex.

1. Introduction

One of the most important methods of mineral processing is flotation. The use of flotation in mineral processing is constantly increasing, so that each year a larger tonnage of minerals is processed using new flotation methods compared to the previous year [1]. Flotation can be considered a physicochemical process that separates the two by taking advantage of the difference in surface properties of valuable minerals and gangue. This difference in surface properties is revealed after pulp preparation with the help of various chemicals such as collectors, foamers, activators and traps. In order for the flotation of the desired particles to occur, air bubbles must attach themselves to the surface of the desired mineral, thus carrying the particles to the water surface [1]. The reason for using agitators inside flotation cells is also this, to allow particles to collide with bubbles more effectively. The valuable minerals attached to the air bubbles create a foam phase. It is obvious that in each flotation cell there is a maximum particle size, if the particle dimensions are larger than this maximum, they will not be able to float [2]. This maximum size of floatable particles is a function of various factors such as the amount and dimensions of the bubbles produced, the degree of turbulence caused by the agitator, the stability of the foam phase, the viscosity of the environment, the

geometry of the cell, the pH of the solution and many other factors [3]. The reason for the decrease in particle recovery with increasing particle size can be traced to the various mechanisms of collision, attachment and separation of particles, which are the main cause of the interaction between the bubble and the particle. More precisely, flotation is a function of the probability of particles being collected by the bubbles [4,3]. In general, each flotation machine must perform four main tasks, which are [5-8]: creating a favorable connection between bubbles and particles, creating a stable interface between pulp and foam, suspending solid particles in the pulp, creating a favorable foaming capacity. The first to third tasks mentioned above in each flotation cell are a function of the characteristics and hydrodynamic conditions of the flotation cell [9]. A schematic view of a mechanical flotation machine, along with its components and how they operate, is shown in Figure (1).

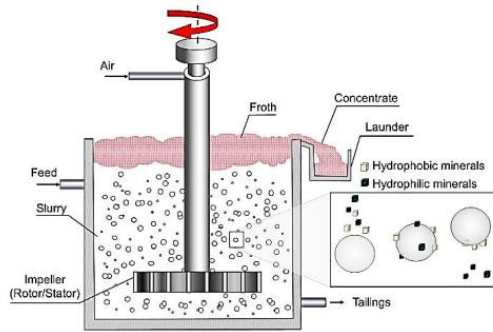


Figure 1-1. Schematic of a mechanical flotation machine [7]

It should be noted that flotation is often used for fine particles of about 10 to 100 microns, because the air bubbles created are often about one millimeter in diameter and are unable to carry larger particles.

2. Modeling

In this research, the commercial software ANSYS Fluent has been used for numerical modeling of the problem. The Volume of Fluid (VOF) is used to track the contact area between two phases and defines the interface through a continuous field of the volume ratio of the phases. For three- or four-phase (e.g., aqueous fluid phase, solid ore phase in the float, and sometimes ambient gas), two or more VOF fields are usually used or a Population Balance Model (PBM) field is used to describe the particle size and distribution.

Three- and four-sided elements (triangular and square) have been used for meshing. The meshing has been done in such a way that the meshes in the central part of the circle, which is the flow inlet, have a higher density. Figure (1) shows a general view of the meshing of the flotation cylinder.

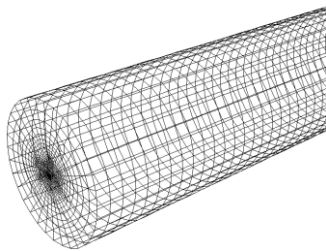


Figure 1. General view of the flotation cylinder grid

Air bubbles enter the flow field from a circle with a diameter of 0.7 mm, which is embedded in the center of the bottom plate of the cylinder. The top plate of the cylinder is also the flow exit. The diameter of the cylinder is 10 cm and its length is 1.70 m.

Flotation columns are not in the form of a simple cylinder and have a series of blades. Common blade placement methods include vertical, horizontal, combined horizontal and vertical, and combined horizontal blade placement.

In the vertical blade placement method, a vertical blade in the form of a rectangular cube is often used inside the flotation column. In this case, the thickness

of the blade is considered to be in the range of 3 to 10 mm and its length is often 12 times the diameter of the column. Usually, a distance of 1.5 times the diameter of the column is considered to be from the bottom plate. In Figure (2), a schematic view of the vertical blade inside the flotation cell can be seen.

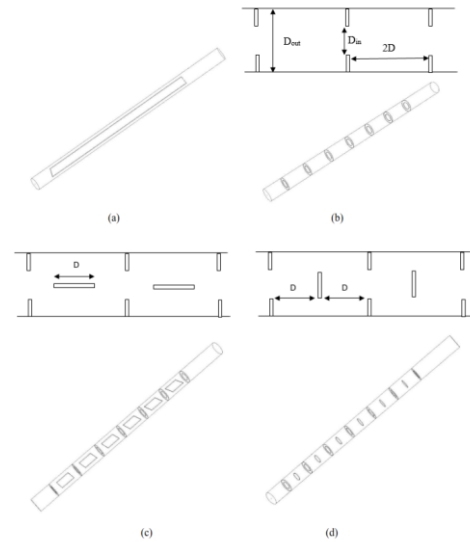


Figure 2. (a)-Flotation column with vertical blade. (b)- Top) Schematic view of horizontal blade placement, bottom) Horizontally bladed flotation column. (c)- (Top) Schematic view of horizontal and vertical mixed blade arrangement, (Bottom) Bladed column. (d)- Top) Schematic view of horizontal mixed bladed flotation column, bottom) Bladed flotation column.

3. Boundary conditions

The flotation column studied in this study consists of three boundaries. The first boundary is the flow inlet, the second boundary is the wall, and the third boundary is the flow outlet. The flow inlet is entered through a circle with a diameter of 0.7 mm, which is concentric with the base of the cylinder. The type of this boundary is considered to be a velocity inlet. The inlet air velocity is considered to be 3.29 cm/s. Two important points that should be mentioned are that firstly, only air flow enters at the flow inlet and no inlet is considered for the continuous phase, which is water. Also, at the inlet, it is assumed that only bubbles with a diameter of 0.5 mm enter the flotation column. The flow outlet is also considered to be a pressure outlet. The side walls of the flotation cylinder are also characterized by the wall boundary condition and the no-slip condition.

4. Independence of the solution from the grid

Table 1. Details of different gridding's to check the grid independence of the solution

Number of nodes on the bottom side	Number of nodes on the bottom plane	Number of nodes on the cylinder
22	370	48970
28	621	104492
32	818	153424
34	962	193248

5. Results

Number equations consecutively. Equation numbers, within parentheses, are to position flush right margin of The main factor in the occurrence of axial mixing phenomenon is the return of water in the water column, the axial velocity of water and its rate of change can be considered as the basis for studying the rate of axial mixing. In Figure (3), the water flow lines and the path that water takes in the middle plane of the flotation column are given.

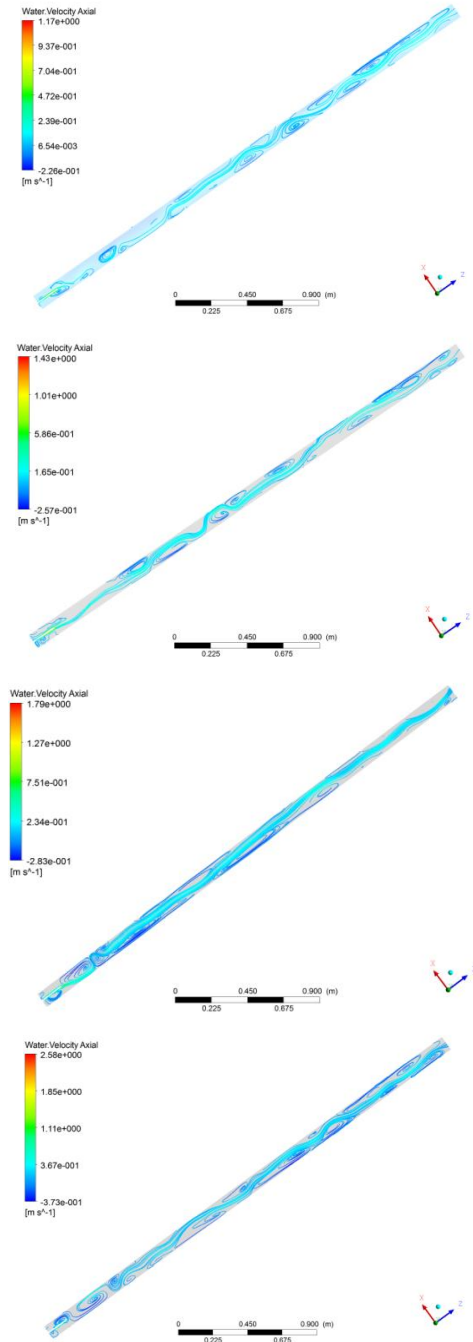


Figure 3. Water flow lines in the middle plane of the column

It can be seen that water returns and moves downwards

at the sides. In other words, air bubbles move from the middle of the column towards the upper end of the column and carry some water upwards with them. After the water bubbles that have moved upwards burst, the water moves downwards and leads to the formation of small vortices at the sides of the column.

The following is an examination of the axial velocity contours of water on a plane close to the outlet in two cases with and without blades for different apparent air velocities. In Figure (4) it can be seen that by placing blades in the column, the axial velocity of water has decreased.

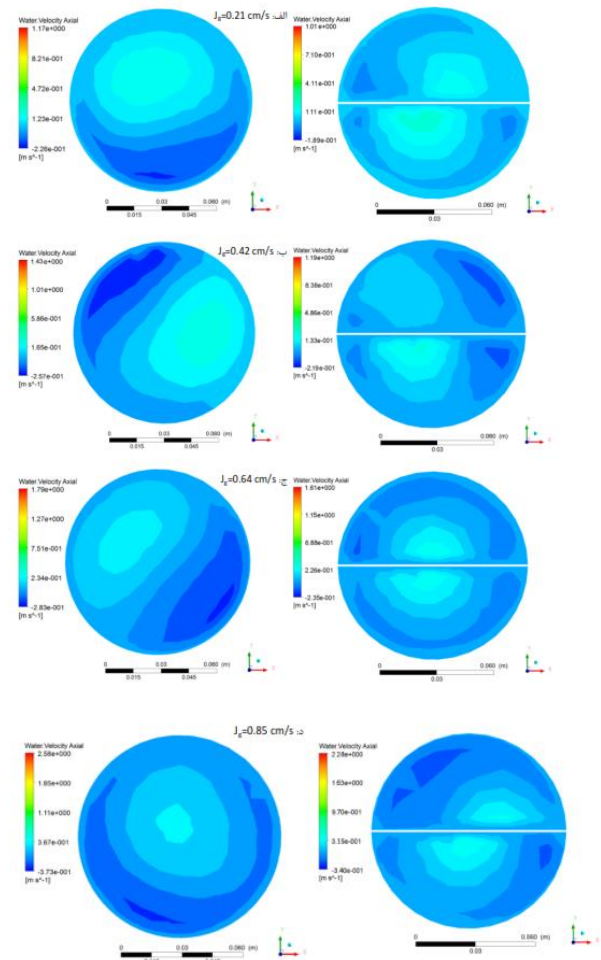


Figure 4. Water axial velocity contours in the plane near the outlet of the flotation cell with and without blades and for different apparent gas velocities

6. Conclusions

The results show that the use of blades inside the flotation column leads to improved performance. In the case of blades inside the column, the axial velocity of the fluid inside the column is reduced, and this reduction leads to increased efficiency and increased copper processing. The greatest reduction in axial velocity is observed when horizontal blades are used, in which case the axial velocity is reduced by about 25 percent compared to the bladeless column. It was also observed that the use of blades inside the flotation column increases the average diameter of the bubbles

inside the column. In this case, the probability of hydrophobic particles colliding with the bubbles increases, and as a result, the performance of the flotation column improves. According to the reported results, the largest increase in the average diameter of the bubbles inside the flotation column is achieved for the vertical blade arrangement inside the flotation column, in which a 94% increase in the bubble diameter inside the column is seen. This value is about 77% for horizontal blades and 78% for mixed horizontal blades. Also, if horizontal and vertical mixed blades are used, the average diameter of the bubbles inside the flotation column increases by 74%. It was also observed that with an increase in the inlet air flow rate and apparent air velocity, axial mixing in the column becomes more intense. The lower the column length to diameter ratio, the greater the axial mixing and the more effective the blade arrangement will be in reducing it. In order to investigate the bubble ascent path in the column, simulations were performed for three bubble sizes with diameters of 1.92, 2.56 and 3.23 mm. Comparison of the bubble path shows that as the bubble size increases, the deviation from the straight vertical path and sinusoidal movements increase. According to the flow lines, when the bubble rises in the water, it experiences lateral force and torque along its path and two counter-rotating vortices are created in the bubble post, which is the main cause of deformation and deviation in the path from the straight line. The results presented showed that increasing the agitator rotation speed from 700 rpm leads to increased separation forces, and as a result, the recovery of copper particles inside the flotation cell decreases. On the other hand, increasing the agitator rotation speed leads to increased instability of the foam phase. The reason for this can be attributed to the production of larger diameter bubbles due to the increase in the agitator rotation speed. Larger bubbles mean more surface energy and, as a result, less copper particle recovery. Also, as the agitator moves closer to the lower part of the flotation cell, the effect of the turbulence caused by the agitator rotation on the phase increases, making the foam phase more unstable and reducing the recovery of copper particles. As the concentration of the foaming agent increases, the size

of the bubbles produced decreases, and as a result, the stability of the foam phase increases, and with increasing the stability of the foam phase, one can expect an increase in the recovery of copper particles. As the percentage of pulp solids increases, the recovery of copper particles also increases.

7. References

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