Large-scale hydraulic optimization of high-efficiency clarifiers in water plants

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Abstract—In order to reveal the hydraulic reasons for the uneven distribution of water flow and velocity in the high-efficiency clarification tank, and the hydraulic reasons for the deposition of sediment on one side, CFD was used to simulate the overall tank. The three-dimensional simulation results showed that without any baffle, the velocity was extremely uneven, and the rotation of the stirring blade around the axis produced a velocity loop, which resulted in a large backflow of the velocity. There were obvious differences in flocs and water flow through the two holes. After adding the existing baffles, the water flow and floc concentration could be much more uniform, but there was still sludge sediment on one side. After further lengthening the existing baffles outside the cylinder and adding 45° baffles in the transition section of the coagulation tank and the sedimentation tank, the inconsistency of flow velocity and floc concentration could be basically solved.

1. Introduction
High-efficiency clarifiers such as Densadeg, Multiflo and Actiglo have been introduced and applied in many water plants in China since 2005 [1-6]. In the operation, the flocs were deposited on the bottom plate on the side of the sedimentation tank in a plant. In addition, the flow throwing the two holes from the coagulation zone to the sedimentation zone were quite different. Engineers took measures to add baffles in the coagulation zone. These measures have achieved certain results, but the improved effects were still not satisfactory.

In order to simulate the effect of further improvement measures and the possibility of evaluating the effect, optimization studies were carried out on the hydraulic inhomogeneity of large-scale high-efficiency clarification tanks to guide subsequent renovation work based on CFD.

2. CFD parameters

2.1. Grids
A tetrahedral mesh was used for meshing. The rotating zone was the area with stirring blades in the coagulation tank. The static zone included the inlet section of the clarification tank and the sedimentation tank. These two zones were connected by the interface.

2.2. Models
The turbulence model was a $k$ - $\varepsilon$ model. The wall function was scalable. The clear water flow field was the initial velocity field and pressure field. The floc deposition was calculated using a two-fluid
multiphase flow model.

2.3. Boundary conditions
The inlet was a velocity boundary of 0.1 m/s. The blade speed was 74 r/min. The inlet particle concentration was given a two-phase volume concentration of 50 mg/L.

The outlet was located in the precipitation zone and was connected to the atmosphere. The average static pressure boundary condition was adopted, and the directional derivative of the two-phase volume fraction along the boundary normal was zero. The free surface was a sliding wall.

2.4. Simulation conditions
The existing baffles were added on the four walls of the stirring blade tank and the transition section from the coagulation zone to the sedimentation zone, Fig.1.

In order to further improve the drift situation, improvements were taken to the existing partitions, such as lengthening the vertical partition outside the agitator barrel, arranging the transition between the coagulation tank and the sedimentation tank at an angle of 45° and increasing the number of partitions in the transition section to three, Fig.2.

The cloud map of the sediment concentration distribution was analysed in the sections parallel to the height of the bottom surface (Y=1m, 2m, 4m, 6m), and the sections perpendicular to the bottom surface the positions of the cross-sections of holes 1 and 2 were respectively Z=2.8m, Z=-2.8m).

3. Results and Discussions

3.1. Existing partitions

3.1.1. Distribution of sediment concentration in horizontal sections
Compared with the no partitions bank, the sediment concentration distribution in the transition section of the coagulation tank and the sedimentation tank was slightly biased to one side, but the concentration distribution was more uniform, Fig.3. The drift and sedimentation could be greatly improved.

3.1.2. Sediment concentration distribution in vertical sections
The concentration distribution of the hole 2 section was larger than that of the hole 1 section, but the concentration difference was much smaller than no partitions, Fig.4. In general, the flow pattern and the distribution of sediment concentration after adding the partition were more improved than no partitions.
3.2. Optimized partitions

3.2.1. Distribution of sediment concentration in horizontal sections
Although the floc concentration distribution in the transition section of the coagulation tank and the sedimentation tank was slightly offset, the concentration distribution was more uniform, which was further improved than the existing partitions, Fig.5.

Fig. 3 The floc concentration of the cross-section from the bottom under the existing partitions

Fig. 4 The floc concentration in vertical section under existing partitions
Fig. 5 The floc concentration of the cross-section from the bottom under the optimized partitions

3.2.2. Sediment concentration distribution in vertical sections
The floc concentration distribution in the section of hole 2 was slightly larger than that of hole 1, but it was better than the existing separator, Fig. 6.
Fig. 6 The floc concentration distribution in vertical section under optimized partitions

4. Conclusion
In this paper, CFD was adopted to study hydraulic numerical simulation of the clarifier to reveal the uneven flow through the two holes. The main conclusions could be summarized as follows:

1. It was shown that without any baffle, the speed distribution on the section was extremely uneven, and the speed loop of the agitator rotating around the axis was not eliminated. Thus the speed on the section had a large backflow, which finally made obvious differences in flocs and water volume through two holes.

2. After adding the existing baffle, the flow and floc concentration distribution were more improved, but there was still sludge on one side.

3. The optimization plan could be that the outer partition of the cylinder was further extended to the bottom of the agitator. The partitions in the transition section of the coagulation tank and the sedimentation tank were arranged at an angle of 45°, and the partitions in the transition section was increased to three.

4. Under the optimized model, the uneven flow velocity distribution and the distribution of sediment concentration would be better improved, and the sediment offset would be effectively suppressed.

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