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Study on Installation Position of Sewage Treatment Mixer

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ABSTRACT

According to the problem that how to choose the installation position for sewage treatment mixer was uncertain, the flow field in the sewage treatment pool was simulated by the software FLUENT 6.3, using unstructured tetrahedral grid, moving coordinate system technology, $k \sim \varepsilon$ turbulence model and the SIMPLE algorithm. The distribution of velocity gradient in the whole pool was analyzed, and the flow field was compared at the different installation angles of sewage treatment mixer. The results show that the fluid flows along the axial direction of sewage treatment mixer, and diffuses along the radial direction. The stirring circulation is evident when the installation deviates from the narrow side, and the flow velocity of the whole pool is relatively uniform and greater than 0.3m/s. It is consistent with their work requirements, which not only improves the efficiency, but also saves costs.

Key words: sewage treatment mixer; simulation; estimated performance; installation angle

INTRODUCTION

With the increasing awareness of environmental protection, the treatment and drainage of wastewater have been paid more and more attention by the government. The sewage treatment is an important measure of the environmental protection department and enterprise's ability to solve the water pollution problem now. The mixing machinery is indispensable during sewage treatment. The sewage treatment mixer is a new kind of efficient diving mix device, which is applicable for the treatment of aeration tank and anaerobic tank in industry, cities and village sewage treatment plants. The sewage treatment mixer is composed of submerged motor, sealing devices, impeller, electric apparatus, etc. The impeller is driven by the submerged motor. The liquid will be revolved and moved by the impeller, and revolving jet will be engendered. The shear stress along with the jet makes the liquid outside mix by friction producing volume flow when the liquid was extremely mixed. In this way, mix and plug flow spread gradually. The sewage treatment mixer generates inducing speed when it is driven by engine power. Generally, the sewage treatment mixer is installed on the sidewall of pool in water. The sewage treatment mixer makes the mixture in pool keep flowing in order to prevent the deposition of active sludge on the bottom. Furthermore, the suspended solid will be distributed evenly when the waste water, backflow and recycling stream mix together. And the micro creature and waste water will get the fully touch. So we can get the effect of the mixing and propelling. The flow velocity should be more than 0.3m/s to insure sufficient reaction of wastewater in pool.

The application of sewage treatment mixer extends the

design technique range of sewage treatment and provides the developing foundation of new crafts and technology. In recent years, many Chinese sewage treatment companies, such as Gaopaidian sewage treatment company in Beijing, Jiangxinzhou sewage treatment company in Nanjing, Weihai sewage project and so on, have been using sewage treatment mixers widely and getting good results. As the application effects of sewage treatment mixer are related to the model of mixer and the pool shape, the fluent field in the pool is complicated, and the installation position of the mixer greatly affects the fluid field. At the present time, the traditional installation method of sewage treatment mixer is vertical to the wall of pool. In this paper, the distribution of fluid field was studied when the sewage treatment mixer is installed at different angles, and the best installation angle of sewage treatment mixer was found [1][2].

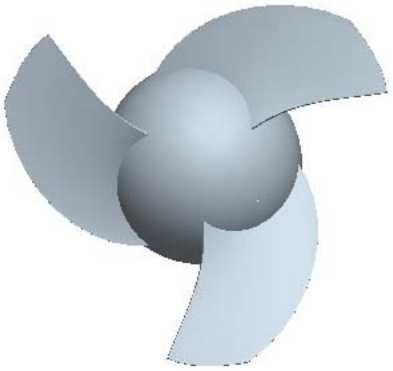
NOMENCLATURE

a	installation angle
k	turbulent kinetic energy
ε	turbulent dissipation rate
n	rotation speed
D	blade diameter
d_h	hub diameter
ρf_i	body force
ρ	density
Z	blades number
$u_j \frac{\partial u_i}{\partial x_j}$	convective term
$\mu \frac{\partial^2 u_i}{\partial x_j^2}$	diffusive term

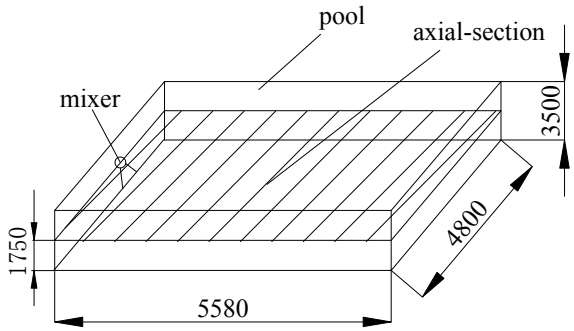
MODEL

In this paper, the sewage treatment mixer with 3 aerofoil blades (Z=3) was produced by a factory in Jiangsu province. Following the axis of the motor, the blades revolve clockwise, and the rotation speed is n=480r/min. As shown in figure 1 (a), the diameter of blade is D=600mm, and diameter of hub is d_h=280mm. As shown in figure 1 (b), the sewage treatment pool is a cube structure of 5 580mm×4 800mm×3 500mm. And as shown in figure 2 and figure 3, the sewage treatment mixer is installed at a sidewall of pool 1 750mm from the bottom and 1 900mm from the narrow side, with α=0˚(normal to pool wall，figure a)，α =15˚(near the narrow side, as shown in figure b), and α=-15˚(deviate from the narrow side, figure c) between axis of the sewage treatment mixer and the pool center line.

The sewage treatment mixer and the sewage treatment pool can be modeled by software PEO/E. Using the software PRO/E, we can get the three-dimensional modeling of the blade by the method of surface fairing and curved surface scanning, and the models of the pool and the mixer will be gotten by the function of rotation and stretching[9]. The models are as shown in Figure 1.



a) The impeller of the sewage treatment mixer



b) The pool

Fig.1 The sewage treatment mixer and the pool

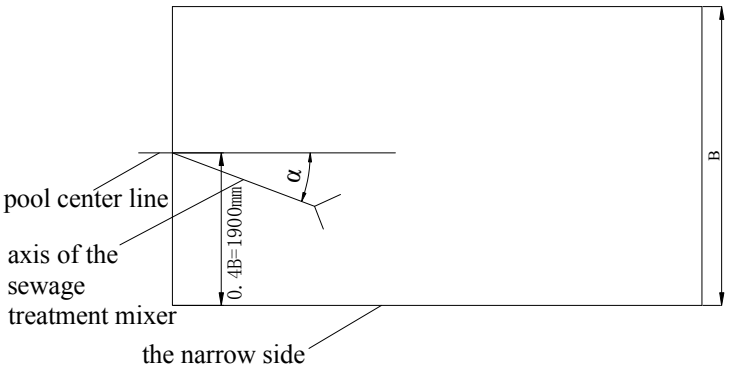


Fig.2 Installation angle of sewage treatment mixer

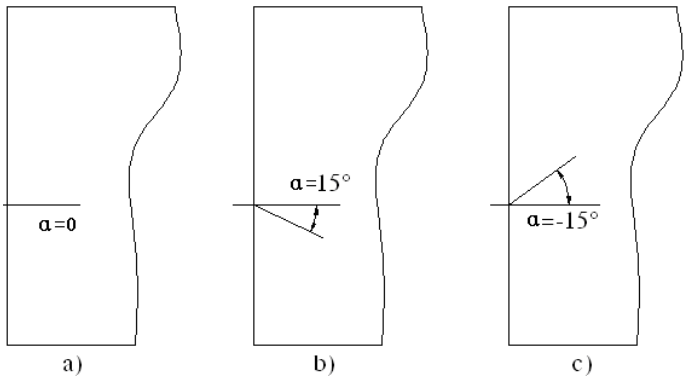


Fig.3 Three kinds of installation angles of sewage treatment mixer

BASIC EQUATIONS AND BOUNDARY CONDITIONS

In the last few years, computational fluid dynamics (CFD) has developed rapidly and was widely applicated. FLUENT, CFX, FLOW3D, FIDAP and ANSYS are applied to the performance prediction and optimization design of hydraulic machinery, such as pumps, water turbines and mixing machinery. Practice has proved that the simulation results can guide production. In this paper, software FLUENT 6.3 was used to simulate the mixing flow of the sewage treatment pool.

BASIC EQUATIONS

Governing equations contain continuity equation, momentum conservation equation, and RNG $k-\varepsilon$ equation. For incompressible fluid, the expression is shown as follows.

$$\frac{\partial \mathrm{u}_j}{\partial x_j}=0 \tag{1}$$

$$\rho\frac{\partial u_i}{\partial t}+u_j\rho\frac{\partial u_i}{\partial x_j}=-\frac{\partial p}{\partial x_i}+\mu\frac{\partial^2 u_i}{\partial x_j^2}+\rho f_i \tag{2}$$

$$\frac{\partial(\rho k)}{\partial t}+\frac{\partial(\rho k u_i)}{\partial x_i}=\frac{\partial}{\partial x_i}[\alpha_k\mu\frac{\partial k}{\partial x_j}]+G_k+\rho\varepsilon \tag{3}$$

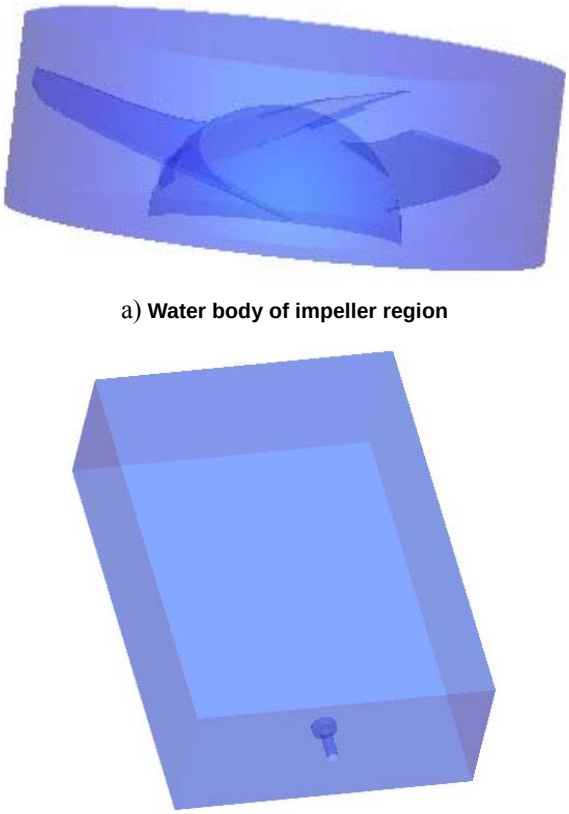
$$\frac{\partial(\rho\varepsilon)}{\partial t}+\frac{\partial(\rho\varepsilon u_i)}{\partial x_i}=\frac{\partial}{\partial x_i}[\alpha_\varepsilon\mu\frac{\partial\varepsilon}{\partial x_j}]+\frac{C_{1\varepsilon}}{\mathrm{k}}G_k-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \tag{4}$$

Where, i,j=1,2,3; $u_j\frac{\partial u_i}{\partial x_j}$ is convective term； $\mu\frac{\partial^2 u_i}{\partial x_j^2}$ is diffusive term； ρf_i is body force； $C_{1\varepsilon}=1.42$； $C_{2\varepsilon}$=1.68； k is turbulent kinetic energy； ε is turbulent dissipation rate[3] [4].

There are mainly four methods of CFD analysis to mixing machinery: Impeller Boundary Condition (IBC), Inner-Outer Method (IO), Multi-Reference Frame (MRF) and Sliding Grid (SG) [5] [6] [7] [8]. In this paper, MRF is used because there is no baffle in the pool. The fluid in the moving region is set to be the same rotate speed as mixing blades, and the fluid in the stationary region is still. The flow field, which gets by the method of MRF, rotates by the angular velocity, so the actual flow field will be gotten.

SIMULATION AREA AND GRIDS

When the sewage treatment mixer works in the pool, the impeller is driven by the motor to circle and mix the liquid, and the whole liquid in the pool would move around. As shown in Figure 4, the calculation region is the pool and the sewage treatment mixer. Figure 4 shows water body of impeller region, which is the moving region. T-Grid is chosen to mesh the model in Gambit. Local refinement is used near the impeller[9]-[12], as shown in figure 5. The node number is about 1,300,000.



a) **Water body of impeller region**

b) **Water body assembly drawing of sewage treatment pool and sewage treatment mixer**

Fig.4 Calculation region

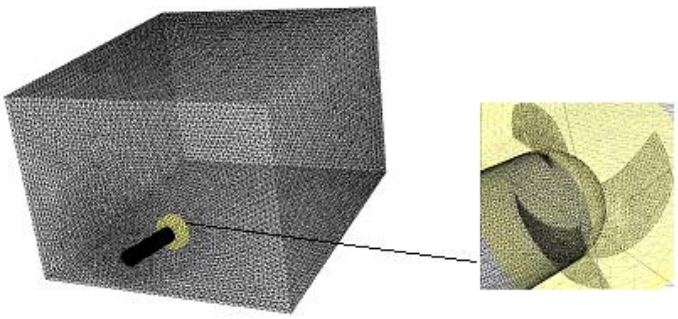


Fig.5 Calculation grid

BOUNDARY CONDITION

The surface of the pool is pressure outlet. All the pool walls, the mixer shaft and the mixer blades surfaces are No-slip boundary. Rotation speed of blades is set to be the same as the motor shaft.

Using MRF method and assuming rotation speed to be constant, based on N-S equation, standard RNG κ - ε equation, SIMPLER algorithm and second order upwind scheme were used to calculate stress coupled equations in FLUENT 6.3. Each item's residual magnitude is 10^{-4} [13] -[19].

SIMULATION RESULTS

In order to get macroscopic rule and general moving

trend of fluid in the sewage treatment pool, we can watch the streamline diagram and velocity vectors of fluid in the sewage treatment pool, which are the most intuitive form.

Figure 6 shows velocity distribution of the blade working pressure face of the sewage treatment mixer. As shown in Figure 6, velocity gradient of the blade working face is quite obvious. From blade hub to flange, velocity increases gradually and velocity gradient changes little.

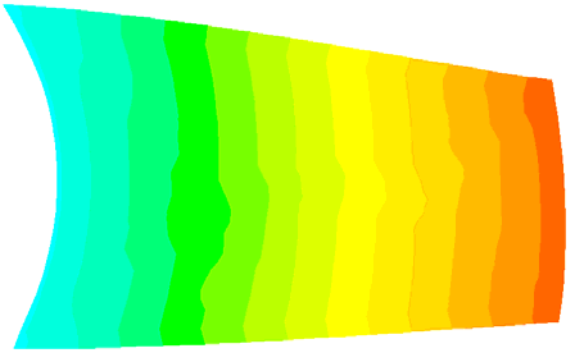


Fig.6 Velocity distribution of blade working face

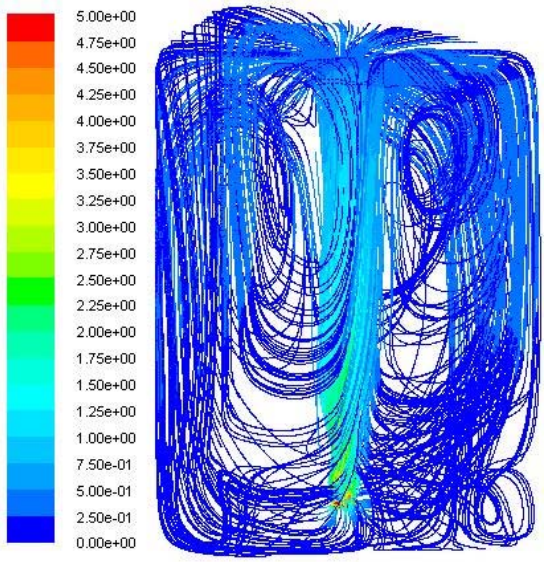
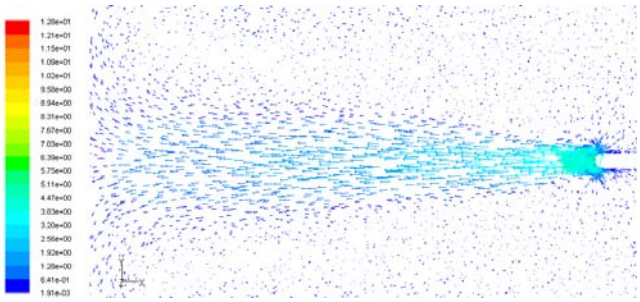


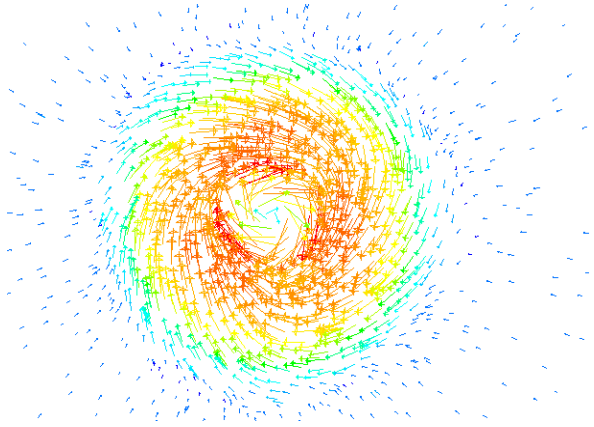
Fig.7 Streamline diagram

As shown in figure 7, it is typical of axial flow mixing pattern. Fluid in circulation channels is unobstructed, and main circulation is well. Velocity of fluid in circulation area is improved.

Figure 8 shows fluid velocity vectors of sewage treatment pool. Vector arrow lines represent velocity direction and value of the fluid particle at this position. Figure 8 (a) and figure 8 (b) show velocity field at axial-section and cross-section. The length of the vector line is proportional to the value of the velocity. Figure 9 shows fluid velocity distribution of axial section in the pool. As shown in figure 8 and figure 9, the field spatial structure information of the sewage treatment pool are obviously. The fluid flows along the axial direction of sewage treatment mixer, and diffuses along the radial. Due to the affect of the boundary wall, backflow and reflecting occur, then some vortex appears. In the process of the fluid flow, the axial velocity decreases gradually, and most fluid gets into circulation again. Only small part of fluid get great influence of the centrifugal force, flow to peripher, and reflect and become backflow when run into the pool wall. These show that the blade of the sewage treatment mixer is the axial blade, and the axial flow is obvious.



a) Velocity vectors of axial-section



b) Velocity vectors of cross-section

Fig.8 Velocity vectors of sewage treatment pool

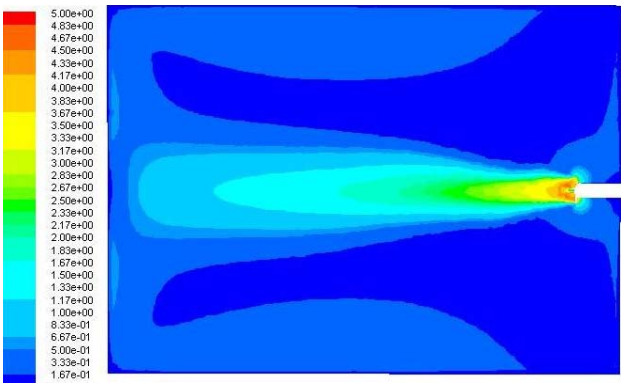


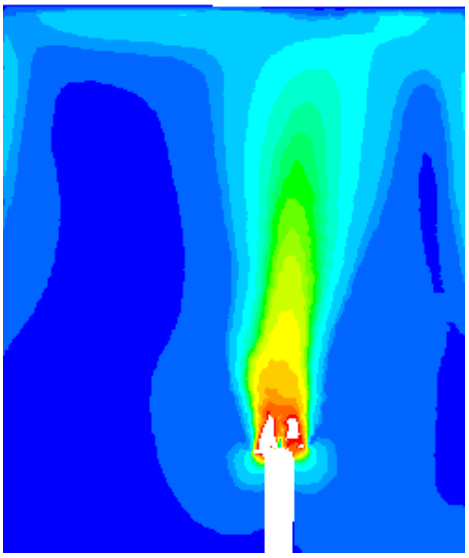
Fig.9 Velocity distribution of axial-section

The distribution of velocity at the depth of 1 750mm is shown in Figure 10 (a), (b), (c), when the sewage treatment mixer works in the three different ways. As shown in figure 10 (a), sewage treatment mixer was installed vertically in the pool wall in the traditional way. From the velocity distribution, we can find the flow velocity of the right portion of pool were larger than 0.3m/s. And the flow velocity of the left portion of pool were lower than 0.3m/s. As shown in figure 10 (b), sewage treatment mixer was installed near the narrow side with the angle of 15˚. From

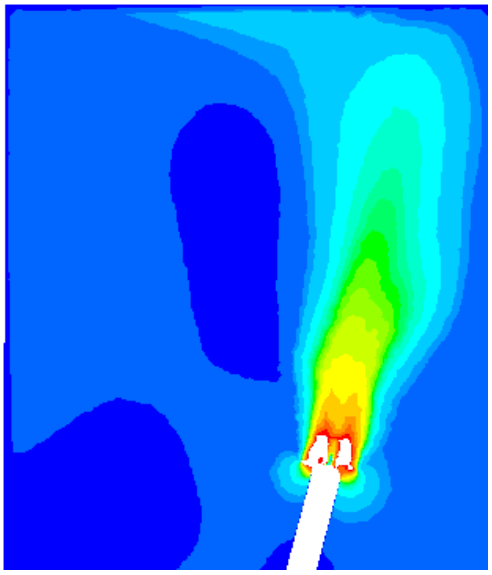
the velocity distribution, the flow velocity of the right portion of pool was larger than the velocity of the left portion of pool. If the ideal flow velocity in pool is needed, the motor speed or impeller diameter should be increased. It will increase cost with lower efficiency. As shown in figure 10 (c), sewage treatment mixer was installed by deviating from the narrow side with the angle of -15˚. The fluid velocity in the pool are uniform and larger than 0.3m/s. Mixing requirement of flow in the pool is satisfied. In the three installations way, the axial power is 5.5KW, 5.3KW, and 5.6KW respectively. There is little difference.

Tab.1 Axial power

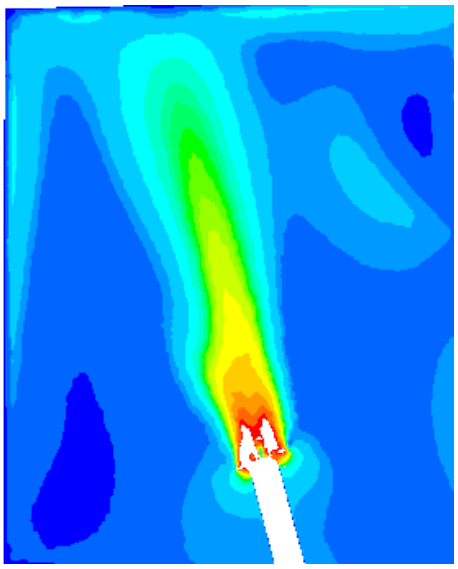
	Installation position(a)	Installation position(b)	Installation position(c)
axial power	5.5kW	5.3kW	5.6kW



a)



b)



c)

Fig.10 Velocity distribution of axial-section

RESULTS

According to the working condition of Sewage treatment mixer, the fluid in Sewage treatment pool was simulated by using FLUENT6.3.The results show:

1） The fluid in sewage treatment pool can be propelled by sewage treatment mixer, and the fluid flows along the axial direction of sewage treatment mixer and diffuses along the radial.

2） Regardless of which kind of installation angle is used, there is little effect on the shaft power of sewage treatment mixer.

3） When the sewage treatment mixer is installed by deviating from the narrow side with the angle of 15˚, the service area of sewage treatment mixer was maximum, and mixing requirement of flow in the pool is satisfied. This installation method can be used widely in projects in order to improve the efficiency, save energy and achieve better influence.

ACKNOWLEDGEMENTS

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