Analysis and Comparative Study on the Pushing Effect of Screw Rod with Different Structural Parameters

Keli Zhao, Aiwei Yu, Yuqi Liu, Qingxi Zhao* and Zunhai Man
School of Mechanical and Aerospace Engineering, Jilin University, China
Email: 1445774208@qq.com

Abstract. The computational fluid dynamics software fluent is used to calculate and study the hydrodynamic performance of the rotating screw in the water flow field. First, UG is used to establish different parameter calculation models, and then the slip grid method in the fluent is used to calculate the flow field state, thrust and torque of the simulated screw rod under different blade angles and number of blade turns, calculate through the above data obtain the screw rod's pushing efficiency, and obtain the best structural parameters of the screw rod when the best pushing effect is achieved through the comparison of experimental data.

1. Introduction
The annual growth rate of sewage discharge in my country has reached 6%. The problem of sewage treatment has attracted people's attention. As a typical sewage treatment equipment, the main working principle of the underwater aerator is to dissolve oxygen into the sewage, increase the oxygen content in the water, and ensure the growth and reproduction of aerobic microorganisms promote the oxidation and decomposition of harmful substances in sewage. It is necessary to improve the dissolved oxygen efficiency of the aerator. Screw rod is an important structure of aerator. Therefore, it is necessary to determine the best structural parameters of the screw rod.

2. Analysis of Underwater Pushing Action of Screw Rod
The screw rod studied in this paper is used for underwater pushing. Its structure is mainly composed of two parts: a hollow shaft and a spiral blade, the diameter of spiral blade is 240mm.

When the screw rod rotates, the water moves in both a straight axis and a spiral around the axis under the push of the screw rod [1]. Assuming that water unit is regarded as the micro-element body A, the force exerted by the spiral blade of the water-element body is shown in figure 1.

Figure 1. Force diagram of water micro-body.
\( r \) is the radius of action of the \( A \) micro-element body on the rotating helix surface; \( F \) is the resultant force of the spiral thrust received by the \( A \) micro-element body, the force is decomposed into tangential component \( F_t \) and normal component \( F_n \); \( \alpha \) is the angle between the normal direction of the helix surface and the helix axis; \( \beta \) is the angle between the normal direction of the helix surface and the resultant force of the micro-element body; \( n \) is the rotating speed of the screw rod, the speed status is shown in figure 2.

![Figure 2. Velocity decomposition diagram of water micro-body.](image)

Through the analysis can obtain the axial sub-velocities \( V_a \) and radial sub-velocities \( V_r \) of the water micro-element body \( A \) as follows:

\[
V_r = \frac{2\pi n}{60} \cdot \sin a (\sin a + \mu \cos a) 
\]

\[
V_a = \frac{\pi n}{60} \cdot \frac{1 - \mu s}{s + 1} 
\]

In the formula, \( S \) is the pitch of screw rod, \( \mu \) is the friction coefficient.

According to the above formula, we can know when the screw rod is in the process of water disturbance operation, there are many factors influencing the effect of pushing, the rotating speed of the screw rod, the blade angles, material and surface accuracy of screw rod all affect the effect of pushing.

3. Evaluation of Screw Rod Pushing Efficiency

For the design of screw rod, the rated power should be as small as possible under the conditions of use, the area of agitation can be as large as possible, in order to obtain a better effect of pushing, this paper draws on the pushing efficiency of the propeller as the evaluation standard, for evaluating the pushing effect of the screw [2].

When the screw rod is rotating in the liquid, the relationship between the screw speed \( n \) and the velocity of the screw rod water inlet can be expressed as speed coefficient \( J \).

\[
J = \frac{V_A}{nD} 
\]

In the formula, \( D \) is the diameter of spiral blade, \( V_A \) is the inlet velocity.

The expression of thrust coefficient \( K_T \) and torque coefficient \( K_Q \) is:

\[
K_T = \frac{T}{\rho n^2 D^4} 
\]

\[
K_Q = \frac{Q}{\rho n^2 D^4} 
\]

In the formula, \( T \) is the thrust generated by the screw, \( \rho \) is the liquid density, \( Q \) is the torque generated by the screw rod.
The expression of the pushing efficiency $\eta$ is:

$$\eta = \frac{J}{2\pi} \frac{k_T}{k_Q}$$

(6)

4. Analysis of Influence of Screw Blade Structure Parameters on the Performance of Pushing

4.1. Flow Field Simulation Settings

According to the characteristics of spiral blade structure, the cylindrical flow field is used to simulate the pushing of the screw rod, establish two research areas: static area (working water area) and dynamic area (screw rod action area), set the range of the dynamic field to (length×diameter) 500mm×240mm, the static range is (length×height) 6000mm×2000mm, the dynamic domain is in the static domain. The static and static field division of the calculated flow field is shown in figure 3.

Figure 3. Flow field simulation setup diagram.

The liquid flow rate at the inlet was set as 0.82m/s in the analysis model, the Reynolds number is $Re=10e+5$, and the speed coefficient is 0.3.

4.2. Analysis of Screw Blade Angle

Screw blade angle $\beta$ is defined as the angle between the screw generatrix and the axis [3]. Set up five sets of experimental comparison models, the blade angle $\beta$ is set to 120°, 105°, 90°, 75°, 60°.

Through the simulation test, the screw blade surface pressure cloud diagram with a 90° blade angle is shown in figure 4. It can be seen that the pressure on the spiral blade surface is different when the blade angle is different, with the decrease of the blade angle, the blade surface pressure gradually increases. This indicates that the thrust of the blades on the water gradually increases, and the increase in thrust will help the pushing of the spiral blades.

Figure 4. The pressure cloud diagram of the screw rod with a 90° blade angle.

The thrust and torque coefficients of the screw rod at different blade angles are shown in figure 5, with the gradual decrease of the blade angle, the thrust coefficient and torque coefficient of the screw rod increase gradually, the efficiency of the screw rod shows a trend of first increasing and then decreasing, when the blade angle is 90°, the thrust coefficient increases from 0.2498 to 0.3742, with the largest increase, the pushing efficiency of screw rod reaches the maximum.
Figure 5. Thrust and torque coefficients of screw rod with different blade angles.

The pushing efficiency of the screw rod at different blade angles is shown in figure 6. It can be seen that when the blade angle is 90°, the pushing efficiency of the screw rod reaches the maximum.

Figure 6. The pushing efficiency of screw rod at different blade angles.

The velocity of the screw rod flow field, the velocity vector of the flow field and the efficiency of the pushing were taken as the evaluation criteria, analyze the effect of blade angle on screw pushing efficiency. It is comprehensively concluded that when the blade angle of the screw rod is 90°, the pushing effect of the screw rod reaches the best.

4.3. Pushing Experiment with Different Spiral Blade Turns

When the pitch of the spiral blade is determined, the number of spiral blade turns represents the length of the spiral blade, the ratio of the length of the spiral blade to the pitch of the blade is the number of turns of the spiral blade.

The lengths of the spiral blades are selected as 132mm, 176mm, 220mm, 264mm, 308mm, and the corresponding spiral turns are 0.6, 0.8, 1.0, 1.2, 1.4.

Through the simulation experiment, the screw rod pushing field velocity at different blade turns is obtained, when the number of turns is 0.6 and 0.8, the flow velocity in the water 4m away from the screw rod is within the range of 0.22m/s-0.25m/s. When the number of turns is 1.0 and 1.2, the flow velocity in the water 4m away from the screw rod is within the range of 0.25m/s-0.33m/s. When the
number of turns is 1.4, the flow velocity in the water 4m away from the screw is within the range of 0.33m/s-0.35m/s. It can be seen that with the increase of the number of spiral blade turns, the range of pushing is also increasing gradually.

The thrust and torque coefficients of the spiral rod at different turns are shown in figure7 [4], with the increase of the number of turns, the thrust coefficient and torque coefficient of the screw rod increase, in the case of the same increase in the number of turns, the thrust coefficient increases gradually as the number of turns tends to be stable, basically stable at about 10%, when the number of blade turns is 1.4, the increase in torque coefficient becomes larger, to about 12%, this results in a decrease in screw rod efficiency at a blade number of 1.4. The change of screw rod efficiency with the number of turns is shown in figure 8.

![Figure 7](image1.png)

**Figure 7.** The thrust coefficient and torque coefficient of screw rod at different turns.

![Figure 8](image2.png)

**Figure 8.** Screw rod efficiency at different turns.

When the number of screw rod turns increases, the pushing efficiency first increases and then decreases. When the number of turns is 1.2, the efficiency of the screw rod reaches the maximum [5]. Comprehensive comparative analysis based on the above results, in consideration of the vibration and other factors during installation and operation, the number of turns of the screw blade is finally selected as 1.2.

5. Conclusion
The different parameters of the screw rod are compared and analyzed by means of comparative simulation test. By comparing and analyzing the performance of the screw rod with different blade angles, it is concluded that when the blade and the axis are at an angle of 90°, the pushing effect is the
best. Through the comparative analysis of the performance of the screw rod with different pitch and number of turns, it is concluded that when the pitch of the spiral blade is 220mm and the number of turns is 1.2, the efficiency of the screw rod can reach the best and the flow pushing effect is the best.

References
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