Based on The Gate Bottom Edge Structures Specific Numerical Simulation of Flow Pattern of Gate

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Abstract. The bottom edge structure is a key factor affecting the flow pattern under the gate. The reasonable selection of bottom edge configuration plays an important role in the safe and stable operation of the gate.

RNG $k - \varepsilon$ model is used to simulate the gate water area. Through numerical simulation, the pressure cloud map and pressure data of monitoring points of water area under the gate are fully simulated. Influence of bottom edge structure on flow pattern. The results show that only the flat bottom gate always has negative pressure zone directly below the bottom edge, and the other three structures have no obvious negative pressure zone and move around the downward inclination Angle with time. According to the analysis of the characteristics of upper support and suction, it can be concluded that the upper support force increases with the increase of the front rake angle, and the upper support force of the flat-bottom gate is negative, showing the characteristics of suction.

1 Introduction

Plane steel gate is widely used in water conservancy projects. Its structure is simple and stable, and it has the functions of controlling water level difference, discharge of water flow and discharge of sediment and floating objects, so it has an indispensable reuse in water conservancy projects. With the development of computer numerical simulation technology, the research work of using computer numerical simulation technology to design the gate has become the mainstream^[1]. As an important part of the design of planar steel gate, the design and selection of bottom edge configuration is particularly important. Reasonable selection of the bottom edge configuration will help the water flow of the gate to be relatively stable, which is helpful to the safe and stable operation of the gate. At the same time, if the selection and design of the bottom edge configuration are not reasonable, the flow pattern will be seriously affected. Resulting in negative pressure and cavitation erosion and other phenomena under the gate, causing the gate vibration and difficult lifting. Further aggravation may destroy the gate and gate groove structure, and seriously threaten the safe operation of water conservancy projects. The corresponding design specifications also put forward specific requirements for the bottom edge design of the gate: under the condition of meeting the actual working conditions, the rear Angle should not be less than 30 degrees, and the front Angle should not be less than 45 degrees^[2]. In practical applications, base-edge configurations can be divided into two categories, including four types, according to the specificity of





Fig. 1. bottom edge structure dimensions

The bottom edge of the four types of configurations have been used in actual hydraulic engineering, among which (a) is flat bottom edge configuration, (b) is sloped back 45 degrees, (c) is sloped forward 60 degrees, (d) is sloped forward 60 degrees, and sloped back 45 degrees. The flat-bottomed steel gate is the simplest structure, but in engineering application, the flow pattern of the flatbottomed steel gate is poor, and it is not suitable for the condition of fast flow rate and high head^[3].

Scholars at home and abroad have done a lot of research on the configuration of the gate bottom edge and the corresponding numerical simulation methods. Most of the previous studies are limited to the flat-bottom steel gate or the single-bottom-edge planar gate, and few analyses are made on the upper support and lower suction action of water on the gate^[4]. This paper uses numerical simulation method. According to the specific configuration of the bottom edge of the sluice, the water pressure neogram under the sluice and the pressure data of the monitoring surface are simulated completely, and the influence of the bottom edge configuration on the flow

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pattern is analyzed, which provides reference for the safe operation of the flat steel sluice gate in water conservancy projects.

2 Calculation model

 $k-\varepsilon$ model is a two-equation model often used in turbulence calculation, including the standard $k-\varepsilon$ model and the RNG $k-\varepsilon$ model. Compared with the standard $k-\varepsilon$ model, the RNG $k-\varepsilon$ model is more accurate and reliable when dealing with complex flow problems. In this paper, turbulence simulation of planar steel gate under different bottom edge configurations and openings is carried out. In this paper, RNG $k-\varepsilon$ model is adopted and the finite volume method is used for discretization.

In addition, the coupling of velocity and pressure is based on SIMPLEC algorithm. Compared with SIMPLE algorithm, SIMPLEC algorithm has faster convergence speed and better calculation results while having wide engineering adaptability.

3 Calculation results and analysis

3.1 Model selection

According to the specific requirements of " Code for Design of Flat Steel Gate for Water Resources and Hydropower Engineering" and based on a certain type of gate, four groups of gate models are set up according to the difference of bottom Angle. The first group is flatbottom gate without bottom Angle. The second group is a forward-leaning upstream inclination of 45 degrees. The third group is the backward dip type with a dip Angle of 60 degrees. The last group is a double-dip type, with an upstream dip Angle of 45 degrees and a downstream dip Angle of 60 degrees, as shown in Fig. 1. In addition, water flow characteristics were analyzed under different opening conditions, bottom edge structure dip Angle and different velocity conditions respectively.

The fluid inlet is set as a velocity type inlet with a flow rate of 10m/s, and the downstream end boundary condition of the fluid is set as a pressure-type outlet. The fluid wall condition is set as smooth and no slip; The length of the total fluid calculation domain is 4.20m, and the section size is 0.40m×0.70m. See Figure 2 below



Fig. 2. Geometric Dimensions

3.2 Calculation Results

In this analysis, the total time is set at 20s, a total of 500 steps, and the length of each step is 0.04s. As shown in Fig. 3, the cloud map of pressure distribution in the downstream field of the four groups of gates at the condition of E = 0.25 opening at t=20s.Through the analysis of the pressure distribution cloud map, it can be drawn that, due to the effect of the gate, the upstream water pressure in the flow field of the four groups of gates is always far greater than the downstream water pressure, and the water pressure drops rapidly near the bottom edge of the gate.

In the case of different opening degrees, there is an obvious negative pressure area directly below the bottom edge of the flat bottom gate. In contrast, due to the existence of the bottom edge Angle of the other three groups of gates, there is no obvious negative pressure area directly below the bottom edge. There are backdip gates in both groups. As shown in Fig. 3, the bottom edge negative pressure area of Group 2 and Group 4 is near the bottom edge backdip Angle. Therefore, when considering the flow state of the gate, we should try to choose the gate with inclination Angle, and avoid using the flat-bottomed gate at high flow rate and low opening for a long time. With double Angle gate, the pressure difference between front and rear gate is smaller and the flow pattern is better.



Fig. 3. Pressure distribution of flow field

With the increase of the opening of the gate, the negative pressure of the flat-bottom gate decreases. As shown in Fig. 4, when the gate opening is increased from E = 0.25 to E = 0.5 and E = 0.75, the size and strength of the negative pressure area directly below the bottom edge of the flat-bottom gate are improved through comparison, and the negative pressure of the water body under the gate is alleviated to a certain extent. Therefore, during the operation of the flat-bottom gate, the situation of low opening for a long time should be avoided as far as possible. From Table 1, it can be seen that with the increase of the opening of the gate, the average pressure at the bottom edge of the gate shows an upward trend.



Fig. 4. Pressure distribution of flow field at different opening

The inlet speed was increased to simulate the condition of fast flow. As shown in Fig. 5, the water pressure in front of the gate increased significantly under the condition of high flow rate on the left, and the size and strength of the negative pressure area under the bottom edge of the gate increased significantly. The negative pressure of the water under the gate was even more serious. It can be seen from Table 1 that the pressure at the bottom edge of the gate decreases sharply with the increase of the flow velocity. According to the analysis, the flat-bottomed steel gate is not suitable for high flow rate, and the possibility of negative pressure and cavitation corrosion is greatly increased under high flow rate.



Fig. 5. Pressure distribution of flow field at different heads

Under the same working conditions, the average pressure at the bottom edge of the planar gate with different bottom edge structures is different to some degree, and the supporting characteristics of water on the gate are also changed accordingly. The correlation is shown in the upper supporting force formula (1): where P is the average pressure at the bottom edge of the gate; γ is the bulk density of water; H is the upstream acting head of the gate. The average pressure at the bottom edge is calculated by numerical simulation. The average pressure at the bottom edge is basically positive pressure. The average pressure of the flat gate is negative and increases with increasing opening.

$$\beta_{\rm t} = P_t / (\gamma H) \tag{1}$$

The variation trend of the average pressure at the bottom edge is explored under the same working conditions in the main use range of the headangle Angle. The Angle of front Angle of the bottom edge changes from 30° to 60° successively. As can be seen from the broken line diagram in Fig. 6, the average pressure at the base

edge changes from negative to positive and shows a trend of gradual increase with the increase of the bow Angle.



Fig. 6. Line diagram of the pressure of the bottom edge changes with the increase of the rake Angle

According to the calculation formula of the upper support force coefficient, the upper support force coefficient of the plane gate with a certain bottom edge dip Angle is positive, showing the characteristics of the upper support. To a large extent, the rake Angle has a positive effect on the bearing characteristics. Within a certain opening degree, the upward force coefficient of the flatbottomed gate is negative, showing the characteristics of downward suction, which affects the normal operation of the gate and easily induces vibration and difficulty in climbing.

4 Conclusion:

In this paper, numerical simulation is used to analyze the water area of the gate. Through the analysis of the gate with different bottom edge structure and working conditions, the influence of bottom edge configuration and different working conditions on the flow pattern and the operation of the gate is obtained.

(1) Through the numerical simulation method, it is easy to produce negative pressure area just below the bottom edge of flat flat gate, and the negative pressure phenomenon is more serious under the condition of low opening and high flow rate. In the selection process of gate, the type of gate without inclination should be avoided as far as possible.

(2) Compared with the other three groups of gate, the gate with double dip Angle has a better drainage effect on the water flow under the gate, the pressure difference between the front and back of the gate is smaller, and the water flow pattern is relatively better.

(3) The average pressure at the bottom edge of each group of gates was calculated. According to the calculation formula of upper support coefficient, the flatbottom gate showed the characteristics of downward suction, which was easy to induce the gate climbing difficulty and cavitation, while the other three groups of sluice gates with inclination showed the characteristics of upward support, which was conducive to the operation of the gate. In the usual range of 30° to 60° , with the increase of the Angle of bow Angle, the pressure at the bottom edge becomes larger, and the upprop characteristic becomes more obvious, which is conducive to the gate climbing.

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