Flow Patterns and Rectification Measures in the Forebay of Pumping Station

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Abstract. Due to land limitation, the forebay in the pumping station is generally not long enough, some disadvantageous flow patterns are easy to appear in the forebay, which is not beneficial to the safety and economic operation of the pump. In this paper, the flow pattern in the forebay of pumping station is taken as the research object, and we focus on the physical model test method, the analysis method of the flow pattern and the rectification measures such as beam, breast wall and column. At the same time, the research results show that the above-mentioned rectification measures are helpful to improve the pumping station inlet conditions and operation reliability.

1. Introduction

The forebay is an important part of the pumping station. Its function is to make the stream spread evenly and smoothly when the stream flows from the approach channel to the inlet conduit, thus providing a better flow pattern for the pumping station[1]. In order to improve the unfavorable flow patterns, such as flow deviation, reverse current and vortex caused by the bend flow in the forebay of pumping station, certain measures should be used to meet the requirements of engineering operation.

At present the domestic and foreign scholars have done a lot of research on the hydraulic characteristics of forebay[2-4]. Based on the Fluent software, Jiang wen et al. simulated the flow field of side-inlet pumping station with the Navier-Stockes equations and the SIMPLEC algorithm method, the complex flow pattern in the forebay of the lateral intake pump station is revealed[5]. Feng jiangang et al. carried out numerical simulation of the flow patterns based on RNG k-ε turbulence model in the forebay of the pumping station, the computed results are consistent with those from physical experiments[6]. Zhang xue et al. analyzed the inlet condition of forebay, aiming at proposing rectifying measures to improve the flow pattern[7]. We do the further research to study on flow patterns and rectification measures by physical experiment.

This pumping station is built as sea water cooling system for the GNPower Dinginin coal fired power station. In the 3 circulating water pumps, these are 2 in operation and 1 standby in all the operation conditions.

2. Model Details

According to the requirement of the research, the simulation range includes the inlet pipe, the inlet forebay of the pump suction chamber, the suction bell mouth. Some part would be simplified simulated.

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2.1 Model scale
Research of pump house is always carried out based on big scale model, in which vortex can be studied and accurate result can be gain. In accordance with the relevant model test procedures and taking into account the accuracy of model test results, model scale is no less than 1:10, diameter size of bell mouth throat should be not less than 100mm in physical model, Reynolds number in bell mouth should be more than 105, Weber number in bell mouth should be more than 240, width of suction room in physical model should be not less than 450mm (300mm in Hydraulic Institute Standards), the minimum water depth is more than 150mm (Hydraulic Institute Standards).

In this project, the results are reasonable when the model scale is 10, by comparing the model parameters at different model scales. The model parameters include model discharge, diameter of bell mouth in model, width of suction room in model, area of bell mouth in model, velocity on bell mouth section in model, Froude number of bell mouth in model, Reynolds number of bell mouth in model, Weber number of bell mouth in model, etc.

2.2 Similarity law
Research on the velocity distribution and vortex in pump house, the Fr criterion and Re criterion should all be considered according to the similarity law. But in the model and the prototype, it cannot satisfy both criteria. Our research model is designed by the Fr criterion, in order to revise the influence of dissimilar of Re number, vortex is checked by increasing velocity in model. One way is to build model in a big model scale; another way is to increase flow velocity in the model. In this test, we choose the second plan, vortex is observed under 1.5 Fr number, according to the Hydraulic Institute Standards.

2.3 Model materials
Model intake tank is made of grey plastic and reinforced with steel. The water diversion pipe, circulating pump house (including forebay, filter room and suction room), bell mouth, are made up of Plexiglas for all-round observation. The outlet pipe of the model is made of PVC pipe. Several water-measuring weirs are installed at the bottom of the model to measure the flow rate. As it shows in Figure 1.

![Figure 1. Photo of model](image)

2.4 Velocity measurement
Velocity measuring sections are set as Figure 2. Coordinate system is established in each section to describe the velocity distribution. As shown in Figure 3, central line of each section is set to be zero, right is positive and left is negative. Velocity in different height is measured in each section.
3. Model test
In this project, operation combination can be classified to two kinds: symmetrical and unsymmetrical operation. Both are analyzed in preliminary test. The result in unsymmetrical operation is worse than that in symmetrical operation. Undesirable flow patterns always happen when the water level is low. For this reason, preliminary model test is carried out under working condition of low water level. This article takes unsymmetrical operation and low water level as example: the water level is -3.0m, discharge is 11.6m³/s, 1# and 2# are working.

3.1 Preliminary model test and analysis
In the preliminary test results, velocity distribution is even in the 1.5D section in the suction room, which means flow pattern become better through the flow channel. But as it shows in Figure 4, velocity is higher than 1m/s in some points in the 2# entrance section. At the same time, it can be observed that velocity distribution in 2# channel is highly impacted by the inlet flow, water level fluctuates violently.
3.2 Model test with rectification measures in forebay

In order to acquire better flow pattern, these are three options chosen to help flow diffusion, further observation is carried out after the phenomenon of channel drift disappears in all sections.

3.2.1 Model test of cross beam scheme. Cross beam of 2m height is set in the middle of the forebay, facing to the middle of the inlet tunnel, model test is carried out to evaluate the effect of the cross beam. Flow pattern in 2# channel entrance is refined according to the Figure 5, which indicated high efficiency of cross beam. In the result, velocity distribution in 1.5D section is even, the water level is more stable in this scheme. But when the discharge enlarges to 1.5 times, vortex can be observed in the suction room, which can induce vibration in the pump and reduce the pump efficiency.

3.2.2 Model Test of Cross Beam and breast wall Scheme. The inlet flow diffuses well with the help of cross beam, and the vortex in the suction chamber disappears after the breast wall is set. The Hydraulic Institute Standards states that “Average swirl angle indicated by the swirl meter must be less than 5 degree, maximum short-term swirl angle can be up to 7 degree”. According to the test results, velocity in the flow channel seems reasonable and swirl angle is less than 3 degree. Unfavorable flow patterns, such as back flow and large bias flow, are not found in all operation modes. It is considered that the cross beam and breast wall scheme can ensure a smooth flow pattern in the channel.

3.2.3 Model Test of Columns Scheme. There are 2 rows of columns with 0.5m×0.5m size, column space of the first row is 0.6m and 0.7m in the second row. The first row of column is 3m far from the entrance, the second row is 2m far from first row. As it shows in Figure 6 and Figure 7, column arrangement of scheme is considered helpful in flow diffusion for this project. Swirl angle is far less than 3 degree in all operation modes according to the test results.
4Conclusion
This study provides a reference for the physical model research of forebay in pumping station, including the design and manufacture of the model, the measurement method of the flow pattern and so on. As it shows that the preliminary test results are not satisfactory, which will cause vibration and reduce the efficiency of the pump due to the influence of the inlet pipe velocity, the water level fluctuation and the vortex in the suction room. Cross beam, breast wall and columns are useful to obtain better flow pattern, these rectification measures can help to diffuse the flow in the forebay and prevent the vortex.

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