Experimental study on generation discharge mismatch between the Three Gorges and Gezhouba

Zhijing Li¹, Caijin Zhou², Dazhi Li¹ and Guizhou Sun¹

¹ Changjiang River Scientific Research Institute, Wuhan 430010, Hubei, China.
² Yangtze River Engineering Consulting Co., Ltd, Wuhan 430010, Hubei, China.
*Corresponding author’s e-mail: lzjketty@126.com

Abstract. Due to the design reasons, the maximum generation flow of the Three Gorges hydropower station does not match the overflow of Gezhouba hydropower station, especially the discharge at peak load in flood season will greatly exceed the full output flow of Gezhouba hydropower station. The excess flow of Gezhouba needs to be discharged from the flood discharge dam section. The potential energy is not converted into electric energy, but directly converted into kinetic energy. The discharge flow velocity is large, which may affect the scour of the downstream reach of the dam. In order to reveal the influence of Gezhouba power plant waste water on the scour of the lower reaches of Gezhouba, this paper carried out a model test study of Gezhouba waste water under the condition that the power generation flow of the Three Gorges and Gezhouba does not match, and analyzed the law of the change of the downstream flow pattern under different waste water conditions of Gezhouba. The results show that the decrease of the abandoned water flow of Gezhouba can help to reduce the flow velocity near the dam downstream, while the influence of the change of the abandoned water flow on the scour downstream is limited.

1. Introduction

The Three Gorges and Gezhouba are inseparable cascade hubs. The distance between the two dams is 38.38 km. Gezhouba hydropower station is a runoff type hydropower station with no regulating storage capacity. According to the comprehensive utilization plan of the Yangtze River Basin, Gezhouba hydropower station is the reverse regulating reservoir and shipping cascade downstream of the Three Gorges project, which is an integral part of the Three Gorges Project [1]. Its main task is to eliminate the influence of unstable flow discharged during the daily regulation of the Three Gorges Project on navigation through the reverse regulation, thus to improve the navigation conditions of the channel from the Three Gorges dam site to Nanjinguan section and Yichang port area, and make use of the partial drop of this section for power generation [2].

After the Three Gorges power station is put into operation, it undertakes the peak load regulation task of the power system. In order to give full play to the capacity benefits of the Three Gorges power station, the Three Gorges power station will increase its output operation when undertaking the peak load of the power system [3]. Due to the design reasons, the maximum generation flow of the Three Gorges hydropower station does not match the over flow of Gezhouba hydropower station, especially the discharge flow during the peak load in flood season will greatly exceed the full output flow of Gezhouba hydropower station [4, 5]. Gezhouba hydropower station is a river bed power house. The power houses of the two hydropower stations are located in Erjiang River and Dajiang River respectively. Erjiang power station is equipped with two 170 MW and five 125 MW water turbine generator sets.
Dajiang power station is equipped with fourteen 125 MW water turbine generator units. Among them, the design flow of 170 MW unit is 1130 m³/s, and the design flow of 125 MW unit is 825 m³/s, so the total design flow of Gezhouba power station generator unit is about 18000 m³/s. If the capacity of 19 units with a single unit capacity of 125 MW is increased to 146 MW, the maximum discharge of Gezhouba can reach about 20000 m³/s [6]. At present, the discharge of the Three Gorges is about 30000 m³/s at full capacity, and that of Gezhouba is about 20000 m³/s at full capacity [7]. The difference between the two is about 10000 m³/s, because Gezhouba is a runoff type power station with no regulation and storage capacity, when the Three Gorges is full capacity in flood season, Gezhouba will exceed its full discharge and result in waste water.

The maximum power generation flow of the Three Gorges hydropower station does not match the overflow of the Gezhouba hydropower station. The excess flow of the Gezhouba needs to be discharged from the flood discharge dam section. The potential energy is not converted into electric energy, but directly converted into kinetic energy. The discharge flow velocity is large, which may affect the scour of the downstream reaches of the dam [8]. In order to better reveal the influence of Gezhouba power plant waste water on the downstream river channel evolution, the model test of Gezhouba waste water is carried out under the condition of mismatch of power generation flow of Three Gorges and Gezhouba, and the law of flow pattern change in the downstream of the project under different waste water conditions of Gezhouba is analyzed.

2. Experimental work

2.1. Model design

The reach simulated by the model starts from Gezhouba junction and ends at Linjiangping, Aijia Town, with a total length of about 18 km. The 1:2000 topographic map of the river channel, which was surveyed by the Three Gorges Hydrological Bureau of the Yangtze River Commission in April 2010, is used to make the model. The two sides of the map are surveyed to the levee and terrace platform, with an elevation of about 52.2-53 m.

According to the experimental research content, requirements and site conditions, the plane scale of the model is 250, the vertical scale is 100, and the model change rate is 2.5. According to the theory of model design, the fixed bed model is designed according to the principle of geometric similarity and flow movement similarity. The corresponding velocity scale is 10, roughness scale is 1.36, and flow scale is 250000.

2.2. Measurements

The model has a water supply pump house, which can adjust the pump speed according to the required flow. The frequency converter communicates with the computer according to the protocol to realize the remote control. Electromagnetic flowmeter is used for flow measurement. The flow information can be converted into digital signals and directly imported into the computer to monitor the model flow. The accuracy error of model inlet flow can be controlled within 2%. The model test adopts the constant flow test method, the upstream water level of the model test is controlled by the upstream water gauge of the hub, and the downstream water level is controlled by the tail gate. Under different working conditions, the flow distribution of the power plant unit and the sluice under different opening and different working conditions of the control hub is obtained.

The water level is measured by the combination of fixed station and movable probe. The water level measuring needle is a type product, the length of the water level measuring needle scale is 40 cm, and the surface of the measuring needle scale is attached with a vernier scale for measurement and reading, with the accuracy of 0.1 mm. The water level probe is fixed above the probe cylinder. The probe directly measures the water surface in the cylinder. The probe cylinder is connected with the model through a connecting pipe. The water level probe is easy to use and not easy to damage.
The flow pattern was observed and recorded by means of visual observation, photography and recording. The cross-section velocity was measured by resistance type propeller current meter and the distribution of each flow measurement section is shown in Figure 1.

![Figure 1. Section distribution of model flow measurement.](image)

2.3. Calibration
The terrain of the model verification test is the actual terrain of the reach in April 2010. The model riverbed is roughened by quincunx shaped gravel with a diameter of about 2 cm, with a spacing of about 10-20 cm. The gravel density is adjusted to meet the similar requirements of the discharge water surface profile at all levels. The verification results show that the main flow position of each section of the model, the vertical surface velocity and the transverse distribution are basically the same as the prototype, the maximum vertical surface velocity deviation of the section is less than 5%, the general vertical surface velocity deviation is less than 8%, the model water level is basically the same as the prototype water level under all levels of discharge, and the water level deviation is less than ± 0.10 m (i.e. the model deviation is ±1.0 mm), which conforms to the river model test regulations shows that the variation of water flow along the model and the comprehensive resistance are basically similar to the prototype.

2.4. Study cases
Considering that the full discharge of the Three Gorges is about 30000 m³/s, the bed forming discharge of Yichang reach is also about 30000 m³/s. In the model test design, the total flow of the project is set as 30000m³/s, and the two conditions are designed according to the power generation flow of Gezhouba project as 18000m³/s and 20000 m³/s respectively. The number of generator sets and corresponding power generation flow of the two power plants in Gezhouba, as well as the discharge flow of the second river drainage gate are shown in Table 1.
Table 1. Flow distribution for each study case.

| Case No. | Total flow (m³/s) | Outlet water level (m) | Erjiang power plant (m³/s) | Dajiang power plant (m³/s) | Erjiang sluice (m³/s) | Waste water rate |
|----------|------------------|------------------------|---------------------------|---------------------------|----------------------|-----------------|
| 1        | 30000            | 45.54                  | 6000/7 units              | 12000/14 units            | 12000                | 40%             |
| 2        | 30000            | 45.54                  | 6700/7 units              | 13300/14 units            | 10000                | 33%             |

3. Results and discussion

Figure 2 to Figure 3 show the depth average velocity change on different vertical lines of L1 and L15 sections under two working conditions. According to the observed average velocity, under the two working conditions, the average velocity of each vertical line near the dam section (L1 section, 0.84km downstream of the dam) is different, the maximum difference is 0.752m/s, and the maximum relative deviation is 60.26%. Generally speaking, the velocity difference does not show a consistent rule, and the velocity of different monitoring points on the section increases or decreases; along the way, with L15 section (3.28km downstream of the dam) as the boundary, the relative deviation of the average velocity on each vertical line of the observation section downstream of L15 section is less than 5%.

Figure 2. Change of depth average velocity of L1 section under two working conditions. Figure 3. Change of depth average velocity of L15 section under two working conditions.

Figure 4 shows the difference of the average velocity along the section under the two conditions. The results show that the difference between the two conditions is not significant. Generally speaking, the average velocity of Case 2 is slightly less than that of Case 1 (mainly within 3.5 km downstream of Gezhouba). The relative deviation decreases with the increase of distance from Gezhouba, and the maximum relative deviation of the average velocity of all the two conditions is within 8%.

From the two working conditions of Gezhouba abandoned water model test, under the condition that the total flow of the project remains unchanged, the increase of Gezhouba power generation flow has little influence on the downstream flow velocity of the dam, and the influence range of the average flow velocity on the different vertical lines of the section near the dam section does not exceed 3.5km. Generally speaking, the average velocity of downstream dam decreases slightly after the increase of power generation flow. According to the analysis, under the test condition, the decrease of abandoned water flow of Gezhouba dam can help to reduce the scour near the dam downstream, but the influence of the change of abandoned water flow on the scour of downstream dam is limited.
4. Conclusion
In view of the flow discarding problem of Gezhouba dam caused by the mismatching of power generation flow between the Three Gorges and Gezhouba, the model test of water discarding of Gezhouba is carried out. Under the condition that the power generation flow of the Three Gorges Project and Gezhouba project does not match, the variation law of the water flow downstream the project is analyzed. The results show that the decrease of the abandoned water flow of Gezhouba can help to reduce the flow velocity near the dam downstream, but the influence of the change of the abandoned water flow on the downstream scour of the dam is limited.

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