Selection and Study of Pump Type for Caohai ~ Dianchi Connection Pump Station Project

Weijuan Hu¹, Wenzhao Sun², Zhiyu Chen³

¹ Kunming Engineering Corporation Limited. Kunming, Yunnan, China
² Kunming Engineering Corporation Limited. Kunming, Yunnan, China
³ Huaneng Lancang River Hydropower Inc. Kunming, Yunnan, China.

*Corresponding author’s email: huwj861230@126.com

Abstract. The Caohai-Dianchi Connection Pump Station Project is part of the Dianchi water quality improvement and stability plan. As a connected pump station connecting Caohai and Dianchi, it plays a role in replacing and cleaning Caohai water. In this paper, based on the construction purpose, layout conditions and parameters of connection pump station, the advantages and disadvantages of centrifugal pumps and mixed flow pumps are given after analysis and comparison from the pump selection principles, stable operation, and economic factor, and the final pump type is determined through comprehensive comparison, which can provide reference value for the design of similar pump stations.

1. Project overview

The drainage area of Dianchi is 2920km², and the lake area is 310km². There are 35 major rivers entering this lake. It is divided into Caohai and Outer lake by the control dam. Caohai Lake covers an area of about 10km², with a lake capacity of 27 million m³, 7 rivers entering the lake, and an artificial exit Xiyuan tunnel. The Outer lake (Dianchi) area is about 300km², with a lake capacity of 1.5 billion cubic meters. There are mainly 28 rivers that enter this lake, and there is a natural exit namely Haikou River. The highest water level of Caohai is about 1886.8m, the normal water level is about 1886.0-1886.5m, the elevation of the bottom of Caohai is about 1885.0m, and the elevation of the dam crest on the coast of Caohai is 1889.0m. The water level in the Outer lake (Dianchi) is about 1887.2m-1887.8m. The task of this project is to draw water from the Caohai and makes it cross the dam crest to flow into the Outer lake (Dianchi).

According to the water level characteristics and water supply requirements of Caohai and the Outer lake, the height difference between the lowest water intake level and the highest point of the water supply pipeline is 10m. According to the pipeline direction and distance data provided by hydraulic engineering professionals, and after preliminary calculation, the main parameters of the connection pump station determined by pipeline edge and local losses as well as local lift capacity losses of valves and fittings are as follows:

(1) Designed flow rate 16.8m³/s (604800m³/h)
(2) Designed lift capacity 10~15m
2. Pump number selection and parameter determination

The pumping station has a designed lift of 10-15m and a designed lift capacity of 16.8m³/s (604800m³/h). Considering the stability and flexibility of the unit operation, the layout scheme of “3 main pumps and 1 backup pump” and “4 main pumps and 1 backup pump” can be adopted. However, because the proposed construction site of the pumping station is near the partitioning dam that separates Caohai and the Outer lake, and the site is located in the suburbs of Kunming, the surrounding residents are dense and the available space is limited, pump stations units should not exceed 4. Considering the characteristics and requirements of the pump station and the water supply process of the pump station, 4 water pumps with Q = 20160m³/h (5.6m³/s) and H = 10~15m were selected. Three of them work and one is standby.

The main parameters of the initial pump station units are shown in Table 1. During the construction phase, the optimal pump parameters will be further optimized based on specific information and the manufacturing research and development capabilities of each pump manufacturer.

| Pump       | Motor          |
|------------|----------------|
| Design discharge | 20160m³/h      |
| Design head     | 10~15m         |
| Maximum efficiency | >85%           |
| Design condition shaft power | 902kW          |
| Speed           | 300r/min       |

3. Pump types selection

3.1 Principles of pump types selection

From the perspective of technology and economy, the main principles of pump selection [1] are:

1. Satisfy the design flow, design lift capacity and operation requirements of different periods of the pumping station, and try to make the working point of the selected pump at the pumping station designing lift capacity near its rated operating point, and when the pump station lift is highest, the working point should be within the efficient zone.

2. Select a pump type with good performance and compatible with the change in lift capacity and flow of the pumping station;

3. When there are multiple types of pumps to choose from, factors such as hydraulic performance, unit cost, project investment, and operation and maintenance management should be comprehensively considered and compared.

For this project, in addition to the principles listed above, the following two points also need to be considered:

1. Restricted by the proposed construction site of the pumping station, the width of the pumping station should not be too large, which is not conducive to project layout.

2. The sound of the pump should not be too loud to reduce the impact on the lives of surrounding residents.

3.2 Basis of pump types selection

| Specific speed | Pump Type            | Scope of application               |
|---------------|----------------------|------------------------------------|
| 30~80         | Low specific speed centrifugal pump |
| 30~300        | Centrifugal pump     | Medium specific speed centrifugal pump |
| 80~150        | 150~300              | High specific speed centrifugal pump |
|               |                      | Various pump stations with low, medium and high head |
Mixed-flow pump
Large flow medium and low head pumping station
500~1000 Axial flow pump
Large-flow low-head pump station, the highest head generally does not exceed 10m

In order to ensure long-term, cavitation-free, efficient and stable operation of the pump, the type and parameter selection of the pump are also important. The usage ranges of various types of pumps are also different [2]. From the perspective of water pump parameters, the pump type depends on the specific speed of the pump. The higher the specific speed, the smaller the pump volume, the better the energy index, and the investment will be more economical. Therefore, when possible, it tends to choose a pump with higher specific speed. However, the increase of specific speed is often restricted by the cavitation, structure and materials of the pump, so the specific speed cannot be increased infinitely within a certain range of lift. The relationship between the type of pump and the specific speed is shown in Table 2:

3.3 Pump types comparison

According to the flow rate and lift capacity parameters of the pumping station, the pump suitable for the pumping station should have a large flow rate and low lift capacity pump. From the consideration of application, it can be preliminarily determined that the pump types suitable for this pumping station are centrifugal pumps and mixed-flow pumps (as the lift capacity of axial flow pumps rarely exceeds 10m, and the lift capacity of mixed-flow pumps can reach 30m).

To finally determine the pump type suitable for the pumping station, it needs to be jointly determined from the performance curves, structural characteristics, safe operation, civil engineering and equipment investment of these two pump types.

(1) From the perspective of performance, the performance curve of centrifugal pump and mixed flow pump is shown in Figure 1:

![Figure 1. Performance curve of centrifugal pump and mixed-flow pump.](image)

Combining Figure 1 with the centrifugal pump and mixed-flow pump points, it can be concluded that the main performance differences between the centrifugal pump and the mixed-flow pump are shown in the following aspects:

a) The starting power of the centrifugal pump is low, and the power is increasing with the increase of the flow rate, and the corresponding pump starting mode should be “started with sluice gate closing”; the starting power of the mixed flow pump is higher, the power is decreasing with the increase of the flow rate, and the starting mode should be “started with sluice gate opening”.

b) The centrifugal pump has better anti-cavitation performance, but the blade cannot be adjusted; the mixed-flow pump has characteristic of adjustable blade, but the anti-cavitation performance is poor.
From a comparison of performance characteristics, both centrifugal pumps and mixed-flow pumps can be used in this pumping station, but considering that the pumping station has the conditions of "started with sluice gate opening", which is convenient to start, and there are no restrictions to improve cavitation performance, so it is more suitable to choose mixed flow pump.

(2) From the perspective of structural characteristics, the centrifugal pump is easy to maintain and repairing, and the rotor can be taken out only by opening the pump cover during maintenance without disassembling the motor and connecting pipes. However, the size of the equipment is large, the noise is high during operation, and the water intake level and medium requirements are high, which means it must be filled with water or installed underwater before start-up; The maintenance of the mixed-flow pump is slightly more complicated, but the operation is relatively simple, the noise is low during operation, and the adaptability is strong. The impeller is submerged in water and can be started directly, which is convenient for automatic operation.

The pump station is relatively close to the residential area, and the water quality is poor. So, from the perspective of structural characteristics, it is more suitable to choose a mixed-flow pump.

(3) From the perspective of safe operation, centrifugal pumps and mixed-flow pumps are more traditional pump types, and the design, manufacturing, and application technologies are relatively mature, so there are no limiting factors in this perspective.

(4) From the perspective of investment in civil construction, according to the parameters of the pumping station, a horizontal centrifugal pump is required, which plane size is large. Although the pump room only needs one floor, the excavation depth is large to meet the submersion depth. Therefore, the excavation volume is large, and the overall investment is large; If a mixed-flow pump is used, vertical installation can be selected, the plane size is small, the motor and the water pump are located on two floors, and the excavation depth is large comparing with the centrifugal pump, but due to the small plane size, the total volume of the mixed-flow pump is smaller than that of the centrifugal pump under the same parameters, and the overall investment is smaller.

(5) From the perspective of equipment investment, because the pumping station is a large-flow low-lift pumping station, and the number of generating units has been determined not to be too much, a single pump has a larger flow rate and a larger pump inlet and outlet diameter. At present, there are not many manufacturers of large-diameter centrifugal pumps at home and abroad, the price difference is large, and the investment controllability is poor; the production technology of mixed-flow pumps of the same diameter is mature, there are many manufacturers and the price difference is not large, and the investment can be better controlled. Therefore, considering this situation, the mixed-flow pump is more suitable for the current status of the pumping station.

4. Conclusion
(1) In summary, from the perspective of performance characteristics and safe operation, both the centrifugal pump and the mixed-flow pump can meet the operating requirements of the pumping station, but from the perspective of convenient long-term operation, it is more suitable to choose a mixed-flow pump; from the structure characteristics and investment in civil construction, the comparison results of mixed-flow pumps are all superior to centrifugal pumps. From the perspective of equipment investment, vertical mixed-flow pumps are more controllable in investment than horizontal double-suction centrifugal pumps, and domestic similar flow of large diameter centrifugal pump application performance is less, the mixed-flow pump production technology is mature, and many similar projects have been put into production. Comprehensive consideration, it is appropriate to plan to adopt mixed-flow pump in this case.

(2) The characteristics of mixed flow pumps are that the structure is relatively simple, and the flow rate is larger than the centrifugal pump with the same impeller diameter but smaller than the axial flow pump. Therefore, it can replace some of the working range of centrifugal pumps and axial flow pumps. It has a wide adaptability and is more suitable for this pumping station.

(3) Combined with the proposed location of the pumping station and the pump parameters, the pumping station should choose a vertical mixed flow pump.
5. Prospect

(1) The pump is the core equipment of the pumping station. The performance of the pump has an important impact on the stability and reliability of the pumping station. It is very important to choose a pump type with the best comprehensive benefits such as good performance, convenient operation and maintenance management, and investment savings for the pumping station based on the actual project situation.

(2) Caohai–Dianchi Connection Pump Station is still in the planning stage. The existing water level parameters and data as the basis for pump type selection are credible but not sufficiently accurate. In the next step, the collection and refinement of hydrological sediment and geology data should be strengthened, and detailed cost comparison results of various selection schemes should be analysed to ensure that the final choice of pump type can be efficient and stable operation, the initial investment is relatively low, and the overall benefit is high.

References

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