Research on a New Type of Low-Speed Water Flow Energy Turbine Pump

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Abstract. As the concept of Beautiful China is deeply rooted in the hearts of the people, most cities have developed riverside and waterfront areas into landscape leisure parks. At present, the vegetation in Jiangbin Park is irrigated with tap water. Flow energy has the characteristics of large reserves, wide distribution and renewable energy. Using this kind of energy to drive the water pump and realize the green irrigation of the vegetation in the riverside park will definitely open up a new way to expand the application of low-flow water flow energy. The project team plans to design a new type of turbine pump, adding a diversion cover and a collection device at the water inlet to reduce the start-up speed of the device and improve the utilization rate of water flow energy under small flow. The project team used planetary gear transmission to effectively improve the traditional hydraulic pump, increasing the torque transmitted to the pump shaft, enabling it to drive the impeller of the hydraulic pump to achieve energy-free pumping.

Keywords: Hydroelectric Power Generation; Turbo Pump; Torque.

1. Research Background and Significance

1.1 Research Background

Water flow energy is a kind of green and pollution-free renewable energy, and its development and utilization has great strategic significance. In the 14th Five-Year Plan, the state emphasizes the development of hydropower energy. Water flow energy has low energy density and large reserves. In the "Special Report on Hydropower Market" issued by the International Energy Agency, it is pointed out that in 2020, the global hydropower generation will be about 4,500 TWh, accounting for one-sixth of the world's power generation (second only to coal and However, most of the current hydroelectric power generation technologies are used in waters with large drop and high flow velocity. There is little research at home and abroad on the utilization of water flow energy with low micro-head and small flow velocity, and a large number of micro-head resources have not been effectively utilized. Moreover, the traditional irrigation of riverside green space mostly adopts the way of tap water artificial irrigation [1]. Among them, the production cost of tap water is high and the production process is complicated. The utilization efficiency of water resources in this method is low, resulting in unnecessary waste of resources and energy, and green plants often die due to water shortage due to artificial irrigation. Therefore, if the low-speed water flow can be effectively used for riverside green plant irrigation, on the one hand, the energy consumed by the production and transportation of tap water can be saved, and on the other hand, the river water can promote root growth and increase root dry weight, making The green plant quality of river water irrigation is better than that of tap water irrigation [2].

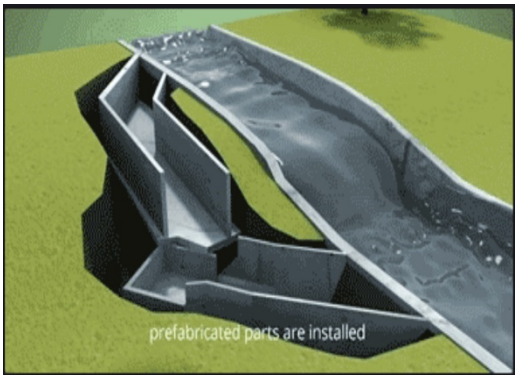


Figure 1. Low flow channel



Figure 2. Plants withered due to untimely irrigation

The water turbine pump is an environmentally friendly and energy-saving water energy conversion tool. It has a relatively simple structure and few energy conversion levels, but requires a high flow rate and a large drop[1]. cannot be used effectively. Based on the characteristics of this device, the project team plans to innovate and transform the turbine pump, and design a turbine pump suitable for low flow waters. According to the distribution characteristics of the flow velocity gradient, a shroud is installed and a collection device is designed on the basis of the shroud structure to reduce the start-up flow rate of the turbine. The water flow enters the pump body through the shroud to impact the water wheel, and the torque generated by the impact water wheel is increased through the planetary gear transmission, so that it can drive the impeller to rotate together. , to realize the direct conversion of water flow energy and the nearby irrigation of river water; it is intended to improve the current situation of using tap water to irrigate green plants in Binjiang Park, and save the production cost and energy consumption of tap water for green plant irrigation[2].

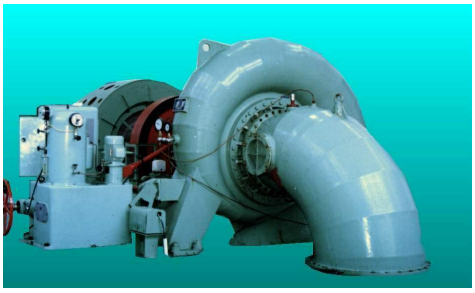


Figure 3. Turbine

1.2 Project Research Significance

With the continuous improvement of economic and social development and people's quality of life, ecological livability and industry are an important trend of global urban development, and urban construction and parkization are advancing.As an important part of urban parks along the river, Jiangbin Park mostly adopts tap water artificial irrigation. Taking Hankou River Beach Park as an example, the total greening area of the second phase is 450 mu. It is estimated that each irrigation water will be about 4,500 tons, and the tap water required for production irrigation will consume about 17,000 kWh of electricity and emit nearly 16.8 tons of carbon dioxide[3].This irrigation method has caused serious waste of resources. In the context of the country's major demand for "carbon peaking and carbon neutrality".

This project is of great significance for water saving and energy saving by exploring the nearby irrigation method of Jiangbin Park without energy consumption.

Low-velocity waters are a resource with large reserves that have not yet been effectively utilized. This project focuses on the efficient use of water-flow energy in low-velocity waters to make energy utilization more complete [3].

2. Research Status and Development Trends at Home and Abroad

With the continuous acceleration of urban modernization, urban parkization is on the rise, and the water consumption for green plant irrigation will be greatly increased. Therefore, it has become a top priority to vigorously carry out research and promotion of water pumping in low-flow waters and a series of follow-up technologies.

my country is rich in water resources, but there are still many that have not been used. The water flow energy hydroelectric power generation device is suitable for advection rivers, canals, drainage ditches, etc., and can be used in the case of lower flow rates to improve the utilization rate of water resources. Therefore, many domestic experts and scholars are committed to improving the power generation efficiency, which is suitable for waters with lower flow rates. There are many studies on impeller optimization of power generation devices such as tidal energy, ocean energy, and wind energy in China. Among them, the design of blades in hydroelectric power generation devices is related to the power generation efficiency of the motor. Therefore, many domestic experts are devoted to the optimization of impellers. In 2016, Pan Cheng et al. designed a horizontal axial flow rotating paddle structure, which was analyzed by numerical simulation based on ANSYS CFX fluid-structure coupling[4]. Studies have shown that the impeller, transmission structure and generator casing of small generators with low flow rate water flow are simple in structure and low in efficiency, and need to be optimized to improve their performance and efficiency. In 2018, Zhang Shunv and others from Kunming University of Science and Technology studied the internal water flow of the long and short blade turbine and the influence of the runner pair blades on the operation of the turbine, established the turbine model, and used simulation software for simulation analysis. Through the simulation analysis and calculation, the working conditions of the turbine under different working conditions are obtained. The research shows that the performance of the turbine with the addition of auxiliary blades is better than that of the turbine without the addition of auxiliary blades. Compared with domestic, foreign countries mainly improve the blade and guide structure, and have high power generation [5]. Through a large number of experiments and CFD three-dimensional non-constant numerical simulation technology abroad, the influence of the number of blades and rotational speed on the output, efficiency and river flow field characteristics of the waterwheel has been studied. The output and efficiency of the blade tip specific speed are higher, and the increase of the number of blades will increase the water level difference between the upstream and downstream and cause greater noise[4].

In the research of this project, the transmission mechanism in the device can indirectly fill the vacancy that the water flow energy is not well utilized in the case of low flow rate. In low-flow waters, the device can collect low-flow water energy and output it to the outside in a more effective form under the action of the transmission mechanism in the device, so as to effectively utilize the low-flow water energy.

3. Project Innovation Point

Structural innovation: The device optimizes the structure of the impeller bone line and the turbine itself, and adds a diversion cover, which reduces the start-up speed of the device and improves the water flow energy utilization and pumping efficiency of the device.

Positioning innovation: no need to supply other types of energy from the outside, the device can collect and convert the energy of low-flow water flow into mechanical energy in a specific environment, and use the mechanical energy for pumping water to realize energy-free pumping technology.

Concept innovation: The concept of nearby irrigation is proposed. The device can be irrigated after pumping water near the riverside, without the need for secondary processing of river water, reducing irrigation procedures, reducing processing and transportation costs, and improving the survival rate of green plants[5].

4. Project Research Content and Research Objectives

4.1 Project Research Content

In this project, a water turbine pump that is used in Jiangbin Park is designed to efficiently absorb the energy of low-flow water flow. Its main research contents include:

4.1.1 The Overall Design of the Water Pump

The device designs the overall structure of the water pump, uses the diffuser to increase the water pressure, and adds a diversion cover and a collection device, so that the water turbine can collect the water flow energy with low water flow speed in advance, reduce the influence of the flow rate gradient on the water turbine, and reduce the speed of the water turbine. At the same time, the traditional turbine itself is improved to improve the hydrodynamic performance of the turbine. Its main mode is to use the water flow energy for pumping without energy consumption, in which the water flow energy enters the turbine with low-speed water flow as a carrier, and is converted into the mechanical energy of the transmission shaft system through the shaft connected to the wheel under the rotation of the wheel. Through the mechanism in the gearbox on the shaft, the torque transmitted to the pump shafting is increased to achieve energy-free pumping. In addition, in order to solve the problem of device movement and stability, the project team plans to install it under the small ship in a suspended manner[6].

4.1.2 Optimization of Impeller Water Wheel

Based on the literature reviewed, the project team proposed a scheme of combining long and short blades for impeller blades and improving the ratio of the diameter of the outlet edge of the long and short blades, so as to improve the internal flow characteristics in this mode, improve the overall efficiency design, and enhance the blade's effect on water flow. control. The blade element-momentum theory is adopted to optimize the structure of the existing tubular turbine, and perform structural simulation to reduce the energy pressure of the turbine operation and improve the overall stability [7]. Based on the combination of theoretical analysis and numerical simulation, it is expected to provide a certain reference for the design and optimization of the device, and to combine it with the structure of the diverter in the submersible pump to achieve the purpose of effectively lifting part of the pump head in the device.

4.1.3 Simulation Experiment of Long and Short Blades

It is proposed to use ANYSY CFX to simulate the length ratio of long and short blades, in order to obtain the best length ratio of long and short blades to optimize the overall efficiency of the lifting device, and to provide a certain theoretical basis for its design and optimization.

4.1.4 Fluid Simulation Experiment on the Whole Device

In order to explore the operating efficiency of the device in this mode, the project team plans to use the Pumplinx pump simulation software to simulate the pump part of the device, simulate the pumping situation at different flow rates, and obtain the water flow velocity distribution and water flow pressure at each position. After analyzing the simulation data, a structural optimization plan is proposed.

4.1.5 Irrigation System Simulation Experiment of the Device

The project team reviewed the existing designs of various sprinkler irrigation systems, and selected the most comprehensive sprinkler irrigation system based on the analysis and comparison of meteorological factors such as precipitation, temperature, wind speed, and relative air humidity, as well as the characteristics of specific plants and local soil conditions[8]. In the later stage, MATLAB will be used to simulate the control system to simulate the operation of the device under certain environmental conditions, and it is expected to obtain and analyze data such as irrigation volume and water flow in a certain month to test the rationality of the overall design.

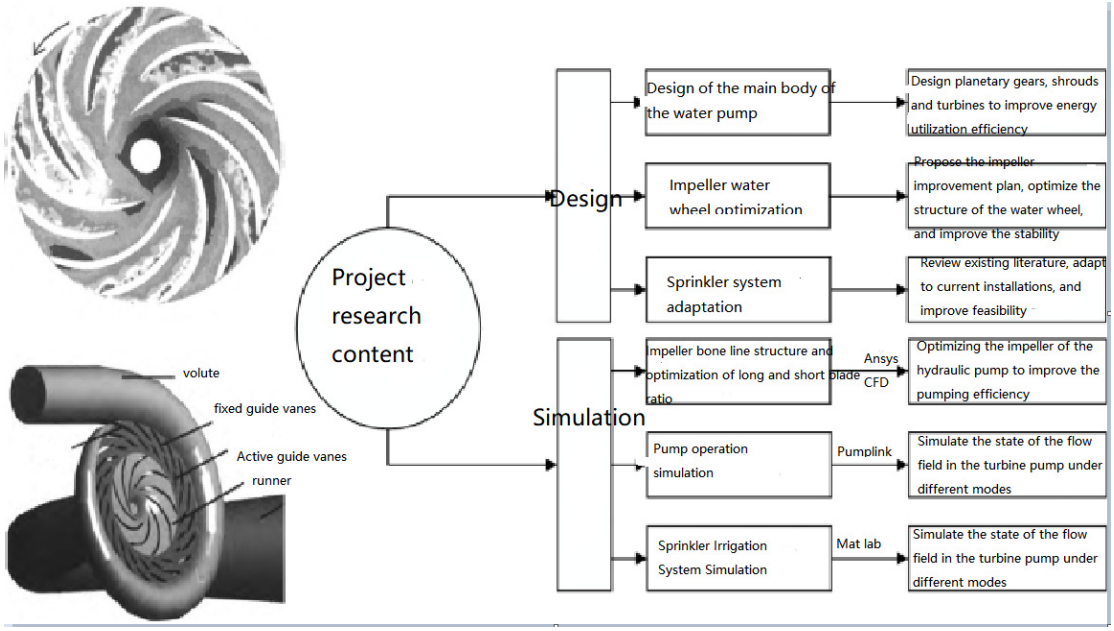


Figure 4. Overview of the research content of the project

4.2 Project Research Goals

Designed to be used in Jiangbin Park to efficiently absorb low-speed water flow energy. Compared with the existing water flow energy collection system, this device can instantly collect and utilize low-speed water flow energy during operation, and is suitable for many types of water flow. Riverside Park.

The use of this device can indirectly reduce the emission of CO2, and at the same time, it can save the corresponding fossil energy, which is conducive to the spirit of "energy saving and emission reduction" advocated by our country.

5. Overall Structure Design

On the whole, the device is mainly composed of impeller, water wheel, planetary wheel, water pumping device, multi-stage diffuser and transmission shaft. The river water enters the device at a low flow rate to impact the water wheel, and the water pressure is increased through the diffuser. The transmission device increases the torque generated by the impact water wheel, so that it can drive the impeller to rotate together. The rotation of the impeller does work on the liquid, and its rotating mechanical energy The pressure of the water can be increased, and finally the high-pressure liquid is pumped out from the outlet to realize the nearby irrigation after pumping.

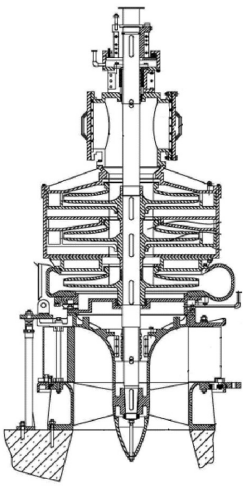


Figure 5. Overall structure design

6. Solved Problem

In terms of improving the utilization rate of energy and reducing the loss of energy conversion, the project team plans to optimize multiple mechanisms to reduce unnecessary friction between the mechanisms, and at the same time, improve the machining accuracy and reduce adverse wear as much as possible.

Regarding the structural design of the impeller bone line outlet side and the ratio of the number of long and short blades, on the basis of referring to the existing literature, the project team plans to increase the number of experiments to reduce its unbalance.

The angle of the blade may affect the force efficiency of the corresponding part. In order to reduce the adverse effect of this phenomenon, the project team will further test and optimize the blade structure, and plan to make it reach the optimal angle under the current state.

7. Research Method

Theoretical research calculation method: CFD analysis of the model designed in this research, for hydraulic machinery, this method has a good effect on improving and optimizing the performance of hydraulic machinery.

Model test method: Carry out experiments by establishing hydraulic models and structural models. If the model and the experiment have a high degree of fit, it proves that the design is stable. Otherwise, carry out the experiment again, and finally achieve the effect that is closer to the actual operating conditions.

Fact feedback method: By comparing the existing structural examples, analyzing the causal relationship of various abnormal phenomena and feeding back new knowledge into the existing device design, it is used to optimize the current design structure and benefit later development [6].

Signal preprocessing method: In mechanical system condition monitoring and fault diagnosis, signal preprocessing is an important step in mechanical feature extraction and health status assessment. At the same time, more complete data sources can be obtained by adopting intelligent information processing methods [7].

8. Benefit Analysis

To calculate the water cost of conventional riverside parks, taking Hankou River Beach Park as an example, the total green area of the second phase of the river beach is 450 mu. The second phase of Tantan requires an average of 4,500 tons of water for each spray irrigation. According to the number of rainless days in Wuhan for 260 days, the annual water spray volume is about 1.17 million tons of water, consumes 4.56 million kWh of electricity, and emits about 4.38 million tons of carbon dioxide. It costs 4.56 million yuan per year for irrigation operations. In addition, the irrigation of Jiangbin Park requires manual work. Take the use of water spray belts in the park as an example. On the basis of calculating the laying length, laying distance and valve of each sprinkler belt, excluding rest and intermittent time, 2 workers need to work for at least 1 day (calculated as 8 hours per day) to complete 1 irrigation. The total cost of completing a single irrigation is about 1,008 yuan, and the annual labor cost is 260,000 yuan.

Table 1. Irrigation-related data of Hankou River Beach Park

total green area	Annual water spray	annual power consumption	Annual CO2 emissions	Annual water treatment cost	annual labor cost
450mu	1.17 million tons	456degrees	4.38 million tons	4.56 million yuan	260,000 yuan

9. Conclusion

The device studied in this project can achieve the purpose of eliminating the need for secondary processing of river water, reducing the irrigation process, optimizing the consumption of fossil energy and CO2 emission, and further improving the “carbon neutrality” and “carbon peaking”. The achievement of the goals is helpful, and at the same time, the corresponding riverside parks can reduce certain management costs.

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