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Review Article

The Manufacture and Application of the Underwater Detection Platform for Water Conservancy Projects

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Abstract

In order to realize the safe, stable and reliable detection of water in long-distance water diversion project and avoid many problems in manual detection of drainage, the underwater vehicle suitable for the detection of long-distance water diversion project is developed. The motion model of the robot is simplified by reducing the thrust coupling of the thruster, and the stability of the robot control system is improved by using multiple decision levels and multiple control modes. An underwater vehicle capable of stable navigation detection within a distance of more than 5km of the high-head water diversion project and capable of autonomous return in distress has been developed. Through field tests, the practicability and reliability of the underwater vehicle in long-distance navigation detection has been proved.

Keywords: Water diversion project; Underwater vehicle; AUV; ROV

Introduction

With the vigorous development of hydropower in China, water diversion projects with complex engineering geological environment, long tunnel line, large tunnel diameter and many structures are emerging. During the long-term service of the water diversion and diversion structures, with the extension of the project operation time, due to the change of the external environment (such as hydraulic scouring, corrosion and temperature stress) and the impact of human error (such as improper design or material selection), various degrees of disease or damage will occur, which will reduce the safety, integrity and serviceability of the overall structure. [1-2] If these diseases or damages are not found in time, it may endanger the integrity and stability of the tunnel and seriously affect its safe operation. Therefore, it is very necessary to test it regularly and evaluate its safety and reliability.

Design Background

At present, the patrol inspection and hidden trouble detection of water diversion and diversion projects mainly rely on manual methods. Due to the influence of environmental factors, the working efficiency and working time of divers underwater are greatly limited, and there are problems such as low detection efficiency, untimely detection of lesions, difficulty in detection of underwater lesions, and difficulty in quantitative evaluation of lesions. In recent years, with the development of artificial intelligence and underwater detection technology, underwater unmanned detection technology has gradually developed from the field of ocean detection to the detection of water conservancy and hydropower projects. First, it has been applied to the detection of underwater building defects in open waters such as reservoir dams and plunge pools, and has achieved good results. On this basis, researchers at home and abroad have begun to carry out innovative exploration for the unmanned detection technology of hydraulic tunnels in closed spaces. In 2022, the Chinese Academy of Water Sciences developed an AUV and ROV duplex underwater vehicle in accordance with the design principle of "generalization and modularization", and carried optical, acoustic and other detection sensors on the robot. In AUV mode, the range of activities of the underwater vehicle is not limited by the umbilical cable, and the adaptive autonomous control ability is strong. The body is powered by its own battery pack, and its own controller completes its own function control; ROV mode has high human-machine interaction and is not limited by the endurance. It completes the power supply and function control of the underwater vehicle body through the umbilical cable [3-5].

Overall Structure

Combined with the design principles of the carrier structure and the installation requirements of each detection sensor, after the carrier static evaluation and hydrodynamic analysis, the main structure of the underwater vehicle adopts the streamline rotary body form, adopting the modular design concept, and simultaneously designs and develops a modular carrier platform, modular electronic control system and navigation system [6,7]. The underwater vehicle is composed of carrier system (main body), control system, power propulsion system, retraction and release system etc. and corresponding interface modules are reserved for power supply, communication transmission, cable automatic retraction and release and other sensing systems; It includes seven functional modules, including bow section, channel propulsion section, DVL section, main control section, energy propulsion section, connection section, and tail camera section. The connection of each module is simple and interchangeable, and the sealing and electrical connection are realized at the same time in the structural connection. The main parameters and functions of the underwater vehicle are as follows:

a. Diameter: 3.24m

b. Total length: 2.3m

c. Submergence depth: >450m

d. Range: 10km@1kn

e. Total length of the optical fiber: 5.2km

f. With remote control and autonomous emergency load dropping function.

g. The travel is measured comprehensively by DVL, inertial navigation and cable length counter.

Control System Function and Architecture

The underwater vehicle control system is divided into water surface control system and underwater control system. The water surface control system is mainly human-computer interaction function, which displays underwater status information and controls commands to the underwater control system. The main function of the underwater control system is to receive the control signal of the water surface control system and control the stable navigation and detection of the underwater vehicle, so as to realize the remote detection of the complex environment of the diversion tunnel of the hydropower station. The control system adopts a distributed control system based on CAN bus, which can realize the random expansion and simplification of functional modules. The modular electronic control system hardware uses the ARM microcontroller with high efficiency and high integration as the basic computing platform to achieve the highest integration and scalability. In order to improve the reliability and maintainability of the system, each cabin adopts independent control nodes, and the control system PCB adopts the form of core control board + backplane. Each control node adopts the same core control board, and the backplane is modified accordingly to adapt to the specific tasks of different nodes. The hardware design of each node of the control system corresponds to the functions that each node needs to achieve, realizing online programming, serial port conversion, power control and other functions [8-11].

Dynamic analysis of underwater vehicle

CFD is used to establish a simplified AUV model and divide the grid, calculate the forces on the model at different speeds in the direct direction, and then fit the drag coefficient. Perform fluid simulation of the underwater vehicle at three speeds of 1, 2 and 3 knots, and perform force analysis. See the following figure for force nephogram. According to the force analysis, the safety factor of 1.2 is selected to select the type of propeller. Figures 1-3 The connection section is arranged with four thrusters uniformly distributed. Through the joint control of the four thrusters, the mobility is increased, the complexity of the drive mechanism is reduced, the performance requirements for a single motor are reduced, and the stability of the system is improved.

Figure 1: Structural layout of underwater vehicle (AUV mode).

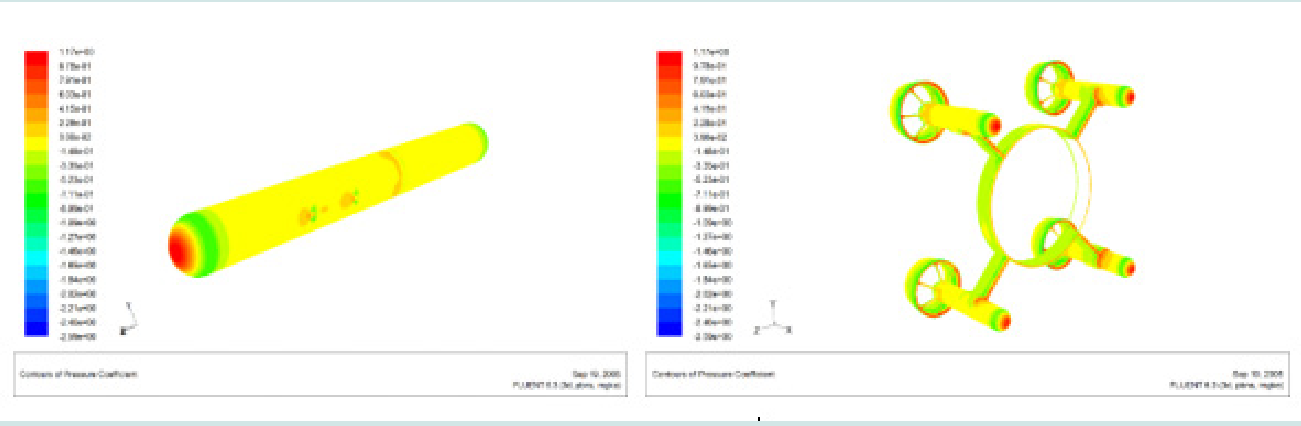

Figure 2: Overall stress nephogram of AUV and propeller (V=3 knots).

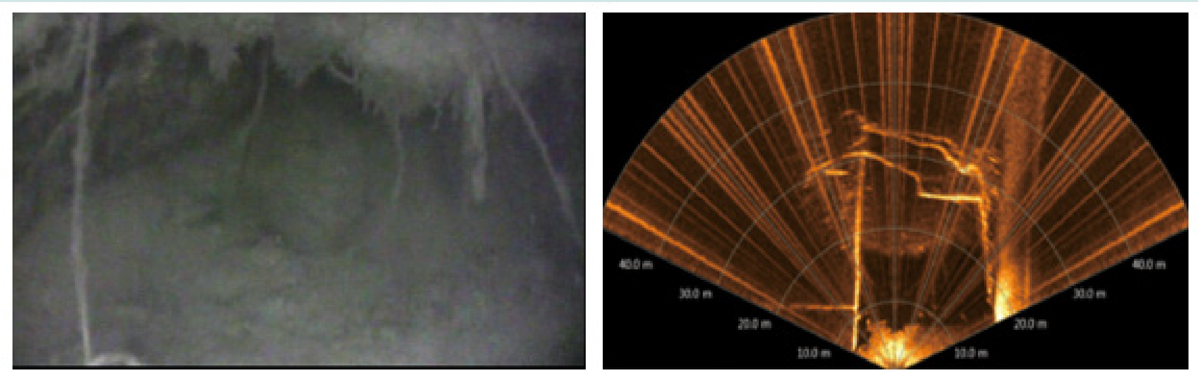

Figure 3: Defect diagram of underwater structure.

Carrying of Underwater Detection Equipment

The bow module of the underwater vehicle is mainly composed of the bow shell of the carrier, camera, LED light, altimeter and node controller, which is responsible for the acquisition and recognition of video images, underwater lighting, etc. The camera supports two degrees of freedom of pan-tilt angle, with an angle range of ± 30°. The stern module is installed with three array cameras of the same specification, and three array LED lamps are distributed at intervals, which can realize real-time observation of the pipe wall. In addition, a set of multi-beam forward looking sonar is installed at the bottom of the robot bow module by means of "removable external mounting" [12]. The scheme of acoustic rough inspection and optical fine inspection is comprehensively adopted to realize non-stop water detection under different conditions such as semi-irrigation, full irrigation and less than half irrigation.

Application Analysis

The underwater vehicle was used to carry out a full-range inspection service in a water diversion and diversion project, and a relatively serious structural defect was found during the inspection process. The practical application also showed that the underwater vehicle has the ability of safe, stable operation and inspection in a long-distance water diversion and diversion project. After completing all the detection tasks, the autonomous homing and emergency dropping functions of the underwater vehicle were verified during the homing process.

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