CASE STUDY ON UNDERWATER INSPECTION METHOD FOR TAILRACE AREA IN HYDROPOWER STATIONS

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ABSTRACT

Nowadays, there are nearly 100,000 hydropower stations in China, including 127 with an altitude over 70m and 71 with an altitude over 100m, and more than half of them have been operated for over 20 years, which makes the underwater inspection for hydraulic structures in hydropower stations very urgent. Because of its deep water level and complex flow regime, the tailrace area is the key and difficult point for underwater inspection of hydraulic structures.

This paper mainly introduces four main methods of underwater inspection, which are underwater TV, air diving, multi-beam sonar and remotely operated vehicle (ROV); and briefly, it describes those methods. Then, taking the underwater inspection for the tailrace area in the left bank of Three Gorges hydropower station in 2014 as an example, an underwater inspection method suitable for the tailrace area of hydropower station was innovatively proposed according to the characteristics of the tailrace area. After that, guided by this innovative method, the inspection of tailrace area in Gezhouba hydropower station was carried out in 2016. The results of the two inspections show that the shape and scope of the tailrace area coincide with the design drawings, and the concrete surface in the tailrace area is basically intact, without obvious uplift and collapse, the overall situation is good.

This new method can clearly show the underwater condition of the tailrace area and meet the requirements of regular inspection, which can be used for underwater inspection of the tailrace area in hydropower stations. Through proper improvement, this method can also be used for the inspection of other areas where the water regime is similar with the tailrace area. And it has some enlightening for underwater inspection of other hydraulic structures in hydropower stations.

Key words *: Hydropower station; Tailrace area; Underwater inspection*

1. INTRODUCTION

With the development of economy and technology, the hydropower industry in China has developed rapidly. Up to now, there are more than 100,000 hydropower stations in China, including 127 with an altitude over 70m and 71 with an altitude over 100m. More than half of them have been operated for over 20 years, which makes the underwater inspection in hydropower stations particularly urgent. The hydraulic structures in hydropower stations are huge, complex, including the underwater parts. In order to fully understand the current status of the hydraulic structures, and to meet the regular inspection requirements, it is necessary to inspect the underwater parts of hydraulic structures regularly and step by step, and to formulate targeted maintenance plans according to corresponding inspection.

Because of its deep water level and complex flow regime, the underwater inspection of the tailrace area in hydraulic structures is very important and difficult. However, the specific water condition in tailrace area changes obviously with the seasonal changes and unit maintenance requirements. Therefore, appropriate underwater inspection method for the tailrace area is very important and necessary.

2. COMMON UNDERWATER INSPECTION METHODS

So far, the commonly used underwater inspection methods are underwater TV, air diving, multi-beam sonar and remotely operated vehicle (ROV). According to the study of relevant data and underwater inspection examples, the applicable conditions and relevant parameters of underwater inspection methods are shown in Table 1.

Table 1 : Applicable conditions and parameters of common underwater inspection methods

Underwater inspection methods	Depth of water	Water Limpidity	Flow velocity	Way to move
Underwater TV	≤ 150m	limpid	< 0.5m/s	dragged by cables
Air diving	≤ 60m	limpid	≤ 0.5m/s	cables or propeller
Multi-beam sonar	10 -11000m	no demand	≤ 5m/s	boat or robot
Remotely Operated Vehicle (ROV)	≤ 300m	limpid	≤ 2m/s	propeller

2.1 Underwater TV

Underwater TV is an application of television that puts cameras under water and takes pictures of underwater targets. The underwater pictures are taken by the cameras and then transmitted back to the display of the host. Currently, the working depth of this method can reach up to150m, and it is suitable for clear water area. This method is used in the environment where the flow velocity is small and stable, generally in still water. It moves in the way of dragging through cables.

2.2 Air diving

Air diving refers to diving in which divers use air as a breathing medium to complete underwater inspection by means of viewing, touching, knocking and others, according to inspection requirements. The depth of diving is generally controlled within 50-60m. And it is suitable for clear water area, this method is used in the environment where the flow velocity is ≤0.5m/s. Under the water, the diver moves through cables or propellers. Generally, because of its low working efficiency, this method is often used in complicated conditions.

2.3 Multi-beam sonar

The multi-beam sonar is a type of sonar that is used to map the seabed, and emits sound waves in a fan shape beneath a ship's hull. Unlike other sonars, multi-beam sonar uses beam-forming to extract directional information from the returning sound waves, producing a swath of depth readings, which is processed by software in order to further obtain the 3D image of underwater structures. The underwater area covered by multi-beam sonar is generally 4-10 times of the water depth, and relevant technical indexes are shown in Table 2.

Table 2 : Relevant technical indexes of multi-beam sonar

Number	Technical indexes	Parameters
1	Transmitting frequency	40Hz
2	NO. of transmitted beams	≥ 240
3	Single beam width	≤ 1°×1°
4	Coverage area	4-10 times of water depth
5	Transmitting angle	Equiangular or equidistant
6	Measuring accuracy	5cm

2.4 Remotely operated vehicle (ROV)

ROV is an underwater mobile device, which is equipped with at least a video camera and lights. Additional equipment is commonly added to expand ROV's capability, which includes magnetometers, a manipulator or cutting arm, water samplers and other equipment. ROV can achieve video capture, target location, image scanning and other functions in the water area with high depth and low velocity. The depth of ROV is generally controlled within 300m, and it is also suitable for clear water area, where it moves through propellers.

3. UNDERWATER INSPECTION CASES

In 2014, an underwater inspection was carried out in the tailrace area of left bank in Three Gorges hydropower station. After that, an underwater inspection method suitable for tailrace area was innovatively proposed according to its flow regime. Guided by this method, the underwater inspection of tailrace area in Gezhouba hydropower station was carried out in 2016.

3.1 Underwater inspection case in Three Gorges hydropower station

3.1.1 *Underwater inspection overview*

It has been more than ten years since the operation of the Three Gorges hydropower station, and no detailed underwater inspection has yet been carried out in the tailrace area. In order to ensure the safety of hydraulic structures, find out the defects in time and provide basic data for later inspection, according to the requirements of dam regular inspection, an underwater inspection for tailrace area in Three Gorges hydropower station was implemented in 2014.

3.1.2 *Underwater inspection process*

The tailrace area of the left bank in Three Gorges hydropower station has the characteristics of high flow velocity, strong scouring and complex flow regime, which makes the underwater inspection in this area more difficult than other areas. In general, the units cannot be fully stopped for underwater inspection, so the underwater inspection in this area is in turbulent status.

At the beginning of the inspection, the Remotely Operated Vehicle (ROV) was put into operation in December 2014. But the inspection couldn't be carried out because of the water regime, which made the ROV could hardly be controlled and could not ensure the quality of the underwater inspection, so as the underwater TV. After many field tests, it was ideal to use the multi-beam sonar for the inspection, so the multi-beam sonar was used with the aid of air diving in this underwater inspection.

When using multi-beam sonar, real time kinematic (RTK) was used as an aid. Through data processing, centimeter level positioning accuracy could be obtained, which greatly improved the measurement accuracy, seeing in Figure 1. Relevant instruments were placed on a working ship, which moved along the set route at a speed of 2m/s. The whole underwater inspection was completed on the working ship.

During the underwater inspection, if special defects needed to be further confirmed, air diving should be used. Equipped with diving equipment, lighting equipment, camera and telephone, divers carried out the inspection according to the pre-determined route. The main inspection contents for divers were erosion, abrasion, cavitation and other defects, of which the basic data would be sent to the ground.

Figure 1 : The real time kinematic on the working ship

3.1.3 *Underwater inspection results*

The results of the underwater inspection in tailrace area showed that the shape and scope of the tailrace area of the left bank in Three Gorges hydropower station were consistent with the design drawings. The concrete surface in this inspected area was basically intact, without obvious uplift and collapse, the overall condition was good. The 3D scanning image of No.14 unit was showed in Figure 2, and the 3D image of No.7 unit was showed in Figure 3.

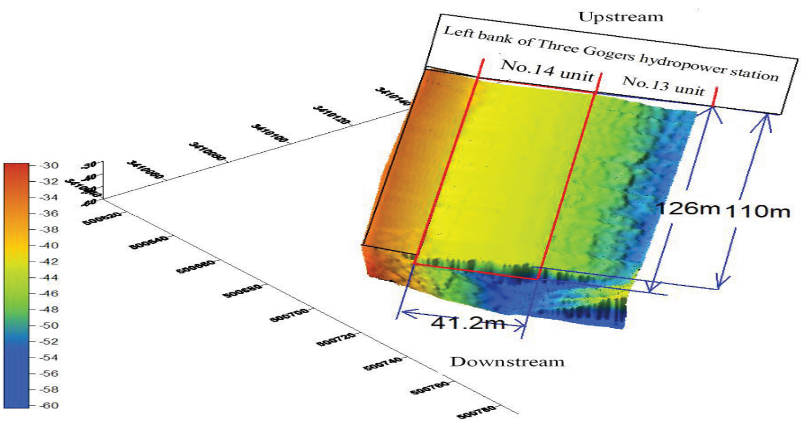

Figure 2 : Scanning image of No.14 unit in tailrace area of left bank in Three Gorges hydropower station

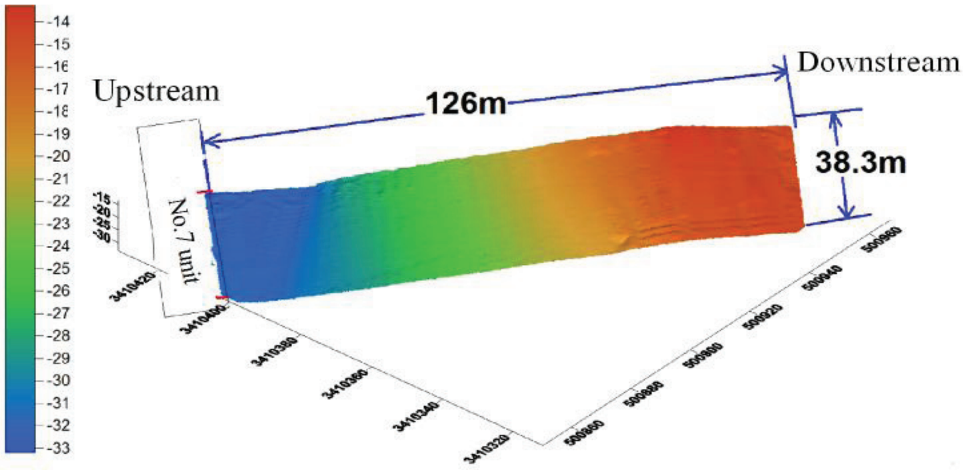

Figure 3 : Scanning image of No.7 unit in tailrace area of left bank in Three Gorges hydropower station

This underwater inspection was mainly based on multi-beam sonar, supplemented by air diving, the inspection results were intuitive, and the image data was easy to save.

3.2 Underwater inspection case in Gezhouba hydropower station

3.2.1 *Underwater inspection overview*

The Gezhouba hydropower station was built in 1988, no comprehensive underwater inspection was carried out in the tailrace area from the beginning to 2016. Based on the underwater inspection in tailrace area of Three Gorges hydropower station in 2014, it was necessary to use multi-beam sonar, combined with air diving, to conduct an underwater inspection in Gezhouba tailrace area, so as to understand the current status in this area and provide basis for next inspection.

3.2.2 *Underwater inspectiont process*

From January to April in 2016, referring to the previous underwater inspection process in Three Gorges hydropower station in 2014, the multi-beam sonar was mainly used for this inspection in the tailrace area of Gezhouba hydropower station. Relevant instruments were fixed on a working ship, where the underwater inspection was completed.

According to the existing data and on-site survey, divers checked the limpidity and depth of the water, and also, they used the current meter to measure the flow velocity to ensure the flow velocity was ≤ 0.5m/s, and the safety of subsequent diving work.

3.2.3 *Underwater inspection results*

As a whole, the tailrace area of Gezhouba hydropower station was in good condition, which was shown in Figure 3. Due to long-term scouring, scoured pits had formed in some area with a diameter of 6-10m and a depth of 2m, as shown in Figure 4. The phenomena of scouring did exist in some area of tailrace area, but the overall topography in tailrace area did not fluctuate much.

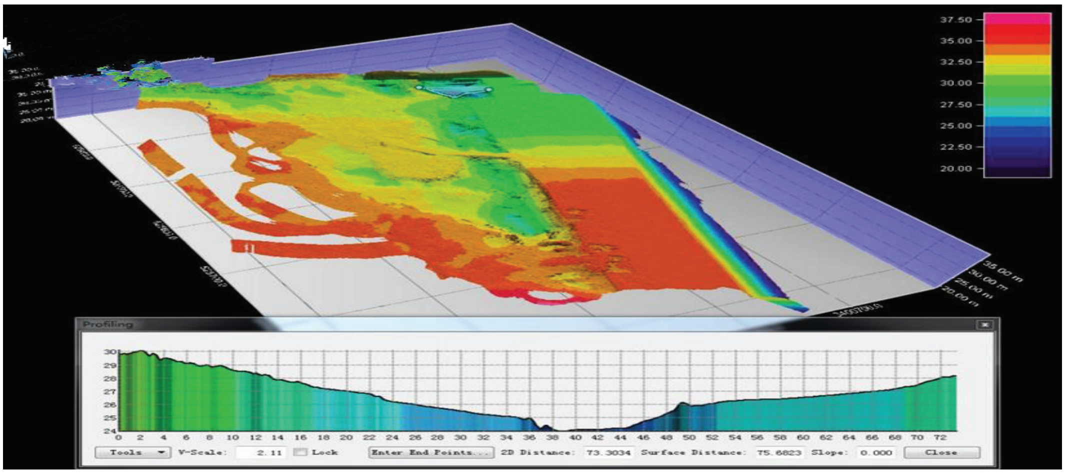

Figure 3 : Overall scanning image of tailrace area in Gezhouba hydropower station

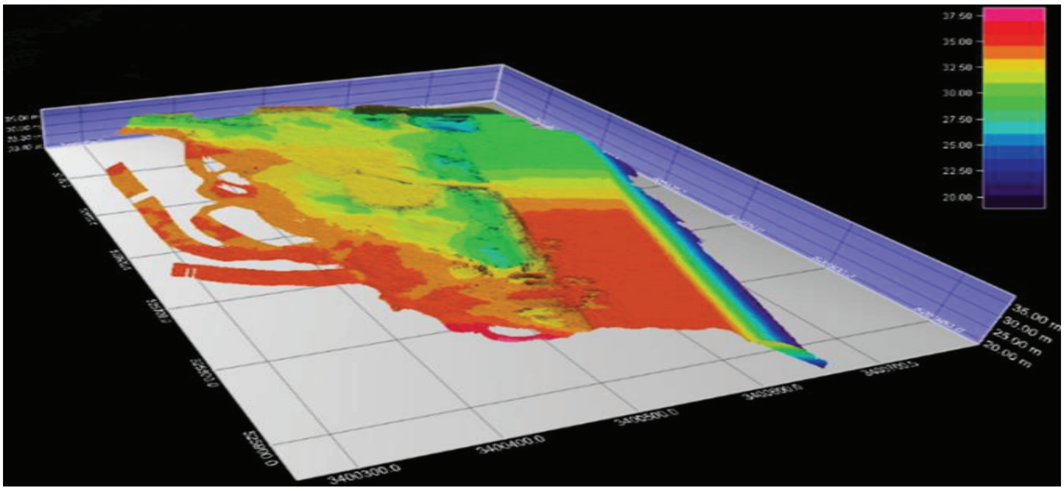

Figure 4 : Scanning image of scoured pits in tailrace area

3.3 Summary

The underwater inspection of tailrace area in hydropower stations mostly occurs in the annual maintenance period, generally from October to May in next year in China. During the period, the rainfall is less and the water is clear, which is conducive to underwater inspection. By testing four main underwater inspection methods one by one in the field, an innovative underwater inspection method suitable for the tailrace area was proposed, which was mainly based on multi-beam sonar, supplemented by air diving.

The results of the two inspections showed that the shape and scope of the tailrace area were consistent with the design drawings, the concrete surface of the tailrace area was basically intact and the overall condition was good.

4. CONCLUSION

The underwater inspection in the tailrace area is of great significance to hydropower stations, which is also conducive to cultivating the emergency management ability and enhancing the core competitiveness. With air diving, the multi-beam sonar can clearly show the underwater situation in the tailrace area and meet the requirements of regular inspection. Though some improvement, this method can also be used in other areas where have similar flow conditions with tailrace area. At the same time, this method has some enlightening for the inspection of other hydraulic structures in hydropower stations.

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