Research on Abrasion Protection Technology of Hydroturbine Components in Gongzui Hydropower Station

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Abstract. The volute and fixed guide vane of Gongzui hydropower station have been used for more than 50 years, and the wear and corrosion of them are serious. Polyurethane mortar is a new kind of anti-abrasion material, which has high bonding strength with the base surface. The elastic polyurethane material greatly improves the anti-cavitation performance of the coating, so that the coating can resist sand wear and hydraulic cavitation. The field test of fixed guide vane, seat ring and volute anti-abrasion of No. 1 unit of Gongzui hydropower station was carried out by Yellow River Institute of Hydraulic Research, YRCC, and combined with the characteristics of Dadu river with high sediment content, the material ratio was optimized, and the construction technology was improved, so as to explore the hydroturbine anti-abrasion technology suitable for the characteristics of sediment and abrasion and cavitation damage. After the success of this technology, it can be used as a demonstration for hydropower stations in Dadu river basin to comprehensively improve the anti-abrasion ability of flow parts and the level of safe production and operation.

Keywords: Gongzui hydropower station; flow parts; abrasion protection; polyurethane mortar.

1. Introduction

The Dadu river basin is planned to develop 28 cascade power stations, with a total installed capacity of about 23.4 million kw. Guodian Dadu river basin hydropower development co., ltd. is responsible for the development of 17 cascade power stations in the main stream, covering 12 counties in three prefectures and two cities in sichuan province (Ganzi prefecture, Aba prefecture, Liangshan prefecture, Ya’an city and Leshan city), with a total installed capacity of about 17.57 million kw. Gongzui hydropower station is located in the middle and lower reaches of Dadu river at the junction of Shawan district and Ebian county, Leshan city, Sichuan province. The development goal is mainly to generate electricity. The project started in March 1966, and was impounded in 1971. In February 1972, the first generating unit was built and put into production in 1978. The normal water level of the project is 528m, the checked flood level is 530m, the dead water level and flood limit water level are 520m, and the corresponding original storage capacity of the three-level characteristic water level is 345 million m³, 373.7 million m³ and 243.2 million m³ respectively, and the influence range of backwater is 42.0km[1]. The upper level of Gongzui reservoir is Shaping hydropower station and the lower level is Tongjiezi hydropower station.

The barrage of hydropower station is a concrete gravity dam with a dam top elevation of 530.5m and the maximum dam height of 85m. The dam top is 447m in length and the designed water head is 48m. The
total installed capacity is 770,000 kW. Seven hydroturbine generator sets with a capacity of 110,000 kW are located in the underground workshop on the left bank and the underground workshop on the right rock[2]. According to the underwater topographic survey report of unit 5~7 in 2013, the silting elevation of barrier platform is almost equal to the elevation of barrier top, and the silting elevation in some places is even greater than the elevation of barrier top. This will lead to the detention grid fall is not in place, seriously affect the blocking effect, and increase the amount of sand, so as to aggravate the abrasion of the turbine. According to the silting measurement report of Gongzui power station in 2016, the storage capacity below flood limit level of 520m is only 0.165 billion m³, and the regulated storage capacity is only 0.88 billion m³, which leads to silting at the entrance of the power generation hole and seriously affects the normal operation of the unit. With the deterioration of the environment in Dadu river basin and the serious deposition of silt in Gongzui reservoir, the abrasion phenomenon of turbine flow parts is becoming more and more serious. Problems such as turbine top cover, leak stop ring, runner blade penetration crack and water diversion cover crack have been reformed and repaired for many times[1, 3-6].

In recent years, Gongzui hydropower station has carried out the project of unit capacity increase, which has improved the turbine, top cover, bottom ring and movable guide vane of the hydroturbine set with serious abrasion, and greatly improved the anti-abrasion ability of the flow parts. However, under the erosion of high-speed sand flow, the fixed guide vane, volute and water diversion pressure steel pipe buried deep in concrete suffer from serious abrasion, as shown in figure 1~2.

![Figure 1. Abrasion of fixed guide vane and seat ring.](image1)

![Figure 2. Abrasion of volute.](image2)

As can be seen from figure 1, due to the erosion of high-speed hyper-concentration flow, the fixed guide blade and seat ring are seriously corroded, with deep pitting and pits appearing on the whole, and part of guide blade base material is seriously damaged, which affects the flow state of the water, leading to the decrease of the support force of the fixed guide blade. As can be seen from figure 2, both the volute and the pressure steel tube have some cavitation failure pits, and the part near the inlet of the fixed guide vane is seriously eroded, and the junction with the seat ring is worn through, which directly affects the safe operation of the volute.

The abrasion problem of hydraulic machinery is a worldwide problem. At present, there is a universal abrasion problem in the units of hydropower stations in service. With the improvement of casting materials and technology of the runner, although it has been restrained to a certain extent, the cavitation of other over flow parts is still serious. Gongzui hydropower station has been in operation for more than 40 years, serious wear and corrosion occurred in the volute and fixed guide vane of the unit. The enveloping angle of the volute is worn through in many places near the seat ring and the fixed guide vane, and a thick oxide skin is formed on the whole volute wall. The thickness of the volute is reduced from...
24mm to 16~18mm, which have a great threat to the safe operation of the unit. The power plant has entrusted the relevant hydropower construction units to use epoxy mortar for a tentative repair. After a flood season, the inspection found that the fixed guide blade was partially detached from the face water surface, but the back water surface was almost completely detached. Therefore, it is urgent to adopt new anti-wear materials to repair the anti-wear of the over-flow parts of Gongzui power station, and find out the anti-wear technology of cascade hydropower station suitable for the sediment characteristics of Dadu river, so as to improve the anti-wear performance and service life of the over-flow parts, and greatly improve the operation benefit of the power station.

2. Abrasion Protection Technical Scheme

At present, the spiral case, fixed guide vane and seat ring of hydraulic turbine are often treated with general anti-corrosion paint or epoxy mortar coating. Under the erosion of water containing sand, anti-corrosion paint or epoxy mortar coating often falls off seriously due to poor adhesion performance or poor cavitation resistance, which cannot play a role in erosion protection. Polyurethane polyurethane mortar coating is a new type of anti-abrasion material with high bonding strength with the base surface. The coating surface is compounded with a layer of elastic polyurethane material, which greatly improves the anti-cavitation performance of the coating, so that the coating can resist both sediment wear and hydraulic cavitation. There have been many successful application experiences in many domestic hydropower stations.

Combining with the high characteristics of the sediment content of the Dadu river, the ratio of the abrasive material is optimized, the construction process of the material is improved, and a hydroturbine abrasion protection technique is explored for the sediment characteristics and the characteristics of the abrasion and erosion. This technique is a demonstration of the technology in the river basin, which can improve the abrasion resistance and the level of safe production of the flow parts of the unit.

2.1. Mechanical Properties of Materials

The polyurethane mortar coating is composed of polyurethane mortar resin, curing agent, hard metal powder, corundum and water resistant agent, the mechanical properties of the coating are excellent, and the adhesion of the base is very strong, the resistance to the abrasion and the resistance of the corrosion resistance is excellent, the coating thickness is 2mm~ 4mm. The mechanical properties and wear resistance of the material can be studied, and the performance of the abrasion protection material is obtained, and the abrasion protection material suitable for the comprehensive ability of the Gongzui hydropower station is optimized, as shown in table 1.

| No. | Items                      | Units | Index                  |
|-----|----------------------------|-------|------------------------|
| 1   | Compressive strength       | MPa   | ≥80                    |
| 2   | Tensile strength           | MPa   | 24~28                  |
| 3   | bending strength           | MPa   | ≥10                    |
| 4   | Bonding strength           | MPa   | >4(concrete); 20~30(steel) |
| 5   | Impact strength            | MPa   | 23~40                  |
| 6   | Abrasion resistance strength | h/(g/cm²) | 10~15                |
| 7   | Cavitation rate            | g/h   | 0.05~0.1               |

2.2. Construction Technology

The construction process of polyurethane mortar is simple, easy to operate, not strict in the construction environment, and can be suitable for the large area construction of the fixed guide vane and the volute. The specific process is as follows:

(1) Preparation before construction
Transport the material to the location of the site, and arrange the construction materials in accordance with the material category. Turn on the power supply and gas source.

(2) The surface of the workpiece is polished and preheated
Treat the location of the mortar to be treated by sandblasting machine, and the original anti-corrosion paint is removed until the metal is exposed. The processing position of the processing position is in advance, using the caterpillar ceramic heating film, the silicon rubber electric blanket and the thermocouple.

(3) Apply primer
Start from top to bottom, then brush the left and right side, and then brush the diagonal direction, and then trim the corner. The coating meets requirements of thin and uniform, unflowing and unoutcrop.

(4) Apply polyurethane mortar
Apply the high strength mortar to the construction position.

(5) Solidification
The mortar is heated and solidified by the heating of the caterpillar ceramic heating film, the silicon rubber electric blanket and the thermopair.

(6) Coating modification
After the coating is completely solidified, the coating is repaired.

![Construction process](image)

**Figure 3.** Construction process

### 3. Technical Difficulties and Construction Results

#### 3.1. Technical Difficulties
The volute of Gongzui hydropower station is protected by traditional heavy anticorrosive coating, but the effect is poor, and it falls off completely after one flood season. The material of the volute is carbon steel, which is corroded seriously by soaking in water for a long time, forming a thick oxide skin. The volute near the water inlet of the unit suffered serious wear and tear under the impact of sand-containing water flow, and the steel plate at the seat ring was worn through, as shown in figure 4.

![Flow passage components](image)

(a) Volute oxide layer (b) The water inlet of the volute

**Figure 4.** Abrasion of flow passage components of Gongzui unit.

The treatment of the base surface directly affects the effect of subsequent coating. The treatment of the base surface must reach the specified roughness and finish. On the grinding, sandblasting and other treatment methods for comprehensive comparison, combined with the treatment efficiency and treatment effect, the first choice is to use high-pressure water gun to scour the volute oxidation layer, surface scum and dust are cleaned, and then use the needle type air shovel to deal with the thick oxide skin, and finally use sandblasting machine for sandblasting. After the combined treatment of "high-pressure water gun + air shovel + sand blasting machine", the surface cleanliness of the metal structure of the volute, seat ring and fixed guide vane should reach the required Sa2.5 level, and the roughness should also reach the requirements of 60~100μm, as shown in figure 5.
3.2. The Effect of Construction

According to the construction process in section 2.2, the polyurethane mortar is uniformly applied to the surface of the volute, the fixed guide vane and the seat ring with strict quality control measures. The construction effect is shown in figure 6.

4. Conclusion

In order to solve the problem of serious abrasion of the over-current components of the turbine unit of Gongzui hydropower station, the fixed guide vane, seat ring and volute of unit 1 in Gongzui hydropower station were studied by using polyurethane mortar. Combining with the characteristics of the sediment content of the Dadu river, the ratio of the abrasive material is optimized, the construction process of the material is improved, and a hydro turbine abrasion protection technique is explored for the sediment characteristics and the characteristics of the abrasion and erosion. After the test is successful, the technology can be applied to the hydropower station in Dadu river basin for demonstration, which can improve the anti-abrasion ability of the over-current components and the level of safe production operation.

Acknowledgement

This research was financially supported by the national natural science foundation of China (51779101, U1965110), and fundamental research funds for the central nonprofit research institutions (HKY-JBYW-2018-01).

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