Research on Welding Technology and Intelligent Repair Technology of Hydraulic Turbine Movable Guide Vane in Yuzixi Hydropower Station

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Abstract: Due to the influence of natural disasters, the sediment content of hydropower station increases in flood season, and the wear of flow passage parts of hydraulic turbine is aggravated, especially the movable guide vane and runner blade. In order to ensure the normal operation of the power plant, it is necessary to repair the seriously worn flow passage components by welding during the maintenance period. Aim at solving that problem that the labor intensity of manual welding repair of the existing power station is high, In this paper, the guide vane of Yuzixi Hydropower Station is taken as the object to study the welding process, and the intelligent welding robot is applied to the welding repair process, and finally the welding repair technology with high welding quality and high degree of intelligence is formed.

1. Introduction

The movable guide vane is the core component of the water distributor of the water turbine, which plays a role in controlling the flow rate and the flow direction[1]during the operation of the water turbine. Due to the abrasion and cavitation of sand, there are large areas and a large number of pits on the surface of the guide vane and the journal of the third section, or the thickness of the guide vane is reduced to varying degrees, resulting in poor closure between the guide vanes and distortion of hydraulic streamline. As a result, the power generation efficiency of the turbine is reduced, and in serious cases, the turbine cannot be shut down due to too large leakage flow[2]. For this reason, the movable guide vane will be repaired by welding at a certain time every year, but the maintenance, repair and repair of the power station also include the welding of other flow passage components, and the welding workload is huge. The existing manual welding type of work in the power station can not cooperate with the highly automated machining type of work, at the same time, welding produces a large number of smoke and harmful gases, which seriously affects the health of operators. Under harsh welding conditions, it is difficult for welders to maintain the stability and consistency of welding work for a long time, thus affecting the welding quality and efficiency.

Therefore, this paper takes the welding repair of guide vane as the research object, based on the intelligent welding robot, forms the welding process by welding customized materials, and carries out the application research of intelligent welding repair on the worn guide vane of power station.

2. Movable Guide Vane for Test

Fig. 1 shows the worn guide vane of Yuzixi Hydropower Station, which is made of 00Cr16Ni5Mo. It can be seen from the figure that the movable guide vane is seriously worn and is not suitable for continuous operation. For those with repair and utilization value, welding repair should be carried out. The guide vane in this paper is transported from Yuzixi Hydropower Station to the test site for welding repair. Fig. 2 shows the movable guide vane after manual welding and grinding.

Fig.1 Worn Movable Guide Vane

Fig.2 Vane after Manual Welding and Grinding

Before that repair, a stainless steel plate with the same material as the movable guide vane is customize, the material is subjected to trial weld, a welding process is formed, and welding relate parameters are obtained.

3. Intelligent Welding Robot System

Intelligent manufacturing can improve production efficiency[3].Therefore, Yaskawa six-axis industrial robot is used as the core component of the system, equipped with Kelda digital welding power supply, with the vision positioning system, and with the self-developed process programming software and process monitoring software, forming a highly intelligent robot system. Table 1 shows the composition of the system, and Figure 3 is the three-dimensional schematic diagram of the surfacing system.

Table 1 Composition of Intelligent Welding Robot System

Yaskawa MH12	1 set	Head tail single axis positioner of Beifu electric control system	1 set
Real time tracking and guiding process package	1 set	Safety device	1 set
Kelda welding system	1 set	Gun cleaning and wire cutting mechanism	1 set
Kelda push-pull wire welding gun	1 set	3D vision system	1 set
Beifu electric control system	1 set	Customized surfacing software	1 set

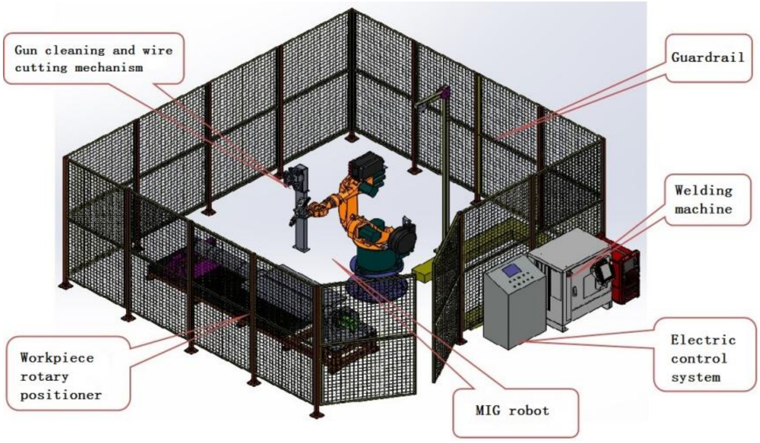

Fig.3 Three Dimensional Schematic Diagram of Surfacing System (Shaft Workpiece)

In order to obtain a more accurate welding process and achieve a better welding repair effect, Kelda servo welding system (as shown in Figure 4), Twin CAT Vision system (as shown in Figure 5) and the self-developed laser welding seam locating system (as seen in Figure 6) are used in this welding.

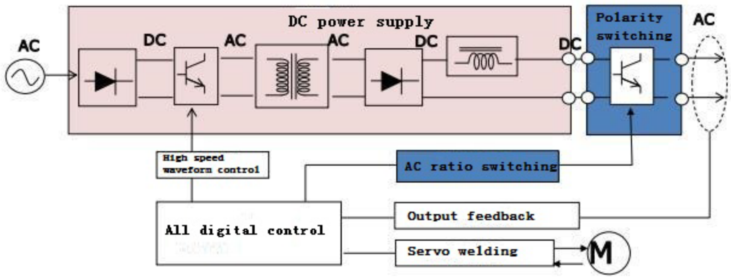

Fig.4 Welding System

Fig.5 Beifu Twincat Vision System

Fig.6 Laser Weld Positioning

Welding software system includes Powermill robot general off-line programming software, welding process expert system and welding monitoring system.

4. Design of Welding Process Flow

In order to realize the rationality of the manufacturing process and the reliability of the structure, the key to solve the problem is to analyze and study the welding deformation and its control[4]. Movable guide vane belongs to shaft work pieces. In view of the key welding problems, the welding repair process flow is formulated:

(1) The user imports the work piece drawing in the system (or inputs the characteristic parameters of the work piece for automatic modeling), and the system generates the test program (including welding path and welding parameters). The test welding test can be carried out on the preset test piece. If there is any problem in the test welding, the operator can correct it in real time;

(2) After the test welding is successful, the system automatically records the qualified process parameters (including robot speed, welding gun angle, posture, welding current, voltage, etc.);

(3) a us imports a product draw in that system, and the system automatically generates all welding seam process paramete tables and robot programs, and numbers the tables and the robot programs in turn;

(4) mount and positioning that workpiece through the tool on the displacement machine;

(5) determine that position of a reference point through the contact position finding function of the robot;

(6) the system carries out overlaying welding, the user can control the welding path of the robot by arranging the welding bead number on the operation interface, and finally generates the welding program of the whole workpiece;

(7) that robot finish all the overlaying weld according to a preset program.

5. Process Test Design

5.1 Welding Target

Surfacing shall be carried out according to the specified WPS, and there shall be no defects such as crack, slag inclusion, undercut, burn-through, pore, crater, lack of fusion and weld discontinuity; Surfacing surface shall be free of oil, moisture and scale that may affect the welding quality; And the tolerance between the workpiece and the model before surfacing is less than 1mm; The surface after surfacing meets the processing requirements.

5.2 Test Procedure

(1) Pretreatment of guide vane to be repaired: machining to model size;

(2) Clean the oil, water and oxide skin on the surface of the guide vane;

(3) build a test platform;

(4) completing the off-line programming work according to the provided three-dimensional model;

(5) Complete robot calibration, workpiece reference calibration, welding gun calibration and other work;

(6) the program is introduced into the robot, and the test is carried out in the state of no arc, so as to ensure the correctness of the track;

(7) Automatic welding in the whole process;

(8) Carry out post-welding inspection.

5.3 Welding Process Test Platform

A test platform is built on the existing MH12 robot. The welding machine adopts the KELDA 350SW welding system, and the welding gun selects the KELDA push-pull wire welding gun. The welding platform is configured, and the welding test sample is placed on the test platform (as shown in Figure 7), with the size of 500mm * 300mm * 20mm. The test sample is welded mainly to verify the welding process. Prepare for subsequent tests.

Fig.7 Welding Process Test Platform

(1)Welding method

MAG single-layer single-pass, multi-layer single-pass and multi-layer multi-pass welding shall be adopted, the shielding gas shall be argon rich mixed gas (95% A_r + 5% CO_2) bottled gas, and the welding wire shall be Φ1.2mm ER415L stainless steel coil welding wire.

(2)Welding process records

Table 2 is the Record of Welding Process Test of Flow Passage Components.

Table 2 Test Process Record

No.	Current (A)	Voltage (V)	Swing welding form	Swing welding speed(mm)	Swing frequency (HZ)	Swing amplitude (mm)	Surfacing gap (mm)
1	200	21	none	100	/	/	/
2	250	24	none	100	/	/	/
3	270	28.2	none	100	/	/	/
4	270	28.2	Triangular pendulum	100	3.5	3	/
5	285	29.5	Triangular pendulum	100	3.5	3	5
6	285	29.5	Triangular pendulum	90	3.5	3	5
7	295	30.7	Triangular pendulum	90	2	3	5
8	295	30.7	Triangular pendulum	90	2	3	5
9	295	30.7	Triangular pendulum	90	3	2	5
10	295	30.7	Triangular pendulum	90	3	2	5
11	295	30.7	Triangular pendulum	90	3	2	5
12	305	31.2	Triangular pendulum	90	3	2	5
13	295	30.5	Triangular pendulum	90	3	2	5
14	295	30.5	Triangular pendulum	90	3	2	5
15	295	30.5	L pendulum	90	3	2	5
16	295	30.5	L pendulum	90	4	3	5
17	295	30.5	L pendulum	90	4	3	6
18	295	30.5	L pendulum	90	4	3	6
19	295	30.5	L pendulum	90	2	4	6
20	295	30.5	L pendulum	90	2	4	6
21	295	30.5	L pendulum	90	3	3	6
22	295	30.5	L pendulum	90	3	3	6

23	295	30.5	L pendulum	90	3	3	6
24	295	30.5	L pendulum	90	3	3	6
25	295	30.5	L pendulum	80	3	3	6
26	295	30.5	L pendulum	80	3	3	7
27	295	30.5	L pendulum	80	3	3	8
28	295	30.5	L pendulum	80	3	3	8
29	295	30.5	L pendulum	80	3	3	5
30	295	30.5	L pendulum	80	3	3	5
31	295	30.5	L pendulum	80	3	3	5
32	295	30.5	L pendulum	80	3	3	5
33	295	30.5	L pendulum	80	3	3	5
34	295	30.5	L pendulum	80	3	3	5
35	295	30.5	L pendulum	80	3	3	5
36	295	30.5	L pendulum	80	3	3	5
37	295	30.5	L pendulum	80	3	3	5
38	295	30.5	L pendulum	80	3	3	5
39	295	30.5	L pendulum	80	3	3	5
40	295	30.5	L pendulum	80	3	3	5
41	295	30.5	L pendulum	80	3	3	5
42	295	30.5	L pendulum	80	3	3	5
43	295	30.5	L pendulum	80	3	3	5
44	295	30.5	L pendulum	80	3	3	5
45	295	30.5	L pendulum	80	3	3	5
46	295	30.5	L pendulum	80	3	3	5
47	295	30.5	L pendulum	80	3	3	5
48	295	30.5	L pendulum	80	3	3	5
49	295	30.5	L pendulum	80	3	3	5
50	295	30.5	L pendulum	80	3	3	5

After 50 surfacing experiments, the appearance of surfacing has been presented, and the appearance of weld bead and height is uniform and smooth, which proves that the intelligent welding robot can realize surfacing. Fig. 8 shows the effect of the sample before and after welding.

(a) before welding *(b) After welding*

Fig.8 Effect of Customized Parts Before and after Welding

Through the realization of the above welding process of customized parts, it shows that the intelligent welding robot can realize surfacing, and the weld and weld bead are uniform and beautiful, so it can carry out the next test.

6. Off-Line Programming Surfacing Test Platform and Test

The off-line programming surfacing test platform is built on the existing KUKA KR16 robot, the welding machine adopts Fronius TPS5000 welding system, the welding gun selects TBI R50W, and is equipped with a head-to-tail single-shaft positioner and a TBI gun cleaning and wire shearing mechanism. Cooperate with offline programming powermill to automatically generate the welding path and weld the actual work piece to verify the feasibility of offline programming. Fig. 9 shows an off-line programming surfacing test platform.

Fig.9 Surfacing Test Platform

6.1 Off-Line Programming

Establish 3D offline models of robot, welding gun and guide vane, and complete offline programming of surfacing based on powermill robot and secondary development program, including path planning, path simulation, program conversion, etc., as shown in Figure 10.

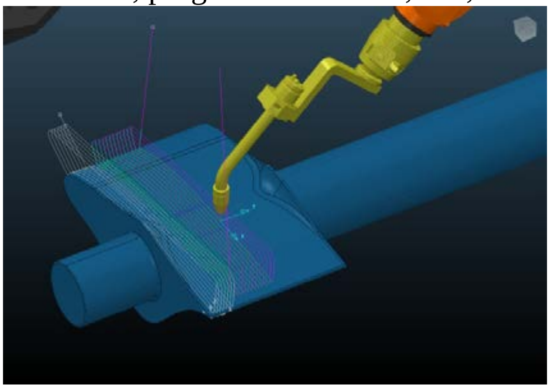

Fig.10 Offline Programming

6.2 Welding Method

MAG single-layer single-pass, multi-layer single-pass and multi-layer multi-pass welding shall be adopted, the shielding gas shall be argon rich mixed gas ($92A_r$ + 8% CO_2) bottled gas, and the welding wire shall be Φ1.2mm solid coil welding wire.

6.3 Welding Effect

The welding effect is shown in Figure 11.

(a) stage 1 *(b) stage 2* *(c) stage 3* *(d) stage4*

Fig.11 Welding Effect At Different Welding Stages

7. Conclusion

Using off-line programming to weld the actual work piece, the overall effect is better than that of manual teaching, and it can adapt to the surface with radian of the work piece, which proves that the intelligent welding robot system can be applied to the surfacing repair of the movable guide vane in Yuzixi Hydropower Station. In the next step, according to the actual needs of the power station, under the condition that the system equipment can enter the site, The system was transported to the foundation pit of the power station, and the movable guide vanes were repaired by welding using the system without dismantling the movable guide vanes during the maintenance period. Through the research on welding robot by this system, it is believed that welding robot technology will also be studied and improved day by day[5].

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