Research on the Key Technology for Robot Intelligent Welding of Q235-Hydraulic Oil Tank

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Abstract: To solve the problems such as low welding efficiency, poor welding molding quality in manual welding of hydraulic oil tank, this paper conducts a research on intelligent robot welding technology for hydraulic oil tank. Aiming at these problems of various types and non-standard sizes of the tanks，this paper designs a flexible fixture for the tanks, and studies the influence between the weld quality and the welding speed, current, voltage, protective gas, and other process parameters through the welding experiment, finally a set of robot welding technology of hydraulic oil tank which in the size of 1000mm×500mm×500mm is formed.

1 INTRODUCTION

The hydraulic oil tank as a key part of the hydraulic system, played a crucial role in storage of hydraulic oil, transmission and ensure the normal operation of the hydraulic system. Therefore, the hydraulic oil tank has a particularly high for welding quality especially air tightness requirements after welding.

At present, the welding of hydraulic oil tank mainly depends on the traditional manual arc welding, some of which are introduced into robot welding, and the welding material usually faces up to 3mm thick plate. Due to the large thermal influence zone in the process of arc welding, the thermal deformation of the workpiece is large, which can produce the complex residual stress,the welding seam is poor and needs polishing after welding. It is easy to form porosity, slag, unmelted and unsoldered welding defects during the welding process. In severe cases, minor cracks occur, causing oil spills in the tank, which causes serious safety problems to the stability of the hydraulic system. Therefore, the research on high quality and high efficiency welding technology of hydraulic oil tank is very important to maintain the stability and safety of hydraulic system.

Robot welding with its high speed, high quality, good flexibility, easy to realize automation, is widely used in shipbuilding, weapons and equipment, marine engineering, automobile industry, railway vehicle, hydraulic equipment manufacturing and other fields, occupies a significant role in manufacturing.Taking the hydraulic oil tank as research object, this paper carried out the research through the welding process, welding seam tracking technology and flexible fixture design.

2 WELDING SYSTEM AND MATERIAL

Figure 1.Robotic arc welding system.

Robotic arc welding system is mainly composed of FANUC M-20i six joint robot, 500kg of two-axis displacement machine, Lincoln R500 arc-welding machine, STT advanced welding process module, automatic wire feeding machine, ABIROB A500 air-cooled welding torch and Torch Clean Station cleaning equipmentas shown in Figure 1.At the same time, it is equipped with J511 welding arc tracking software, J536 starting point seeking software, J532 multi-layer welding software.

2.2 The Welding Object

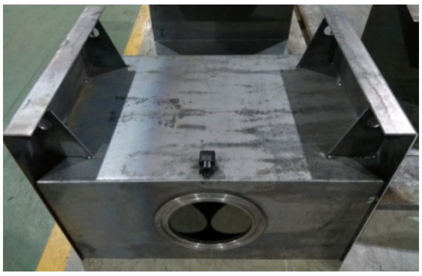

Figure2. Hydraulic oil tank.

The welding object is a type of tire vulcanizing machine oil tank and its size is 1000mm×500mm×500mm as shown in Figure 2.

The material is Q235-A steel, its chemical composition is shown in Table 1.

Table 1:The chemical composition of welding material.

Material	Chemical composition （%）				
Q 235-A	C	Mn	Si	S	P
			≤		
	0.14~ 0.22	0.30~ 0.65	0 .30	0 .05	0 .045

The metallurgical reaction of welding material in welding process is closely related to the formation of welding porosity[1].When the carbon content in the liquid weld is high and the deoxidation is deficient, there are more FeO in the molten pool.When the molten pool temperature drops, the following reaction will occur[2]:

$$[C]+[O]=CO\uparrow$$

$$[FeO]+[C]=[Fe]+CO\uparrow$$

$$[MnO]+[C]=[Mn]+CO\uparrow$$

$$[SiO2]+2[C]=[SiO]+CO\uparrow$$

If the molten pool has started to crystallize, then CO will be unable to escape and produce a CO porosity. The higher the carbon content of the welding material itself, the more likely it is to produce a CO gas, thus forming a porosity.

The Si and Mn in the welding materials are deoxidized elements which can effectively inhibit the production of CO gases.But the contents of Si and Mn in parent material are usually not high.Therefore, the wire with high content of Si and Mn, such as H08Mn2Si wire, can effectively suppress the keyhole-induced porosity [3].

3 EXPERIMENTAL STUDY ON ROBOT WELDING PROCESS

The welding process test involves the influence of parameters such as welding voltage, current, welding speed, shielding gas (type and flow rate) on the quality of welding seam. Huang Jiaqing[4], from zhong che zhu zhou electric locomotive co., LTD, has studied the welding process of the locomotive bogie hollow shaft robot. The experimental results show that it is better to use 80% Ar + 20% CO^2 mixture protective gas than the CO^2 protective gas in welding process and the microstructure of the welding joint consists of acicular ferrite as shown in Figure 3.The microstructure of the overheat zone in the thermal area of welding is obviously grown as shown in Figure 4, and its tissue is consists of pre-eutectoid ferrite, pearlite and a small number of bainite.

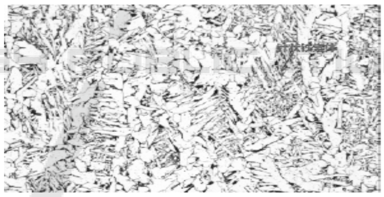

Figure 3 The microstructure of weld seam[4].

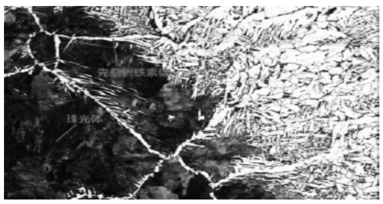

Figure 4.The microstructure of the fusion area[4].

During the early stage of the welding process test, the welding voltage, current, welding speed, protective gas (type and velocity), arc starting and stopping control parameters did not match properly, which lead to welding quality is not ideal as shown in Figures 5 and 6.The quality of the start and end point of arc welding is poor, the surface of welding seam is discontinuous and raised serious.

Figure 5.The weld molding under the immature process parameter (1).

Figure 6.The weld molding under the immature process parameter (2).

After a lot of process experiments and refer to the relevant welding literature, the author finally determined the better welding parameters of 5mm and 8mm these two kinds of common plate thick fuel tank as shown in table 2 and 3.

Table2: Welding process parameters of 5mm thick Q235 carbon steel plate.

Material property	Type	Plate	Material	Q235
	Thicknes	5mm	Weld form	tailor welded
General parameters	Weld Mode	11-18 Rapid ArMix	Wire diameter	φ1.2 mm
	Protective gas	80%Ar+ 20%CO_2	Gas velocity	25L/ Min
	Torch angle	10°	Electrode extension	12mm
Welding process parameter	Welding voltage	23.6V	Welding current	200A
	Weldingspeed	235mm/s	Time	/
Arc starting control	Welding current	Welding voltage	Time	
	126A	18V	0.01s	
Arc extinguishing control	Welding current	Welding voltage	Time	
	140A	18V	0.30s	
Welding release	Welding current	Welding voltage	Time	
	200A	20V	0.10s	
Welding piceure				
Problem analysis	The weld seam is smooth, continuous, without convex.The averageweld reinforcement is 0.3mm hight and the weld width is 5.5-6.0 mm, the overall surface quality is better.			

Table3: Welding process parameters of 8mm thick Q235 carbon steel plate.

Material property	Type	Plate	Material	Q235
	Thicknes	8mm	Weld form	tailor welded
General parameters	Weld Mode	41 CVArMix	Wire diameter	φ1.2 mm
	Protective gas	80%Ar+ 20%CO_2	Gas velocity	25L/ Min
	Torch angle	10°	Electrode extension	12mm
Welding process parameter	Welding voltage	27.9V	Welding curren	300A
	Weldingspeed	245mm/s	Time	/
Arc starting control	Welding current	Welding voltage	Time	
	240A	22V	0.04s	
Arc extinguishing control	Welding current	Welding voltage	Time	
	240A	22V	0.03s	
Welding release	Welding current	Welding voltage	Time	
	200A	20V	0.10s	
Welding piceure				
Problem analysis	The weld is smooth, without obvious bulge, and the end point of arc is flat.			

4 THE RESEARCH ON SEAM TRACKING TECHNOLOGY

Because the processing error of the tank plate is larger(about 1~3mm), the source of the error mainly includes the followings: (1) The dimensional error and deformation caused by the shearing process of plate shearing machine;(2) The bending process would produce dimensional error. Beside, because the welding process would produce thermal deformation, it causes current teaching programming can not meet the requirements of real-time seam tracking. Therefore, seam tracking technology should be introduced.

In the research of seam tracking technology, Sun Li, Lin Tao and others from Shanghai Jiao Tong University[5], Gao Xiangdong, Ding Dukun and others from Guangdong University of Technology[6], have studied a seam tracking technique based on machine vision, Zhang Wenzeng, Chen Qiang and others from Tsinghua

University[7], Sun Mei,Du Jun and others from Nantong University[8], have studied the trajectory tracking technology of welding robot based on 3D stereovision. Although the above scholars have made many achievements, we consider the cost of the program and the ease of implementation of the technology, this article studied welding seam tracking technology based on arc sensor(The principle is shown in Figure 7).

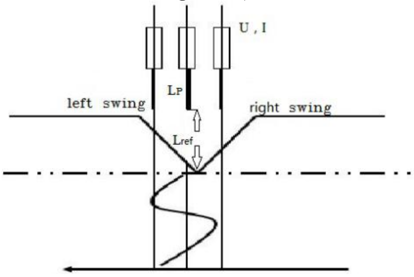

Figure 7.Working principle of arc sensor.

By establishing a simplified numerical model between the output voltage Uo and the arc length Larc and the corresponding current Iarc, and compare the current Iarc at different distances with the reference current Iref of the system, thus realizing the position tracking of the welding seam in the periodic swing welding process.

Among them, the voltage drop of electrode extension is:

$$U_P = R_P L_P I_{arc} \quad (1)$$

In the formula, RP is resistance per unit electrode extension. Lp for electrode extension.

The relation between the voltage Uarc and the current Iarc and the arc length Larc is:

$$U_{arc} = KL_{arc} + R_{arc} I_{arc} \quad (2)$$

In the formula, K is a unit of arc long voltage drop, L_{arc} is arc length, and R_{arc} is arc equivalent resistance.

In the process of welding, the supplyenergy between welding power and welding arc should be balanced[9]. That is to say, the output voltage of the welder U_O is equal to the arc load voltage U_S, while the arc load voltage U_S includes the arc voltage U_{arc} and the voltage drop of electrode extension U_P as follows:

$$U_O = U_S = U_{arc} + U_P \quad (3)$$

Comprehensive formula (1), (2), (3) available

$$U_o = KL_{arc} + R_{arc} I_{arc} + R_S L_S I_{arc} \quad (4)$$

In the welding process, the distance from the welding wire to the bottom of the V type weld is set to the reference distance $L_{ref.}$ According to the formula (4), we can see the value of the corresponding current at this time, and set it as the reference current I_{ref} in the system. In welding process, the distance of the wire from the bottom of v-shaped weld will change in real time by setting the welding torch to swing welding. At this point, the currentvalue of the arc sensor is I_{arc} as shown in Figure 8-10.Comparing with the reference current I_{ref}, when the welding trajectory is located in the center of the weld as shown in Figure 8, $I_{arc}=I_{ref}$, the current waveform is symmetrical, and the torch is advancing along the current weld trajectory; When the welding seam trajectory deviate left or right of the weld seam as shown Figure 9 and 10, $I_{arc} \neq I_{ref}$.At this time, the position of welding gun is modified continuously during the welding process, to searched the position of $I_{arc} = I_{ref,}$ which can achieve the purpose of real-time weld tracking.

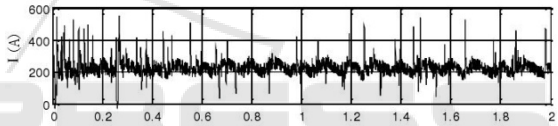

Figure 8.Current waveform diagram when the welding trajectory is located in the center of the weld [10].

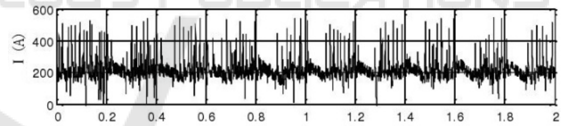

Figure 9.Current waveform diagram when the welding trajectory deviate left of the weld seam [10].

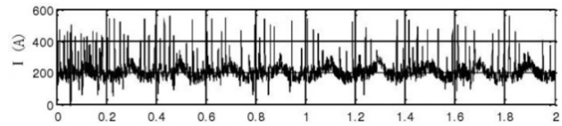

Figure 10.Current waveform diagram when the welding trajectory deviate right of the weld seam [10].

5 FLEXIBLE FIXTURE DESIGN

At present, most hydraulic stations are designed and manufactured in non-standard format, which results in various types and sizes of the fuel tanks. Furthermore, the plates have a certain size error in cutting and bending process. Therefore, it is necessary to have some flexibility for the corresponding fixture clamping device, which can be compatible with different types of fuel tank for quick loading and positioning. Aiming at the above problems, this paper designs a flexible fuel tank fixture based on pneumatic four-jaw as shown in figure 11 and 12.

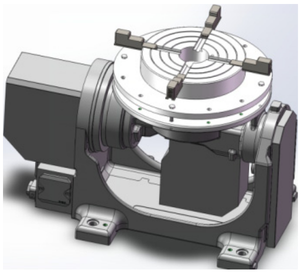

Figure 11.3D design of fuel tank fixture (1).

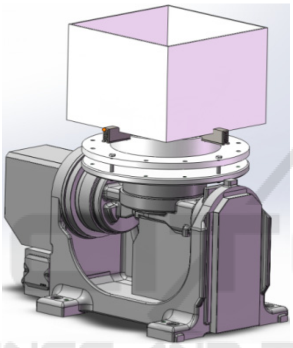

Figure 12.3D design of fuel tank fixture (2).

6 CONCLUSION AND PROSPECT

(1) Using robot to weld fuel tanks at the production site, the speed can be as high as 245mm/s. With special fixture, it can realize batch welding, high welding efficiency and good welding quality. The workload of a robot is equivalent to 3 to 4 ordinary welders. Besides, in the case of reasonable welding process, the welding qualification rate is high, the rework quantity is small, the labor cost is greatly saved, and the economic benefit is significant.

(2) In the aspect of study on seam tracking technique，the research of this paper only based on arc sensing at the present stage. Tracking stability and compatibility is relatively poor and we are going to conduct the study of weld tracking technology based on machine vision.

(3) At the present stage, this paper just studied welding process and fixture design of fuel tank.The follow-up will be carried out through the test of welding quality research, such as ultrasonic testing, tensile and bending, metallographic experiment, focusing on analysis of welding seam inside the porosity, crack defects, and then optimize the welding process.

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