

# Hull tag welding based on offline programming

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**Abstract**— In view of the current inaccurate positioning of the hull tag word and the unstable welding result, this paper proposes to weld the tag word by applying the robot offline programming method. Firstly, by analyzing the hull tag and classifying the tag words, the welding task objects are identified through the welding scene analysis. The welding of the tag words is completed by off-line programming. The welding results show that the welding quality and efficiency are improved; the marking coordinates are accurately positioned; and the working environment is improved.

**Index Terms**— Hull welding, hull tag word, Robot welding, Offline programming

## I. INTRODUCTION

At present, the welding of the hull tag of China's shipyards is mainly manual welding. The welding method is to establish the welding base plane through a piece of white paper, and then determine the welding position of the marking words by chalk scribing, so there are many problems in the welding process of the marking words. The main issues are as follows:

Welding quality problems of mark words. On ships, the tag word is one of the ways to indicate the characteristics of the hull. Therefore, the welding quality of the mark words should be as good as possible, and the welding pattern should be as beautiful as possible. In the actual welding process, the welding workers are not affected by the welding environment and their own state, and the quality of the marked characters is not high, and sometimes the welding deviation occurs.

(2) The problem of positioning the hull tag word. When marker welding is carried out in shipyards, the position of the mark word is usually read on the drawing, then the welding position of the mark word is determined by measurement, and finally the welding position of the mark word is obtained by drawing the line. In this process, it is difficult to accurately determine the position of the marker word due to the measurement error and the error obtained by drawing the line.

(3) The efficiency of manual welding. At present, when the shipyard welds the mark word, the welding method adopted is manual welding. The result of manual welding will be affected by the state of the worker, and the stability of the arm should be maintained during the welding process of the mark word, so it is difficult for the welder to weld. The welding speed of the mark word. According to statistics, the actual welding time of workers is less than 30% of their working time<sup>[1]</sup>.

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The application of welding robots to weld marking characters is an important application of industrial robots in hull manufacturing. At present, industrial robots are often used in the field of ships for welding between plates, and there is little research on the welding of hull logo fonts. Therefore, research on welding robots with the function of welding mark characters is of great significance for improving welding quality and welding efficiency.

## II. CLASSIFICATION OF HULL SIGNS

### A. Classification of tag words

The various signs of the ship are an integral part of modern ships, they have been proposed at the time of ship design and are placed on various parts of the ship before the ship is completed or delivered<sup>[2]</sup>. It is placed on the hull plate, the open deck or the exterior of the superstructure, and is mainly used to display the sign of the ship to the outside world, called the external sign. A sign that is placed inside the ship for display to people on board, called an internal sign. Among the hull signs, the internal signs are mostly identification signs, such as safety signs, fire equipment signs, emergency escape signs and so on. Since the number of mark words is large and there are many types, in this paper, the mark words are welded, so only the mark words are classified when classifying the marks. They are mainly divided into five categories:

(1) Tonnage, ship name and Hong Kong identity

The tonnage mark is generally set at the front wall of the superstructure; the name of the ship is set above the maximum waterline on the ship's first side of the ship, on the upper deck or on the hull plate below the first floor deck, and the other is placed above the maximum waterline at the end of the ship. , on the hull plate below the upper deck; the port name and IMO number are usually set below the tail name. The tonnage of the ship and the IMO logo are piled up with welding beads, and the paint with the contrast of the color of the hull paint is painted. The name of the ship is usually cut by 4mm or 5mm steel plate. The ship name mark is welded by manual welding. On the hull plate; the ship's port mark is the same as the tail ship name except for the smaller font.

(2) Equipment mark

The equipment mark is mainly the push sign. The push-pull sign shall be placed on the transverse bulkhead of the pushed ship, indicating that it can be pushed up by the pushing device. There are three commonly used push-pull tag (the first one is composed of the letters TUG and T-marks, the letter spacing is 120mm, the height is 400mm, the width is 320mm; the second is composed of the letters TUG and the arrow; the third is composed of the letters TUG and indicator arrows are composed.). The push-up mark is generally cut from a 6~8mm steel plate and fixed to the hull plate by welding.

(3) Hull structure mark

The hull structure mark is mainly composed of the tank and sewage well sign, the rib number sign, the cargo hold and its depth mark, the no smoking sign and the bulkhead sign. In order to indicate the characteristics of the tank and sewage well sign, the signs are usually placed at the four corners of the tank, sewage tank, sewage well and submarine door on the hull plate to show their outline and indicate the tank (well, door) Name of the hull; the rib number of the hull is set on the sideline or bulwark of the main deck near the deck. Starting from 0, the ribs are marked with weld beads every 5th rib; in the hatchway of each cargo hold The CC (Cargo Hold Center) mark shall be provided on the outer line of the outer edge of the board (facing the open air); for cargo ships carrying dangerous goods, a non-smoking sign shall be provided at a position easily visible on the ship, such as the side center line of the cargo hatch coaming; All types of ships are required to have a transverse bulkhead sign showing the position of the main transverse bulkhead on the hull plate to indicate the location of the watertight subdivision. For large ships, the sign can be enlarged accordingly to highlight the subdivision of the cargo hold.

The hull structure mark is made of 6mm steel plate, fixed on the ship's shell by welding, and painted with the contrast of the hull paint color contrast; the rib number is generally not painted; the cargo hold and its depth mark are generally It is surrounded by bead welding and coated with a coating that is in sharp contrast with the color of the hull paint; the draught mark is generally surrounded by welding beads and coated with a coating that contrasts significantly with the color of the hull paint; the bulkhead marking is generally 6~8mm. The steel plate is cut and welded on the outer surface of the hull, and the coating with the contrast of the color of the hull paint is painted.

#### (4) draught sign

The first and last drafts should be placed as close as possible to the vertical line. However, the tail draught scale is often difficult to set up due to the fact that the hull line shape near the waterline is too flat (the angle between the tangent and the horizontal plane is less than 30°), and the position can be adjusted according to the actual situation or the upper and lower segments can be set.

The drafting ruler usually has a steel plate of 6mm~8mm, which is fixed on the outer hull plate by welding, or is formed by electric welding, and after being smoothed, it is coated with a paint with a large contrast with the color of the hull paint. For example, when the base color is dark, the draft ruler is usually painted white, and when the base color is light, it should be painted in black or other contrasting colors.

#### (5) Underwater inspection mark

The underwater inspection mark is mainly composed of the water discharge plug mark, the sounder and the log probe mark, the sounder and the log probe mark. The drain plug mark is set on the outer plate near the drain plug; the hull direction mark is set at the center line of the flat bottom keel of the ship bottom, and a mark is set at a certain distance, generally arranged at the center point of the length of each watertight compartment, the specific quantity Determined according to the size of the ship and the requirements of use. The drain plug logo is cut from a 6mm steel plate and coated with a coating that contrasts significantly with the color of the hull paint. The depth sounder and the log probe mark are cut from a 6mm steel plate, encircling the probe, welded to the outer hull of the hull, and coated with a coating that contrasts

significantly with the color of the hull paint. The hull direction mark is cut from a 6mm steel plate, welded to the ship's floor and coated with a coating that contrasts significantly with the color of the hull paint.

#### B. mark word welding analysis

In the current ship construction, there are two main ways to weld the mark to the ship. The first one is to obtain the mark word model by cutting the steel plate, and then to weld to the hull; the second is to form the weld bead by hand welding. The purpose of marking the word soldering. Compared with the hand-welded mark word, the mark word of the steel plate cutting is more beautiful. The disadvantage is that the fixed position of the mark word cut by the steel plate is difficult to weld, the welding takes a long time, and the waste of steel is serious.

In this paper, the welding of the hull marker word is achieved by applying the robot to the purpose of welding. In the actual welding process of the shipyard, the welding method of the mark word is manual welding. The advantage of the hand-welded marker word is flexibility, the welding site has less influence on the welder, and the purpose of welding the mark word can be achieved by various auxiliary work methods. The application robot has many restrictions on the welding of hull marking characters. In the actual welding process of the shipyard, it will be limited by factors such as space and location. It is impossible to weld the marking characters of various parts of the ship. Therefore, in this paper, it is necessary to analyze Which of the hull markers can be soldered by robots and which require manual soldering.

In the above, by classification of the mark words, you can know the ship namemark, the port of registry mark, the tank and sewage well sign, the bulkhead mark, the drain plug mark, the sounder and the log probe mark, the hull direction mark, etc. The mark word model is obtained by cutting the steel plate and then fixed to the hull plate by welding. Since it is difficult to fix the welding position of the mark word when the application robot performs welding on the cut font, it is difficult to perform off-line programming welding of the mark word by the robot.

Ship tonnage and IMO logo, rib number mark, cargo hold and its depth mark, no smoking sign, draught mark, etc. are welded bead welds welded to the hull plate, rib number mark, cargo hold and its depth mark, non-smoking The logo is on the flat panel and the application of robotic welding is completely feasible. In the hull markings, except for the draught mark, the welding of the remaining marks is done in the segmentation stage, and the draught mark is welded in the dock.

### III. HULL TAG WORD OFFLINE PROGRAMMING

In the process of marking word welding, the entire offline programming work can be divided into two parts. The first part is for offline programming work, and the second part is for preparation before welding, including welding materials, shielding gas, and welding parameter settings. Waiting for work. These two parts of the work do not conflict in the actual operation, and can be carried out simultaneously (Figure 1) <sup>[3]</sup>

#### A. Offline simulation

##### (1) Welding posture planning

During the welding trajectory simulation process, if the

running trajectory fails to achieve the desired effect or the calculation fails, the trajectory can be adjusted by the optimization panel to achieve the desired effect. During the initial trajectory, the attitude at the end of the tool should remain constant, from the beginning to the end of the tool coordinate system in the X-axis direction toward the front of the weld. If the trajectory is to be followed, that is, while the operation is running, the X direction of the end of the tool is always along the direction of the trajectory. In Robot\_OLP, the interpolation mode of the robot can be set. The interpolation posture selection methods mainly include: attitude stabilization and following trajectory. If the welding path follows the direction of the trajectory movement, the following trajectory option is selected in the interpolation posture, and the robot can follow the direction of the welding trajectory.

During the trajectory operation, if it is necessary to keep the Y axis consistent with the direction of the welding trajectory, an optimized trajectory is required. In the offline simulation process, if the welding trajectory is to be optimized, the offline simulation model is firstly parameterized, and the tool coordinate end posture is adjusted by trajectory optimization in the trajectory optimization panel, and the robot can be obtained in the welding process by optimizing the panel. Possible problems, then analyze the optimization problem to get a solution to the problem. Trajectory optimization is not only used to adjust the end posture of the tool. If the singular point, wrist reversal, axis limit, overtravel, unreachable or interference occurs during the trajectory operation, the trajectory adjustment can also be optimized, and the trajectory can also be analyzed. The state of the process at different locations. The red indicates the singular point, the yellow indicates the wrist joint flips, the green indicates the robot axis limit, the brown indicates the interference, the blue indicates the robot welding position is unreachable, and the yellow wrist joint flips. Figure 2 shows the trajectory posture before the trajectory optimization, and the trajectory posture after the optimization in Fig. 3.

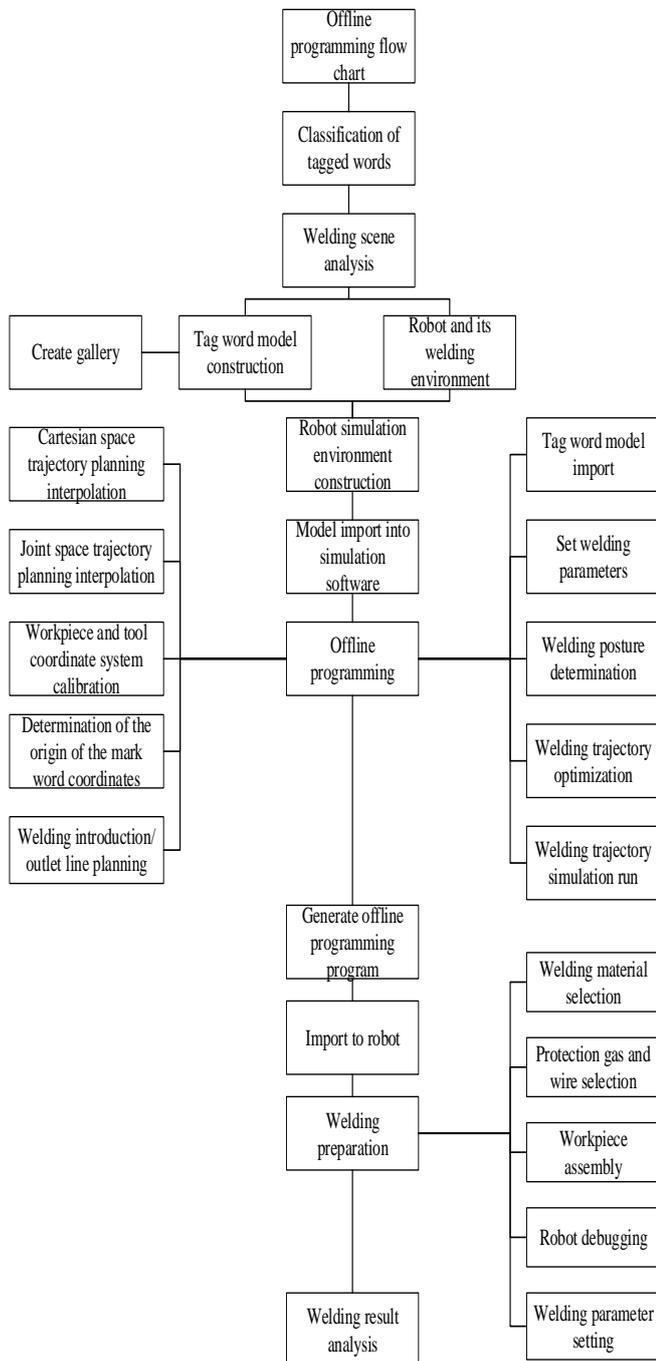


Figure 1 Marker word offline programming welding flow chart



Figure 2 Trajectory posture before optimization

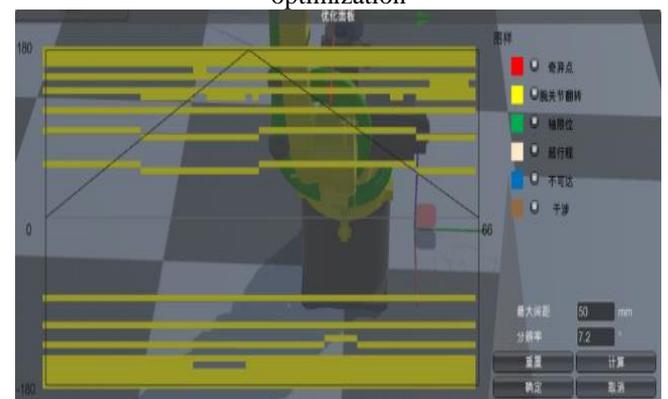


Figure 3 Optimized trajectory

It can be seen from figure 3 that the robot will be affected by the axis limit during operation. By adjusting the welding posture of the robot, the welding process of the robot will no longer be affected by the axis limit, so that the welding can be carried out.

(2) Simulation operation

In the running interface, according to the planned running curve, the simulated welding track can be simulated by simulation operation, as shown in Figure 4.

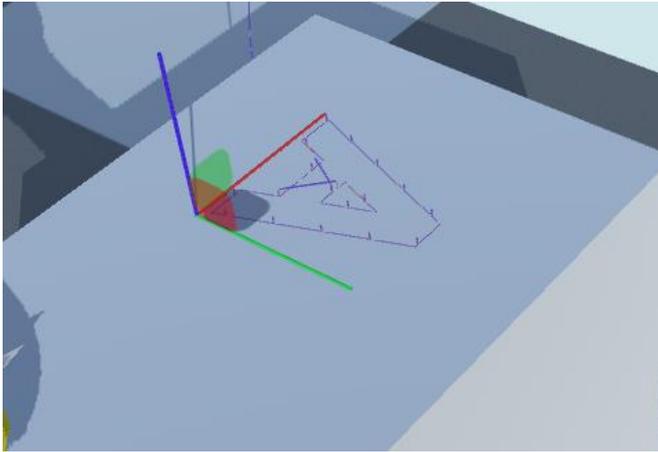


Figure 4 hull marker word trajectory simulation diagram

B. Implementation of offline programming program

Model construction, trajectory optimization and off-line simulation during off-line programming are aimed at the implementation of off-line programming.

During the welding process, the excessive speed of each axis may increase the wear of the robot and reduce the service life of the robot. Therefore, when the robot is running, the speed of each axis should be adjusted according to the actual situation. There are two ways to adjust the speed of each axis. One is to manually input the speed of each axis that has been standardized, and the other is to adjust the running speed of each axis by dragging the scroll bar on the interface. After each axis speed adjustment is completed, the running speed value in the upper right corner of the running interface will also change. (Figure 5).

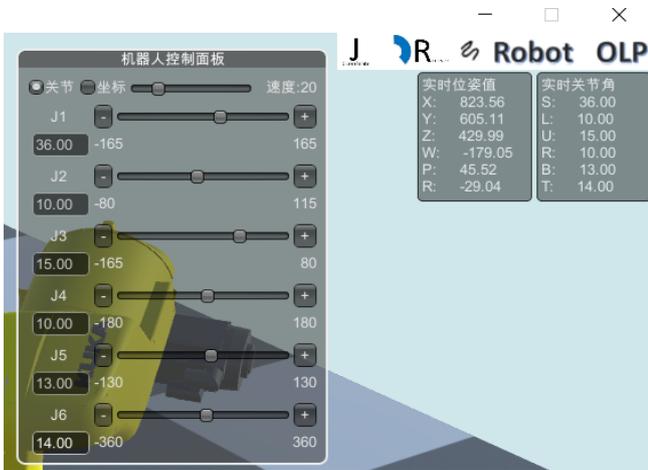


Figure 5 Robot real-time motion status

The implementation of the offline programming program lies in the correctness of its simulation and related parameter settings. For the welding of the mark word, the correct setting of the coordinates of the tool and the workpiece has a considerable influence on the welding result. In software, the offline programming process first sets the tool coordinates and the workpiece coordinates, rather than importing the tag word model first. Before the coordinate setting, the initial coordinate of the tool coordinate system and the workpiece coordinate system is 0 points, and it can be filled according to the coordinates already calibrated above (Figure 6). If the coordinates are not set first, the coordinate analysis of the unimported points will fail, and the model will not be imported correctly (Figure 7).



Figure 6 Tool and workpiece coordinate system parameter settings

quadlist.count:0

The inverse solution of the 65th point of this curve is wrong.  
The inverse solution of the 64th point of this curve is wrong.  
The inverse solution of the 63th point of this curve is wrong.  
The inverse solution of the 62th point of this curve is wrong.  
The inverse solution of the 61th point of this curve is wrong.

Figure 7 Model import failure error

As shown in the figure above, if the mark word size is different during the mark word welding process, you can set the parameters for  $S_x$  and  $S_y$ . If the length and width are expanded by 1.5 times, we can set the parameter factor of  $S_x$ ,  $S_y$  to 1.5, where  $S_x$  is the horizontal scaling factor and  $S_y$  is the vertical scaling factor. In the actual welding process, we will encounter multiple letters in the same horizontal plane. In order to save time and cost, we can set multiple letters in an offline program, and adjust the two letters according to the actual situation. spacing. Finally, increase the welding arcing and arc extinguishing commands. Where L is the spacing between two short solid lines in the dashed line, M is the length of the short solid line, and D is the spacing between the two letters. As shown in Figure 8.

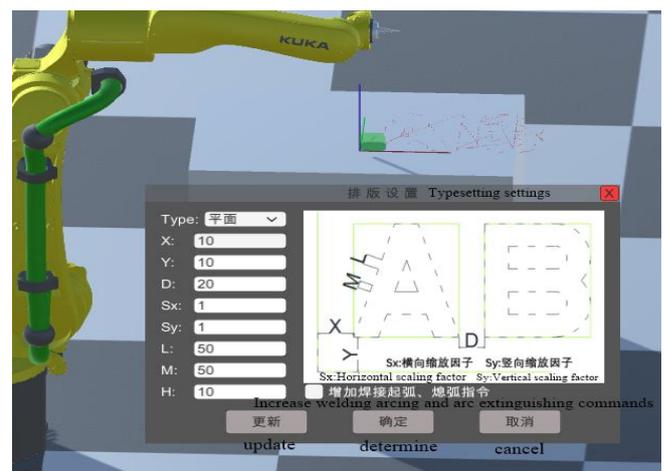


Figure 8 tag word layout settings

The setting of the welding parameters is mainly to set the welding speed. If the welding speed is too fast, it may collide with the staff, or because the welding speed is too fast, the welding of the mark words will not be properly welded, and the marked words will be welded. Air welding or welding width is too small. After the welding parameters are set, the

offline programming program is finally generated by operations such as model calculation, loading, and welding track operation. After the offline programming program is generated, the edited files will be saved in two different formats, namely the dat file and the src file.

#### IV. WELDING OF HULL TAG

##### C. Selection of welding materials

- (1) Since the test was carried out in the laboratory, in order to better interface with the shipyard, the shipyard was investigated in the selection of welding materials, so the steel used in this paper is Class A marine steel;
- (2) Most of the markings on the hull that need to be welded are located on the hull plate. In order to meet the mechanical properties of the weld zone of the base metal after welding and the corrosion resistance under seawater conditions, and to ensure the welding requirements of the robot, the diameter is selected. JQ.MG70S-6 solid carbon steel welding wire of 1.2mm;
- (3) The shielding gas can isolate the contact between the air in the welding area and the welding trajectory, so that the trajectory of the welding is not oxidized, and the welding fumes are greatly reduced during the welding process, thereby reducing air pollution. Therefore, the experimentally selected protective gas was 80% Ar+20% CO<sub>2</sub>, and the gas flow rate was 15 L/min.

##### D. Welding test

###### (1) Marking word welding test

In the mark word welding test, the test platform used was the KUKA KR8 R1420 arc HW welding robot. The welding power source was Germany EWM Phoenix 551 Puls inverter split welding power supply is a fully digital inverter welding power supply. The model of the robot control cabinet is KR C4. Standard type. The steel used is A grade marine steel, the protective gas is 80% Ar+20% CO<sub>2</sub>, and the JQ.MG70S-6 solid carbon steel welding wire with a wire diameter of 1.2 mm. The welding parameters were a welding voltage of 16.2 V, a welding current of 113 A, and a wire feed speed of 5 m/min. The welding results are shown in Figure 9.



Figure 9 hull marker word "D, S" welding

###### (2) Welding results and analysis

The welding results are shown in Figure 10. The welding font is clear and accurate, and the weld is easy to identify and meet the welding specifications of the weld. In the robot welding process, the walking track is more accurate, and the welding

speed is much higher than that of manual welding. Since there is no pause in the welding process of the mark word, the welding can be formed at one time, thus reducing the deformation of the mark word pattern caused by multiple welding and Stress concentration in the welding area.

In the robot welding process, the welding result has a great relationship with the setting of the robot welding parameters. The correct setting of the welding parameters makes the welding pattern beautiful, and the setting of the wrong parameters may result in the welding being not in the position to be welded. After the offline programming program is generated, the welding parameters are constant during the welding process, so the welds welded by the robot are less affected by the external influence, thus ensuring the quality of the welding. When welding the mark words by hand, the quality of the welded welds is uneven due to factors such as mood, weather, light, and fatigue caused by long-term welding. The robot is used to weld the mark words without considering the influence of external conditions on the workers. Therefore, the application of the robot to weld the mark words can greatly improve the welding efficiency and the welding quality.

#### V. CONCLUSION

Based on the research of offline programming technology, this paper clarifies which hull marking words can be welded by offline programming at the present stage by marking word classification and welding analysis. The welding of the mark words is completed by off-line simulation and generation of a welding program. In the welding process, the A-class marine steel was selected as the welding workpiece, and the shielding gas was 80% Ar+20%CO<sub>2</sub>. Through a series of welding parameters test, the welding voltage was determined to be 16.2V, the welding current was 113A, and the wire feeding speed was determined. It is 5m/min. Welding experiments have shown that the welding fonts are clear and accurate, and the welds specifications are easy to identify and meet the welding

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