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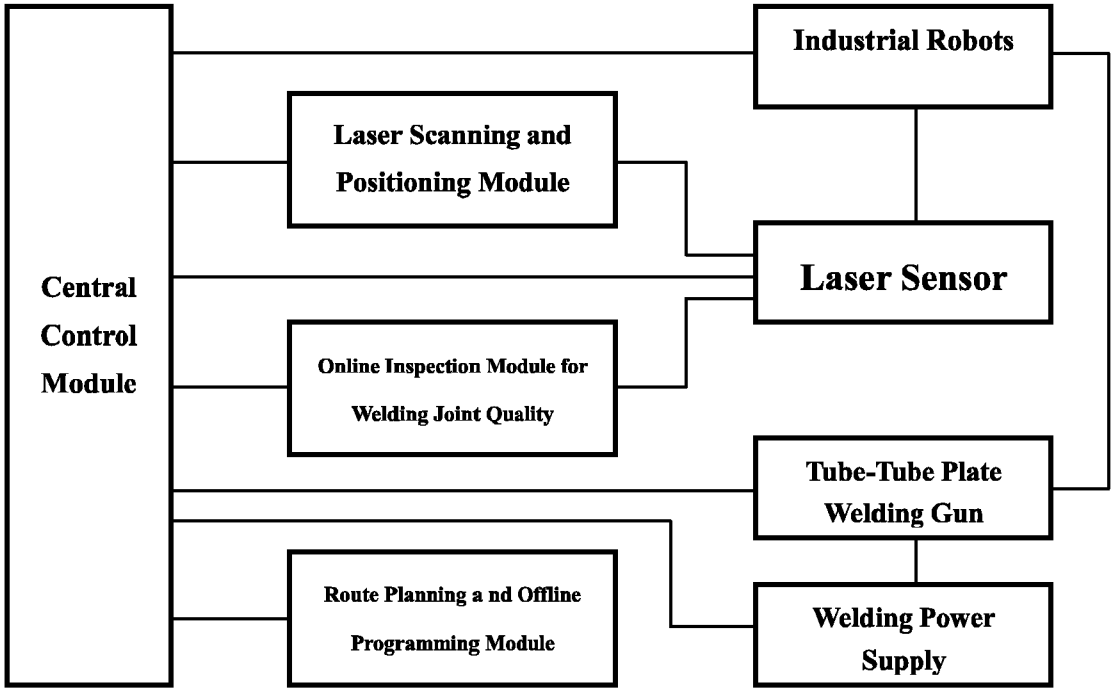
Central Control Module
Industrial Robots
Laser Scanning and Positioning Module
Laser Sensor
Online Inspection Module for Welding Joint Quality
Tube-Tube Plate Welding Gun
Route Planning a nd Offline Programming Module
Welding Power Supply

Fig. 1

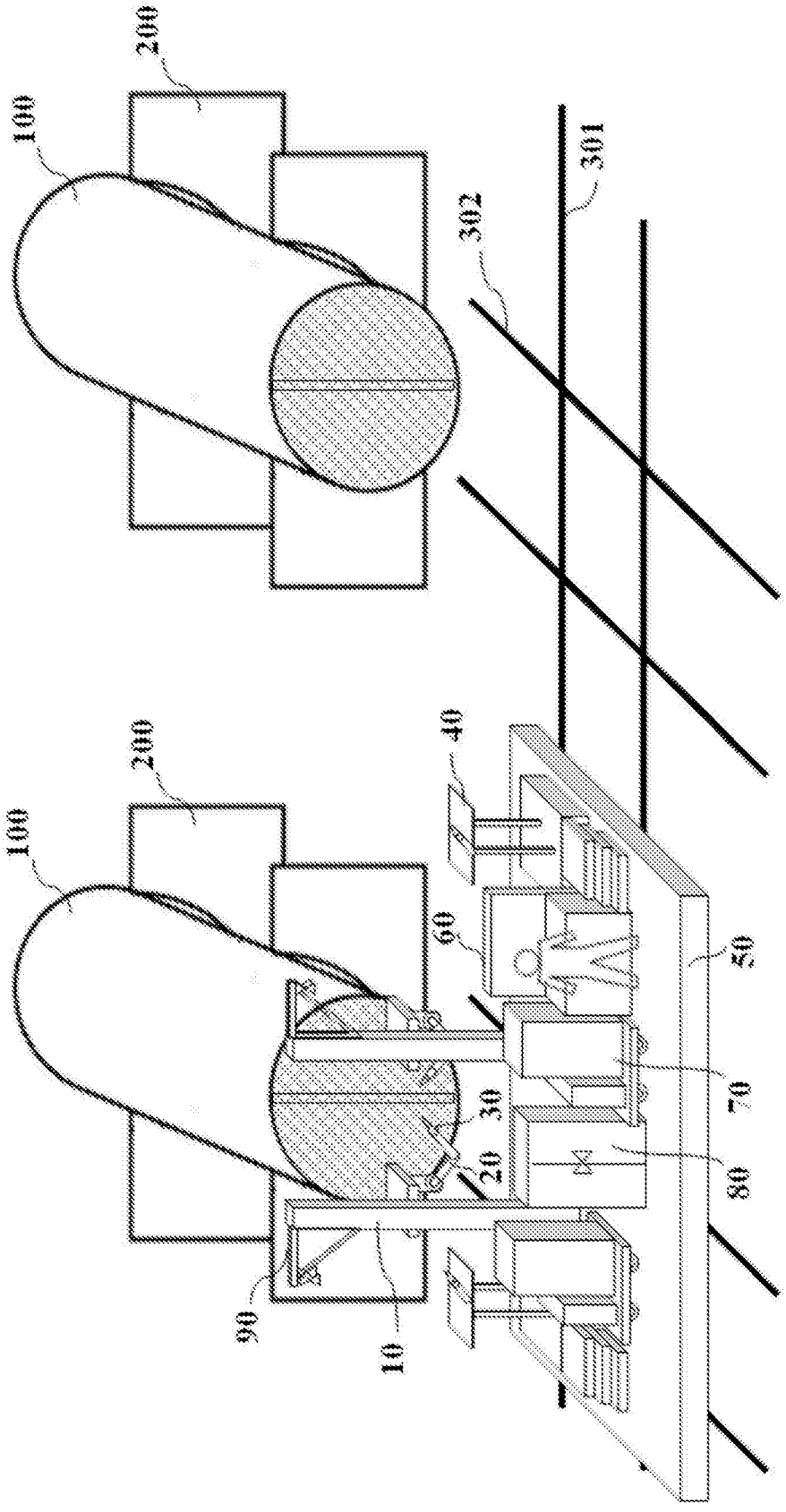

Fig. 2

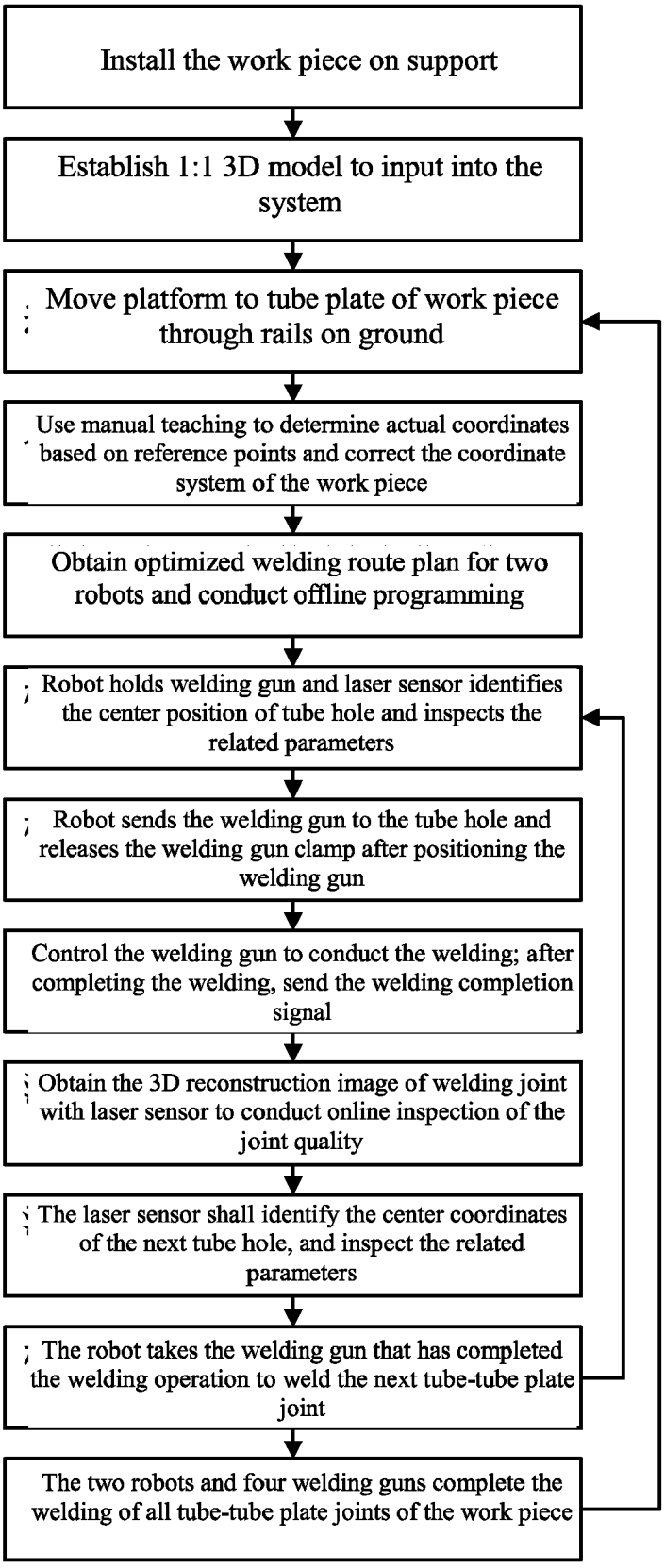
Install the work piece on support
Establish 1:1 3D model to input into the system
Move platform to tube plate of work piece through rails on ground
Use manual teaching to determine actual coordinates based on reference points and correct the coordinate system of the work piece
Obtain optimized welding route plan for two robots and conduct offline programming
Robot holds welding gun and laser sensor identifies the center position of tube hole and inspects the related parameters
Robot sends the welding gun to the tube hole and releases the welding gun clamp after positioning the welding gun
Control the welding gun to conduct the welding; after completing the welding, send the welding completion signal
Obtain the 3D reconstruction image of welding joint with laser sensor to conduct online inspection of the joint quality
The laser sensor shall identify the center coordinates of the next tube hole, and inspect the related parameters
The robot takes the welding gun that has completed the welding operation to weld the next tube-tube plate joint
The two robots and four welding guns complete the welding of all tube-tube plate joints of the work piece

Fig. 3

A Robot Welding System and Its Welding Method

Technical field

This invention involves the automatic welding system and method in the field of intelligent robot welding technologies, specifically, the robot welding system and method for welding the tube-tube plate of vapor generator of main equipment of nuclear island.

Background of the invention

Nuclear power has such advantages as cleanliness, constant power supply capacity, and less geological restrictions. Nuclear power is the important orientation of energy development in the future. According to the National Nuclear Power Development Plan, by 2020, the total installed capacity of nuclear power of China will reach 40 million KW, and the ratio of nuclear power in the total installed capacity of electricity power of China will be improved to 4% with an annual power generation output of 260~280 billion KWh. The construction periods of nuclear power projects will significantly influence their economics. Vapor generator is the main equipment of nuclear island, and the welding of the tube-tube plate during its manufacturing is a key process. The quality and efficiency of tube-tube plate welding will directly influence the corrosion resistance and air-tightness on the tube plate side and the progress of the construction of the vapor generator. The number of joints for the tube-tube plate welding. Take AP1000 vapor generator as instance, there will be 20050 tube-tube plate welding joints. At present, the welding is mainly made by holding the tube-tube plate welding guns manually, which has a low welding efficiency.

Disclosure of the invention

This invention has proposed a robot welding system and its welding methods for the tube-tube plate welding of vapor generator of nuclear island against the

current condition of the manual tube-tube plate welding of vapor generator, which has such functions as the identification and guidance of the initial welding position during the automatic tube-tube plate welding process, route planning and offline programming, the automatic tube-tube plate welding with robot, the automatic inspection and replacement of tungsten electrodes and the online inspection of welding joint quality.

To achieve the above targets, the present invention provides a robot welding system, which has a central control module and the following devices connected to it through signals and controlled by it:

At least one industrial robot with six degrees of freedom, whose working scope shall be overlapped to cover all welding positions of the tubes-tubes plate welding joints;

At least one tubes-tubes plate welding gun; each industrial robot shall hold at least one corresponding tube-tube plate welding gun at the corresponding tube hole; the tubes-tubes plate welding gun at each tube hole shall be used to weld the joints of tube-tube plate.

Welding joint quality online inspection module: to conduct online inspection on the quality of welding joints according to the appearances of such joints.

Preferentially, said robot welding system has a route planning and offline programming module signally connecting to and under the control of the central control module, to plan the welding routes for several industrial robots to prevent crushes of the robots, and conduct the offline programming over the established plans.

Preferentially, the said robot welding system has a laser scanning and positioning module connecting to and under the control of the central control module through signals, which could scan the tube hole with is laser sensor to obtain the coordinates of the center of the cycle as the reference values for the identification and guidance of the initial welding positions.

Preferentially, the said robot welding system has two industrial robots and each robot holes two tube-tube plate welding guns used to conduct automatic argon

tungsten-arc welding over the tube-tube plate joints.

Preferentially, the said industrial robots are installed on the corresponding vertical supports and can move horizontally along the supports; and the said industrial robots are able to move up and down on the vertical supports.

Preferentially, the said vertical supports are installed on the system platform and could move with the platform; and the said system platform could move to each tube-plate of any work piece to be welded along the rails on the ground;

The said work pieces are the vapor generators placed on their supports.

Preferentially, the following devices are installed on the said system platform:

Automatic replacement platform for tungsten electrodes: the platform is within the operation scope of the corresponding industrial robot to replace tungsten electrodes;

Welding power supply: to supply power to the said tube-tube plate welding guns;

Robot control cabinet: to install the control devices for each industrial robot;

Central control platform: to install the said central control module, online inspection module for welding joint quality, route planning and offline programming module and laser scanning and positioning module.

Preferentially, the said vertical supports shall be installed with corresponding harness supports to place the wires of the industrial robots and the corresponding tube-tube plate welding guns;

The ground rails of the said system platform include horizontal and longitudinal rails.

Preferentially, the said online inspection module for welding joint quality is to conduct online inspection based on the 3D reconstruction image of the welding joints that are made according to the results of the scanning of the joints with the laser sensor.

Preferentially, the said laser sensor is installed on the front end of the arm of the said industrial robot.

Another technical solution in this invention is to provide a welding method of

the robot welding system, including the following processes:

Install several work pieces on their corresponding supports;

Move the system platform to the tube plate of one of the work piece through the ground rails to enable the devices installed on the system platform of the robot welding system to conduct corresponding operations:

Each industrial robot shall hold one of the corresponding welding gun to the welding position of the tube hole to be welded on the tube plate to position the welding gun. After positioning the welding gun, the robot shall release the welding gun clamp to hold another corresponding welding gun;

The positioned welding gun shall start the welding according to the commands from the central control module. After completing the tubes-tubes plate welding, a welding completion signal will be sent. The industrial robot will grab the welding gun that has sent the completion signal and put it to the next tube hole for positioning to conduct the next tubes-tubes plate welding;

After completing the welding of all tubes and tube plates on one work piece through the cooperation between the industrial robots and their welding guns, the system platform will be moved to the tube plate of another work piece through the ground rails until all the tubes-tubes plate joints are welded.

Preferentially, the above welding method further includes: each industrial robot shall drive the movement of the laser sensor installed on its front arm to scan the tube hole to be welded on the tube plate and determine the center position of the tube hole with the laser scanning and positioning module to enable the industrial robot to send one of the corresponding welding guns to the welding position of the tube hole.

Preferentially, the said welding method further includes: after completing the welding of one tubes-tubes plate joint, the tubes-tubse plate welding joint shall be scanned with the laser sensor to obtain the 3D reconstruction image of the welding joint through the online inspection module and conduct online inspection and default alarming over the quality of the joint quality against the joint appearance.

Preferentially, the said welding method further includes: after installing

several work pieces on their own supports, the 1:1 3D models will be established for the work pieces, which will be inputted into the robot control system; and, after moving the system platform to the front of the tube plate of any work piece, manual instruction operation shall be conducted for the industrial robots, and the actual coordinates of the work piece shall be confirmed based on several reference points to correct the coordinate system of the 3D model of the work piece; and the route planning and offline programming module shall be used to implement the anti-crush plan for the welding routes of several industrial robots, and conduct the offline programming for the plan.

Preferentially, when any welding gun has been put into the welding position of the tube hole to be welded by industrial robot, the pneumatic auxiliary positioning expand tube installed in the upper part of the welding gun shall be inserted into the tube hole, and the expand tube shall automatically expand after the welding gun reaches the axial position. After confirming the expansion, the robot shall release the gun clamp.

This invention exposes a robot welding system and its welding method, which is within the automation technology field for robot welding, and applicable to the tube-tube plate welding of vapor generator, the main equipment of nuclear island. The industrial robots in the invention have such advantages as high working efficiency, stability, reliability and high repeating precision. Using robots to replace manual works in welding operation has obvious advantages in terms of improving welding efficiency, ensuring product quality and stability, improving working conditions and reducing workload.

The invention could be used to realize the identification and automatic guide; route planning and offline programming; automatic tubes-tubes plate welding with robots; and the online inspection of welding joint quality, which is of great importance to the improvement of the efficiency of tube-tube plate welding, the guarantee of the stability of welding joint quality, the reduction of delivery period of vapor generators and the enhance of the nuclear power economics.

Description of figures

Fig. 1 is about the structure of the robot welding system for the tube-tube plate welding of vapor generator, the main equipment of nuclear island;

Fig. 2 is about the layout of the said robot welding system;

Fig. 3 is about the flow chart of the welding method of the said robot welding system.

Preferred embodiments of the invention

The embodiments of the invention will be described in detailed as follows based on the figures: the embodiments shall be implemented based on the technical method of this invention. The detailed implementation method and operation process are provided, but the protection scope of this invention is not limited to the following embodiments.

As can be seen in Fig. 1, this invention provides a robot welding system for the tubes-tubes plate welding of vapor generator, the main equipment of unclear island, including: industrial robots (two for the embodiment), the route planning and offline programming module, the laser scanning and positioning module, the tubes-tubes plate welding gun and power supply, the online inspection module for welding joint quality, and the central control module used to control the operations of the above modules and work pieces.

Where, the two industrial robots with Six Degrees of Freedom (the “robots” hereafter) are installed the vertical supports with guide rails, which could be moved horizontally. The robots could be moved up and down on the supports to complete the welding of the upper part of the tube plate and the lower part of the tubes-tubes plate. The vertical supports can move horizontally on the guide rails, to take the robots move horizontally, complete the welding of the left part of the tube plate and the right part of the tubes-tubes plate. Therefore, with the vertical supports, the robots could be moved up, down, left and right. With the overlaying of the working scopes of the two robots, the whole tube plate surface could be covered to realize the welding of all tubes and tube plates with the two robots.

The said route planning and offline program module could be used to plan the welding routes of the two robots, and optimize the routes through simulation to obtain the optimized route planning plan, improve welding efficiency and prevent the crush of the two robots. For the optimized route planning plan, the offline programming is used to replace the complicated manual teaching programming to improve the efficiency of the tubes-tubes plate welding of vapor generator.

The said laser scanning and positioning module could be used to conduct laser scanning of tube holes through laser sensor, and obtain the coordinates of the cycle center of the tube holes through corresponding algorithm, which shall be the space position coordinates that can be identified by the robots. According to coordinates, the robots could be controlled to reach the cycle center of the tube hole to realize the identification and automatic guidance of the initial welding position for the tubes-tubes plate welding.

This invention uses specific tubes-tubes plate welding guns and tubes-tubes plate welding power supply. The robots hold the welding guns which will be positioned by inserting the positioning core into the tube hole. Under the protection of two-layer protection gas cover, the tungsten electrode would rotate automatically to complete the automatic tungsten electrode-arc welding of the tubes-tubes plate (in the embodiment, it is used to implement the automatic tungsten electrode-arc welding without filler rod). With the two robots, the automatic tungsten electrode-arc welding of the tubes-tubes plate joints could be completed with the four tubes-tubes plate welding guns of the two robots. That is to say, each robot and can hold two corresponding welding guns to complete welding at different tube holes.

The online inspection module for welding joint quality could be used to conduct he online inspection of the joints of tubes-tubes plate welding. After welding the tubes-tubes plate joints, the joints shall be scanned with the laser sensor and then the appearances of the tubes-tubes plate welding joints will be obtained through 3D reconstruction, according to the appearances, air holes, slag inclusion, undercuts and other flaws can be automatically identified, thus to realize the online inspection of the quality of the joints.

The said central control module could be used to control the laser sensor to scan the tube hole to realize the identification and guidance of the initial welding positions; control the route planning and offline programming module to plan the welding routes and conduct offline programming; control the robots to hold the welding guns to conduct the automatic tubes-tubes plate welding; according to the appearance of the tungsten electrode, automatically detect and change the tungsten electrode, control the laser sensor to scan the welding joints to obtain the appearances of the joints to conduct the online inspection of the joint quality according to the appearances of the joints.

Fig. 2 is about the structure of the robot welding system of the example. The robot welding system in the example includes: system platform 50, and two groups of devices installed on the system platform 50 and moving along the horizontal rails 301 or longitudinal rails 302 on the ground; each device group composed of vertical support 10, harness support 90, industrial robots with Six Degrees of Freedom 20, tubes-tubes plate welding power supply 70, tubes-tube splate welding guns 30, and automatic tungsten electrode replacement platform 40; and the central control platform 60 and the robot control cabinet 80 installed on the system platform 50 for the two groups of devices (the function modules corresponding to control the two group of devices are installed respectively in the platform of cabinet).

The figure also shows two vapor generators 100 and their tube plates to be welded and the respective supports 200 of the two vapor generators. If the layout of the two vapor generators 100 (the work pieces hereafter) is different from that specified in Fig. 2, the layout of the guide rails on the ground could be adjusted appropriately to smoothly move the system platform 50 to the tube plate of each work piece.

As mentioned above, the vertical support 10 could move the robot 20 on it to move horizontally, and move the robot 20 on the vertical support 10 up and down. The horizontal movement of the vertical support 10 could be realized by the moving of the system platform 50. If needed, guide rails could be installed on the system platform 50 for the movement of the vertical support 10.

The harness support 90 is installed on the vertical support 10, and the wires of the tubes-tubes plate welding guns 30 connecting the welding power supply 70 and others corresponding to each robot 20 are tied to the supports to prevent the intervene or open circuit caused by the involvement of the wires during the welding operation.

The automatic tungsten electrode replacement platform 40 is within the operation scope of the robots 20, which is used to replace the tungsten electrodes. The automatic tungsten electrode replacement platform 40 could be used to rest the tubes-tubes plate welding guns 30. Steps could be installed on the system platform 50 to the automatic tungsten electrode replacement platform 40 to facilitate the operators to check the conditions of the related devices.

The mentioned route planning and offline programming module, the laser scanning and positioning module, the online inspection module for joint quality, and the central control module are installed in the central control platform 60. The control systems of the robots could be installed in the central control platform 60 and/or the robot control cabinet 80.

As can be seen in Fig. 3, the welding method realized through the robot welding equipment with the present application includes the following steps:

S1. Install and fix the two vapor generators (work pieces) on their respective support;

S2. Establish the 1:1 3D models of the work pieces, which shall be inputted into the robot control system.

S3. Move the system platform to the appropriate positon right in front of the tube plate of one work piece through the horizontal and longitudinal guide rails on the ground and fix the platform;

S4. Use the manual teaching to confirm the actual coordinates of the work pieces based on 3 to 4 reference points and correct the coordinate systems of the 3D models of the work pieces;

S5. Optimize the tubes-tubes plate welding routes of the two robots to obtain the optimized welding route plan and conduct offline programming;

S6. The robot moves to the welding gun placement supports to take one welding gun, identify the center position of the tube hole to be welded with the laser sensor installed on the front arm of the robot and detect the assembly depth of the tube and the expand tube gap;

S7. The robot takes the welding gun to the welding position, and inserts the welding positioning core shaft into the tube hole to be welded. The pneumatic auxiliary positioning expand tube installed in the upper part of the welding gun shall be inserted into the tube hole, and the expand tube shall automatically expand after the welding gun reaches the axial position. After confirming the expansion, the robot shall release the gun clamp.

S8. Launch the tubes-tubes plate welding program to control the positioned welding gun to start the welding operation, and send the welding completion signal after welding each tube-tube plate joint;

S9. The robots shall cooperate with laser sensor to scan the tubes-tubes plate welding joints, and obtain the appearances of the welding joints through 3D reconstruction to identify any defects through the automatic identification of the appearances of the joints to stop the welding operation and give an alarm in case of any defect;

S10. The robot shall cooperate with the laser sensor to scan the next tube hole to identify its center coordinates, detect the tube assembly depth and expand tube gap, and give an alarm in case of non-conformance;

S11. After receiving the welding completion signal from any welding gun, the robot will automatically position and take the welding gun to weld the next tubed-tubes plate joint.

S12. Repeat steps S6~S11, the robot and its other corresponding welding gun shall operate in the same way. The timings of using the two welding guns of one robot are staggered. The two welding guns of the other robot shall be operated in the same way. In this way, all tubes-tubes plate joints of one work piece (vapor generator) shall be automatically welded with the two robots and four welding guns.

S13. Move the system platform to the appropriate position in the front of the

tube plate of the next work piece through the horizontal and longitudinal guide rails on the ground and fix the system platform;

S14. Repeat the steps of S4 to S11 to complete the welding of all tubes-tubes plate joints of the work piece (vapor generator).

The present application could be used to realize the functions as the identification and guidance of the initial welding positions of the tubes-tubes plate welding operation of the vapor generator of the nuclear main equipment, the welding route planning and offline programming; the automatic robot welding of the tubes-tubes joints, the automatic inspection and replacement of tungsten electrodes, and the online inspection of the welding joint quality. The welding system for tubes-tubes plate joints of vapor generator could effectively improve the efficiency of the tubes-tubes plate welding, enhance the stability of the joints quality, and reduce the delivery periods of vapor generators.

Although the contents of the invention have been introduced in detailed through the above preferential example, the above description shall not be deemed as the limitation to the invention. After reading the above contents, the technical personnel in this field may be aware of various modifications and replacements of the invention. Therefore, the protection scope of the invention shall be limited with the attached claims.

Claims

1. A robot welding system for tube-tube plate welding, wherein,

said robot welding system has a central control module, and the following devices signally connected to and under the control of said module:

at least one industrial robot with six degrees of freedom, wherein a working scope of the at least one industrial robot covers the welding positions of all tube holes on each of the work pieces;

a plurality of tube-tube plate welding guns for welding tube-tube plate welding joints after being positioned at respective corresponding tube holes, wherein any one of the industrial robots is configured for taking and placing the plurality of tube-tube plate welding guns corresponding to the industrial robot in a staggered manner, wherein each of the industrial robots is configured for grabbing one of the welding guns corresponding to the industrial robot and placing the welding gun at the welding position of one of the tube holes on the tube plate, and after the welding gun is inserted into the tube hole, through a positioning core shaft and is positioned, the industrial robot releases a welding gun clamp, so as to grab another welding gun corresponding to the industrial robot and place the another welding gun at the welding position of another tube hole;

an online inspection module for welding joint quality for performing an online inspection for a welding joint quality online according to the appearances of the welding joints; and,

a system platform capable of moving to the tube plate of each of the work pieces along a ground guide rail, wherein each of the industrial robots is installed on a vertical support on the system platform and movable horizontally along the system platform.

2. The robot welding system of claim 1, wherein,

said robot welding system has a route planning and offline programming module signally connecting to and under the control of the

central control module, for planning the welding routes for several industrial robots to prevent clashes of the robots, and conduct the offline programming over the established plans.

3. The robot welding system of claim 2, wherein,

said robot welding system has a laser scanning and positioning module connecting to and under the control of the central control module through signals, for scanning the tube holes with its laser sensor to obtain the coordinates of the center of the cycle as the reference values for the identification and guidance of the initial welding positions.

4. The robot welding system of claim 1, wherein,

said robot welding system has two industrial robots and each robot holes two tube-tube plate welding guns used to conduct automatic argon tungsten-arc welding over the tube-tube plate joints.

5. The robot welding system of claim 4, wherein,

said industrial robots are installed on the corresponding vertical supports and can move up and down horizontally along the supports.

6. The robot welding system of claim 1, wherein,

said work pieces are the vapor generators placed on their supports.

7. The robot welding system of claim 3, wherein,

following devices are installed on the said system platform:

automatic replacement platform for tungsten electrodes: the platform is within the operation scope of the corresponding industrial robot to replace tungsten electrodes;

welding power supply: to supply power to said tube-tube plate welding guns;

robot control cabinet: to install a control device for each industrial robot;

central control platform: to install the said central control module, online inspection module for welding joint quality, route planning and offline programming module and laser scanning and positioning module.

8. The robot welding system of claim 5, wherein,

said vertical supports shall be installed with corresponding harness supports to place the wires of the industrial robots and the corresponding tube-tube plate welding guns;

the ground rails of said system platform include horizontal and longitudinal rails.

9. The robot welding system of claim 1, wherein,

said online inspection module for welding joint quality is to conduct online inspection based on the 3D reconstruction image of the welding joints that are made according to the results of the scanning of the joints with the laser sensor.

10. The robot welding system of claim 3 or claim 9, wherein,

said laser sensor is installed on the front end of the arm of the said industrial robot.

11. A method of tube-tube plate welding based on a robot welding system, comprising the steps of :

installing a plurality of work pieces on respective supports;

moving a system platform to a front of a tube plate of one of the work pieces through a ground guide rail, to allow equipment of the robot welding system arranged on the system platform to perform corresponding operations under the control of a control module:

providing at least one industrial robot, wherein the at least one industrial robot takes and places a plurality of tube-tube plate welding guns corresponding to the industrial robot in a staggered manner: the industrial robot grabbing one of the welding guns and placing the welding gun at a welding position of one of tube holes on the tube plate, and after the welding gun is inserted into the tube hole through a positioning core shaft and is positioned, the industrial robot releasing a welding gun clamp so as to grab another welding gun corresponding to the industrial robot and placing the another welding gun at the welding position of another tube hole;

starting welding with the positioned welding guns according to commands from the central control module, to weld tube-tube plate welding joints corresponding to a current tube hole, sending a welding completion signal after completing the welding, then the industrial robot grabbing the welding gun that has sent the welding completion signal and put the welding gun to a welding position of another tube hole to be welded; and,

after the industrial robots cooperating with the respective welding guns to complete the welding of all the tube-tube plates of one of the work pieces, the system platform moving to the front of a tube plate of a further work piece through the ground guide rail to complete the welding of all the tube-tube plates on the further work piece.

12. The welding method of claim 11, wherein,

said welding method further includes:

the or each industrial robot shall drive the movement of the laser sensor installed on its front arm to scan the tube hole to be welded on the tube plate and determine the center position of the tube hole with the laser scanning and positioning module to enable the industrial robot to send one of the corresponding welding guns to the welding position of the tube hole.

13. The welding method of claim 11, wherein,

said welding method further includes:

after completing the welding of one tube-tube plate joint, the tube-tube plate welding joint shall be scanned with the laser sensor to obtain the 3D reconstruction image of the welding joint through the online inspection module and conduct online inspection and default alarming over the quality of the joint quality against the joint appearance.

14. The welding method of claim 11, wherein,

said welding method further includes:

after installing several work pieces on their own supports, the 1:1 3D models will be established for the work pieces, which will be input into the robot control system; and, after moving the system platform to the front of the tube plate of any work piece, manual instruction operation shall be conducted for the industrial robots, and the actual coordinates of the work piece shall be confirmed based on several reference points to correct the coordinate system of the 3D model of the work piece; and the route planning and offline programming module shall be used to implement the anti-crush plan for the welding routes of several industrial robots, and conduct the offline programming for the plan.

15. The welding method of claim 11, wherein,

when any welding gun has been put into the welding position of the tube hole to be welded by industrial robot, the pneumatic auxiliary positioning expand tube installed in the upper part of the welding gun shall be inserted into the tube hole, and the expand tube shall automatically expand after the welding gun reaches the axial position, after confirming the expansion, the robot shall release the gun clamp.