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(54) REMOTE OPERATION METHOD FOR REMOTE OPERATION WELDING SYSTEM, AND WELDING SYSTEM

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(57) **ABSTRACT**

A remote operation method for a welding system enabling manual operation of a welding robot includes: capturing image data for a certain position using one or more imaging devices, displaying the image data using a display device, receiving, from an operator via an operation terminal, an instruction to execute a contact detection function by a welding torch of the welding robot, moving the welding torch during execution of the contact detection function on the basis of the instruction given to the welding robot and received via the operation terminal, and adjusting, if the welding torch has detected contact with a surrounding component by the contact detection function, the position of the welding torch on the basis of the position of contact.

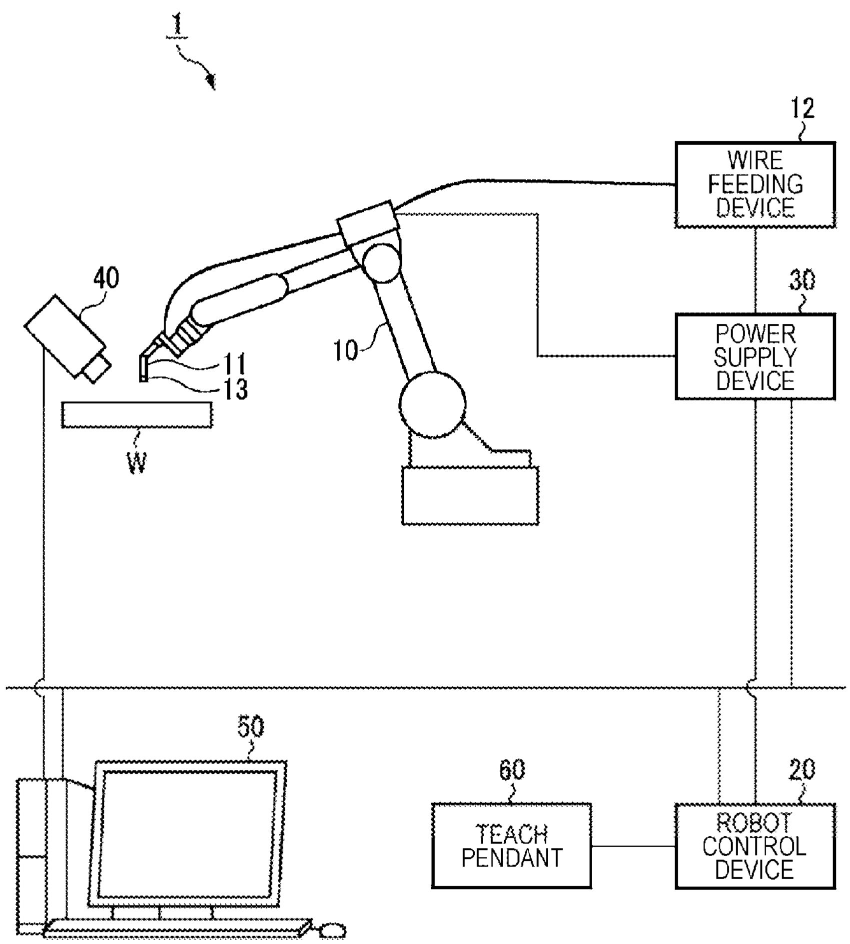


FIG. 1

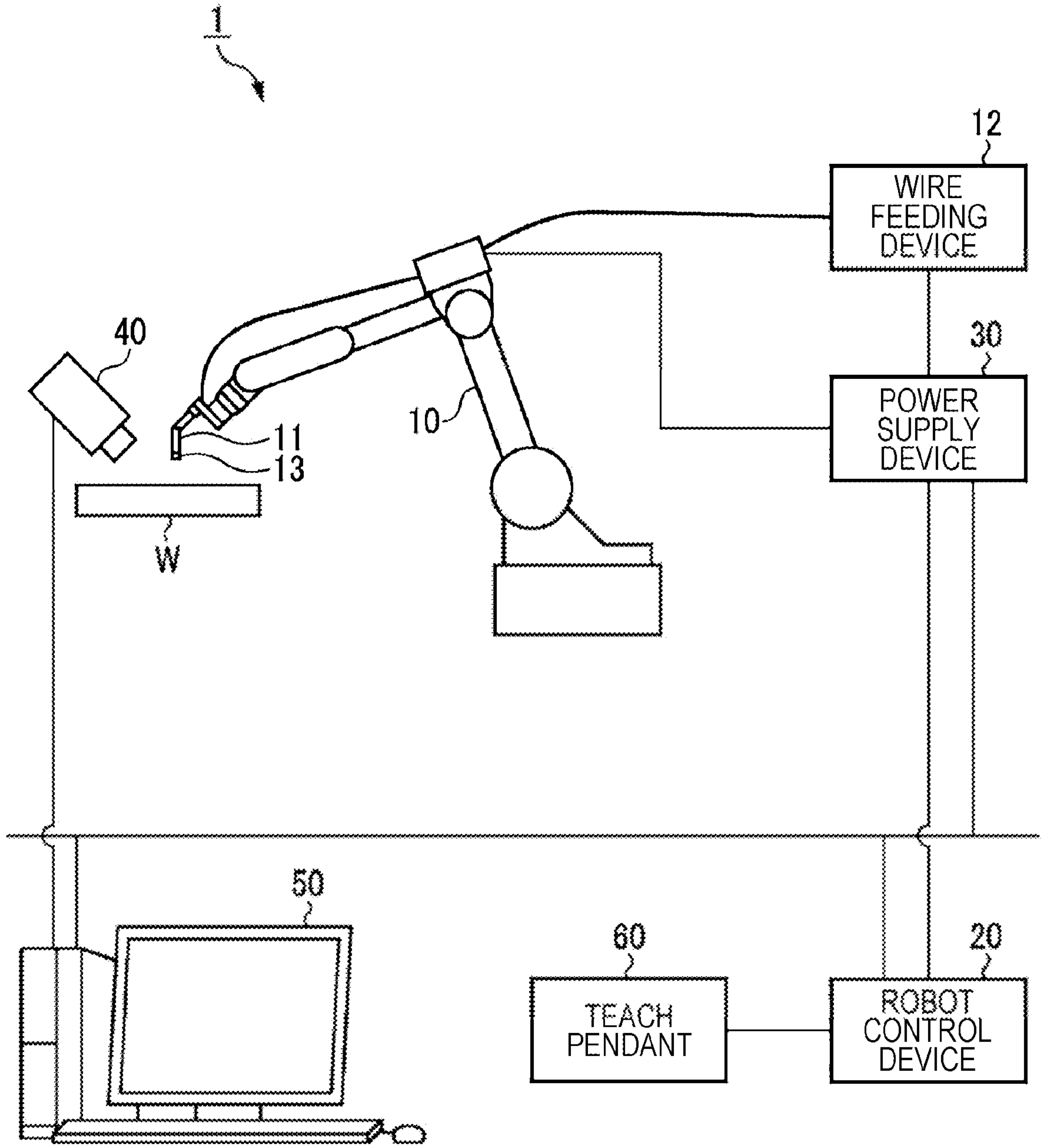

1
12
WIRE FEEDING DEVICE
30
POWER SUPPLY DEVICE
40
11
13
10
W
50
60
TEACH PENDANT
20
ROBOT CONTROL DEVICE

FIG. 2

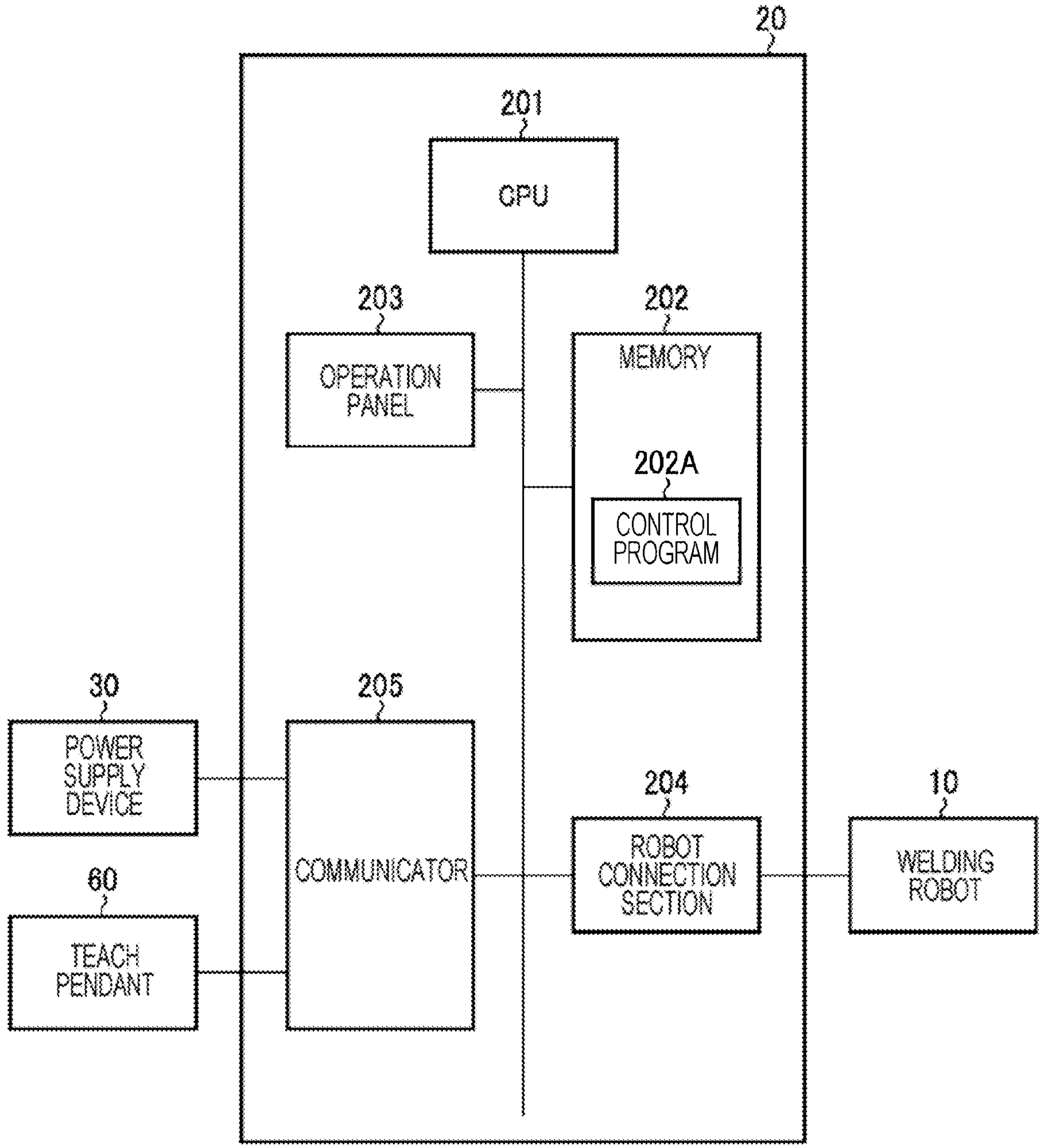

20
201
CPU
203
OPERATION PANEL
202
MEMORY
202A
CONTROL PROGRAM
30
POWER SUPPLY DEVICE
205
COMMUNICATOR
204
ROBOT CONNECTION SECTION
10
WELDING ROBOT
60
TEACH PENDANT

FIG. 3

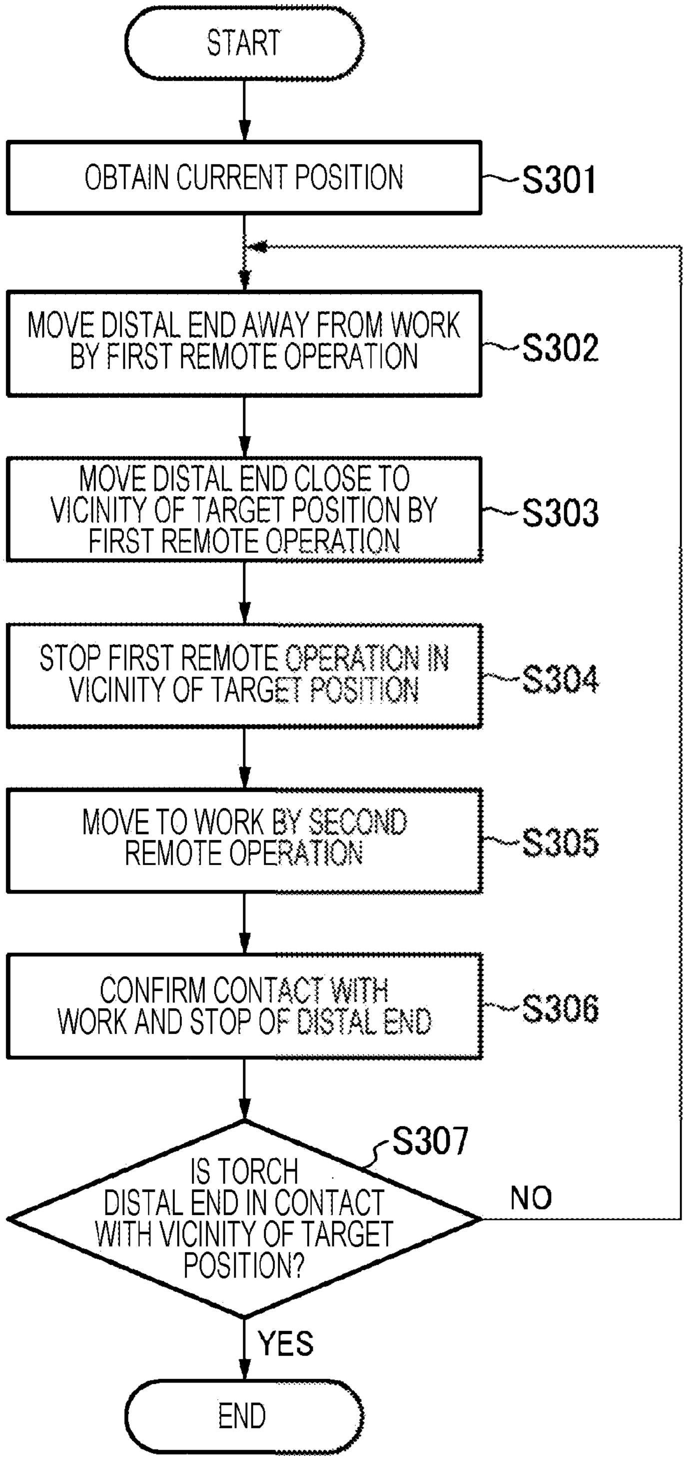

START
OBTAIN CURRENT POSITION
S301
MOVE DISTAL END AWAY FROM WORK BY FIRST REMOTE OPERATION
S302
MOVE DISTAL END CLOSE TO VICINITY OF TARGET POSITION BY FIRST REMOTE OPERATION
S303
STOP FIRST REMOTE OPERATION IN VICINITY OF TARGET POSITION
S304
MOVE TO WORK BY SECOND REMOTE OPERATION
S305
CONFIRM CONTACT WITH WORK AND STOP OF DISTAL END
S306
S307
IS TORCH DISTAL END IN CONTACT WITH VICINITY OF TARGET POSITION?
NO
YES
END

FIG. 4A

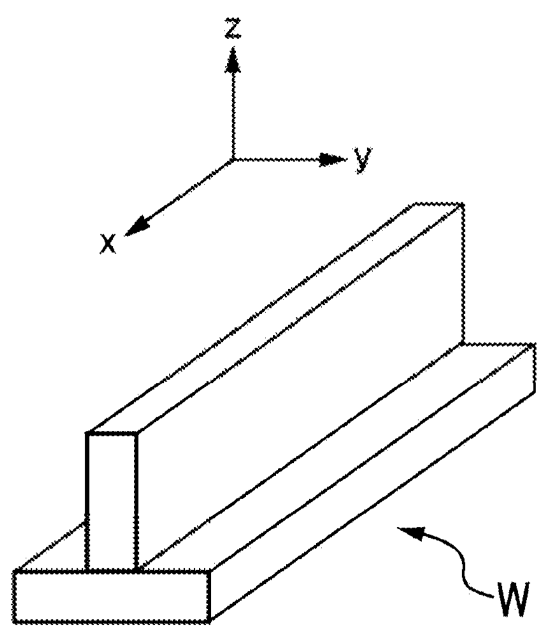


FIG. 4B

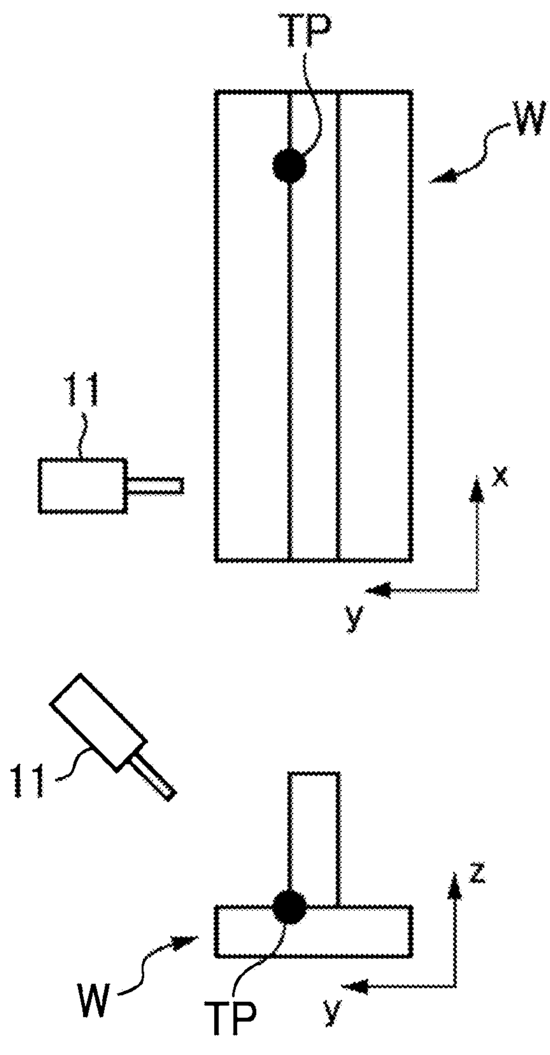


FIG. 4C

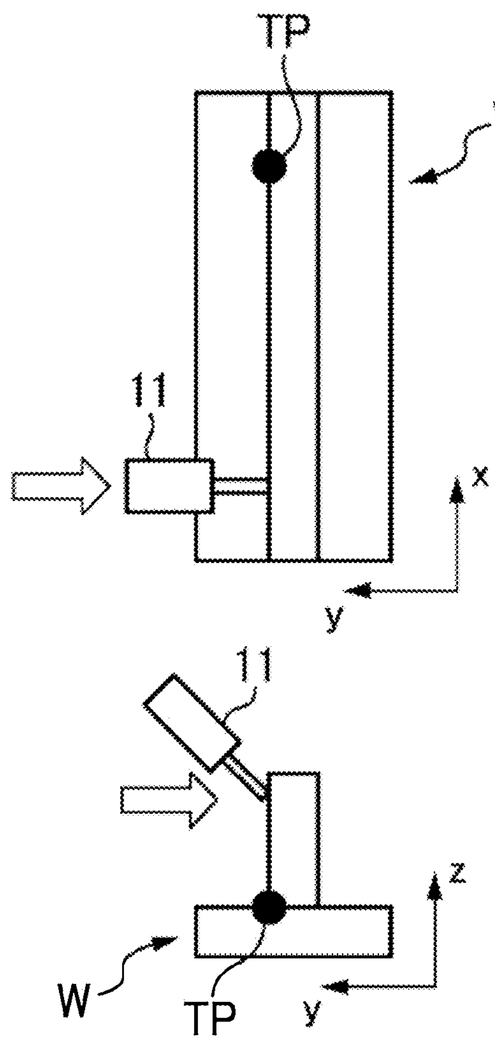


FIG. 4D

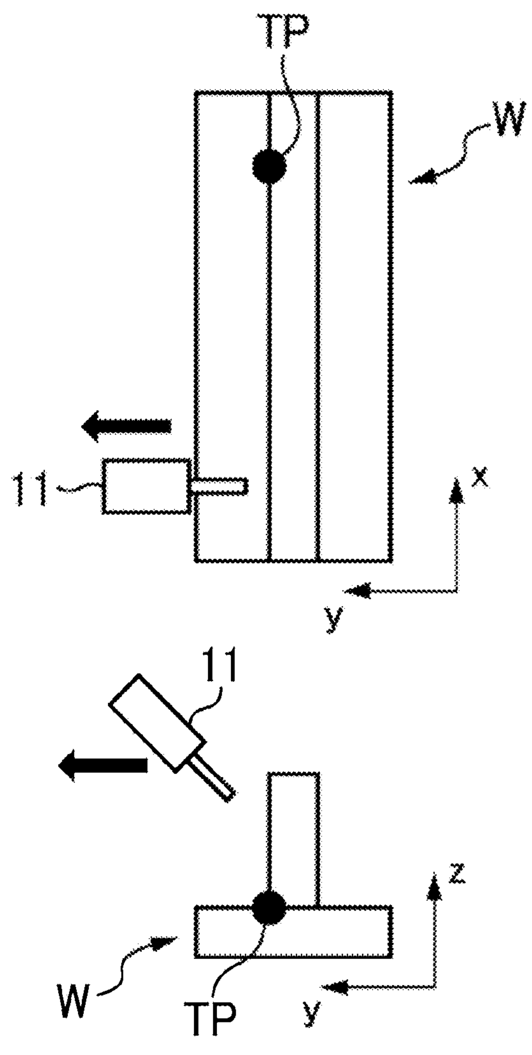


FIG. 4E

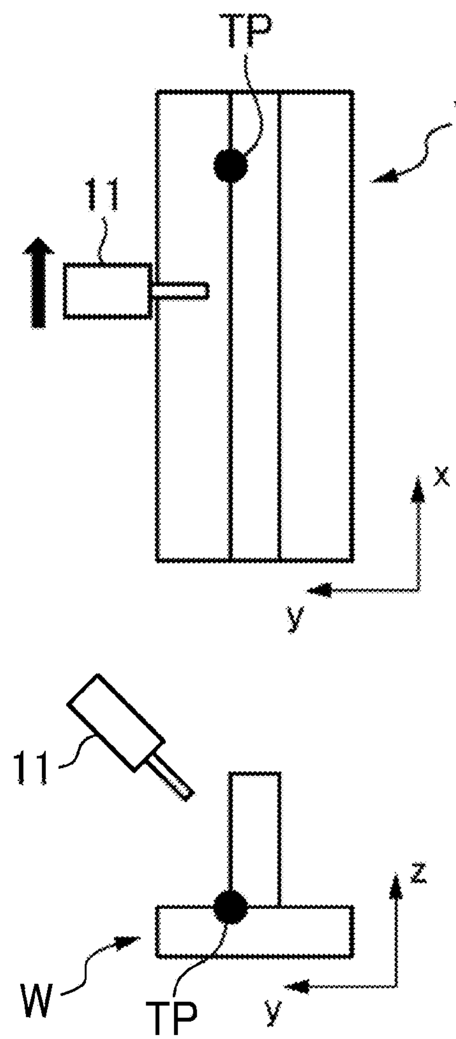


FIG. 4F

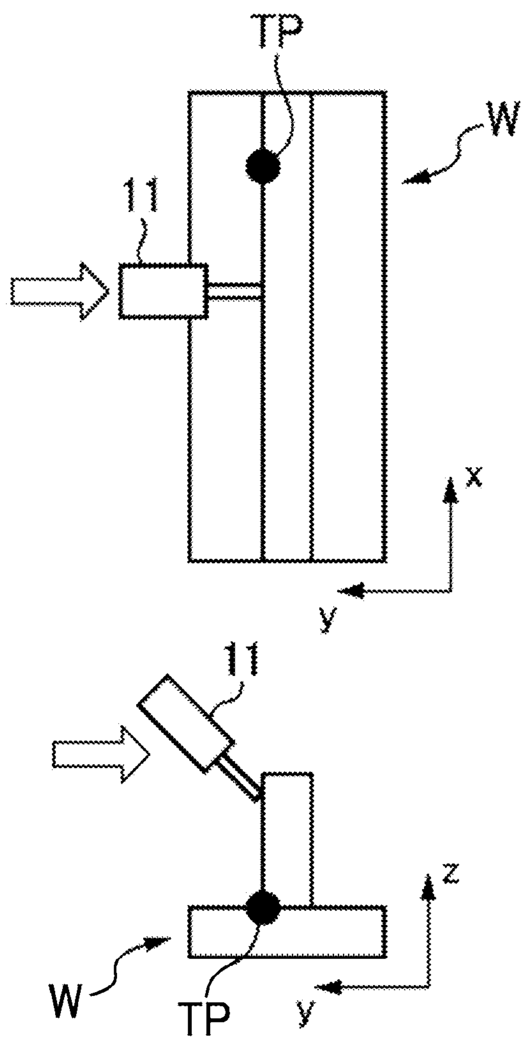


FIG. 4G

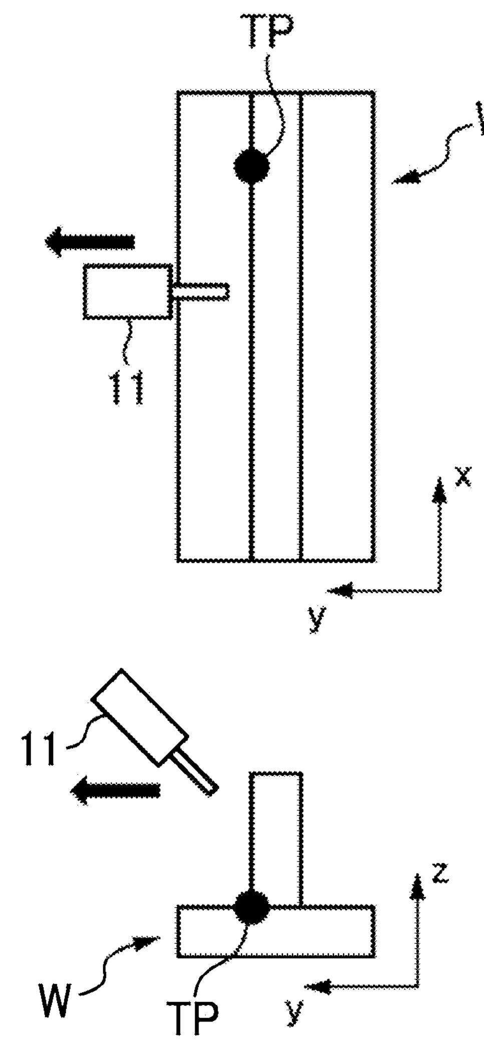


FIG. 4H

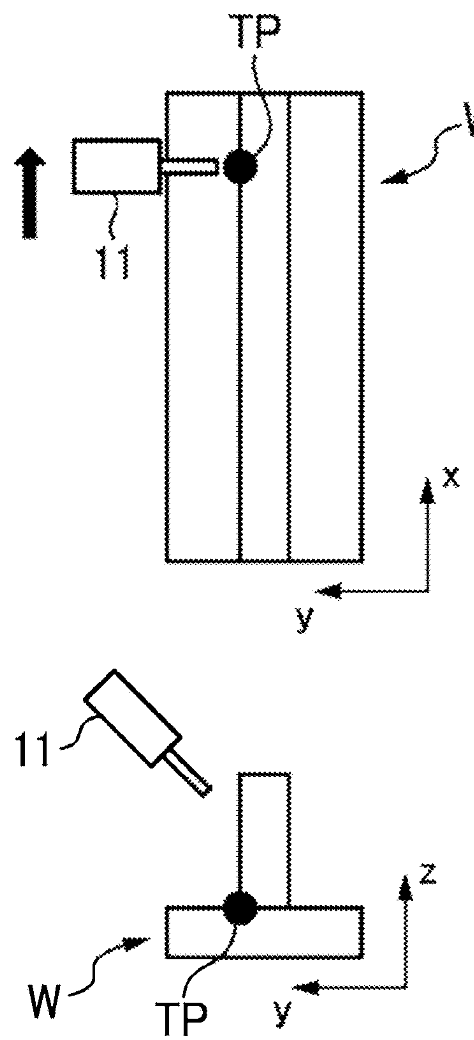


FIG. 4I

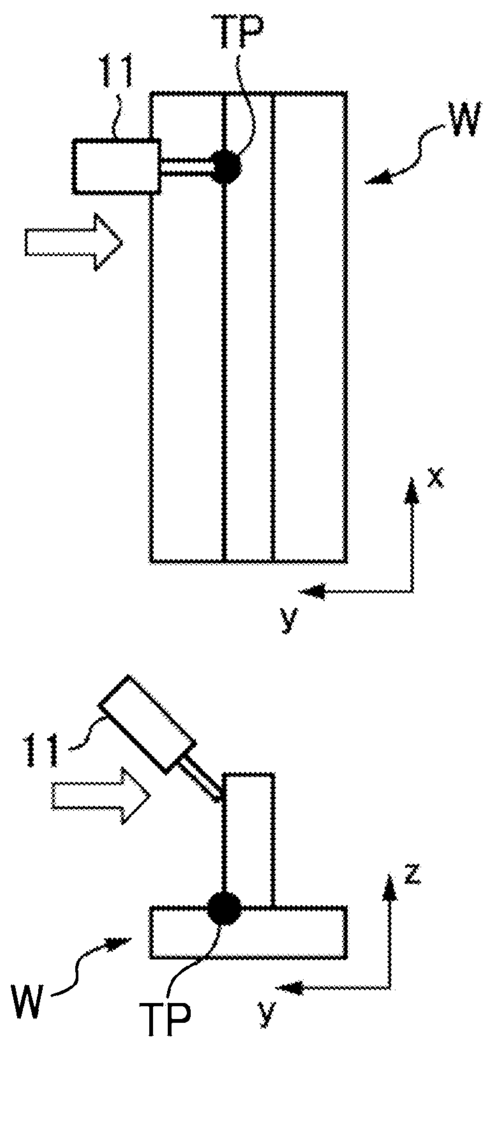


FIG. 4J

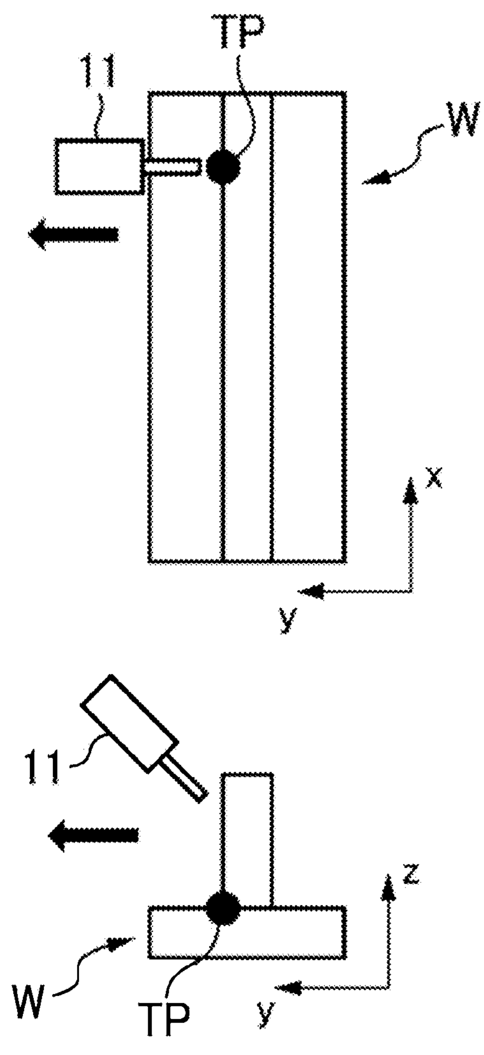


FIG. 4K

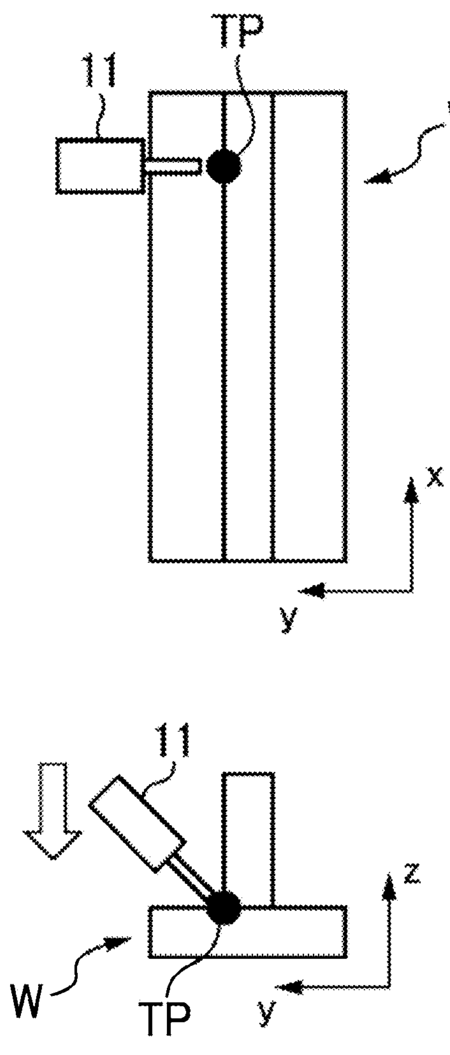


FIG. 4L

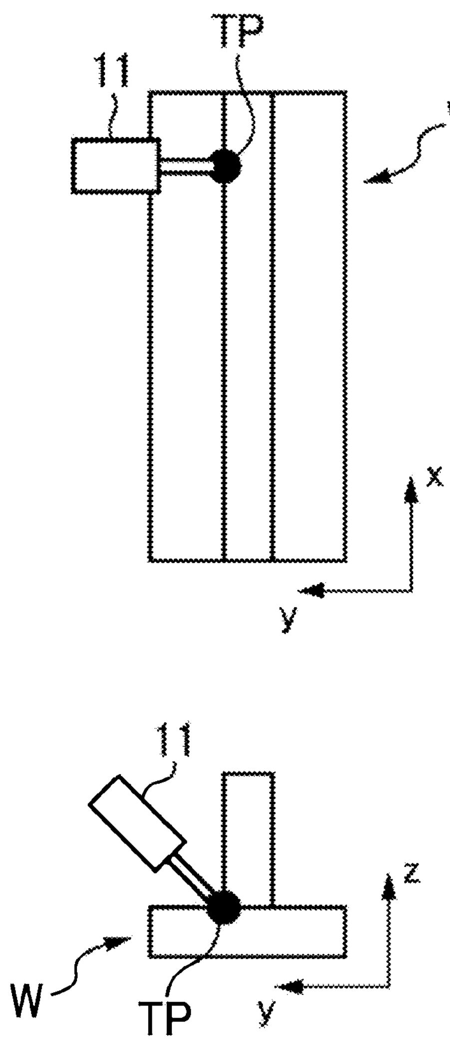


FIG. 5

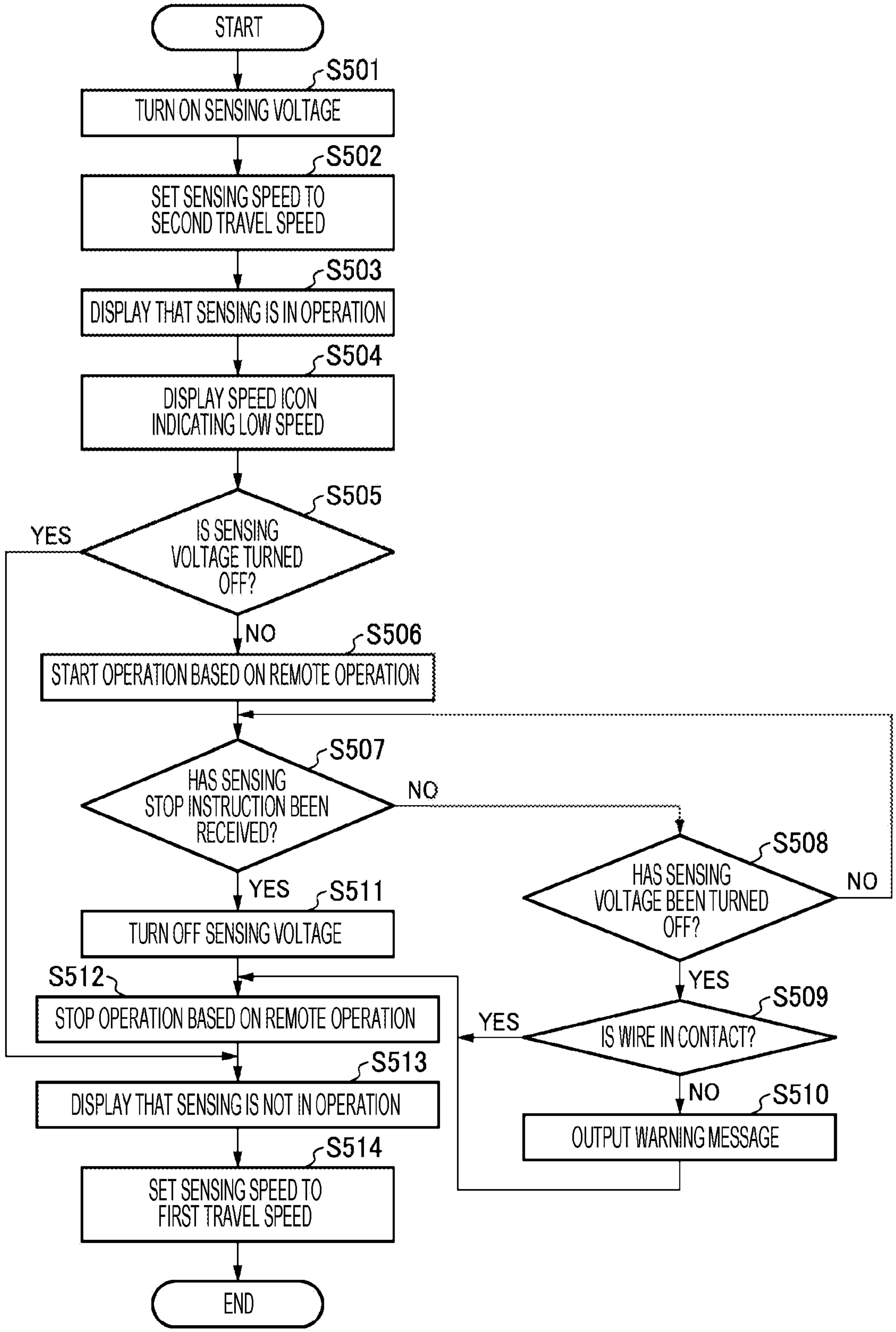

START
S501
TURN ON SENSING VOLTAGE
S502
SET SENSING SPEED TO SECOND TRAVEL SPEED
S503
DISPLAY THAT SENSING IS IN OPERATION
S504
DISPLAY SPEED ICON INDICATING LOW SPEED
S505
IS SENSING VOLTAGE TURNED OFF?
YES
NO
S506
START OPERATION BASED ON REMOTE OPERATION
S507
HAS SENSING STOP INSTRUCTION BEEN RECEIVED?
NO
YES
S508
HAS SENSING VOLTAGE BEEN TURNED OFF?
NO
YES
S509
IS WIRE IN CONTACT?
YES
NO
S510
OUTPUT WARNING MESSAGE
S511
TURN OFF SENSING VOLTAGE
S512
STOP OPERATION BASED ON REMOTE OPERATION
S513
DISPLAY THAT SENSING IS NOT IN OPERATION
S514
SET SENSING SPEED TO FIRST TRAVEL SPEED
END

FIG. 6

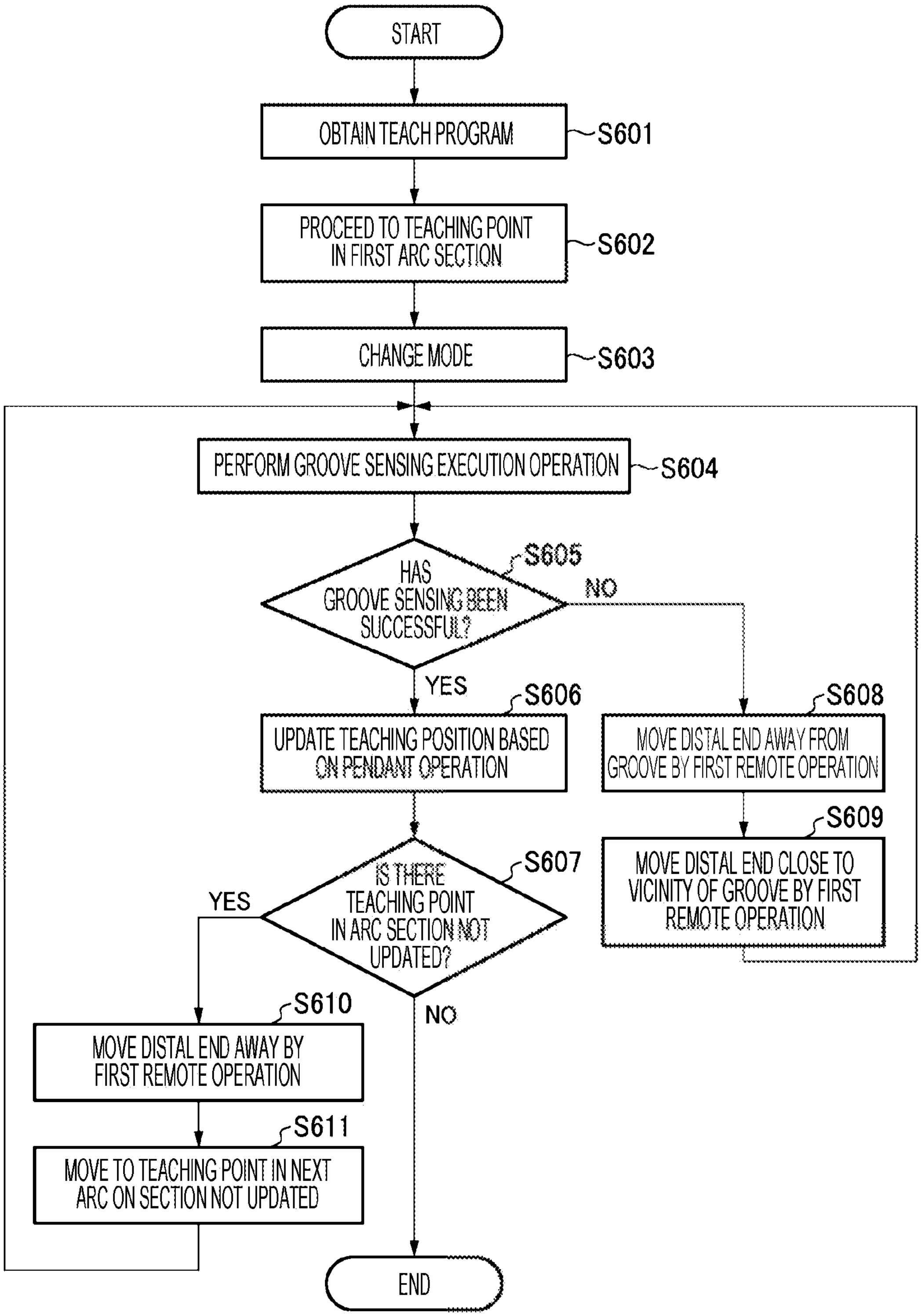

START
OBTAIN TEACH PROGRAM
S601
PROCEED TO TEACHING POINT IN FIRST ARC SECTION
S602
CHANGE MODE
S603
PERFORM GROOVE SENSING EXECUTION OPERATION
S604
HAS GROOVE SENSING BEEN SUCCESSFUL?
S605
NO
YES
UPDATE TEACHING POSITION BASED ON PENDANT OPERATION
S606
MOVE DISTAL END AWAY FROM GROOVE BY FIRST REMOTE OPERATION
S608
MOVE DISTAL END CLOSE TO VICINITY OF GROOVE BY FIRST REMOTE OPERATION
S609
IS THERE TEACHING POINT IN ARC SECTION NOT UPDATED?
S607
YES
NO
MOVE DISTAL END AWAY BY FIRST REMOTE OPERATION
S610
MOVE TO TEACHING POINT IN NEXT ARC ON SECTION NOT UPDATED
S611
END

FIG. 7A

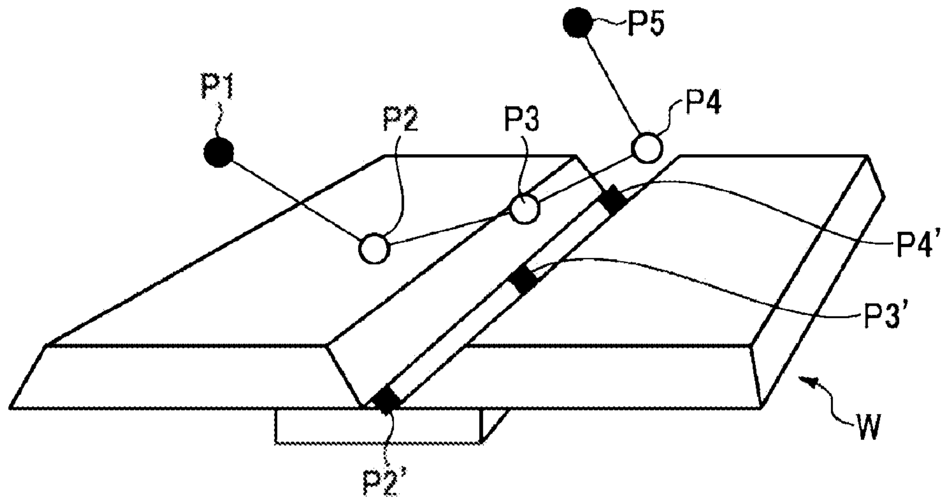


FIG. 7B

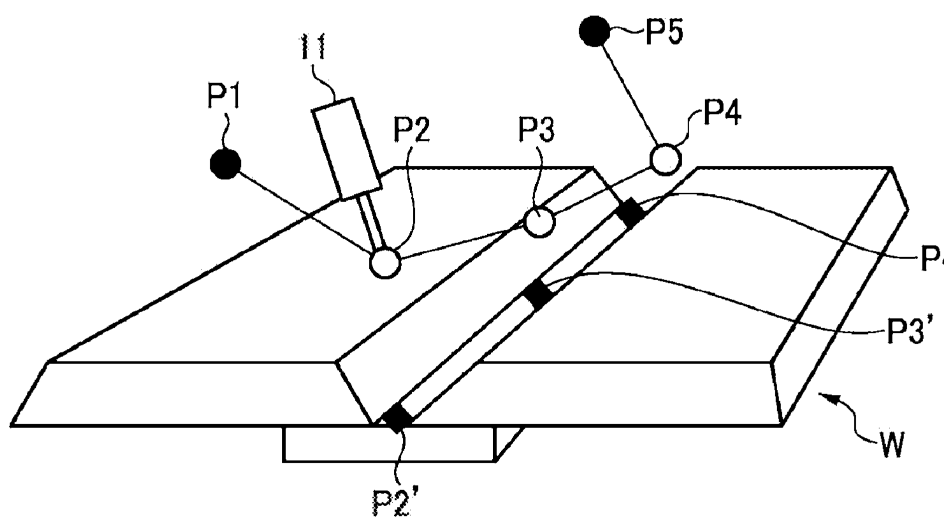


FIG. 7C

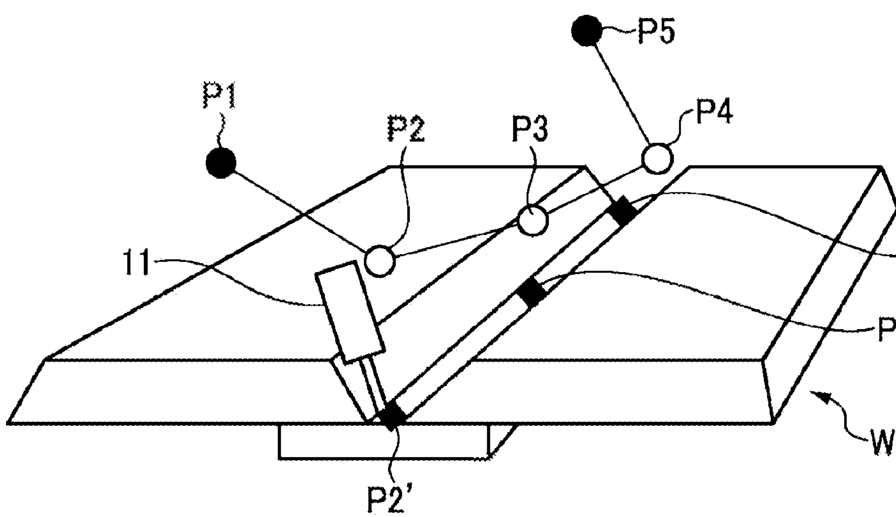


FIG. 8

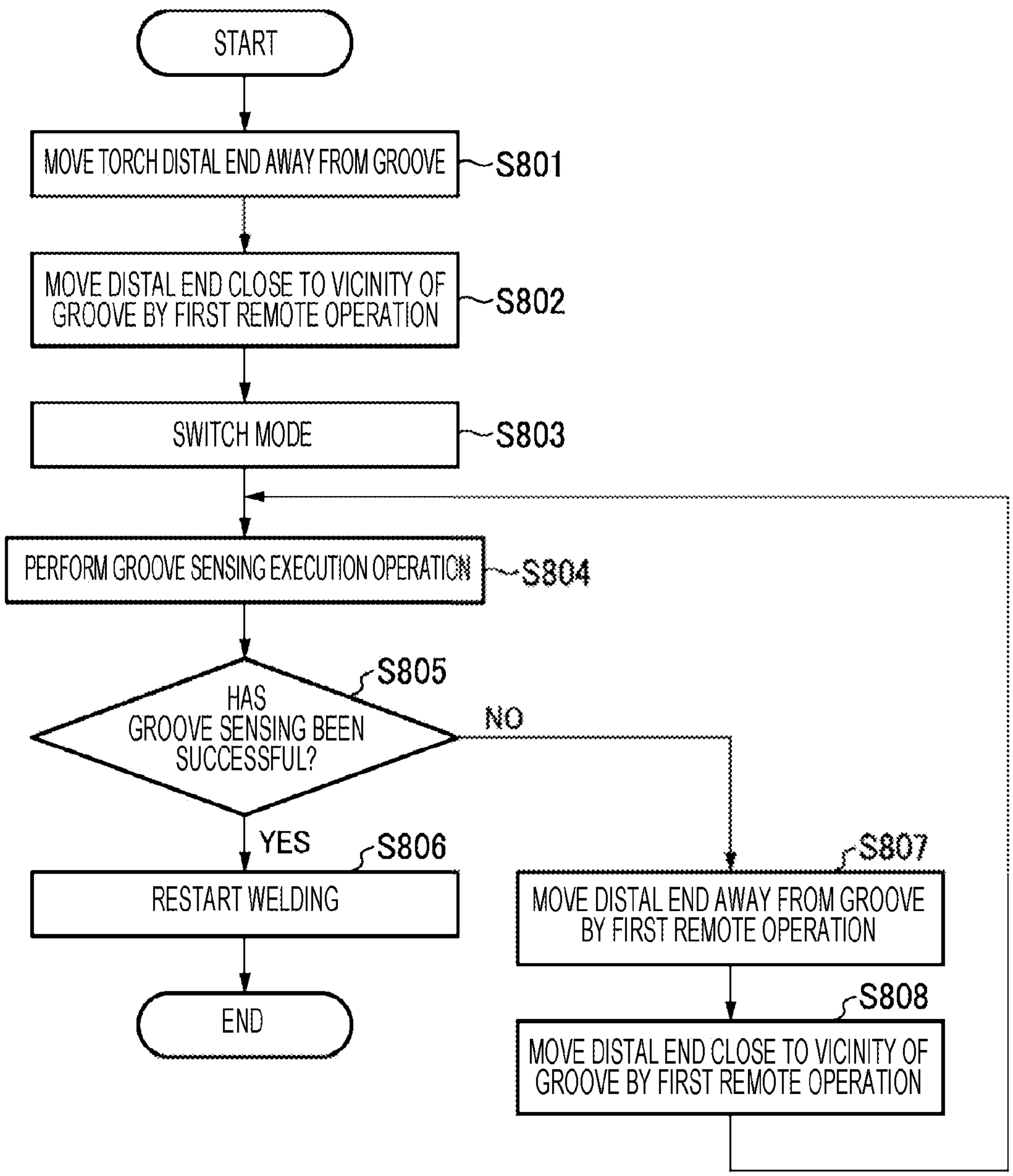

START
MOVE TORCH DISTAL END AWAY FROM GROOVE
S801
MOVE DISTAL END CLOSE TO VICINITY OF GROOVE BY FIRST REMOTE OPERATION
S802
SWITCH MODE
S803
PERFORM GROOVE SENSING EXECUTION OPERATION
S804
HAS GROOVE SENSING BEEN SUCCESSFUL?
S805
NO
YES
S806
RESTART WELDING
END
S807
MOVE DISTAL END AWAY FROM GROOVE BY FIRST REMOTE OPERATION
S808
MOVE DISTAL END CLOSE TO VICINITY OF GROOVE BY FIRST REMOTE OPERATION

FIG. 9A

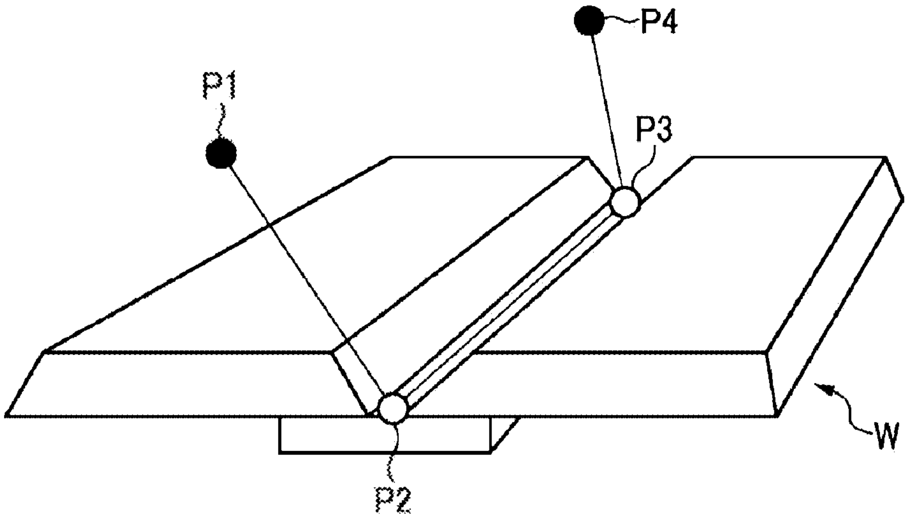


FIG. 9B

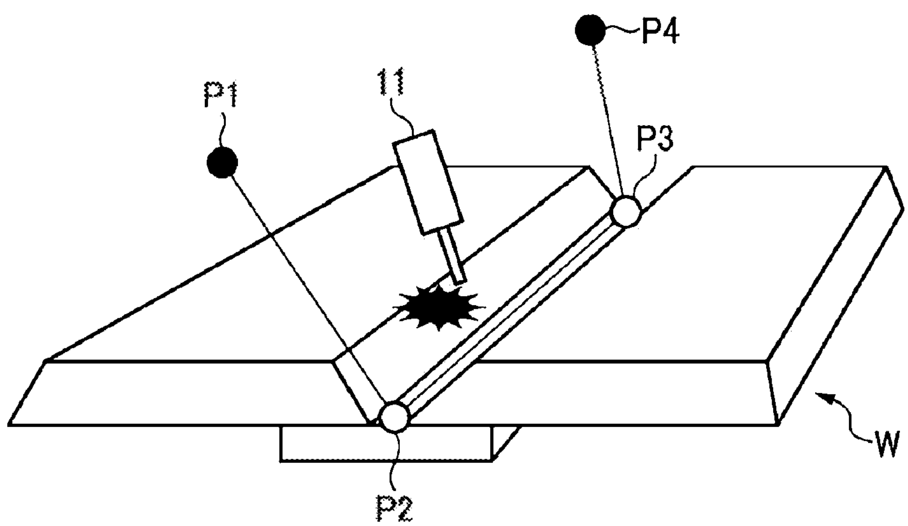
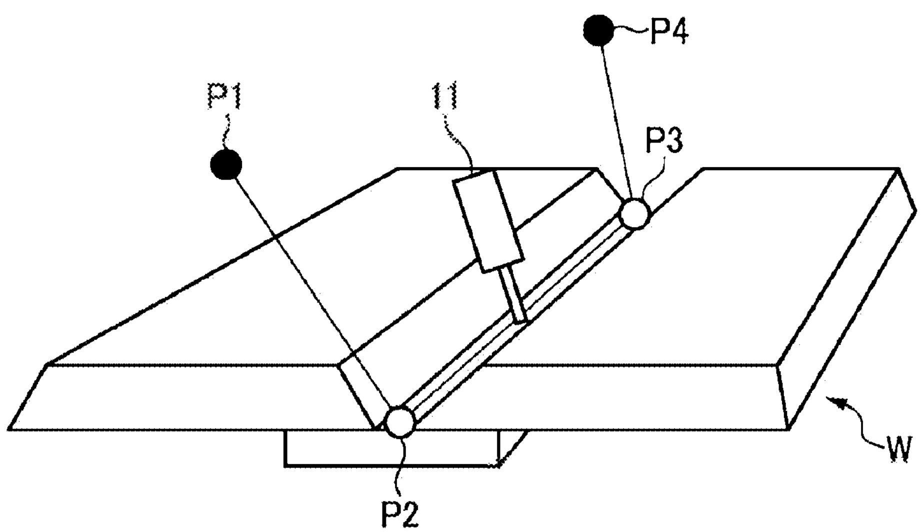


FIG. 9C



REMOTE OPERATION METHOD FOR REMOTE OPERATION WELDING SYSTEM, AND WELDING SYSTEM

TECHNICAL FIELD

[0001] The present invention relates to a remote operation method for remote operation welding system, and a welding system.

BACKGROUND ART

[0002] As a precondition to implement automatic operation and work of an articulated welding robot, it has been necessary for an operator to teach the robot in advance the positions, robot postures and welding conditions related to operations such as a welding operation, a sensing operation, and an operation of moving to a different work area. When welding is stopped due to an error at the time of automatic operation of a welding robot, an operator may manually perform correction work such as position adjustment.

[0003] Like this, when a welding robot system (hereinafter also referred to as a "welding system") including a welding robot is managed, an operator may need to manually operate (hereinafter also referred to as "manual operation") the welding robot. Meanwhile, depending on the welding environment, an operator may not be able to be close to the vicinity of the robot. In such an environment, a problem arises in that various types of work cannot be performed appropriately in a situation where a manual operation is needed, for example, in teaching work or correction work during welding.

[0004] To cope with the problem as mentioned above, the technique as in PTL 1 has been disclosed. PTL 1 discloses a technique that enables all teaching works and welding works to be remotely operated by an operator using an articulated welding robot to obtain a satisfactory welded portion even in an environment where a worker cannot be close to the welding robot or cannot stay nearby for a long time when teaching welding work, for example, in an environment of the nuclear reactor of a nuclear power plant.

CITATION LIST

Patent Literature

[0005] PTL 1: Japanese Unexamined Patent Application Publication No. 2002-96169

SUMMARY OF INVENTION

Technical Problem

[0006] As in PTL 1, even in an environment where a worker cannot be close to the welding robot, a manual operation is made possible by performing remote operation while checking image data captured using a CCD (Charge Coupled Device) camera attached to the distal end of the welding robot. However, the number of installable visual sensors such as CCD cameras is limited in a welding environment, and blind spots may occur. For example, for high-quality welding, extremely delicate work such as target positioning in the order of mm needs to be manually performed at the groove of a work (may be referred to as a base material or a workpiece). In PTL 1, only one visual sensor is attached to the distal end of the welding robot, thus many blind spots occur, and it is difficult to perform various works appropriately. In addition, a situation may occur in which depending on the posture and arrangement of the welding robot, the area of interest is difficult to be visually recognized from an image obtained by the visual sensor, or depending on the performance of the visual sensor, the area of interest cannot be obtained with sufficient clarity. When the welding torch is brought into contact with a surrounding component due to an incorrect operation of an operator, damage to the welding robot, for example, damage to the torch or wire bending may occur.

[0007] Therefore, a function of supporting the manual operation for a welding robot installed remotely while preventing damage to the welding robot has been called for.

[0008] It is an object of the present invention to provide a remote operation method for remote operation welding system and a welding system which enable an operator to appropriately perform various works when the operator manually operates a welding robot installed remotely.

Solution to Problem

[0009] In order to solve the above-described problem, the present invention has the following configuration. Specifically, a remote operation method for welding system enabling remote manual operation of a welding robot, the remote operation method comprising:

- **[0010]** a process of acquiring image data at any position using one or more imaging devices;
- **[0011]** a process of displaying the image data using a display device;
- **[0012]** a process of receiving, from an operator via an operation terminal, an instruction to execute a contact detection function by a welding torch of the welding robot; and
- **[0013]** an operation process of moving the welding torch during execution of the contact detection function based on the instruction given to the welding robot and received via the operation terminal.

[0014] When the welding torch detects contact with a surrounding component by the contact detection function in the operation process, a position of the welding torch is adjusted based on a position of the contact.

[0015] In addition, the present invention has the following configuration as another aspect. Specifically, a welding system comprising:

- **[0016]** a welding robot including a welding torch;
- **[0017]** one or more imaging devices;
- **[0018]** a display device; and
- **[0019]** an operation terminal for manually operating the welding robot remotely.

[0020] The welding system includes:

- **[0021]** an acquisition unit configured to acquire image data at any position using the one or more imaging devices;
- **[0022]** a display unit configured to display the image data using the display device;
- **[0023]** a receiving unit configured to receive, from an operator via the operation terminal, an instruction to execute a contact detection function by the welding torch; and
- **[0024]** an operation unit configured to move the welding torch based on an instruction to the welding robot received during execution of the contact detection function via the operation terminal.

[0025] When the welding torch detects contact with a surrounding component by the contact detection function, the operation unit adjusts a position of the welding torch based on a position of the contact.

Advantageous Effects of Invention

[0026] According to the present invention, it is possible to provide a support function for performing a manual operation of a welding system remotely.

BRIEF DESCRIPTION OF DRAWINGS

[0027] FIG. **1** is a schematic view illustrating an example of a system configuration according to an embodiment of the present invention.
[0028] FIG. **2** is a block diagram illustrating a configuration example of a robot control device according to the embodiment of the present invention.
[0029] FIG. **3** is a flowchart of a sensing process according to the embodiment of the present invention.
[0030] FIG. **4**A is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0031] FIG. **4**B is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0032] FIG. **4**C is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0033] FIG. **4**D is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0034] FIG. **4**E is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0035] FIG. **4**F is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0036] FIG. **4**G is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0037] FIG. **4**H is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0038] FIG. **4**I is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0039] FIG. **4**J is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0040] FIG. **4**K is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0041] FIG. **4**L is a conceptual view for explaining a series of flow of a welding torch for a remote operation according to the embodiment of the present invention.
[0042] FIG. **5** is a flowchart of a sensing process according to the embodiment of the present invention.
[0043] FIG. **6** is a flowchart of an adjustment process for a teaching program according to the embodiment of the present invention.
[0044] FIG. **7**A is a conceptual view for explaining an adjustment process for a teaching program according to the embodiment of the present invention.
[0045] FIG. **7**B is a conceptual view for explaining an adjustment process for the teaching program according to the embodiment of the present invention.
[0046] FIG. **7**C is a conceptual view for explaining an adjustment process for the teaching program according to the embodiment of the present invention.
[0047] FIG. **8** is a flowchart of a groove sensing process according to the embodiment of the present invention.
[0048] FIG. **9**A is a conceptual view for explaining a groove sensing process at the time of error occurrence according to the embodiment of the present invention.
[0049] FIG. **9**B is a conceptual view for explaining a groove sensing process at the time of error occurrence according to the embodiment of the present invention.
[0050] FIG. **9**C is a conceptual view for explaining a groove sensing process at the time of error occurrence according to the embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0051] In the following, an embodiment of the present invention will be described with reference to the drawings. Note that the embodiment described below is an embodiment for explaining the present invention, and it is not intended that the present invention be interpreted in a limited sense. All components described in each embodiment are not necessarily required components to solve the problem of the present invention. In the drawings, the same components are labeled with the same reference numerals to show correspondence relationship thereof.

[0052] The remote operation method and the remote operation welding robot system according to the present invention are useful not only for welding, but also for additive manufacturing technology utilizing GMAW, specifically, wire and arc additive manufacturing (WAAM). The term, additive manufacturing may be used as the term in lamination molding or rapid prototyping in a broad sense; however, in the present invention, the term is used in additive manufacturing in a unified manner. When the technique according to the present invention is applied to the additive manufacturing technology, "welding" is rephrased as "melt bonding", "additive manufacturing" or "lamination molding". For example, when the technique is treated as welding, "welding behavior" is used; however, when the present invention is utilized as additive manufacturing, "welding behavior" may be rephrased as "melt bonding behavior". When the technique is treated as welding, "welding system" is used; however, when the present invention is utilized as additive manufacturing, "welding system" may be rephrased as "additive manufacturing system".

[Configuration of Welding System]

[0053] FIG. **1** illustrates a configuration example of a welding system **1** according to the present embodiment. The welding system **1** illustrated in FIG. **1** includes a welding robot **10**, a robot control device **20**, a power supply device **30**, a visual sensor **40**, a data processing device **50**, and a teach pendant **60**. When the technique according to the present invention is applied to additive manufacturing, for example, the welding system **1** may be interpreted as an additive manufacturing system, and the welding robot **10** may be interpreted as a robot for additive manufacturing. In that case, depending on the system to be applied, a further component may be included.

[0054] The welding robot **10** illustrated in FIG. **1** is comprised of an articulated robot with six axes, and a welding torch **11** for GMAW is attached to the distal end thereof. Note that GMAW includes e.g., MIG (Metal Inert Gas) welding and NAG (Metal Active Gas) welding, and in the present embodiment, MAG welding will be described as an example. The welding robot **10** is not limited to the articulated robot with six axes, and for example, a portable small robot may be used.

[0055] From a wire feeding device **12**, a welding wire **13** is supplied to the welding torch **11**. The welding wire **13** is fed from the distal end of the welding torch **11** to a welding point. The power supply device **30** supplies electric power to the welding wire **13**. Due to the electric power, an arc voltage is applied across the welding wire **13** and work W to generate an arc. The power supply device **30** is provided with a current sensor (not illustrated) that detects a welding current which flows during welding from the welding wire **13** to the work W, and a voltage sensor (not illustrated) that detects the arc voltage across the welding wire **13** and the work W.

[0056] The power supply device **30** includes a processor and a storage which are not illustrated. The processor is comprised of e.g., a CPU (Central Processing Unit). The storage is comprised of a volatile or non-volatile memory such as an HDD (Hard Disk Drive), a ROM (Read Only Memory) and a RAM (Random Access Memory). The processor controls the electric power to be applied to the welding wire **13** by executing a computer program for power supply control stored in the storage. The power supply device **30** is also connected to the wire feeding device **12**, and the processor controls the feed speed and the feed amount of the welding wire **13**.

[0057] The composition and type of the welding wire **13** may be selected according to the object to be welded. The type of the welding wire **13** may include e.g., solid wire and flux wire containing flux. The material for the welding wire **13** may include e.g., mild steel, stainless steel, aluminum, and titanium, and the wire surface may be plated with copper or the like. In addition, the diameter of the welding wire **13** is not limited to a specific value. In the present embodiment, as an example, a welding wire having an upper limit diameter of 1.6 mm and a lower limit diameter of 0.8 mm may be used.

[0058] The visual sensor **40** is comprised of e.g., a CCD (Charge Coupled Device) camera. The installation position of the visual sensor **40** is not limited to a specific position, and the visual sensor **40** may be directly attached to the welding robot **10**, or may be fixed to a specific location in the surrounding as a surveillance camera. When the visual sensor **40** is directly attached to the welding robot **10**, the visual sensor **40** is moved to capture the vicinity of the distal end of the welding torch **11** in coordination with the operation of the welding robot **10**. The number of cameras included in the visual sensor **40** may be a plural number. For example, the visual sensor **40** may be formed using multiple cameras having different functions and installation positions.

[0059] In the present embodiment, the configuration using a fixed visual sensor **40** will be described as an example, the visual sensor **40** being installed in an environment where the welding robot **10** is utilized. When the visual sensor **40** is fixed to a location other than the welding robot **10**, it is preferable to adopt a camera having at least PTZ functions as the visual sensor **40**, and pan, tilt, and zoom may be controlled in coordination with the operation of the welding robot **10**. Along with the operation of the welding robot **10**, the visual sensor **40** may obtain the image of the distal end, as the work position, of the welding torch **11**, and additionally, may obtain any image by an operator, as the user of the data processing device **50**, specifying pan, tilt, zoom to check the range as a target, and providing direction on image capture settings. Specifically, it is preferable to obtain image data including at least one of the vicinity of the welding torch **11** of the welding robot or the vicinity of a weld line. The image capture settings include e.g., frame rate, the number of pixels in image, resolution, and shutter speed.

[0060] The data processing device **50** includes e.g., a CPU, a ROM, a RAM, a hard disk drive, an I/O interface, a communication interface, a video output interface, and a display unit (hereinafter also referred to as a display) which are not illustrated. The data processing device **50** may be comprised of e.g., an information processing device such as a PC (Personal Computer). The data processing device **50** can display at least video data captured in real time at any frame rate by the visual sensor **40** on a display by cooperation of the above-mentioned components. When the visual sensor **40** is a fixed surveillance camera as in the present embodiment, the data processing device **5*o*** may further include a visual sensor controller. In addition, the data processing device **50** may be provided with an image processor that can change the brightness, contrast etc. of displayed video data, or provided with a storage that records and stores video. Note that a series of process from input of an image to real-time image display on a display may be performed by a software installed on the data processing device **50**.

[0061] The components included in the welding system **1** are communicably connected by various wired/wireless communication systems. The communication systems here are not limited to one type, and connection may be made by combining multiple communication systems.

[Configuration of Robot Control Device]

[0062] FIG. **2** illustrates a configuration example of the robot control device **20** that controls the operation of the welding robot **10**. The robot control device **20** includes a CPU **201** that controls the entire device, a memory **202** that stores data, an operation panel **203** including multiple switches, a robot connection section **204**, and a communicator **205**. The memory **202** is comprised of a volatile or non-volatile storage device such as a ROM, a RAM, an HDD. The memory **202** stores a control program **202**A used for control of the welding robot **10**. The CPU **201** controls various operations of the welding robot **10** by executing the control program **202**A.

[0063] For input of instructions to the robot control device **20**, the operation panel **203** and the teach pendant **60** can be used, and primarily, the teach pendant **60** is utilized. The teach pendant **60** is coupled to the body of the robot control device **20** via the communicator **205**. The operator can input a teaching program using the teach pendant **60**. The robot control device **20** controls the welding robot **10** in accordance with the teaching program input from the teach pendant **60**. Note that the teaching program can be automatically generated based on CAD (Computer-Aided Design) information using, for example, a computer which is not illustrated. The operation details defined in the teaching program are not limited to a specific one, and may vary with the specifications and welding method of the welding robot **10**.

[0064] The teach pendant **60** enables manual operation of the welding robot **10** via the robot control device **20**. In the present embodiment, a welding robot adopting a teaching-playback method is used. In this method, an operator manually operates the welding robot **10** to perform teaching works, such as providing teaching points on an operation line, a weld line of the welding robot **10** and storing the positions thereof, storing the coordinate information on the posture of the welding robot **10**, and inputting a welding condition. Thus, the teaching program used for automatically operating the welding robot **10** is generated. When the welding robot **10** is stopped due to an error occurred in the middle of welding during automatic operation of the welding robot **10**, an operator can perform correction work such as changing the target position by manually operating the welding robot **10** using the teach pendant **60**.

[0065] The robot connection section **204** is connected to a drive circuit of the welding robot **10**. The CPU **201** outputs a control signal based on the control program **202**A to a drive circuit (not illustrated) included in the welding robot **10** via the robot connection section **204**.

[0066] The communicator **205** includes a communication module for wired or wireless communication. The communicator **205** is used for communication of data and signals with the power supply device **30**, the data processing device **50**, and the teach pendant **60**. The system and standard of communication used by the communicator **205** are not limited to specific ones, and multiple systems may be combined or a different system may be used for each device connected. From the power supply device **30**, for example, the current value of a welding current detected by a current sensor (not illustrated), and the voltage value of an arc voltage detected by a voltage sensor (not illustrated) are given to the CPU **201** via the communicator **205**.

[0067] The robot control device **20** also controls the travel speed and the extension direction of the welding torch **11** by the control of each axis of the welding robot **10**. When a weaving operation is performed, the robot control device **20** also controls the weaving operation of the welding robot **10** according to the preset cycle, amplitude, and welding speed. The weaving operation refers to alternate swinging of the welding torch **11** in a direction intersecting with a travel direction of welding, i.e., a welding direction. The robot control device **20** performs weld line tracking control along with the weaving operation. The weld line tracking control is an operation of controlling the position on the right and left with respect to the travel direction of the welding torch **11** so that bead is formed along the weld line. In addition, the robot control device **20** also controls the feed speed of the welding wire **13** by controlling the wire feeding device **12** via the power supply device **30**.

[Remote Operation Method]

[0068] In the present embodiment, a description will be given assuming that an operator utilizing the welding system **1** controls and teaches the remotely located welding robot **10** using the teach pendant **60** and the data processing device **50**. In this case, the welding robot **10** and the visual sensor **40** are installed at a position away, i.e., remotely from an operator and the data processing device **50**, and the operator visually recognizes an image of work W set in the vicinity of the welding robot **10** via the display of the data processing device **50**, the image being captured by the visual sensor **40**. The operator checks the image of the work W, thereby performing various operations while recognizing the positional relationship between the welding robot **10**, particularly, the welding torch **11** and the work W.

[0069] In this process, the operator visually recognizes the work W and the welding robot **10** indirectly using the image captured by the visual sensor **40**, thus as mentioned above, blind spots may occur or a situation may occur in which the object is hard to be visually recognized clearly. Particularly, in the case of fillet welding, the object is difficult to be visually recognized clearly, and it is difficult for the operator to grasp the welding position three-dimensionally. In the case of welding of a groove, in addition to the difficulty in clear visual recognition, blind spots may occur. In addition, although fine control is needed for the contact state between the vicinity of the distal end of the welding robot **10** and the work W, in a situation in which the object is hard to be visually recognized, the position of the distal end of the welding torch **11** is prevented from being finely adjusted without applying a load of contact more than necessary. As a result, in order to avoid contact with the welding torch **11**, the distance between the work W and the welding torch **11** is provided more than necessary, thus teaching of an appropriate position of the welding torch **11** is not possible.

[0070] Thus, in the present embodiment, contact between the welding robot **10** and the work W is detected appropriately at the time of remote operation, and the convenience of teaching work by an operator is improved.

[0071] FIG. **3** is a flowchart showing the flow of grasping the position on the work W related to welding by an operator at the time of remote operation. In this process, the robot control device **20** performs the process while receiving various operations by the operator via the teach pendant **60**.

[0072] In S**301**, the operator grasps the current position of a predetermined part of the current welding robot **10** from an image displayed on the data processing device **50**. Here, the predetermined part will be described using an example of the distal end of the welding torch **11**. The distal end of the welding torch **11** referred to herein indicates the distal end position of the welding wire **13** which has been fed via the welding torch **11** and has a predetermined extension. First, the robot control device **20** applies electric power (hereinafter also referred to as "sensing voltage") for detection to the welding torch **11** or the welding wire **13**. The robot control device **20** then moves the welding torch **11** in a predetermined direction to cause contact with the work W. The predetermined direction is based on the instructions to the teach pendant **60** by the operator. The contact of the work W with the welding wire **13** at the distal end of the welding torch **11** causes the operation of the welding robot **10** to be stopped, thus the positional relationship between the work W and the welding wire **13** is identified by the position of the welding wire **13**.

[0073] In S**302**, the operator moves the welding torch **11** away from the work W. The distance and direction for moving away may be based on the instructions of the operator. Let "first remote operation" be the remote operation performed by the operator in a state where a sensing voltage is not being applied, and "second remote operation" be the remote operation performed by the operator in a state where a sensing voltage is being applied. The travel speed of the "first remote operation" is referred to as the "first travel speed", and the travel speed of the "second remote operation" is referred to as the "second travel speed". Therefore, the process of S**301** is performed by the "second remote operation" based on the instructions of the operator, and the process of S**302** is performed by the "first remote operation" based on the instructions of the operator.

[0074] For setting the "first travel speed" and the "second travel speed", different speed levels are provided in advance, and in the present embodiment, as the "first travel speed", any speed level can be selected from four predetermined speed levels "high", "middle", "intermediate low", and "low". Also, as the "second travel speed", any speed level can be selected by a numerical value 100 to 1 from predetermined "maximum speed" to "minimum speed". The "high" in the "first travel speed" corresponds to 100 in the "second travel speed", and the "low" corresponds to 3. As long as the setting is not changed, the "second travel speed" is 3 which is the same speed as the "low" in the "first travel speed". The second travel speed is preferably set lower than the first travel speed, at least the second travel speed is such a speed that can be decelerated to zero almost simultaneously with detection of a voltage change generated when contact between the welding torch **11** and the work W occurs. When a change in the voltage is detected, the robot control device **20** automatically switched to the "first remote operation".

[0075] In S**303**, the operator operates the welding robot **10** by the first remote operation via the teach pendant **60** based on any target position, and the current position obtained in S**301** so that the distal end of the welding torch **11** approaches the target position.

[0076] In S**304**, the operator operates the teach pendant **60** to stop the welding torch **11** at the position where the distal end thereof is away from the target position by a certain distance. Here, the operator stops the first remote operation. The certain distance here may be determined at the discretion of the operator.

[0077] In S**305**, the operator uses the teach pendant **60** to switch to the second remote operation, and move the welding torch **11** to cause the distal end thereof to come into contact with the work W.

[0078] In S**306**, the robot control device **20** stops the operation with the distal end of the welding torch **11** in contact with the work W. At this point, the operator confirms that the welding torch **11** has come into contact the work W and stopped.

[0079] In S**307**, the operator determines whether the contact position at the distal end of the welding torch **11** is in a predetermined range from the target position. The predetermined range here may be determined as a range of acceptable error at the discretion of the operator. When the contact is not made in the predetermined range (NO in S**307**), the process by the operator is returned to S**302**, and the process is repeated. When the contact is made at a position in the predetermined range (YES in S**307**), the process flow is completed.

[0080] Next, an operation example of the welding torch **11** in remote operation to which the sensing process is applied will be described. FIGS. **4**A to **4**L are views for explaining a series of operation flow of the welding torch **11** performed via instructions from the teach pendant **60** by the operator in the remote operation according to the present embodiment. FIGS. **4**A to **4**L each illustrate the positional relationship between the work W and the welding torch **11** with a view along the z-axis associated with a view along the x-axis. A specific description will be given with reference to FIGS. **4**A to **4**L according to the flow of the flowchart illustrated in FIG. **3**. As illustrated in FIG. **4**A, a description will be given using an example of the work W consisting of two members disposed to be perpendicular to each other.

[0081] FIG. **4**B illustrates a state example before the start of the process of S**301** of FIG. **3**. First, as illustrated in FIG. **4**C, in order to obtain the current position of the welding torch **11**, the operator gives instructions to the robot control device **20** via the teach pendant **60** to cause the welding torch **11** to come into contact with the work W by the second remote operation. This corresponds to the process of S**301** of FIG. **3**. Here, an example has been illustrated in which the welding torch **11** is moved in the y-axis direction, but may be configured to be moved in another axis.

[0082] Next, as illustrated in FIG. **4**D, after contact between the distal end of the welding torch **11** and the work W, the sensing voltage is released, and switching is made to the first remote operation. Subsequently, the operator moves the welding torch **11** away from the work W. This corresponds to the process of S**302** of FIG. **3**. Here, an example is shown in which the direction of moving away is opposite to the direction in which the work W approaches in FIG. **4**C.

[0083] Next, as illustrated in FIG. **4**E, the operator moves the welding torch **11** in a direction closer to the target position by still the first remote operation via the teach pendant **60**. This corresponds to the process of S**303** of FIG. **3**.

[0084] Next, as illustrated in FIG. **4**F, after moving the welding torch **11** by a predetermined distance, the operator switches to the second remote operation via the teach pendant **60**, and moves the welding torch **11** to cause the distal end thereof to come into contact with the work W. This corresponds to the process of S **305** of FIG. **3**. At this point, since the contact position between the work W and the welding torch **11** is not within a predetermined range from the target position (corresponding to NO in S**307** of FIG. **3**), the process is further repeated.

[0085] FIG. **4**G corresponds to the process of S**302** repeated. Also, FIG. **4**H corresponds to the process of S**303** repeated. In addition, FIG. **4**I corresponds to the process of S**306** repeated. At this point, it is identified that the coordinates in the x-axis and the y-axis out of three axes, the x-axis, the y-axis, the z-axis match the target position. Meanwhile, in the z-axis direction, the contact position is not within a predetermined range from the target position (corresponding to NO in S**307** of FIG. **3**), the process is further repeated.

[0086] FIG. **4**J corresponds to the process of S**302** further repeated. Next, FIG. **4**K corresponds to the process of S**303** further repeated. Since the position of the x-axis and the y-axis are already adjusted, the operator moves the welding torch **11** in a direction in which adjustment is not made, that is, in the z-axis direction in this example via the teach pendant **60** so as to approach the target position. The operator switches to the second remote operation in advance, and moves the welding torch **11** in a direction in which adjustment is not made.

[0087] As illustrated in FIG. **4**L, when a contact state between the distal end of the welding torch **11** and the vicinity of the target position is achieved, remote adjustment operation by the operator is completed.

[0088] When the visual sensor **40** is disposed to capture the work W from the near-side direction of the weld line, for example, in the state of FIG. **4**C and the state of FIG. **4**F, the position of the welding torch **11** and the target position overlap in the image of the visual sensor **40**, which presumably makes it difficult for the operator to visually recognize the target position. Depending on the performance, for example, the resolution of the visual sensor **40**, the target position in the work W may not be able to be captured clearly, and in such a situation, presumably, it is difficult for the operator visually recognize the target position. As a result, when the operator makes a teaching program, it may be difficult to specify an appropriate target position. Thus, it is possible to provide a support function for making a teaching program with higher accuracy by causing the welding system **1** to perform the control as described above when the position on the work W is identified.

[0089] FIG. **5** is a flowchart showing the flow of process to be performed by the robot control device **20** when the operator of the welding system **1** starts the "second remote operation" using the teach pendant **60**. In other words, the present flowchart is executed by the robot control device **20** when the operator of the welding system **1** performs an operation to detect contact between the work W and the distal end of the welding torch **11** using the teach pendant **60**. Therefore, the present flowchart may be executed in each of the processes in S**301**, S**305**, S**306** illustrated in FIG. **3**.

[0090] As described above, at the time of remote operation, an image around the welding torch **11** is captured by the visual sensor **40**, and displayed on the display of the data processing device **50** as appropriate so that the operator can visually recognize the image. The image capture settings for the visual sensor **40** may be adjustable at the discretion of the operator.

[0091] In S**501**, when the operator starts the "second remote operation" using the teach pendant **60**, the robot control device **20** applies a sensing voltage to detect contact at the distal end of the welding torch **11** based on instructions from the teach pendant **60**. In the present embodiment, a touch sensor system is used for the second remote operation, and a voltage is applied across the work W and the welding wire **13** at the distal end of the welding torch **11**, and phenomenon of voltage drop is utilized, which occurs when the welding wire **13** comes into contact with the work W. Consequently, the work position and groove position are detected. Note that the contact detection function is not limited to this, and it is possible to use a pressure sensor that detects contact by a pressure generated when contact between the welding torch and the base material occurs, and a voltage detection sensor that detects contact by a load voltage applied to a motor when contact between the welding torch and the base material occurs. Note that when the operator starts the contact detection function on the teach pendant **60**, a sensing voltage may be continued to be applied across the work and at least one of the welding wire and a nozzle included in the welding torch until the contact detection function is terminated or contact between the welding torch and the base material occurs once.

[0092] In S**502**, the robot control device **20** sets the travel speed of the welding torch **11**, i.e., the speed of the second remote operation to the second travel speed.

[0093] In S**503**, on a display (not illustrated) included in the teach pendant **60**, the robot control device **20** displays that the second remote operation is being performed, specifically, the sensing operation is being performed. The display method here is not limited to a specific one, and for example, the color of an icon displayed on the display may be changed, or a message may be displayed.

[0094] In S**504**, on the display (not illustrated) included in the teach pendant **60**, the robot control device **20** displays that the sensing operation is being performed at the low speed, that is, the second travel speed. The display method here is not limited to a specific one, and for example, an icon may be displayed in association with the icon displayed in S**503**.

[0095] In S**505**, the robot control device **20** determines whether the sensing voltage applied to the welding torch **11** has been turned OFF. In other words, the robot control device **20** determines whether the welding torch **11** and the work W are in contact with each other at the start of the sensing operation. When these are in contact with each other, the sensing voltage is OFF at this point. When the sensing voltage is OFF (YES in S**505**), the robot control device **20** stops application of the sensing voltage, and the process of the robot control device **20** proceeds to S**513**. Meanwhile, when the sensing voltage is ON (NO in S**505**), the process of the robot control device **20** proceeds to S**506**.

[0096] In S**506**, the robot control device **20** starts to move the welding torch **11** in response to reception of a remote operation by the operator via the teach pendant **60**.

[0097] In S**507**, the robot control device **20** determines whether a sensing stop instruction has been received from the operator via the teach pendant **60** during the sensing operation. The sensing stop instruction may be made, for example, by releasing any button provided in the teach pendant **60**. When the sensing stop instruction is received (YES in S**507**), the process of the robot control device **20** proceeds to S**511**. Meanwhile, when the sensing stop instruction is not received (NO in S**507**), the sensing operation is continued, and the process of the robot control device **20** proceeds to S**508**.

[0098] In S**508**, the robot control device **20** determines whether the sensing voltage applied to the welding torch **11** has been turned OFF. In other words, the robot control device **20** determines whether the welding torch **11** has come into contact with the work W. When these are in contact, the sensing voltage is OFF at this point. When the sensing voltage is OFF (YES in S**508**), the process of the robot control device **20** proceeds to S**509**. Meanwhile, when the sensing voltage is ON (NO in S**508**), the sensing operation is continued, and the process of the robot control device **20** returns to S**507**.

[0099] In S**509**, the robot control device **20** determines whether the welding wire **13** at the distal end of the welding torch **11** has come into contact with the work W. In the present embodiment, using the setting that the signal terminal to detect reduction in the sensing voltage varies with the position of contact, it is determined whether the welding wire **13** at the distal end of the welding torch **11** has come into contact with the work W, or whether a portion other than the welding wire **13** has come into contact with the work W. When the welding wire **13** has come into contact with the work W (YES in S**509**), the process of the robot control device **20** proceeds to S**512**. Meanwhile, when the welding wire **13** has not come into contact with the work W (NO in S**509**), an unexpected position on the welding torch **11** has come into contact with the work W, thus the process of the robot control device **20** proceeds to S**510** in which a warning is issued. In the present embodiment, a state in which the sensing voltage is OFF, and the welding wire **13** and the work W are not in contact is presumably achieved when a nozzle part included in the welding torch **11** has come into contact with the work W. Even when a nozzle part comes into contact with the work W, the sensing voltage decreases, and the contact is detectable, which can be used as means to prevent damage to the torch.

[0100] In S**510**, the robot control device **20** displays a warning message on the display of the teach pendant **60**. The detail of the warning message is not limited to a specific one, and may be a notification indicating that the work W and a portion other than the distal end of the welding torch **11** are in contact with each other.

[0101] In S**511**, the robot control device **20** turns OFF the sensing voltage.

[0102] In S**512**, the robot control device **20** stops the operation based on the remote operation.

[0103] In S**513**, on the display (not illustrated) included in the teach pendant **60**, the robot control device **20** displays that the sensing operation is not being performed. The display here may be made by returning the display made in S**503** to the original.

[0104] In **8514**, the robot control device **20** sets the travel speed of the welding torch **11** to "low" of the first travel speed. The process flow is then completed.

[0105] As described above, each time instructions to start the "second remote operation" are given by the operator via the teach pendant **60**, the process flow illustrated in FIG. **5** is executed from the start to the end. Therefore, the process flow is executable in each step illustrated in FIG. **3**.

[0106] Thus, the present embodiment makes it possible to provide a function of supporting the manual operation for a welding robot installed remotely while preventing damage to the welding robot.

[Modification 1]

[0107] A modification will be described in which the support function related to the remote operation shown in the embodiment is applied when the details of a teaching program manually generated are adjusted, or updated. As the target position on the work W, the teaching point specified in a teaching program will be described as an example. The welding robot **10** and the visual sensor **40** are installed at a position away, i.e., remotely from an operator and the data processing device **50**, and the operator visually recognizes an image of the work W set in the vicinity of the welding robot **10** via the display of the data processing device **50**, the image being captured by the visual sensor **40**. The operator then adjusts the parameters of the teaching program by operating the teach pendant **60** while checking the image of the work W.

[0108] For example, teaching programs already generated are being universally utilized for various welding systems. Since the mechanical error for each welding system and deviation of the installation position of the work may occur, the parameters of the teaching program need to be adjusted in this environment. In this situation, adjustment of the parameters by remote operation can be facilitated using the above-described support function according to the embodiment.

[0109] FIG. **6** illustrates a flowchart for an adjustment process for the position parameters of the teaching program in this example. Here, an example of detecting the position of the groove of the work W, and adjusting the teaching position will be described.

[0110] In S**601**, the robot control device **20** obtains a teaching program. A teaching program may be obtained in such a manner that a teaching program already generated is read from the location specified by an operator. Alternatively, a teaching program directly input by an operator may be obtained.

[0111] In S**602**, the robot control device **20** moves the welding torch **11** to a first teaching point of the section for welding specified in the teaching program generated in S**601**.

[0112] In S**603**, the operator switches the mode via the teach pendant **60**. The mode here corresponds to the mode specifically for the process to be applied when the details of the above-mentioned teaching program manually generated are adjusted, or updated. At this point, the robot control device **20** may notify the operator via the display of the teach pendant **60** that the mode has been switched.

[0113] In S**604**, the robot control device **20** receives, via the teach pendant **60**, an execution operation for sensing (hereinafter referred to as groove sensing) the groove position. The robot control device **20** starts the groove sensing based on the received operation. In this process, the sensing operation based on the groove shape is automatically performed based on the instructions by the operator via the teach pendant **60**. Note that the sensing operation based on the groove shape may be operated by the operator. The robot control device **20** attempts to move the distal end of the welding torch **11** to a central position of the groove while detecting contact with the vicinity of the groove. The move of the groove to the central position may be such that the welding torch **11** is moved based on a movement pattern defined in advance, and is automatically controlled so as to approach the central position depending on the contact situation.

[0114] In S**605**, the operator determines whether the groove sensing has been successful. Successful groove sensing indicates a case where the distal end of the welding torch **11** is located at the groove center at the teaching point of current interest. The distal end of the welding torch **11** referred to herein indicates the distal end position of the welding wire which has been fed via the welding torch **11** and has a predetermined extension. When the groove sensing has been successful (YES in S**605**), the process of the operator proceeds to S**606**. Meanwhile, when the operator determines that the groove sensing has been unsuccessful, specifically, the distal end is not located at a central position of the groove at the teaching point of interest, or determines in the middle of groove sensing that even if a series of groove sensing operation based on the groove shape is continued till the end, the distal end of the robot cannot be located at a central position of the groove (NO in S**605**), the process of the operator proceeds to S**608**.

[0115] In S**606**, the operator updates the target central position of the groove as the teaching position via the teach pendant **60**. Subsequently, the process of the operator proceeds to S**607**.

[0116] In S**607**, the operator determines whether any unprocessed teaching point in the section for welding is left in the teaching program generated in S**601**. When any unprocessed teaching point is left (YES in S**607**), the flow proceeds to S**610**. When no unprocessed teaching point is left (NO in S**607**), the process flow is completed. At this point, the mode may be automatically returned to the previous mode switched in S**603**, or the mode may be maintained until instructions from the operator are received.

[0117] In S**608**, the operator moves the distal end of the welding torch **11** away from the vicinity of the groove by the first remote operation via the teach pendant **60**. The process of the operator then proceeds to S**609**.

[0118] In S**609**, the operator causes the distal end of the welding torch **11** to move closer to the vicinity of the groove by the first remote operation. The movement here may be based on instructions by the operator via the teach pendant **60**, or may be set according to the positions and shape of the groove detected so far. The process of the operator is then returned to S**604**, and the sensing operation for the groove at the teaching point of current interest is repeated.

[0119] In S**610**, the operator moves the distal end of the welding torch **11** away by the first remote operation via the Leach pendant **60**.

[0120] In S**611**, the operator moves the distal end of the welding torch **11** to the vicinity of the next unprocessed teaching point by the first remote operation via the teach pendant **60**. The process of the operator is then returned to S**604** and repeated.

[0121] A specific description will be given with reference to FIGS. **7**A to **7**C according to the flow of the flowchart illustrated in FIG. **6**. Here, a description will be given using an example of the work W in which a groove is provided between two members, and a backing material is disposed on the backside of the groove as illustrated in FIG. **7**A.

[0122] In the example of FIG. **7**A, start point P**1** and end point P**5** are set in a certain welding section in a teaching program, and three teaching points P**2** to P**4** are specified therebetween. The teaching points P**2** to P**4** have different values from those of welding points P**2'** to P**4'** to be actually welded. Thus, in the teaching program, it is required that the values of the teaching points P**2** to P**4** be set to be equal to or substantially equal to those of the welding points P**2'** to P**4'**. Note that welding points P**2'** to P**4'** correspond to a central position of the groove.

[0123] First, as illustrated in FIG. **78**, the welding robot **10** focuses on the teaching point P**2** as the first teaching point. This corresponds to the process of S**602** of FIG. **6**. The operator performs the process along the flow until the process of S**606**, thus upon identification of the center of the groove at the position of the welding point P**2'** as illustrated in FIG. **7**C, gives update instructions for the parameter of the teaching program, particularly, the position parameter, and updates the teaching program. Such an operation is similarly performed on the teaching points P**3**, P**4**, thus the teaching program is updated.

[0124] Thus, according to this example, work support for adjusting the parameters of the teaching program can be performed. As a result, welding with higher accuracy can be achieved.

[Modification 2]

[0125] A modification is described in which the support function for the remote operation shown in the embodiment is used for adjusting the distal end position of the welding torch **11** upon occurrence of an error in the middle of welding.

[0126] For example, when some sort of error occurs during welding, the position of the welding torch **11** needs to be moved by remote operation to a position where welding can resume. At this point, it is possible to facilitate the adjustment of the position of the welding torch **11** using the sensing process according to the above-described embodiment in order to prevent the welding torch **11** from coming into contact with or being disposed at an inappropriate position of the work.

[0127] FIG. **8** illustrates a flowchart for the process of adjusting the position of the welding torch **11** during welding in this example. Here, an example of detecting the position of the groove of the work W, and positioning the welding torch **11** at the groove center will be described. It is assumed that welding has been performed before the start of the process flow of FIG. **8**, and some sort of error has occurred during welding, and welding is stopped. In this case, the process flow is started.

[0128] In **8801**, the robot control device **20** moves the distal end of the welding torch **11** away from the work. The distal end of the welding torch **11** referred to herein indicates the distal end position of the welding wire which has been fed via the welding torch **11** and has a predetermined extension. The travel direction here may be defined in advance, or may be set according to the details of welding performed so far and the shape of the work.

[0129] In S**802**, the operator moves the distal end of the welding torch **11** close to the vicinity of the groove by the first remote operation via the teach pendant **60**.

[0130] In S**803**, the robot control device **20** switches the mode based on instructions by the operator via the teach pendant **60**. The mode here corresponds to the mode when the sensing operation by the above-described remote operation is performed. At this point, the robot control device **20** may notify the operator via the display of the teach pendant **60** that the mode has been switched.

[0131] In S**804**, the operator performs sensing in the groove by the second remote operation via the teach pendant **60**. The operator attempts to move the distal end of the welding torch **11** to a central position of the groove while detecting contact with the vicinity of the groove. The move to the central position of the groove may be such that the welding torch **31** is moved based a pre-defined movement pattern, and is automatically controlled so as to approach the central position depending on the contact situation.

[0132] In S**805**, the operator determines whether the groove sensing has been successful. Successful groove sensing operation indicates the case where the operator determines that the distal end of the welding torch **11** is located at the center of the groove. When the groove sensing operation has been successful (YES in S**805**), the process of the operator proceeds to S**806**. Meanwhile, when the groove sensing operation has been unsuccessful (NO in S**805**), the process of the operator proceeds to S**807**.

[0133] In S**806**, the operator gives instructions to the robot control device **20** based on the identified position to resume welding. In addition, the robot control device **20** switches the mode changed in S**803** to the mode at the time of welding.

[0134] In **6807**, the operator moves the distal end of the welding torch **11** away from the vicinity of the groove by the first remote operation via the teach pendant **60**. The process of the operator then proceeds to S**808**.

[0135] In S**808**, the operator moves the distal end of the welding torch **11** close to the vicinity of the groove by the first remote operation. The movement here may be based on instructions by the operator via the teach pendant **60**, or may be set according to the positions and shape of the groove detected so far. The process of the operator is then returned to S**804**, and the sensing operation for the groove at the teaching point of current interest is repeated.

[0136] A specific description will be given with reference to FIGS. **9**A to **9**C according to the flow of the flowchart illustrated in FIG. **8**. Here, a description will be given using an example of the work W in which a groove is provided between two members, and a backing material is disposed on the backside of the groove as illustrated in FIG. **8**A.

[0137] In the example of FIG. **9**A, start point P**1** and end point P**4** are set in a certain welding section in a teaching program, and two welding points P**2**, P**3** are specified therebetween. The welding robot **10** performs welding over the section from welding point P**2** to P**3** based on the teaching program.

[0138] As illustrated in FIG. **9**B, it is assumed that welding is stopped due to occurrence of error caused by contact between the welding torch **11** and the work W during welding. In this case, the process flow of FIG. **8** is started. As a result of the process of FIG. **8**, the welding torch **11** is placed at the groove center as illustrated in FIG. **9**C, and welding is resumed.

[0139] Thus, according to this example, even when welding is interrupted due to an error, it is possible to appropriately perform the support for the operation of welding by the operator by adjusting the position of the welding torch **11** using the support function according to the remote operation.

OTHER EMBODIMENTS

[0140] In the embodiment, when the sensing operation is performed, the welding torch **11** itself is moved, thereby detecting contact with the work W, and identifying the positional relationship therebetween. Without being limited to this configuration, and for example, the positional relationship between the welding torch **11** and the work W may be identified by adjusting the feed speed of the welding wire **13** projected from the welding torch **11**, and detecting contact between the fed welding wire **13** and the work W. This configuration can be utilized, for example, when it is known that the work W is located in the extension direction of the welding wire **13**.

[0141] In the embodiment, an example has been illustrated in which the robot control device **20** controls the welding torch **11** based on the remote operation performed by an operator via the teach pendant **60**. In each process included in the process flow, the subject that performs the process is not necessarily limited to the one in the above configuration. For example, part of the operation described above as based on individual instructions by an operator may be automatically performed by the welding system **1**.

[0142] In the present invention, programs and application for implementing the above-described one or more functions of the embodiment are supplied to a system or an apparatus using a network or a storage medium, and the one or more functions can be implemented by a process of reading and executing the programs by one or more processors in a computer of the system or the apparatus.

[0143] Alternatively, the implementation may be achieved by a circuit that implements one or more functions. Note that as the circuit that implements one or more functions, e.g., ASIC (Application Specific Integrated Circuit) and FPGA (Field Programmable Gate Array) may be mentioned.

[0144] As described above, the present specification discloses the following matters.

[0145] (1) A remote operation method for welding system enabling remote manual operation of a welding robot, the remote operation method comprising:

- **[0146]** a process of acquiring image data at any position using one or more imaging devices;
- **[0147]** a process of displaying the image data using a display device;
- **[0148]** a process of receiving, from an operator via an operation terminal, an instruction to execute a contact detection function by a welding torch of the welding robot; and
- **[0149]** an operation process of moving the welding torch during execution of the contact detection function based on the instruction given to the welding robot and received via the operation terminal.

[0150] When the welding torch detects contact with a surrounding component by the contact detection function in the operation process, a position of the welding torch is adjusted based on a position of the contact.

[0151] With this configuration, when a manual operation is performed on a welding robot installed remotely, an operator can perform various works appropriately.

- **[0152]** (2) The remote operation method for welding system according to (1), further comprising
- **[0153]** an update process of receiving an update instruction to a parameter of a teaching program used in the welding system, wherein in the update process, an instruction to update a position parameter specified in the teaching program is received based on the position of the contact detected by the contact detection function.

[0154] With this configuration, even by remote operation, position adjustment of the welding robot can be made with high accuracy, and it is possible to make adjustment of the parameter of the teaching program to an appropriate position.

[0155] (3) The remote operation method for welding system according to (1) or (2), in which in the operation process, during execution of the contact detection function, at least one of a travel speed of the welding torch or a feed speed of a welding wire from the welding torch is set to a first speed.

[0156] With this configuration, during a remote operation, contact with the work can be detected using the welding torch and the feed speed of the welding wire.

[0157] (4) The remote operation method for welding system according to (3), in which the first speed is lower than a second speed when the contact detection function is not in execution.

[0158] With this configuration, during execution of the contact detection function, the speed related to detection is set low so that even if contact occurs, the control can be stopped immediately, and fine control can be performed.

[0159] (5) The remote operation method for welding system according to any one of (1) to (4), in which detection by the contact detection function is made based on a change in voltage, load, or motor load which occurs at a time of contact.

[0160] With this configuration, contact can be detected by the contact detection function based on various principles such as a change in voltage, load or motor load.

[0161] (6) The remote operation method for welding system according to any one of (1) to (5), in which during execution of the contact detection function, the operator is notified via the operation terminal or the display device that the contact detection function is in execution.

[0162] With this configuration, an operator can easily recognize that the contact detection function is not in execution, which can improve the convenience of the operation.

[0163] (7) The remote operation method for welding system according to any one of (1) to (6), in which the one or more imaging devices change an image capture position in coordination with movement of the welding torch.

[0164] With this configuration, the image capture position is changed along with the movement of the welding torch, thus the operability of the remote operation by the operator can be improved.

[0165] (8) A welding system comprising:

- **[0166]** a welding robot including a welding torch;
- **[0167]** one or more imaging devices;
- **[0168]** a display device; and
- **[0169]** an operation terminal for manually operating the welding robot remotely.

[0170] The welding system includes:

- **[0171]** an acquisition unit configured to acquire image data at any position using the one or more imaging devices;
- **[0172]** a display unit configured to display the image data using the display device;
- **[0173]** a receiving unit configured to receive, from an operator via the operation terminal, an instruction to execute a contact detection function by the welding torch; and
- **[0174]** an operation unit configured to move the welding torch based on an instruction to the welding robot received during execution of the contact detection function via the operation terminal

[0175] When the welding torch detects contact with a surrounding component by the contact detection function, the operation unit adjusts a position of the welding torch based on a position of the contact.

[0176] With this configuration, when a manual operation is performed on a welding robot installed remotely, an operator can perform various works appropriately.

[0177] Although various embodiments have been described above, needless to say that the present invention is not limited to such examples. It is apparent that various modification examples and alteration examples will occur to those skilled in the art within the scope described in the appended claims, and it should be understood that those examples naturally fall within the technical scope of the present invention. In a range without departing from the spirit of the invention, the components in the above embodiments may be combined in any manner.

[0178] The present application is based on Japanese Patent Application (No. 2022-099056) filed on Jun. 20, 2022, the entire contents of which are incorporated herein by reference.

REFERENCE SIGNS LIST

[0179] **1** welding system
[0180] **10** welding robot
[0181] **11** welding torch
[0182] **12** wire feeding device
[0183] **13** welding wire
[0184] **20** robot control device
[0185] **201** CPU
[0186] **202** memory
[0187] **202**A control program
[0188] **203** operation panel
[0189] **204** robot connection section
[0190] **205** communicator
[0191] **30** power supply device
[0192] **40** visual sensor
[0193] **50** data processing device
[0194] **60** teach pendant
[0195] W work

1. A remote operation method for welding system enabling remote manual operation of a welding robot, the remote operation method comprising:

- a process of acquiring image data at any position using one or more imaging devices;
- a process of displaying the image data using a display device;
- a process of receiving, from an operator via an operation terminal, an instruction to execute a contact detection function by a welding torch of the welding robot; and
- an operation process of moving the welding torch during execution of the contact detection function based on the instruction given to the welding robot and received via the operation terminal,
- wherein when the welding torch detects contact with a surrounding component by the contact detection function in the operation process, a position of the welding torch is adjusted based on a position of the contact.

2. The remote operation method for welding system according to claim **1**, further comprising

- an update process of receiving an update instruction to a parameter of a teaching program used in the welding system,
- wherein in the update process, an instruction to update a position parameter specified in the teaching program is received based on the position of the contact detected by the contact detection function.

3. The remote operation method for welding system according to claim **1**,

- wherein in the operation process, during execution of the contact detection function, at least one of a travel speed of the welding torch or a feed speed of a welding wire from the welding torch is set to a first speed.

4. The remote operation method for welding system according to claim **3**,

- wherein the first speed is lower than a second speed when the contact detection function is not in execution.

5. The remote operation method for welding system according to claim **1**,

- wherein detection by the contact detection function is made based on a change in voltage, load, or motor load which occurs at a time of contact.

6. The remote operation method for welding system according to claim **1**, wherein during execution of the contact detection function, the operator is notified via the operation terminal or the display device that the contact detection function is in execution.

7. The remote operation method for welding system according to claim **1**,

wherein the one or more imaging devices change an image capture position in coordination with movement of the welding torch.

8. A welding system comprising:

a welding robot including a welding torch;

one or more imaging devices;

a display device; and

an operation terminal for manually operating the welding robot remotely,

wherein the welding system includes:

an acquisition unit configured to acquire image data at any position using the one or more imaging devices,

a display unit configured to display the image data using the display device,

a receiving unit configured to receive, from an operator via the operation terminal, an instruction to execute a contact detection function by the welding torch, and

an operation unit configured to move the welding torch based on an instruction to the welding robot received during execution of the contact detection function via the operation terminal,

wherein when the welding torch detects contact with a surrounding component by the contact detection function, the operation unit adjusts a position of the welding torch based on a position of the contact.

9. The remote operation method for welding system according to claim **2**,

wherein in the operation process, during execution of the contact detection function, at least one of a travel speed of the welding torch or a feed speed of a welding wire from the welding torch is set to a first speed.

10. The remote operation method for welding system according to claim **9**,

wherein the first speed is lower than a second speed when the contact detection function is not in execution.

11. The remote operation method for welding system according to claim **2**,

wherein detection by the contact detection function is made based on a change in voltage, load, or motor load which occurs at a time of contact.

12. The remote operation method for welding system according to claim **2**,

wherein during execution of the contact detection function, the operator is notified via the operation terminal or the display device that the contact detection function is in execution.

13. The remote operation method for welding system according to claim **2**,

wherein the one or more imaging devices change an image capture position in coordination with movement of the welding torch.

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