

Study on the all position automatic pipeline backing weld machine

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Abstract: As a result of the lower backing weld efficiency, the applying of automatic welding is seriously limited. So a kind of special automatic welder is designed and manufactured for backing weld. This paper introduces the character of the assembled pulse CO₂ arc welding machine which has strong penetrability. It specifies the technology of controlling the parameters of all position automatic welding by computer and multi-axis controller. Moreover typical welding procedure parameters are provided. It is proved by examination that the economical and practical equipment and technology are suitable for the long-distance transmission pipeline, and it has a good foreground of spreading and applying.

Key words: pipeline; all position; backing weld; metal transfer; sensor

1 Introduction

Pipe transportation is with low cost, high efficiency and safety, and the pipe construction will enter a peak period in the future 10 years. With the improvement of the project construction, not only the technology, quality and construction plan but also the advanced technology and equipment will be required more. During the project of West-East natural gas transmission, the automatic welding is put into use for the first time, and it completed more than 800 km of the main pipeline. Its advantage is fully shown by its high efficiency and speed, and there is a bright future for the automatic welding of the pipeline.

The project application proved that the advantage of the advanced technology is achieved by the improvement of all the relevant technology. Most construction companies didn't adopted automatic backing weld, so the efficiency and progress of the backing weld is very low, which became the choke point of the construction progress. If the whole imported technology and equipment are adopted, the cost is rather high, and technology is very complex, and the present technology and economy ability of most construction company could not meet such requirement, so it is an urgent task to develop the high efficient pipeline backing weld machine.

By deeply studying the special welder, all position controlling technology and welding procedure, a whole economical and practical system of automatic backing weld equipment and the relevant procedure is successfully completed in this article. The application shows that this production can be used for the welding of the pipeline, and it has good foreground of spreading and

applying.

2 Characters of the welder^[1-3]

Now CO₂ arc welding has already become a better method, but its arc penetrability and stability couldn't make sure to realize the all position welding on the condition of closed groove. The American STT welder realized the exact control during the melt transition. It achieved the steady CO₂ arc welding process and it has used abroad for backing weld. But on the condition of closed groove, the arc penetrability is not strong enough to ensure the backing weld be put up successfully, so the special welder must be explored first.

By analyzing the metal transfer process of CO₂ arc welding, using the control method of STT for reference and studying the CO₂ arc welding character, the special welder is designed and manufactured, the characters of welder is as follows.

1) Adopt the control technology of assembled pulse metal transfer. The exact control for the metal transfer is realized by adjusting the detail character of the pulse. The pulse wave is corresponding with the metal transfer state. The control principle is illustrated in Fig. 1.

2) Inverter adopts PWM soft switch to make the switch stress is almost 0 while MOSFET is working; this improved the reliability of the welding machine and lower the interference to the welding head. The main circuit of the welder is as Fig. 2.

3) The special single chip control system is designed to realize the saving and transform of the background current, peak current, wire feed speed and standing time, meanwhile communicate with the industrial personal computer system online to realize the

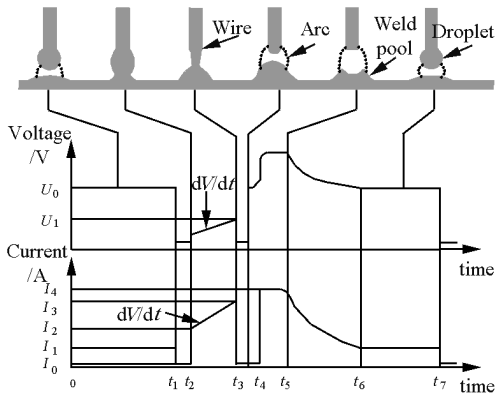


Fig. 1 Illustration of metal transfer

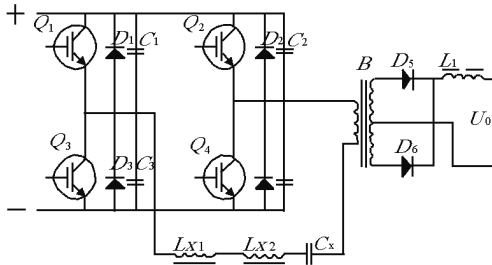


Fig. 2 Main circuit

is confirmed by the tests. Welding input and pool state at different position is controlled by switching automatically under the control of the computer.

3.1 Design of hardware and driving software

3.1.1 Components of the control system

The actions which need to be controlled during welding are movement of welding head, swing and position adjustment of welding gun, detection of the space angle position of welding head and conversion of welding parameters at different sections. So two step motors and one DC servo motor need to be drove, meanwhile the signal from the angle sensor should be collected and dealt in real-time. In addition, the control instructions of the multifunctional operating box should be collected and dealt with so that it can be adjusted artificially during welding.

Considering the hard welding condition, the welding wave and control functions is realized by adopting the industry control machine as core, together with the multi-function drive system which is combined by the multi-axes motion controller. In addition, the whole system should be controlled by communicating with the single chip system in the welding machine. Composing of the system is illustrated in Fig. 4.

harmonious control in all the welding sections.

3 Research on the automatic control technology of all position backing weld

During all position backing weld process, in different position, liquid metal will flow along the stressed direction, this will not only influence the stability of the welding but also will cause some other disadvantages, so different welding parameters should be adopted for different position.

For backing weld, the rear side should melt well and form well, and the control of welding parameter is also required strictly, so the separation should be clear and in detail as Fig. 3. The pipe circle is separated into eudipleural 24 sections, and then be welded downwards according to athwart and clockwise direction.

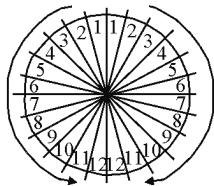


Fig. 3 Welding sections of all position

Welding parameter table is worked out according to the welding parameter (peak current, background current, wire feed speed, standing time, etc.) which

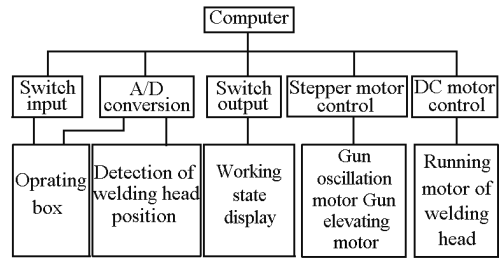


Fig. 4 Composing of industrial control system

3.1.2 Chosing of main drive control components

Drive control components are main part of the system. Its performance and quality will influent the capability and reliability of welding machine. For the construction equipment which is applied outside, consider not only the excellent technology characters but also the reliability during designing. Details are as follows.

1) Industrial control machine system use the ISA to extend the CPU card, SIPC Elite CPU 133MHz main frequency. A/D conversion board and multi-function board will be extended according to control requirement.

2) The swing of welding gun and wire extension are controlled by the step motor. Step angle of oscillation motor is 3.75° and elevating motor is 1.8° .

3) Step motor is drove by the multi-axes motion controller which is core with intelligent CMOS chip. It

has super integration and capability of resisting interference. It forms the motor controller together with industrial control computer, and program with C language. Fig. 5 is the connection diagram of multi-axes motion controller.

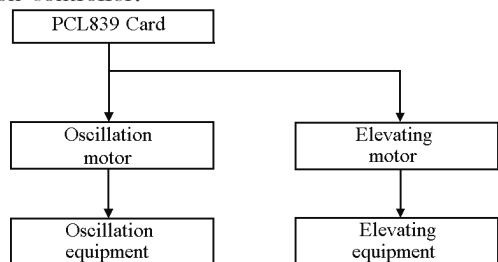


Fig. 5 Connection diagram of multi-axes motion controller

3.2 Programming of control software

Design of software system includes two parts, it is that single chip system and industrial control system. Both systems are input and modified welding parameters by notebook computer.

The software of single chip control system is mainly used to save and control the parameters of background current, peak current, standing time, wire feed speed, and communicate with industrial control system. It is programmed by assemble language. Welding parameters are input and modified by notebook computer, and the person-computer interface is programmed with VB, this can assure not only the interface simple and clean, but also the control reliability.

3.2.1 Design of main program system

As a result of large quantity data of collection and management, and high real-time requirement, industrial control machine is adopted to control the welding process together with the multi-axes motion controller.

Control system includes adjustment before welding, preview function, starting and completion of welding, TXD, backtrack, etc. It is mainly used to control the movement of welding head, wave of welding gun, high and low adjustment of welding gun, center welding gun, etc. In addition, the angle position of welding head is detected by the angle sensor. Together with the single chip system, welding parameters are switched at different sections; meanwhile welding head position and system working state are shown. Flow chart of main program is shown as Fig. 6.

3.2.2 Design of operating interface and communication programs

In automatic welding, all position welding parameters, which are required by the welding procedure, should be input, set and saved in the industrial machine storage unit by computer. During welding, the

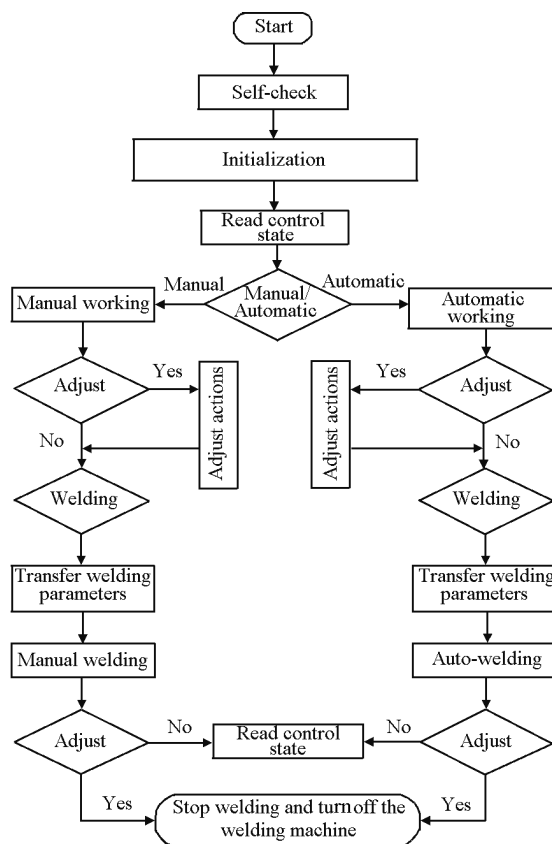


Fig. 6 Flow chart of main program

welding machine will change the welding parameters automatically at different position to finish the welding process under the control of programs. So the software of man-computer communication interface and other relevant software should be designed. It includes: a. interface style, b. content arrangement, c. input style, d. connection of drive control, e. communication style. Fig. 7 shows the man-computer mutual startup interface. It mainly shows product name, type and produced company, and leads to other interface to input and modify the welding parameters.

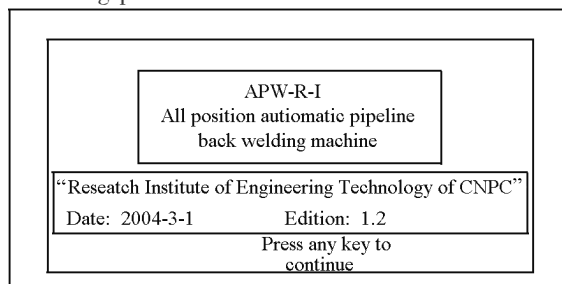


Fig. 7 Startup interface

It will enter parameter setting interface when pressing F1 at the program main interface, parameters (oscillation range and speed, welding speed, wave

selection, current group number, etc.) at different zones can be input in turn. It will enter the welding parameter load interface when pressing F2. 1 ~ 50 grade and document name will be shown in this interface, inputting the document grade is OK. Press F3 to modify the parameters, after confirming all the parameters are correct, press F4 to parameter transfer interface. At this time press the transfer key of the control box, and then press the Enter key, and then the parameter can be input the industrial control machine. After finish the transfer, press any key to return the main program interface. Press F5 to exit main program and return DOS system.

4 Study on the system of the space angle sensor in the all-position welder

4.1 The character and shortage of the space angle sensor in existence

There are many kinds of sensors to detect the space angle position of the equipment. They can be classified to solid oscillation type, liquid oscillation type, complex type, photoelectric encoder counter type, etc. And just the type of solid oscillation includes strain type, resistance type, capacitance type, inductance type, vibrating wire type, magnetoresistance type and so on^[4]. The sensor using to detect the space angle position of welding processing must meet the requirements as below:

- 1) The detecting angle range and precision satisfy the requirements of all position welding.
- 2) It has smaller size and can be installed to adapt to the construction of the welding head.
- 3) The construction of the sensor should resist the shaking and accidental impacting of field working.
- 4) Its output signal can resist the strong electromagnetic interference.

By analyzing the experiment, it can be found that the magnetoresistance angle sensor can satisfy the requirements of all position welding better. The angle sensor core with photoelectric encoder counter can output all position controlling signals within range of 360°, and it has higher precision. But because of the damageable inner component, it can't resist the shaking and impacting in actual using. And because of the bigger size, it is difficult to meet the miniaturization requirements of the welding head.

4.2 Study on the new angle sensor

It uses high-powered semiconductor magnetoresistance (MR organ) as sense organ, and drives permanent magnet turning by gravitational pendulum so that the MR organ can induce the change of the flux. The change of the rotation angle between the permanent

magnet and the MR organ is transformed to the change of the resistance, so the gradient angle is transformed to standard electrical signal and then output. Structure of the sensor is illustrated in Fig. 8.

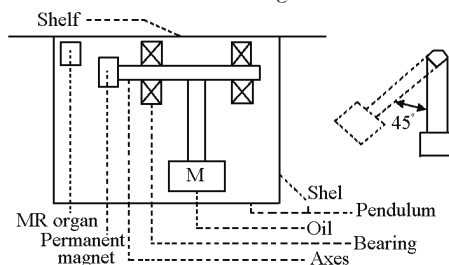


Fig. 8 Structure of the magnetoresistance angle sensor

Because the magnetoresistance angle sensor usually outputs sine wave electrical signal, its linear range is limited ($\pm 45^\circ$). It is that the conversion rate is smaller at 90°, which can't ensure the controlling precision near 12 o'clock and 6 o'clock. So in this paper the linear range is extended to be more than 200° by signal processing technology. And the new sensor satisfies the controlling requirements of all position downwards welding between 0° and 180°.

To assure the detecting stability and avoid the effect of outside shaking, the special damp oil is injected into the angle sensor. At the same time because the parameters of the semiconductors are sensitive to the temperature, we use the thermistor to compensate the temperature, and then resolve the question of temperature stability. In addition, to resist the strong electromagnetic interference from pulse power to the sensor, some steps such as current transfers, band-pass filter, signal insulation, electromagnetism shield, etc. are adopted to assure the veracity and reliability of the controlling signal.

4.3 Performance and characters

Summarized, the special angle sensor which is designed in this paper has characters as below:

- 1) Because of the no-touch structure, it has no mechanical abrasion besides the axletree. So it has high reliability and long using life.
- 2) Bigger original signal, wider linear range, and higher resolution.
- 3) No electrical noise from itself, having high Signal-to-Noise ratio.
- 4) MR organ can induce the magnetic field without influence of the water, oil, gas, powder in the clearance and the environment temperature. So it can suit the environment better.
- 5) Compact structure, easily realized the equipment system miniaturization.

5 Design and manufacture of the mechanism executing system

5.1 Welding track

Open type rigid annular tracks are adopted in this system. It is mainly composed of rack bar, guide rail, support ring and adjustment screw. For convenience of installation and adjustment the eccentric assembly organ is designed.

5.2 Welding head

Gear-rack bar transmission mode is adopted for the running of the welding carriage. In order to simplify the structure the motor with decelerator is used to drive running gear directly. This design reduces the transmission and saves the weight of the carriage.

5.3 Oscillation system of welding gun

The oscillation mechanism is designed as a rectilinear reciprocating motion. It only swings lightly and quickly at some local part during backing weld, so rectilinear reciprocating can realize higher frequency by controlling.

5.4 Adjustment system of welding gun

Wire extension needs to be adjusted in real time during welding process. The welding gun is adjusted by step motor driving and sliding screw transmitting. The adjustment range of welding gun is 100 mm.

6 Study on welding procedure

6.1 Determining of backing weld joint^[5]

By analyzing present technology, double U type groove recommended by Italian PWT Company has a certain theoretic reference and construction experience. Hence welding experiment is put up under the condition of double U groove, and with zero root opening. Groove structure is illustrated in Fig. 9.

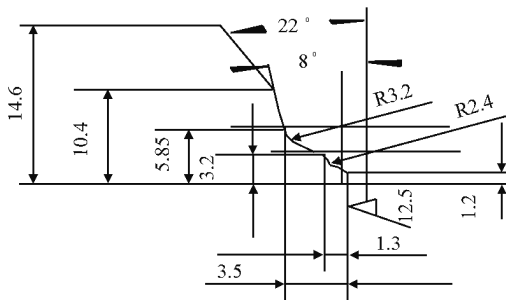


Fig. 9 Double U groove of all position backing weld

6.2 Welding procedure

Choose $\phi 1\ 016\ \text{mm} \times 14.6\ \text{mm}$ and $\phi 1\ 016\ \text{mm} \times 17.4\ \text{mm}$ X70 steel pipe, then process the groove as Fig. 9, and align them without clearance. After subar-
ea, input the welding parameter of different sections by

notebook computer, and then weld downwards under the control of automatic control system.

Indigenous CO₂ arc welding wire (JM 58 produced in Jintai) is adopted for experiment, and diameter of wire is $\phi 1.2\ \text{mm}$, protection gas is CO₂ 100%. By adjusting the main welding parameters of peak current, background current, current attenuation time, wire feed speed, and observing rear forming, the typical welding parameters are obtained.

Purpose of this article is to make welding machine, control technology and welding procedure home-made instead of importation. So indigenous wire CO₂ 100% is used in all the experiment in order to save the cost. So not all the procedure are the same as those recommended by PWT (imported wire and mixed gas are used for PWT). In addition, some details of the groove is adjusted to improve the melt range and ensure the quality of all position welding.

The groove coherence is strictly required in all position backing weld. Because the tolerance of ellipticity and pipe wall couldn't be avoided, it is hard to control the root face. Sometimes there will be clearance in some sections after alignment. This makes it difficult to weld. In order to solve this problem, the pipe end should be propped up to round during groove process and joint alignment; in addition, welding parameters should be adjusted to adapt it better. It can meet the requirement when local root opening is 0.5 mm, root face is 0.9 ~ 1.2 mm, misalignment is 0.5 mm. Increasing the oscillation range for the wider root opening can also obtain qualified welding joint.

Completed backing weld line of $\phi 1\ 016\ \text{mm}$ pipe is illustrated in Fig. 10. Both sides of welding joint form well.

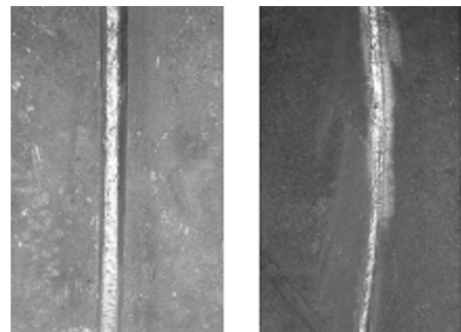


Fig. 10 Both sides of welding joint

Typical parameters of backing weld is shown as Table 1, size of pipe is $\phi 1\ 016\ \text{mm} \times 17.4\ \text{mm}$, material is X70 steel with double U groove, welding material is $\phi 1.2\ \text{JM58}$ wire of Jintai, CO₂ 100% is adopted as protection gas, and gas flux is 20 L/min, welding joint is fine.

Table 1 Typical parameters of all position backing weld

Position	Welding speed/ ($\text{cm} \cdot \text{min}^{-1}$)	Wire feed speed/ ($\text{cm} \cdot \text{min}^{-1}$)	Peak current/A	background level/A	Oscillation range/mm	Oscillation speed/($\text{mm} \cdot \text{s}^{-1}$)	Stay time/s
0	30.0	550	350	40	2.0	10	0.00
1	31.0	560	355	45	2.0	10	0.00
2	31.5	570	360	50	0	0	/
3	32.5	580	365	55	0	0	/
4	34.0	570	360	60	0	0	/
5	34.5	560	355	55	0	0	/
6	35.0	550	350	50	0	0	/
7	34.0	540	340	45	0	0	/
8	33.0	530	335	40	0	0	/
9	32.5	520	330	38	2.0	10	0.00
10	32.0	500	320	37	2.0	10	0.4
11	32.0	500	320	36	2.0	10	0.4

7 Conclusions

1) By improving the energy density of the arc, the special welder can increase the arc penetrability, reduce the welding splash, and assure the welding stability and good welding forming.

2) This research adopts embedded industrial control system together with multi-axes motion controller. Further more it meets the requirement of welding by designing hardware and software system.

3) Core with magnetoresistance, the special angle sensor of all position automatic welding is designed and manufactured. It's linear range is extended to 200° . And it satisfies the controlling requirements of all position downwards welding.

4) The designed welder system and welding procedure is suitable for double U groove and indigenous wires. While working the purity of CO_2 is 100%, pipe

diameter is more than 600 mm, root opening is $0 \sim 0.5$ mm, root face is 1 ± 0.5 mm. Welding speed is twice the MMA.

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Foundation item: Key science research item of CNPC (03B411106)