

A computer control system for automatic TIG welding of aluminium alloy sheets

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Abstract Aimed at the welding technological requirements of the missile shell, a computer control system for automatic TIG welding of aluminium alloy sheets has been developed in this paper. The hardware of the system is composed of the four sub-systems, i.e. welding power source, arc length controller, welding wire feeder and welding head traveller. The software of the system comprises the on-line executing program and the off-line serving program. The operating principle, specifications and control function of the system are introduced. The experiments indicate that the system possesses rational hardware structure and practical software function, and has solved the problem of high frequency interference to the computer control system. Therefore, the control system can satisfy the requirements of automatic TIG welding of the missile shell.

Key words computer control, high frequency interference, automatic TIG welding, aluminium alloy sheet

0 Introduction

In space industry, the shell of a certain type of missile is welded with two half-shells of aluminium alloy in the longitudinal direction by TIG welding method, which are 1.2~3.0 mm thick and more than 2.4 m long. Before TIG welding operation, a certain number of circular reinforced frames at a definite distance has been tacked on the outer surfaces of the two half-shells, so the two half-shells cannot be clamped continuously by the fixture, seen in Fig. 1. In this case, if welding is performed with the constant energy input along the entire bead, the distortion or burnt through in the locations of the reinforced frames will be taken place. In order to solve the problem, a special automatic welding system in which welding parameters will adjust their values according the different position of workpieces should be used. Therefore, a computer control system for automatic TIG welding of aluminium alloy sheets has been developed in this paper.

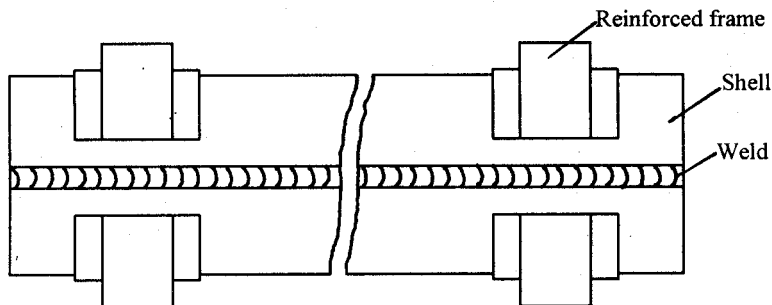


Fig.1 Schematic drawing for the outer structure of missile-shell

1 Hardware

The computer control system consists of computer, interfaces, executive bodies and terminals, as shown in Fig.2.

The computer is an industrial-control computer, thus possessing excellent anti-interference and compatibility. The interfaces, which are isolated by photoelectric cells, mainly carry out the signal conversion between the computer and the executive bodies. The terminals, namely remote control panel, special keyboard, monitor and printer, are used to perform input, modification, display and output of welding parameters.

The executive bodies, composed of welding power source, arc length controller, welding wire feeder and welding head traveler, are the most important parts which mainly accomplish various operations required for automatic TIG welding. For the convenience of introduction, the entire system can be divided into the four sub-systems, i.e. welding power source, arc length controller, welding wire feeder and welding head traveler.

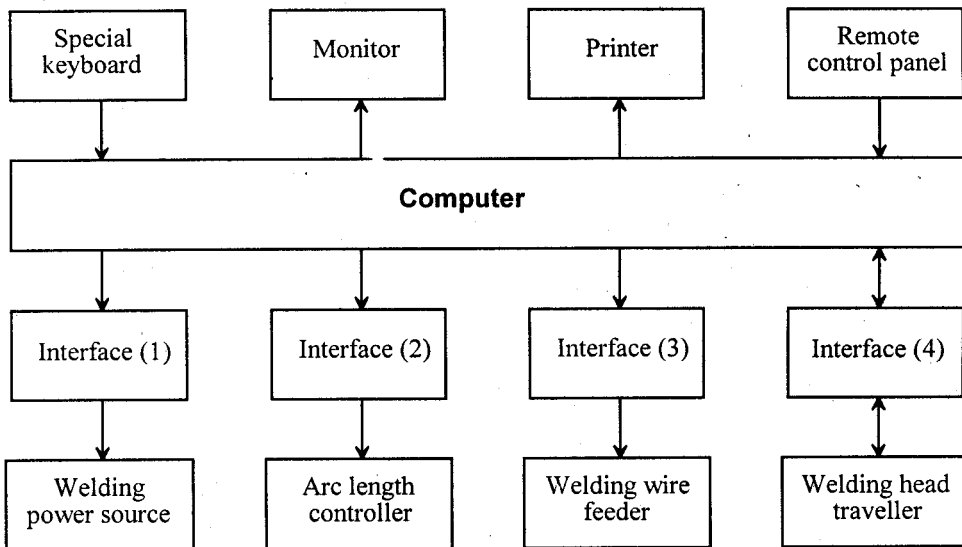


Fig.2 Block diagram of the computer control system for automatic TIG welding

1.1 Welding power source control system

The welding power source control system is a current negative-feedback control system in which the presetting signal V_{IG} is a controlling parameter and the welding current I is a controlled parameter (seen in Fig.3). It can accomplish constant current control and pulse output. That is to say, if the computer transmits any presetting signal V_{IG} through the D/A card, the main body of the welding power source will supply a corresponding current I (DC or AC). Besides, a high frequency oscillator is used to ignite and stabilize the arc, so the computer control system may be interfered seriously by it ^[1,2]. In order to solve the problem, the following anti-interference measures have been taken in the hardware design:

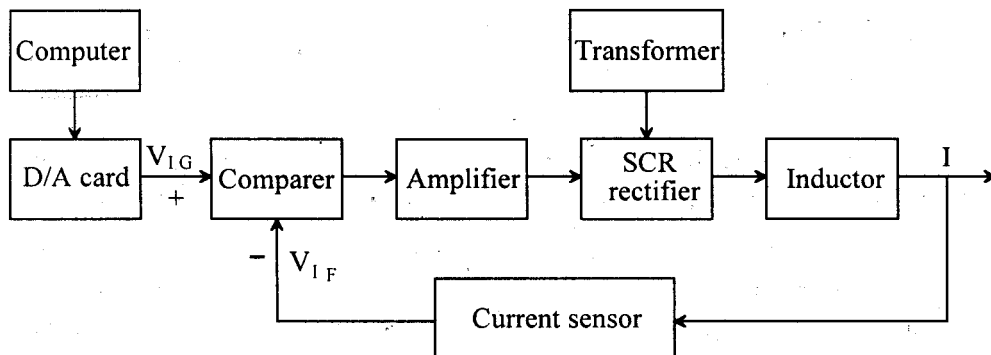


Fig.3 Block diagram of the welding power source control system

(1) The computer should be shielded in a metal box and placed in a location away from the main body of the welding power source;

(2) The interface between the computer and the main body of the welding power source should be isolated with photoelectric cells;

(3) The input and output cables of the computer should be twisted-pair shield cables;

(4) The shield box of the computer and the outer casing of the main body of the welding power source should be grounded independently.

By means of the above measures, the welding power source control system can operate reliably. Its specifications are as follows:

Welding current 5~360 A, with the current control precision of 1 A;

Pulse frequency 0.5~15 Hz and pulse duration ratio 10~100 %;

AC balance ratio 30~70 %.

1.2 Arc length control system

During automatic TIG welding of aluminium alloy sheets, the arc length may change with the distortion of the sheets, thus affecting the appearance of weld or yielding weld defects such as burn through and incomplete penetration. In order to solve the problem, an arc length control system is developed (shown in Fig. 4).

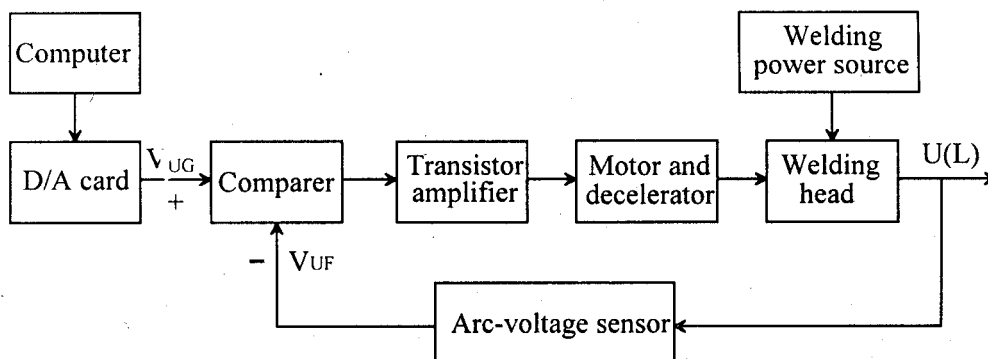


Fig.4 Block diagram of the arc length control system

In substance, the arc length control system is an arc-voltage negative-feedback control system in which the presetting signal V_{UG} is a controlling parameter and the arc voltage U , corresponding to the arc length L is a controlled parameter. Therefore, the presetting signal V_{UG} has a corresponding relation to the arc voltage U or the arc length L . That is to say, if the computer transmits any presetting signal V_{UG} through the D/A card, the system will maintain a corresponding arc voltage U or arc length L .

In the system, the control of arc length is accomplished through arc voltage sensing, so the key to arc length control is to draw a feedback signal, i.e. the positive-half-wave voltage of AC arc, which can really represent the arc length L , among the complex voltage waveforms of AC TIG welding^[3]. The arc voltage sensor developed in this paper can do it and has an isolating function to prevent high frequency interference.

In order to raise the dynamic response speed of the system, a low-inertia motor should be used. The experiments show that the specifications of the arc length control system are as follows:

Static precision 0.1 V; positive half-wave arc voltage range 5~20 V; dynamic response time 0.15 s; adjusting speed of arc length 2 mm/s.

1.3 Welding wire feeding control system

The welding wire feeding control system is an armature-voltage negative-feedback control system in which the presetting signal V_{SG} is a controlling parameter and the welding wire feeding speed V_s is a controlled parameter (see Fig. 5). The test shows that the wire feeding speed V_s has a linear relation to the presetting signal V_{SG} , so the computer is able to control the wire feeding speed with the presetting signal V_{SG} transmitted by the D/A card.

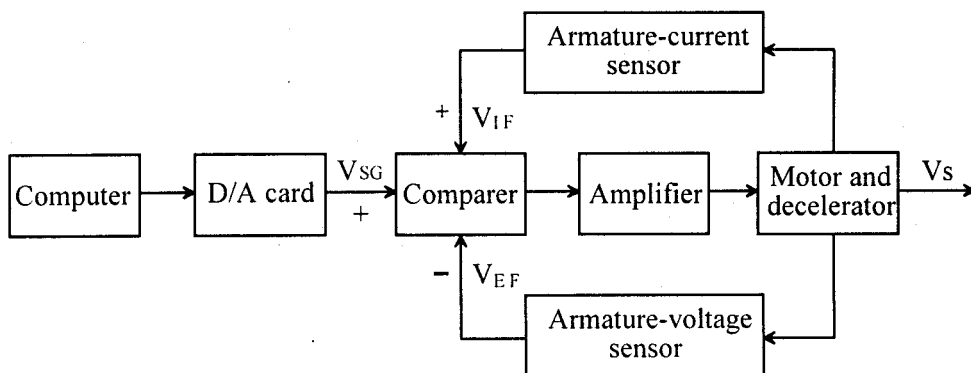


Fig.5 Block diagram of the welding wire feeding control system

In order to restrain the effect of load moment on wire feeding speed, an armature-current positive-feedback control method is adopted in the system (seen in Fig.4). The experiments indicate that the variation of wire feeding speed is not more than 6% when the load moment varies by 10 %, and that the stable range of wire feeding speed is 100~2000 mm/min.

1.4 Welding head traveling control system

As mentioned above in Introduction, an automatic process in which welding parameters can adjust their value according the different positions of the workpieces should be used in welding of the missile shell, so we must really know the practical position of the traveling arc. To attain this goal, we use a position-type servo-motor as the executive component of the welding head traveling control system (seen in Fig. 6).

In the system, the rotating transformer is an important sensor. It can draw the position-speed information from the servo-motor and feed it back to the servo-driver, thus accomplishing a dual closed-loop control of position and speed.

The position control card is an interface of the computer to the servo-driver. By means of it, on the one hand the computer transmits the position-speed signal to the servo-driver, on the other hand the servo-driver transmits the position-speed information, fed back by the rotating transformer, to the computer. In this way, the computer can accomplish a real-time control of the servo-motor and provide the proper welding parameters according to the practical position of the traveling arc.

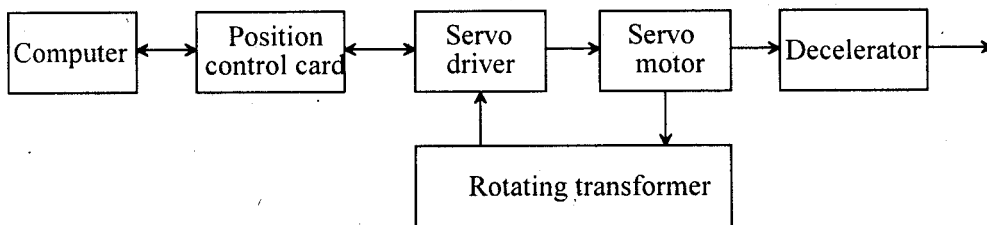


Fig. 6 Block diagram of the welding head traveling control system

The experiments indicate that the relative error of positioning of the system is not more than 0.03%, and the head traveling speed range is 50~2400 mm/min.

2 Software

Considering the needs of process control and man-machine dialogue, C-language is used as the compiling language of the computer control system. According to the characteristics of the control system, the software function of the system can be divided into the two types of off-line serving function and on-line executing function. Besides, the effective measures in the software design have been adopted to prevent high frequency from interfering the computer control system.

2.1 Off-line serving function

The off-line serving function of the computer control system is accomplished through a man-machine dialogue menu in Chinese. Its main contents comprise the creation, modification, storage, printout, copy and deletion of operating files (seen in Fig. 7). Besides, "System help" and "Report printout" are included in the off-line serving function to tell the operator how to

use the computer control system and how to set up the records of welding technological parameters.

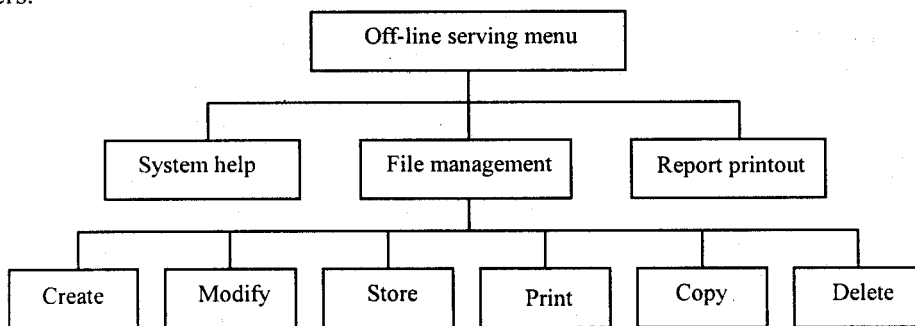


Fig.7 Off-line serving function of the computer control system

2.2 On-line executing function

The on-line executing function is a fundamental function of the computer control system. It is composed of tack welding, automatic welding and simulative welding (see Fig. 8). The on-line executing object is the operating file compiled by the operator. When the computer runs an operating file, it first examines whether the operating file can conform to the prescribed grammar. If a grammatical mistake arises, the computer will indicate the characteristic and location of the mistake so that the operator can correct it. Only according thoroughly with the prescribed grammar can the operating file be executed.

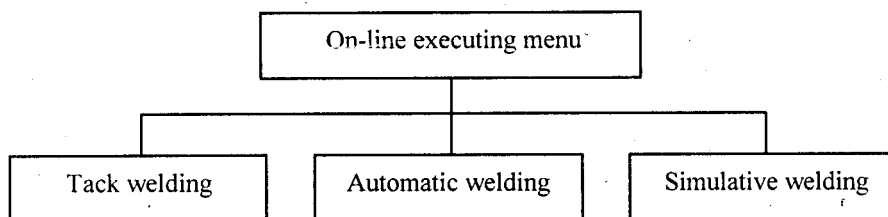


Fig.8 On-line executing function of the computer control system

Tack welding is used, before automatic welding of the missile shell, to join partially workpieces so as to raise the rigidity of workpieces and reduce welding distortion. According to specific conditions, the operator can move the welding head to the suitable position and perform tack welding conveniently by means of the remote control panel. Tack welding parameters, including welding current, welding speed, wire feeding speed and tacking length, are set up in the operating file compiled by the operator before tack welding. In order to improve the quality of tack welding, the computer control system automatically provides the function of crater-fill.

Automatic welding is the ultimate aim of the control system. Automatic welding parameters, including welding current (in substance, welding current comprises peak current, background current, pulse frequency and pulse duration ratio), arc voltage, welding speed and wire feeding

speed, are not only set up according to the position of the workpieces before welding, but also modified by the remote control panel at any time in course of welding. The variations of welding parameters with the positions of the workpieces are displayed, in the form of graph or numeral, simultaneously on the color monitor and on the remote control panel.

In order to guarantee the quality of automatic welding of aluminium alloy sheets, the operator can set up the arc-start current and make use of the function of crater-fill provided by the computer control system. In course of automatic welding, if an abnormal phenomenon, such as burn through, occurs, the operator will be able to break off the welding process by means of the remote control panel and to perform temporary disposals. After this, the system automatically enables the welding head to return to the arc-extinguished position and re-ignites arc so as to continue welding according to the original parameters set up in the operating file.

Simulative welding is used to examine whether the automatic welding operating file compiled by the operator will be suitable for the requirements of automatic welding technology. Its executing process is similar to that of automatic welding, but none of the executive bodies is operative except the welding head traveler. During simulative welding, welding parameters can be displayed and modified, and the simulative process can be break off by the operator.

3 Experiments

The samples are 1.0 m long and 0.2 m wide. In order to reflect the effect of reinforced frames on welding quality, a set of discontinuous key-type fixture is used to clamp the samples. The specific experimental conditions are shown in Table 1.

Table 1 Experimental conditions

Sample material	Sample thickness	Wire material	Wire diameter	W- electrode diameter	Ar gas flow
LF6	1.2 mm	LF6	2.0 mm	2.4 mm	10 l/min

Tack welding is performed in accordance with the proper parameters (see Table 2). The experiments show that neither crater nor crack has occurred, and that the tip of welding wire has not stuck to the bead and the weld reinforcement is moderate as well. Clearly, the quality of tack welding is very good.

Table 2 Tack welding parameters

Welding current	Arc length	Wire feeding speed	Welding speed	Tack length
55 A	3 mm	350 mm/min	100 mm/min	4 mm

Automatic welding is performed according to the given welding parameters (see Table 3). It is found that the welding process is very steady (neither short-circuit nor burn-through has occurred) and the weld has a good appearance (the surface ripple is even, the weld width uniform and the weld surface bright and clean, as seen in Fig. 9). The X-ray inspection identifies that there is neither porosity nor crack inside the weld (shown in Fig. 10). These

results indicate that the control system can satisfactorily accomplish automatic welding of aluminium alloy sheets, thus fulfilling the technological requirements of automatic TIG welding of the missile shell.

Table 3 Automatic welding parameters

	Clamped position	Free position
Peak current, A	120	90
Background current, A	50	40
Pulse frequency, Hz	1	1
Pulse duration ratio, %	50	50
AC balance ratio, %	50	50
Arc voltage, V	13.0	13.4
Welding speed, mm/min	200	200
Wire feeding speed, mm/min	450	450

Note. Arc voltage means the positive-half-wave voltage of AC arc.

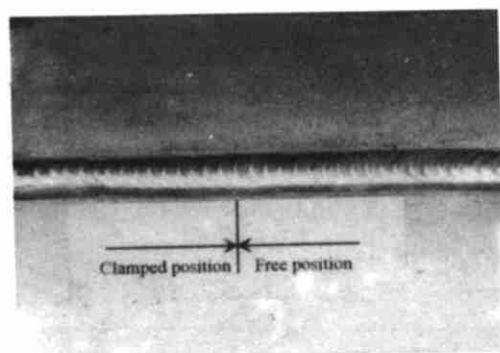


Fig. 9 Photograph of the weld appearance

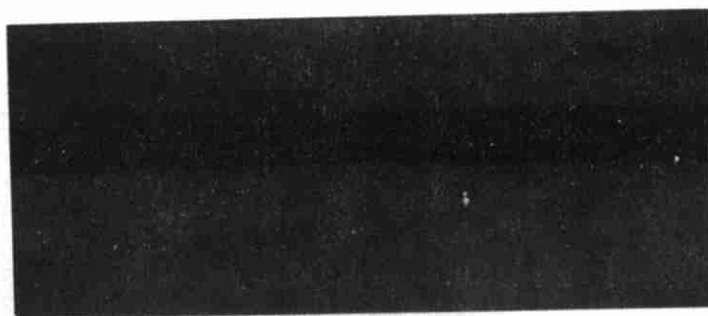


Fig. 10 X-ray photograph of the weld

4 Conclusions

(1) The control system developed in this paper attains the following specifications: the current control precision is 1 A; the arc length control precision is 0.1 V; and the relative positioning error is not more than 0.03 %.

(2) The control system can accomplish tack welding, automatic welding and simulative welding. The welding process is very steady and the weld is characterized by even surface ripple, uniform width, bright and clean surface, and free of porosity and crack. Therefore, the system can fulfill the welding technological requirements of the missile shell.

(3) The effective measures for preventing high frequency from interfering the computer control system has been taken in the hardware and software designs, thus guaranteeing the operative reliability of the system.

(4) The control system is developed for automatic TIG welding of aluminium alloy sheets, but it is suited for automatic TIG welding of other materials as well.

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