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Simulation of droplet transfer process and current waveform control of CO_2 arc welding ①

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[Abstract] A simulation system used in the arc welding short-circuit transfer process and current waveform control process was developed in this paper. The simulation results are basically consistent with welding technical experiments. The simulation system can be used to simulate and test the current waveform control parameters with welding variables. By this simulation system, the influence regularities of the current waveform control parameters in the CO_2 arc welding droplet short-circuit transfer process can be got. Moreover, the basic mode of real-time current waveform control can be also established by the simulation testing.

[Key words] CO_2 arc welding; droplet transfer; current waveform control; computer simulation
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1 INTRODUCTION

CO_2 shielded arc welding is one of the welding technologies with higher efficiency, lower energy consumption, less hydrogen content and high anti-oxidation ability. The short-circuit transfer is a main form in CO_2 arc welding process, but it has too much spattering, and unsatisfying weliding formation which restrain its further application.

The current waveform control is an effective method for decreasing spattering. But different waveform control models and different waveform control parameters have great effects on spattering. Through a lot of welding experiments, optimum waveform control parameters and better control effect on decreasing spattering were got[1~6]. In order to develop and test some new type waveform controllers, new simulation system should be used to investigate the droplet transfer process of arc welding. At present, the theoretical analysis or technical experiments are still basic research methods of the CO_2 arc welding process. Some modern simulation algorithms and techniques can be used to study and analyze the arc welding process[7~10]. A digital simulation mode for a system consisted of inverter and nonlinear load is developed with MATLAB simulation software. The simulation mode directly indicates the features of the system by means of visual modeling graph. Waveform of main state variables in dynamic process of CO_2 arc welding is given by the simulation[11].

Up to now, only few studies have been concentrated on the simulation of the current waveform control process and its arc welding short-circuit transfer process. Thus, in the present paper, the influence regularities of welding parameters and current waveform control parameters are studied by the simulation of arc welding droplet transfer process[12~14]. Its objective is to show the action instant and the parameters values of waveform control. Moreover, the basic mode of real-time current waveform control of droplet short-circuit transfer process can be also established by the simulation.

2 MAIN CIRCUIT OF WAVEFORM CONTROL AND ARC WELDING POWER SOURCE

Fig. 1 is a one-knob self-optimizing microcomputer control system and current waveform controller of CO_2 welding machine[12].

The main purpose of the waveform control is to improve the welding performance, reduce spattering and adjust the dynamica characteristics of CO_2 welding process through the real time control of the current waveform. As shown in Fig. 1, a new style current waveform controller is developed. The controller is composed of two sets of waveform generator, one of which is used for the real-time control of the current waveform during the short-circuit, and the other is used for the real-time control of the current waveform in the short-circuit rear-time and arc beginning instant. The controller is parallel connection to arc and works discontinuously, which makes its loading time shorter. Meanwhile, the width, the length, and the time of current wave chopping can be adjusted. In order to get an ideal control pattern of current waveform and its parameters, the simulation technique is a cheap method.

Fig. 2 is a simplified circuit of multiple - form

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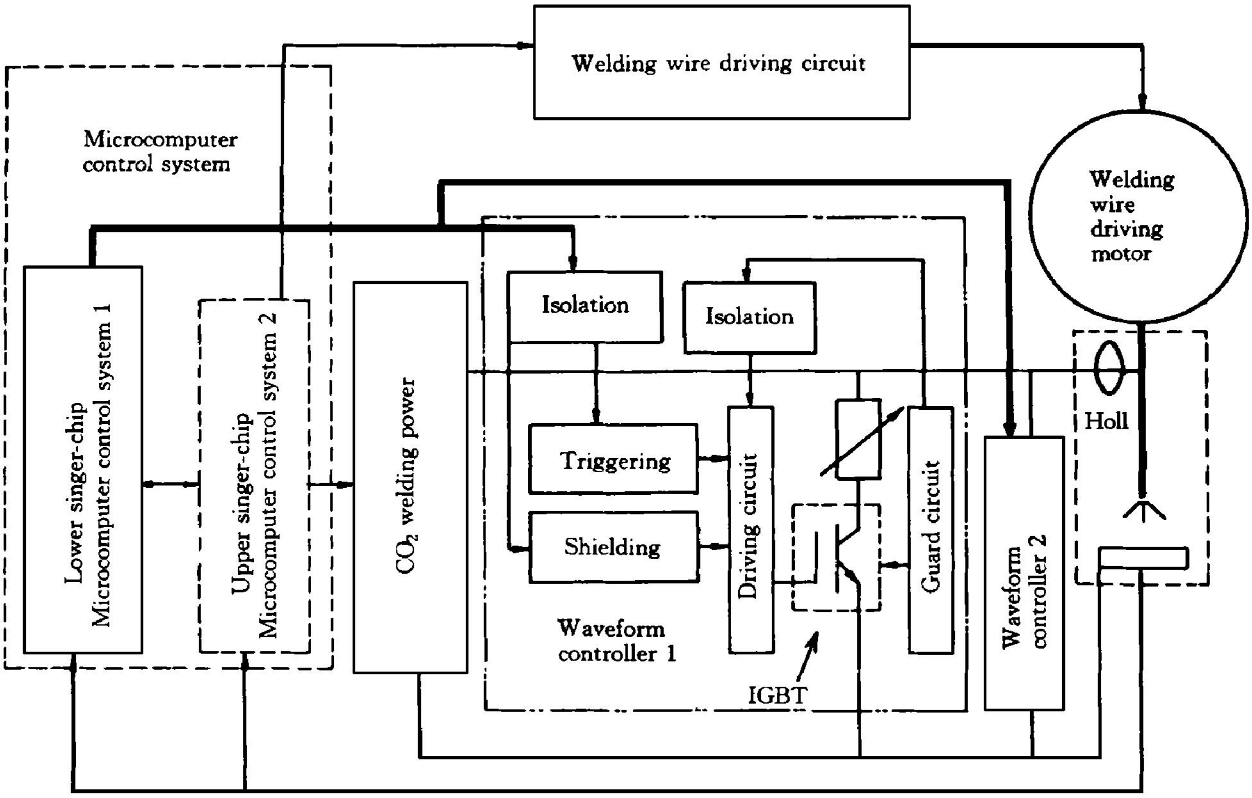

Fig. 1 Microcomputer control system and current waveform controller of CO_2 welding machine

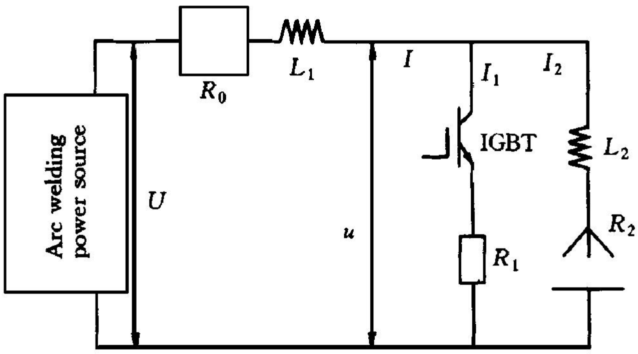

Fig. 2 Schematic of simplified waveform control circuit and arc welding power

waveform control system and CO_2 arc welding power source[12~14]. IGBT (isolated gate bipolar transistor) and its series resistance R_1 play a divided-flow action, and have a multiple relation to arc welding power source. Arc welding process can be analyzed by studying the instant action process of IGBT. As shown in Fig. 2, the current waveform control circuit of the system is equal to a divided-flow controller.

The work principle of the system is as follows. IGBT usually is located at a turn-off state. It will be turned on in an instant controlled by microcomputer only when the negative current pulse is generated. Thus the energy consumption of IGBT in the waveform controller will be lower, and the generated heat by the device will also be lower. It will profit to protect IGBT.

In Fig. 2, I is the output current of arc welding power source, u is the voltage between arc and electric cable, I_1 is the current flowing through IGBT, I_2 is the current of arc, L_1 is the inductance of reactor, L_2 is the inductance of electric cable, R_0 is the internal resistance of power source, R_2 is the resistance of arc and electric cable, R_1 is the adjustable series resistance containing IGBT internal resistance, which can be used to control the current flowed through IGBT or the depth of waveform control. In order to avoid the over-current burn out of IGBT, R_1 should be greater than 0.05 Ω.

3 PHYSICAL MODEL OF ARC WELDING DROPLET TRANSFER PROCESS

Fig. 3 is a physical model for simulating the arc welding droplet transfer process and waveform controlling.

4 MATHEMATICAL MODEL OF ARC WELDING DROPLET TRANSFER PROCESS

Based on the principle shown in Figs. 1~ 3, the mathematical model for simulating the arc welding droplet transfer process and waveform controlling can be got.

When IGBT is put through, the following formulas can be got:

$$\left.\begin{aligned} L_2\frac{dI_2}{dt}+I_2R_2=I_1R_1=u \\ I_1+I_2=I \\ U=IR_0+L_1\frac{dI}{dt}+u \end{aligned}\right\} \qquad (1)$$

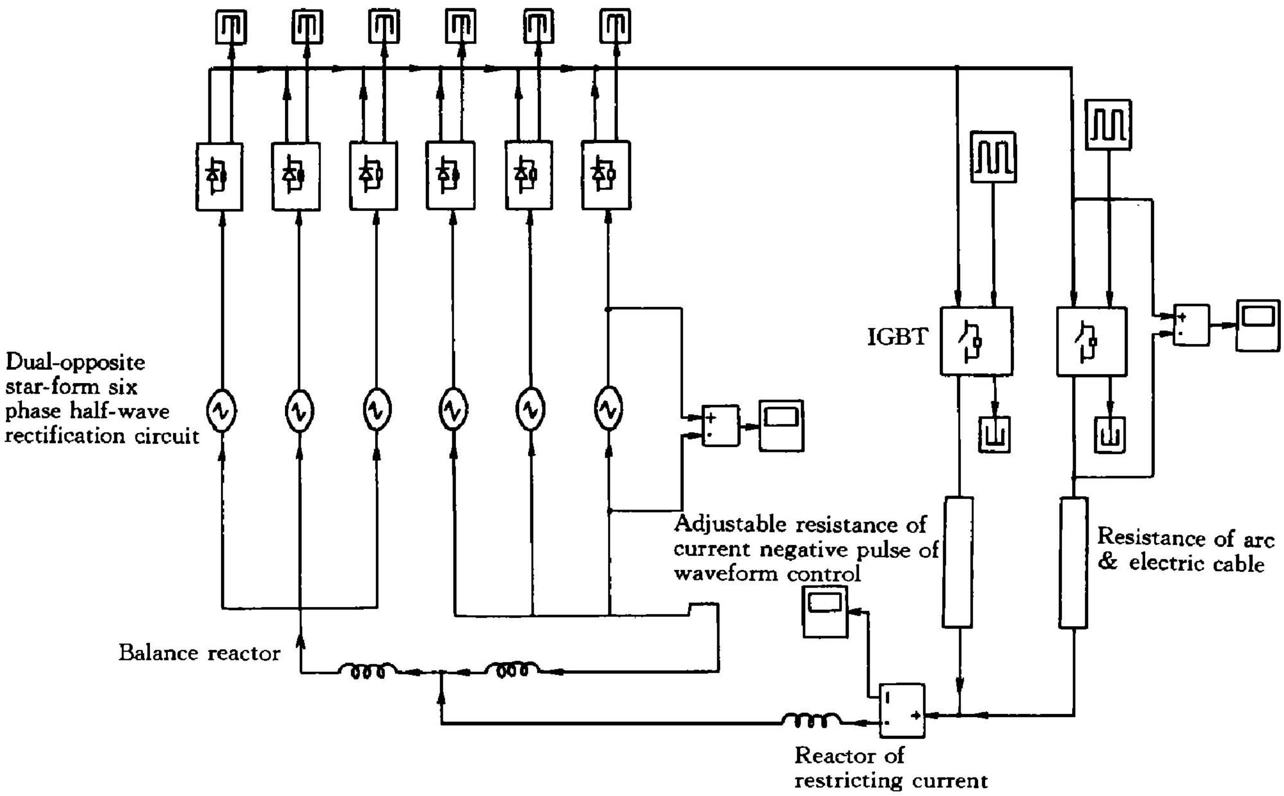

Fig. 3 Physical model of arc welding droplet transfer process and waveform control

By derivation, we can get:

$$U = \frac{L_1L_2}{R_1}\frac{d^2I_2}{dt^2} + \left(\frac{R_0L_2+R_1L_1+R_2L_1}{R_1} + L_2\right)\frac{dI_2}{dt} + \left[R_2+\frac{R_0}{R_1}(R_1+R_2)\right]I_2 \quad (2)$$

When waveform control is generated, the voltage and total current can be got:

$$U = I\left(R_0+\frac{R_1R_2}{R_1+R_2}\right) + L_1\frac{dI}{dt} \quad (3)$$

$$I = \frac{U}{R_0+R_2+\frac{R_1R_2}{R_1}} + \left[I_{20}-\frac{U}{R_0+R_2+\frac{R_1R_2}{R_1}}\right]\cdot \exp\left[-\frac{R_0+R_2+\frac{R_1R_2}{R_1}}{L_1}t\right] \quad (4)$$

When waveform control is terminated, the voltage and total current are

$$U = I(R_0+R_2) + L_1\frac{dI}{dt} \quad (5)$$

$$I = \frac{U}{R} + \left(I'_{20}-\frac{U}{R}\right)\exp\left(-\frac{R}{L_1}t\right) = \frac{U}{R_0+R_2} + \left(I'_{20}-\frac{U}{R_0+R_2}\right)\exp\left(-\frac{R}{L_1}t\right) \quad (6)$$

where

$$I'_{20} = \frac{U}{R_0+\frac{R_1R_2}{R_1+R_2}} + \left(I_{20}-\frac{U}{R_0+\frac{R_1R_2}{R_1+R_2}}\right)\exp\left(-\frac{R_0+\frac{R_1R_2}{R_1+R_2}}{L}t\right) \quad (7)$$

5 RESULTS AND ANALYSES OF SIMULATION

Based on the simulation, Fig. 4 shows the results of arc voltage and current in the arc welding droplet transfer process and waveform controlling.

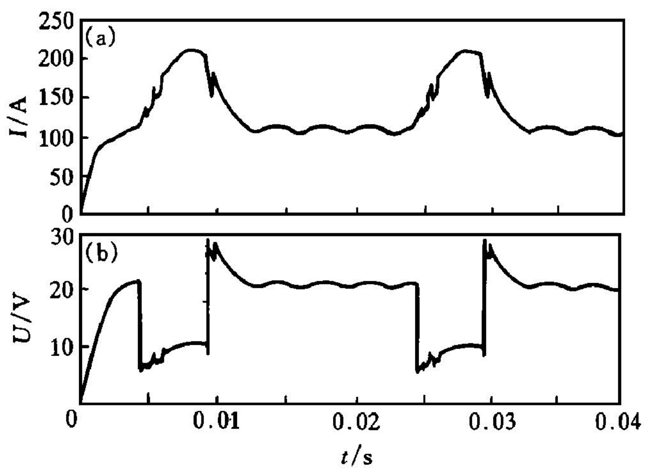

Fig. 4 Simulation results of arc voltage and current in arc welding droplet transfer process and waveform controlling

As shown in Fig. 4, the influence regularities of current waveform control parameters in the CO_2 arc welding droplet transfer process is given. The simulation results conform with welding experiment.

When waveform control is generated, the arc current is less than that when waveform control is not generated, and is also less than the total current of the power source.

When circuit parameters are invariable, the variable arc resistance R_2 will influence the total current and the divided-flow action of the waveform controller. Thus, the effect of waveform control is different.

When the waveform control width is identical, the level of the waveform control is referable to the waveform control location t_0, the current average value $\overline{I}$, and the series resistance of the waveform controller R_1. It is in direct ratio to t_0, but in inverse ratio to the resistance R_1.

According to the results of simulation and welding experiment, the recommendation values of the current waveform control parameters can be obtained, and the influence regularities of waveform control parameters on the CO_2 arc welding droplet short-circuit transfer can be got also. Moreover, according to these results, the basic mode of real-time current waveform control can be also established by the simulation. That is, the action time or position of waveform control, the width Δt and the height ΔI of the current negative pulse can be determined according to the welding variables.

6 CONCLUSIONS

1) The simulation system used in the arc welding short-circuit transfer process and current waveform control process is developed and the simulation results are basically consistent with welding experiments.

2) The simulation results show that the simulation system can be used to simulate and test the influence regularities of welding parameters and current waveform control parameters in the arc welding droplet transfer process, and can be spread to other welding process.

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