Wire Feeding Speed Control for Improving Welding Performances in Inverter Arc Welding Machine

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Abstract - *In the conventional wire feeder drives of welding machine, one thyristor or MOSFET device was used for half-wave phase control circuit and direct EMF measurement was used for sensing the wire feed rate. But the method using one switching device has poor response for sudden disturbance and it has latent speed ripple. It can affect some welding performance such as spatter generation and irregular bead formming. Therefore, the welding performance using full-bridge PWM speed control scheme was compared with conventional driving scheme and experimented in this paper. The results of experiment confirm the posibility of welding perfomance improvement by proposed constant speed control scheme in wire feeding drive of welding machine.*

I. INTRODUCTION

The system configuration of CO_2 inverter arc welding machine is consist of diode rectifier part, inverter part, high frequency rectifier part, and wire feeding DC motor. The system configuration and control block diagram of inverter arc welding machine is depicted in Fig. 1.

The welding current magnitude is determined by wire feeding rate directly.[1][2] And the welding perfomance is determined by welding current waveform. Therefore, in these days many researchers have been tried to find out any current and voltage waveform profile which makes less spatter generation and good bead formming which is an important facter in welding too.[3][4] But, in these efforts, the welding performance have beens rarely improved because there is disregard of wire feeding speed fluctuation in their researches.

The conventional wire feeder driving scheme in welding machine adopts half-wave phase control circuit. The circuit and the voltage-current waveforms of thyristor and MOSFET based topology is shown in Fig.2 and Fig.3. These two topology is half-wave phase control circuit and it has current ripple of 60Hz.[5] So, this current ripple will produce the torque and speed ripple. Moreover these topology cannot achieve constant speed control over all welding conditon.

Generally the mechanical time constant is very lager than electrical time constant. So, in conventional wire feeding drives which adopts phase control scheme, the speed fluctuation by ripple current is quite small. But, at this small effect, the welding current can be irregular. Therefore, this irregular current wave- form makes poor welding performance.

In addition, the variation of arc pressure and a lot of noise which can effect on the welding performance will disturb constant wire feeding speed too.

Therefore, to achive good welding performance by the constant speed regulation, the full bridge

MOSFET inverter was proposed in this paper. The controller consist of the speed and torque control loop for constant speed control.[6]

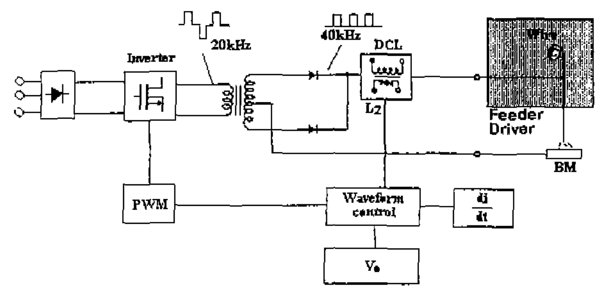
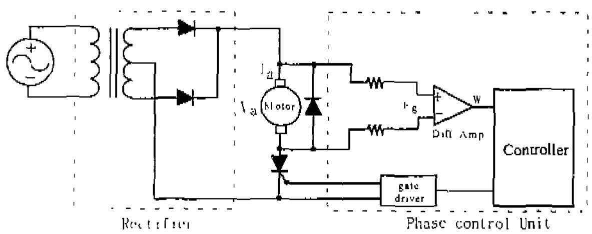
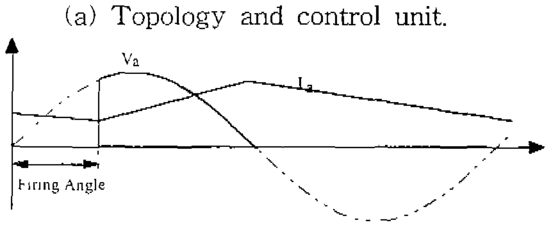


Fig. 1. Inverter arc welding machine control scheme.

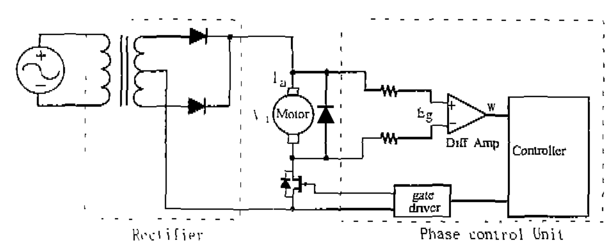


(a) Topology and control unit.

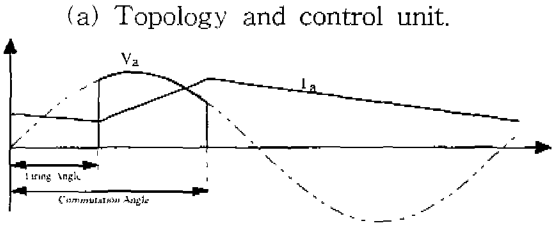


(b) Appllied voltage and ripple current.

Fig. 2. Half-wave phase control scheme using one thyristor.



(a) Topology and control unit.



(b) Appllied voltage and ripple current.

Fig. 3. Half-wave phase control scheme using one MOSFET.

Ⅱ. THE PROPOSED SYSTEM

Eq.(1)-(4) represent electrical and mechanical equations for DC motor. Here, v_a and i_a are armature voltage and current respectively. Eq.(1) and Eq.(2) are electrical equation and mechanical equation respectively, and these two equations are coupled by Eq.(3) and Eq.(4).[5] In Eq.(3) back e.m.f. is propotional to rotor angular velocity on permanent magnet DC motor (PMDCM).

Using Eq.(3), in conventional wire feeding speed control, the back e.m.f sensing method is used for speed sensing. But, the back e.m.f can not be measured exactly, because it appears on winding.

Eq.(2) and Eq.(4) shows that the mechanical speed fluctuation can be arised by the current ripple in conventional speed control scheme.

$$L_a\frac{di_a}{dt} = Va - R_aI_a - E_g \qquad (1)$$

$$J_a\frac{dw_a}{dt} = T_e - T_l - B_aw_a \qquad (2)$$

$$E_g = K_ew_a \qquad (3)$$

$$T_e = K_tI_a \qquad (4)$$

here, L_a : armature inductance
R_a : armature resistance
E_g : back e.m.f
T_l : load torque
J_a : rotor inertia
w_a: rotor angular velocity
K_e : back e.m.f constant(=Kt)
K_t : torque constant

So, in the proposed system, the speed sensor is rotory encoder, and for the motor drive, PWM inverter was used. The block diagram of CO_2 inverter arc welding machine is depicted Fig. 1 and it shows conventional welding current control is shown. The proposed motor speed control scheme is applied to the shadow region for the welding performance evaluation on experiment.

The wire feeding DC motor is drived by inverter and constant speed controller which has speed and current regulation loop for wide control bandwidth and immunity from noise.

The welding current dial on the control pannel gives the speed command for motor drive system. And the frequency-to-voltage converter(F/V converter) changes the encoder output pulse to continuous voltage level for rotor speed feedback. Fig.4 show the control block diagram of wire feeding DC motor. In the block diagram, the command on feeding speed is compared with real feeding speed, and the speed error is amplified by PI controller, then the output of PI speed controller become the input of current controller as a current command. The current controller regulates the armature current to trace current command which comes from speed controller.

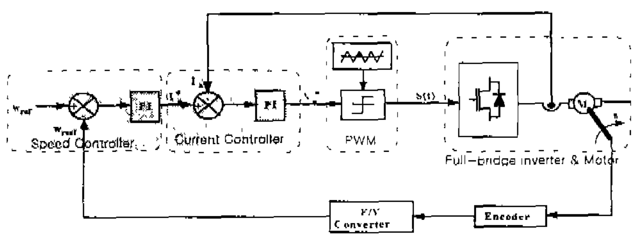


Fig. 4. Proposed wire feeding motor control scheme.

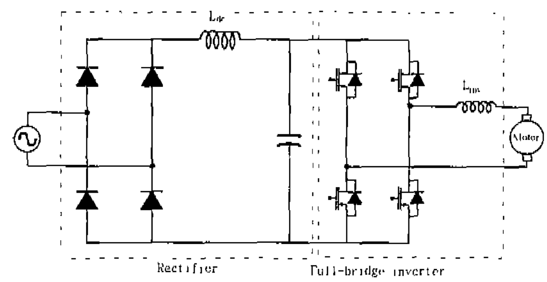
Table 1. Specification of wire feeding DC motor

DC motor	
Rated output	75W
Rated torque	2.0 kg · cm
Rated RPM	3600 rpm
Rated input voltage	24V
Rated input current	5.0A
Rotor inertia	1.5 kg · cm^2
Armature resistance	0.68Ω
Armature inductance	0.045mH
Enduced voltate constant	5.3mV/rpm.
Torque constant	0.52kg · cm/A
Friction constant	0.08 g · cm/rpm
Mechanical constant	38 msec
Electrical constant	0.066 msec

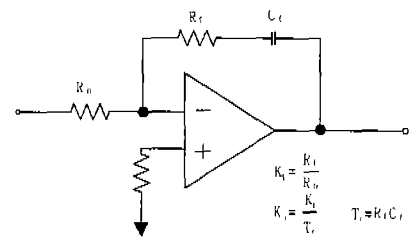
Ⅲ. HARDWARE IMPLEMENTATION

The hardware configuration can be seen in Fig. 5(a), four MOSFETs are used for accelera-tion and deceleration by current control. The diode rectifier is shown for DC source, that is not exist in conventional phase control scheme. Because rotor inductance which is shown in the Table 1. is too small , for small current ripple, inductor is inserted on the inverter output side. In Table.1, the all specification of wire feeder motor is shown.

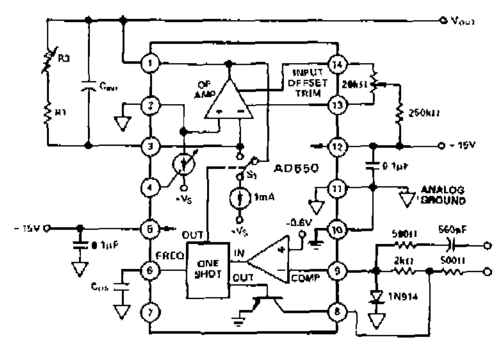
The PI controller for speed and current control loop was made with OP-AMPs as shown in Fig.5(b). The encoder resolution is 524 pulse/revolution and the encoder inertia is very small compare with the rotor inertia. The F/V converter shown in Fig.5(c) is AD664 which has wide frequency range. The gate driver circuit is configured with IR2112 drive chips and it is shown in Fig.5(d).



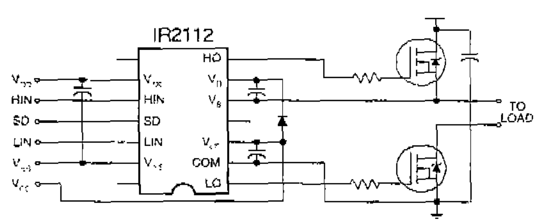
(a) Rectifer and Full-bridge inverter



(b) PI controller



(c) F/V converter circuit



(d) Gate Driver circuit

Fig. 5. Hardware implementaion

Ⅳ. EXPERIMENTAL RESULT

The welding performance comparison between the proposed method and the conventional wire feeder drive is the object on this paper. Therefore, welding perfomance is evaluated by the experiment. In welding performance evaluation, the quantity of spatter generation and the number of instant short-circuit and the bead formming are important factors. So in this paper, the performance was evaluated with these factors.

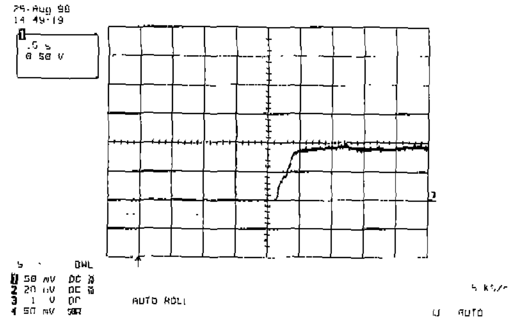
The experiment was done in the range of 100A, 200A, 300A welding current respectively. And the generated spatter was gathered in the box made of copper. The waveform of arc voltage and current was analyzed by MATLAB script.

Fig. 6 and Fig. 7 shows the step input response of the conventional and the proposed driving scheme respectively. In Fig. 6, conventional method shows the slow start characteristic, about 0.1msec, compared with proposed method in Fig. 7. In the steady state, the speed ripple was reduced.

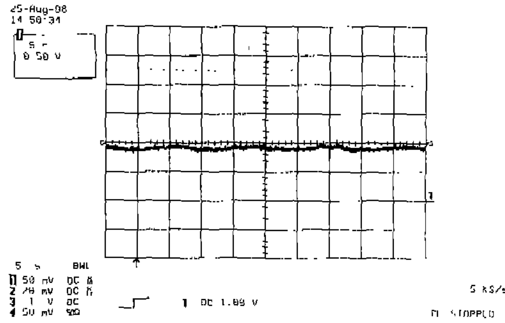
Fig. 8 and Fig. 9 shows voltage and current waveforms and their V-I curve respectively for the conventional method and proposed method for welding operation at 100A, 200A, 300A welding current. In Fig. 8 the instant short-circuit metal transfer is shown more frequently than Fig. 9, and in the V-I curve this phenomena can be seen because the number of line which put across the inner area means the number of the instant short-circuit metal transfer.

Fig. 10 shows spatter generation histogram. These results mean unwanted instantaneous short circuiting which affects spatter generation was lessen by proposed wire feeder driving control, in the case of 300A welding current, the spatter was reduced to about 43%.

The above experimental results confirm that the speed ripple of wire feeder affect spatter generation directly. Therefore, welding performace can be improved by getting rid of the speed ripple of wire feeder using constant speed control method.

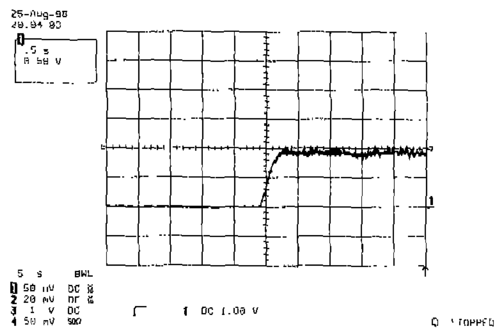


(a) setp response

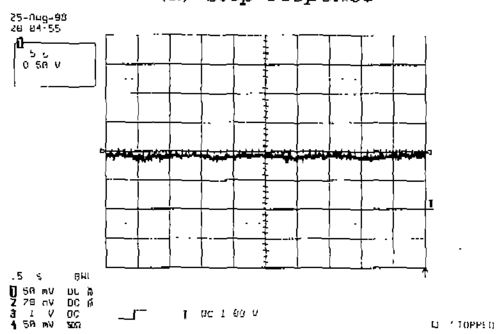


(b) steady state response

Fig. 6. Wire feeder step characteristic and steady state response in conventional wire feeder drive.

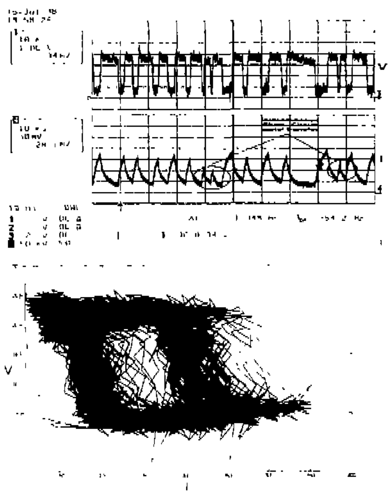


(a) step response

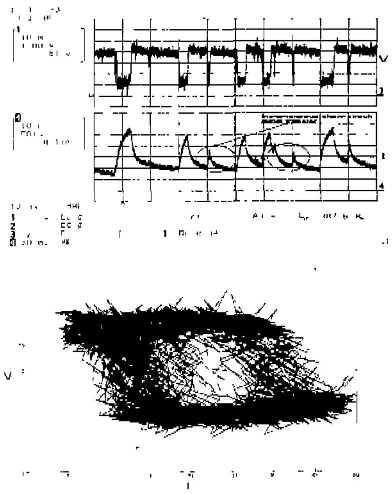


(b) steady state response

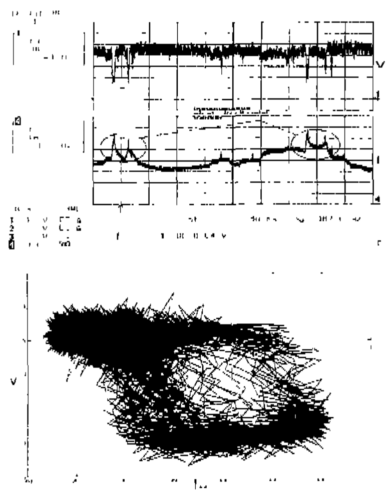
Fig. 7. Wire feeder step response and steady state response in proposed wire feeder drive.



(a) 100A(r.m.s)

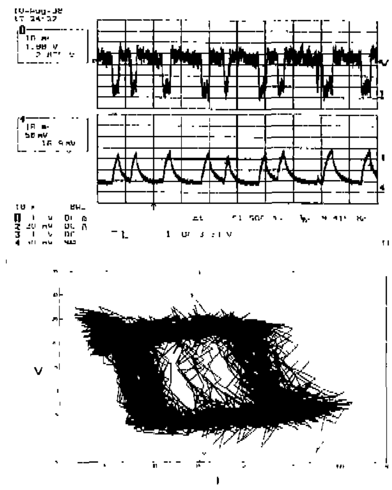


(b) 200A(r.m.s)

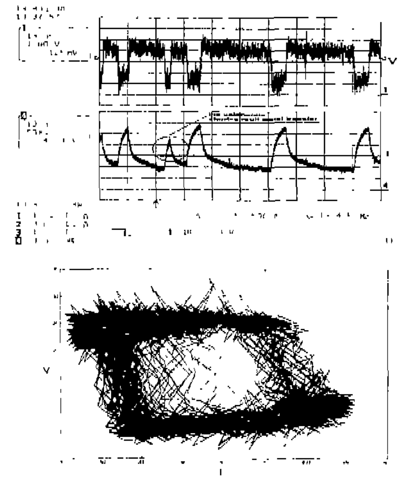


(c) 300A(r.m.s)

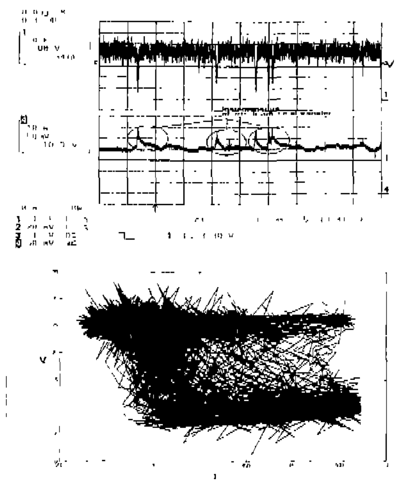
Fig. 8. Welding current and voltage and V-I curve by conventional speed control scheme



(a) 100A(r.m.s)



(b) 200A(r.m.s)



(c) 300A(r.m.s)

Fig. 9. Welding current and voltage and V-I curve by proposed speed control scheme

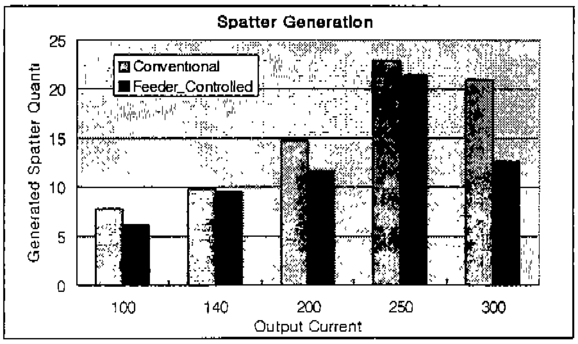


Fig. 10. Spatter generation comparison.

V. CONCLUSION

For the welding performance improvement, PWM full-bridge servo-amplifier was proposed in this paper and evaluated through the experimental results for conventional control and proposed control scheme respectively.

The start-up characteristics was considered and compared with two control method. In the sense of welding current and voltage waveform, the proposed controller shows more regular characteristic and less short-circuitting interval which affect for amount of spatter generation.

From the experimental spatter generation histogram, we can confirm that unwanted instantaneous short-circuit metal transfer was lessen by proposed wire feeder driving control and the quantity of generated spatter was reduced.

In the next study, we will consider low-cost control scheme which has good speed regulation characteristics for welding machine application .

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