A Study on Welding Performance Improvement of Inverter Arc Welding Machine using Instantaneous Output Current Control Method

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ABSTRACT - *According to the adoption of inverter circuit topology for welding machine area, the improvement of welding performance can be achieved. However conventional CO_2 inverter arc welding machine uses the constant voltage characteristics. So the metal transfer is performed under unoptimum condition in the sence of spatter generation..*

In this paper the new control algorithm is proposed for welding machine, which is the instantaneous output current control method using single chip microprocessor. But the optimum waveform of welding current is still uncertain, as a first step for figuring out the optimized waveforms, this study was performed. And as a result of performance test of the proposed system, it was demonstrated that all of the waveform variation parameter could be set individually and the generated spatter is reduced compared to conventional inverter arc welding machine.

1. INTRODUCTION

According to the application of power electronics technology, in the GMA(Gas Metal Arc) welding machine area higher quality, less spatter generation and more automation are required. It can be achived by high-frequency inverter arc welding machine is being studied. Generally the GMAW(Gas Metal Arc Welding) is widely used in the industrial area, which can be classified into MIG(using Argon gas), MAG(using Argon+CO_2 gas) and CO_2 GMAW by shilding gas which prevent oxidizing molten pool or globule. Especially among these GMA welding machine CO_2 GMA welding machine is most widely used because the price of shilding gas is less expensive.. But it has a major disadvantage which is more spatter generation during the welding procedure. The spatter which is generated during welding procedure is the small article radiated to space, nozzle and base metal and additional work to remove this spatter is needed. These days most study on the GMAW area is to reduce the spatter generation by using new inverter control method or by adoption of new electrode wire.

The metal transfer modes of CO_2 GMA welding machine are mainly short-circuit and globular mode. These metal transfer modes are determinded by the magnitude of output current. In the low output current level the short-circuit metal transfer is peformed and in the high output current level the globular metal transfer is peformed.

In the region of low welding output current, i.e. less than about 200A, consumable wire electrode is melt by the arc heat between the tip of the wire and the molten pool or base metal, and then molten wire is enlarged and contacted with molten pool or base metal. At this point, it forms the short-circuit bridge and it cause large output current to flow, so large output current breaks the short-circuit bridge and arc re-ignites. After metal transfer mode short-circuit and arc state is repeated. By using high precision camera it is known that the spatter is mainly generated at the instant of short-circuit forming and arc re-ignites state.

In the high current region(200-300A), in addition to the type of spatter described above, another spatter phenomenon exists: the large current flows just before the short circuit is broken and an arc is established. Consequently large spatter is made.

This paper presents new instantaneous output current control method. The main control algorithm of proposed one is to reduce spatter, which is generated in the short-circuit, by controlling output current instantaneously using digital current controller.

2. CIRCUIT CONFIGURATION OF INVERTER ARC WELDING MACHINE

The main system of CO_2 inverter arc welding machine is composed of power conversion circuit, wire feeder controller and gas flow controller. The main function of power converter is to generate stable output dc voltage through diode rectifier, full-bridge inverter, transformer, output side rectifier and reactor as shown in Fig. 1. Generally conventional CO_2 inverter arc welding machine has constant output voltage characteristics and output current is determinded by wire feeder velocity. The gas flow controller maintains constant gas flow during welding procedure.

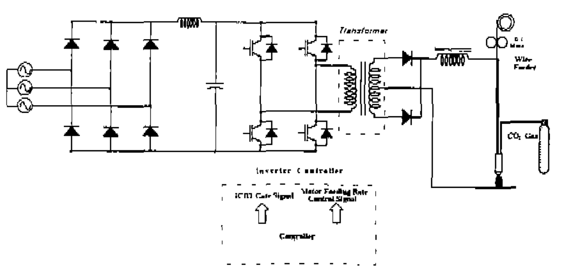


Fig. 1 The CO_2 inverter arc welding machine circuit

2.1 Operation of Inverter for Welding Machine

Fig. 2 shows circuit configuration and operating modes of full-bridge inverter for welding machine. As shown in Fig. 2 there are four operating modes according to the state of four switches and current paths. Table 1 rcpresents the relation between inverter swiching function and state of these switches.

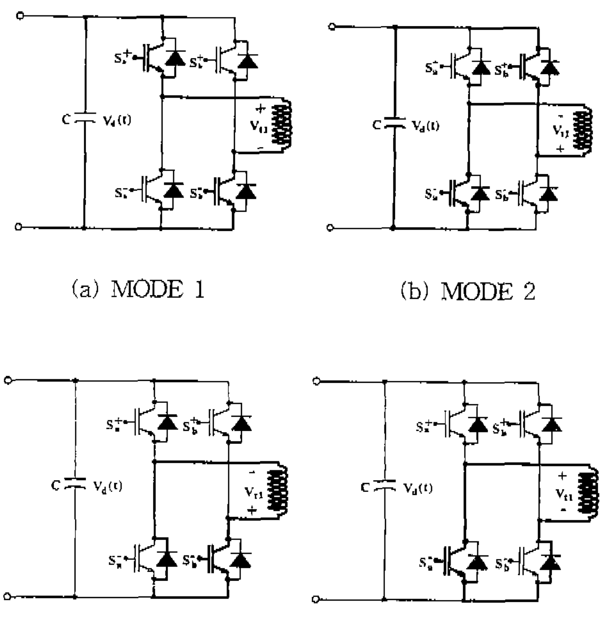
Table 1 Relation between switch function and on state of these switches.

Switching Function	Switch On state
1	S_a^+, S_b^-
0	$, S_a^+, S_b^+$
-1	S_a^-, S_b^+

The circuit equation of inverter output voltage v_o is expressed as followes:

$$| n^{-1} S v_d | = L\frac{di_o}{dt} + v_o \qquad (1)$$

(where S:switching function, v_d :dc link voltage, di_o :inverter output current)



(a) MODE 1 (b) MODE 2

(c) MODE 3 (d) MODE 4

Fig. 2 Circuit operation mode of inverter.

3. PROPOSED INVERTER ARC WELDING MACHINE

The conventional CO_2 inverter arc welding machine outputs the constant voltage. The output current is decided by the wire feeder velocity. The metal transfer under these condition is performed itself according to power. Therefore it is not the optimum condition of the metal transfer in the view of spatter generation, due to the fact that the metal transfer of CO_2 inverter arc welding machine is directly related to output voltage and current. Fig. 3 shows the short-circuit metal transfer according to output voltage and current waveform of conventional inverter arc welding machine. As shown in Fig. 3 when the molten globule contact to base metal the short- circuit occures and the output voltage is lowered. After that the output current is increased rapidly. When the short-circuit bridge is broken, the arc is regenerated and output voltage is increased. In the view of spatter generation, when these instantces of the short-circuit and arc state is occured more spatter is generated.

In this paper, the new control algorithm is proposed, which is instantaneous output current control method using single chip microprocessor. The main control algorithm is to reduce spatter generation at the instance of short-circuit occurence by controlling output current instantaneously. Fig. 4 shows the block diagram of proposed inverter arc welding machine. The current controller of the proposed system measures the output voltage continuously. The measured output voltage is used to find short-circuit voltage the current controller outputes the current reference signal which is to maintain output current to base current level during 1-2 msec to form short-circuit bridge, and then increases to the adequate value to break short-circuit bridge to restart arc state.

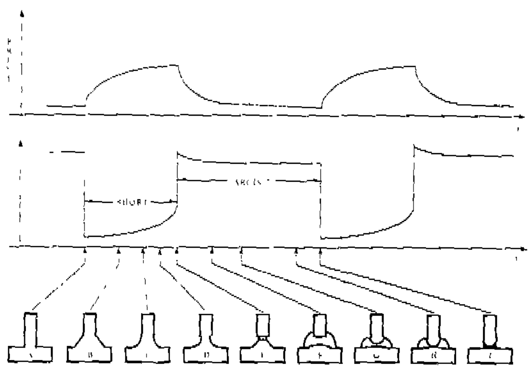
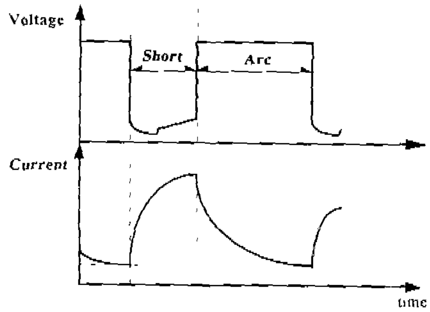
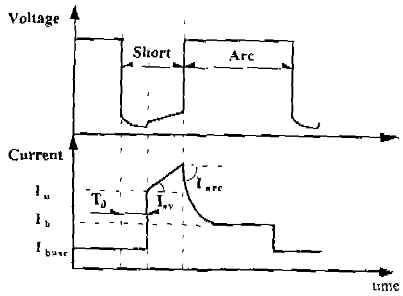


Fig. 3 Short-circuit metal transfer procedure.



(a) conventional inverter arc welding machine



(b) proposed inverter arc welding machine

Fig. 5 Current and voltage waveform of inverter arc welding machine.

Fig 5 shows the output voltage and current waveform of the proposed welding machine. In this figure there is many parameteres of current reference signal to control. i.e. T_d, I_u, I_{sv}, I_{arc}, I_b, I_{sh}. These control parameteres of the current reference signal can be changed by the program. The optimal paramerter of the current reference signal is represented in this paper. Fig. 6 showes control flow-chart of proposed welding machine.

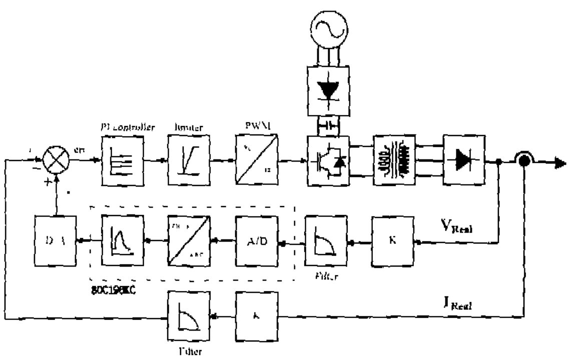


Fig. 4 Control block diagram of proposed inverter arc welding machine.

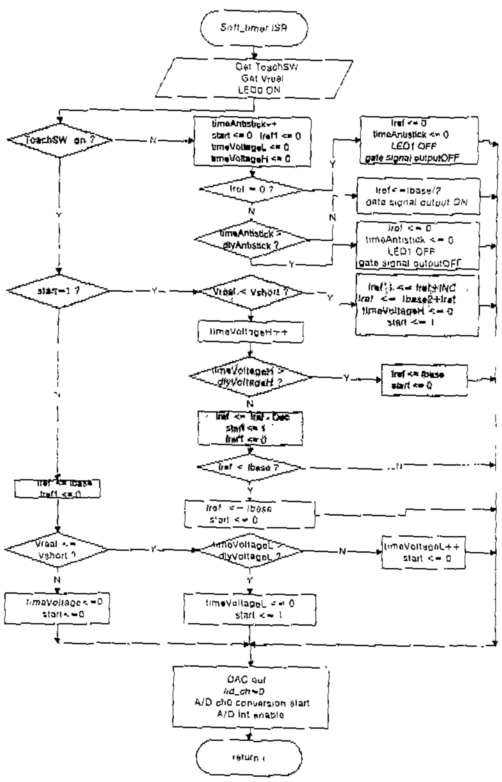


Fig. 6 Control flowchart of proposed inverter arc welding machine.

4. EXPERIMENTAL RESULTS

In this section the characteristics of output voltage and current waveforms are analyzed and welding performances are compared between conventional and proposed inverter arc welding machine. Table 2 showes experimental condition of inverter arc welding machine.

Table 2. Experimental condition of inverter arc welding machine.

Output Current (RMS)	Output Voltage (RMS)	Wire Feeding Rate (RPM)
100 A	18 V	19.5 RPM
200 A	23 V	51.5 RPM
300 A	29 V	102.3 RPM
The used shilding Gas : CO_2		
The distance of electrode and base metal : 2.5 cm		
The base metal : Steel (Thickness : 8mm)		

Fig. 7 shows the otuput voltage and current waveformes of conventional inverter arc welding machine. Fig. 7(a) and (b) shows the output current waveforms of 100A and 200A respectively, which is the RMS value. In this figure the peak value of the output current, which is directly related to metal transfer mode, fluctuates and short-circuit cycle changes irregularly. This means that the molten globules of feeding wire are formed irregulary and it cause more spatter.

Fig. 8 shows the waveforms of proposed inverter arc welding machine. The RMS value of output current is simular to the conventional inverter arc welding machin. As shown in this figure the peak value of the otuput current is controlled regularly and the short-circuit cycle is maintained nearly constant. It means that the volume of molten globules are formed uniformly and the short-circuit metal transfer is stabilized. It is possible to expect spatter reduction due to stable short-circuit metal transfer.

Fig. 9 and 10 show the V-I curves of conventional and proposed one. By frankly in these figure the curves circulate in square waveform. The V-I curves of proposed one is more regular compare to conventional one. Especially it is known that the inner loops of the square waveform is caused by irregular metal transfer. The more inner loops exist the more unstable metal transfers are performed. Therefore from the comparison of these figures the proposed inverter arc welding machine can reduce spatter and stabilize the cycle of short-circuit metal transfer.

Fig. 11 shows the comparison of spatter generation for conventional and proposed inverter arc welding machine. As shown in this figure the proposed system can reduce spatter at least 20 % more. The maximun reduced rate is occured at the low current level(100A), and the reduced rate is about 50 %. Fig. 12 shows the beed state of conventional and proposed inverter arc welding machine. In the view of beed state the proposed system shows regular uniform in the width of welding region and there are very little sticked spatter around the welding region.

So through the welding performance characteristics the proposed instantaneous current controlled inverter arc welding machine is able to reduce spatter and to enhance overall welding performance characteristics.

5. CONCLUSION

In this paper, the analysis of welding phenomenon for CO_2 inverter arc welding machine and the enhancement of welding performance through instantaneous output current control method is studied. Through the expriment of proposed welding machine the obtained major characteristics are as follows;

1) To reduce spatter generation compared to conventional inverter arc welding machine
2) To maintain regular cycle of short-circuit metal transfer
3) To enhance beed state by output current control method
4) To develop digital controller for instantaneous output current control

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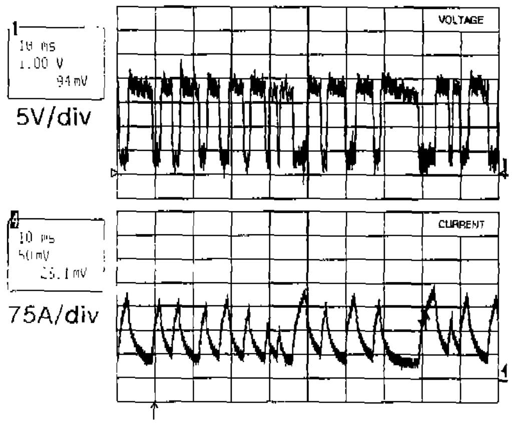
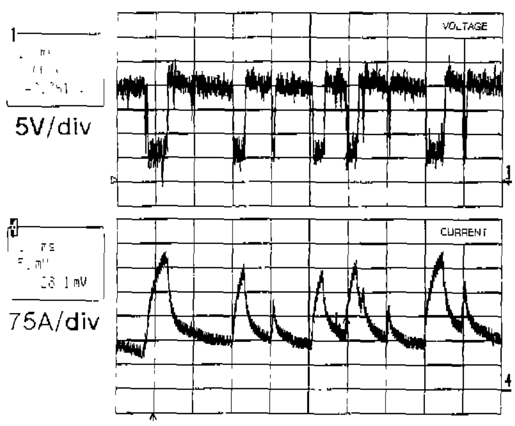
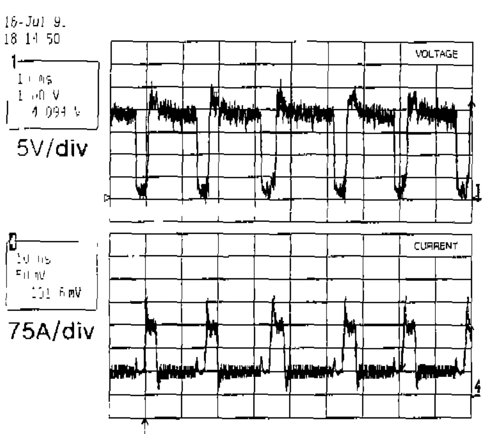


(a) 100 A

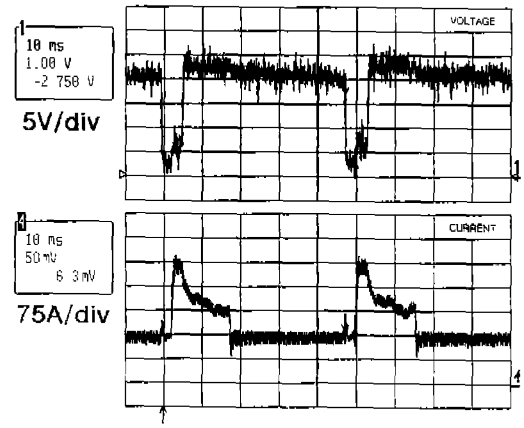


(b) 200 A

Fig. 7 Output voltage and current waveform of conventional inverter arc welding machine (10msec/div)

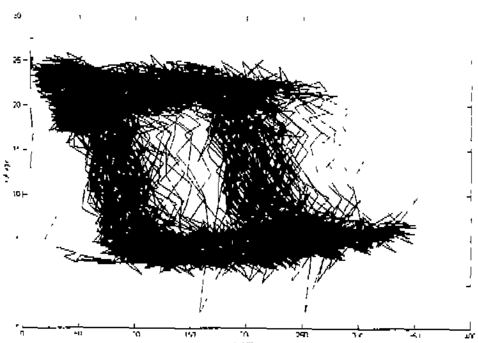


(b) 100 A

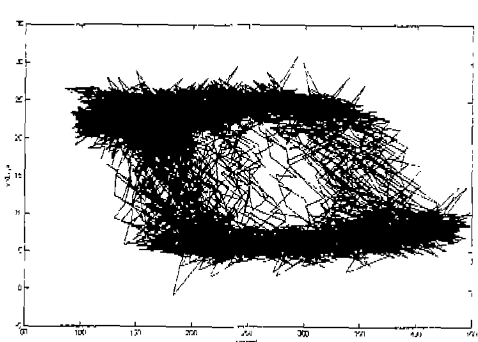


(b) 200 A

Fig. 8 Output voltage and current waveform of proposed inverter arc welding machine (10msec/div)

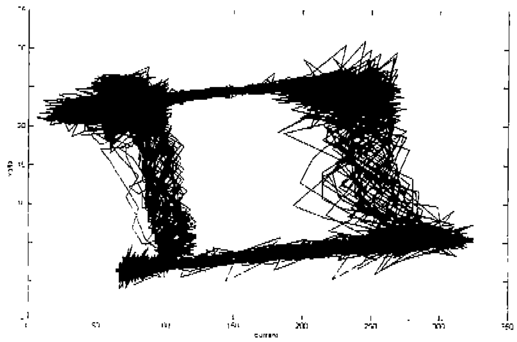


(a) 100 A

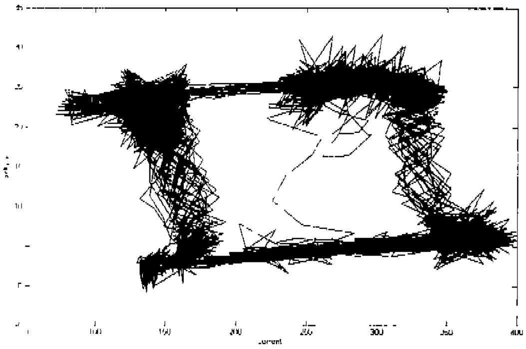


(b) 200 A

Fig. 9 V-I curves of conventional inverter arc welding machine

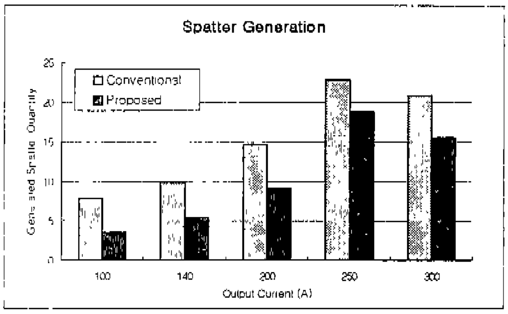


(a) 100 A

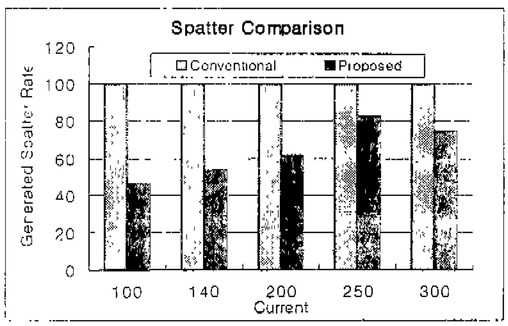


(b) 200 A

Fig. 10 V-I curves of proposed inverter arc welding machine



(a) generated spatter quanty



(b) generated spatter comparison

Fig. 11 Comparison of generated spatter.

(a) Conventional inverter arc welding machine

(b) Proposed inverter arc welding machine

Fig. 12 Comparison of bead state.