RECENT ADVANCES IN WELDING POWER SYSTEMS FOR AUTOMATED WELDING

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INTRODUCTION

Since the 1982 introduction of inverter control technology into an arc welding power source, it has proliferated throughout gas shielded arc welding processes in Japan. The requirements for inverter sources have been based upon the improvement of welding performance coming from high-speed control of current, rather on than many improvements on functional aspects such as miniaturization weight reduction and of electricity. Particularly, efforts for the most part have focused on the analyses of welding arc phenomena and how to control the phenomena with external parameters. Consequently various waveform control systems have been developed 1,2).

Recently Japanese industries have been faced with a serious problem: the shortage of skilled welders. To overcome this problem, the demand for development of a welding system that allows even inexperienced welders to weld easily has grown immensely. For example, the fuzzy controlled welding power system has been developed to make welding easier by automatically adjusting the output of the current and voltage, thereby making up for the insufficient skill of the welder.

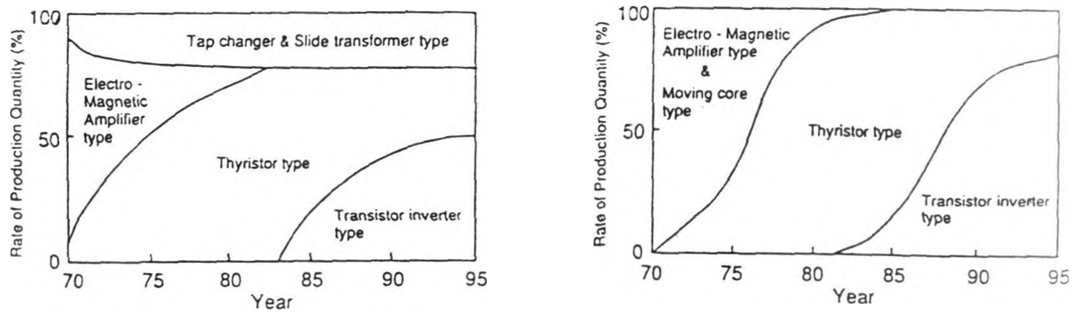
In this paper, the following are described features and trends of inverter controlled arc welding power supplies, various types of power supplies with controlled current waveforms, and a new power system controlled by a microprocessor.

Development of Arc Welding Power Supply

Change in output control method in arc welding power supply

Figure 1(a), (b) shows the change in the spread of welding power supplies being used in gas shielding arc welding in Japan. Around 1970, the thyristor was adopted in a DC power supply as an output control device in place of a magnetic amplifier. Thus the function of welding power supply was greatly improved. In 1982, a GMA welding power supply with a transistor inverter capable of much higher-speed control of current was developed with BJT and its application has advanced in pulsed GMA welding and in AC GMA welding. Since then, with improvements in its function and performance, the inverterized power source has come into use throughout the fields of gas shielded arc welding.

The GTA welding power supply is shown in Fig 1(b). The change from thyristor control to inverter is similar to that in GMA welding. Its use exceeded 50% towards the end of the 80s, and today reaches nearly 80%.



(a) GMA welding power supply (b) GTA welding power supply

Fig 1 Change in spread of control method of welding power supply (in Japan)

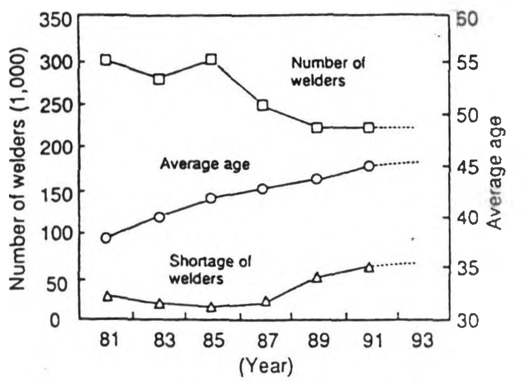


Fig 2 : Transition in number of welders

Shortage of welders in Japan

Figure 2 shows the change in the number of welders and the average age of welders in Japan. There were around 300,000 welders in 1981 and around 210,000 in 1991, a decrease of about 30% in 10 years. The average age of welders has also increased much in this decade.

Under the situation mentioned above, automatization and robotization of welding work have been carried forward with requirements for a much more functionalized welding power source. Also for semi-automatic welding the development of a new welding power system has been required so that an inexperienced welder can produce a proper weld.

In order to meet these demands a new welding power supply having waveform control of current and a new system based on fuzzy control theory have been developed.

Control of welding arc phenomena by inverter power supply

Since welding arc phenomena such as arc strike, electrode melting, metal transfer and molten pool formation are very quick and intricate, it has been generally accepted that high-speed and precise adjustment of current should be required to regulate these phenomena by the output control of power supply.

Figure 3 shows the charateristic time or the proper frequency of above phenomena and the controllable frequency of major output control devices of welding power supplies. It can be seen that the inverterization of the welding power supply has extended the capability of high-speed control of welding arc phenomena.

Recently, a new high performance inverter controlled welding power system, using a higher-speed and higherpower switching device controlled by a micro-processor, has been developed. This makes it possible to control the complicate waveform of output current and to improve greatly the performance of the welding operation.

Trend in Control circuit Technology of Inverter

Figure 4 shows the block diagram of inverter controlled welding power supplies for various welding pro-

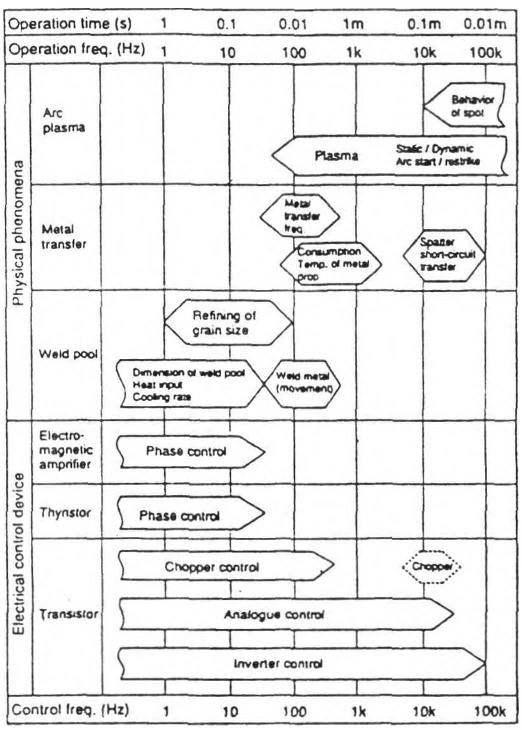


Fig 3 : Relation between charecterstics time of arc welding phenomena and control frequency of various kinds of power supplies

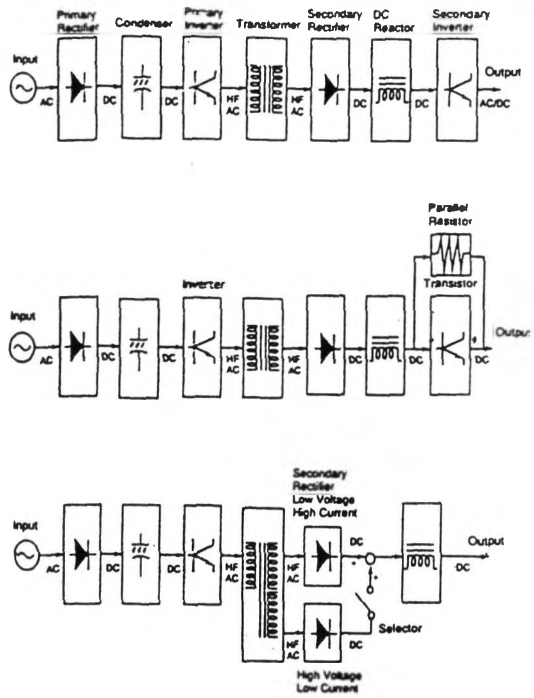


Fig 4 : Block diagram of output circuit

a AC/DC GTA welding power supply

b Short circuit GMA welding power supply

c. DC GTA welding/plasma cutting power supply

Item \ Power device	Thyristor	BJT	MOSFET	IGBT
Circuit Symbol				
Current Capability	B 400A	B 600A	C 100A	B 600A
Voltage Capability	B 2500V	B 1200V	C 500V	B 1200V
Switching Speed	C 20 μs	B 5 μs	A 0.3 μs	A 1 μs
Easy Drive	C Forced comutation	B Current drive	A Voltage drive	A Voltage drive

A : Excellent B : Good C : Fair

Fig 5 : Power devices for inverter controlled welding power supply

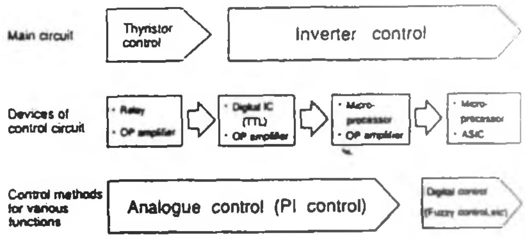


Fig 6 . Change in the main parts used for control curcuit

cesses. In an AC/DC GTA welding power supply, a secondary inverter is added in the subsequent step to the DC reactor to convert the output to AC again[3]).

In a short-circuit GMA welding power supply, a switching device with parallel resistor is provided in subsequent step to the DC reactor, It means to control the welding current more rapidly to suppress the spattering related with short-circuiting transfer of molten metal.

Figure 5 compares power devices used in inverter controlled welding power supplies. In the thyristor control, handling high power is easy, but the switching speed is low and the drive circuit is complicated. The BJT (Bipolar Junction Transistor) of large capacity and high-speed switching is widely used, but because it uses the current drive, its disadvantage is that Much power is needed to drive the system compared to that required by other devices. The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) offers higher-speed switching than other devices and allows low power driving. However it has a lower current capacity than other devices. The IGBT (Insulated Gate Bipolar Transistor) is a newly developed device which has the advantages of both the BJT and MOSFET large capacity, high-speed switching and ease in driving. In the future the IGBT is likely will be used the main power device inverter.

Figure 6 shows the change in the main parts used in the control circuit.

A relay and OP amplifier are used in thyristor controlled welding power supplies, and digital ICs are used in inverter controlled welding power supplies. After that, in order to reduce the number of electronic parts micro-processors are used in inverter welding power supplies. Recently, the main parts of the control circuit

Output current \ Welding process		MMA	GTA	GMA CO$_2$	GMA MAG	GMA MIG
A C		▩	◎	○	○	○
DC	Constant	◎	◎	◎	◎	◎
DC	Low frequency pulse	▩	◎	▩	▩	○
DC	Medium frequency pulse	▩	◎	○	◎	◎
DC	High frequency pulse	▩	◎	▩	▩	▩
A C - D C hybrid		▩	○	▩	▩	○

◎ : Widely used ○ : Presented the reports, or partially used ▩ : No report

Fig 7 : Application of inverter controlled welding power supply

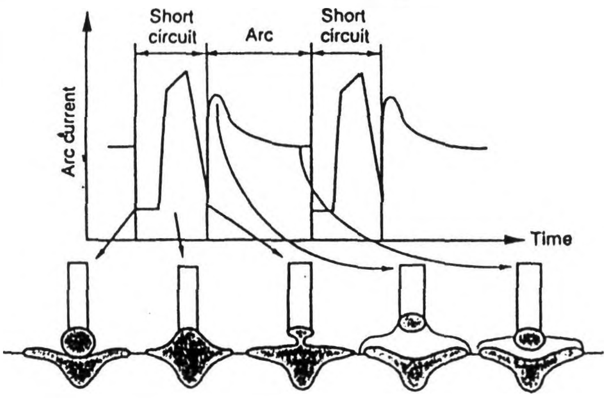


Fig 8 : A typical current waveform control in short curcuit transfer.

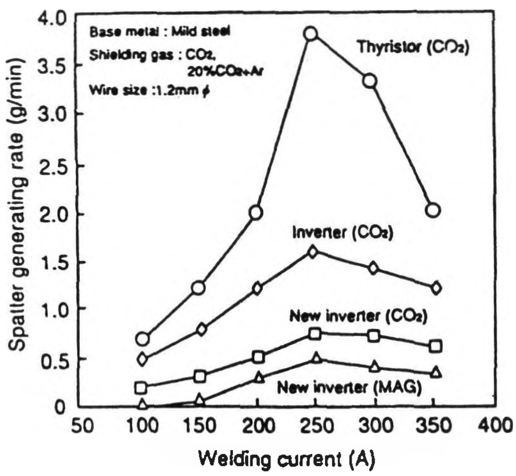


Fig 9 : Comparison in spatter generating rate of various types of welding power supplies.

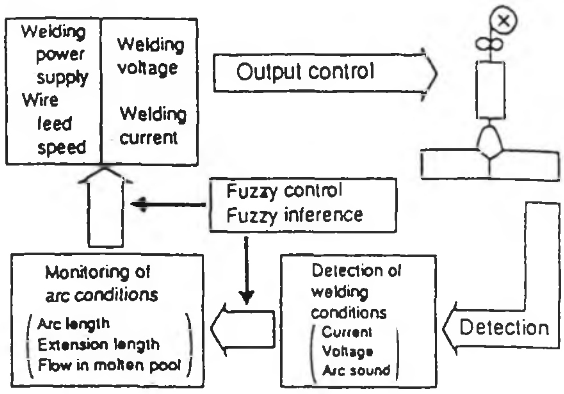


Fig 10 : Conception of automatic output control by fuzzy theory

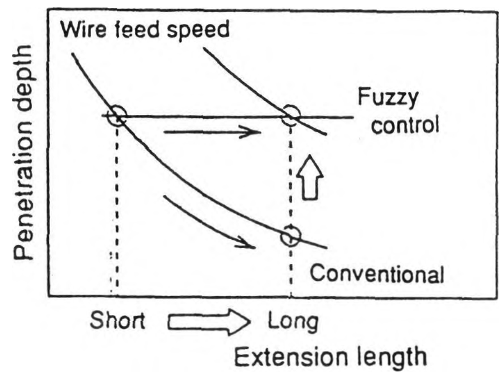


Fig 11 : Effect of fuzzy control on penetration depth

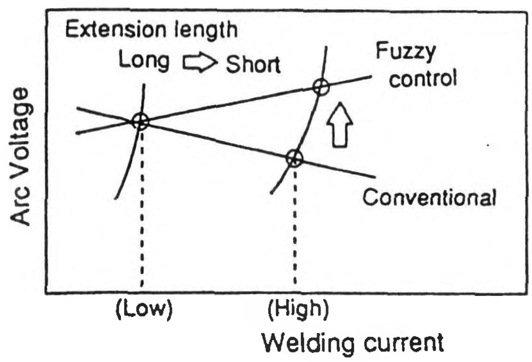


Fig 12 : Effect of fuzzy control on arc suitability

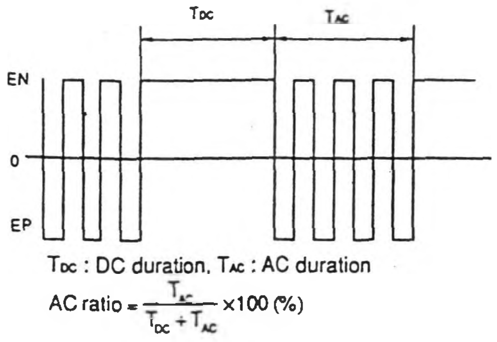


Fig 13 Welding current waveform of AC/DC hybrid type

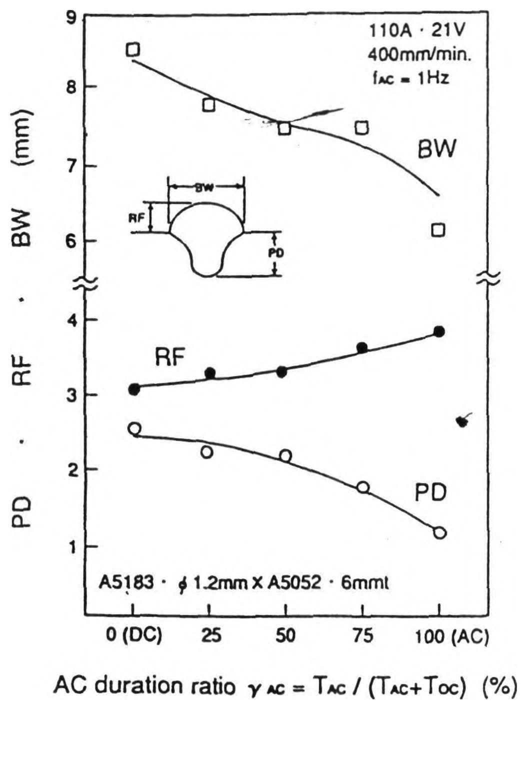


Fig 14 Effect of AC duration ratio on bead parameters

have been transferred gradually to a circuit with higher workability such as the ASIC (Application Specific Integrated Circuit), and more precise micro-processors.

In the control method, the more flexible digital control is progressing because it is indispensable for applying fuzzy control to a welding power supply.

Various Types of Arc Welding Power System

Figure 7 shows the present application of inverter controlled power supply to various kinds of arc welding processes. In the figure the control of output current is classified into AC, DC and their hybrid types.

Current waveform control in short arc welding

Figure 8 shows an example of controlled waveform of the welding current in short arc welding. The current is decreased immediately after detecting a bridge of wire metal and weld pool, which results in soft bridging. After that, the current is increased to excite the pinch effect and then is reduced again before detaching wire metal from the pool and restriking arc.

When the arc restrikes, V-I characteristics of power supply are adjusted to an appropriate one to promote the stability and regularity of droplet formation and arc length. Figure 9 shows the effect of waveform control on spatter production during welding. The newly developed power supply mentioned above can reduce spatter production remarkably.

Fuzzy controlled GMA welding process

Figure 10 shows the concept of fuzzy controlled welding power system. A skilled welder steadily adjusts the output parameter (output voltage

Item / Subjects	Stage	Conventional Technology	Future Trend
High Power factor	Input	Condenser Input Smoothing	Switching Mode Rectifier
Low EMI	Inverter	Hard Switching PWM Converter	· Soft Switching PWM Converter · Resonant Converter
	Rectifier	Fast Recovery Diode	Soft Recovery Diode
High speed control Smaller size	Inverter	· Thyristor · B J T	· MOSFET · IGBT · Mos Gate Thyristor

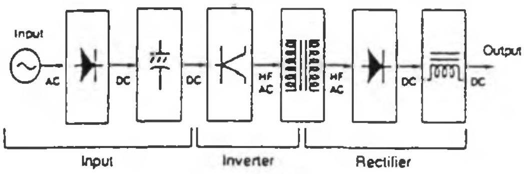


Fig 15 The future trend of inverter techonology

and wire feed speed) through observing the changes in arc length, wire extension, arc and weld pool behaviours, arc sound and so on. New welding power systems based on the above concept have been developed, aiming to consider to knowledge of a skilled welder and controlling the output parameter of power supply.

Figure 11 shows an example of fuzzy control of the wire feed rate. With a conventional power supply, when the extension length of wire increases, the welding current decreases, and consequently the penetration depth decreases. However, by detecting the change in extension length with fuzzy inference and controlling the wire feed speed, the depth of weld pool can be held constant[4])

Figure 12 shows fuzzy control of output voltage. With a conventional power supply, the decrease in extension length causes the increase in welding current and decrease in arc length. With fuzzy control of output voltage, arc length can be kept constant[5])

AC/DC hybrid type power supply

Figure 13 shows a schematic diagram of the welding current waveform of a typical AC/DC hybrid type inverter power supply. Figure 14 shows the effect of AC duration ratio (which is shown in Fig. 13) on the changes in penetration depth, weld reinforcement, and bead width in the welding of aluminium alloy. Very frequent adjustment of this AC duration ratio makes possible the control of weld bead parameters[6]).

Future Trends

Figure 15 summarizes the future trends of inverter technology of welding power systems. The reduction of electromagnetic emmission is particularly an urgent and important issue to be solved. Related to this problem, a resonance type inverter might be developed.

On the other hand, demand for developing welding systems that allow even an inexperienced welder to weld easily will grow, accompanied by the need for improved automatization of welding operations.

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