

# Сварка, родственные процессы и технологии Welding and related processes

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## A HIGH POWER GENERATOR OF GAS METAL ARC WELDING – SPRAY TRANSFER MODE

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**Abstract.** A high-power generator was designed for gas metal arc welding – spray transfer mode. The switching frequency of the H-bridge inverter was fixed at 30 kHz. The inverter unit consisted of four transistor modules (insulated gate bipolar transistor, IGBT) of the MG12200D-BA1MM N-channel type. The high level of the gate-emitter control pulses was 15 V, and the low level of the gate-emitter control pulses was 0 V. The generator had three basic operating points: the first point was at an output current of 150 A with a pulse width of 10  $\mu$ s (duty cycle 30 %), the second point was at an output current of 200 A with a pulse width of 13  $\mu$ s (duty cycle 40 %), and the third operating point was at an output current of 250 A with a pulse width of 17  $\mu$ s (duty cycle 50 %). The wires (0.035 inch ER70S7, 0.035 inch ER70S7, 0.035 inch ER70S7) were used as the electrodes for the output currents of 150, 200, 250 A respectively. A coil (Ls) of 10  $\mu$ H and a variable resistor (Rs) of 10  $\Omega$  were connected in series to limit the output current of the generator.

**Keywords:** gas metal arc welding, spray transfer mode, H-bridge inverter, IGBT transistors

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## ГЕНЕРАТОР ВЫСОКОЙ МОЩНОСТИ ДЛЯ СВАРКИ МЕТАЛЛИЧЕСКИМ ЭЛЕКТРОДОМ В ГАЗОВОЙ СРЕДЕ – РЕЖИМ ПЕРЕНОСА СТРУЙНЫМ ТОКОМ

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**Аннотация.** Разработан генератор высокой мощности для сварки металлическим электродом в газовой среде – режим переноса струйным током. Частота коммутации инвертора H-bridge была зафиксирована на уровне 30 кГц. Блок инвертора состоял из четырех транзисторных модулей (биполярный транзистор с изолированным затвором, IGBT) типа MG12200D-BA1MM N-канального типа. Высокий уровень управляющих импульсов затвор-эмиттер составлял 15 В, а низкий уровень управляющих импульсов затвор-эмиттер составлял 0 В. Генератор имел три основные рабочие точки: первая точка была при выходном токе 150 А с шириной импульса 10 мкс (скважность 30 %), вторая точка была при выходном токе 200 А с шириной импульса 13 мкс (скважность 40 %), а третья рабочая точка была при выходном токе 250 А с шириной импульса 17 мкс (скважность 50 %). Провода (0,035 дюйма ER70S7, 0,035 дюйма ER70S7, 0,035 дюйма ER70S7) использовались в качестве электродов для выходных токов 150, 200, 250 А соответственно. Катушка (Ls) 10 мкГн и переменный резистор (Rs) 10 Ом были соединены последовательно для ограничения выходного тока генератора.

**Ключевые слова:** дуговая сварка металлическим электродом в среде защитного газа, режим струйного переноса, инвертор с H-мостовой схемой, IGBT-транзисторы

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### Introduction

The gas metal arc welding (GMAW) process uses four basic modes to transfer metal from the electrode to the work piece. Each mode of transfer depends on the welding process, the welding power supply, and the consumable, and each has its own distinct characteristics and applications. Several variables dictate the type of transfer you use, including the amount and type of welding current, the electrode chemistry, electrode surface, electrode diameter, shielding gas, and the contact tip-to-work distance.

### Short-Circuit Transfer Welding

In short-circuit transfer, the electrode touches the work and short circuits, causing the metal to transfer as a result of the short. This happens at a rate of 20 to more than 200 times per second.

The advantage of the short-circuit transfer is its low energy. This method is normally used on thin material 1/4 inch or less, and for root passes on pipe with no backing. It can be used to weld in all positions. The most common shielding gas for the short-circuit transfer mode for carbon steel electrodes is 75 % Ar/25 % CO<sub>2</sub>. Numerous three-part shielding gas mixes are also available for carbon steel and stainless steel for this mode of transfer.

### Globular Transfer Welding

Globular transfer means the weld metal transfers across the arc in large droplets, usually larger than the diameter of the electrode being used. This mode of transfer generally is used on carbon steel only and uses 100 percent CO<sub>2</sub> shielding gas. The method typically is used to weld in the flat and horizontal positions because the droplet size is large and would be more difficult to control if used in the vertical and overhead positions compared to the short-circuit arc transfer.

### Pulse-Spray Transfer Welding

In the pulse-spray transfer mode, the power supply cycles between a high spray transfer current and a low background current. This allows for super cooling of the weld pool during the background cycle, making it slightly different than a true spray transfer. Ideally, in each cycle one droplet transfers from the electrode to the weld pool. Because of the low background current, this mode of transfer can be used to weld out of position on thick sections with higher energy than the short-circuit transfer, thus producing a higher average current and improved

side-wall fusion. Additionally, it can be used to lower heat input and reduce distortion when high travel speeds are not needed or cannot be achieved because of equipment or throughput limitations.

### Spray Transfer Welding

Spray transfer is named for the spray of tiny molten droplets across the arc, similar to spray coming out of a garden hose when the opening is restricted. Spray transfer usually is smaller than the diameter of the wire and uses relatively high voltage and wire feed speeds or amperage. Unlike short-circuit transfer, once the arc is established, it is on at all times. This method produces very little spatter and is most often used on thick metals in the flat and horizontal positions.

The major factor in choosing a carbon steel electrode is sometimes the amount of silicate islands that remain on the weld bead surface. This is especially the case if it needs to minimize post weld cleaning time or if the finished product will be painted. For this reason, it is better to choose an ER70S-3, ER70S-4, or ER70S-7 electrode [1, 2].

This paper has only focused on spray transfer welding.

### 1. Experimental Procedure

The welding machine consists of a three-phase voltage source (220 V, 50 Hz), a full bridge rectifier unit, a low-pass filter (LPF), a H-bridge inverter unit [3, 4], and finally a load unit with a current limiter (Ls, Rs) as shown in the block diagram (Fig. 1) and in the schematic circuit (Fig. 2).

Fig. 1 shows the block diagram of the three-phase welding machine.

Fig. 2 shows the schematic circuit of the three-phase welding machine.

Fig. 3 shows Gate-Emitter voltage of the IGBT transistor.

Fig. 4 shows the equivalent circuit of the three-phase welding machine.

A H-bridge inverter unit consists of four transistor modules (Insulated Gate Bipolar Transistor, IGBT) type MG12200D-BA1MM channel N. Diodes D7, D8, D9, D10 in the inverter unit are built-in diodes.

All modules (Q1, Q2, Q3, Q4) in the inverter work as switches (on-off), Switching frequency is 30 kHz, Maximum duty cycle of the Gate-Emitter square signal is 50 %. Gate-Emitter voltage of the module is 15 V. Shielding Gas 95 % Ar/5 % O<sub>2</sub>.

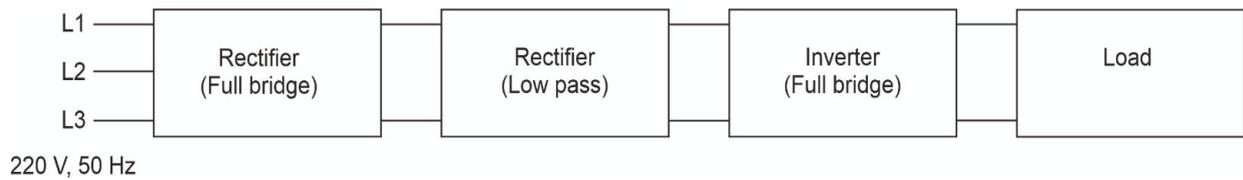


Fig. 1. Welding machine block diagram

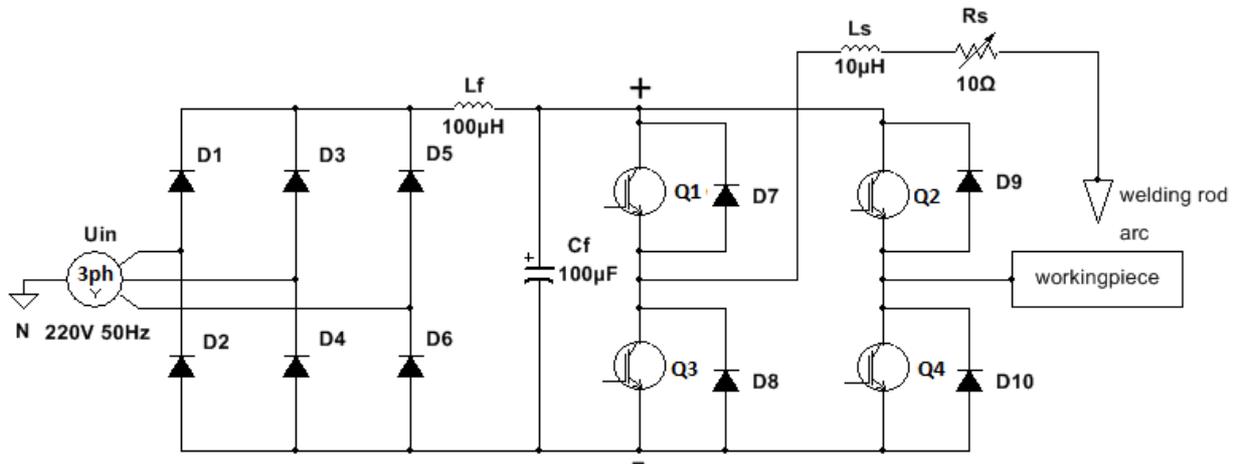


Fig. 2. Welding schematic circuit

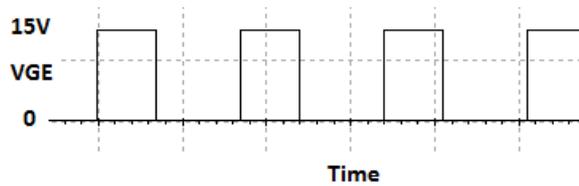


Fig. 3. Gate-Emitter square control signal

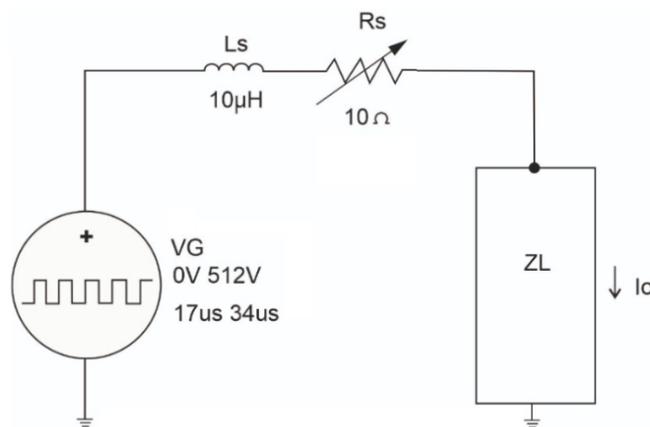


Fig. 4. Equivalent circuit

Table 1 shows the main technical parameters of the module MG12200D-BA1MM [5].

The electric discharge regimes of plasma are dark discharge, glow discharge, and arc discharge (Fig. 4). Working regime of welding machine is arc discharge (Thermal arc) as shown in Fig. 5. In this regime (Thermal arc)

the current is directly proportional to the voltage.

The thermal arc temperature can range from around 5500 °F (3000 °C) to above 36,000 °F (20,000 °C) [6].

Fig. 6 shows the Spry GMAW drop transfer mode. The CTWD (contact tip-to-work piece distance) was 16 mm in all measurements.

Table 1

Technical parameters of the module MG12200D-BA1MM

The presence of a built-in diode	YES
Maximum Collector-Emitter voltage, V	1200
Maximum DC current of the collector at 25 °C, A	300
Maximum Gate-Emitter voltage, V	20
Maximum Gate-Emitter threshold voltage, V	7
Collector-Emitter saturation voltage, V	1.8
Maximum Collector power dissipation, W	1400
Rise time (tr), ns	60
Maximum junction temperature (Tj), °C	+150
Collector capacity, pF	1040

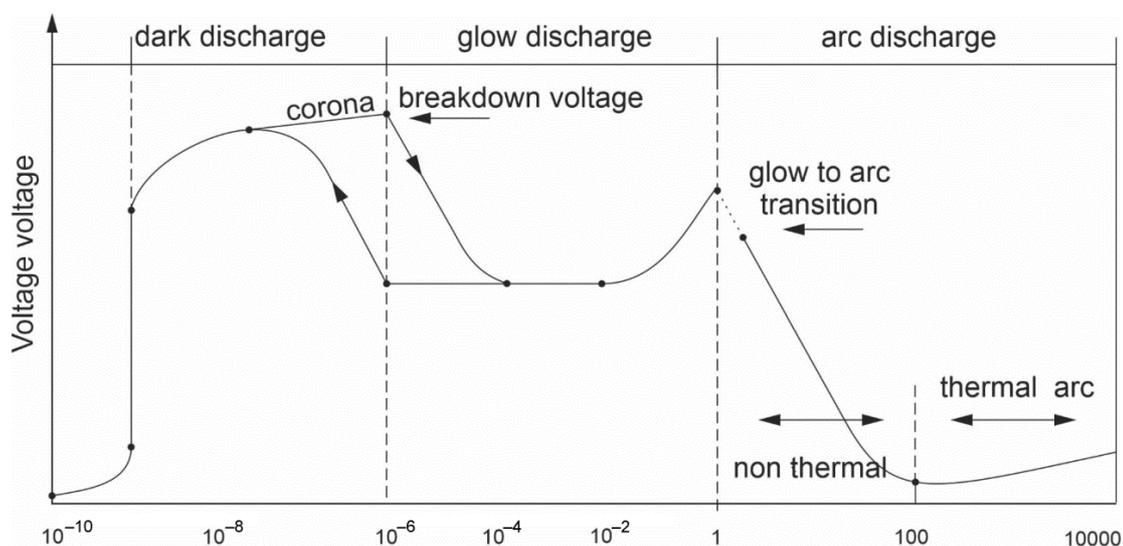


Fig. 5. Electric discharge regimes

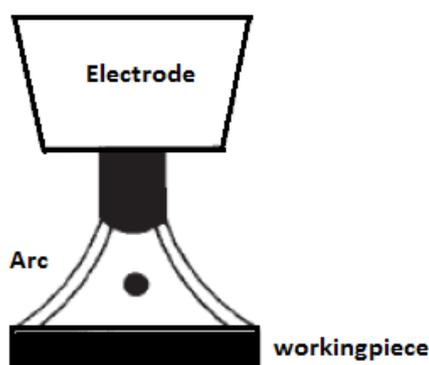


Fig. 6. Spry GMAW drop transfer mode

## 2. Results

ER70S7 is a general purpose GMAW wire suitable for many carbon steel welding applications but with substantially greater manganese provides slightly better wetting and weld appearance with slightly higher tensile and yield strengths as well.

Table 2 shows the technical parameters of the Spry GMAW.

Fig. 7 shows three basic operating points: the first point was 150 A at a 10 μs pulse width using a 0.035-inch ER70S7 wire [7], the second was 200 A at a 13 μs pulse width (0.045-inch ER70S7 wire), and the third was 250 A at a 17 μs pulse width (0.062-inch ER70S7 wire). The range of the average load current (I<sub>o</sub>) was 150–250 A.

Table 2

Technical parameters of the Spry GMAW

f, kHz	Duty cycle of the Gate-Emitter signal	I <sub>o</sub> , A	Shielding gas	Gas flow, l/min	CTWD, mm	Electrode	Wire diameter, inch
30	30 %	150	95 % Ar 5 % O <sub>2</sub>	15	16	ER70S	0.035
30	40 %	200	95 % Ar 5 % O <sub>2</sub>	15	16	ER70S	0.045
30	50 %	250	95 % Ar 5 % O <sub>2</sub>	15	16	ER70S	0.062

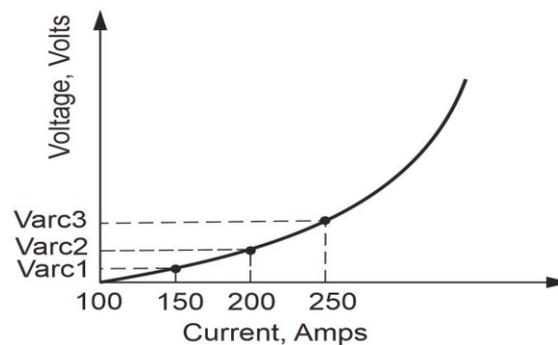


Fig. 7. Electric discharge, Thermal arc

### Conclusion

The paper has presented an experimental investigation about the welding machine operating in the GMAW considering spray mode because spray transfer achieves greater productivity over globular and short-circuiting transfers that use lower currents and wire feed, increasing the wire feed and voltage to achieve spray transfer generates higher deposition rates. Spray transfer had no spatter, good wash, good deposition, good bead appearance. In other hand

spray transfer had a very hot arc, flat and horizontal only, limited penetration, couldn't weld thin materials, minor defects like improper fusion.

Droplet size was much smaller than the wire diameter, a mix of 95 % Ar 5 % O<sub>2</sub> gas was used as an inert gas. The welding machine had three operating points in spray mode the first point was 150 A at a 10 μs pulse width, the second was 200 A at a 13 μs pulse width, and the third point was 250 A at a 17 μs pulse width.

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