Key Engineering Materials
ISSN: 1662-9795, Vols. 291-292, pp 567-572
doi:10.4028/www.scientific.net/KEM.291-292.567

Online: 2005-08-15

Research on Highly Efficient EDM Pulse Power Supply and Its Experiments

Y. K. Wang[1], B. Y. Song [1] and W. S. Zhao [2]

[1] Nontraditional Machining Institute, Harbin Institute of Technology, Harbin 150001, China

[2] School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai 200030, China

Keywords: EDM Pulse Power Supply, Pulse Width Modulation, Power Factor Correction, High Efficiency

Abstract. Their efficiency and their power factor of conventional independent electrical discharge machining (EDM) pulse power supplies with the current-limiting-resistor circuit is so low that they do not meet the need of advanced EDM technologies. The design of highly efficient EDM pulse power supply based on switching circuit pulse width modulation current closed-loop principle has been initiated. It is composed of such three stages as a single-phase active power factor correction preregulator, a full-bridge phase shift resonant converter based on machining current closed-loop control and a pulse generator based on machining sequence control. Therefore, the efficiency of the new system is considerably increased to about 70%, its weight and size is decreased much. Its power factor is a great deal increased to about 0.95. Experiment results have demonstrated that the highly efficient EDM pulse power supply is capable of low electrode wear, high speed, stable machining.

Introduction

Till now conventional independent EDM pulse power supplies whose efficiency is lower than 30% are widely equipped with EDM machines [1,2]. Their undesirable efficiency is due to their circuit structure which consists of a DC power supply, a power device, a current-limiting resistor and a spark gap between an electrode and a work-piece connected in series (Fig.1). The current-limiting resistor divides at least 5/8 of DC power supply output voltage. Hence, it accounts for about 70% output power from the DC power supply which can not be used for discharge machining. The conventional independent pulse power supplies are large because they require a large DC power supply, large high-power resistors, large heat-dissipating fans and heat-dissipating space. So many branches have to be parallel to increase peak machining current. In addition, what is increasingly serious is that the power factor of conventional independent EDM pulse power supplies is so low that they do not meet the need of modern power supply criterions since there are not power factor correctors inside them.

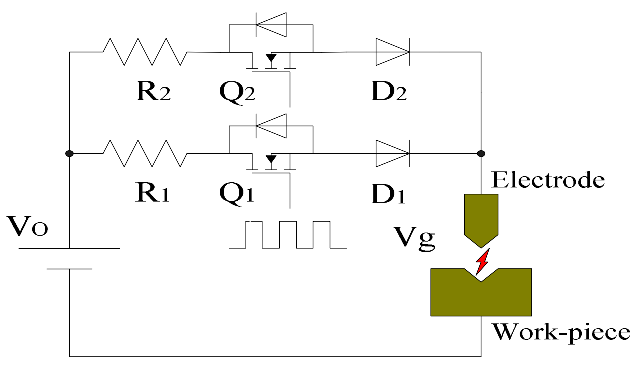


Fig.1 The diagram of conventional EDM pulse power supplies

The disadvantages of conventional independent EDM pulse power supplies in low power efficiency and lower power factor seriously hinder the development of advanced EDM technologies.

Energy-saving EDM pulse power supplies with new types of main circuits and machining current control strategies have been replacing conventional independent EDM pulse power supplies [3-6]. The two aspects of energy-saving EDM pulse power supplies need still been improved, the low power factor and the machining current with a tail. Their AC input rectifiers with a diode bridge and a capacitor result in their low power factor. All energy-saving EDM pulse power supplies are based on highly efficient switching circuits, in which the inductor is connected with the gap in series. The release of the energy stored in the inductor through the gap while the power devices are switched off during pulse interval is responsible for their machining current with a tail. The machining current with a tail causes easily arcs. Sometimes the surface of the work-pieces is burned fatally due to the arcs. The presented highly efficient EDM pulse power supply with the three stages aims at increasing the power factor and the efficiency and eliminating the tail of machining current.

Experimental Prototype

The design of highly efficient EDM pulse power supply has been initiated (Fig.2), in which an inductor is substituted for the current-limiting resistor. It is composed of three stages connected in series, which are all typical circuit topologies. The first stage is a single-phase active power factor corrector so that its power factor is increased considerably. The second stage is a full-bridge phase-shift resonant converter based on current closed-loop to control machining current. Because of this, its switching frequency is up to 100 kHz. The higher switching frequency leads to a great increase in system response speed and a great reduction in weight and size. Consequently, based on its own current closed-loop control, the prototype has an ability to adjust its output machining current promptly to keep machining current constant when AC input and gap voltage fluctuate, and even if the gap is a short circuit. The constant machining current is the reason for the better surface quality. In the contrast, the conventional pulse power supply has no ability to keep machining current constant when AC input and gap voltage fluctuate.

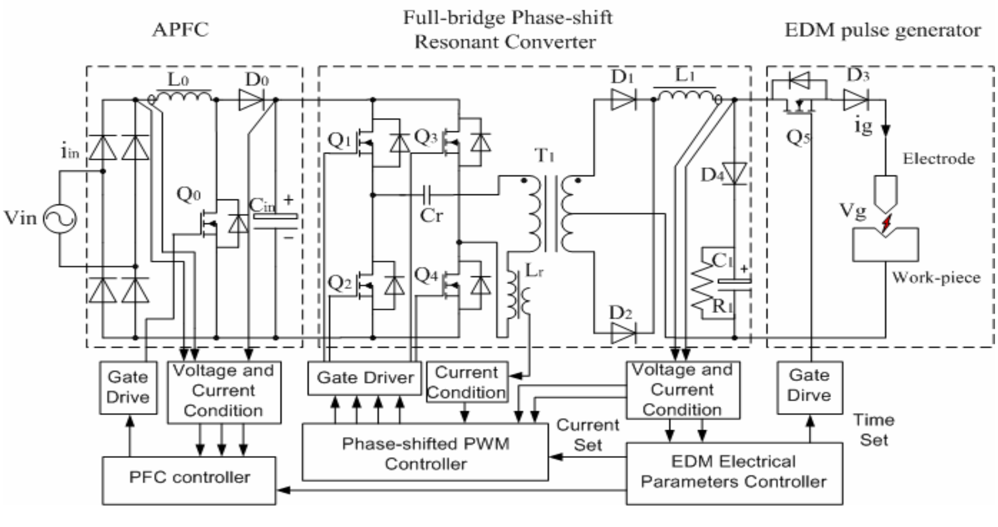


Fig.2 The diagram of the highly efficient EDM pulse power supply

The third stage is the power device Q_5, the diode D_3 and the gap connected in series to control discharge machining phase conversion. The power device Q_5 is used to control machining sequence. It is switched on from the beginning of ignition delay time to the end of discharge duration. When it is switched off during pulse interval, it prevents machining current from traveling to the sparkle gap immediately. As a result, the output machining current of the prototype is a pulse without a tail. That the power device Q_5 is used to cut out connecting electrical connection between the power supply and the gap is good for the dielectric fluid, which is the same as the conventional independent pulse power supply. Diodes D_3 is used to prevent reverse current traveling from the high voltage circuit to its own.

The prototype is capable of producing impulse current with peak current, discharge duration and pulse interval adjusted respectively. The amplitude of the peak current is dependent upon the reference of current closed-loop of the second stage. The on/off of the power device Q_5 leads to alternate operation of the two machining phases, discharge duration and pulse interval. The reference of the current closed-loop, the on/off period and communication with the host-computer of the EDM machine are all dependent upon the electrical parameter controller, a low-cost embedded microprocessor.

All the above three stages are highly efficient switching circuits. Therefore, the prototype is highly efficient.

Experiments and Power Factor Tests

Experimental Condition. The experimental prototype is installed in the EDM machine instead of its own conventional independent pulse power supply. The rest of the EDM machine, such as its mechanism, its server subsystem and its dielectric fluid cycling subsystem, is still used to try a performance experiment of the prototype. The machining parameters are shown in Table 1

Table 1 the machining parameters

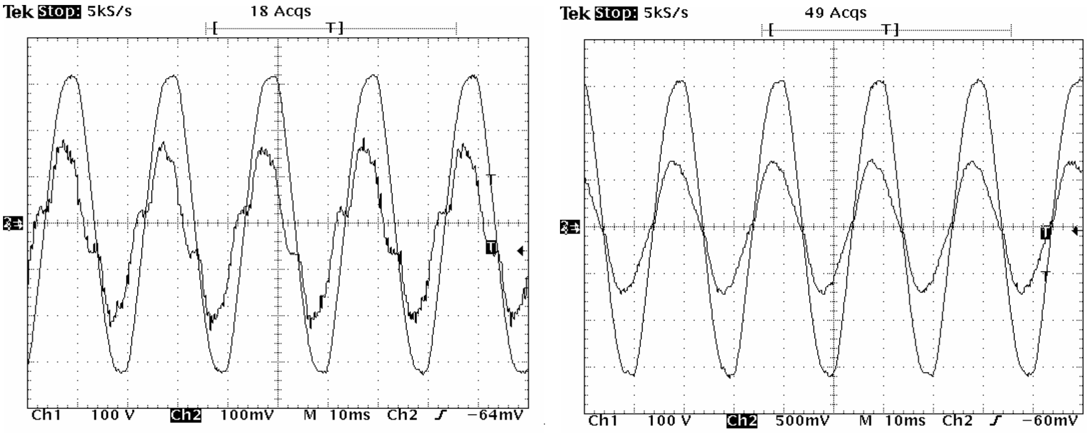
Parameter	data
discharge duration ton	400μs
pulse interval toff	100μs
high voltage	250V
up-down height	4mm
machining duration	4s
server reference voltage	40V
flushing	no
the work-piece	5Ge15
the electrode	copper, 20*20mm

Power Factor Test. A digital electrical parameter detector is connected between AC input and the experimental prototype to test such electrical parameters as power factor and total harmonic distortion (Table 2). At the same time, an oscilloscope is used to monitor AC input voltage and current (Fig.3). The AC input current is transformed with a current sensor.

Table 2 Electrical parameters test results of the experimental prototype

Peak current (A)	AC input voltage (V)	AC input current (A)	Output power (W)	Power Factor	AC input frequency	Total Harmonic Distortion (%)
10	236.2	1.192	248	0.88	50	22.6%
15	235.4	2.286	511	0.95	50	14.5%
20	234.3	3.809	866	0.97	50	10.3%
25	231.7	4.819	1090	0.96	50	9.5%

Table 2 and Fig.3 show that the bigger the output peak current of the experimental prototype is, the bigger its power factor is, and the smaller its input total harmonic distortion is. Its power factor is a little above 0.95 as long as its output peak current is bigger than 15A. Its input total harmonic distortion is less than 10% when its output peak current is more than 25A.

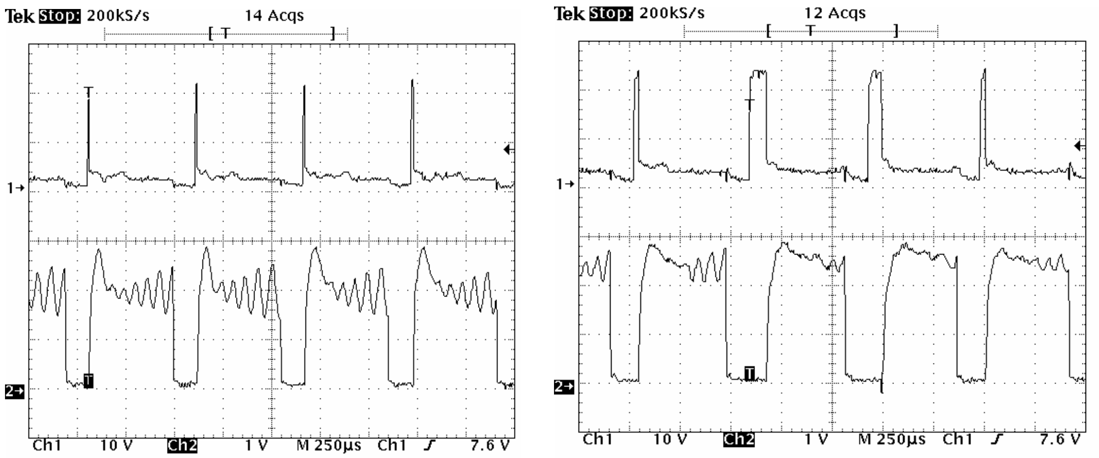


Ch1：AC input voltage, 100V/div
Ch2：AC input current，1A/div
a. peak machining current 10A

Ch1：input voltage, 100V/div
Ch2：input current，5A/div
b. peak machining current 25A

Fig.3 Input AC voltage and current of the experimental prototype

Output characteristics. The gap voltage and machining current are monitored by an oscilloscope during the course of sparkle discharge on the EDM machine installed the prototype. The waveforms of the gap characteristics of the machine installed the prototype (Fig.4), which are distinguished by such three phases as ignition delay time, discharge duration and pulse interval, are quite the same as those of the machine installed the conventional independent pulse power supply.

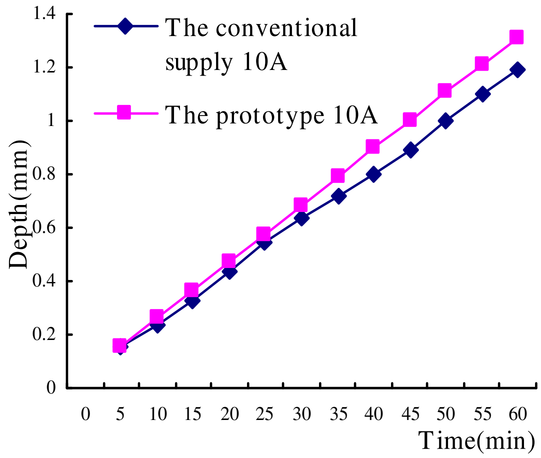


Ch1：gap voltage, 100V/div
Ch2：machining current，10A/div
a. peak machining current 20A

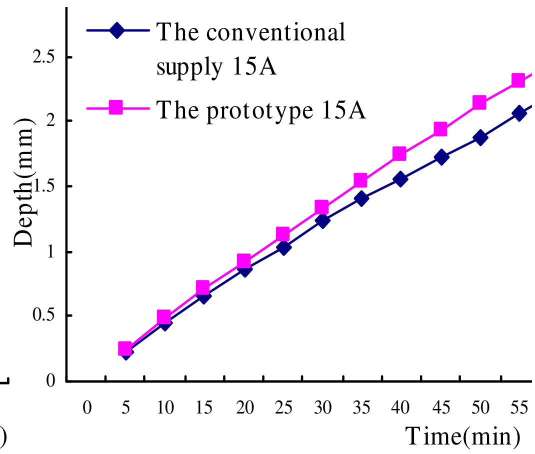
Ch1：gap voltage, 100V/div
Ch2：machining current，10A/div
b. peak machining current 25A

Fig.4 The gap waveform of the EDM machine installed the prototype

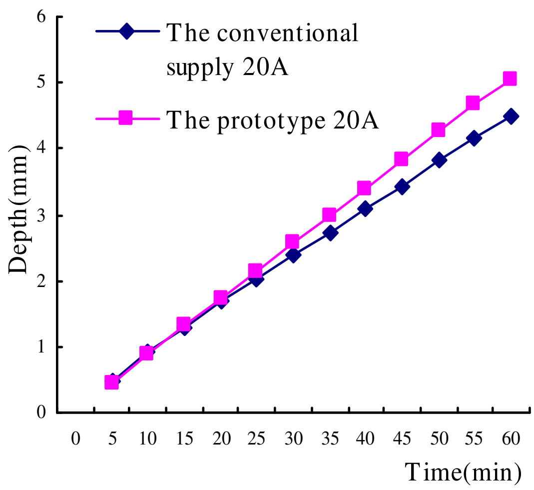
Performance experiments. The comparative experiments are conducted using the EDM machine installed the prototype and the own conventional pulse power supply respectively to verify the performance of the prototype. The same machining parameters are shown in Table 1. The machining depth is noted every 5 minutes during the two group comparative experiments with peak current 10A, 15A, 20A and 25A respectively (Fig.5). The prototype and the own conventional pulse power supply are equally matched in terms of electrode wear and material removal rate.



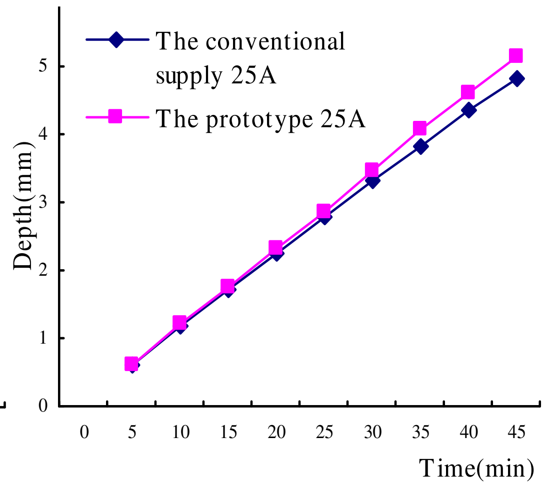
a. peak machining current 10A



b. peak machining current 15A



c. peak machinig current 20A



d. peak machining current 25A

Fig.5 Comparative experiments of two pulse generators

Conclusions

The research on green energy-saving EDM pulse power supply has become increasingly important and urgent in the field of EDM. A new application for resonant converter and power factor corrector in EDM pulse power supply has been proposed.

1. The single-phase active power factor corrector contributes to a great increase in its power factor. Its power factor is a great deal increased to about 0.95.

2. The full-bridge phase shift resonant converter based on machining current closed-loop control contributes to the great increase in its efficiency and the great reduction of its weight and size. The efficiency of the new system is considerably increased to about 70%.

3. The pulse generator contributes to the pulse machining current without a tail.

The system is nearly the same as conventional independent EDM pulse power supply in their output voltage and current characteristics during such three circulating phases as ignition delay time, discharge duration and pulse interval. First experiments have been carried out on an EDM system and the prototype has been proved to be well suited to fulfill the EDM requirements on low electrode wear, high speed, stable machining.

Acknowledgment

The research was supported by Grant No. 01112110029 from Science and Technology Development Projects of Harbin in China, and by Grant No.E0205 from Natural Science Foundation of Heilongjiang Province in China.

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Advances in Abrasive Technology VIII
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