MICRO-ENERGY PULSE POWER SUPPLY WITH NANOSECOND PULSE WIDTH FOR EDM

Fang Ji[1], Yong-bin Zhang[2], Guang-min Liu[3] and Jian-guo He[3]
Institute of Machinery Manufacturing Technology, Mianshan Road 64#, Mianyang, Sichuan, 621900, China

Keywords: Electrical discharging machining, Micro-energy, Pulse power supply.

Abstract: Micro-energy pulse power supply is required in order to manufacture workpiece with micro-nano meter precision in electrical discharging machining (EDM). The paper analyzes two kinds of typical pulse power supplies and their important elements. Afterwards, another one kind of new micro-energy pulse power supply is presented. The experiments and analysis have been done for the new power supply. Accordingly, some important circuits have been modified, for example, the discharging circuit and driving circuit for the metallic oxide semiconductor field effect transistor (MOSFET). The modification improves the performance of the new pulse power supply so that the pulse width of the new pulse power supply could be less than that of the typical pulse power supply for electrical discharging machining. The least pulse width is obtained. It is less than 60 nanoseconds and its least energy of single pulse is less than 10-6 joule. Subsequently, the pulse waveform is adjusted considering the impedance matching of the discharging circuit in order that the pulse waveform has no oscillation and no overshot. The adjusted pulse waveform is good to detect discharging status correctly and sensitively.

1 INTRODUCTION

The independent pulse power supply and RC pulse power supply are two typical pulse power supplies applied in electrical discharging machining. The independent pulse power supply has the advantages: discharging frequency may be high, pulse parameters may be adjustable, self-adapted control may be easy. But it still has the disadvantages: maintaining voltage limits the energy of single pulse to decrease, the energy of single pulse is more than 10^{-7} joule. The disadvantages make independent pulse power supply difficult to manufacture workpiece with micro-nano meter precision. The other typical pulse power supply is RC pulse power supply. It is easy to obtain small energy of 10^{-7} joule of single pulse. But, it is difficult to adjust the pulse parameters. It has no channel to release residual charge between two electrodes. It is not easy to control energy of pulse. Electrical arc discharging happens frequently and the discharging consistency is not good. The researches show that the machining mass in micro-nano meter scale needs a kind of micro-energy pulse power supply. Its pulse parameters must be easy to control and its lowest energy of single pulse must reach 10^{-7} joule.

The independent pulse power supply is shown in Figure.1. The energy of single pulse W_0 is related to instantaneous discharging voltage $u(t)$, instantaneous discharging current $i(t)$ and pulse width T. Their relation may be written as $W_0 = \int_0^T u(t)i(t)dt$. According to the relation, it is obvious that there are three ways to decrease energy of single pulse: decreasing the voltage, decreasing the current or increasing the frequency. However, there exists maintaining voltage which is the least voltage to discharge between electrodes. The discharging voltage must be larger than the maintaining voltage. It limits the decrease of the discharging voltage. Additionally, the increase of frequency may be restricted by the frequency response of the MOSFET. Therefore, it is difficult to acquire less energy of single pulse for independent pulse power supply and the lowest pulse energy can only reach 10^{-6} joule. The RC pulse power supply is shown in Figure.2. The energy W_{RC} stored in the capacitor may be described as the relation between the capacitance C of capacitor, the capacitance C' of circuit and the discharging voltage U :

Ji F., Zhang Y., Guang-min L. and He J. (2009).
MICRO-ENERGY PULSE POWER SUPPLY WITH NANOSECOND PULSE WIDTH FOR EDM.
In *Proceedings of the 6th International Conference on Informatics in Control, Automation and Robotics - Signal Processing, Systems Modeling and Control*, pages 205-209
DOI: 10.5220/0001966202050209

$W_{RC} = \frac{1}{2}(C + C')U^2$. Hereby, there are two ways to decrease the energy of single pulse: decreasing the capacitance and the voltage. Normally speaking, the first way seems better. But, the capacitance C' usually varies from 100pF to 10000pF in the circuit and it is hard to reduce. Thus, decreasing discharging voltage may be the most important way to reduce the energy of single pulse. The new research shows that the discharging voltage will not be limited by maintaining voltage and may be as low as 7 volts for RC pulse power supply. The minimum energy of single pulse may reach 10^{-7} joule. Whereas, the present RC pulse power supply is difficult to control and residual charge is easy to accumulate between electrodes, which is not good for consistency of machining. The low discharging voltage will brings the discharging distance to be close which is not good to remove the leftover.

At present, there are many researchers who are developing the micro-energy pulse power supply for EDM. The least pulse width is 90 nanoseconds developed by Zhao, but there exists obvious electromagnetic oscillation; The least pulse width is 80 nanoseconds developed by Han, but the width is width of current, not width of voltage. It is well-known that the pulse width of current is less than that of voltage because of the discharging delay. The paper presents one kind of micro-energy pulse power supply which integrates the advantages of both independent pulse power supply and RC pulse power supply. Its least energy of single pulse can reach 10^{-7} joule. It has a special circuit to release residual charge between electrodes.

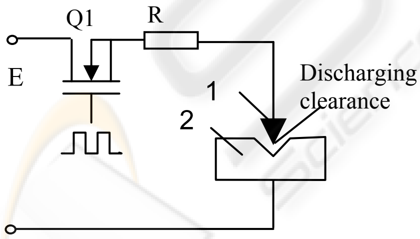

Figure 1: Schematics of independent pulse power supply.

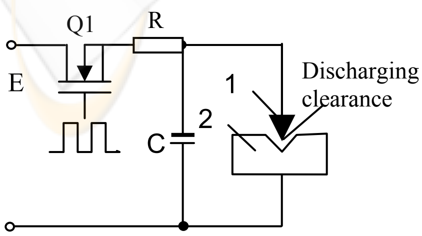

Figure 2: Schematics of typical RC pulse power supply.

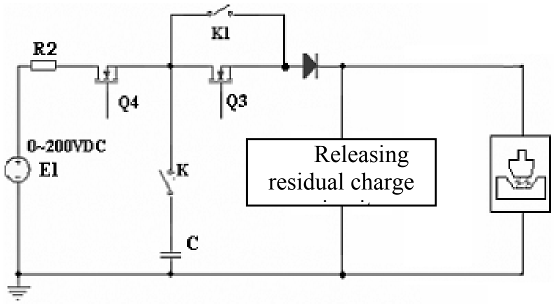

Figure 3: Shematics of micro-energy pulse power supply with nanosecond pulse width.

2 PRINCIPLE OF THE MICRO-ENERGY PULSE POWER SUPPLY

The micro-energy pulse power supply presented in the paper is shown in Figure.3. The current will charge capacitor C through MOSFET Q4 and resistor R2 when the switch K1 is disconnected and the switch K is connected. The energy in capacitor is decided by the charging time and it can influence the machining mass of single pulse. Then, the energy in capacitor will transfer to the discharging clearance between workpiece and tool electrode when Q4 is disconnected and the Q3 is connected. Afterwards, Q3 will be disconnected and the releasing residual charge circuit will remove the residual energy in order to avoid unnecessary discharging between electrodes. At last, the releasing residual charge circuit will be disconnected. The whole work period of single pulse is over and the next period may begin. A programmable logic element is applied in the system circuit to control the MOSFETs. Thus, some logic operations are done by hardware rapidly, which may reduce the delay time and decrease the pulse width. In addition, a special high-speed micro-control unit (MCU) is configured as counter for pulse so that fuzzy control may be done according to the number of pulse. The main elements in the system circuit are high-speed MOSFETs. They can work at high frequency. They influence the minimum energy of single pulse and the machining efficiency of the pulse power supply. However, there exists nonlinearity between gate voltage and source voltage during charging and discharging because of capacitance in MOSFET. Therefore, the internal wastage will increase and the reliability will decrease. This is a disadvantage. But, it can be reduced by high-speed driving circuit for the MOSFET. The driving circuit has instantaneous strong current so that the MOSFET may be connected or disconnected quickly. Thus, the pulse width less than 60 nanoseconds may be obtained.

3 EXPERIMENTS AND ANALYSIS

Some experiments have been done in the paper. Then, analysis and improvements have been given for optimized pulse power supply, for example, the modification of driving circuit, the comparison of MOSFETs, the impedance matching, discharging circuit and detection of discharging status, etc.

3.1 Modification of the Driving Circuit

The system circuit adopts a driving chip with complementary emitter follower which has strong capability to drive gate of MOSFET. Otherwise, the impedance of the driving circuit is low. Thus, the charging and discharging for the gate of MOSFET can be finished quickly. There are four waveforms in Figure.4. They are different because their impedances are not equal. The impedances vary from large to small by the order 1 to 4. It is obvious that decreasing impedance may improve the waveform. The fourth waveform is adopted in the paper. The overshot at rising edge and undershot at falling edge are good for connecting and disconnecting of MOSFET.

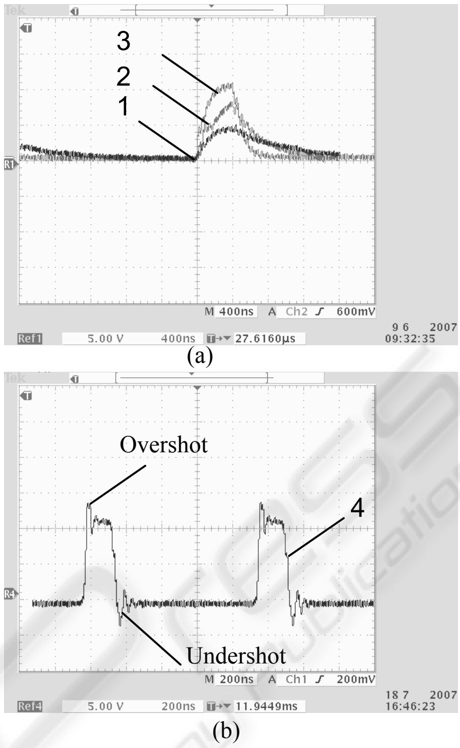

Figure 4: Different waveforms of driving circuit with different impedances. The impedance varies from large to small by the order 1 to 4.

3.2 Comparison of the MOSFET

Comparison experiments of MOSFETs have been done to select the best kind of MOSFET when the parameters of the system circuit are of no difference. Three kinds of MOSFETs are selected for further experiments after some previous experiments. The corresponding waveforms of different MOSFETs are shown in Figure.5. It can be found that there still exist some undershots for the 1st and 2nd waveform. The 3rd waveform is the best one. Hereby, the 3rd MOSFET is fixed for the pulse power supply.

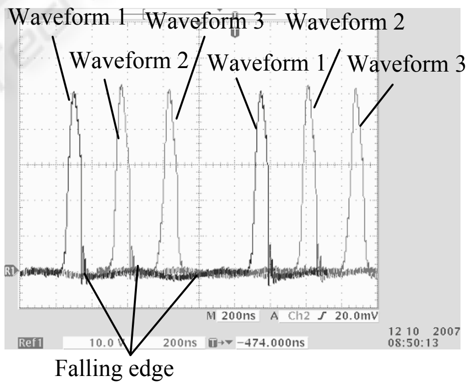

Figure 5: Different waveforms of different MOSFETs.

3.3 Matching of the Impedance

There are two special results during the experiments of pulse power supply: Firstly, the waveform of MOSFET will be different when the voltage is different, even though the electronical elements are all same. It is shown in Figure.6. The overshot will appear at the rising edge with the increase of voltage. The reason is that the rise of voltage results in the rise of varying rate of current. The capacitor will be charged more quickly, which makes overshot at rising edge of voltage. Secondly, the waveform of MOSFET will also be different when electronical element is changed for different machining currents. It is shown in Figure.7. The overshot will appear for some elements. The reason is that the impedances are different for different elements. The less the impedance is, the larger the overshot will be.

However, their falling edges are similar because of the releasing residual charge circuit. Therefore, the impedance must be matched for the optimized waveform and detection accuracy of discharging status.

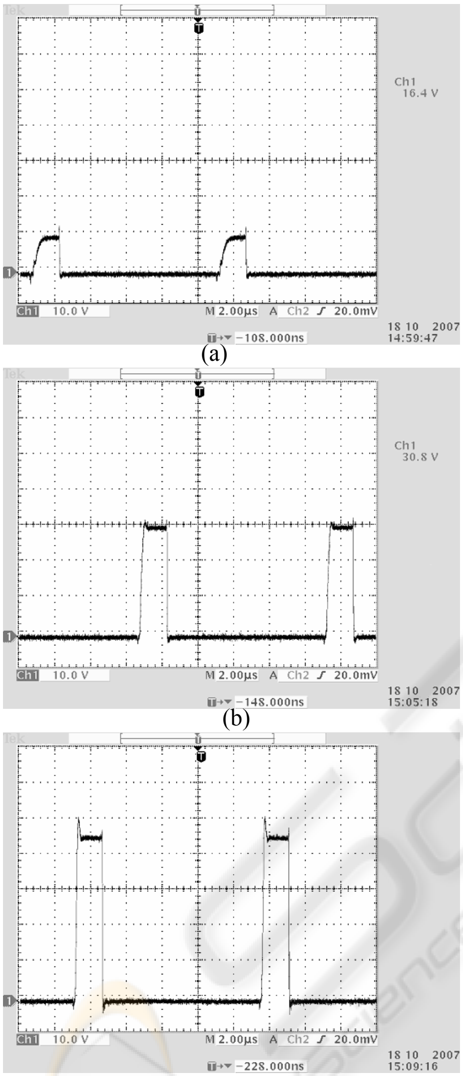

Figure 6: Waveforms with different voltages and same electronical element.

3.4 Discharging Experiment at High Frequency

The least pulse width of the micro-energy pulse power supply described in the paper can be less than 60 nanoseconds after some experiments and optimization above. The discharging experiments

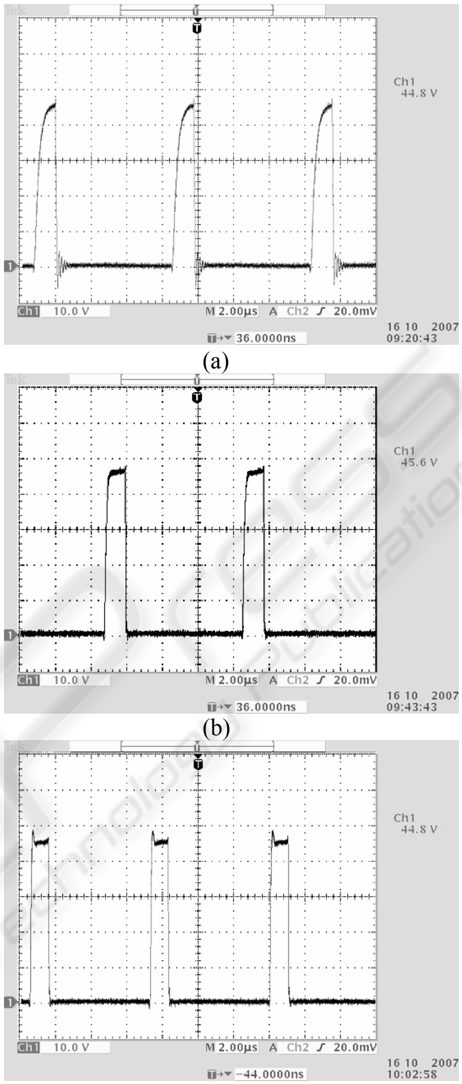

Figure 7: Waveforms with same voltage and different electronical elements.

have been done subsequently. The open waveform and discharging waveform are shown in Figure.8. It is easy to watch the spark between the anode and the cathode during the experiments. There exist some discharging marks on the surface of the workpiece. The energy of single pulse can be calculated by the equation $W_0 = \int_0^T u(t)i(t)dt$ and reaches to 10^{-7} joule.

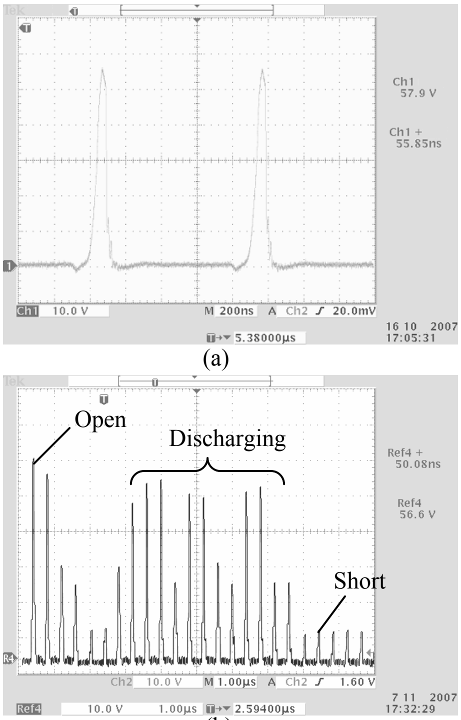

Figure 8: Open waveforms and discharging waveforms of the pulse power supply.

3.5 Detection of Discharging Status

Detection of discharging status is very important in the pulse power supply. Its result will be fed back to the control center. It provides the main information used to adjust the parameters of pulse power supply timely. The corresponding circuit must be modified accurately. But, the signal from discharging clearance is periodic and changed quickly, which will bring variance, even oscillation, to the detection circuit. The signal is shown in Figure.9. Thus, some filters are applied in the circuit. Some noise is limited and the signal is improved evidently. It is shown in Figure.10.

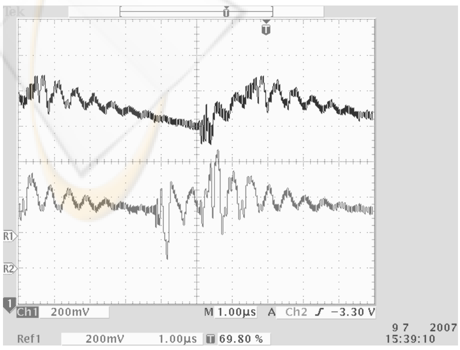

Figure 9: Voltage of open clearance with interference.

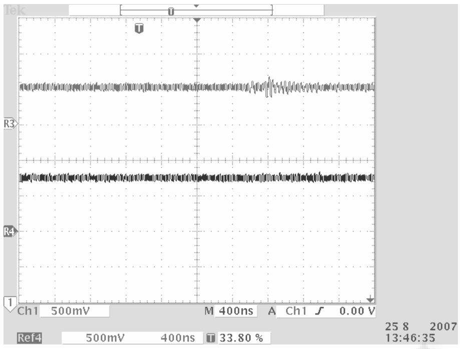

Figure 10: Voltage of open clearance without interference.

4 CONCLUSIONS

The micro-energy pulse power supply is the key part of EDM in micro-nano meter scale. The paper analyzes the characters of two present typical pulse power supplies of EDM, gives the driving circuit consisted of low impedance element and complementary emitter follower. The paper also adds active releasing residual charge circuit, selects the best MOSFET and matches the impedance for different waveforms. At last, optimized waveform is obtained without overshot and undershot. The minimum energy of the pulse power supply reaches 10^{-7} joule and the least pulse width is less than 60 nanoseconds.

REFERENCES

Ao Ming-wu, Zhang Yong, Li Zhi-yong, 2003, Research on a micro-energy pulse power source used by micro-EDM, *Aviation Precision Manufacturing Technology*.

Chi Guan-xin, Di Shi-chun, 2004, Study on key technology for intricate micro parts on MWEDM, *Manufacturing Technology and Machine Tool*.

Y.S. Wong a,., M. Rahmana, H.S. Lima, H. Hanb, N. Ravib, 2003, Investigation of micro-EDM material removal characteristics, *Journal of Materials Processing Technology*.

He Guang-ming, Zhao Wan-sheng, 1999, Research of Nanosecond-class pulse generator, *Electromachining*.

Han Fu-zhu, Chen li, Zhou Xiao-guang, 2005, Foundational research on pulse generator technology in micro-EDM, *Electromachining & Mould*.

Cao Feng-guo s, 2005, *Electro discharge machining technology*, Beijing: Chemical Industry Pres.

Pei Jing-yu, Guo Chang-ning, Deng Qi-lin, 2004, Dual-Channel MOSFET Sub- Microsecond Micro- Energy Pulse Power Source Used in Electrical Discharge Machining, *Journal of Shanghai Jiaotong University*.