Research on Micro-arc Oxidation Power Supply with High and Low Frequency Coupled Pulse

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Abstract. A novel micro-arc oxidation power supply with high and low frequency coupled pulse was presented, which was proposed to improve the performance of the fabricated ceramic coatings. The micro-arc oxidation power supply was composed of the human machine interface, the main control board, the three-phase SCR driving circuit, the main circuit power device and the cooling system. The inputting of parameters and the monitoring of power supply process were realized by HMI. The ARM of main control board was communicated via USB to RS232. The voltage regulating part of the main circuit was driven by three-phase SCR to adjust the voltage value during the micro-arc oxidation process. The load test shows that the power supply was realized the output of coupled pulse, and the coatings was smooth which prepared by coupled pulse.

Keywords: Micro arc oxidation; High and low frequency; Coupled pulse; Full-bridge topologies.

1. Introduction
Micro-arc oxidation[1] (MAO) as a new method of surface treatment, with its advantages of energy saving and environmental protection, has received widespread attention from researchers[2]. The energy provided by the MAO power supply has an influence on the structure and performance of the coatings. Ma yuezhou [3] developed a power system with MAO and electrodeposition, which realized the surface treatment of light metals by MAO. Mei Jianwei et al. [4] designed the digital multi degree-of-freedom MAO power supply which achieved the positive polarity power and negative polarity power by adjusting two sets of thyristors. Yang shiyian [5] developed the flyback MAO power supply which used the fly-back topology to control the current pulse and the secondary energy of the transformer. However, the high-frequency pulses coupled to MAO pulses have not been reported. Using appropriate methods to improve the process of MAO, to solve the problem of low porosity and loose tissue of the loose layer during the growth of the coating, has become a key factor in improving the performance of the coating prepared by MAO.

2. System Structure
The schematic diagram of MAO power supply with high and low frequency coupled pulse was shown in Fig.1(a). The power supply output two sets of pulses, one for the output of MAO pulses (pulse 1), which was the low frequency constant current or constant voltage. The other (pulse 2) was used to output high-frequency pulses during the pulse width. The two-channel pulses were coupled to generate high and low frequency coupled pulses that output to both ends of the work-piece. The waveform of the pulse was shown in Fig.1(b). The main pulse frequency of MAO was 100~1000 Hz, and the high-frequency pulse was 0~40 kHz.
The structure of the MAO power supply with high and low frequency coupled pulse was shown in Fig. 2. The parameters inputting and the monitoring of power supply process were realized by HMI. The ARM of main control board was communicated via USB to RS232 with the HMI. The IGBT drive circuit amplified the signal output from the FPGA, drove the IGBT output pulses to the main circuit. The current and voltage detection was used to closed-loop control. The cooling system was used to control the agitating pump during the MAO.

Figure 2. The structure of the MAO power with high- low frequency coupled pulse

3. Power Hardware

The structure of the main control board was shown in Fig. 3. Its control core consisted of ARM's STM32F103 and FPGA's EP3C25Q240. The STM32F103 was included RS232, the current acquisition ADC, the voltage acquisition ADC, the signal conditioning circuit, and I/O. The EP3C25Q240 was included the DAC output, the three-phase thyristor driving circuit, the DDS pulse generator and the driving circuit. The grouped pulse parameters were transmitted from the STM32F103 to the EP3C25Q240 via SPI and then outputted by DAC. The outputted parameters controlled the three-phase thyristor driving circuit and adjusted the voltage value during MAO. The voltage and current values during the working process were processed by the signal modulating circuit and then transmitted to the current and voltage acquisition ADC channels, respectively. The RS232 was used for the parameter interaction between the main control board and the HMI.

Figure 3. The structure of the main control board
3.1. Current Detection Circuit

The schematic diagram of the current detection circuit was shown in Fig.4. The detection signals were transmitted to the LF353. The LF353 circuit was a non-inverting operational amplifier. Its gain multiple can be adjusted by VR1, VR2, and filtered by capacitor C4 at the same time. The current signal in the STM32 ADC acquisition terminal processed by the LF353 detected the current value which in MAO processing.

![Figure 4. The current detection circuit](image)

3.2. Voltage Detection Circuit

The schematic diagram of the voltage detection circuit was shown in Fig.5. The voltage was divided by resistors R5, R6, and R7. The R7 collected the decayed voltage. The voltage was filtered by filter L1 through the current limit of R8 and R9, and filtered by capacitor C6 at the same time. Also, the voltage was transmitted to the reverse integration circuit composed of LF353. This reverse integration circuit composed of LF353 calculated the collected voltage value. Finally, it was output to the ADC acquisition terminal of STM32F103 to collect the voltage value of the power supply during the MAO processing.

![Figure 5. The voltage detection circuit](image)

3.3. Power Circuit

The main circuit topology structure of the power supply with high and low frequency coupled pulse was shown in Fig.6. The two sets of pulses were regulated by the transformer and rectified by the three-phase thyristor. The MAO adopted the full-bridge topology, the high-frequency pulse was adopted by the buck topology. The SCR full-bridge rectifier circuit composed of SCR1-SCR6, the SCR rectifier circuit composed of SCR7-SCR12 and the controllable full-bridge rectifier circuit composed of SCR13-SCR18, respectively. The three sets of circuits were filtered by capacitor and resistor groups separately. The direct current adjusted the voltage was achieved.
4. Power Software

The software flow of STM32F103 controller was shown in Fig. 7. The system initialization was completed, and the mode settings of the HMI were received, which including MAO processing parameters and high-frequency pulse parameters. Then the controller waited for external start processing. When process starting, the parameters set by the HMI were calculated and transmitted to EP3C25Q240 via SPI. The voltage value of MAO and high-frequency output were adjusted to the set value.

4.1. HMI

The control interface of the power supply was shown in Fig. 8. The HMI was composed of the display part, the parameter setting part, the trend part and the button part. The display section was used to display the real-time parameter values detected by the current and voltage sensors. The parameters in the parameter setting part were used to set various processing parameters in the MAO process.

4.2. Load Test

The waveforms of the key nodes on the group pulse power supply were shown in Fig. 9. The low frequency pulse waveform of MAO pulse was shown in Figure 9 (a). The high frequency pulse waveform was shown in Fig. 9 (b). The coupled pulse was realized which used in micro-arc oxidation function, as shown in Fig. 9 (c). The power supply was realized a stable coupled pulse.

4.3. MAO Test

The surface protrusion and the diameter of micro-pore on MAO coatings prepared by coupled pulse were decreased. The high-frequency pulse coupled to MAO pulse, which generated the high-frequency oscillation effectively promoted the process of MAO, so that the surface quality of the prepared coatings was improved.

5. Conclusion

A novel micro-arc oxidation power supply with high - low frequency coupled pulse was presented.
The high-frequency and low frequency pulse was coupled by three-phase SCR to adjust the voltage value during the MAO process which used the current detection and voltage detection by ARM. The HMI was used to human-machine interface. The load test shows that the power supply was realized the output of coupled pulse, and the coatings was smooth prepared by coupled pulse.

![Waveform of the power](image)

**Figure 9.** Waveform of the power

![Mao coatings prepared before and after coupled pulse](image)

**Figure 10.** Mao coatings prepared before and after coupled pulse

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