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MATLAB Modeling of Component in Electrical Discharge Machining (EDM) Pulses

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Abstract: Electrical Discharge Machining (EDM), is a machining technique for working with conductive materials. During the EDM process, electrical discharge energy is transformed into thermal energy, leading to the erosion of the workpiece. The energy utilized by the EDM process is represented by the time-dependent current, which determines the energy density employed for workpiece erosion. Ideally, during a discharge event, the current pulse should exhibit a square wave shape. However, in practice, EDM circuits often incorporate parasitic components that lead to non-square waveforms or transient currents. In this paper, we describe the simulation of parasitic components using MATLAB, revealing that these components alter the signal waveform and affect the achievement of a square pulse wave in MRR. The presence of parasitic components results in transient current patterns during the discharge phase and, consequently, a reduction in MRR. The implementation of a square wave current, however, enhances the MRR value and increases the efficiency of the EDM process

Keywords: EDM, Pulses, MATLAB, MRR

I. Introduction

Electrical Discharge Machining, commonly referred to as EDM, is a machining technique for working with conductive materials. It involves the utilization of electrical discharges passing through a gap, typically ranging from 10 to 50 micrometers [1-4]. An EDM system is comprised of several essential components, including a power generator, a workpiece positioning system, and a flushing system [1-3].

During the EDM process, electrical discharge energy is transformed into thermal energy, leading to the erosion of the workpiece. The erosion process necessitates very high temperatures to affect the material of the workpiece. The electric discharge plays a crucial role in ensuring the efficient functioning of EDM. Several conditions influence the electric discharge, including current and voltage pulse, pulse duration, and spark gap [1-3]. The energy utilized by the EDM process is represented by the time-dependent current, which determines the energy density employed for workpiece erosion. This effect has implications for parameters like Tool Wear Ratio (TWR), Material Removal Rate (MRR), and other machining characteristics [5][6].

Additionally, the configuration of the electric current pulse can exert an influence on the attributes of the EDM process. Ideally, during a discharge event, the current pulse should exhibit a square wave shape. However, in practice, EDM circuits often incorporate parasitic components that lead to non-square waveforms or transient currents, as illustrated in Figure 1.

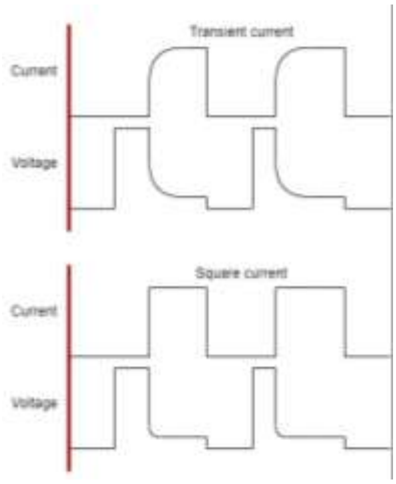


Fig.1. Transient current and square current

Previous researchers have explored the use of square wave pulses in EDM. Tsai et al. [7] studied the impact of current pulse characteristics on EDM performance. Shinohara et al. [8] experimented with various current pulse shapes to assess Material Removal Rate (MRR). Li et al. [9] introduced a power supply with adjustable current pulse shapes, and Wu et al. [10] presented a pulse power generator for controlling different current shapes. In this paper, we describe the simulation of parasitic components using MATLAB, revealing that these components alter the signal waveform and affect the achievement of a square pulse wave in MRR.

2. Research Method

2.1. Model of EDM Pulse

An EDM pulse power generator is employed to examine the current pulse pattern within the EDM process. The EDM pulse power generator is depicted in Figure 2. The current pulse in EDM can be divided into three distinct phases: the initial phase, ignition phase, and discharge phase.

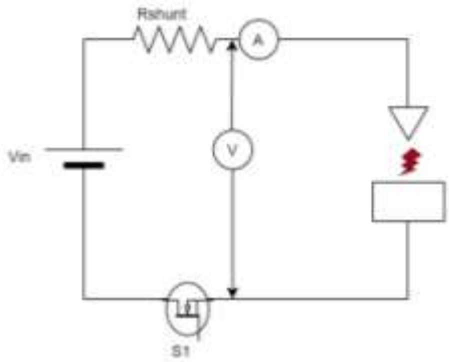


Fig.2. EDM power generator

The initial phase corresponds to the state in which the Metal Oxide Semiconductor Field Effect Transistor (MOSFET) (S1) is in the off position. During this stage, there is no discharge or open circuit, resulting in a gap voltage (v) of zero. The circuit configuration during the initial phase is illustrated in Figure 3.

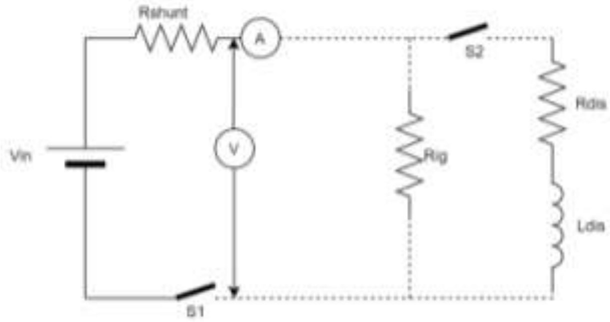


Fig.3. Initial phase

The ignition phase represents the moment when the MOSFET (S1) begins to activate, initiating the establishment of an electric field. In practical terms, during this phase, an electric field is generated, creating an ionized path between the electrode and the workpiece. It's important to note that this phase does not entail discharge; however, the gap voltage remains at a similar level to the power supply voltage. The circuit configuration during the ignition phase is depicted in Figure 4

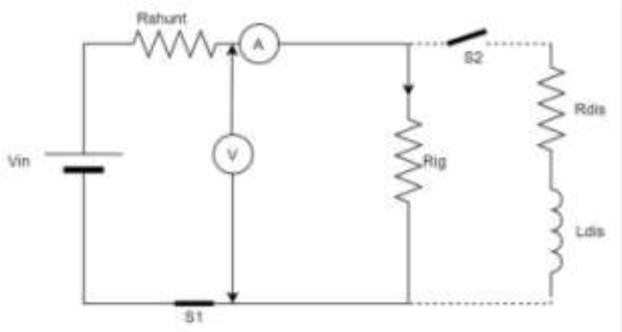


Fig.4. Ignition phase

The discharge phase is characterized by the activation of switch S2. In practical terms, a plasma channel forms due to dielectric ionization. Current discharge takes place within the circuits, leading to a voltage drop and the emergence of electrical current. The presence of parasitic components (Ldis and Rdis) induces transient currents during the EDM process. The conditions in the discharge phase are depicted in Figure 5.

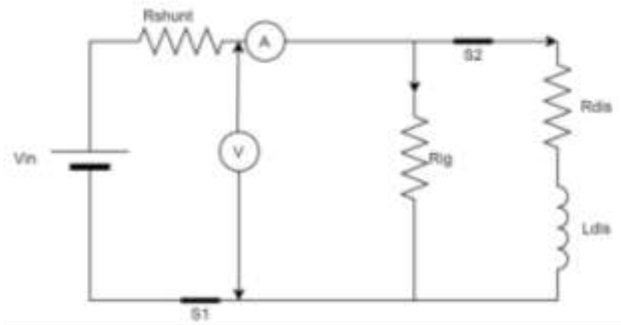


Fig.5. Discharge phase

Various parameters are employed to quantify the erosion rate in the EDM process, including the discharge pulse On-time (Ton), gap voltage (Vdis), frequency (f), discharge current (Igap), and material properties factor (α) [11-15]. For instance, the material properties factor for a copper electrode and a steel workpiece is determined to be 2 × 10-12 m^3/J.

Therefore, MRR as formulated by A. Yahya et al [13-15], the erosion rate is given by the Equation (1).

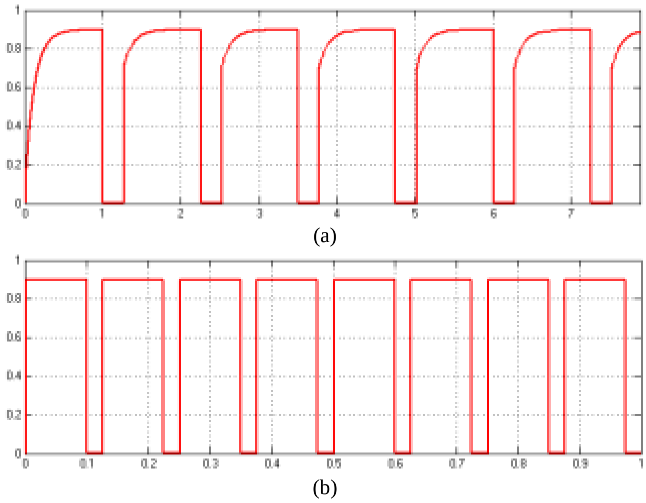
$$MRR = C\alpha V_{dis} I_{gap} T_d f \left[2.71 \times 10^{-7} \left(\frac{T_{on}}{T_{dis}}\right)^3 - 9.66 \times 10^{-5} \left(\frac{T_{on}}{T_{dis}}\right)^2 + 8.37 \times 10^{-3} \left(\frac{T_{on}}{T_{dis}}\right) + 0.81\right] \quad (1)$$

Here, C represents a dimensionless constant. In this simulation, Ton remains valid up to 400 µs, and the discharge time Tdis is 2 µs [15]. The distinction between the transient current waveform and the square current waveform is determined by the overall area under the current curve during the discharge phase.

3. Results and Discussion

3.1. EDM Pulses

The simulation was carried out using an electrical model within the Simulink software in MATLAB. Figure 6 displays the simulation outcomes for various conditions. The first set of conditions, depicted in Figure 6(a), involves the circuit with parasitic components, while Figure 6(b) represents circuits without these components. A comparison between the two conditions vividly illustrates the impact of parasitic components during the discharge phase.

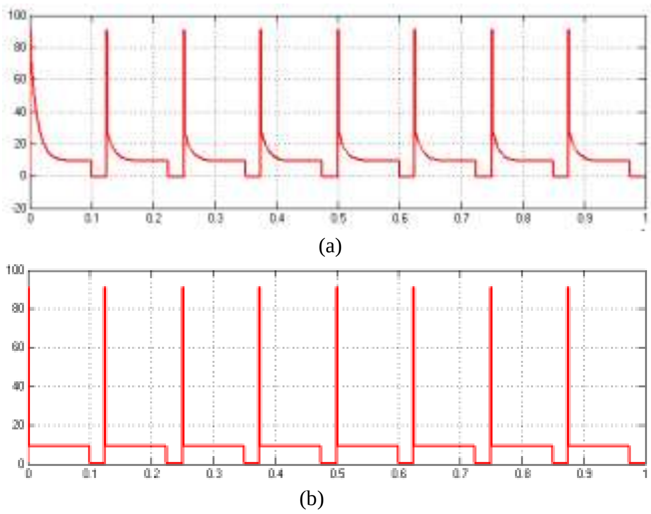


(a)

(b)

Fig.6. Discharge current (a) with parasitic component, (b) without parasitic component

Figure 7 presents the simulation outcomes for gap voltage under various conditions. In Figure 7(a), you can see the circuits with parasitic components, while Figure 7(b) displays circuits without these components.



(a)

(b)

Fig.7. Discharge voltage (a) with parasitic component, (b) without parasitic component

The presence of parasitic components leads to transient currents occurring in the initial phase of the discharge current, preventing the attainment of maximum current density. The discharge current density has a significant impact on the energy density responsible for eroding the workpiece.

3.2. MRR Result

Referring to Figure 6, the current waveform exhibits noticeable differences based on the presence or absence of parasitic components. This discrepancy also leads to variations in the current density profile. In particular, the current with parasitic components, as depicted in Figure 6(a), is smaller in magnitude compared to the current without these parasitic components, as seen in Figure 6(b). To compare Material Removal Rate (MRR) with pulse On-time (Ton) for different discharge currents, we present a graphical representation. On this graph, the y-axis represents MRR, while the x-axis represents pulse On-time (Ton).

Figure 8 provides a comparative analysis of MRR, which signifies the erosion rate, between discharge currents with parasitic components and those without. As indicated in Figure 8, MRR is higher for the discharge current without parasitic components in comparison to the scenario with parasitic components. On average, MRR experiences a 0.12 mm^3/min increase, with the maximum increase reaching 0.22 mm^3/min.

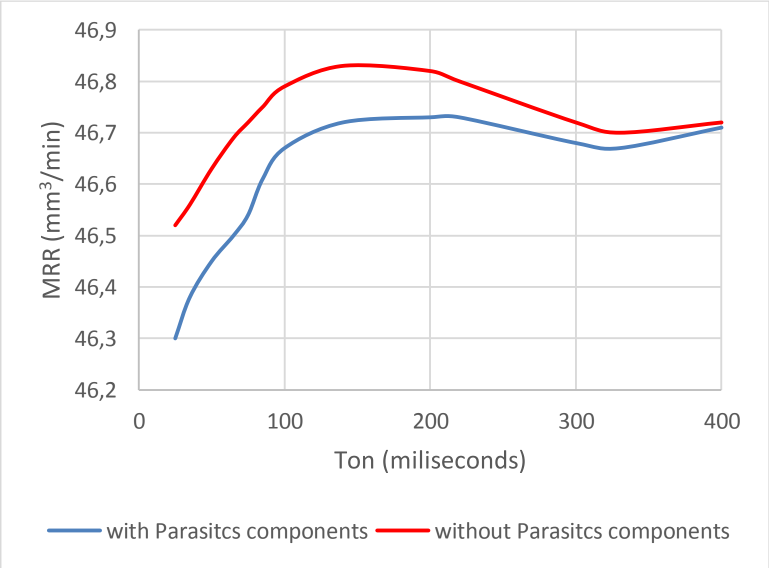


Fig.8. MRR comparison

The configuration of the discharge current has a direct impact on the current density profile, and this, in turn, influences the value of MRR. It is a well-established fact that parasitic components persist within the EDM circuit and cannot be entirely eliminated. However, if it becomes possible to generate a rectangular waveform for the discharge current, it would lead to a more efficient MRR.

4. Conclusion

This paper has demonstrated the simulation of EDM pulses and conducted a comparison of MRR between scenarios with and without parasitic components. The presence of parasitic components results in transient current patterns during the discharge phase and, consequently, a reduction in MRR. The implementation of a square wave current, however, enhances the MRR value and increases the efficiency of the EDM process.

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