FE Simulation of material removal and surface properties for EDM during single and multiple spark occurrences

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ABSTRACT

Electrical Discharging Machining (EDM) represents an effective machining process for hard-to-machine materials and high-aspect ratio geometric features. While EDM related research is on-going, it lacks level of fundamental understanding. This has also limited the development of CAE based modeling platforms that enable industrial users to predict workpiece properties such as surface roughness.

In this study, the objective is to develop a Finite Element(FE) based model to simulate material removal and predict surface topography. Currently, a two-dimensional model representing a single spark occurrence has been developed using FEA program. The model incorporates a Gaussian heat source to simulate the effect of the plasma column. The FE model has been found to have good agreement with a test condition using a single spark. Work is presently underway to assess and validate model robustness under a wider range of conditions based on machining experiments conducted using a micro EDM machine. Work will be undertaken to develop a modeling strategy for multiple spark occurrences and to conduct simulations using a 3D FE model.

Keywords: electrical discharge machining, simulation, finite element, spark, material removal

1 INTRODUCTION

Electrical Discharging Machining (EDM) represents an effective machining process because precise manufacturing not related to hardness and strength is possible, and it costs low. Recently, smaller mechanical and electronic devices are commonly used. So, application field of EDM is expanding. EDM process is expressed simply like Figure 1. Figure 2 is schematic diagram of EDM process.

Accordingly, EDM related researches are on-going. However, it lacks the well-developed technological base and level of fundamental understanding that characterizes other metal cutting technologies. This has also limited the development of CAE based modeling platforms that enable industrial users to predict electrode wear and workpiece properties such as surface roughness and residual stress levels.[2].

Therefore, material removal and surface properties in EDM process can be modeled using a simplified representation in this study. We develop Finite Element(FE) based model using commercial FEA program. Model incoporate a Gaussian heat source model and time dependent boundary conditions to simulate heat transfer. Also, material removal is represented simply by damage model. We are ensuring valid of model through simulation and experiment. The objective is to enable industrial users to simulate material removal and predict workpiece properties such as surface roughness.

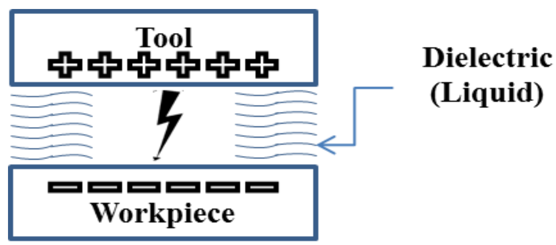


Figure 1: Simple expression of the EDM process

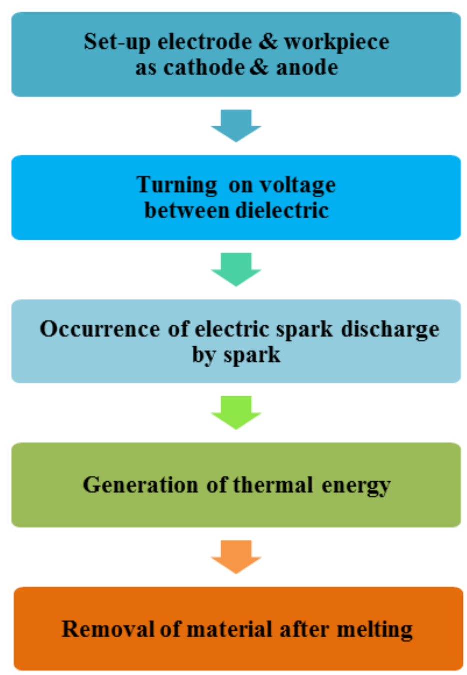


Figure 2: Schematic diagram of the EDM process

2 FINITE ELEMENT(FE) MODEL

It is hypothesized that material removal can be simulated using damage model. For verifying validation of our hypothesis, we follow previous research(영어논문) and compare results.

We use a commercial FEA program, DEFORM, to simulate EDM process. A two-dimensional model representing a single spark occurrence for a Cu cathode and L6 tool steel anode has been developed. L6 steel is commonly used in many EDM applications.

Material removal happens as a result of the heat flux which is applied on the workpiece by plasma discharging. The model incorporates a Gaussian heat source and time dependent boundary conditions to simulate the effect of the plasma column. Heat input model is represented as:

$$q = FVI \exp(-\frac{r^2}{a^2}) \quad (1)$$

where F stands for the fraction of the total energy, V and I are the voltage and current, respectively, r the radial distance at any point from the central axis of the plasma. Originally, a is proportional with time, but hypothesized equal to the final radius of crater.

And temperature-dependent damage model is used for material removal. If temperature attains melting temperature of material, material will be removed.

The FE model has been found to have good agreement with a test condition using a single spark.

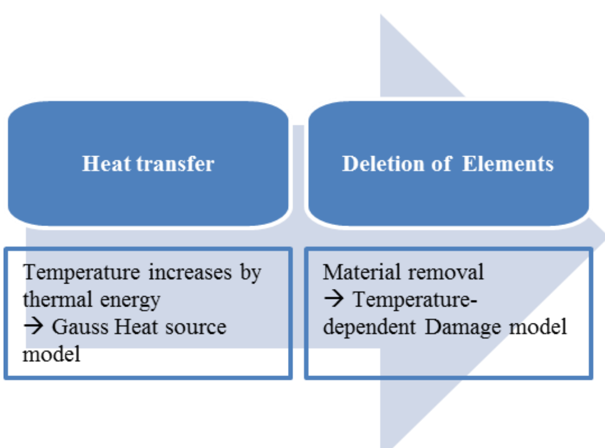
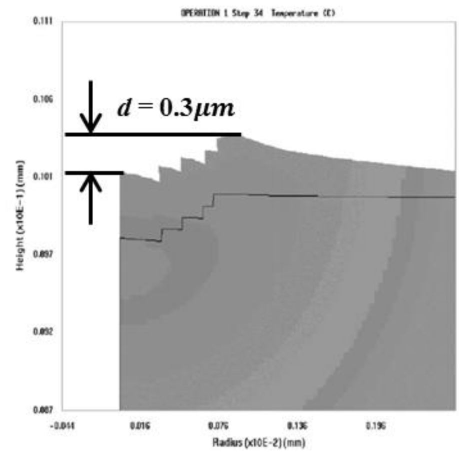


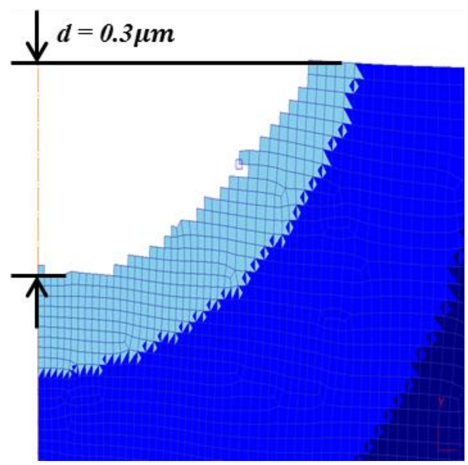
Figure 3: Concept of FE based model

Table 1: Level of conditions

Voltage(V)	Resistance(Ω)	Capacitance (μF)
86	10	0.1
108	40	0.52
	70	0.9



(a) Reference[1]



(b) FE based model

Figure 4: Comparison of result

3 EXPERIMENT USING SINGLE SPARK

3.1 Preparation of Experiment

In this paper, CAE based modeling platforms is made using FEA program, and compare it with experiment to validate model robustness. For feasibility secure, experiments with several conditions are conducted using micro EDM machine. Material of specimen is SKD11(AISI D2 steel), very hard material. Brass is used as electrode.

We can control voltage, resistance and capacitance in micro EDM machine. There are 2-level voltage, 3-level resistance and 3-level capacitance like Table 1. We use combinations of conditions. Both single spark and multi spark are possible, but we use single spark occurrence. Each condition are repeated three times with same electrode.

Material : Brass

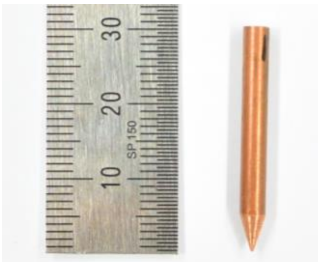
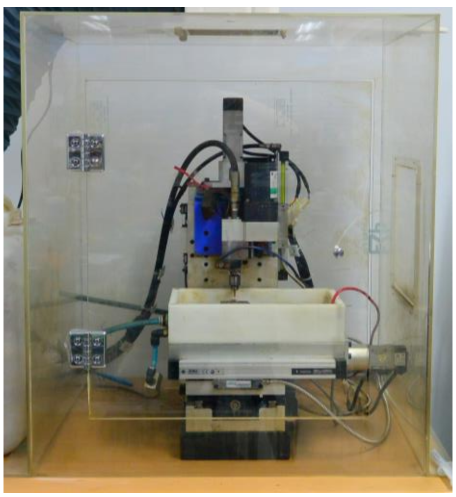


Figure 5: Electrode



(a)

(b)

Figure 6: Micro EDM machine

3.2 Result of Experiment

Figure 7 is shape from experiment using micro EDM machine(Figure 6). Two and three dimensional profile of crater derived from experiment are obtained using Atomic Force Microscope(AFM).

The diameter is 25 µm and the depth is 8 µm as you can see in (a) of Figure 8. But as you see (b) in Figure 8, the surface of crater is rough. We suppose the reason why initial surface roughness isn't considered and vibration of system have an effect.

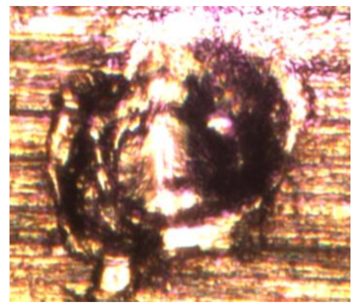
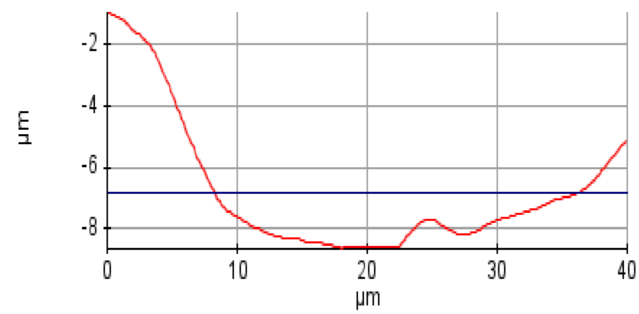
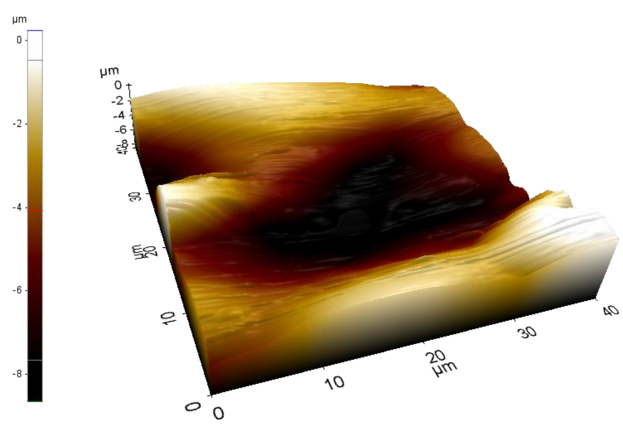


Figure 7: Shape of crater



(a)



(b)

Figure 8: Profile of Crater (a) 2D (b) 3D

4 CONCLUSION

In this research, FE based model to simulate micro EDM process is developed. Thermal energy is calculated using Gaussian heat source equation and applied as boundary conditions. Furthermore, material removal is represented simply using damage model. It can be conducted using commercial FEA program. So, many industrial users can use without other training.

Work will be undertaken to compare results with several experimental conditions and make secure validity of model. This will then be scaled up to model multiple spark occurrences and incorporate other surface geometries. A modeling strategy for multiple spark occurrences will be developed and conduct simulations using a 3D FE model.

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