GEOMETRIC SIMULATION BASED TOOL WEAR COMPENSATION IN MICRO DIE-SINKING EDM PROCESS

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INTRODUCTION
The die-sinking EDM process, a machining process widely used in industrial fields, casts a desired shape by using a tool electrode that is in the opposite shape to that desired. Because it is easily applied to machine a three-dimensional shape, the die-sinking EDM process is largely used for machining a die and mold. There has recently been an increase in demand for the minimization of parts in the fields of biomedical, optical science, and electronics; this has allowed the micro die-sinking EDM process to be widely used in various applications along with other micromachining methods [1]. Research on the conventional die-sinking EDM process has focused attention on predicting and improving the material removal rate (MRR) as well as predicting and decreasing surface roughness and tool wear. However, in the case of the micro die-sinking EDM process, research on tool wear and its influence on the machined shape is a more immediate requirement. Because the EDM process is based on thermal energy, tool wear during the EDM process is an unavoidable problem that deteriorates the form accuracy of the products. In general, the micro-EDM process has a lower material removal rate than the mechanical cutting processes [2]. Increasing the discharge energy to increase the machining speed results in a higher tool wear ratio [3]. Therefore, an increased material removal rate causes more tool wear and machining error. In addition, as machining progresses, an edge of the tool becomes more worn and becomes round [4]. This is because the tool removes a larger amount of workpiece per unit area at edges. In particular, the tool wear in the micro die-sinking EDM process is greater than that in the conventional die-sinking EDM process [1].

This is because in the micro-sinking EDM process, the discharge energy and resulting size of the crater do not decrease as much as the tool and workpiece become small.

In this study, the geometric simulation based tool wear compensation method in micro die-sinking EDM process is proposed. The proposed geometric simulation precisely represents the geometries of a machined workpiece and the evolution of the tool shape caused by tool wear during the machining. Therefore, the simulation can be used for tool wear compensation. A compensation method for the tool shape design with which a desired shape is machined is proposed, taking tool wear into consideration.

SIMULATION MODEL
To simulate a micro-EDM process, the process is mathematically and geometrically modeled in consideration of the tool shape, tool path, and other machining parameters such as the material properties, electrical power, and pulse frequency.

Two Z-maps are used to represent the configurations of the bottom surface of the tool and top surface of the workpiece during machining. Figure 1 shows the schematic diagram for the three-dimensional geometric model. The simulation comprises three steps:
1) Calculation of tool element positions
2) Search of spark points
3) Removal of material
These steps are repeated until the simulation of the EDM process is complete.

TOOL WEAR COMPENSATION METHOD
Figure 2 shows a scheme for tool wear compensation. As shown in Figure 2(a), tool wear during machining causes machining error,
FIGURE 1. Schematic diagram of three-dimensional geometric model

which prevents the desired shape from being made. As shown in Figure 2(b), the simulation can be used to predict the tool wear and machining error of the machined workpiece. The predicted machining error is reflected in the tool shape for tool wear compensation. The shape of a tool to machine the desired shape is designed and derived by the simulation. Compensation simulation is performed iteratively to improve geometrical accuracy of the designed tool shape and reduce machining error. Figure 3 shows a schematic diagram of an iterative compensation simulation.

EXPERIMENTAL VERIFICATION

To verify the proposed compensation method, an iterative simulation and machining experiment were performed to fabricate a hemisphere feature. Figure 4 shows the fabricated tool electrode which was designed by the iterative simulation. The tool was sharper than that of the hemisphere. Figure 5 shows the SEM image of the machined cavity and the cross-section of the cavity measured by the microscope. The shape of the machined cavity took the target hemispheric shape of 400 μm in radius.

REFERENCES


