

Intelligent CAD Tool to Solve Challenges in the Design of Orbiting EDM Electrode

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ABSTRACT

Orbiting EDM introduces additional electrode motion to enhance debris removal mechanism during machining process. This method offers superior machining quality towards static EDM due to advancement of debris removal and subsequently becomes a common process to produce precise and complex parts. However, designers often encounter difficulties to design electrode used for orbiting purposes. Aside from adjusting the electrode for machining overcut, the electrode also has to consider for the chosen orbit motion into geometry design, otherwise the final product will not meet design requirements due to deviated product dimension. These two factors have to be adjusted concurrently, following the characteristic of spark machining influenced by orbital motion. There is no CAD package that currently supports geometry adjustment for orbiting motion of EDM process in the market. Therefore, designers always perform manual electrode compensation for both orbit motion as well machining overcut. Manual compensation for both factors is considered as a big challenge for parts possesses intricate geometry, prone to human-error and consumes huge amount of design time. This research aims to facilitate those difficulties encountered on tool design process using the principle of inverse Minkowski sum. A detail explanation about electrode design steps and its validation is presented in the paper. This algorithm is integrated and developed in commercial CAD software as an intelligent tool to automate the electrode design process. Several samples of automotive parts with complex geometry are tested with this tool. The developed tool facilitates an easy process for compensating machining overcut and orbit motion simultaneously, cuts excessive electrode design time, also avoid geometry failure caused by human-error on manual design with promising result.

INTRODUCTION

There has been an increasing demand for complex and precise parts in automotive industries. Current manufacturing processes entangle CNC milling operation and electrical discharge machining (EDM), or spark machining, to produce such parts. CNC milling requires several steps, several tools, and several machines, followed by subsequent finishing processes such as polishing or other surface treatments that consume a substantial amount of time. Considering current significant improvement in material hardness, parts made from hard materials sometimes cannot be formed using milling tools efficiently. During production process, components possess with intricate geometry sometimes need to be divided into several sub-parts due to machining axis limitation of milling machines, hence prolong production lead time.

EDM is commonly employed in the area where high-precision cavities and molds have to be created, e.g. in the production of aerospace components, medical appliances, automotive parts, and so forth. This process is frequently used to generate intricate shapes that cannot or not efficient to be made through conventional milling. Although current high speed milling (HSM) technology has improved greatly, there are other areas where EDM excels the manufacturing of specialized components or exotic materials. Auto-parts which have intermittent cuts, like engine mounts, housing support, brake disc, are preferable to be machined by EDM since they require no contact and no force, thus prevents deformation on the machined surface. For parts with unique geometry, making a special milling tool is inefficient and costly. Producing EDM electrodes is more plausible than making special cutting tools since EDM electrodes can be made from soft materials, e.g. copper alloys or graphite, which are easy to machine with less production cost. In some cases, some molds require heat treatment after milled. Post milling

treatment may alter accuracy due to material deformation on the surface. Therefore, to maintain the accuracy of the machined part, pre-milled molds can be initially heat-treated and subsequently followed by spark machining since EDM can machine any conductive materials regardless of its hardness [1]. By doing so, the accuracy can be maintained without difficulty. Such examples are few areas that not feasible by traditional machining.

The advancement of material hardness often make EDM as the first option on the machining floor since milling tools are constrained by material hardness. However, EDM possesses low machining efficiency due to excess electrode wear and low material removal rate (MRR). Electrode wear is partly caused by poor mechanism of debris removal from EDM working gap, also due to improper selection of electrode material or machining parameters. Orbiting or planetary technique is one of EDM methods used to improve machining efficiency through enhancement of debris removal [1]. In this technique, the electrode moves along a controlled cycle, hence creates more space and extra pumping action to remove debris easily from the working gap. [Figure 1](#) shows the movement of the electrode during orbiting.

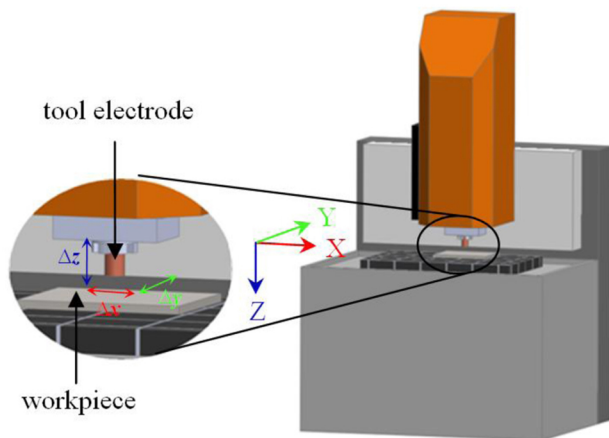


Figure 1. Electrode movement during orbiting EDM.

Orbiting provides a consistent surface finish, even wear, and maintains perfect round geometry or sharp details depending on the orbiting cycle chosen [2]. Despite efficiency improvement caused by orbiting application, designing electrode for orbiting purposes is somehow complicated. The challenge arises as the electrode has to be simultaneously adjusted for machining overcut (discharge gap) and orbiting motion. Manual design using uniform electrode offset has been used to this day in electrode design process. However, manual design is more prone to failure when the required shape has complex geometry [3]. Therefore, most design engineers prefer to design the electrodes which covering only small area of the required shape and do separate machining to form the whole shape. Even though this technique prolongs machining time, it avoids inaccuracy on the produced parts

due to incorrect electrode geometry [4]. Manual design also relies heavily to designer's knowledge of orbiting effect to the final geometry of spark machining.

This study aims to facilitate those difficulties encountered on the electrode design of orbiting EDM. A new method is proposed to compensate for both discharge gap and orbiting motion simultaneously to produce accurate electrode geometry based on the chosen orbit cycle. The compensation strategy is well-formulated and integrated with commercial CAD software to automate electrode design process. This strategy also covers electrode validation to confirm the effectiveness of produced electrode for creating part which agrees the blueprint. Detail of the developed theory for compensating both factors is discussed in section 2. Section 3 covers the theory implementation in CAD software and how the design automation is performed. Several models for automotive parts have been successfully processed with the developed method.

METHODOLOGY

Mold or die design cannot be separated from a tooling system. The tooling mostly involves how the mold details are designed, how to manufacture each of the detail, how much the manufacturing process will cost and so forth. This step may only consumes around 15-24% of total production time and cost [5], however, it stipulates the whole manufacturing processes, both on manufacturing line as well as the total cost. Generally, spark machining splits the design model into several sub-parts for the ease of machining and to avoid inaccuracy caused by electrode geometry. Each of the sub-part utilizes several processes for roughing and finishing, thus mold production time becomes incredibly long to get the whole shape done. Orbiting EDM can create complex contour with high quality finish with fewer electrodes, hence subsequent finishing process is not required. Therefore, orbiting EDM creates more efficient machining process by reducing the number of mold details and further saving up mold manufacturing time.

Precise parts or molds made by EDM process demand accurate electrode geometries. In the design of static EDM electrodes, the shape of electrode is obtained by taking the mirror shape of required part minus a thin layer of machining overcut on all EDM surfaces. EDM surfaces are the surfaces that burn, or face-to-face with the workpiece. The overcut or discharge gap is defined from a specific combination of machining parameters, which is applied uniformly throughout the electrode surfaces. Hence, manual electrode design can be done with a precise result, as depicted in [Figure 2](#), by subtracting a constant thickness of discharge gap from the electrode surfaces. In the contrary, orbiting introduces additional electrode movement during machining, which cycles to a pre-determined machining depth. Hence, electrodes designed for orbiting purposes have to consider the

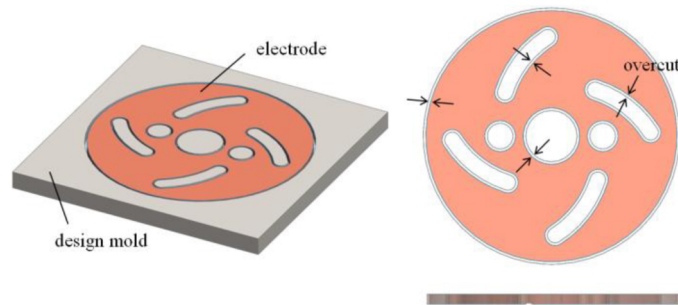


Figure 2. Manual electrode design by extracting uniform thickness of discharge gap to the electrode surface.

(a)					
(b)					
(c)					
	Design model	Uniform offset	Shaped electrode	EDM orbit	Product model

Figure 3. Sample of uniform electrode extraction and its effect to the product geometry by orbiting method.

chosen orbit motion into electrode final geometry, otherwise the final product dimensions will deviate from the blueprint [6].

Unlike static EDM electrodes, only few shapes like cylinders or cuboids that can be compensated uniformly thus yield accurate results for orbiting EDM process. A moderate to complex geometry parts cannot be compensated using a uniform offset thickness. Figure 3 shows sample of electrodes created by uniform offset and the respective product geometry for three different shapes. Fig. 3(a) and Fig. 3(b) confirm identical dimensions between design model to the product model created by electrode produced with uniform offset. However, this method failed to produce exact dimensions as requested for the last shape of Fig. 3, as the

product has different dimensions on all corners. Uniform offset application is valid only for straight edges and circles, not for corner radii or slanted edges. These figures are only simple prismatic geometries. The situation becomes a lot more complex for non-prismatic cavities since the electrodes have to be adjusted for both discharge gap and orbit motion.

2.1. Electrode Design Principle

As can be seen from Fig. 3, it is obvious that uniform thickness of electrode offset is not suitable to compensate for orbiting motion due to deviated dimensions created on the product. To obtain a correct electrode shape for a particular orbit path, this work utilizes the inverse Minkowski sum principle to shape the electrode.