ELECTRICAL DISCHARGE MACHINING OF SILICON CARBIDE USING BRASS ELECTRODE

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ABSTRAK

Siliconized Silicon carbide, SiSiC dapat diklasifikasikan sebagai semikonduktor dan mempunyai sifat-sifat fizikal seperti kekerasan yang tinggi, kadar pengaliran haba yang tinggi dan kadar pengembangan bahan terhadap haba yang rendah. SiSiC biasanya digunakan pada suhu tinggi seperti dalam penukar haba, pembakar dan brek cakera. *Die sinking EDM* adalah satu proses pemesinan bukan konvensional dan boleh didapati sebagai alternatif kepada pemesinan konvensional terutamanya untuk memotong bentuk bahan yang kompleks dan mempunyai kekerasan yang tinggi. Tembaga atau *Brass* adalah jenis bahan yang biasa digunakan sebagai elektrod dalam proses EDM selain *copper, graphite, copper-tungsten* dan *molibdenum*. *Brass* tidak tahan lasak terhadap kehausan seperti *copper* atau *tungsten,* tetapi ia adalah lebih mudah untuk dimesin dan dibentuk menjadi bentuk yg diingini untuk tujuan pemesinan melalui *die sinking EDM*. Kajian ini tertumpu kepada analisis pembolehubah untuk *EDM die sinking* proses pada SiSiC. Elektrod tembaga digunakan untuk proses tersebut. Pembolehubah EDM seperti arus puncak, voltan, tempoh pemesinan *(pulse duration)* dan selang rehat *(pulse interval)* dipilih sebagai faktor yang dikawal. Kesannya terhadap kadar pemotongan bahan, kadar kehausan elektrod dan kekasaran permukaan pada bahan uji dalam proses tersebut dikaji. *Design of Experiments* metodologi dilaksanakan untuk mereka bentuk eksperimen dan analisis varians, ANOVA digunakan untuk menganalisa keputusan eksperimen. Model matematik diterbitkan secara berasingan bagi setiap pencapaian proses yang dikaji berdasarkan pembolehubah yang mempunyai kesan yang besar ke atas keputusan eksperimen. Untuk memastikan model matematik adalah sah, process pengesahan dilakukan. Hasil optimum terhadap kadar pembuangan bahan, kadar kehausan elektrod dan kekasaran permukaan dalam operasi *EDM die sinking* yang terlibat akhirnya ditentukan.

ABSTRACT

Siliconized silicon carbide, SiSiC is classified as semiconductor and characterized as high hardness, high thermal conductivity, low thermal expansion and typically low porosity materials. SiSiC normally used under high temperature condition such as for heat exchangers, burners, disc brakes and mechanical seals. Die sinking EDM is a non-conventional machining process and available as an alternative to conventional machining to cut certain form and types of material especially to cut complex shape of high strength material. Brass is typical types of material to be used as electrode in EDM process besides copper, graphite, copper-tungsten and molybdenum. Brass does not resist wear as well as copper or tungsten, but is much easier to machine and can be die-cast or extruded for specialized applications. This study is focused on the parameter analysis for EDM die sinking process on SiSiC. Brass electrode is used for the process. EDM parameters; peak current, voltage, pulse duration and pulse interval are selected as the controllable factors. Their effects on material removal rate, tool wear rate and surface roughness on the process are to be studied. Design of experiment methodology is implemented to design the experiment and analysis of variance, ANOVA will be applied for the result analysis. The mathematical models are developed separately for each of the investigated process performances based from the significant effects on the responses. To ensure the mathematical models are valid, confirmation runs are performed with three different parameters setup. The optimum result of material removal rate, tool wear rate and surface roughness in region of finishing operation of EDM die sinking process are finally determined.

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CHAPTER 1

INTRODUCTION

1.1 Project Background and Rationale

Electrical discharge machining or popularly known as EDM is basically one of available nonconventional material removal techniques in metal processing nowadays which is widely used in production punches, mould and dies. It is also generally used for manufacturing of parts for automotive industry, aerospace and surgical components. This process can be efficiently applied in machining of electrically conductive components independent from their hardness, shape, and toughness [1, 2, 29].

EDM is a well-established machining option for manufacturing of geometrically complex or hard material parts that are extremely difficult or not economic to be machined by conventional machining processes [3]. The non-contact machining techniques between tool or better known as electrode in this process and the work part have been continuously evolving from a mere tool and die making process to a micro scale application machining, i.e. micro EDM alternatively attracting a significant amount of research and development interests.

In recent years, EDM researchers have developed a number of ways to improve the sparking efficiency in order to expand the quality and productivity of EDM including some unique experimental concepts that depart from the EDM traditional sparking phenomenon. Despite a range of different approaches, new researches share the almost similar objectives of achieving more efficient metal removal coupled with a reduction in tool wear and improved surface quality [2]. For each and every method introduced and employed in EDM process, the main objectives are the same: to enhance the capability of machining performance, to get better output product, to develop technique to machine new materials with increasing demand in details, quality and also to have better working conditions during the process application [3, 4].

EDM has brought many improvements in terms of quality, ability and productivity in machining process in recent years. The capability especially of machining complex components and hard material has made EDM as one of the most popular and preferred choice machining processes. The contribution of EDM to industries such as cutting new hard materials make EDM technology remains indispensable [5, 22, 26].

According to Sharanjit *et al.* [4], EDM can be classified into five types namely die-sinking EDM, wire-cut EDM, micro EDM, powder mixed EDM and dry EDM. In die sinking EDM process, based on this project, a ‘mirror’ image of the tool or electrode, basically from graphite or copper, is produced on the surface of the workpiece, that facing the electrode perpendicularly. The numerical control monitors the gap conditions (voltage and current) and synchronously controls the movement of the tool in different axes and the pulse generator. The dielectric liquid, used or needed between the tool and the workpiece, is filtrated to remove debris particles and decomposition products. In this process electrical energy turns into thermal energy through a series of discrete electrical discharges occurring between the electrode and workpiece immersed in a dielectric fluid. The thermal energy generates a channel of plasma between the cathode and anode. When the pulsating direct current supply is turned off, the plasma channel breaks down. This causes a sudden reduction in the temperature allowing the circulating dielectric fluid to implore the plasma channel and flush the molten material from the workpiece surface.

1.2 Research Statement

For this project, an investigation will be performed to study about the process of die sinking EDM on silicon carbide using brass electrode according to the Design of Experiment methodology. Based on the literature reviews, not much information gained about the similar process since the electrode used normally graphite or copper only and always differences or variations in terms of other condition such as selection of parameters to be investigated, selection of dielectric and sometimes with powder additives but the objectives tend to the similar direction of improving the surface roughness and material removal rate, reducing the tool wear rate by optimizing the process parameters including the electrical parameters such as peak voltage, peak current, pulse duration, polarity, electrode gap, pulse interval & pulse wave form and also non electrical parameters such as flushing, electrode rotation and workpiece rotation.

Reaction bonded or siliconized silicon carbide (SiSiC) is the material of the workpiece assigned to be machined with die sinking EDM in this project. It is an important non-oxide ceramic which has diverse industrial applications. In fact, it has exclusive properties such as high hardness and strength, chemical and thermal stability, high melting point, oxidation resistance, high erosion resistance, etc. All of these qualities make SiSiC a perfect candidate for high power, high temperature electronic devices as well as abrasion and cutting applications. Quite a lot of works were reported on SiSiC synthesis since the manufacturing process initiated by Acheson in 1892 [34]. Silicon carbide has attracted much attention a few decades ago because it has a good match of chemical, mechanical and thermal properties that makes it a semiconductor of choice for harsh environment applications. These applications include high radiation exposure, operation in high temperature and corrosive media. To obtain high-performance SiSiC ceramics, fine powder with narrow particles-size distribution as well as high purity are required. For this purpose, many effective methods have been developed.

1.3 Research Objectives

The objectives of the research are:-

i. To determine the significant parameters that influences the machining responses during die sinking EDM of Silicon Carbide.

ii. To evaluate the performance of die sinking EDM on silicon carbide with respect to various responses such as tool wear rate, overcut, material removal rate and surface quality.

iii. To establish separate mathematical models for the performance measures of EDM with the function of the selected controllable factors.

1.4 Scope of Study

The research for this project is limited to the following scope of study:-

i. Die sinking EDM Machine will be employed for the machining process.

ii. Reaction bonded silicon carbide (SiSiC) will be used as workpiece material.

iii. Brass of diameter 10mm will be used as electrode for the process.

iv. Machining parameters, namely peak voltage, peak current, pulse duration and pulse interval will be studied.

v. Quality characteristics, namely material removal rate, tool wear rate, surface roughness and radial overcut will be studied.

vi. Design of Experiments methodology will be applied for the research.

1.5 Significance of the Study

i. To gain better understanding and scientific knowledge of die sinking EDM of silicon carbide in terms of cutting parameters and quality characteristics.

ii. To establish acceptable range of cutting parameters when performing die sinking EDM of silicon carbide using brass electrode.

iii. To develop a mathematical model in predicting the material removal rate, surface roughness and tool wear rate according to the parameters setting.

iv. To determine or set the direction for future investigations to improve the die sinking EDM.

1.6 Research Questions

i. What are the best parameter settings for die sinking EDM of silicon carbide using brass electrode?

ii. Which parameter is the most significant parameter for the best quality of surface roughness when performing die sinking EDM of silicon carbide using brass electrode?

iii. What are the other parameters that should be considered when performing die sinking EDM?

iv. Which are the best research methods and procedures need to be used for systematic investigations?

v. What are the steps to optimize the cutting parameters of the process?

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the related theory topics to the research will be discussed based on the literature reviews done on journals, articles and technical books. It will be started with the topic of EDM, specifically Die Sinking EDM as the process for the project including introduction to EDM, types of EDM processes, mechanism of material removal in EDM Die Sinking and the machining system. Then it will be discussed about the parameters in EDM including electrical and non-electrical parameters, which some of them will be investigated in this as the controlled variables.

Machining characteristics will be explained as the following topic, which is focussed on the three most important EDM performances, namely the material removal rate, tool wear rate and the surface roughness in detailed including the significant factors or variables that affect the EDM performances. Since electrode also plays an important role in EDM, there will also be some explanation about it in terms of material, characteristics, geometric forms and control systems of the electrode for the machining process.

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