ELECTRICAL DISCHARGE MACHINING OF SILICON CARBIDE USING COPPER ELECTRODE

ARASH MAZAHERI SARABI

A project report submitted in partial fulfillment of the

requirements for the award of the degree of

Master of Mechanical Engineering

(Advanced Manufacturing Technology)

Faculty of Mechanical Engineering

Universiti Teknologi Malaysia

JANUARY 2013

To my beloved Mother and Father

ACKNOWLEDGEMENTS

Here, I would like to express my special thanks to my project supervisor, Associate Professor Hamidon Bin Musa for his continuous and valuable advice and guidance. He has given me inspiration and motivation to realize this project and carry on facing new challenges in experiment.

Moreover I also would like to extend my deepest gratitude to all lecturers of Faculty of Mechanical Engineering. I also wish to thank Mr. Aidid, Mr. Sazali and Mr. Roslin and all the FKM technical staff for their help and guidance during the implementation of the project.

Lastly, I would like to thank everyone who was involved directly or indirectly in completing this project. May all your contribution, kindness and support receive the full blessing from God.

ABSTRAK

Silikon karbida adalah bahan semikonduktor yang menjadi popular kerana ciri-ciri yang istimewa. Tetapi, kegunnannya adalah terhad disebabkan kesukaran pemprosesan. Proses pemesinan termaju didapati menjadi cara yang terbaik dan ekonomi untuk memesin bahan ini. Walanbagaimanpun, parameter tertentu perlu dikawal untuk memastikan ketepatan dan kecekapan proses. Kajian ini membentangkan analisis beberapa parameter dalam pemesinan terhadap bahan ini. Silikon karbida yang digunakan dalam kajian ini terhad kepada jenis *Reaction Bonded Silicon Carbide* (SiSiC).

Kesan Beberapa parameter menetapkan seperti *on-time* (ON), *discharge current* (I), *off-time* (OFF) dan Kekutuban (Pol) pada kadar pembuangan bahan (MRR), *surface roughness* (Ra), nisbah kehausan alat (TWR), dan kekasaran permukaan (Ra) dikaji. Analisis telah dilakukan menggunakan Pakar Rekabentuk Perisian design expert dengan melaksanakan keadah reka bentuk eksperimen. Daripada analisis ini, kesan yang signifikan ditentukan. Seterusnye, model matematik yang mengambil kira kesan yang penting sahaja dibangunkan. Dalam usaha untuk memastikan kesahihan model, Ujian pengesahan dilakukan dengan tiga parameter persediaan yang berbeza. Akhirnya, tetapan optimum untuk mendapatkan kadar pembuangan bahan maksimum, nisbah ke hausan alat minimum dan kekasaran permukaan minimum ditentukan.

Secara keseluruhannya, hasil kajian menunjukkan bahawa kesan denyutan pada masa dan Kekutuban adalah dominan bagi semua tindak balas yang terlibat.

ABSTRACT

Silicon Carbide is the semiconductor material that becoming popular because of its special characteristic. But, its application is limited due to processing difficulty. Advance machining process is found to be the best and economic way to fabricate this material. However, certain parameters need to be controlled for controlling the accuracy and efficiency of the process. This study presents analysis of some parameters in EDM machining of this material. The Silicon Carbide used for the study is limited to Reaction Bonded Silicon Carbide (SiSiC).

Several effects of parameter setting such as on-time (ON), discharge current (I), off-time (OFF) and polarity (Pol) on material removal rate (MRR), surface roughness (Ra), tool wear ratio (TWR), and surface roughness (R_a) is studied. The analysis was done using Design Expert Software by implementing design of experiment method. From this analysis, the significant effect(s) is determined. From that, the mathematical models that consist of only significant effect(s) are established. In order to ensure validity of the model, conformation run is done with three different parameters setup. Finally, the optimum setting to get maximum material removal rate, minimum tool wear ratio and minimum surface roughness is determined.

Overall, the results show that the effects of pulse on-time and Polarity are dominant for all responses established.

Table of contents

LIST OF TABLES

LIST OF FIGRES

LIST OF SYMBOLS

MRR	Material Removal Rate
TWR	Tool Wear Ratio
Ra	Surface Roughness
SiC	Silicon Carbide
SiSiC	Siliconised Silicon Carbide
Adj R-Square	Adjusted R-Square
Pred R-Square	Predicted R-Sqaure
Std. Dev.	Standard Deviation
EDM	Electrical Discharge Machining
DOE	Design of Experiment
ANOVA	Analysis of Variance

LIST OF APPENDIXES

CHAPTER 1

INTRODUCTION

1.1 Introduction

In this age of technology and development, humans try to solve a lot of problems and at the same time bring in many new materials. Silicon carbide ceramic is one of the materials that has been invented especially for the automotive and aerospace industry. It is an unusual material that is widely used in structural applications because of its properties of excellent oxidation resistance, high mechanical strength at elevated temperature, high hardness, high corrosion resistance, high thermal conductivity and high thermal shock resistance impact due to strong covalent Si-C bonds. But, because of the properties of this material, it makes SiC difficult to be machined by conventional method. [1]

With the invention of Silicon Carbide, Electro Discharge Machining (EDM) is playing an important role because it can remove material through erosion regardless of the material hardness. This is due to the fact that no cutting force will be induced during machining. Other than silicon carbide, any material that is electrically conductive can be machined through this process. [1, 2]

This research is conducted to mainly evaluate the machining performance of Silicon carbide using copper electrode which is a highly conductive and easy to machine material. The majority of silicon carbide material types are expensive. Because of that, proper planning on manufacturing is critical. Improper planning and lack of machining data or suitable parameter setting will increase the waste of material, time and finally increase the manufacturing cost. By this statement, it shows that research in this area is really important to be performed. [3]

1.2 Problem Statement

EDM is a non-conventional machining technology that focuses on machining of super hard conductive material. Because of this potential, it is extensively used specially in the automotive and aerospace industries. Like conventional machining operation, some suitable parameter settings need to be determined before conducting the machining operation. It is to ensure that the machining process will be done in an efficient and accurate manner. Every material that has different material properties will have different suitability of parameter setting. For EDM operation, the conductivity and melting temperature of material will play an important role. Many other machining parameters will also influence its processing. Hence the best solution to get a high machining efficiency is by developing appropriate mathematical models for the specific material in hand. [4]

Diverse researches have been done on this machining process including the selection of machining parameter for different materials in order to get best results. But, until now the study is far from extensive. Although there is up-to-date data base that comes together with the machine, it only covers for certain parameters and for some material. Furthermore, the manufacturer's guidelines for the selection of machining parameters are traditional in nature and do not ensure finest and economically efficient use of the machines. [3]

In EDM, the major challenge is to minimize the overcut and also to get the maximum material removal rate (MRR) in regard to the best surface roughness (of course when doing finishing job). [5]

Previous researches have been carried out on the machining of various types of ceramic materials using EDM. However studies involving die sinking EDM Siliconised Silicon Carbide (SiSiC) are few. As mentioned earlier, only electrically conductive materials can be machined using this method. Silicon carbide that has electrical resistance of more than 100 Ω cm will affect the EDM machining efficiency. This study will be carrying out to investigate the relationship between the certain parameters of machining and quality parameters of EDM process involving SiSiC. [4, 6, 7]

1.3 Objective of the Research

The objectives of this study are:

(i) To identify the significant machining parameters and their effect on material removal rate (MRR), surface roughness (Ra) and overall tool wear ratio (TWR).

(ii) To identify the optimum setting for maximum material removal rate (MRR), minimum surface roughness (Ra), minimum tool wear ratio (TWR)

Overall, the main objective of the project is to analyze the parameter settings of EDM on SiSiC.

1.4 Scope of the Research

The scopes of this research are:

(i) The material that will be used is limited to reaction bonded silicon carbide (RBSiC).

(ii) Discharge On-Time, Discharge Current, Off-Time and Tool polarity will be studied as machining parameters.

(iii) Material Removal Rate, Tool Wear Ratio and Surface Roughness will be studied as Quality Parameters.

(iv) Copper electrode will be employed.

(v) DOE will be used in this study.

1.5 Research Question

The research questions for this study are:

(i) What are the parameter settings that significant on the material removal rate (MRR), tool wear ratio (TWR), and surface roughness (Ra)?

(ii) What is the relationship of every significant parameter on material removal rate (MRR), tool wear ratio (TWR), and surface roughness (Ra)?

(iii) How the material removal rate (MRR), tool wear ratio (TWR), and surface roughness (Ra) will be varied with varying of significant parameter setting?

(iv) What is the optimum setting for material removal rate (MRR), tool wear ratio (TWR) and surface roughness (Ra)?

1.6 Significance of the Study

The research finding will give information on the factors that will contribute to the studied responses namely material removal rate (MRR), tool wear ratio (TWR), and surface roughness (Ra). Since there is still a lack of information on EDM of conductive ceramic until now, the information will be beneficial for potential users including those in the aerospace and automotive industries. The information on the machining parameters will provide useful reference for better efficiency of silicon carbide machining process.

Reference

[1] El-Hofy, Hassan. *Advanced Machining Processes.* McGraw Hill, 2005.

[2] Jain, V.K. *Advanced (Non-traditional) Machining Processes.*

[3] (2012). Chapter 3 - The Current Situation in Ultra-Precision Technology – Silicon Single Crystals as an Example. Advances in CMP Polishing Technologies. D. Toshiro, D. M. Ioan, I. D. M. Syuhei KurokawaA2 - Toshiro Doi and K. Syuhei. Oxford, William Andrew Publishing: 15-111.

[4] Jahan, M. P., M. Rahman, et al. (2011). "A review on the conventional and micro-electrodischarge machining of tungsten carbide." International Journal of Machine Tools and Manufacture 51(12): 837-858.

[5] König, W., D. F. Dauw, et al. (1988). "EDM-Future Steps towards the Machining of Ceramics." CIRP Annals - Manufacturing Technology 37(2): 623-631.

[6] Ji, R., Y. Liu, et al. (2011). "Experimental research on machining characteristics of SiC ceramic with end electric discharge milling." Journal of Mechanical Science and Technology 25(6): 1535-1542.

[7] Liu, Y., R. Ji, et al. (2008). "Electric discharge milling of silicon carbide ceramic with high electrical resistivity." International Journal of Machine Tools and Manufacture 48(12–13): 1504-1508.

[8] Kiyak, M. and O. Çakır (2007). "Examination of machining parameters on surface roughness in EDM of tool steel." Journal of Materials Processing Technology 191(1–3): 141-144.

[9] Mahardika, M., T. Tsujimoto, et al. (2008). "A new approach on the determination of ease of machining by EDM processes." International Journal of Machine Tools and Manufacture 48(7–8): 746-760.

[10] Mohd Abbas, N., D. G. Solomon, et al. (2007). "A review on current research trends in electrical discharge machining (EDM)." International Journal of Machine Tools and Manufacture 47(7–8): 1214-1228.

[11] *http://www.vulcanmold.com*.

[12] Matoorian, P., S. Sulaiman, et al. (2008). "An experimental study for optimization of electrical discharge turning (EDT) process." Journal of Materials Processing Technology 204(1–3): 350-356.

[13] NorlianaMohdAbbas, D. S., Md.FuadBahari (2006). "A review on current research trends in electrical discharge machining." Machine Tools and manufacture.

[14] Schumacher, B. M. (2004). "After 60 years of EDM the discharge process remains still disputed." Journal of Materials Processing Technology 149(1–3): 376-381.

[15] R.Venkataraman. "Multi Objective Optimization of Electro Discharge Machining of Resin Bonded Silicon Carbide." *Applied Mechanics and Materials*, 2012: 1556-1560.

[16] Tani, T., Y. Fukuzawa, et al. (2004). "Machining phenomena in WEDM of insulating ceramics." Journal of Materials Processing Technology 149(1–3): 124-128.

[17] Luis, C. J., I. Puertas, et al. (2005). "Material removal rate and electrode wear study on the EDM of silicon carbide." Journal of Materials Processing Technology 164–165(0): 889-896.

[18] Leão, F. N. and I. R. Pashby (2004). "A review on the use of environmentally-friendly dielectric fluids in electrical discharge machining." Journal of Materials Processing Technology 149(1–3): 341-346.

[19] Tsai, Y. Y., C. H. Tseng, et al. (2008). "Development of a combined machining method using electrorheological fluids for EDM." Journal of Materials Processing Technology 201(1–3): 565-569.

[20] Puertas, I., C. J. Luis, et al. (2005). "Spacing roughness parameters study on the EDM of silicon carbide." Journal of Materials Processing Technology 164–165(0): 1590-1596.

[21] Yonghong, L., J. Zhixin, et al. (1997). "Study on hole machining of non-conducting ceramics by gas-filled electrodischarge and electrochemical compound machining." Journal of Materials Processing Technology 69(1–3): 198-202.

[22] Chen, P.-Y., J. McKittrick, et al. "Biological materials: Functional adaptations and bioinspired designs." Progress in Materials Science (2000).

[23] Puertas, I. and C. J. Luis (2004). "A study on the electrical discharge machining of conductive ceramics." Journal of Materials Processing Technology 153–154(0): 1033-1038.

[24] Baker, A. R., D. J. Dawson, et al. (1987). "Ceramics and composite materials for precision engine components." Materials & Design 8(6): 315-323.

[25] Orlova, T. S., V. V. Popov, et al. (2011). "Electrical properties of biomorphic SiC ceramics and SiC/Si composites fabricated from medium density fiberboard." Journal of the European Ceramic Society 31(7): 1317-1323.

[26] Lenk, Reinhard, Aniko Nagy, Hans-Jurgen Richter, and Anja Techel. "Material development for laser sintering technique." 2006.

[27] Ji, Renjie, Yonghong Liu, Yanzhen Zhang, Baoping Cai, Jianmin Ma, and Hang Li. "Optimizing machining parameters of silicon carbide ceramics with ED milling and mechanical grinding combined process." *Int J Adv Manuf Technol*, 2010: 195–204.

[28] Montgomery, D.C. *Design and Analysis of Experiments. 7th edition.* John Wiley & Sons, Inc. New York.

[29] Antony, J. (2003). 8 - Some useful and practical tips for making your industrial experiments successful. Design of Experiments for Engineers and Scientists. Oxford, Butterworth-Heinemann: 93-104.