SIMULATION AND OPTIMIZATION OF ELECTRICAL DISCHARGE MACHINING PROCESS USING MATLAB

ELNAZ KARIMPOUR

UNIVERSITI TEKNOLOGI MALAYSIA

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ELNAZ KARIMPOUR

A project report submitted in partial fulfilment
of the requirements for the award of the degree of
Master of Engineering (Electrical – Mechatronics & Automatic Control)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

JUNE 2014

I dedicate this dissertation to three beloved people. To my adored husband helped me find my way and a big part of my success in life. He always respire me to try for bright future. To my precious parents who are the foundation to my life. I am really honored to have them. Everything that I am now is because of them.

ACKNOWLEDGEMENT

First and foremost I would like to thank God giving me the power to believe in my passion and pursue my dreams. I could never have done this without the faith I have in God, the Almighty. I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals. I would like to extend my sincere thanks to all of them. First of all, I greatly appreciative of my two supervisors, Dr Sophan Wahudi Nawawi and Dr Azli Yahya, who have supported me to finish my master project. I am highly indebted to them for their guidance and constant supervision. My thanks and appreciations also go to Mr Trias Andromeda, PHD student in EDM research group for providing necessary information regarding the project and also for his support in completing the project. Apart from that, I would like to express my sincere gratitude to my husbands for his inspiration, moral support and motivation. Last but not least, I would like to thank my parents for their unconditional support, both financially and emotionally throughout my degree. It became the vital encouragement for me to accomplish this project.

ABSTRACT

Electrical discharge machining (EDM) is a nonconventional milling in which holes or shape can be created without any contact between electrode and work piece during the material removal process. Throughout the machining process a series of stochastic sparks are produced when the gap between electrode and work piece is very narrow just about 10 to 50 microns. Controlling this gap in micro dimension not only depends on electrode position but also on work piece surface. So a combination of PID controller and EDM process is used to monitor the gap. In this study an indirect measurement of surface position is carried out by implementing voltage average gap model. And Simulink models have been done to simulate the dynamic behavior of EDM system. Finally Particle Swarm Optimization technique is applied to find optimal performance parameters to have maximum Material Removal Rate.

ABSTRAK

Pemesinan nyahcas elektrik (EDM) adalah proses pemesinan secara bukan konvensional di mana lubang atau bentuk akan dihasilkan tanpa sebarang sentuhan antara elektrod dan bahan yang ingin dimesin (bahan kerja). Sepanjang proses pemesinan, satu siri bunga api yang dihasilkan secara stokastik dihasilkan dimana jurang antara elektrod dan benda kerja adalah sangat kecil, iaitu hanya kira-kira 10 hingga 50 mikron. Mengawal jurang ini dalam dimensi mikro bukan sahaja bergantung kepada kedudukan elektrod tetapi juga bergantung kepada kedudukan bahan yang dimesin tersebut. Jadi, gabungan di antara Pengawal Kamiran Berkadaran (PID) dan proses EDM digunakan untuk memantau jarak di antara elektrod dan bahan kerja. Dalam penyelidikan ini, pengukuran tidak langsung kedudukan permukaan bahan kerja telah digunakan dalam model voltan purata jurang. Model telah dilakukan untuk membuat simulasi pergerakan dinamik sistem EDM dengan menggunakan SIMULINK. Seterusnya, kaedah Pengoptimuman Zarah Berkelompok (*Particle Swarm Optimization*) digunakan bagi mencari parameter yang optimum untuk mencapai Kadar Pembuangan Bahan dengan kadar yang maksimum.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

EDM	-	Electrical Discharge Machining
MRR	-	Material Removal Rate
PSO	-	Particle Swarm Optimization
RC	-	Resonant Converter
ZN	-	Ziegler-Nichols
GA	-	Genetic Algorithm
ANN	-	Artificial Neural Network
DC	-	Direct Current
ACO	-	ANT Colony Optimization
DE	-	Differential Evolution
PID	-	Proportional Integral Derivative
PSD	-	Power Spectral Density
PI	-	Proportional Integral
IAE	-	Integral Absolute Error
DOE	-	Design of Experiment
DSP	-	Digital Signal Processor
AR	-	Auto Regressive
MD	-	Molecular Dynamics

PMEDM	-	Powder Mixed Electric Discharge Machining
FEM	-	Finite Element Method
DOA	-	Dimensional Analysis
RERF	-	Reduced Erosion Rate Factor
WEDM	-	Wire Electrical Discharge Machined
WLT	-	White Layer Thickness
ANFIS	-	Adaptive Neuro-Fuzzy Inference
FL	-	Fuzzy Logic
S/N	-	Signal to Noise
TWR	-	Tool Wear Ratio
CLA	-	Centre Line Average
ANOVA	-	Analysis of Variance
EW	-	Electrode Wear
MOGA	-	Multi Objective Genetic Algorithm
MOPSO	-	Multi Objective Particle Swarm Optimization

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Electrical discharge machining (EDM) is a nonconventional milling in which there is no contact between electrode and work piece during the material removal process. Hence no press is needed in this procedure; it is convenient for most work pieces even harder than electrode. So this method is usually used for grinding of high solidity steel and also any kinds of metal alloy. Moreover, with EDM we can produce complicated and precise holes and hovels which cannot be produced with traditional milling methods. During the milling process a series of stochastic sparks are produced when the distance of electrode from work piece is very small just about 10 to 50 microns. Spark is a process in which current discharge occurs suddenly with high frequency. Then, the current flows through the gap between electrode and work piece filled with dielectric fluid. Finally, electrical current changes to thermal energy and melts the work piece. Furthermore, it can be observed that use of EDM for biomedical science is in progress these days due to its outstanding application in lubrication of implant joint. Elders or patients who suffer from diseases such as osteoarthritis, rheumatoid arthritis, bone tumors and traumas need to implant joints. Moreover, in many cases damaged joint will be replaced with metal head and cup. Besides that, to prolong life span of joint we can use EDM to create holes in microns

for lubrication. If we reach a good surface finish the lump of fluid in holes not only eases movement of metal head on metal joint but also improves the life span.

Figure 1.1 : Electrical Discharge Machine (EDM)
(Canadian Industrial Machinery, March 1, 2010)

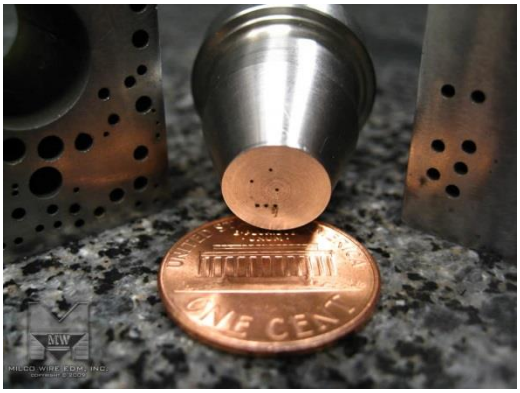

Figure 1.2 : Small hole EDM drilling (MILCO Wire EDM, 2010)

There are many types of EDM such as Milling, grinding, Abrasive Grinding, Wire Grinding, Wire EDM and Die-sinking EDM. However, Wire EDM and Die-sinking EDM have more usages compared to other. In this project Die-sinking EDM will be emphasized. Die-sinking EDM consists of servo system with DC motor, gap

voltage and current pulse power generator. The objectives that will be discussed in EDM model are position control of DC motor, material removal rate and surface finish. DC motor should be controlled in a definite distance about 10 to 50 microns to maintain the gap. The definition of material removal rate is dimension of holes produced divided by $t_{on}+t_{off}$. Due to high hardness of materials sometimes machining becomes very time consuming. In addition, decreasing the duration of machining or inversely improving of MRR is aimed. Another problem is the creation of craters on the work piece surface caused by discontinuous current and leads to the surface erosion.

The two most common EDM systems are as illustrated in Figure 1.1 and Figure 1.2 are:

1. Die-sinking EDM: it is used in high precision machining of metal such as micro-hole machining of metals.
2. Wire EDM: in this type a continuous wire is used as the electrode to cut an electrically conductive workpiece for through-hole machining.

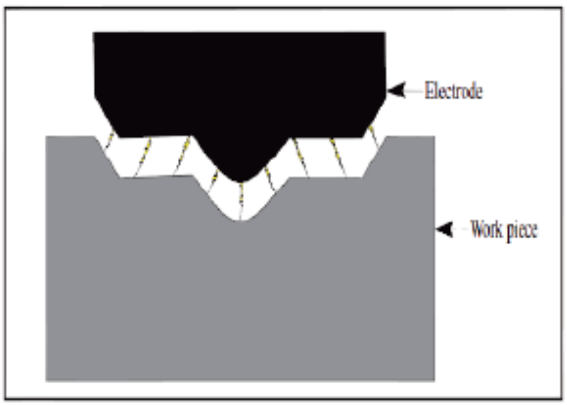

Figure 1.3 : Simple Structures of Die-Sinking EDM System (Ming, C. L. 2012)

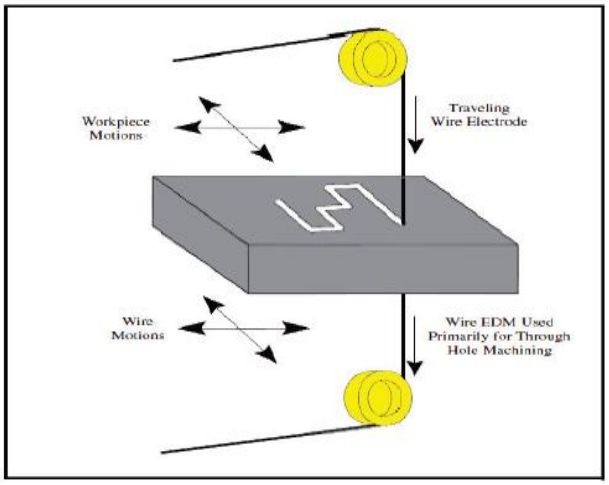

Figure 1.4 : Simple Structures of Wire EDM System (Ming, C. L. 2012)

Basically, EDM system consists of the following subsystems as shown in Figure 1.5:

1. DC Power Supply
2. Servo Mechanism System
3. Flushing System
4. Dielectric Fluid
5. Electrode and workpiece

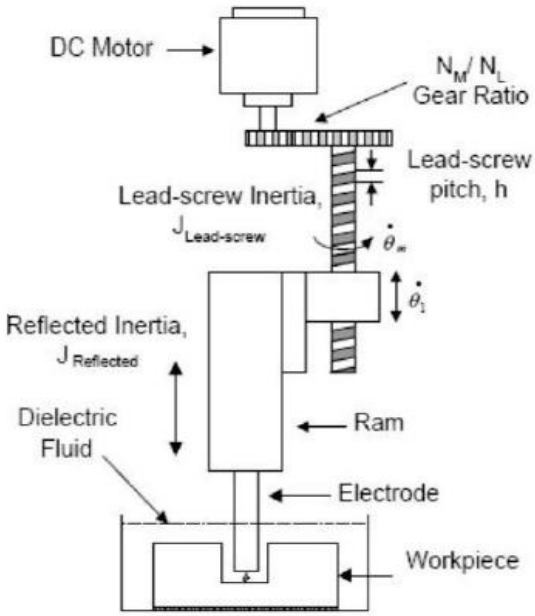

Figure 1.5 : Die Sinking EDM With Main Parts (Yahya A. 2005)

Figure 1.6 illustrates the voltage waveform, current flow and pulse train from the top to the bottom respectively. As be presented in this figure the high voltage, open circuit voltage V_{oc} is created when the timer turns on. So the ionization occurs through the gap. At the end of delay time t_d the resistance of dielectric falls due to a high electric field appears in the gap. So a high current I_{gap} flows between the electrode and work piece during t_{on}. As well as the voltage decreases to V_{arc} considered as working voltage. Therefore, machining takes place during t_{on}. After this time the characteristic of dielectric which broke down through t_{on} will be improved during t_{off} and there is an interruption in the current. The volume of

material removed is directly proportional the quantity and duration that current flows. Since the ionization starts with some delay, the current appear only some part of t_{on}. For instance, in second pulse only small amount of metal has been removed and in the following pulse there is no current during t_{on}. The delay time t_d is related to the gap between the electrode and work piece.

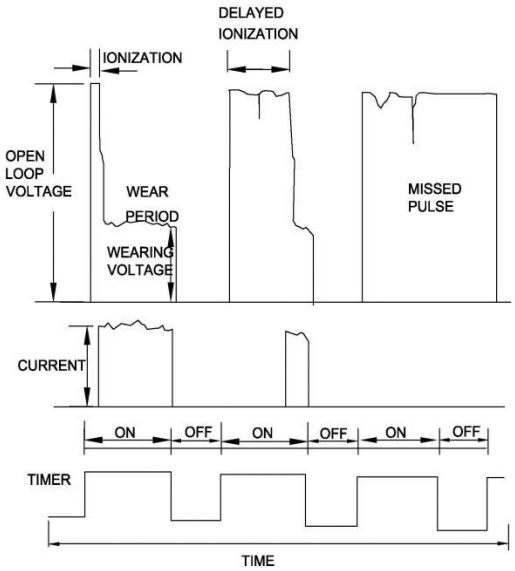

Figure 1.6 : Voltage Waveform, Current Flow and Pulse Train
(Oscar, C., et al. 2009)

1.2 Problem Statement

Throughout the machining process in Electrical Discharge Machining (EDM), a series of stochastic sparks are produced when the gap between electrode and work piece is very small just about 10 to 50 microns. Controlling this gap in micro dimension not only depends on electrode position but also work piece surface changing during material removal process. This project contains some enhancements comparing the other works relating to the EDM simulation. In this study an indirect measurement of surface position is carried out by implementing voltage average gap

model. And Simulink models have been done to simulate the dynamic behavior of EDM system. Since Material Removal Rate (MRR) can also affect the gap, our aim is to have higher MRR with the optimization technique.

1.3 Objectives of Study

There are total of three objectives to be achieved upon the completion of this project. The objectives of this study are:

(i) Simulation of EDM process including three subsystems: breakdown model, material removal rate and average voltage gap model.

(ii) Simulation of single loop servo system (position control and velocity control).

(iii) Optimization of EDM Process using Particle Swarm Optimization (PSO).

1.4 Scope and Limitations of Study

EDM model is considered a combination of two main models, servo system and EDM process. This project work focus on EDM process. It starts by conducting literature review in order to understand the method of the design approach. Then proceed to simulate the combination of two main models in Matlab. In simulation the model of the servo system was developed by using the Transfer Function approach. As well as the EDM process model was simulated in Matlab consist of three sub-models, material removal rate model, the breakdown model and the average gap voltage model. In this research the mathematical model which has been already developed by using Dimensional Analysis technique by (Yahya A. 2005) is

selected to get the mathematical model of the material removal rate. And also only two simple PID controllers are used for improving DC servo motor system performance. Finally the PSO technique will be implemented to optimize the EDM process to have higher MRR with proper choosing of EDM parameters.

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