

CHAPTER 1

INTRODUCTION

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1.1 PREWORD

Electric discharge machining (EDM) is one of the modern non-conventional machining methods for manufacturing geometrically complex or hard materials parts that are extremely difficult to machine by conventional machining processes.

The recent developments in the field of EDM have progressed due to the growing application of EDM process and the challenges being faced by the modern manufacturing industries, from the development of new materials that are hard and difficult to machine such as tool steels, composites, ceramics, hastalloy, nitralloy, waspalloy, nemonics, carbides, stainless steel, heat resistant steel, etc. being widely used in die and mould making industries, aerospace, aeronautics and nuclear industries. Many of these materials also find applications in other industries owing to their high strength to weight ratio, hardness and heat resisting qualities. EDM has also made its presence felt in the new fields such as sports, medical and surgical instruments, optical, dental and jewellery industries, including automotive R&D areas (*Stovicek, 1993*).

EDM technology is increasingly being used in tool, die and mould making industries, for machining of heat treated tool steels and advanced materials (super alloys, ceramics and metal matrix composites) requiring high precision, complex shapes and high surface finish. Heat treated tool steels have proved to be extremely difficult to machine using traditional processes, due to rapid tool wear, low machining rates, inability to generate complex shapes and imparting better surface finish (*Shankar Singh et al., 2004*). Review of the research work reveals that much work has been done on various aspects of electric discharge machining on low carbon steels, carbides and few die steels. Shanker Singh *et al.* (2004) investigated the EDM characteristics of hardened tool steel using copper, copper tungsten, brass and aluminium electrode materials. Their

investigations indicate that the output parameters (material removal rate, diametral overcut, electrode wear and surface roughness) of EDM increase with increase in pulsed current and the best machining rate are achieved with copper and aluminium electrodes. They reported that copper have minimal wear and aluminium have considerable high wear with increase in the current. Their investigations also indicate that aluminium electrodes give the better surface finish at low value current compare to copper electrode and give the worse surface finish at high value current compare to copper electrode. They reported this on the basis of only one trial at each condition. Therefore that finding may be seen with skepticism. But they did not find an optimum combination of machining parameters for smallest surface roughness in finishing condition and highest material removal rate in roughing condition.

From the literature survey, it has been observed that no work has been done with copper electroplated tool electrode materials on the work material SKD 11 hardened (64 HRC) tool steel. No attempt has been made to optimize the input variables using Pareto ANOVA technique. The cost of aluminium electrodes per unit volume is 60% the cost of the copper electrode based on Malaysian market. So, if the aluminium or copper coated aluminium electrode tools show a performance as good as the performance of copper electrodes, the high cost copper electrode can be replaced by low cost tools. There exists a great need for investigating the performance of aluminium, copper electroplated aluminium electrode materials verse a vice copper electrodes and the effect of input variables on material removal rate, electrode wear ratio, diametral overcut and surface roughness in electric-discharge machining of SKD 11 hardened tool steel with these electrodes. Finally to find an optimum combination of machining parameters for smallest surface roughness in finishing conditions and highest material removal rate in roughing conditions is important.

1.2 OBJECTIVES

The objectives of this work are to:

- a) Study the influence of operating parameters on EDM characteristics of hardened tool steel (Designation: SKD 11) with aluminium, copper and copper electroplated aluminium electrodes.
- b) Find optimum combination of machining parameters for smallest surface roughness in finishing conditions and highest material removal rate in roughing conditions using aluminium electrode and compare the performance at the optimum machining conditions with copper electroplated aluminium and copper electrodes under similar conditions.
- c) Find optimum combination of machining parameters for smallest surface roughness in finishing conditions and highest material removal rate in roughing conditions using copper electroplated aluminium electrode and compare the performance at the optimum machining conditions with copper electrode under similar conditions.

1.3 PROJECT SCOPE

Four main input variables have been chosen for the study; pulse on time, discharge current, discharge voltage and flushing pressure. The output parameters that have been chosen to be studied are metal removal rate, surface finish, diametral overcut and electrode wear ratio.

The CONDITION FILE in the EDM machine (available in the EDM lab of the Department of Engineering Design and Manufacture, University of Malaya) contains a total of 60 machining condition created by combining 10 conditions for machining from roughing to finishing with six standard parameters (ON, OFF, IP, V, SV, PL) selected

on the basis of the electrode/workpiece material combination and machining performance. The machining conditions chosen for this work is C 340 (low electrode wear).

In this study, Taguchi Parametric Robust Design, with inner $L_8 2^7$ orthogonal array and 3 replications for the outer array, has been used to plan the experiments and Pareto ANOVA is used to determine the optimum machining parameters. The machining parameters that are optimized are discharge current, pulse on time, discharge voltage and flushing pressure for maximum metal removal rate and minimum surface roughness.

1.4 METHODOLOGY

a) *Confirmation of thesis title*

After some literature review and discussion with the supervisor, the title was confirmed.

b) *Literature review*

Further literature review was conducted. Recent researches and developments in EDM were reviewed. These were sources from the library and the World Wide Web or Internet. A report on the literature review is given in Chapter 2.

c) *Planning of Experimental runs*

Taguchi Parametric Robust Design, based on orthogonal array $L_8(2^7)$ has been used to plan the experiments. The controllable operating parameters on EDM characteristics that are chosen are pulse on time, discharge current, discharge voltage and flushing pressure. Each operating parameters has two level values.

Table 1.1 $L_8(2^7)$ Orthogonal Array for Screening Experiments

Experiment number	Column number						
	1	2	3	4	5	6	7
1	0	0	0	0	0	0	0
2	0	0	0	1	1	1	1
3	0	1	1	0	0	1	1
4	0	1	1	1	1	0	0
5	1	0	1	0	1	0	1
6	1	0	1	1	0	1	0
7	1	1	0	0	1	1	0
8	1	1	0	1	0	0	1
Basic mark	a	b	ab	c	ac	bc	abc
Assignment	A	B	A x B	C	A x C	B x C	D

Table 1.2 Basic Structure of Parameter Design for Screening Experiments

Array type	Inner array (L_8)							Outer array (one-way layout)		
Experiment number	Control factor assignment and column number							Raw data:		
	A	B	A x B	C	A x C	B x C	D	Noise factor N_o		
	1	2	3	4	5	6	7	y_1	y_2	y_3
1	0	0	0	0	0	0	0			
2	0	0	0	1	1	1	1			
3	0	1	1	0	0	1	1			
4	0	1	1	1	1	0	0			
5	1	0	1	0	1	0	1			
6	1	0	1	1	0	1	0			
7	1	1	0	0	1	1	0			
8	1	1	0	1	0	0	1			

Where A -- discharge current, A

C -- flushing pressure, kg/cm^2

B - pulse on time, μsec

D -- discharge voltage, V

f) *Final planning for finishing and roughing condition*

Based on the screening experiments results, the two levels value of operating parameters for finishing and roughing condition were set. The $L_8(2^7)$ orthogonal array layout given in **Table 1.3** and the basic structure of Taguchi Parametric Robust Design used in this experiments given in **Table 1.4**.

Table 1.3 $L_8(2^7)$ Orthogonal Array for Final Planning

Experiment number	Column number						
	1	2	3	4	5	6	7
1	0	0	0	0	0	0	0
2	0	0	0	1	1	1	1
3	0	1	1	0	0	1	1
4	0	1	1	1	1	0	0
5	1	0	1	0	1	0	1
6	1	0	1	1	0	1	0
7	1	1	0	0	1	1	0
8	1	1	0	1	0	0	1
Basic mark	a	b	ab	c	ac	bc	abc
Assignment	A	D	A x D	B	C	D x B	C x D

Table 1.4 Basic Structure of Parameter Design for Final Planning

Array type	Inner array (L_8)							Outer array (one-way layout)		
Experiment number	Control factor assignment and column number							Raw data:		
	A	D	A x D	B	C	D x B	C x D	Noise factor N_0		
	1	2	3	4	5	6	7	y_1	y_2	y_3
1	0	0	0	0	0	0	0			
2	0	0	0	1	1	1	1			
3	0	1	1	0	0	1	1			
4	0	1	1	1	1	0	0			
5	1	0	1	0	1	0	1			
6	1	0	1	1	0	1	0			
7	1	1	0	0	1	1	0			
8	1	1	0	1	0	0	1			

Where A – discharge current, A

C – flushing pressure, kg/cm^2 B - pulse on time, μsec

D – discharge voltage, V

The allocation of factors and their interactions are different in the final planning of experimental conditions as compared to the screening experiments. Therefore, the conditions for rough and finish machining as shows in **Table 1.3** and **1.4** are used in these experiments.

g) ***Experiment.***

Experiments were performed according to the input parameters in the orthogonal design.

h) ***Collection of data and analysis of results.***

The results were analysed graphically as well as statistically. Pareto ANOVA is used to determine the optimum combination of parameters.

i) ***Documentation.***

All the data and results were compiled and documented into a report.

j) ***Submission of report.***

The report will be submitted on the submission date to the dean office.

The flow of this project is shown schematically in the flow chart in **Figure 1.1**

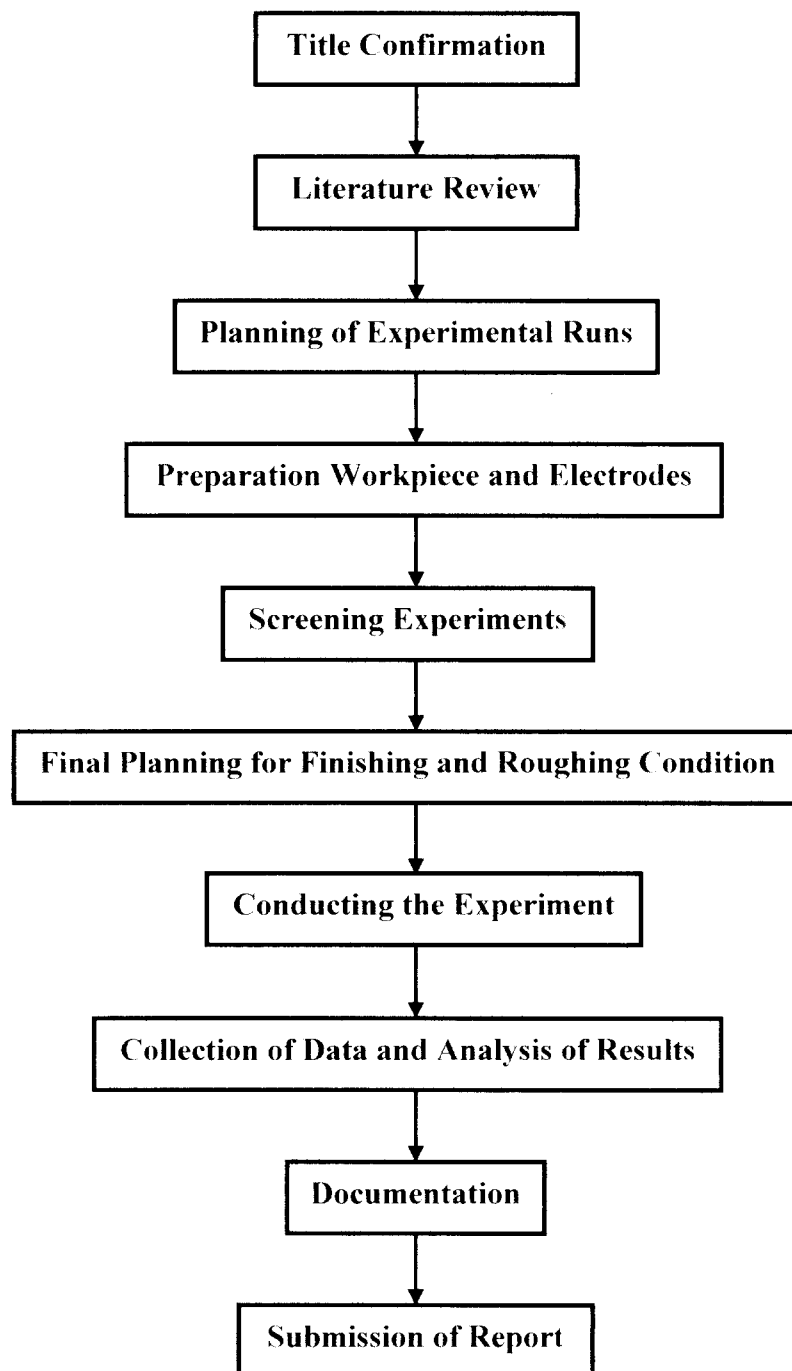


Figure 1.1 **Flow Chart**