

## TABLE OF CONTENTS

<b>HALAMAN PENGESAHAN</b>	ii
<b>HALAMAN PERNYATAAN</b>	iii
<b>NASKAH SOAL TUGAS AKHIR</b>	iv
<b>PROLOGUE</b>	v
<b>TABLE OF CONTENTS</b>	vi
<b>LIST OF TABLES</b>	ix
<b>LIST OF FIGURES</b>	x
<b>LIST OF APPENDIX</b>	xi
<b>LIST OF NOTATION</b>	xii
<b>ABSTRACT</b>	xiv
<b>CHAPTER I INTRODUCTION</b>	1
1.1 Research Background	1
1.2 Problem Formulation	3
1.3 Assumptions and Problem Boundaries	3
1.4 Research Objectives	4
1.5 Benefits of Research	4
<b>CHAPTER II LITERATURE REVIEW</b>	5
<b>CHAPTER III THEORETICAL BACKGROUND</b>	9
3.1 Electro Chemical Machining (ECM)	9
3.2 Multilayered Microfilters	12
3.3 Material Removal Rate	14
3.4 Design of Experiments	14
3.5 Statistical Analysis	16

3.5.1	Data Distribution Normality Test	17
3.5.2	Analysis of Variance	18
3.5.3	Regression Analysis	19
3.6	Classical Assumptions Test	19
3.6.1	Residual Distribution Normality Test	20
3.6.2	Heteroscedasticity Test	20
3.6.3	Multicollinearity Test	20
3.7	Experimental Effect Model	21
	<b>CHAPTER IV RESEARCH METHOD</b>	<b>22</b>
4.1	Object of Research	22
4.2	Research Materials	22
4.3	Research Tools	24
4.4	Experiment Procedures	24
4.5	Research Procedures	25
4.6	Flow Chart of Research	27
4.7	Experiment and Collecting Data Procedures	29
4.8	Experimental Result Measurement Procedures	30
	<b>CHAPTER V RESULT AND DISCUSSION</b>	<b>32</b>
5.1	Experiment Results	32
5.2	Experiment Results Analysis	33
5.2.1	MRR Analysis	33
5.2.2	Overcut Analysis	35
5.3	Statistical Analysis	36
5.3.1	Material Removal Rate (MRR)	36
5.3.2	Overcut	41

5.4	Mathematical Model Building	45
5.4.1	Mathematical Model for MRR	46
5.4.2	Mathematical Model for Overcut	47
5.5	Parameter Combination Analysis	48
	<b>CHAPTER VI CONCLUSION AND RECOMMENDATION</b>	50
6.1	Conclusion	50
6.2	Recommendation	50
	<b>REFERENCES</b>	51
	<b>APPENDICES</b>	53

## LIST OF TABLES

Table 2.1 Related Researches	6
Table 3.1 Analysis of Variance for 2 Factors (Montgomery & Runger, 2003)	18
Table 4.1 Parameters and Their Levels	25
Table 5.1 Factors and Their Levels	32
Table 5.2 Run Order of the Experiment	33
Table 5.3 Experimental MRR Result	33
Table 5.4 Comparison of Theoretical MRR and Experimental MRR	35
Table 5.5 Overcut Experimental Result	35
Table 5.6 Normality Test Result of MRR	37
Table 5.7 Analysis of Variance of MRR	37
Table 5.8 F Test Result for MRR	38
Table 5.9 T Test Result for MRR	39
Table 5.10 Goodness of Fit Test Result for MRR	39
Table 5.11 Result of Residual Normality Test for MRR	40
Table 5.12 Heteroscedasticity Test Result for MRR	40
Table 5.13 Variance Inflation Factor of MRR	41
Table 5.14 Normality Test Result for Overcut	41
Table 5.15 Result of Analysis of Variance for Overcut	42
Table 5.16 F Test Result for Overcut	42
Table 5.17 T Test Result for Overcut	43
Table 5.18 Goodness of Fit Result for Overcut	44
Table 5.19 Residual Normality Test Result for Overcut	44
Table 5.20 Heteroscedasticity Test Result for Overcut	45
Table 5.21 Variance Inflation Factor of Overcut	45
Table 5.22 Coefficients to Build Model for MRR	46
Table 5.23 Coefficients to Build Model for Overcut	47

## LIST OF FIGURES

Figure 3.1 Principal of ECM (Lee, 2000)	11
Figure 3.2 Microfilters (Gu & Miki, 2009)	13
Figure 3.3 General Model of System/ Process (Montgomery & Runger, 2003)	15
Figure 4.1 Electro-chemical Machine (Sudiarso et al, 2012)	22
Figure 4.2 Dimension of Workpiece (mm)	22
Figure 4.3 Isolation Area Dimension	23
Figure 4.4 Isolated Top-Side of Raw Material	23
Figure 4.5 Electrode Tool	23
Figure 4.6. Surface of Electrode Tool	24
Figure 4.7 Flow Chart of Research	27
Figure 4.8 Digital Scale Sartorius	31
Figure 4.9 Dinolite Digital Microscope	31
Figure 4.10 Overcut Measurement Sectors	31
Figure 5.1 Relationship between 2 Factors of Experiment	32
Figure 5.2 Comparison of MRR	34
Figure 5.3 Plot of Overcut	36
Figure 5.4 Hypothesis Test Acceptance Area for MRR	39
Figure 5.5 Hypothesis Test Acceptance Area for MRR	43
Figure 5.6 Plotting of Levels to the Mathematical Model for MRR	46
Figure 5.7 Plotting of Levels to the Mathematical Model for Overcut	47
Figure 5.8 Intersection of MRR and Overcut for Voltage	48
Figure 5.9 Intersection of MRR and Overcut for NaCl Concentration	49

## LIST OF APPENDIX

Appendix 1 Specifications of Stainless Steel 204.....	53
Appendix 2 Atomic Weight and Valence of Substances .....	56
Appendix 3 Calculation of Electrochemical Equivalent SS 204 and Theoretical MRR.....	57
Appendix 4 Value of MRR and overcut of each specimen.....	58

## LIST OF NOTATION

a	= Level of Factor A
A	= Atomic Weight (g/mol)
ANOVA	= Analysis of Variance
B	= Level of Factor B
B0	= Average of Experimental Result
B1	= Coefficient of factor-1
B2	= Coefficient of factor-2
B12	= Coefficient of interaction factor
C	= NaCl concentration (g/L)
Calculated D	= Absolute Value of Kolgomorov Smirnov Test
Calculated F	= Variability Value of ANOVA
Calculated T	= Calculation Value of T-Test
Calculated Z	= Calculation Value of Kolgomorov Smirnov Test
d	= Density (g/cm <sup>3</sup> )
D of Table	= Table Value of Kolgomorov Smirnov Test
d workpiece	= Workpiece dimension (mm)
df	= Degree of Freedom
disolated	= Isolation dimension (mm)
dL	= Lower Level Value of Durbin Watson Table
DoE	= Design of Experiment
dU	= Upper Level Value of Durbin Watson Table
DW	= Durbin Watson
Ea	= Electrochemical Equivalent (g)
ECM	= Electrochemical Machine
EP	= ECM
F	= Faraday Number (96500 As)
F of Table	= Table Value of ANOVA

H0	= Null Hypothesis
H1	= Alternate Hypothesis
I	= Electrical Current (A)
m1	= Workpiece Initial Mass before Machining (g)
m2	= Workpiece Mass after Machining (g)
MRR	= Material Removal Rate (g/s)
MRR $\hat{Y}$	= Prediction value of MRR
n	= Number of Replication
n level	= Number of Levels
OC	= Overcut
Overcut $\hat{Y}$	= Prediction value of overcut
OFAT	= One Factor at a Time
P-value	= Asymp. Sig or Significance Value of Calculation
R <sup>2</sup>	= R-square
SS	= Sum of Square
SS A	= Sum of Square of Factor A
SS B	= Sum of Square of Factor B,
SS AB	= Sum of Square of Interaction
SS E	= Sum of Square of Error
SS T	= Total Sum of Square,
t	= Machining Time (s)
T	= Number of Treatment
T of Table	= Table Value of T-Test
VIF	= Variance Inflation Factor
X <sub>1</sub>	= Level of Voltage (-1 or 0 or +1),
X <sub>1</sub> X <sub>2</sub>	= optimum level of factor interaction (-1 or 0 or +1)
X <sub>2</sub>	= Level of NaCl concentration (-1 or 0 or +1), and
Z of Table	= Table Value of Kolgomorov Smirnov Test