UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

EFFECT OF WIRE ELECTRICAL DISCAHRGE MACHINING (WEDM) PARAMETERS AND ADDITIVE TREATMENT ON SURFACE ROUGHNESS AND DIMENSIONAL STABILITY OF TOOL STEEL

Chew Seow Lee

Master of Manufacturing Engineering

(Manufacturing System Engineering)

2013

EFFECT OF WIRE ELECTRICAL DISCAHRGE MACHINING (WEDM) PARAMETERS AND ADDITIVE TREATMENT ON SURFACE ROUGHNESS AND DIMENSIONAL STABILITY OF TOOL STEEL

CHEW SEOW LEE

A thesis submitted
in fulfillment of the requirements for the degree of
Master of Manufacturing Engineering (Manufacturing System Engineering)

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2013

DEDICATION

I dedicate my research work to my beloved parents for their support. I am also taking this opportunity to dedicate this work to my loving hubby who has given me the everlasting momentum to pursue my master degree and endless supports to complete my thesis. Not forgetting also to dedicate this work to my family members and many friends who have rendered supported to me throughout the process. I will always appreciate all they have done. Without their love and support this work would not have been made possible.

TABLE OF CONTENT

ABSTRACT

The research study presented in this paper is to evaluate the wire electrical discharge machining process parameters; the pulse-on time and wire speed and the options of additive treatment on the work-piece after the conventional hardening process with sub-zero treatment on dimensional stability and surface roughness. The interaction among the input factors also do investigated to determine if there is significant pattern observed. A series of experiments have been performed on XW 42 cold work tool steel plate with the dimensions of 65mm x 130mm with thicknesses of 10 mm. The test specimens have machined by using different pulse-on time, wire speed and the options of sub-zero treatment by the NEEM Technology Series W-CUT-C-10 WEDM machine. A full factorial Design of Experiments procedure was used in this study. This experiment was based on two level of study with two replicates. The ANOVA analysis was undertaken to determine the significant input factors that affecting the output responses. SOLID Video Measuring Machine was used to measure the diameters of the WEDM output and Surface Roughness Tester was used to measure its surface roughness. Experimental equipments used in this research study have undergone the measurement system analysis to ensure all the data taken are reliable and within the specified confidence level required. The experiment results revealed that input factor pulse-on time has posted significance effect on the surface roughness and dimensional stability of XW 42 tool steel, whereas input factor wire speed shown to have no significance effect on these two output responses. Experiment results also revealed that sub-zero treatment have significance effect on the dimensional stability of the XW 42 tool steel but there was no significance effect on the surface roughness of this tool steel.

ABSTRAK

Kajian yang dipaparkan dalam kertas kerja ini ialah untuk mengkaji proses parameter Mesin Discas Elektrik Wayar (WEDM) iaitu nadi pada masa dan kelajuan wayar dengan opsyen proses aditif (sub-sifar) pada bahan kerja selepas proses pengerasan samada memepunyai kesan ke atas kestabilan dimensi dan kekasaran permukaan pada bahan kerja. Interaksi antara faktor- faktor input juga diselidik untuk memastikan samada corak yang ketara diperhatikan dalam kajian ini. Satu siri eksperimen telah dilakukan ke atas XW 42 alat plat keluli kerja sejuk yang berdimensi 65mm X 130mm dengan ketebalan 10mm. Spesimen uji telah dimesin dengan WEDM Neem Teknologi Siri W-CUT-C-10 dengan nadi pada masa, kelajuan wayar dengan opsyen proses sub-sifar pada bahan kerja. Prosedur Faktoran Penuh Reka Bentuk Eksperimen digunakan dalam kajian ini. Eksperimen ini memandukan pengajian 2 tingkat dan 2 pereplikaan. Analisis ANOVA telah digunakan untuk menentukan samada faktor input memberi kesan yang nyata ke atas reaksi output. Mesin video pengukuran 'Solid' telah digunakan untuk mengukur diamater pada output WEDM manakala penguji kekasaran permukaan 'Mitutoyo' telah digunakan untuk mengukur kekasaran permukaan bahan kerja yang telah dimesinkan. Alat-alat eksperimen yang digunakan dalam pengkajian ini telah melalui Sistem Analisis Pengukuran untuk memastikan semua data yang telah dikumpulkan boleh dipercayai dan berada dalam lingkungan tingkat keyakinan spesifik. Keputusan eksperimen telah menunjukkan faktor input nadi pada masa memberi kesan yang ketara ke atas kekasaran permukaan dan kestabilan dimensi pada bahan kerja XW 42 yang telah dimesinkan, manakala faktor input kelajuan wayar tidak menunjukkan kesan ketara ke atas reaksi output ini. Keputusan eksperimen ini juga menunjukkan proses sub-sifar mempunyai kesan yang ketara ke atas kestabilan dimensi pada bahan kerja XW 42 tetapi tiada kesan yang ketara ke atas kekasaran permukaan bahan kerja ini.

ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest and sincere appreciation to my supervisor, Dr Nur Izan Syahriah Binti Hussein, who has supported me throughout the entire period of preparing this thesis. Without her guidance and knowledge sharing, it is impossible for me to complete my thesis in a timely manner.

I am also very thankful to the management of College of Community Kepala Batas, Penang for allowing me to conduct my research experiment at their facility. Furthermore, I would like to acknowledge my appreciation to Mr Mohanadhas Kanagaraj, who has rendered invaluable assistance while carrying out my experiment. His valuable information and kind assistance enable me to complete my experiment successfully.

I would like to acknowledge and thankful to the management and technical team of Solid Precision Engineering Sdn Bhd in the overall measurement activities for this research.

Last but not least, I am very grateful to my hubby, Mr Boey Kok Hoong for his continuous motivation and spiritual support to sustain me in completing this thesis.

DECLARATION

I declare that the thesis entitle "Effect of Wire Electrical Discharge Machining (WEDM) Parameters and Additive Treatment on Surface Roughness and Dimensional Stability on Tool Steel" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature:

....

Name : Chew Seow Lee

Date : 12 June 2013

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Master of Manufacturing (Manufacturing System Engineering). The member of supervisory committee is as follow:

DR NUR IZAN SYAHRIAH BINTI HUSSEIN

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
Avg	-	Average
Bhd	-	Berhad
C	-	Carbon
CNC	-	Computer Numerical Controller
Cr	-	Chromium
Din	-	Diameter In
Dout	-	Diameter Out
DOE	-	Design of Experiments
Fe	-	Ferrum
http	-	Hypertext Transfer Protocol
HRc	-	Hardness Rockwell C scale
*I*p	-	Peak Current
μm	-	Micron
m/min	-	meter per minute
Mn	-	Manganese
Mo	-	Molybdenum
mm	-	Milimeter
Pulse ON	-	Pulse-on time
Ra	-	Average Roughness
Sdn	-	Sendirian
Si	-	Silicon
Tx	-	Treatment
V	-	Vanadium
VMM	-	Video Measuring Machine
WEDM	-	Wire Electrical Discharge Machining
www	-	World Wide Web
XW 42	-	Alloy steel grade from ASSAB

CHAPTER 1

INTRODUCTION

1.0 Background

Wire Electrical Discharge Machining (WEDM) is a non–traditional machining process which is widely used to manufacture components with intricate shapes, different hardness and profiles, which is popular used especially in the tool and die making industry. Even though, the use of WEDM has evolved from making a simple means of tools and dies to the best alternative of producing complex component, but to fabricate an accurate and precise die still remains as a difficult task for these die manufacturers. This research is carried out to evaluate the WEDM parameters on pulse-on time, wire speed and the effect of additive treatment (sub-zero treatment) on work-piece to reveal their impact on surface roughness of the XW 42 tool steel and the dimensional stability of the output, so as to assist the die-making industry to enhance their precision, hence revolutionizing the tool and die industries.

1.1 Problem Statement

The ideal case is to derive a dimensional stable work-piece and surface roughness below 2 μm with minimum cost and time on WEDM process. Under the present practices in the tool and die manufacturing, in order to derive better surface roughness and dimensional stability in terms of accuracy and precision in the work-piece is by performing numerous cuts on the WEDM process, commonly on the minimum of 3 cuts in order to derive surface roughness under 2μm and precision and accuracy below 20μm. This will not only impose additional cost on WEDM job but also extended the lead time for the job.

Even though lot of efforts have been carries out by many researchers and industrialists in the wide area of WEDM parameters optimization. WEDM parameter such as pulse-on time, pulse-off time and peak current by Nihat and Can (2003), Ahmet and Ulas (2004), and Kanlayasiri and Boonmung (2007), wire tension by Anish *et. al.* (2012), WEDM output responses such as surface roughness by Mustafa and Alp (2000), effect of cryogenics by Molinari e*t. al.* (2001) and Zhirafar *et. al.* (2007) which mainly focuses on the tool wears.

The propose solution is to perform a study on WEDM parameters that have significant effect on surface roughness and dimensional stability on XW 42 tool steel. The aims is to derive an optimum input factors that able to yield surface roughness of below 2μm and dimensional stability below 20μm. WEDM parameters to be put into investigation are pulse-on time and wire speed and options of additive treatment by means of sub-zero process after the conventional heat treatment on the XW 42 tool steel.

1.2 Value of the Research

The successful research outcomes may post great significance value in the following areas:-

i) Ability in fabricating a more precision tool and die. Better compete in today's competitive market environment.

ii) The well managed and controlled WEDM surface roughness will lead to better prediction and management of tool wear for an improved tool life.

1.3 Research Objectives

This research study will be targeted in deriving the following summarized objectives:

i) To investigate the significant interaction of the inputs factors (pulse-on time, wire speed, additive treatment) to the output responses (surface roughness and dimensional stability).

ii) To propose suitable input factors and variables that will simultaneously satisfy the the surface roughness and dimensional stability in terms of accuracy and precision of WEDM on XW 42 tool steel.

iii) To compare the effect of with and without sub-zero treatment on XW 42 tool steel.

1.4 Scope of Study

All the research experimental procedures, results and analysis are within this following scope:

i) Wire Electro-Discharge Machining used – Legend II Neem Technology.

ii) XW42 tool steel will be used as the work-piece material.

iii) Zinc coated brass wire of diameter 0.25mm will be used.

iv) Parameter for the input factors to be studied are pulse-on time, wire speed and effect of the sub-zero treatment on the work-piece.

v) Output responses to be investigated are surface roughness and dimensional stability of the work-piece.

vi) The full factorial on the Design of Experiment (DOE) tool will be evaluated using Minitab software Release 15.1.30.0.

1.5 Activity Plans

The activity plans and scheduling for this research study as illustrated in the attached Gantt chart in Appendix A.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This research experimentation is to study on the effect of wire electrical discharge machining (WEDM) parameters and the effect of additive treatment on surface roughness and dimensional stability of the tool steel. The WEDM is an advanced machining process which is widely used to machine tool steel. The WEDM parameters on pulse-on time and wire speed will be studied. The selected work-piece material used is XW 42 tool steel and additive treatment mentioned above is a sub- zero process. This study is to evaluate surface roughness and dimensional stability of XW 42 tool steel on WEDM process and the sub-zero treatment. Under this chapter, information and literatures finding on XW 42 tool steel, the fundamental of WEDM and its corresponding parameters and the process of heat treatment as well as the additive treatment will be discussed.

2.1 Tool Steel Material

The tool steel used for this research experiment is from XW 42 grade tool steel from ASSAB Corporation. Alternatively, it also named as D2 under AISI/ASTM coding, 1.2379 from Germany W-No, 2312 under Sweden SS code, 03-11 under Sandvik Coromant CMC in Table 2.1. It consists of high-carbon and high chromium alloyed with molybdenum and vanadium characterized by:

i) High compressive strength.

ii) High wear resistance.

iii) High stability in hardening.

iv) Good through hardening properties.

v) Good resistance to tempering-back.

XW 42 grade is a versatile tool steel, proposed for tools which require high wear resistance, with moderate shock resistance (toughness), harder materials; when forming with tools subjected to bending stresses and where high impact loads are involved. It can be supplied in various finishes, such as hot-rolled, pre-machined and fine machined condition, also available in the form of hollow bar and rings. XW 42 can be used for blanking, fine-blanking, punching, other cutting, forming, cropping, shearing, trimming, and crimping processes.

Table 2.1 Material codes comparisons (Source: Sandvik-Coromant, 2012)

Uddeholm grades	ASSAB	Sandvik Coromant CMC	Sweden SS	Germany W.-No	USA AISI/ASTM
Cold work steels					
ARNE ®	DF-2	02.1	2140	1.2510	O1
VANADIS 23	ASP-23		2725	1.3344	M3 Class 2
VANADIS 30	ASP-30		2726	(1.3204)	-
VANADIS 60	ASP-60		2727	1.3241	-
CARMO/CALMAX	/635H/635			1.2358	
CHIPPER ®/VIKING	VIKING		-	(1.2631)	-
FERMO ®	-		-	-	-
RIGOR ®	XW-10	03.11	2260	1.2379	A2
SVERKER ® 3	XW-5	03.11	-	1.2436	D6
SVERKER ® 21	XW-41	03.11	2312	1.2379	D2
VANADIS 10	VANADIS 0	-	2310	-	-
VANADIS 4	VANADIS 4	-	-	-	-
VANADIS 6	VANADIS 6	-	-	-	

2.1.1 Chemical Composition of XW 42

XW 42 tool steel consists of 84.35% of iron, 1.55% of Carbon, whereby this grade of material is heat treatable, categorized under high carbon steel. Other remaining compositions are silicone, manganese, chromium, molybdenum and vanadium in Table 2.2.

Table 2.2 Chemical compositions of XW 42 (Source: ASSAB, 2013)

Component Elements Properties	Metric	English
Carbon, C	1.55 %	1.55 %
Chromium, Cr	11.8 %	11.8 %
Iron, Fe	84.35 %	84.35 %
Manganese, Mn	0.40 %	0.40 %
Molybdenum, Mo	0.80 %	0.80 %
Silicon, Si	0.30 %	0.30 %
Vanadium, V	0.80 %	0.80 %

2.1.2 Physical and Mechanical Properties of XW 42

Following are the physical and mechanical properties of XW 42 as shown in Table 2.3 and Table 2.4.

Table 2.3 Physical properties of XW 42 (Source: ASSAB, 2013)

Physical Properties	Metric	English
Density	7.67 g/cc	0.277 lb/in^3
	7.61 g/cc @Temperature 400 °C	0.275 lb/in^3 @Temperature 752 °F
	7.64 g/cc @Temperature 200 °C	0.276 lb/in^3 @Temperature 392 °F

Table 2.4 Mechanical properties of XW 42 (Source: ASSAB, 2013)

Mechanical Properties	Metric	English	Comments
Hardness, Rockwell C	41	41	1020°C Austenitizing temperature, for tempering at 650°C
	44	44	1050°C Austenitizing temperature, for tempering at 650°C
	55	55	1020°C Austenitizing temperature, for tempering at 550°C
	57	57	1050°C Austenitizing temperature, for tempering at 400°C
	59	59	1020°C Austenitizing temperature, for tempering at 400°C
	60	60	1050°C Austenitizing temperature, for tempering at 200°C
	61	61	At 980°C during hardening, soaking time 30 minutes
	62	62	1050°C Austenitizing temperature, for tempering at 550°C
	62	62	Hardened and tempered.
	62.5	62.5	At 980°C during hardening, soaking time 60 minutes
	63	63	1020°C Austenitizing temperature, for tempering at 200°C
	64.25	64.25	At 1060°C during hardening, soaking time 30 minutes
	65	65	At 1020°C during hardening, soaking time 30 minutes
	65.5	65.5	At 1020°C during hardening, soaking time 60 minutes
Modulus of Elasticity	193 GPa	28000 ksi	
	173 GPa @Temperature 400 °C	25100 ksi @Temperature 752 °F	
Compressive Strength	1900 MPa	276000 psi	HRC 55 R_c0.2
	2200 MPa	319000 psi	HRC 62 R_c0.2.

2.1.3 Thermal Properties of XW 42

Following are the thermal properties of XW 42 as shown in Table 2.5.

Table 2.5 Thermal properties of XW 42 (Source: ASSAB, 2013)

Thermal Properties	Metric	English
CTE, linear	12.4 µm/m-°C @Temperature 20.0 - 200 °C	6.89 µin/in-°F @Temperature 68.0 - 392 °F
	13.4 µm/m-°C @Temperature 20.0 - 400 °C	7.44 µin/in-°F @Temperature 68.0 - 752 °F
Specific Heat Capacity	0.460 J/g-°C @Temperature 20.0 °C	0.110 BTU/lb-°F @Temperature 68.0 °F
Thermal Conductivity	20.0 W/m-K @Temperature 20.0 °C	139 BTU-in/hr-ft²-°F @Temperature 68.0 °F
	21.0 W/m-K @Temperature 200 °C	146 BTU-in/hr-ft²-°F @Temperature 392 °F
	23.0 W/m-K @Temperature 400 °C	160 BTU-in/hr-ft²-°F @Temperature 752 °F

2.2 Wire Electrical Discharge Machining (WEDM)

Today, as we embrace the 21st century, there are many types, various features and improvements of wire electrical discharge machining (WEDM) machines in the market, but the principle of the WEDM are still the same as applied to every WEDM machines. To carry out this study, the fundamental and principle and practical uses of WEDM are very important. WEDM was introduced in the late 1960s'. It has revolutionized the tool and die-making industries. It is the most exciting and diversified machine tool and offering numerous benefits to tool and die fabricator introducing many unique functions as summarized below:

i) WEDM is capable to machine any hardness of conductive materials, range from common materials such as tool steel, copper, and graphite, to exotic space-age alloys including titanium, carbide, polycrystalline diamond compacts as well as conductive ceramics.

ii) In WEDM, there is no physical contact between wire and work-piece, therefore there is no pressure imparted on the work-piece.

iii) WEDM timing, accuracy, surface finish for the WEDM processes are predictable. Generally, WEDM produces better surface finishing as compare to other machining process such as milling cutters which will leave over tooling marks. Subsequent surface finishing process can be omitted due to less or no residual burrs on the work-piece.

iv) WEDM is highly automated, hence provides designers more latitude in tool and dies design, better management and control of manufacturing.

There are various sizes and types of WEDM such as flush or submerged type machines to fit the needs of the consumer. Large scale WEDM machine able to machine work-pieces more than 4 metric tons and can cut work-piece with the thickness more than 500 mm. There is a standardize Automatic Wire Threaders (AWT) equipment installed on most WEDM models which consists of table travels in X-Y axis and U / V travels as shown at Figure 2.1. WEDM is also capable of performing tapers cut of 20-30 degrees depending on the work-piece thickness.

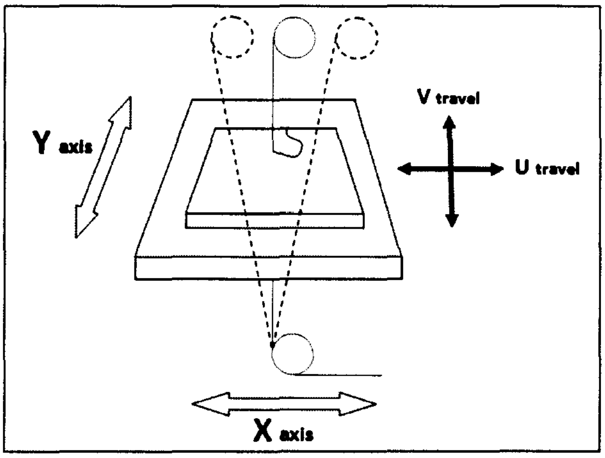

Figure 2.1 WEDM Table Movement

2.2.1 Principle of WEDM

WEDM machine uses CNC movement to produce the intricate shape and profile during its operation. It is a thermal mass reducing process that uses a continuous-traveling vertical wire under tension as an electrode with dimension range of 0.05 ~ 0.25mm remove material by means of rapid, controlled, repetitive spark.