Faculty of Manufacturing Engineering

PARAMETER OPTIMIZATION ON HYBRID MICRO WIRE ELECTRICAL DISCHARGE TURNING

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PARAMETER OPTIMIZATION ON HYBRID MICRO WIRE ELECTRICAL DISCHARGE TURNING

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DECLARATION

I declare that this thesis entitled “Parameter Optimization on Hybrid Micro Wire Electrical Discharge Turning” 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 : ……

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature	: ……..
Supervisor Name	: ASSOC. PROF. DR. RAJA IZAMSHAH BIN RAJA ABDULLAH
Date	: ……..

DEDICATION

This thesis is dedicated to

my beloved and great parents, who never stop giving of themselves in countless ways,

my beloved brother and sisters, who stands by me when things look bleak and hope this thesis may inspire you to excel in any field in which you venture during your life journey

ABSTRACT

Micro-machining is expected to play an important role in today's manufacturing technology. However, the traditional down-scaling process creates challenges relating to process stability and materials behaviour especially for small difficult-to-machine made materials. Therefore, a suitable material removal process to perform micro-machining on cylindrical components is spark erosion process. In this study, the new hybrid micro-machining process is developed. This process is synonym with the name of wire electrical discharged turning (WEDT) which incorporates a turning process of rotating workpiece to continuous travelling electrode wire in electrical discharged conditions produced by wire electrical discharge machine. The objective of this research is to develop and evaluate the advance machinery and equipment for rotary axis mechanism that is being used to rotate the workpieces. The research focuses on optimizing the process parameter of hybrid WEDT for micro-machining straight shaft cylindrical component made of Ti6Al4V as materials. The issues pertaining to hybrid WEDT process on surface roughness (Ra) in the past have been explored comprehensively. The rotary axis mechanism that works well with WEDM machine has been successfully developed and the micro turning operations has been performed. The parameter optimization consideration on Ra begins with two stage screening. Firstly, the suitable combination parameter and its range is properly selected. Then, the selection of appropriate parameters and range is further screened by Taguchi orthogonal array L_{12}. From the 11 process parameters that consist of electrical, non-electrical and rotary axis mechanism characteristics, only four has been selected to perform optimization by response surface methodology (RSM) which are intensity of pulse, voltage open, wire tension and rotational spindle speed. The other parameters are fixed at best level to produce low Ra value which is identified by Alicona Infinite Focus microscope (IFM). The optimal Ra that is produced by experiment through desirability approach is as much as 4.0143 μm with relative error as much as 5.9% compared to the prediction. The parameter and its level are pulse intensity of 8 Notch, wire tension of 14.8 Newton, voltage of 7 Notch and rotational spindle speed of 2390 rev/min. The machined parts surface is being deteriorated accordingly to the violent energy density generated by high pulse intensity and voltage, low wire tension and spindle speed.

ABSTRAK

Pemesinan mikro dianggarkan memain peranan penting dalam teknologi pembuatan kini. Namun, pemesinan penskalaan kecil bagi proses tradisional adalah mencabar, ia berkait dengan kestabilan proses dan sifat bahan terutama jenis bahan sukar dimesin bahkan dalam penskalaan kecil. Oleh itu, proses pemotongan yang sesuai dalam melaksanakan pemesinan mikro pada bendakerja berbentuk silinder adalah proses cucuhan hakisan. Dalam penyelidikan ini, proses pemesinan hibrid mikro terbaru telah dibangunkan. Proses ini sinonim dengan nama pemesinan larik wayar nyahcas elektrik (WEDT) dimana ia menggabungkan putaran bendakerja terhadap wayar elektrod dalam persekitaran nyahcas elektrik yang dibekalkan oleh mesin wayar nyahcas elektrik. Objektif penyelidikan ini untuk membangun dan menilai terhadap mesin dan kelengkapan termaju bagi mekanisme paksi putar yang digunakan untuk memutarkan bendakerja. Penyelidikan ini memfokuskan pengoptimum parameter bagi proses hibrid mikro WEDT dalam pemesinan mikro komponen silinder berbentuk aci lurus yang diperbuat oleh bahan Ti6Al4V. Isu yang berkaitan proses hibrid WEDT terhadap kekasaran permukaan (Ra) pada kajian lepas telah dikaji secara menyeluruh. Mekanisme paksi putaran yang berfungsi dengan baik pada mesin WEDM telah berjaya dibangunkan dan melaksanakan operasi melarik mikro. Pengoptimum parameter untuk Ra bermula dengan dua peringkat penyaringan. Pertama, kombinasi dan julat yang sesuai diantara parameter dipilih. Seterusnya, penyaringan peringkat kedua dilakukan dengan menggunakan teknik Taguchi pada parameter dan julat yang telah dipilih. Daripada 11 parameter yang dipilih, hanya empat sahaja parameter yang dibawa dan dioptimumkan oleh kaedah metodologi permukaan sambutan (RSM) iaitu keamatan denyutan, voltan buka, ketegangan wayar dan kelajuan putaran spindel. Parameter yang lain dikekalkan pada tahap minimum terhadap prestasi Ra yang mana ia diukur oleh mikroskop Alicona Infiniti Fokus Mikroskop (IFM). Keoptimalan Ra hasil daripada eksperimen yang telah dibangunkan dengan kaedah kebolehinginan bernilai 4.0143 μm dengan ralat relatif sebanyak 5.9% apabila dibandingkan dengan nilai ramalan. Kemerosotan prestasi pada permukaan bendakerja dialami apabila keamatan denyutan dan voltan buka ditetapkan tinggi disamping ketegangan wayar yang kendur dan kelajuan putaran spindel yang perlahan.

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σ	-	(Sigma) units for stress calculation
μ	-	(Micro) metric unit denoting a factor of 10−6 or represent small
α	-	(Alpha) coded-unit distance for axial points in central composite design
δ	-	Deflection
df	-	Degrees of Freedom
k	-	number of factors in design
R^2	-	Index of determination
n	-	number of observations in sample
P	-	Probability Value
V	-	(volt) unit for electric potential difference
D	-	Diameter
T	-	Thickness
ID	-	Inside Diameter
OD	-	Outside Diameter
Pa	-	(pascal) unit of pressure/stress
Ω	-	(Ohm) unit of electrical resistance
LA	-	Machine power supply low
MP	-	Machine power supply medium
HP	-	Machine power supply high
L, l	-	Length
Ra	-	Arithmetic average surface roughness

LIST OF ABBREVIATIONS

3D	-	Three Dimension
ABEC	-	Annular Bearing Engineering Committee
AC	-	Alternating Current
AISI	-	American Iron and Steel Institute
ANOVA	-	Analysis of Variance
C.V.	-	Coefficient of Variation
CAD	-	Computer-Aided Design
CAM	-	Computer-Aided Manufacturing
CCD	-	Central Composite Design
CNC	-	Computer Numerical Control
CWEDT	-	Cylindrical Wire Electrical Discharge Turning
DC	-	Direct Current
EDM	-	Electrical Discharge Machining
FCCD	-	Face-centred Central Composite Design
FI	-	Factor Interaction
HSS	-	High Speed Steel
ICSP	-	In Circuit Serial Programming
IDE	-	Integrated Development Environment
IFM	-	Infinite Focus Microscope
Ip	-	Intensity of Pulse
ISO	-	International Standardization Organization
LCD	-	Liquid-Crystal Display
LED	-	Light-Emitting Diode
LQ	-	Liquid Quantity
LR	-	Liquid Resistivity

M	-	Metric
MRR	-	Material Removal Rate
OA	-	Orthogonal Array
OFF	-	Off Time
PIC	-	Programmable Interface Controllers
PRESS	-	Predicted Residual Error Sum of Squares
PT	-	Pre-Tension
PWM	-	Pulse-Width Modulation
RSM	-	Response Surface Methodology
SA	-	Stabilizer A
SB	-	Stabilizer B
SC	-	Stabilizer C
SE	-	Stabilizer E
SEM	-	Scanning Electron Microscopy
Si_3N_4	-	Silicon Nitride
Ti6Al4V	-	Titanium Alloy Grade 5
USB	-	Universal Serial Bus
VG	-	Voltage Gap
Vo	-	Voltage Open
WEDG	-	Wire Electrical Discharge Grinding
WEDM	-	Wire Electrical Discharge Machining
WEDT	-	Wire Electrical Discharge Turning
WS	-	Wire Speed
WT	-	Wire Tension

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