



Faculty of Manufacturing Engineering

SURFACE INTEGRITY AND TOOL WEAR OF HARDENED HTCS-150 STEEL (52 HRC) IN MILLING WITH TiAlN COATED CARBIDE

Anis Afuza binti Azhar

Master of Science in Manufacturing Engineering

2019

**SURFACE INTEGRITY AND TOOL WEAR OF HARDENED HTCS-150 STEEL
(52 HRC) IN MILLING WITH TiAlN COATED CARBIDE**

ANIS AFUZA BINTI AZHAR

**A thesis submitted
in fulfilment of the requirements for the degree of Master of Science
in Manufacturing Engineering**

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

I declare that this thesis entitled “Surface Integrity and Tool Wear of Hardened HTCS-150 Steel (52 HRC) in Milling with TiAlN Coated Carbide” 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 : Anis Afuza binti Azhar.....

Date :

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 : PM. Ir. Dr. Mohd Hadzlev Bin Abu Bakar
:.....

Date :.....

DEDICATION

To my beloved mother, father, husband, parent-in-law, my family and all my supportive friends.

ABSTRACT

Recent development in metal stamping introduced a new die namely hardened High Thermal Conductivity Steel-150 (HTC-150). Understanding the cutting parameters, surface characteristics and cutting tool wear during machining this new die would lead to efficiency in machining operation. This research concentrated on the finishing process in machining HTCS-150 hardened steel (52 HRC) using ball nose end mill TiAlN coated carbide insert. The purpose of this study is to develop the regression model and optimization focused on the relationship between the cutting parameters (cutting speed, feed rate and axial depth of cut) and the response (surface roughness and cutting tool wear) by using Box-Behnken approach under Response Surface Methodology (RSM) experimental design. In addition to model development, Analysis of Variance (ANOVA) was employed to identify significant factors that influenced the surface roughness and cutting tool wear. Further analysis of surface characteristics and cutting tool wear were observed under Scanning Electron Microscope (SEM). Experimental processes were carried out using Variaxis MAZAK CNC 5 axis milling, assisted by the Design Expert 10 analysis software. Ranges of cutting parameters selected were 120-130 m/min cutting speeds, 0.3-0.5 mm/tooth feed rates, 0.1-0.5 mm axial depth of cut and 0.01 mm constant radial depth of cut. The results show the model developed adequately represent the process with modeling validation runs within the 90% of prediction interval and their residual errors compared to the predicted values were less than 10%. The optimization results show that the lowest surface roughness achieved at 125 m/min cutting speed, 0.30 mm/tooth feed rate and 0.1 mm axial depth of cut. Combination of cutting parameters for the lowest cutting tool wear recorded as 130 m/min cutting speed, 0.4 mm/tooth feed rate and 0.1 mm axial depth of cut. The ANOVA analysis shows that for the surface roughness, most influenced cutting parameters was axial depth of cut followed by feed rate and cutting speed. Meanwhile, for cutting tool wear, feed rate and depth of cut recorded as most influenced cutting parameter followed by cutting speed. Observation using SEM observed that feed marks, scratch, adhered material, smeared material, and surface porosity were major defects on the machined surface. Analysis of wear characteristics presented abrasion, coating delamination, adhesion, formation of built-up edge and chipping were among failure mechanisms observed. The results from experimental provide useful information to obtain ultra-fine surface finish and decrease the cutting tool wear during machining HTCS based materials to minimize post processing activities.

ABSTRAK

Perkembangan terbaru dalam logam hantakan panas memperkenalkan acuan baru iaitu Besi Berkonduktiviti Haba Tinggi (HTCS-150) yang dikeraskan. Memahami parameter pemotongan, ciri-ciri permukaan dan kehausan mata alat semasa pemesinan acuan baru ini akan membawa kepada kecekapan dalam operasi pemesinan. Penyelidikan ini tertumpu pada proses pemesinan akhir dalam pemesinan HTCS-150 yang dikeraskan (52 HRC) dengan menggunakan mata alat karbida bersalut TiAlN endmill yang berbentuk separa bulatan. Objektif kajian ini adalah untuk membina model matematik dan menumpukan optimasi kepada hubungkait antara pembolehubah pemotongan (kelajuan pemotongan, kadar kemasukan dan kedalaman pemotongan) dan hasil pemesinan (kekasaran permukaan dan kadar kehausan mata alat) dengan menggunakan pendekatan Box-Behnken di bawah Response Surface Methodology (RSM). Sebagai penambahan kepada pembinaan model matematik, Analisis of varians (ANOVA) digunakan untuk mengenalpasti faktor-faktor penting yang mempengaruhi kekasaran permukaan dan kehausan mata alat. Seterusnya, analisis lanjut tentang kekasaran permukaan dan kehausan mata alat telah diperhatikan di bawah Imbasan Electron Mikroskop (SEM). Proses eksperimen dijalankan menggunakan mesin kisar menegak MAZAK 5 paksi dan perisian Design Expert 10 iaitu sebagai perisian analisis. Julat parameter pemotongan yang dipilih adalah 120-130 m/min untuk kelajuan pemesinan, 0.3-0.5 mm/mata alat untuk kadar kemasukan dan 0.1-0.5 mm bagi kedalaman pemotongan secara menegak, manakala kedalaman bagi pemotongan secara paksi Y (melintang) adalah tetap iaitu 0.01mm. Keputusan menunjukkan model yang dibentuk cukup untuk menggambarkan proses kajian dengan ujian pengesahan model dengan kadar 90% jarak ramalan dan baki ralat perbandingan kepada nilai ramalan adalah kurang daripada 10%. Keputusan optimisasi menunjukkan kekasaran permukaan paling rendah dicapai pada kelajuan pemotongan 125 m/min, kadar kemasukan 0.3 mm/mata alat dan kedalam pemotongan 0.1 mm. Gabungan pembolehubah pemotongan untuk menghasilkan kadar kehausan mata alat paling rendah pula dicatatkan pada kelajuan pemesinan 130 m/min, kadar kemasukan 0.40 mm/mata alat dan kedalam pemotongan 0.1 mm. Bagi kekasaran permukaan, analisis ANOVA menunjukkan pembolehubah pemotongan yang paling mempengaruhi hasil kekasaran permukaan adalah kedalam pemotongan diikuti oleh kadar kemasukan dan seterusnya kelajuan pemotongan. Manakala untuk kadar kehausan mata alat, kadar kemasukan dan kedalam permukaan dicatat sebagai pembolehubah pemotongan yang paling mempengaruhi diikuti kelajuan pemesinan. Pemerhatian dengan menggunakan SEM menunjukkan tanda kemasukan, calar, bahan tambahan, bahan pelet dan keliangan yang terdapat pada permukaan merupakan kecacatan yang utama pada permukaan yang dimesin. Hasil daripada percubaan memberikan maklumat berguna untuk mendapatkan permukaan ultra-halus dan mengurangkan alat pakai selama pemesinan bahan berdasarkan HTCS untuk meminimalkan kegiatan pemprosesan pelanjutan.

ACKNOWLEDGEMENTS

The success of this research has been due to the invaluable contributions of various individuals. I would like to take this opportunity to acknowledge their efforts. First, I would like to express my sincere appreciation to my supervisor, PM. Ir. Dr. Mohd Hadzley bin Abu Bakar for his support, encouragement, invaluable advice and exceptional guidance throughout my master bachelor study. I would also like to thank the members of my advisory committee Dr. Mohd Shahir bin Kasim for their scientific inputs and advice.

I would like to acknowledge the support from Universiti Teknikal Malaysia Melaka, and The Ministry of Higher Education, Malaysia through MyBrain UTeM 2016-2018 and the grant FRGS/1/2017/TK03/FKP-AMC/F00341 for providing the opportunity, time and scholarship which enabled this research to be carried out. I would also express my gratitude to Miyazu (M) Sdn Bhd for material supplies. In addition, special thanks to assistant engineers from Faculty of Manufacturing Engineering especially Mr. Hanafiah, Mr. Azhar, Mr. Taufik and others for contributing the progress of this research. Lastly, I would like also thank all my colleagues for their assistance and input knowledge to make this study succeed.

I wish to thank my beloved mother, father, my parents-in-law and family for their continuous support and encouragement. Special thank goes to my husband Muhammad Nazirul Hisyam bin Mokhtar for the unconditional trust, unbreakable support and unreserved motivation he has provided.

TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATION	
ABSTRACT	i
ABSTRAK	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	ix
LIST OF APPENDICES	xiii
LIST OF ABBREVIATIONS	xiv
LIST OF SYMBOLS	xvi
LIST OF PUBLICATIONS	xvii
CHAPTER	
1. INTRODUCTION	1
1.1 Research background	1
1.2 Problem statement	3
1.3 Research objectives	4
1.4 Scope of research	4
1.5 Significant of research	6
1.6 Organization of thesis	6
2. LITERATURE REVIEW	8
2.1 Introduction	8
2.2 Cutting tools	12
2.2.1 Carbide	14
2.2.2 Coating	15
2.3 Material of the workpiece	17
2.3.1 High thermal conductivity steel 150	17
2.3.2 AISI D2 tool steel	18
2.4 Cutting parameters	19
2.4.1 Effect of cutting parameters on tool wear	20
2.4.2 Effect of cutting parameters on surface finish	20
2.5 Analysis to represent quality of die machining	22
2.5.1 Surface integrity	22
2.5.2 Surface profile	22
2.5.3 Tool wear and wear mechanism	26
2.5.3.1 Flank wear	27
2.5.3.2 Notch wear	29
2.5.3.3 Crater wear	29
2.6 Modelling and optimization of machining performance	35
2.6.1 Response surface methodology	35
2.6.2 Box behnken design	37
2.7 Previous study on machining of die with ball end mill	39
2.8 Summary	45

3. METHODOLOGY	46
3.1 Project flow chart	46
3.2 Experimental design and variable	48
3.2.1 Design of experiment	48
3.3 Research procedure	52
3.3.1 Workpiece preparation	53
3.4 Tool holder and insert preparation	57
3.4.1 Mitsubishi end mill ball-nose insert	57
3.4.2 Insert tool holder	59
3.5 Experimental setup	60
3.6 Equipment	61
3.6.1 CNC milling	61
3.6.2 Measuring instrument	62
3.6.2.1 Tool wear measurement	63
3.6.2.2 Surface roughness, ra measurement	64
3.6.2.3 Mitutoyo wizard hardness tester	65
3.6.3 Tool and workpiece specimen preparation	65
3.6.4 Scanning electron microscopy	66
3.7 Summary	68
4. RESULT AND DISCUSSION	69
4.1 Response surface methodology analysis	69
4.1.1 Result of surface roughness	70
4.1.1.1 Surface roughness profile	71
4.1.1.2 ANOVA analysis of the response surface quadratic model for surface roughness	72
4.1.1.3 Diagnose of the surface roughness	74
4.1.1.4 Determination of significant factors influencing surface roughness	77
4.1.1.5 The equation in terms of coded factors and terms of actual factors in surface roughness model	83
4.1.1.6 Surface roughness model validation	84
4.1.1.7 Percentage error between predicted and experimental of surface roughness	84
4.1.2 Result of tool wear performance	85
4.1.2.1 Tool wear	86
4.1.2.2 ANOVA analysis of the response surface quadratic model for tool wear	87
4.1.2.3 Diagnose of the tool wear	89
4.1.2.4 Determination of significant factors influencing tool wear	91
4.1.2.5 The equation in terms of coded factors and terms of actual factors in tool wear model	97
4.1.2.6 Tool wear model validation	98
4.1.2.7 Percentage error between predicted and experimental of tool wear	98

4.2 Observation surface profile	100
4.3 Analysis tool wear and wear mechanism	103
4.4 Summary	108
5. CONCLUSION AND RECOMMENDATION	110
5.1 Conclusion	110
5.2 New contribution to body of knowledge	112
5.3 Recommendation	112
REFERENCES	114
APPENDICES	127

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	The physical and mechanical properties of HTCS-150 tool steel under 300K test temperature (Rovalma, 2012)	17
2.2	Thermal properties of HTCS-150 tool steel under 300K test temperature (Rovalma, 2012)	17
2.3	Properties of HTCS-150 alloy compared with a conventional metal stamping die, AISI D2 steel (Rovalma, 2012)	18
2.4	Chemical properties of AISI D2 tool steel (%wt) (Rovalma, 2012)	18
2.5	Mechanical properties of the AISI D2 tool steel (wt. %)	19
2.6	Coded factor levels for a Box–Behnken design for a three-variable system	38
2.7	Summarizing of past research of milling machine while using ball end mill on dies and the research response	39
3.1	Machining parameter level	48
3.2	Controlled machining parameters for study	51
3.3	Machining layout based on Box-Behnken approach	51
3.4	HTCS-150 material chemical composition in %wt (at specific location after tested using EDAX)	53
3.5	Physical and mechanical properties of HTCS-150 tool steel under	54

	300K test temperature (Rovalma, 2012)	
3.6	Thermal properties of HTCS-150 tool steel under 300K test temperature (Rovalma, 2012)	54
3.7	Insert tool holder detail dimension value (Mitsubishi, 2013)	60
3.8	The specification of SJ-301 MITUTOYO portable surface roughness tester	65
3.9	The specification of Mitsubishi RA-90	66
3.10	ZEISS EVO 50 machine specification	67
4.1	Experimental design	70
4.2	Experimental design and surface roughness result	71
4.3	Sequential model sum of square for surface roughness model	72
4.4	Model summary statistics	72
4.5	Lack of fit test for surface roughness model	72
4.6	ANOVA analysis table for surface roughness response	73
4.7	Fit statistics of surface roughness	74
4.8	Result for validation process of surface roughness	84
4.9	The average value of percentage error	85
4.10	The combination of machining parameters and results of tool wear	86
4.11	Sequential model sum of squares (SMSS) analysis for tool wear model	87
4.12	Lack of fit test for tool wear model	87
4.13	ANOVA analysis table for tool wear	88
4.14	Model summary statistics of tool wear	89
4.15	Result for validation process of tool wear model	98
4.16	The average value of percentage error	99

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	HTCS-150 raw material during machining to shaped according stamping design (Azhar, 2017)	9
2.2	Machining HTCS-150 at rough condition (Azhar, 2017)	10
2.3	Finish machining die part for assembly process (Azhar, 2017)	11
2.4	Hardness of tool materials versus temperature	13
2.5	Hardness and toughness of tool materials (Dadic, 2013)	14
2.6	The surface damage profile (Ezilarasan, et al., 2011)	23
2.7	Crack (Fatin, 2015)	24
2.8	Feed mark and smeared material (Hassan et al., 2014)	24
2.9	Scratch (Fatin, 2015)	25
2.10	Metal debris (Hassan et al., 2014)	26
2.11	The different wear mechanisms (Tache and Dumitru, 2008)	27
2.12	Flank wear on the ball nose end mill (Hamaguchi et al., 2011)	28
2.13	The flank wear curve (Stephenson and Agapiou, 1997)	28
2.14	Notch wear (Kassim et al., 2013)	29
2.15	Crater wear (Bhatt et al., 2010)	30
2.16	Abrasive wear (Da Silva et al., 2011)	31
2.17	Adhesive wear (Da Silva et al., 2011)	32

2.18	Diffusion wear (Gastel et al., 2001)	33
2.19	Schematic image of cutting tool with BUE (Hassan, 2010)	34
2.20	BUE on the DOC line (Kasim et al., 2013)	34
2.21	Chipping (Liew and Ding, 2008)	35
2.22	Points representing the experimental runs of a three-factor Box–Behnken	38
3.1	Flow chart of the study	47
3.2	RSM approach flow chart	50
3.3	Experimental process procedure summary	52
3.4	EDAX analysis of HTCS-150 tool steel	54
3.5	Mitshubishi EDM-Wire Cut	55
3.6	HTCS-150 workpiece dimensions	56
3.7	Mitutoyo hardness tester machine	56
3.8	Final experiment work piece material block	57
3.9	The PVD-TiAlN coated code number SFRT20 Tool insert supply by MITSHUBISHI material	58
3.10	The micrographic PVD-TiAlN coated tools, showing the coating layer approximately 4 μm	58
3.11	Dimension and geometry of PVD-TiAlN coated carbide insert	59
3.12	Mitsubishi tool holder	59
3.13	Mitsubishi insert tool holder dimension	60
3.14	Cutting tool positioning on workpiece	61
3.15	(a) DMU 60 monoblock milling machine; (b) Experiment setup; (c) Probe	62

3.16	Mitutoyo tool maker microscope	63
3.17	Tool wear measurement on Mitutoyo tool maker microscope	63
3.18	SJ-301 MITUTOYO Portable surface roughness tester	64
3.19	MITSUBISHI RA-90 electrical discharge wire machine	66
3.20	ZEEIS EVO 50 Scanning electron microscope	67
3.21	Insert tools layout in EVO 50 ZEISS machine chamber	68
4.1	Normal plot of residual analysis of surface roughness model	75
4.2	Studentized residuals versus predicted values for surface roughness	75
4.3	Externally studentized residuals for surface roughness	76
4.4	Box-Cox plot for surface roughness model diagnostic	77
4.5	Effect of cutting speeds on surface roughness	78
4.6	Effect of feed rates on surface roughness	79
4.7	Effect of depth of cut on surface roughness	81
4.8	3D response effects of feed rates and cutting speeds on surface roughness	82
4.9	Counter plots of effect of feed rates and cutting speeds on surface roughness	82
4.10	Comparison between predicted and experimental value	85
4.11	Normal probability plot for tool wear	90
4.12	Studentized residuals versus predicted Values for tool wear	90
4.13	Externally Studentized Residuals for tool wear	91
4.14	The cutting speed influenced on tool wear	92
4.15	Effect of feed rate on tool wear	94

4.16	Effect of axial depth of cut responds on tool wear	95
4.17	3D response effects of feed rates and cutting speeds on tool wear	96
4.18	Counter plots of effect of feed rates and cutting speeds on tool wear	96
4.19	Comparison between predicted and experimental value	99
4.20	Scratch on workpiece surface (cutting speed: 130m/min, feed rate: 0.4mm/tooth and depth of cut: 0.1mm.)	101
4.21	Smearred material on the workpiece surface (cutting speed: 120m/min, feed rate: 0.30mm/tooth and depth of cut: 0.30mm.)	102
4.22	Adhered material (cutting speed: 120m/min, feed rate: 0.40mm/tooth and depth of cut: 0.50mm.)	102
4.23	Porosity on the workpiece surface (cutting speed: 130m/min, feed rate: 0.5mm/tooth and depth of cut: 0.30mm.)	103
4.24	Flank wear	104
4.25	Clean appearance of wear	106
4.26	Adhesive wear (V_c : 125 m/min, f_z : 0.40 m/min, DOC: 0.30m)	106
4.27	Built up edge (BUE) (V_c : 130 m/min, f_z : 0.40 m/min, DOC: 0.50m)	107
4.28	Chipping (V_c : 125 m/min, f_z : 0.40 mm/min and depth of cut 0.30m)	108

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	SEM image of surface profiles and tool wear at different cutting parameters	127

LIST OF ABBREVIATIONS

HTCS	-	High Thermal Conductivity Steel
CADCAM	-	Computer-Aided Design and Manufacturing
CVD	-	Chemical Vapor Diffusion
HSM	-	High Speed Machining
CNC	-	Computer Numerical Control
TiAlN	-	Titanium Aluminum Nitride
TiN	-	Titanium Nitride
TiCN	-	Titanium Carbonitride
SEM	-	Scanning Electron Microscope
EDM		Electro Discharge Machine
RPM	-	Rotation Per Minute
Al	-	Aluminum
Al ₂ O ₃	-	Aluminum Oxide
C	-	Carbon
Ti	-	Titanium
Si	-	Silicon
Mn	-	Manganese
S	-	Sulfur
Cr	-	Chromium
Cu	-	Copper

Sn	-	Tin
Mg	-	Magnesium
ISO	-	International Organization for Standardization
VB	-	Flank wear
BUE	-	Built Up Edge
BUL	-	Built Up Layer
DOC		Depth Of Cut
RDOC	-	Radial Depth Of Cut
ADOC	-	Axial Depth Of Cut
SMSS	-	Sum Model of Square Sequential
RSM	-	Response Surface Methodology
BBD	-	Box-Behnken Design
PCD	-	Polycrystalline Diamond
HSS	-	High Speed Steel
PCBN	-	Polycrystalline Cubic Boron Nitride
AISI	-	America International Standard Institute
MMC	-	Metal Matrix Composites
ANOVA	-	Analysis of Variance

LIST OF SYMBOLS

$^{\circ}\text{C}$	-	Degree Celsius
μm	-	Micrometer
%	-	Percent
a_p	-	Radial depth of cut
a_e	-	Axial depth of cut
F_z	-	Feed rate
Kv	-	Kilo volt
m/min	-	Meter per minute
mm	-	Millimeter
min	-	Minute
Vc	-	Cutting speed
W/m.k	-	Watts per meter kelvin
Ra	-	Average surface roughness
MPa	-	Megapascal

LIST OF PUBLICATIONS

Journal

1. Hadzley, A. B., Anis, A. A., Farizan, M. N., Osman, M. H., Norfauzi, T., & Noorazizi, S. (2018). Analysis of Surface Integrity and Formation of Material Side Flow in Dry and Wet Machining of Aluminum Alloy. *Journal of Advanced Manufacturing Technology (JAMT)*, 12(1 (1)), 501-512.
2. Hadzley, A. B., Azahar, W. M., Anis, A. A., Izamshah, R., Amran, M., Kasim, S., & Noorazizi, S. (2018). Development of Surface Roughness Prediction Model using Response Surface Methodology for End Milling of HTCS-150. *Journal of Advanced Manufacturing Technology (JAMT)*, 12(1 (1)), 467-476.

CHAPTER 1

INTRODUCTION

1.1 Research background

Machining is a manufacturing process that transforms the raw material into the desired shape. The process use cutting tools to remove unwanted materials by shearing the workpiece with engaging rotating parts in opposite direction. There are three domain methods that are classified in machining operations, namely milling, drilling and turning. Other processes such as sawing, boring, broaching and shaping also considered categorised under machining operations. For each machining process, a specific machine tool is needed to facilitate the process according to the designated tasks.

One of the significant applications of machining is to manufacture die for metal stamping application. Metal stamping is a process of fabricating metal parts and forming the metal parts into an ideal shape by applying high pressure to a blank piece (Karbasiyan and Tekkaya, 2010). The stamping machine incorporates a special made die which provides the stamped part shape and this process also widely used and found in automotive industry as the process capable to make intricate, accurate, strong and durable parts in huge quantities. Many automotive parts are already applied using this technology, for example chassis component, roof rail, bumper, fender, and bonnets. Method that commonly used for mould and die manufacturing is end milling process. In die machining, the main challenge is the high surface of material hardness and curvy workpiece geometries that will affect and contribute to short lead times (Becze et al., 2000). At the same time, due to the quality

awareness of the dies long life term, requirement for the best qualities of surface finish becomes more significant.

For manufacturer of mould and die, a great challenge occurs when they have to fulfil the necessity to have a good surface quality on complex free-form shape. The challenge could be worsened when the material being used was in hardened condition. The introduction of High Thermal Conductivity Steel-150 (HTCS-150), with hardness of 52 HRC for hot stamping application highlighted the requirement to strategically study the formulation of optimization of surface roughness and tool wear that can facilitate holistic guideline to machine this new material. In industry, specific die normally being machined in rough and finish conditions before manually polished by hands of operators. The present techniques to complete the required surface finish for mould and die component by manual polishing has a tendency to minimise the productivity and difficulty in ensuring the component accuracy. The major concern in machining hardened materials is the necessity for a fine surface roughness process due to its properties such as high wear resistance, high compressive strength and high stability in hardening.

In this study, a new developed material namely HTCS-150 hardened steel is being systematically investigated based on its machinability according to the control parameters of cutting speed, feed rate and axial depth of cut. This project aims to study the wear performance and surface integrity in machining HTCS-150 hardened steel using TiAlN coated carbide. The milling operation has been performed by using a MAZAK variaxis 5-axis CNC milling machine where the surface finishing of HTCS-150 hardened steel has been monitored at different cutting parameters, parallel with the tool wear behaviour. The understanding and correct use of the cutting tool and parameters in producing a fine surface finishing will lead to the reduction in cycle times which is achieved through the increasing level of the parameter.