Faculty of Manufacturing Engineering

ANALYSIS OF SURFACE INTERGRITY AND TOOL WEAR DURING MACHINING HIGH THERMAL CONDUCTIVITY STEEL 150 (HTCS-150)

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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 : Ir. Dr. Mohd Hadzley Bin Abu Bakar

Date : 19/12/2017

DECLARATION

I declare that this thesis entitled "Analysis of Surface Integrity and Tool Wear during Machining High Thermal Conductivity Steel 150 (HTCS-150)" 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 : Wan Mohd Azahar Bin Wan Mohd Yusoff

Date : 19-12-2017

DEDICATION

To my beloved mother, parent-in-law, my wife, my brothers and sisters

ABSTRACT

High Thermal Conductivity Steel 150 (HTCS-150) is a new material that applied as a die to assist efficient heat transfer in a hot stamping process. Machining process of HTCS-150 die involved from roughing to finishing process assisted by CADCAM and CNC machining. This research concentrated on study when finish machining of HTCS-150 using ball nose end mill TiAlN coated carbide insert. The intent of this research 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 machining outcome (surface roughness and tool wear) using Response Surface Methodology (RSM) and Box-Behknen experimental design. Consequent to model development, Analysis of Variance (ANOVA), Scanning Electron Microscope (SEM) were employed to identify significant factors and surface characteristics that influenced the surface roughness and tool wear. Experimental processes were carried out using Variaxis MAZAK CNC 5 axis vertical Milling, assisted by the Design Expert 6.0 analysis software. Ranges of cutting parameters selected were 484-553 m/min cutting speeds, 0.31-0.36 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 develop 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 518.50 m/min cutting speed, 0.31 mm/tooth feed rate of and 0.10 mm axial depth of cut. Combination of cutting parameters for the lowest tool wear recorded as 551 m/min cutting speed, 0.36 mm/tooth feed rate and 0.18 mm axial depth of cut. The ANOVA analysis shows that for surface roughness, most influenced cutting parameters was cutting speed followed by axial depth of cut and feed rate. Meanwhile, for tool wear, feed rate recorded as most influenced cutting parameter followed by cutting speed and axial depth of cut. Observation using SEM observed that feed marks, material pullout, adhered material and surface porosity were major defects on the machined surface. For tool wear, coating delamination, abrasive wear, Built-up Layer, adhesive wear and chipping were among failure mechanisms observed. The analysis results from this research are useful to increase the surface quality and decrease the tool wear as the industry player can reduce the period for finishing process to get the finest quality surface and lowest production cost.

ABSTRAK

Besi Berkonductiviti Haba Tinggi (HTCS-150) merupakan bahan baru yang digunakan sebagai acuan dalam membantu memindahkan haba yang berkesan bagi prosess hentakan panas. Proses permesinan acuan dari HTCS-150 melibatkan proses dari permesinan secara kasar sehingga pemesinan akhir (halus) yang dibantu oleh pengunaan CADCAM dan Mesin berbantu komputer (CNC). Penyelidikan ini menumpukan kepada kajian proses pemesinan akhir HTCS-150 dengan mengunakan 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 Kaedah Tindakbalas Permukaan (RSM) manakala Box-Behnken yang berperanan sebagai perancang kajian. Berlanjutan dari membina model matematik, Analisis varians (ANOVA) dan Imbasan Electron Mikroskop (SEM) digunakan untuk mengenalpasti faktor yang ketara dan kateristik permukaan yang mempengaruhi kekasaran permukaan dan kadar kehausan mata alat. Proses ujikaji dijalankan dengan gabunagan penggunakan mesin kisar menegak MAZAK 5 paksi dan perisian Design Expert 6.0 iaitu sebagai perisian analisis. Julat parameter pemotongan yang dipilih adalah 484-553 m/min untuk kelajuan pemesinan, 0.31-0.36 mm/mata alat untuk kadar kemasukan dan 01-0.5 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 mengambarkan proses kajian dengan ujian pengesahan model dengan kadar 90% jarak ramalan dan baki ralat perbandingan kepada nilai ramalan adalah kurang daripda 10%. Keputusan optimisasi menunjukkan kekasaran permukaan paling rendah dicapai pada kelajuan pemotongan 518.50 m/min, kadar kemasukan 0.31 mm/mata alat dan kedalam pemotongan 0.10 mm. Gabungan pembolehubah permotongan untuk menghasilkan kadar kehausan mata alat paling rendah pula dicatatkan pada kelajuan pemesinan 551 m/min, kadar kemasukan 0.36 mm/mata alat dan kedalaman pemotongan 0.10 mm. Bagi kekasaran permukaan, analisis ANOVA menunjukkan pembolehubah permotongan yang paling mempengaruhi hasil kekasaran permukaan adalah kelajuan pemotongan diikuti oleh kedalaman pemotongan dan kadar kemasukkan. Manakala untuk kadar kehausan mata alat, kadar kemasukan dicatat sebagai pembolehubah pemotongan yang paling mempengaruhi diikuti kelajuan pemesinan dan kedalaman permukaan. Pemerhatian

dengan mengunnakan SEM menunjukkan tanda kemasukan, bahan terkeluar dari asal, bahan melekat dan keliagan yang terdapat pada permukaan merupakan kecacatan yang utama pada permukaan yang dimesin. Manakala, lapisan disalut tertanggal, kehausan kasar, kehausan melekat, lapisan bahan terbina dan kesan menyerpih merupakan mekanisma kegagalan yang terjadi untuk pemerhatian keatas kadar kehausan mata alat. Keputusan analisis dari kajian ini amat berguna untuk meningkatkan kualiti permukaan dan menurunkan kadar kehausan mata alat. Selain itu, pemain industry juga dapat mengurangkan jangka masa proses akhir untuk mendapatkan kualiti permukaan yang paling halus dan kos pembuatan yang rendah.

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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
EDX	-	Energy Dispersive X-ray
EDM		Electro discharge machine
RPM	-	Rotation per minute
Al	-	Aluminum
Al_2O_3	-	Aluminum oxide
C	-	Carbon
Ti	-	Titanium
Si	-	Silicon
Mn	-	Manganese
S	-	Sulfur
Cr	-	Chromium

Cu	-	Copper
Sn	-	Tin
Mg	-	Magnesium
P	-	Phosphorus
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 of square sequential model
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	-	High Silicon Aluminum Alloy
ANOVA	-	Analysis of Variance

LIST OF SYMBOLS

°C	-	degree Celsius
μm	-	micrometer
%	-	percent
a_p	-	radial depth of cut
a_e	-	Axial depth of cut
N	-	spindle speed
kV	-	Kilo volt
m/min	-	meter per minute
mm	-	milimeter
min	-	minute
D	-	diameter
R	-	radius
Vc	-	cutting speed
V_f	-	Feed rate
π	-	Pai = 3.142
W/m.k	-	watts per meter kelvin
λ	-	Lambda
Fe_3C	-	iron
G	-	graphite
Ra	-	average surface roughness
Mpa	-	megapascal

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