الجامعة الإسلامية العالمية ماليزيا
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

EFFECTS OF ONLINE WORKPIECE PREHEATING ON THE MACHINABILITY OF HARDENED STEEL AISI H13 DURING END MILLING AND DEVELOPMENT OF PREDICTION MODELS USING RSM

BY

ABDULLAH MOHAMMAD KHALID HAFIZ

A dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science in Manufacturing Engineering

Kulliyyah of Engineering
International Islamic University Malaysia

NOVEMBER 2008

ABSTRACT

Hardened materials like AISI H13 tool steel are generally regarded as a difficult to cut materials because of their high hardness due to intense carbon content, which however allows them to be used extensively in the hot working tools, dies and moulds. The challenges in machining steels at their hardened state led the way to many research works in amelioration its machinability. This Masters dissertation introduces online heating as one of the new variable parameters to improve the machinability of H13 hardened steel. In the current work the influence of heating parameter i.e. heating temperature; cutting variable, such as cutting speed, feed and axial depth of cut and cutting tool materials, TiAlN coated carbide and PCBN inserts; on different aspects of machinability of H13, were investigated during end milling operation on a CNC Vertical Machining Center (VMC). The study includes identification of relationship between tool life and surface roughness on one hand and the variable parameters, mentioned above on the other. The machining experiments were conducted in two phases, namely, room temperature and preheated machining condition. Response Surface Methodology (RSM) was used to develop empirical models of surface roughness and tool life both for room temperature and preheated machining condition using the data generated from the machining experiments. The comparison between room temperature and preheated machining were made in terms of surface roughness, tool life and machine tool vibration. It was found that preheating had reduced the tool wear, surface roughness and vibration acceleration amplitudes to a desired level. The effects of preheating temperature were also investigated on the chip morphology during the end milling of AISI H13 tool steel, which resulted in reduction of primary chip serration frequency.

ملخص البحث

ا ادة اُصلبة مثل الأداة ا ديدية AISI H13 تعتـ عموماً مادة صعبة القطع لسبب قسوتها العالية لكو ا تـوي على مستوى حاد من كاربون. على أية حال، هذه القسوة العالية علها تستعمل على نطاق واسع الأدوات العاملة ا ارة، والقوالب والأشكال. فإن التحديات جعل ا ديد مناسبا للماكينة (machining) حالتهم ا صلبة جعلت الطريق إ عديد من البحوث. هذا البحث ا قدم لنيل درجة ا اجستـ تقدم تسخ workpiece القبل؛ لتكون variable parameter جديدة مستهدفا إ تطوير machinability للحديد ا صلبة AISI H13. هذه العملية ا الية، التأث لدرجة ا رارة الدافئة و عناصر القطع، مثل سرعة القطع، و الامتداد، و العمق ا وري للقطع، قد اخت أثناء عملية end milling CNC Vertical Machining Centre (VMC). إن أدوات القطع ا ستعملة فيها كانت TiAIN coated carbide و PCBN inserts. تتضمن هذه الدراسة تعريف العلاقة بـ حياة الأداة (tool life) و ا شونة السطحية وبـ العناصر ا ؤشرات (variable parameters) ا ذكورة. لقد أجريت ارب machining مرحلتـ ؛ و ا درجة ا رارة للغرفة و preheated machining. فإن ا نهج ا تخذ كان Response Surface Methodology (RSM) و هذا أ ذ لتطوير اذج رياضية للخشونة السطحية وحياة الأداة، وكلتا ا متعلقتان بدرجة ا رارة للغرفة و حال preheated machining مستخدمة البيانات ا ستنتجة من ارب machining. فإن ا قارنة بـ درجة ا رارة للغرفة و preheated machining جعلت من ناحية ا شونة السطحية، حياة الأداة، واهتزاز آلة مكنية. فوجد بأن preheated machining قد ا إقلال tool wear، وا شونة السطحية، و vibration acceleration amplitudes إ مستوى مرغوب. فإن التأث ات لـ preheating temperature قد اخت ت أيضا على chip morphology أثناء end milling للأداة ا ديدية AISI H13، اا أدت إ فيض primary chip serration frequency.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Manufacturing Engineering.

……………………………………
A.K.M. Nurul Amin
Supervisor

I certify that I have read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science in Manufacturing Engineering.

…………………………………….
A.N. Mustafizul Karim
Internal Examiner

…………………………………….
Mohd. Hamdi Abd Shukor
External Examiner

The dissertation was submitted to the Department of Manufacturing and Materials Engineering and is accepted as partial fulfilment of the requirements for the degree of Master of Science in Manufacturing Engineering.

……………………………………..
Erry Yulian T. Adesta
Head, Department of Manufacturing and Materials Engineering

The dissertation was submitted to the Kulliyyah of Engineering and is accepted as partial fulfilment of the requirements for the degree of Master of Science in Manufacturing Engineering.

……………………………………
Ahmad Faris Ismail
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Nafish Sarwar Islam

Signature.. Date . ……………………….

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

STUDY THE PROPERTIES OF WOOD FIBER REINFORCED PLASTIC COMPOSITE.

No part of this unpublished research may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise without prior written permission of the copyright holder except as provided below.

1. Any material contained in or derived from this unpublished research may only be used by others in their writing with due acknowledgement.

2. IIUM or its library will have the right to make transmit copies (print of electronic) for institutional and academic purposes.

3. The IIUM library will have the right to make, store in a retrieval system and supply copies of this unpublished research if requested by other universities and research libraries.

Affirmed by Nafish Sarwar Islam

……………………………..　　　　　　　……………………………..
Signature　　　　　　　　　　　　　　Date

ACKNOWLEDGEMENTS

In the Name of Allah, the Most Compassionate, the Most Merciful

I would like to express my utmost gratitude and thankfulness to Allah subhanahu ta'ala for the shower of His blessings and mercies that I have successfully completed my research work. In particular, sincere appreciation and thanks to my thesis supervisor Prof. Dr. A.K.M Nurul Amin, for his relentless guidance, patience and support throughout the project.

I would also like to thank all the staff and technicians from different office and laboratories of Kulliyyah of Engineering, particularly Br Sabri, Production laboratory; Br. Ibrahim, Metallohraphy laboratory and Br. Kahar, Measurement and Instrumentation laboratory for guiding me to use their equipment.

I would like to pay my gratitude to Bro. Amri Bin Lajis, PhD student from Department of Manufacturing and Material Engineering for his friendly cooperation and inspirations.

This study was conducted under the e-science project (03-01-08-SF0003) titled as “Enhancement of Machinability of Hardened Steel in End Milling Using Advanced Cutting Methods and Tools”, funded by the Ministry of Science, Technology and Innovation (MOSTI), Malaysia. I would take the opportunity to acknowledge the financial support of the ministry. I also wish to thank Research Center of IIUM for their inspiration and overall management of the project.

At last, heartfelt appreciation goes to my family members who are always behind the inspiration of my works.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3.D.	Three Dimensional
A.N.O.V.A.	Analysis of Variance Approach
C.C.D.	Central Composite Design
C.N.C.	Computer Numerical Control
D.A.Q.	Data Acquisition
D.F.	Degrees of Freedom
M.S.	Mean Square
P.C.BN	Polycrystalline Boron Nitride
P.H.M.	Preheated Machining
R.S.M.	Response Surface Methodology
R.T.M.	Room temperature Machining
S.E.M.	Scanning Electron Microscope
S.S.	Sum of Square
V.M.C	Vertical Machining Center

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Advances in cutting tool material and machine tool technologies have made possible the direct machining of hardened tool steels. Hard machining, a frequently used term in today's machine tool industries, refers to the machining of material with a hardness value over 45 HRC. The concept of hard machining was introduced during 70s. However, the rigorous industrial adoption of hard machining was not made until recently during the last decade. The technique provides a viable and very often more economical alternative to the traditional machining followed by heat treatment and grinding process. An advantage in hard machining is the possible elimination of final grinding and polishing process while still meeting the dimensional and surface roughness specifications, thus leaving a scope of avoiding the heat treatment process between the roughing and finishing operation. Furthermore, only a single fixture set-up is required in carrying out the complete machining process from the raw hardened material straight to the finished product (Junz Wang et al, 2003).

The superior mechanical properties, like, high hardness, wear resistance, retention of hardness at elevated temperature and resistance to deformation and failure under high loads allowed the applications of hardened tool steel like AISI H13 in wide areas. AISI H13 has become popular for mold and die making because it can sustain severe operating conditions and ensure longer service life. Nevertheless these unique properties of AISI H13 render some adverse effects on its processing in terms of machinability.

Since the inception of hard machining concept, many investigative works have been done on the machinability of hardened tool steels. Although not as extensively investigated as hard turning, hard milling has been recently receiving increasing attention from the research community. Majority of the recent research works in hard milling are centered in the areas of the tool wear investigation, chip formation mechanism and surface integrity issues with less concentration on the works related to machinability enhancement. In this regard, this thesis work adopted a hot machining technique using high frequency induction heating as a method to improve the machinability of AISI H13 tool steel during the end milling operation using TiAlN coated carbide and PCBN tool inserts. Response Surface Methodology (RSM) was used in the work in developing empirical mathematical models for both room temperature and workpiece preheated machining conditions. In the hot machining experiments the heating temperature has been considered as a variable along with other cutting parameters. The results obtained from both room temperature and hot machining experiments have also been compared to assess the machinability improvement of AISI H13 tool steel as a result of workpiece preheating.

1.2 PROBLEM STATEMENT

In hard machining, detailed works on the tool wear mechanism, surface finish and integrity; tool geometry and effect on the machining parameters have been carried out by many researchers and metal cutting scientists. However, investigations for machinability enhancement have received less attention in hard milling. Machinability of hardened tool steel is poor due to excessive tool wear, high heat generation during machining and poor quality of the machined surface. The proposed online workpiece preheating during machining operation could be a viable means of improving the machinability of the material. The heating temperature can be made as a variable to assess its effect on machinability in comparison with conventional machining. However, at the same time, it is very important to set the level of the temperature, since excessive high temperature may adversely affect the hardness of the material. The machinability is needed to be addressed by establishing the relationship between the main process parameters and their corresponding responses- surface finish and tool life. It is also very important to investigate the effects of online workpiece heating on chip formation and chatter vibration.

1.3 OBJECTIVES OF THE STUDY

The main aim of this research is to determine the effect of online workpiece heating on end milling of hardened tool steel AISI H13 using TiAlN coated carbide and PCBN tool inserts. The specific objectives of the work can be described as follows:

- To determine the effects of cutting parameters namely cutting speed, feed and axial depth of cut on the tool wear and surface finish
- To determine the combined effect of heating and cutting parameters on surface finish and tool wear
- To develop the appropriate prediction models of tool life and surface finish using Response Surface Methodology (RSM) both for room temperature and workpiece preheated machining
- To draw a comparison between conventional room temperature and preheated machining to assess the effects of preheating on the machinability of AISI H13 tool steel.
- To determine the effect of machining parameters and preheating temperature on vibration and chatter.