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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

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

BY

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requirements for the degree of Master of Science in
Manufacturing Engineering

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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

AISI H13

(machining)

workpiece

AISI

machinability

variable parameter

.H13

.CNC Vertical Machining Centre (VMC) end milling

.PCBN inserts TiAlN coated carbide

variable)

(tool life)

machining

(parameters

Response Surface Methodology (RSM)

.preheated machining

.machining

preheated machining

preheated machining

vibration acceleration

tool wear

preheated machining

chip

preheating temperature

amplitudes

primary chip

AISI H13

end milling

morphology

.serration frequency

APPROVAL PAGE

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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.

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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.