UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION PHENOMENA OF FLANK WEAR AT INITIAL STAGE DURING CUTTING PROCESS OF STAINLESS STEEL 304

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Process) (Hons.)

by

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DECLARATION

I hereby, declare this report entitled “INVESTIGATION PHENOMENA OF FLANK WEAR AT INITIAL STAGE DURING CUTTING PROCESS OF STAINLESS STEEL 304” is the results of my own research except as cited in the reference.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Process) (Hons.). The member of the supervisory is as follow:

………………………………

(DR. MOHD SHAHIR BIN KASIM)

ABSTRAK

Keluli tahan karat 304 adalah aloi keluli berdasarkan kromium-nikel yang digunakan secara meluas dalam industri petrokimia dan agak dikenali sebagai sukar untuk bahan dimesin kerana pengerasan kerja yang tinggi dan membina kelebihan (BUE). Kadar haus rusuk alat pemotongan terjejas kerana kelemahan sifat-sifatnya yang menyebabkan ubah bentuk memotong alat geometri. Untuk memahami keadaan ini, kajian ini dijalankan untuk memenuhi objektif berikut; untuk menyiasat kadar haus rusuk pada peringkat awal dalam tempoh yang dinyatakan pelbagai pemotongan parameter, untuk mengenal pasti kesan memotong parameter pada kadar haus dan untuk menentukan dan mengesahkan parameter proses yang optimum yang memberikan kadar haus rendah. Metodologi Response Surface (RSM) melalui Historical Data digunakan untuk menganalisis hubungan antara parameter pemotongan dengan memotong penggunaan alat. Seramai beberapa eksperimen 9 dijalankan. Parameter pemesinan yang terpilih adalah Vc m / min = 80, 110 dan 140, Fz mm / put = 0.10, 0.15 dan 0.2 dan tetap ap = 0,2 mm. Tungsten karbida bersalut dengan TiAlN digunakan sebagai alat memotong dalam kajian ini. Pembentukan haus rusuk diukur dan diperhatikan dengan menggunakan mikroskop pembuat alatan dan mikroskop stereo. Merujuk keputusan, menunjukkan bahawa kadar suapan mempengaruhi rusuk kadar haus pesat. Oleh kerana peningkatan kadar suapan, kenaikan kadar haus. Optimum memotong parameter Vc m / min = 80, fz mm / put = 0.10 dan ap = 0.2mm dihasilkan dengan menggunakan ANOVA dan mengesahkan oleh ujian pemesinan. peratusan ralat antara kadar haus rusuk sebenar dan diramalkan adalah 7.70%.

ABSTRACT

304 Stainless Steel is a chromium-nickel based steel alloy that is widely used in petrochemical industries and relatively known as difficult to be machined material due to its high work hardening and built up edge (BUE). The flank wear rate of the cutting tool is affected due to its drawbacks properties which resulting in the deformation of cutting tool geometry. To understand this condition, this research is conducted to meet the following objectives; to investigate flank wear rate at initial stage within specified cutting parameter range, to identify the effect of cutting parameter on the wear rate and to determine and validate the optimum process parameter that gives lowest wear rate. Response Surface Methodology (RSM) through Historical Data is used to analyse the relationship between the cutting parameters with cutting tool wear. A total 9 number of experiments are carried out. The selected machining parameters were Vc m/min = 80, 110 and 140, Fz mm/rev = 0.10, 0.15 and 0.2 and fixed ap = 0.2 mm. Tungsten carbide coated with TiAlN is used as cutting tool in this research. Formation of flank wear is measured and observed by using toolmaker microscope and stereo microscope. Referring the results, indicates that the feed rate influence the rapid flank wear rate. As the feed rate increase, the wear rate increases. Optimum cutting parameter Vc m/min = 80, fz mm/rev = 0.10 and ap = 0.2mm is generated by using ANOVA and validate by test machining. Error percentage between actual and predicted flank wear rate is 7.70%.

DEDICATION

For my beloved family

Fyp Supervisor

And

FKP's Students

ACKNOWLEDGEMENT

Praise the lord for helping me to complete this final year report successfully in time with great manner even though a lot of obstacle had to be face through the journey in completing this assignment that have been honoured to me in style. Moreover, here I would also like to express my gratitude to my parents who have helped me in many ways such as contributed ideas and money to make sure my final year project flows smoothly without any major problems.

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TABLE OF CONTENT

CHAPTER 3: RESEARCH METHODOLOGY

CHAPTER 4: RESULTS AND DISCUSSION

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

Al	-	Aluminium
ANOVA	-	Analysis of variance
a_p	-	Depth of cut
BUE	-	Build up edge
C	-	Carbon
CNC	-	Computer Numerical Control
Co	-	Cobalt
Cr	-	Chromium
CrN	-	Chromium Nitride
DOC	-	Design of Experiment
F	-	Force
Fe	-	Iron
f_z	-	Feed rate
HSM	-	High speed machining
ISO	-	International Standard Organization
Mn	-	Manganese
Mo	-	Molybdenum
MRR	-	Material rate removal
Ni	-	Nickel
O_2	-	Oxygen
PVD	-	Physical vapour deposition
RSM	-	Response Surface Methodology
Si	-	Silicone
T	-	Tool Travel
Ti	-	Titanium
TiAlN	-	Titanium Aluminium Nitride
TiN	-	Titanium Nitride
VB	-	Flank wear

VB_3	-	Non-uniform flank wear
Vc	-	Cutting speed
WC	-	Tungsten carbide
$\dot{V}b$	-	Flank Wear Rate

CHAPTER 1

INTRODUCTION

In this chapter, it summarizes a brief introduction on project background. This chapter also deals with information on problem statement, project objectives and project scopes.

1.1 Project Background

The most well used metal shaping process in mechanical manufacturing industry is machining (turning, milling, drilling). Machining or ‘metal cutting’ process defined as a thin layer, the chip or swarf is removed from a larger body by using a wedge-shaped tool (Childs et. al., 2000). Machining process is a common way to remove material from an engineering part into desired shape and dimension (Bhuiyan, 2012). Semi-orthogonal cutting or well known as turning operation is one of the most typically used metal cutting operation in experimental work and manufacturing engineering components (Trent, et. al., 2000). This turning process is a common and all time favoured metal cutting operation which high quality finished surfaces is produced. Turning classified as a very important machining process because unwanted material removed from the surface of a rotating cylindrical part with a single point cutting tool. Due to these conditions, many researchers have studied the turning process in the recent years.

Austenitic 304 Stainless Steel is one of a very high corrosion resistance and wide range of excellent mechanical properties that is widely used in petrochemical industries, food processing equipment, kitchen utensils. However, 304 Stainless Steel also possess few drawbacks such as high work hardening, high built up edge (BUE) and low heat conductivity. Due to the following drawbacks, 304 Stainless Steel classified under difficult to be machined material and poor machinability stainless steel (Hossein, 2005). Most of the difficult situations aroused when machining 304 Stainless Steel reported was tool flank wear, crater wear, irregular wear formation and BUE formation on the tool flank and rake face respectively. In addition, the formation of BUE worsening cutting performance by increasing of flanking and notch wear formation. This unpredictable formation leads to premature tool failure (Kasim et. al., 2014).

Generally, efforts to improve its machinability of 304 Stainless Steel in term of increasing machining parameters are still not satisfied; impel researches to view from different angles. However, the studies of the flank wear phenomena at initial stage during cutting process of 304 Stainless Steel will reveals some output that able to increase cutting tool life which directly the machinability of 304 Stainless Steel is improvised. Therefore, this research has been established to investigate phenomena of flank wear at initial stage during cutting process of 304 Stainless Steel.

1.2 Problem Statement

Metal cutting needs a different approach to be environmental friendly to meet few environmental regulation requirements, especially for petrochemical industry. Dry machining method is the ideal, because it is more fulfill the requested requirement and it quite impossible for lubrication fluid to enter the machining area since this research focusing on high speed machining in a very short time (initial stage). Heat generation is found to be the main contribution for the most problems faced during machining of 304 Stainless Steel. During the cutting process of 304 Stainless Steel, the reciprocal action between tool and the workpiece causes intense friction at the tool and workpiece interface, which results flank wear. The aim of this project is to investigate the phenomena of flank wear at initial stage of cutting process of 304 Stainless Steel under different process parameter. Most of the past researches focus on the complete experimental investigation but have not been studied the formation of flank wear during initial stage of 304 Stainless Steel cutting process. The machining cost apparently will be increasing along with increases of tool wear. Apart from that tool wear also will cause very low surface finish and inaccurate final geometry. Tool life generally defined as the amount of unexceptional performance or service provided by a virgin tool or a cutting point till it is affirmed failed.(Wagh et. al., 2013) Rapid tool wear in machining has long been recognized as a challenging obstacle in this industry (Li H.Z et. al., 2006). It is well known that coating can reduce tool wear and enhance machining quality. The rapid wear rate in the initial stage during cutting process abrades the coating on the cutting tool which consequently degrades the cutting tool life span.

1.3 Objectives

1) To investigate flank wear rate at initial stage within specified cutting parameter range.

2) To identify the effect of cutting parameter on the flank wear rate**.**

3) To determine and validate the optimum process parameter that gives lowest flank wear rate.

1.4 Project Scope

This research will explore the cutting tool performance by identify the formation of flank wear. Cutting speed, feed rate and depth of cut are several process parameter need to be considered in getting a minimum amount of flank wear. Stainless Steel 304 150mm length and 50mm diameter are materials that being used in this experiment. The machining process is conducted by using 3-axis CNC Lathe machine. The turning process is carried out under the dry machining method. The type of insert coating selected is TiAlN. After the machining done, the flank wear will be measured and captured by using tool maker microscope and stereo microscope. The recorded data will be analysed and optimum parameter obtained and validated by using Design Expert 6.0.

CHAPTER 2

LITERATURE REVIEW

In this chapter will be summarized the review on previous study and research related to this subject. This chapter carefully examined based on the sources and described to justify the statement with proof of research or study related.

2.1 304 Stainless Steel

Austenitic 304 Stainless Steel or also known as 18/8 (18% Cr, 8% Ni) is a type of alloy steel that contain chromium-nickel (Cr-Ni) content and low carbon along with varying volume of Silicon (Si), Manganese (Mn), and Molybdenum (Mo) refer to Table 2.1 that explains the chemical composition of 304 Stainless Steel.(Kulkarni et. al., 2013) The presence of chromium yield a thin layer of oxide or ‘passive layer’ on the surface of the steel in order to restrict corrosion on the surface and exhibits attractive appearance (retrieved from British Stainless Steel Association website at http://www.bssa.org.uk/). Austenitic 304 Stainless Steel is very reasonable for use in high temperature environment for example; aircraft fittings, cryogenic vessel, chemical equipment and etc. Due to its wide range excellent mechanical and physical properties refer Table 2.2 such as high ductility, toughness, strength and relatively low proof strength makes them often selected for construction and petrochemical industry materials. eMachineShop Handbook (2004) states that the 304 Stainless Steel can be only hardened by cold working not by heat treatment.

As per stated below are the advantageous properties of 304 Stainless Steel compared to other steels:

- High corrosion resistance.
- High cryogenic toughness and hot strength.
- High work hardening rate.
- High ductility.
- High strength and hardness.
- Low maintenance an attractive appearance.

Table 2.1: Chemical Composition of Type 304 Stainless Steel
(Source: Yamashin Steel Co.Inc)

Classification	Specification		Chemical Composition, Wt%							
	JIT	**AISI**	**C**	**Cr**	**Fe**	**Mn**	**Ni**	**P**	**S**	**Si**
Austenitic	SUS 304	304	Max 0.08	18-20	66.34-74	Max 2	8-10.5	Max 0.045	Max 0.03	Max 1

Table 2.2: Mechanical & Physical properties of Type 304 Stainless Steel (Source: 10th edition Metals Handbook)

Properties	Value
Density	**0.289 lb/in^3**
Hardness Rockwell B	**70 B**
Ultimate Tensile Strength	**73200 psi**
Yield Tensile Strength	**31200 psi**
Modulus of Elasticity	**28000-29000 ksi**
Poisson's Ratio	**0.29**
Shear Modulus	**12500 ksi**

2.2 Machinability of 304 Stainless Steel

There are no any specific definition describes the term machinability. According to the Sandvick Corromant Handbook (2003) the term machinability gives a meaning that the ability of the workpiece materials to be machined after takes in count of the wear it forms on the cutting edge and the chip formation. In another hand, Nadia (2015) states that the machinability describes how the workpiece react to the cutting operation. The occurrence of undisturbed cutting action and a fair tool life identified as good machinability. Refer to the Figure 2.1 the Type 304 Stainless Steel having an average machinability rating as much as 50% and maximum rating of 60% when compared to other grades of stainless steel. Apart from that, generally stainless steel having low machinability when compared to mild steel and aluminium.

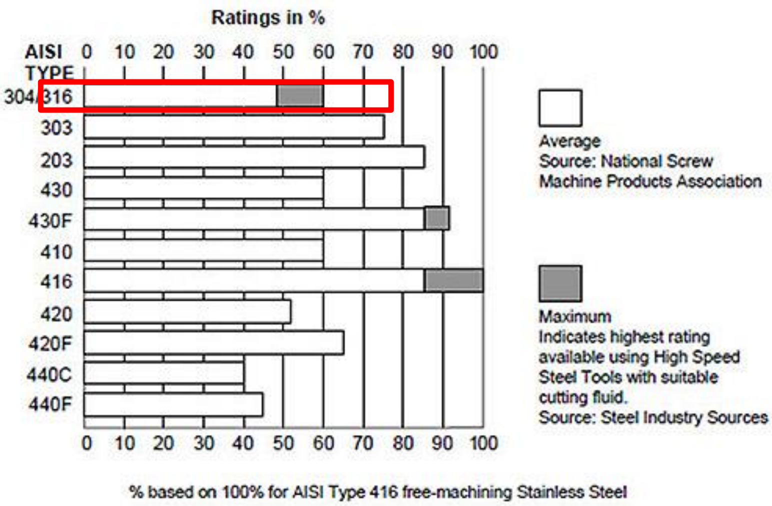

Figure 2.1: Machinability rating comparison between Stainless Steel Grades (Source: Sandvick Corromant)

The formation of notch wear is caused by the hard surface and chips formed by work hardening. In addition, the hardening condition also generating huge amount of heat when machining and tends to soften the metal (Zhuang, et. al., 2014). As the metal is softening the coating from the edge of substrate material is abraded. 304 Stainless Steel endure work hardening as the hardness is increased by cause of heat formed from the cutting operation. Therefore, no materials will be soften up to certain level of temperature and make it difficult to be machined. The 304 Stainless Steel encountered problem in machining which will cause it to face two major problems. The problems are short cutting tool life span and quality of surface finish. High cutting force during machining is the major cause for this trouble. The excellent properties like high work hardening rate and toughness causing the cutting force to boost during machining.

304 Stainless Steel relatively still consider has a good machinability if compared to Inconel 718. Its machinability can be enhanced by applying the following rules;

- Cutting edge must be kept sharp to avoid work hardening.
- Cuts should be light but deep enough to prevent rubbing over surface.
- Huge amount of coolant and lubricants required to reduce the heat generated.
- Increase in material removal rate increase machinability.

2.3 Machining

The most well used metal shaping in mechanical manufacturing industry is Machining (turning, milling, drilling). It described as the major part of manufacturing industry revolution. Metal machining is efficient of high precision, it could produce engineering components with a tolerance range of 50 µm and surface finish of 1µm (Childs et al., 2000). Apart from that, this type of stainless steel also very adaptable and able to form complex shapes with varying size range fast and cheap. Figure 2.2 in the next page shows the typical accuracy and complexity with size range of machining can be achieved by 304 Stainless Steel.

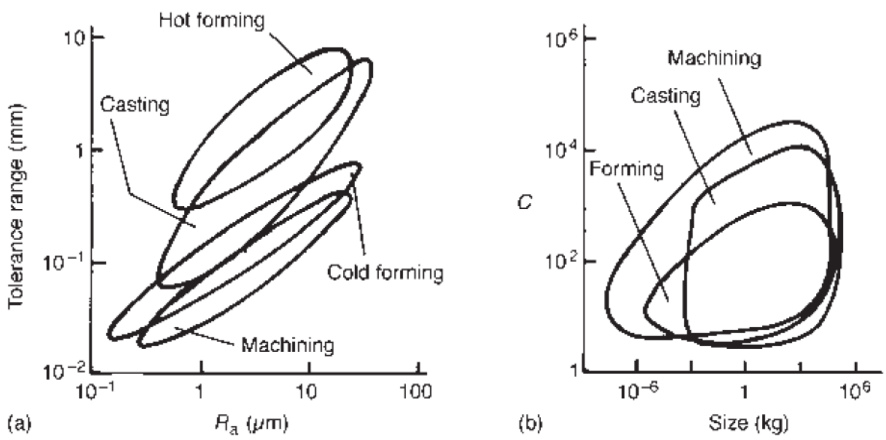

Figure 2.2: Typical accuracy & finish with complexity & size achievable by machining process (Source: Metal Machining Theory)