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EFFECT OF BURR FORMATION AND SURFACE ROUGHNESS IN SURFACE GRINDING OF XW-42 ALLOY

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DEDICATION

I dedicated my research work to my sincere gratitude goes to my friends, classmates, my beloved family and my parents for giving me life in the first place and encouragement to pursue my studies. Especially to my lovely wife for her unremitting love and encouragements, to my two boys for their obedient and independent that enabled me to complete this work, and little cute new born baby boy with under care of my lovely wife.

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ABSTRACT

This paper presents an investigation on Burr Formation Height (BFH) and surface roughness (Ra) in Surface Grinding (SG) machining. The burr height and Ra in XW-42 alloy steel are studied as a function of machining variables, which are Depth of Grind (DOG), Wheel Speed (WS) and Number of Pass (TIME) to help illuminate the burr formation and Ra mechanisms. A series of Design of Experiments (DOE) with full factorial design was conducted to study the optimum parameters as a process function. The significance of the grinding parameters on the selected responses was evaluated using analysis of variance ANOVA. Empirical grinding models were developed by using regression analysis which considered on the significant effect of input factors and the model will be used to obtain optimum output responses (theoretical result) set as optimum parameters. Subsequently, carry out experimental again based on optimum parameters to validate the model by comparing both theoretically result and experimental result. The range of the accuracy must be in a range of ±15% which is called marginal of error.

ABSTRAK

Kertas kerja ini adalah membentangkan suatu penyiasatan ke atas Ketinggian Pembentukan duri (BFH) dan kekasaran permukaan (Ra) dengan kegunaan masin pengasah permukaan (SG) diatas XW-42 aloi keluli dikaji sebagai fungsi pembolehubah pemesinan. Kedalaman pengasah (DOG), Kelajuan batu pengasah (WS) dan Bilangan laluan pangasah (TIME) untuk membantu menerangkan pembentukan BFH dan Ra. Satu siri Rekabentuk Eksperimen (DOE) dengan reka bentuk faktorial penuh telah dijalankan untuk mengkaji parameter yang dalam keadaan yang terbaik sebagai fungsi proses. Kepentingan parameter pengisaran kepada tindak balas terpilih telah dinilai dengan kegunaan analisis ANOVA. Model Empirikal pengasah telah dirumuskan dengan kegunaan analisis regresi atas kesan faktor yang bermakna kamudian model ini akan digunakan untuk mendapatkan hasil sambutan yang terbaik (hasil teori) dan tetapkan parameter sebagai yang terbaik. Selepas itu, menjalankan eksperimen sekali lagi berdasarkan parameter yang terbaik untuk mengesahkan model dengan pembandingan kedua-dua hasil teori dan hasil kajian. Rangkaian ketepatan mestilah dalam pelbagai ± 15% yang dinamakan sebagai sedikit kesilapan.

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DECLARATION

I declare that this thesis entitle "**EFFECT OF BURR FORMATION AND SURFACE ROUGHNESS IN SURFACE GRINDING OF XW-42 ALLOY**" 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 : ____________________.

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Date : 18-June-2013 .

APPROVAL

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

DR. MOHD HADZLEY BIN ABU BAKAR

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LIST OF ABBREVIATIONS

AISI	-	American Iron and Steel Institute
Al_2O_3	-	Aluminum Oxide
ANOVA	-	Analysis of Variance
Bhd	-	Berhad
BFH	-	Burr Formation Height
C	-	Carbon
CAD	-	Computer Aided Design
cBN	-	Cubic Boron Nitride
CNC	-	Computer Numerical Controller
Cr	-	Chromium
DF	-	Degree of Freedom
DOE	-	Design of Experiments
DOG	-	Depth of Grind
ECDF	-	Empirical Cumulative Distribution Function
Fig	-	Figure
ft/min	-	feet per minute
GR&R	-	Repeatability and Reproducibility
http	-	Hypertext Transfer Protocol
HRc	-	Hardness Rockwell C scale
JMTi	-	Japan Malaysia Technical Institute
JIS	-	Japanese Industrial Standards
μm	-	Micron
Mn	-	Manganese
Mo	-	molybdenum
mm	-	milimeter
m/min	-	meter per minute
MS	-	Mean Squares
m/s	-	meter per second

Ra	-	Average Roughness
rpm	-	revolution per minute
RSM	-	Response Surface Methodology
Sdn	-	Sendirian
Si	-	Silicon
SiC	-	Silicon Carbide
SG	-	Surface Grinding
SS	-	Sum of Squares
TIME	-	Number of Pass
V	-	Vanadium
VESB	-	Vipton Engineering Sendirian Berhad
www	-	world wide web
WS	-	Wheel Speed
XW-42	-	Alloy steel grade from ASSAB
<	-	Less Than
>	-	More Than

CHAPTER 1

INTRODUCTION

1.0 Background

The grinding process was invented in the middle of the 15th century; however the first grinding machine was not built until year 1830. The foundation of grinding is based on the progressive abrasive movement over the work-piece and wear by some amount of grits embedded in the grinding wheel. Surface Grinding (SG) is one of grinding process that removes material on flat work-piece. SG is one of the widely use machine for tool making industries to complete entire die and punch fabrication.

Nowadays, technology is getting more advanced with a more demanding design from engineers worldwide. Quality demands by design engineer on the steel work-piece functionality and roughness are increasing. The engineer can design the work-piece with clean edge on CAD designing software but in actual fact the edge is controlled by machine parameters rather than clean edge of work-piece. For that reason, grinding technology has improved tremendously since the SG machine is equipped with Computer Numerical Controller (CNC) which is able to control the machine process parameters to obtain higher precision results. SG offers the possibility of achieving high stock removal rate with a very efficient grind. Furthermore, the life expectancy of the grinding wheel is generally longer since the cutting forces are weaker.

1.1 Problem Statement

SG fits perfectly within the scope of this approach and has already proved its efficiency in the grinding of steel components. Yet, some of the work-piece with specific material properties requires extra attention because the hard surface of the work-piece might give some problems to the machine and usually not well controlled by machinist in Vipton Engineering Sdn, Bhd. (VESB) tool shop. VESB is one of the tools making company located at northern Malaysia where a state named Penang. The company consists of 6 units SG machines for tool and die fabrication.

Recent activities record from the organization shows a lot of wastage and this created additional non-productive time on reprocess activities after the grinding process. All the wastages are due to burrs formation after the process. Besides creating additional non-productive time, burrs affects grinding parameters setting, processes or clog up the wheel with particles that leads to re-dressing of wheel. Otherwise machinist can continue operating without much problems and also finished part of die and punch. Burr Formation Height (BFH) will cause bluntness to the tool. If the burrs are not removed from the work-piece for form fit functional purpose, it can cause injuries to workers. For example, burrs formation that has sharp edges can lead to finger injuries during handling by assembly workers. The other example is the burrs that initially stick to a component edge can create a gap between two components after assembling process, thus causing the joints became loose during functioning of a product and subsequently caused damages.

Records from VESB organization shows that approximately 72% of the company sales are purely for die and punch tool fabrication while about 46% of the specific sales were returned from customer for re-work. Quoted by Aurich (2009) research work, he mentioned the production cost expenses caused by the impact of burrs, chips and part cleaning are estimated up to 500 million Euro in Germany country alone. To conduct further research in this area is to check the material used as work-piece. 100% from the specific sales for die and punch tool fabrication are using XW-42 alloy steel series material, and hardness requirement from die and punch tool industry always at a range of 58 to 60 HRc so that the tool has higher toughness and pro-long its life. In general, concurrence to die and punch tool industry, XW-42 alloy steel is selected for fabrication so as to meet the application.

Refer to the interviewed with tool shop manager regards to the problems, the feedback received is that variances of machine parameters will depend on the machinist experiences. With this scenario as a problem, this research needs to be carried out and look at the area in SG machine on XW-42 needed through machine parameters optimization. As what can be seen here, the return of work-piece from customer is about 46%, it means that the balance percentage can be accepted by customers. In this research, we will focus on the possibility of optimizing machine parameters on XW-42 material which are usually not well control by machinists in the tool shop. In order to achieve the optimization, numerous efforts have been carried out by many researchers as well as many industries in wide range of SG machine parameter. Hence, less efforts and studies were placed into the research of the interactions between burrs, machine parameters and other effect on XW-42 alloy steel.

In this research,we focus purely on SG machine parameters variances. The parameters variances, take it as input factor for this study to see how significant of input factor changes that effect on burrs, or any interact between input factors effect on the burrs. According to tool shop manager again, discussed about the variance of parameters from time to time in grinding, that will be: -

Depth of Grind (DOG), Wheel Speed (WS) and Number of Pass (TIME), Work-piece hardness after heat treatment, feed rate, wheel abrasive grit finest, abrasive material, coolant, wheel dressing etc.

This research will focus on DOG, WS and TIME as input factors because all 3 input factors are the parameters from SG machine operation.

1.2 Objective

There are many machining parameters affecting the SG performance. In order to achieve research goal below are the main aims:

i) To determine the inputs factors level that will concurrently satisfy the set of burrs height of SG on XW-42 alloy steel.

ii) To investigate if any significant interaction effect on the input factors to the output responses.

iii) To ensure, DOG needs to observe since ginding wheel gets friction with work-piece and it can affect the surface roughness (Ra).

Refered to Machine's Handbook (2000, pg 703) grinding process capable to meet Ra in a range of 1.6μm to 0.1μm. Therefore, in this study will cover wider range to optimise the SG parameters, provided the optimised parameters which able to meet Ra result in the range of 1.6μm to 0.1μm.

1.3 Scope of Study

The scope of the research consists of :

i) XW-42 alloy steel will be used as test work-piece.

ii) Parameter for the input factors to be studied are DOG, WS and TIME.

iii) SG Machining will be used – OKAMOTO ACC52DXNC Precision Systems.

iv) Machine will be used in JMTi Penang.

v) Output response to be investigated are Burrs Formation Height (BFH) and Ra of the work-piece.

vi) The full factorial on the Design of Experiment (DOE) and ANOVA tool will be evaluated using Minitab software Release 15.

Beside that, coolant is widely used for for grinding process because it is to reduce heat generated during grinding wheel friction with work-piece surface. The heat generated by the work-piece will gets micro cracking and subsurface damage. Therefore in this research experiment, coolant will be used to reduce heat generated to prevent micro crack but it will not consider as machine parameter in the research. The results of experiment must consider in different perspective of parameter to get accurate results too.

1.4 Value of the Research

The successful research outcomes may post great significance in:-

i) The well controlled and managed die and punch tool burrs formation will leads to better life-prediction and management of tool wear for an improved tool life.

ii) Implementation and sustainable of optimised parameters are the most important aspect for an organization to set a standard for the machinist to follow. Better compete in today's competitive market environment.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter will covered some information and literatures findings on XW-42 alloy steel, fundamental of SG and its corresponding parameters, BFH as well as Ra.

2.1 Tool Steel Properties

XW-42 alloy steel is the commonly used material to fabricate die and punch tool industry. The industry recommended this steel as it fulfil important requirements like having a very high wear resistance performance and moderate toughness. Referred to XW-42 alloy steel specification below, its material consists of high-carbon and high-chromium tool steel alloyed with molybdenum and vanadium characterised by shown in Fig. 2.1 & Fig. 2.2, high wear resistance, high compressive strength, good through-hardening properties, good dimension stability during heat treatment and good resistance to tempering back.

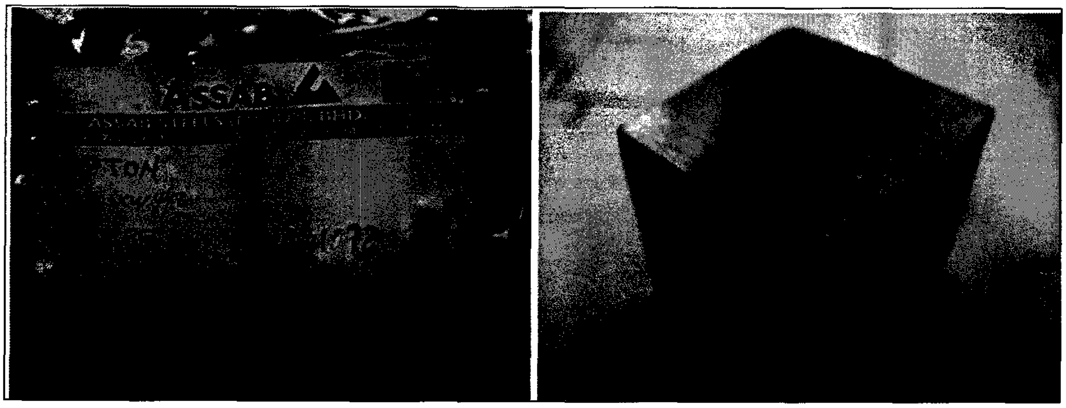

Fig. 2.1 XW-42 from ASSAB Steels

Typical analysis %	C 1.55	Si 0.3	Mn 0.3	Cr 11.6	Mo 0.8	V 0.9
Standard specification	AISI D2, WNr. 1.2379, SKD 11					
Delivery condition	Soft annealed to max. 240 HB					
Colour code	Yellow / White					

Fig. 2.2 XW-42 Chemical Composition (Source: <http://www.assab-malaysia.com> 28/12/12)

2.1.1 Heat Treatment

Heat treatment of work-piece is one of the processes to increase of its toughness, resistance to penetration and long lasting by changing of micro structures, which result when the metal is cooled rapidly. According to Assab (2009) XW-42 steel specification, the hardness recommended for die and punch tool at the range of 58 HRc to 60 HRc see Fig. 2.3(a). The recommended hardening process is preheating the work-piece at 650°C to 750°C, then austenitising temperature at 1000°C to 1040°C. The quenching media required are forced gas, martempering bath at 180°C to 500°C then cool in air blast and quench in warm oil at approximately 80°C. Right after tempered, work-piece temperature reaches at 50°C to 70°C. XW-42 hardens through in all standard sizes. Tempering process temperature will be choosing from the graph shown in Fig. 2.3 (b) where it according to the hardness requirement on the work-piece.

Tools for: Blanking, fine blanking, punching, cropping, shearing, trimming, clipping	< 3mm	60 - 62	58 - 60
	3 - 6mm	58 - 60	54 - 56
	6 - 10mm	54 - 56	-
Short cold shears Shredding knives for plastic waste Granulator knives			56 - 60
Circular shears			58 - 60
Clipping, trimming tools for forgings { Hot			58 - 60
Clipping, trimming tools for forgings { Cold			56 - 58
Wood milling cutters, reamers, broachers			58 - 60

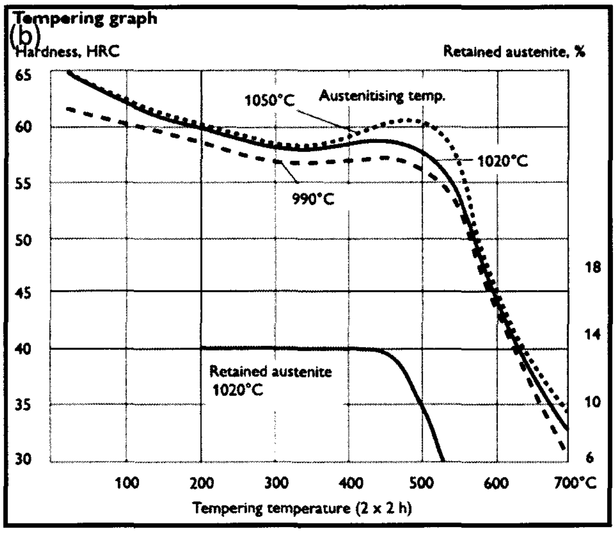

Fig. 2.3(a) Hardness recommendation, (b) tempering graph (Source: <http://www.assab-malaysia.com> 28/12/12)

2.2 Description of the Surface Grinding Process

According to Woodbury (1959), the foundation of grinding is based on the progressive abrasive movement over the work-piece and wear by some amount of grits embedded in the grinding wheel. Different machinist has different techniques to handle SG process whereby a bulk work-piece is to be formed into a final shape with required dimensions. From the grinding process point of view, it utilizes hard abrasive particles that are bonded onto a metal base wheel by techniques such as resin bond, metal bond, vitrified bond or electroplated. Generally in SG it used individual abrasive grain act as cutting tool, which is the main difference compared with other cutting techniques which used one or a finite number of cutting edges for material removal shown in Fig. 2.4.

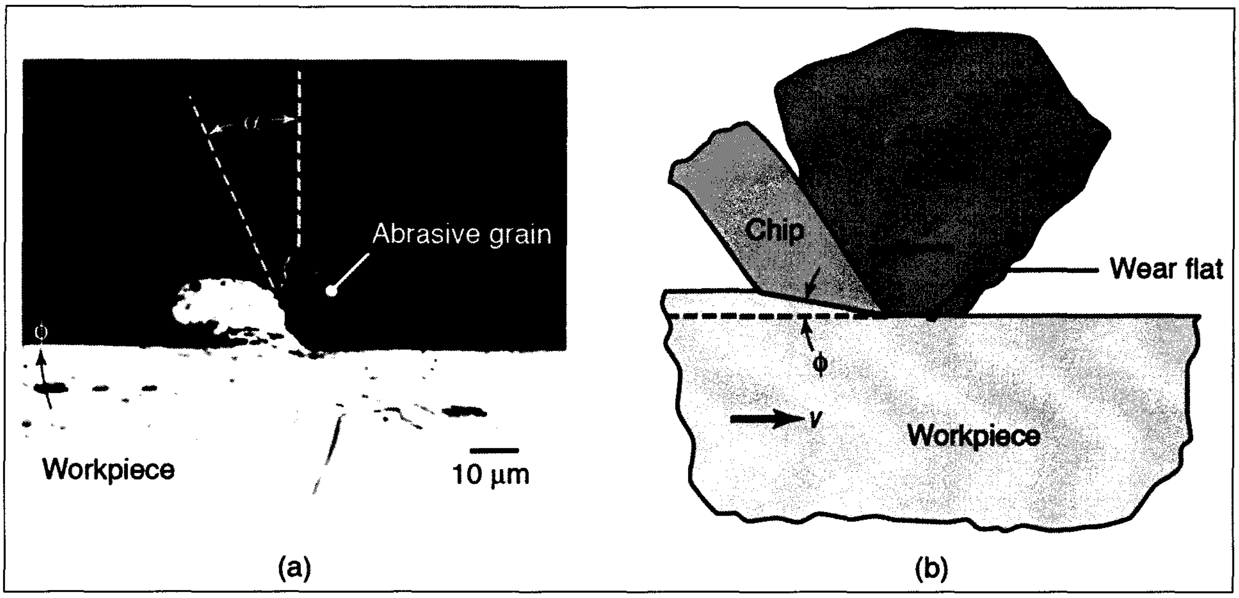

Fig. 2.4 Grinding chip being produced by a abrasive grain (Kalpakjian, 2010)

Grinding parameters and process can be observed best in the SG operation see Fig. 2.6. Kalpakjian (2010), defined the action of an abrasive grains have major differences compared to single-point cutting tool and it can be summarized as below: -

i) The individual abrasive grains are spaced randomly along the periphery of the wheel with irregular shape shown in Fig. 2.5

ii) The average rake angle of the grain is highly negative, typically – 60° or even less. Consequently, grinding chip undergo much larger plastic deformation than operate in other machining processes.

iii) Grains with radial shape over the peripheral surface of a wheel vary; therefore, not all grains are active during grinding process.

iv) Surface grinding speed (i.e., cutting speed) in grinding is extremely high, normally from 20 to 30 m/s. and perhaps it can goes as high as 150 m/s in high-speed grinding where specially designed and manufactured wheels will be used.

Grinding wheel with outer diameter of D, grind off a layer of metal a depth of d (wheel depth of grind), the wheel rotates and individual grain on the periphery of the wheel