AN EXPERIMENTAL STUDY OF THE IMPACT OF CYLINDRICAL GRINDING PARAMETER ON SURFACE ROUGHNESS

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DECLARATION

I hereby, declared this report entitled “An Experimental Study of the Impact of Cylindrical Grinding Parameter on Surface Roughness” is the results of my own research except as cited in references.

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This PSM submitted to the senate of UTeM and has been as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process). The member of the supervisory committee is as follow:

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Project Supervisor
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This report presented an investigation of impact of cylindrical grinding parameter to surface roughness on SUS316 stainless steel. Grinding is the most common process when the workpiece demands good surface, dimensional and geometrical quality. In this experiment, the finding is the actual effect of surface roughness and the relationship for each parameter that have been choosing. The method that has been used to design the experiment was Design of Experiment (DOE) full factorial with two levels. The surface roughness of workpiece have been analyzes by using a Portable Roughness Measurement Machine. The data will be compared and analyzed using MINITAB 14 software. The graphs have been created to shows the optimum factor and interaction between the factors. This experiment runs using three factors which are traverse speed, work speed and depth of cut.
ABSTRAK

DEDICATION

To:
Abd Rahim Bin Ahmad
Esah Bt Mat Nor
Mohd Nor Hakim
Nor Solelah
Mas Izzatul
Mohd Reza
I wish to acknowledge and express my gratitude and appreciation to (i) my supervisor, Mr Mohd Shahir Bin Mohd Kasim for his supervision, encouragement, suggestion and assistance through the research; (ii) my parents, Mr. Abd Rahim bin Ahmad and Madam Esah Bt Mat Nor whose constant encouragement, faith and confidence besides continuously moral support

It is a pleasure for me to express huge gratitude to all individuals and colleagues who have contribute so much throughout my study. I could offer here only an inadequate gesture of my appreciation and all of your good deeds will always be in my mind.

Wassalam….

Nurul Hidayah bt Abd Rahim
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CHAPTER 1
INTRODUCTION

1.1 Introduction

Grinding is the indicated process when the workpiece demands good surface, dimensional and geometrical quality (Steve et al., 2005). Grinding is a machining process that employs an abrasive grinding wheel rotating at high speed to remove material from a softer material (Ioan et al., 2007). Due to this, the grinding process is one of the last steps in the machining operation chain. In modern industry, grinding technology is highly developed according to particular product and process requirements.

The important thing to concern is the relation between the input parameters and output characteristics. Most of the machining researchers said that this process is very a tough task in grinding. From journal of Hassui (2003), most of the shop floor, there are the experience operators located to make a decision of cutting parameter in grinding process. The problem of this practice is that these decisions are based on subjective criteria, which will occur an error during the process. Kwak (2005) showed that the various grinding parameters affect the geometric error generated during the surface grinding by using the Taguchi method and the geometric error was been predicted by means of the response surface method. Many experimental investigations reveal that depth of cut, wheel speed, and work speed are the major influential parameters that affect the quality of the ground part (Alagumurthi et al., 2006).
In this study, the Design of Experiment (DOE) has been used in order to see the relationship between the variables (feed rate, depth of cut, and speed rate) of cylindrical grinding on surface roughness of SUS316L. By doing this project, the surface roughness for different parameters will be determined and will be compared to the various runs in surface quality. This research will be focused on understanding the effects of three specific parameters within a small range operating condition.

1.2 Problem Statement

In many industries, one of the final steps is the surface grinding that is used to surface finishing of the product. This process is necessary because forming, shaping, and machining processes alone do not achieve high enough dimensional accuracy or good quality surface finishes. The importance of surface roughness to the industry is due to a realization of the importance of manufacturing processes at the final step in the design and desired by the industry to reduce cost and improve the quality of product to compete in an international marketing. The purpose of this research was to find the variable parameter that can produce an optimum effect on the surface roughness of stainless steel 316L. This research has used stainless steel as a material compared to other researchers.

The problems may include the thermal damage, rough surface, vibration, chatter wheel glazing, and rapid wheel wear. Common problems encountered have been analyzed purposely to show how the parameters could be optimized and at the same time improving the grinding quality. In automotive industry, the most influence characteristics in life and leakage performance of a reciprocating sealing system such as piston rings was surface roughness. The functions of piston ring are to seal off the combustion pressure, to distribute and control the oil, to transfer heat and stabilize the piston but the problem of scuffing is likely to occur if the surface roughness is too high or too low (Andersson, 2002).
The vibration analysis techniques commonly used in industry for machine condition monitoring (S. Ebersbach, Z. Peng, 2008) so as been indicated in this journal a vibration analysis has been considered to be proceeded in this experiment as this data analysis may help practitioner or engineers to improved the noise reduction and signature detection. Through this data, engineers can determine the machine performance and maintain the quality of the products.

To show the relationship between cutting parameter and surface roughness, the experiment has been design by using DOE (Design of Experiment) method. This method is actually appropriate to measure the machine performance and the data has resulted in a short period.

### 1.3 Objective

There are three main objectives by doing this project:

a) To find the significant and non-significant factors that effect surface roughness on stainless steel 316L.

b) To find the optimum parameter which affect a surface roughness of Stainless Steel 316L.

c) To develop a mathematical model of surface roughness
1.4 **Scope of project**

Several elements were considered in order to achieve the goals of this study successfully:

a) Choose variable parameters.

b) Design of experiment by using DOE method

c) Analyze the surface roughness by using a portable surface roughness measurement.

d) Find the optimum effects of the surface roughness.
1.5 Project Organization

This project consisted of six chapter including PSM II, and I, which are:

Chapter 1 introduces of grinding process, problem arises in industry, which drive to develop this objectives and scope of this project.

Chapter 2 reviews on the literature from journal, books and internet. The area covered including surface roughness, cutting parameter, vibration etc.

Chapter 3 describes methodology to develop the experiment, the requirement to ensure this experiment completely run.

Chapter 4 containing all the analysis graph about the surface roughness and vibration, interrelation between cutting parameters and surface roughness and relation between vibration and surface roughness.

Chapter 5 discussed the analysis graph and focused on significant effects.

Chapter 6 conclusion and summarization the objectives of this project and recommendations for the future study has been suggested.
2.1 Surface Roughness

In manufacturing industry, surface roughness is an important design consideration. Roughness is defined as closely spaced, irregular deviations on a small scale; it is expressed in terms of height, width and distance along the surface (Kalpakjian, 2006). There are several factors that should to be considering in finishing process to improve surface quality. Surface waviness and surface roughness are the parameters that most commonly in surface metrology. The Roughness produced by grinding was commonly from 0.2 to 0.8 µm (Luca et al., 2004).

After finishing process, it can see the pattern on workpieces which known as surface finish or surface roughness (John, 2004). Surface roughness generally describe by two methods. The arithmetic mean value (Ra) is based on the schematic illustration of a rough surface. Then is the root-mean-square roughness (Rq) formerly identified as RMS.

The unit generally used for surface roughness is µm (micron). Kalpakjian et al. (2006), noted that surface cannot be described by its Ra or Rq value alone, since these value are average. Two surfaces may have the same roughness value but have actual topography which is very different.
In engineering practice, there is some requirement for manufacturing product for example Bearing ball is 0.025 μm, Crankshaft bearing is 0.32 μm, Brake drums is 1.6 μm and Clutch-disk faces is 3.2 μm. The result from the experiment can be compared with that value.

### 2.1.1 Theoretical Model of Surface Roughness

This model is design to understand how cutting parameter affecting a surface roughness. The standard equation is as follow (Vernon, 2003):

\[
Ra = \frac{f^2}{32r_c}
\]  

Where \( Ra \) = surface roughness (mm), \( f \) = Feed rate (mm/rev), \( r_c \) = tool nose radius (mm). This equation show that if feed of rate increase then surface roughness increase also. The tool nose radius will decrease surface roughness when the value of \( r_c \) is increase.

### 2.1.2 Factors Effecting Surface Roughness

Surface roughness on workpiece can be determined by study the process parameter. These factors can be divided into three groups:

a) Setup variables
b) Tool variables
c) Workpiece variables

It is impossible to find all the variables that impact surface roughness in cylindrical grinding. In addition, it is costly and time-consuming to discern the effect of every
variable on the workpiece. In order to simplify the problem, one needs to eliminate or select specific variables that correspond to practical application. In this project, the setup variables will be choosing to complete this analysis.

2.1.2.1 Setup Variables

The most commonly variables in cylindrical grinding are the machine setup. Cutting speed, feed rate and depth of cut have a very significant impact on the surface quality. Surface roughness is related to feed rate and work speed (Saglam, 2005). Eduardo et al (2004) noted that roughness increase along with the in feed rates.

Sahin and Motorcu (2005) noted the surface roughness increased with the increase of feed rate but decreased with cutting speed and depth of cut. The feed rate has the most dominant effect on surface roughness value produced by coated carbide tools.

Choi et al. (2007) have developed grinding process models for cylindrical grinding processes based on the systematic analysis and experiment. In the experiment, there are several setup variables including dressing depth of cut (mm), dressing lead (mm/rev), surface speed of the workpiece (mm/s), surface speed of the grinding wheel (m/s) and depth of cut (mm/rev). This experiment was design in three levels and run 18 experiments.

Kwak et al. (2005) have done an analysis of grinding power and surface roughness in external cylindrical grinding of hardened SCM440 steel using the response surface method. The result (Fig 2.1) showed that increasing the depth of cut changed the maximum height of the surface roughness more than the centerline average height. The surface roughness was dominantly affected by the change of the workpiece speed.
Fig 2.2 shows the centerline average height of the surface roughness for different depths of cut and traverse speeds.

Figure 2.1: Effect of depth of cut on surface roughness with constant workpiece speed (Kwak et al., 2005)
Kruszynski (2005) noted that the proper selection process in their analysis is peripheral speed, traverse feed and depth of cut which essential utility of coming up to product quality requirements.

Qian et al. (2000) have use the traverse mode grinding parameter (Table 2.2) in their experiment. This experiment was carry out to investigate a high efficiency precision grinding of bearing steel to evaluate the suitability and feasibility of ELID (Electrolytic in process dressing) grinding as a super finishing technique for bearing components. The samples were evaluated with respect to roughness, waviness roundness and residual stress. The increasing of depth of cut and traverse rate worsens surface finish.

Specific energy requirements in grinding are defined as the energy per unit volume of material ground from the workpiece surface and shown in Table 2.1.
Table 2.1: Approximate Specific-Energy Requirements for Surface Grinding  
(Kalpakjian, 2006)

<table>
<thead>
<tr>
<th>Workpiece material</th>
<th>Hardness</th>
<th>Specific energy (W. s/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>150 HB</td>
<td>7-27</td>
</tr>
<tr>
<td>Cast iron (class 40)</td>
<td>215 HB</td>
<td>12-60</td>
</tr>
<tr>
<td>Low-carbon steel (1020)</td>
<td>110 HB</td>
<td>14-68</td>
</tr>
<tr>
<td>Titanium alloy</td>
<td>300 HB</td>
<td>16-55</td>
</tr>
<tr>
<td>Tool steel (T15)</td>
<td>67 HRC</td>
<td>18-82</td>
</tr>
</tbody>
</table>

Table 2.2: Traverse mode grinding parameter (Qian et al., 2000)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Level investigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grinding speed ($V_s$)</td>
<td>12 ~ 20 m/s</td>
</tr>
<tr>
<td>Workpiece speed ($V_w$)</td>
<td>0.035 ~ 0.105 m/s</td>
</tr>
<tr>
<td>Traverse feedrate ($V_t$)</td>
<td>1.5 ~ 4.5 mm/s</td>
</tr>
<tr>
<td>Depth of cut (d)</td>
<td>0.5 ~ 2 μm</td>
</tr>
</tbody>
</table>

There are so many factors to be considered when selecting work speed that it is impracticable to lay down definite speeds for given types of work. The work speed most suitable for normal operating conditions are usually within the surface speed range of 18 to 30 m/min. Low work speed causes a hard wheel to glaze if the cut is light or load if the cut is deep. Slower work speeds can be effectively used in conjunction with soft wheels and deep cuts. If the work is rotated too fast it may vibrate, preventing the production of a truly round cylinder or causing breakdown of the wheel face. If the work speed is increased the wheel tends to act softer. The wheel infeed or dressing should be operates at each end of the traverse so as to distribute the work over the whole width of the grinding wheel.