UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EFFECT OF CUTTING PARAMETER ON ROUGHNESS DURING SURFACE GRINDING OF INCONEL 718

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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APPROVAL

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

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(Dr. Mohd Shahir Kasim)

ABSTRACT

Surface grinding is a finishing process where it will give the surface roughness of the product lower than before. By this process, smooth surface can be produced. In order to do this process, surface grinding machine is used. The parameters that are variable in order to get the smoother surface roughness are traverse speed, depth of cut and number of passes. The surface roughness is identified by using portable surface roughness machine. The surface of the material look closer by using a stereo microscope. In this experiment, there are 19 runs. Historical data under Response Surface Methodology (RSM) is used to construct and analyze the data. Analysis of variance (ANOVA) is used in order to look for the trend of the parameter towards the surface roughness. After the analysis is done, the parameters can be known whether it is significant or non-significant. A factor that is significant and not significant has been identified. Traverse speed and depth of cut are significant factors while the number of passes is not a significant factor in this experiment. A model is created after a trend have been developed. In order to know whether the model is valid to use, validation of the model is done. The number of errors produced is indicated whether the model is valid or not. The model was valid as the error from actual value and predicted value of surface roughness is 9.86%, which is less than the maximum acceptable error. The future surface roughness can be predicted by insert the parameters into the model. The optimum response were achieved by traverse speed of 9173 mm/min, depth of cut of 7 µm, and 10 number of passes. From this experiment, Inconel 718 can have low surface roughness even though it is difficult to machine.

ABSTRAK

Pengisaran permukaan adalah satu proses akhir di mana ia akan memberikan kekasaran pada permukaan produk lebih rendah daripada sebelumnya. Melalui proses ini, permukaan licin boleh dihasilkan. Bagi melakukan proses ini, mesin pengisaran permukaan digunakan. Parameter yang berubah untuk mendapatkan kekasaran permukaan yang licin adalah kelajuan mendatar, kedalaman pemotongan dan bilangan laluan. Kekasaran permukaan dapat dikenalpasti dengan menggunakan mesin mudah alih kekasaran permukaan. Permukaan bahan dapat dilihat dengan lebih dekat dengan menggunakan mikroskop stereo. Eksperimen ini, terdapat 19 kali operasi. Data sejarah di bawah Kaedah Sambutan Permukaan (RSM) digunakan untuk membina dan menganalisis data. Analisis varians (ANOVA) digunakan untuk mencari arah aliran parameter terhadap kekasaran permukaan. Selepas analisis dilakukan, parameter boleh diketahui sama ada memberi kesan atau tidak. Faktor yang penting dan tidak penting telah dikenal pasti. Kelajuan melintang dan kedalaman pemotongan adalah penting manakala bilangan laluan adalah bukan faktor penting bagi eksperimen ini. Model dicipta selepas arah aliran telah terhasil. Untuk mengetahui sama ada model itu adalah sah untuk digunakan, pengesahan model dilakukan. Bilangan ralat yang terhasil menunjukkan sama ada model itu adalah sah atau tidak. Model ini adalah sah kerana ralat daripada nilai sebenar dan nilai ramalan kekasaran permukaan adalah 9.86% dimana kurang daripada ralat maksimum yang boleh diterima. Kekasaran permukaan boleh diramal dengan memasukkan parameter ke dalam model. Hasil optimum dicapai dengan kelajuan melintang sebanyak 9173 mm / min, kedalaman pemotongan sebanyak 7 µm, dan bilangan laluan adalah 10. Daripada eksperimen ini, Inconel 718 boleh mempunyai kekasaran permukaan yang rendah walaupun ianya sukar untuk pemesinan.

DEDICATION

To my beloved parents,
Yaakob Mohd Amin
Masrifah Haji Maskor

My beloved siblings,
Muhammad Asyraf Yaakob
Syaza Amirah Yaakob
Syarah ‘Afifah Yaakob
Muhammad Aizat Yaakob
Nurul Adiilah Yaakob
Muhammad Amirul ‘Adli Yaakob
Muhammad Arief Akmal Yaakob

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Grinding is a chip-removal process that uses an individual abrasive grain as the cutting tool (Kalpakjian & Stevent, 2014). Rowe (2009) defined that grinding is a term used in modern manufacturing practice to describe machining with high-speed abrasive wheels, pads, and belts. In other word, grinding is a machining process that employs an abrasive grinding wheel rotating at high speed to remove material from a softer material (Marinescu et al, 2006). It is one of the last steps in machining operation chain and highly developed to particular product and process requirement. In this study, surface grinding machine is used.

Aslan and Budak (2014) stated that grinding can be a cost effective alternative even for roughing operations of some hard-to-machine materials. It is important to know the relation between input parameter and its response or output characteristic. Input parameter that usually researcher vary it are speed, feed rate, depth of cut, type of wheel, grit, usage of coolant and force. In this study, three parameters are vary which are traverse speed, depth of cut and number of passes.

The output or the response that is going to study is the surface roughness of the material. Surface roughness is choose as the response because, it is one of the quality measures, especially in industry of manufacturing (Davim, 2010). In the shop floor, the usual practice is to allocate to the grinding process the most experimented operators, who use their experience to take decisions related to the process (Hassui & Diniz, 2003). Moreover, the machining conditions used play a key role in deciding the surface quality (Mankar & Jadhav, 2007). This shows that the surface quality is not easily predicted by its parameter.

1.2 Problem Statement

Surface grinding is one of the final steps that is used to surface finish of the product. This because, the product that was not done by finishing process will result bad surface roughness. It is important for the product to get the desired surface roughness as to improve the quality of product and survive in industry (Whitehouse, 2004). By choosing survival in industry, it will give a good opportunity to suggest the result and applied it in industry. Choosing problems that can give result that have merit (Alon, 2009).

In this study, Inconel 718 which is Nickel base alloy is the material of specimen. This type of material is not only has high strength, fatigue resistance, corrosion resistance, and heat resistance, but also possesses lower thermal conductivity (Tso, 1995b). This type of material has a wide variety of particular purposes. It is mainly applied in reciprocating engines, stack gas reheater and aircraft gas turbines. However, Nickel-base super alloy, Inconel 718, is generally known to be one of the most difficult materials to machine because of its high hardness, high strength at high temperatures (Nalbant et al, 2007). Machinability is refer to the work material being machined in ease way under a given set of cutting parameters conditions where the main parameters of machinability assessment are surface roughness, cutting force and tool life (Choudhury & El-Baradie, 1999).

There will be several effect to the sample which grind with one type of grinding wheel. The purpose of this research is to find the good parameter that can produce optimum effect on the surface roughness of Inconel 718. Due to the hardness of the Inconel 718 with the type of grinding wheel, depth of cut will affect the surface roughness (Ulutan & Ozel, 2011). This research also develop to know the best feed rate that will give the best surface roughness. At the end of this study, a model can be created based on the experimental run. There are narrow attention on grinding process of Inconel 718.

Understanding the behaviour of Inconel 718 in the grinding process is vital importance as it is limited attention on machinability of Inconel 718 (Tso, 1995b).

1.3 Objectives

While grinding, there will be changes in surface roughness of Inconel 718 due to different parameter used. There are three objectives that will be executed which are:

a) To identify the significant and non-significant factors that affect surface roughness on Inconel 718.
b) To identify the optimum parameter which affect surface roughness of Inconel 718.
c) To develop a mathematical model of surface roughness.

1.4 Scope

Surface grinding machine is used in order to grind the surface of the material. The material that is going to be grind is Nickel base alloy which is Inconel 718. The sample size of the material is 123 x 31 x 30 mm. Traverse speed, depth of cut and number of pass is vary in order to find significant and non-significant factor of surface grinding.

Design of Experiment (DOE) is used to design the experimental run. By using Design Expert software, this research applies the historical data approach which is under response surface methodology to study the surface roughness. The surface roughness is measured from the surface grinding machine. 19 experimental run is construct in order to analyse the trend of the surface roughness. Each of the variable parameter is vary in three values. The values are decided by previous study and the range of parameter that the machine can handle. The parameter input that is constant for every experiment are type of wheel and coolant used. Type of wheel that is used is aluminium oxide (Al_2O_3) while the type of coolant is Synkool 300G which is synthetic water soluble coolant.

In order to identify its surface roughness after it is grind on its parameter, portable surface roughness machine is used. Arithmetic mean value, Ra is used which the standard is Jis 94. In order to look closer on the surface topography, stereo microscope is used. Data collected is then be analysed by analysis variance (ANOVA).

If there is a void on the surface of the material after grind, the size of the void is not going to be measured. The chip formation also will not be analyse. The attention is more on its surface roughness.

1.5 Report Organization

This report consist of five chapters. First chapter is explaining about the background of the study and problem statement which develop objectives and scope.

Second chapter is revolve on literature review from journal, books and web sites that related to the surface roughness of Inconel 718. It also include the parameters that will affect the surface roughness. At the end of this chapter will include summary of sum previous research related to this study.

Third chapter explaining about the method used to execute the experiment. Apparatus, tools, software and material used in the experiment also explain in this chapter. The design of experiment was also explained in this chapter.

In chapter four, the result obtain from the experiment are shown. Analysis from the result also included in this chapter. The discussion which is the explanation from the result also discussed in this chapter.

The last chapter which is chapter five is the conclusion for the whole experiment. The result from the achievement of objective is concluded.

CHAPTER 2

LITERATURE REVIEW

2.1 Surface roughness

Surface roughness is a component of surface texture. Surface roughness, not surprisingly, is closely related to uncut chip thickness (Marinescu et al., 2006). In other word, roughness is defined as narrowly spaced, uneven deviations on a small scale; it is expressed in terms of its width, height and distance along the surface (Kalpakjian & Stevent, 2014). There are two methods of surface roughness which are arithmetic mean value (Ra) and root-mean-square roughness (Rq). The arithmetic mean value is based on the schematic illustration of a rough surface and defined as (Hashimoto et al., 2012):

$$Ra = \frac{a + b + c + d + \cdots}{n} \qquad (1)$$

Where all ordinates a, b, c, …, are absolute values and n is the number of readings. In the other hand, root-mean-square roughness is defined as

$$Rq = \sqrt{\frac{a^2 + b^2 + c^2 + d^2 + \cdots}{n}} \qquad (2)$$

The unit of surface roughness generally used micro meter, (μm). Figure 2.1 shows the surface characteristics that the roughness is measured. The figure shows a surface that has been produced by some machining process. There are two orders of structure. The roughness with its typical roughness spacing and roughness height represents the more narrowly spaced peaks and valleys. Usually, roughness is produced by the basic process of surface forming.

The pick direction measurement is measure on the waviness of the surface. It consists of broadly spaced irregularities and is often produced by vibrations in the machine. In the other hand, feed direction is measure on the lay. Term lay is used to represent the direction of the dominant pattern of texture on the surface. Machining processes that produced surfaces ordinarily have a strong lay pattern (Vorburger & Raja, 1990).

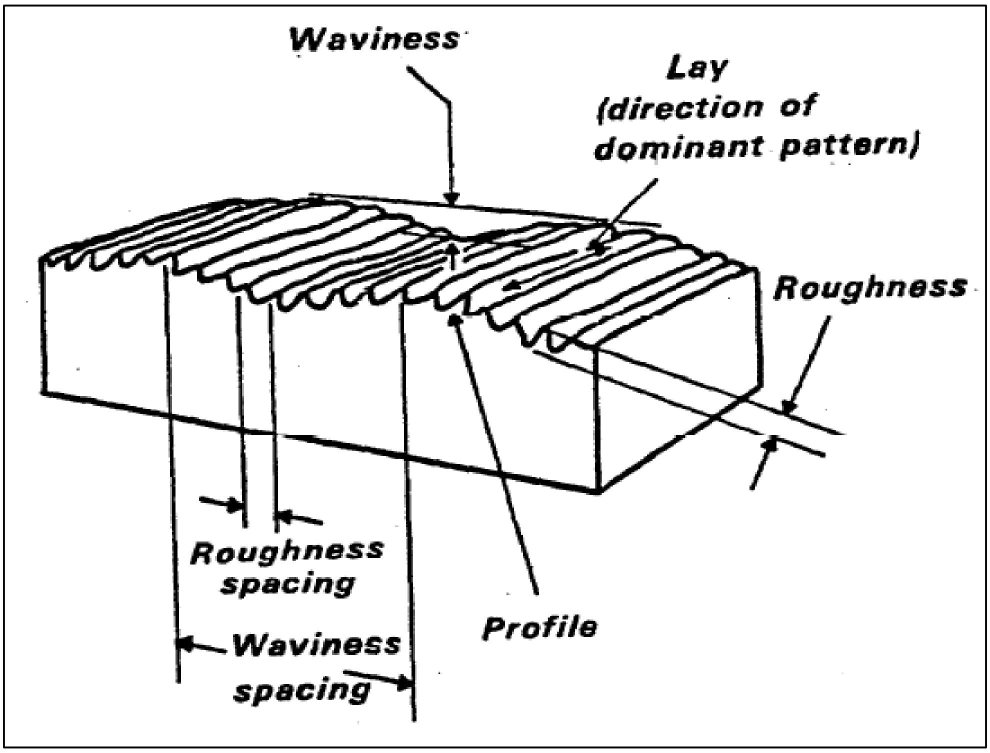

Figure 2.1: Surface Characterisrics and Terminologies (Vorburger & Raja, 1990).

Surface integrity is important in manufactured products as it affects various properties of the manufactured parts like corrosion rate, stress corrosion cracking, wear, fracture toughness magnetic properties and dimensional stability (Demir et al., 2010).

2.2 Grinding Parameters

Grinding is different from turning and milling processes. It is important to know the grinding parameter in order to understand on how process adjustments change cycle time, part quality and wheel performance. Usually, it is quite limited in understanding the number of grinding parameters. Surface roughness is affected by wheel speed, traverse speed, feed rate, type of workpiece, depth of cut, type of wheel, and other parameter (Razali, 2010).

2.2.1 Depth of cut

Depth of cut is the most basic grinding parameter. Depth of cut is the depth of material removed per revolution or table. The real depth of cut a_e is the depth of cut that has been cut by grinding process. Typically, real depth of cut is approximately a quarter of programmed depth of cut a_p depending on the workpiece hardness (Rowe, 2009). Based on Singh et al (2014), depth of cut is the most significant parameter that effect the surface roughness. It can be said that, the higher the depth of cut, the higher the surface roughness. Furthermore, the increase in depth of cut will increased the maximum chip thickness which resulted in poor surface quality (Shokrani et al., 2012).

Moreover, lower depth of cut resulted lower surface roughness, while higher depth of cut resulted in higher values of surface roughness due to the higher values of peaks height (Arunachalam et al., 2004).

2.2.2 Traverse speed

Grinding operations considered two dimensional motions in a common plane which are wheel and workpiece motions. The equivalent terms of work speed are traverse speed and table speed (Marinescu et al., 2006). Traverse grinding involves the addition of cross feed which is traverse motion of the grinding wheel relative to the workpiece in a direction perpendicular to the plane of the wheel rotation (Malkin & Guo, 2008).

The workpiece metal will be stick by magnetic worktable of surface grinding machine. However, Inconel 718 is not magnetize, therefore clamping mechanism is used to attach the workpiece. If the traverse speed is different, the surface roughness of the workpiece will also be different. The surface roughness increases with decreasing grinding wheel speed and increasing table speed and down-feed (Tso, 1995b). By increasing the traverse speed, the surface roughness will also increase (Shokrani et al., 2012). This because, reduce work speed will reduce waviness (Drive, 2007).

2.2.3 Number of pass

Grinding process is different from other process like turning and milling as it can do in two ways which are in single stage or multi-pass grinding. By applying multi-pass grinding, the surface roughness can be improved and better than single stage. The single of grinding process did not give the surface roughness as smooth as multi-pass grinding (Azizi, 2008). Therefore, number of passes is considered as variable parameter in this study.

2.2.4 Wheel speed

The higher the grinding speed, the lower the forces and surface roughness that allowing higher removal rate. The advantages of high-speed grinding are high productivity, accuracy and quality. It also will reduce manufacturing complexity and improve process reliability. By applying high-speed grinding, it will result better integrity, better accuracy, faster machining and high-efficiency grinding (Rowe, 2009).

The effect of increasing the speed of wheel with constant work speed and depth of cut will result low material removal rate by each grain. Surface roughness, grinding force, and wheel wear are also reduced (Rowe, 2009). In the other hand, the effect of increasing wheel speed with increasing material removal rate in directly proportional will result constant grinding force, roughness and wheel wear. Figure 2.2 shows the effect of increasing wheel speed for both situation.

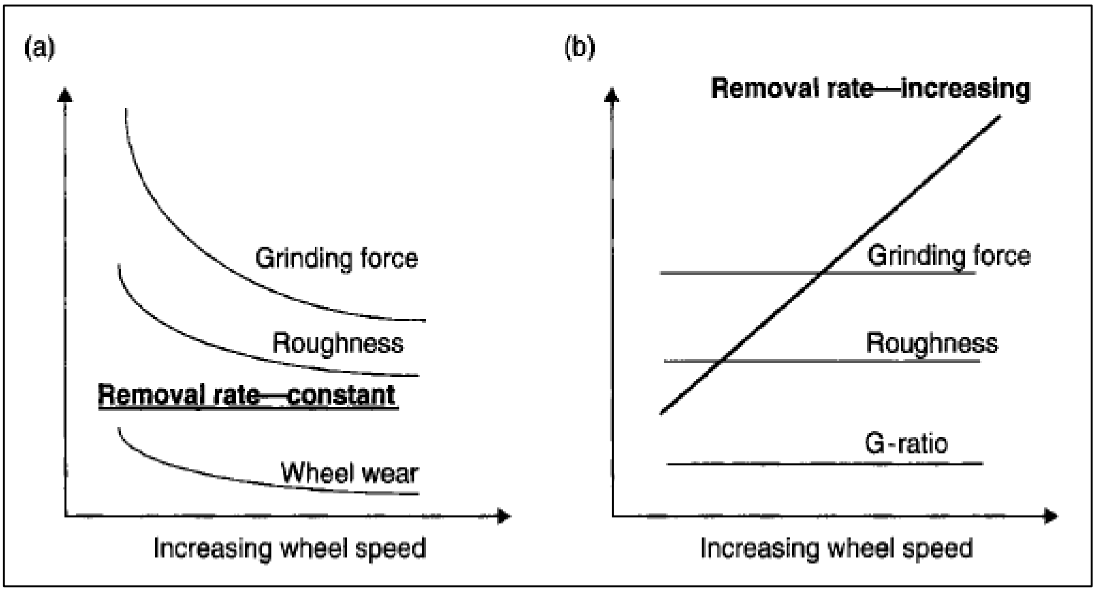

Figure 2.2: Effect of increasing wheel speed a) at constant removal rate and b) at increasing removal rate (Rowe, 2009).

2.3 Surface grinding machine

Grinding process will composed of chip formation. At the very first stage of the interaction between abrasive grit and the workpiece, plastic deformation occurs, temperature of the workpiece increases and let normal stress to exceed yield stress of the material (Aslan & Budak, 2014). After a certain point, abrasive grit starts to penetrate into the material and starts to displace it, which is responsible for the ploughing forces. Finally, grit starts to shearing action and removes the chip from workpiece (Aslan & Budak, 2014). Factor of applying grinding process is because of it gives high accuracy. Furthermore, high removal rate that is required by the material can be applied by grinding process. Machining of hard materials is also one of the factor that grinding process is applied (Marinescu et al., 2006).

Rowe (2009) identify that the input for grinding process are speeds, feeds, tools, materials, labour, energy and cost. Grinding process also has disturbances which will affect the output of the process. The disturbances are vibrations, tool shape errors, static deflections, initial workpiece shape, temperature flactuations and machine errors. By present of those disturbances, the output will be affected. This will result, inaccurate value. Therefore, it is important to run the experiment in condition of absent or minimum disturbance.

The productive outputs are shape and accuracy, machined parts, production rate, surface integrity and surface texture. Surface texture is the nature of a surface as defined by the three characteristics which are lay, surface roughness and waviness. The small local deviations of a surface from the perfectly flat ideal is comprise. In the other hand, surface condition of a workpiece after being modified by a manufacturing process where it change the properties of the material is the surface integrity. There are also non-productive outputs which are waste fluid, noise, tool wear, swarf, heat, and mist (Rowe, 2009). Those non-productive outputs are produce during or after grinding process.

Down-cut is one of the grinding process. The advantages of conventional down-cut grinding are its surface roughness and reduced wheel wear as the force tend to be lower (Rowe, 2009). There will be material removal in down-cut grinding as shown in Figure 2.3. There are three stages of metal removal which are rubbing, cutting and ploughing. Some grains rub without ploughing. There also some grains plough without cutting and some grains experience all three stages. It is depending on increasing depth of grain penetration into the surface (Rowe, 2009). Figure 2.4 shows rubbing, ploughing and cutting through the arc of contact.

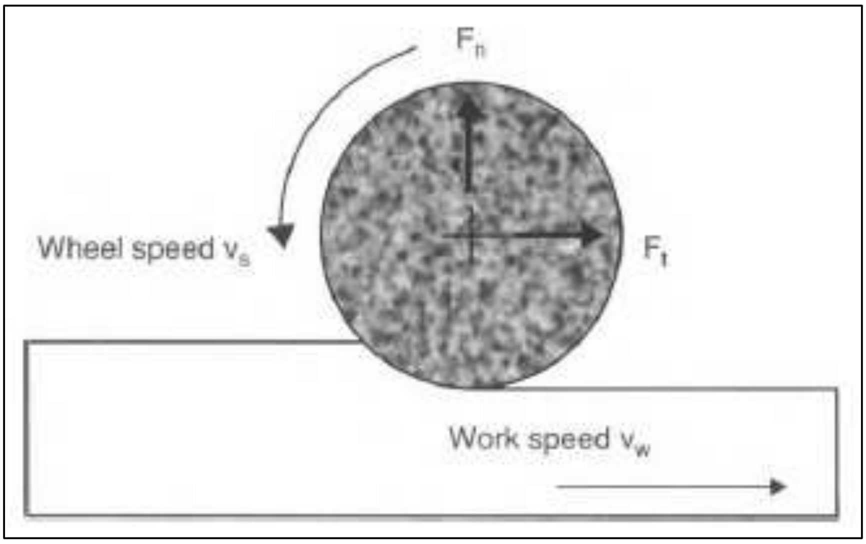

Figure 2.3: Material removal as workpiece the grinding wheel in down-cut grinding (Rowe, 2009).