TAGUCHI APPROACH ON SURFACE INTEGRITY OF TITANIUM IN TURNING OPERATION USING TIN COATED CUTTING TOOL

AIDA AZWA BT A.HALIM

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FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "Taguchi approach on surface Integrity of Titanium in Turning Operation Using Tin Coated Cutting Tool." is written by Aida Azwa Bt A.Halim. I have examined the final copy of this project and in my opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I here with recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

(JASRI BIN MOHAMAD)

Examiner Signature

SUPERVISOR'S DECLARATION

I hereby declare that I have read this project report and in my opinion this project report is sufficient in terms of scope and quality for the award of the Degree in Mechanical Engineering

Signature	:	....
Name of Supervisor	:	MOHAMED REZA ZALANI BIN MOHAMED SUFFIAN
Date	:	06 DISEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurently submitted for award of other degree.

Signature : ....

Name : AIDA AZWA BT A.HALIM

ID Number: 871018-05-5418

Date : 06 DISEMBER 2009

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ABSTRACT

Modern manufacturers, seeking to remain competitive in the market, rely on their manufacturing engineers and production personnel to quickly and effectively set up manufacturing process for new products. Taguchi Parameter design is a powerful and efficient method for optimizing quality and performance output of manufacturing processes, thus a powerful tool for meeting this challenge. This thesis discusses an investigation into use the Taguchi Parameter Design for optimizing surface roughness generated by a Computer Numerical Controller (CNC) lathe. Control parameters being consider in this thesis are cutting speed, feed rate and depth of cut. After experimentally turning sample workpiece using the selected orthogonal array and the parameters, this study expected produce an optimum combination of controlled parameter for the surface roughness. And from the result generated, the correlation for surface roughness with the cutting parameters satisfies a reasonable degree of approximation. Cutting speeds are a significant parameter in influencing the surface roughness.

ABSTRAK

Pembuatan zaman moden, mencari factor untuk terus bersaing di pasaran, perlu bergantung kepada jurutera pembuatan dan operator pengeluar untuk bekerja dengan cepat dan effektif dalam menyediakan proses pembuatan untuk produk baru. Kaedah parameter Taguchi adalah satu kaedah yang berguna dan berkesan untuk mengoptimumkan kualiti kesan penghasilan , oleh itu , ia merupakan suatu kaedah yang berguna untuk mengatasi cabaran ini. Tesis ini membincangkan suatu kajian dalam menggunakan kaedah parameter Taguchi untuk mengoptimumkan kekasaran permukaan yang dihasilkan oleh mesin larik. Parameter yang dipilih dalam tesis ini ialah kelajuan pemotongan, kadar potongan dan kedalaman potongan. Selepas selesai melarikkan bahan kerja berdasarkan susunan orthogonal dan parameter, kajian ini dijangka dapat menghasilkan satu kombinasi parameter yang optimum untuk kekasaran permukaan. Dan dari keputusan yang dihasilkan, korelasi untuk kekasaran permukaan dengan parameter pemotongan memenuhi tahap pendekatan yang sewajarnya. Kelajuan pemotongan dan kedalaman pemotongan merupakan parameter yang signifikan dalam mempengaruhi kekasaran permukaan.

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LIST OF SYMBOLS

DF	Degrees of freedom from each source.
F	Calculate by dividing the factor MS by the error MS.
M.S.D	Mean square deviation
MS	Mean squares are found by dividing the sum of squares by the degrees of freedom.
P	Use to determine whether a factor is significant; typically compare against an alpha value of 0.05. If the p-value is lower than 0.05, then the factor is significant.
Ra	Surface roughness.
S/N	Signal-to-noise.
SS	Sum of squares between groups (factor) and the sum of squares within groups (error).
TiN	Titanium.
VHN	Vicker's hardness test.
α	Alpha.
β	Beta.

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

Titanium is extremely difficult to machine materials. The machinability of titanium and its alloys is generally considered to be poor owing to several inherent properties of materials. The aims of this project were to investigate surface integrity effects when machining titanium by tin coated cutting tool.

The first coating to be used successfully to machine steel in industry and still the most recognized, distinguished by its attractive bright gold colour. The Tin coating was first used on High Speed Steel (HSS) tooling because it could be applied below 500 deg C, the temperature at which HSS starts to soften. However the many advantages of the Tin coating were obvious to the cemented carbide industry, and in 1985 the first Tin coated cemented carbide cutting tool inserts were introduced for turning applications.

Surface integrity is the description and control of the many possible alterations in a surface layer caused during machining, including their effects on the material properties and the performance of the surface in services. It is also concerned primarily with the host of effects below the visible surface or so called subsurface alterations in a machining process. Field (1998) and Roger (1971) elaborated the surface integrity as the description and control of the many possible alterations in a surface layer caused during machining, including their effects on the material properties and the performance of the surface in service. Surface integrity is concerned primarily with the host of effects on a machining process which is below the visible surface. The subsurface characteristics occur in various layers of zones. Abrao et al. (1995) found changes in surface texture and hardness together with subsurface microstructure alterations when cutting hard enable steels with ceramic and PCBN tool materials. Field (1998) presented various machining surface alteration results including drilling, turning and milling in his technical paper. Surface integrity in different machining processes was investigated by Leskovar and Peklenik (1982) and Bryne et al. (1997).

Measurement of the macro-hardness of materials is a quick and simple method of obtaining mechanical property data for the bulk material from a small sample. It is also widely used for the quality control of surface treatments processes. However, when concerned with coatings and surface properties of importance to friction and wear processes for instance, the macro-indentation depth would be too large relative to the surface-scale features. Where materials have a fine microstructure, are multi-phase, non-homogeneous or prone to cracking, macro-hardness measurements will be highly variable and will not identify individual surface features. It is here that micro-hardness measurements are appropriate.

1.1 PROJECT BACKGROUND

The term surface integrity is used to describe the quality and condition of the surface region of a component. Specialized test were conducted to characterize surface integrity such as surface texture (roughness and lay), macrostructure (macrocracks and surface defects), microstructure (microcracks and plastic deformation), and microhardness. In this project, the focus will be on surface roughness and microhardness test.

Titanium alloy are widely used in aeroengine fan blades and turbochargers due to the exceptional strength to weight ratio (Ezungwu, 2005), and high temperature performance (Zoya and Krishnamurty, 2000). The researchers always selected titanium alloy as a material that will be investigated since it has high strength-to-weight ratio characteristics.

Machined surface integrity of titanium depends on several factors such as cutting speed, tool wear, feed, tool materials, and geometry (Amin et al., 2007). That is why researchers from many institutions will run experiments to determine which factors contribute in good performance of titanium alloy. Most factors selected are cutting speed, depth of cut, and feed rate, so do as in this project.

Measurement of the macro-hardness of materials is a quick and simple method of obtaining mechanical property data for the bulk material from a small sample. It is also widely used for the quality control of surface treatments processes. However, when concerned with coatings and surface properties of importance to friction and wear processes for instance, the macro-indentation depth would be too large relative to the surface-scale features.

Materials have a fine microstructure, are multi-phase, non-homogeneous or prone to cracking, macro-hardness measurements will be highly variable and will not identify individual surface features. It is here that micro-hardness measurements are appropriate.

1.2 PROBLEM STATEMENT

The researches on surface integrity and hardness are to extent of these a defect depends on the interaction of the mechanical and thermal energy produced on the workpiece material properties. The defects produced from different machining procedures can significantly affect the performance of the final component.

The level of parameter is the main point because it will affect the surface of the workpiece, it also to avoid from scratch marks or inaccuracies in the cut. In a turning operation, it is important task to select a good combination of parameter level for achieving high cutting performance. Generally, this combination is hard to find.

1.3 PROJECT OBJECTIVES

The objectives of the project are:

i. Demonstrate a systematic procedure of using Taguchi parameter design in process control of turning machine.
ii. Determine turning parameters effect on surface roughness of titanium.

iii. Investigating the effect of cutting speed, feed of rate and depth of cut to surface hardness and surface structure of titanium.

1.4 SCOPE OF PROJECT

The scope of project involve to this study are:

i. Used the application of Taguchi method to optimize the cutting parameter for turning operation.
ii. The experiments were performed on a Computer Numerical Control Turning machine.
iii. Surface integrity characterizations conducted where surface roughness measured using a stylus Perthometer, macrostructure and microhardness measured using Vickers indenter.
iv. *MINITAB* software use in analyze the collected result.

1.5 SIGNIFICANT OF SCOPE

The significant of scope for this research are:

i. Reduce the sensitivity of engineering designs to uncontrollable factors or noise.
ii. For optimizing machining performance with minimum cost and time to industrial readers.

1.6 SUMMARY

This chapter discussed about the project background such as the important of this manufacturing optimization. It also described the problem statement of this project, the important to the study, the objective and the scope of the project (limitation of the project).

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In modern industry the goal is to manufacture low cost, high quality products in short time. Turning is the first most common method for cutting and especially for the finishing machined parts. In a turning operation, it is important task to select cutting parameters for achieving high cutting performance. Cutting parameters are reflected on surface roughness, surface texture and dimensional deviations of the product. Surface roughness, which is used to determine and to evaluate the quality of a product, is one of the major quality attributes of a turning product. Surface roughness is a measure of the technological quality of a product and a factor that greatly influences manufacturing cost. It describes the geometry of the machined surfaces and combined with the surface texture. The mechanism behind the formation of surface roughness is very complicated and process dependent. To select the cutting parameters properly, several mathematical models based on statistical regression or neural network techniques have been constructed to establish the relationship between the cutting performance and cutting parameters (M. Nalbant, et. al, 2006).

There were four purposes of this research. The first was to demonstrate a systematic procedure of using Taguchi parameter design in process control of turning machines. The second was to demonstrate a use of the Taguchi parameter design in order to identify the optimum surface roughness performance with a particular combination of cutting parameters in a turning operation. The third was to demonstrate the microstructure (microcracks and plastic deformation) and microhardness of titanium.

2.2 TAGUCHI METHOD

Taguchi has developed a methodology for the application of designed experiments, including a practitioner's handbook. This methodology has taken the design of experiments from the exclusive world of the statistician and brought it more fully into the world of manufacturing. Taguchi introduces his approach, using experimental design for designing products processes so as to be robust to environmental conditions and designing and developing products or processes so as to be robust to component variation, and also to minimizing variation around a target value (M. Nalbant, et. al, 2006).

The objective of the parameter design is to optimize the settings of the process parameter values for improving performance characteristics and to identify the product parameter values under the optimal process parameter values. In addition, it is expected that the optimal process parameter values obtained from the parameter design are insensitive to the variation of environmental conditions and other noise factors. Therefore, the parameter design is the key step in the Taguchi method to achieving high quality without increasing cost (M. Nalbant, et. al, 2006).

A large number of experiments have to be carried out when the number of the process parameters increases. To solve this task, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. A loss function is then defined to calculate the deviation between the experimental value and the desired value. Taguchi recommends the use of the loss function to measure the performance characteristic deviating from the desired value. The value of the loss function is further transformed into a signal-to-noise (S/N) ratio. Usually, there are three categories of the performance characteristic in the analysis of the S/N ratio, that is, the lower-the-better, the higher-the-better, and the nominal- the-better. The S/N ratio for each level of process parameters is computed based on the S/N analysis. Regardless of the category of the performance characteristic, the larger S/N ratio corresponds to the better performance characteristic. Therefore, the optimal level of the process parameters is the level with the highest S/N ratio. Furthermore, a statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant. With the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. In this paper, the cutting parameter design by the Taguchi method is adopted to obtain optimal machining performance in turning (M. Nalbant, et. al, 2006).

Nominal is the best : $S/N_T = 10 \log \left(\frac{\bar{y}}{s^2 y}\right)$ Eq.2.1

Larger-is-the better (maximize) : $S/N_L = -10 \log \left(\frac{1}{n} \sum_{i=1}^{n} \frac{1}{y^2 i}\right)$ Eq.2.2

Smaller-is-the better (minimize) : $S/N_L = -10 \log \left(\frac{1}{n} \sum_{i=1}^{n} y^2 i\right)$ Eq.2.3

Where, $\bar{y}$, is the average of observed data, s^2y is the variance of y, n is the number of observations and y is the observed data. Notice that these S/N ratios are expressed on a decibel scale. We would use S/NT if the objective is to reduce variability around a specific target, S/NL if the system is optimized when the response is as large as possible, and S/NS if the system is optimized when the response is as small as possible. Factor levels that maximize the appropriate S/N ratio are optimal. The goal of this research was to produce minimum surface roughness (Ra) in a turning operation. Smaller Ra values represent better or improved surface roughness (M. Nalbant, et. al, 2006).

2.3 WORKPIECE MATERIAL

The workpiece material investigated in the project is titanium alloy Ti-6Al-4V. Titanium alloys are designated by major alloy and amount (see ASTM specification B-265), and are generally grouped into three classes based on their microstructural features. These classes are known as alpha-, beta-, and alpha-beta-titanium alloys, the terms denoting the stable phase or phases at room temperature (J. Sun, Y.B. Guo, 2008).

Figure 2.1: Titanium alloy Ti-6Al-4V.

Alloying elements can be used to stabilize the hexagonal-clode-packed alpha phase or the body-centered-cubic beta phase, and heat treatments can be applied to manipulate structure and improve properties. Because its properties are generally between those of steel and aluminium, its importance has been increasing rapidly.

The yield strength of commercially pure titanium is about 210 MPa (30 ksi), but this can be raised to 1300 MPa (190 ksi) or higher through alloying and heat treatment, a strength comparable to that of many heat-treated alloys steels. Density, on the other hand, is only 56% that of steel (making strength-to-weight quite attractive), and the modulus of elasticity ratio is also about one-half (R. Perryman, C.D Ellis, 2005).

Zoya and Krishnamurthy (2002) reported that surface roughness value decrease with the increase of cutting speed in the range of 150-185 m/min, but increased in the range of 185-350 m/min when turning stabilized titanium alloys. Several researchers found that surface roughness values become larger at high cutting speeds in turning Ti-6Al-4V (Ribeiro et al., 2003) and in end milling Ti-6Al-4V using WC-Co and PCD insert (Amin et al., 2007).