Optimization of Cutting Parameters for Surface Roughness in CNC Turning Machining With Aluminum Alloy 6061 Material

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LIST OF SYMBOLS

ANOVA	Analysis of Variance
DOE	Design of Experiment
OA	Orthogonal Array
g	Gram
QC	Quality Characteristic
MSD	Mean Standard Deviation
CF	Correction Factor
S’	Factor sum of squares
P	Percentage
S/N	Single to Noise Raito
ST	Total sum of square
SA	Sum of square of Factor A
PA	Percentage Deviation of Factor A
SB	Sum of square of Factor B
PB	Percentage Deviation of Factor B
SC	Sum of square of Factor C
PC	Percentage Deviation of Factor C
T	Sum of all observations
$\sum \boldsymbol{Yi}^2$	Sum of square Deviation
µm	Micrometer
MRR	Material Removal Rate
Ra	Surface Roughness

Pengoptimuman Memotong Parameter Untuk Kekasaran Permukaan Dalam CNC Pemesinan Beralih Dengan Aloi Aluminium 6061 Bahan

ABSTRAK

Proses Pemesinan melibatkan parameter proses banyak. Mencapai dimensi yang tepat, kualiti permukaan yang baik, dan penyingkiran logam dimaksimumkan adalah penting. Ini kerja-kerja penyelidikan menerangkan pengoptimuman memotong parameter untuk kekasaran permukaan dalam CNC pemesinan beralih dengan aloi aluminium 6061 yang ketara. Mengawal kualiti permukaan yang dikehendaki adalah perlu. Dalam kajian ini, kaedah Taguchi digunakan untuk mencari parameter pemotongan optimum untuk kekasaran permukaan dalam menjadikan. L-9 tatasusunan ortogon, nisbah isyarat-hingar dan analisis varians bekerja untuk mengkaji ciri-ciri prestasi dalam operasi beralih aloi aluminium 6061 menggunakan sisipan tidak bersalut. Pengetahuan tepat parameter optimum akan memudahkan pengurangan kos pemesinan dan meningkatkan kualiti produk. Kajian semasa proses menukarkan terpakai metodologi permukaan respons kepada parameter proses paling berkesan, iaitu, makanan, memotong kelajuan, dan kedalaman pemotongan yang dioptimumkan mempertimbangkan kekasaran permukaan dan kadar pembuangan bahan.

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ABSTRACT

Machining process involves many process parameters. Achieving accurate dimensions, good surface quality, and maximized metal removal are of utmost importance. This research work describes the optimization of cutting parameters for the surface roughness in CNC turning machining with aluminum alloy 6061 material. Controlling the required surface quality is necessary. In this study, Taguchi method is used to find the optimal cutting parameters for surface roughness in turning. L-9 orthogonal array, signal-to-noise ratio, and analysis of variance are employed to study the performance characteristics in the turning operations of aluminum alloy 6061 using uncoated inserts. A precise knowledge of these optimum parameters would facilitate reduction of machining costs and improve product quality. The current study on turning process applies a response surface methodology on the most effective process parameters, namely, feed, cutting speed, and depth of cut, which are optimized considering the surface roughness and material removal rate. The results of the machining experiments were used to characterize the main factors affecting surface roughness by the Analysis of Variance (ANOVA) method. Feed rate and speed of cutting founds to be a most influencing parameter for the surface roughness in the shaping process whereas depth of cut is found to be significantly affecting the MRR.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production cost. Surface roughness has an impact on the mechanical properties, as surface roughness of machined part is a significant design specification that is known to have considerable influence on properties. The quality of surface is a factor of importance in the evaluation of machine tool productivity. Hence, it is important to achieve a consistent surface finish and tolerance. Turning is the 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 affect surface roughness, surface texture and dimensional deviations of the product. Surface roughness is a factor that greatly influences manufacturing cost. It describes the geometry of the machined surfaces and it has combined with the surface texture. To select the cutting parameters properly, several mathematical models based on neural network or statistical regression techniques have been constructed to establish the relationship between the cutting performance and cutting parameters (Nalbant et al ., 2007).

1.2 Problem Statement

The best possible surface quality within the given constraints for precision components machining has been the key issue. Some of the study reveals that the surface roughness is the most important requirement along with geometrical and dimensional qualities (Thangarasu , el at 2013). In many machining operations had found the various parameters affecting the responses .The choice of high-speed manufacturing process is for lower cost, productivity and quality requirements. Higher productivity with best quality of precision in manufacturing. Experimental observations one model CNC machining. The effects of cutting speed, feed, and depth of cut, nose radius and other factors on the surface roughness, in machining it have been evaluated and models are developed for the requirements.

In order to produce a good quality product at a minimal cost, every manufacturing company seeks for a low surface roughness, low tool wear, and high Material Removal Rate (MRR). All these three outputs are the most critical in the turning process that had taken into consideration. Thus, the selection of machining parameter such as cutting speed, feed rate and depth of cut is very important because they directly influences surface roughness and Material Removal Rate. It is very difficult to select machining parameters that can provide good performance for all the problems simultaneously. Many of the parameter selected can optimize either one of this output only at one time. Therefore, this study will determine the optimum machining parameter that can improve all output problems simultaneously.

1.3 Objectives

The objectives of the study highlighted below:

- To identify the quality characteristics of machining by measuring Surface Roughness and Material Removal Rate optimized during cutting operation.
- To analyze the effect of input machining parameters on output response, surface roughness, and metal removal rate.
- To validate the optimum parameters for CNC machining application for aluminum alloy material.

1.4 Scopes of the Project

The study is under scopes of:

I. Turning process used for aluminum alloy 6061 as the work piece.

II. Turning process used uncoated carbides as cutting tool.

III. Mechanical properties are test to use as a quality measurement for cutting speed.

IV. Straight turning operation.

V. Parameter selection in CNC machining experiment based on the trial and error tests.

1.5 Significant of Project

The best parameter setting of cutting in CNC machine can be optimal from experiment results, to find obtain optimal cut performance in order to maximize quality characteristics of machining in cut area. The results of experiment can give advantage to manufacturing industrial.

1.6 Report Structure

Chapter 1 briefly descripts about the introduction, which consist background of the study, problem statement, objective and scope. The background of study will discuss about the cutting process in turning machine, which are the main manufacturing process in the research followed by the problem statement. The objective also mention earlier in the chapter to make clear what the purpose this research in done and what the outcome of the research become in deep more specific.

Chapter 2 The section discuss detail on the previous process, method and application related to this study ,much information gathered in this chapter and will be used in this study.

Chapter 3 is mainly about the procedure, theory and tools. The flowchart of methodology is given in this chapter. Besides that, the equipment and tools selection for this study are discussed in details. The theory behind the analysis is also mentioned in this chapter.

Chapter 4 discusses the result, calculation and discussion from graphs and tables of results. The results are evaluated and concluded.

Chapter 5 is about the conclusion and summarizes all the study objectives, future work recommendation and commercialization of the research.

1.7 Summary

This chapter mainly discuss the introduction of cut parameter list of objectives that want to achieves, the scopes of study and overview of the chapter's content in the next chapter, the theory and application of methods are briefly discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Many researches are investigating about factors have considerable effect on cut process and improve its performance has continuously received much attention in worldwide. Since the advent of CNC machining researchers/manufacturers are looking forward for methods that provide high productivity and high speed machining. Considering of machining parameter optimization started out as early as 1907, when existence of an optimum cutting speed for maximizing material removal rate in single-pass turning operations. Research on machining parameter optimization has increased since the 1950's. In 1960's, presented a theoretical analysis of optimization of machining process and proposed an analytical procedure. (Rachayya et al., 2012) to determine the cutting speed for a single- pass turning operation with fixed feed rate and depth of cut by using two different objectives (i) maximum production rate and (ii) minimum machining cost.

2.2 Literature Survey of Machinability

2.2.1 Introduction

A good number of researchers reported regarding the machining of high to mild strength materials. The following review is based on the turning of mild and high strength material. The following review is relation to the surface finish, tool life, and cutting speed obtained during turning of mild and high strength materials (Murthy et al 2014).

2.2.2 Machinability Assessment

The important aspects involved machining various materials. In summary, suggest that for machining high strength materials, the tool should be refractory to avoid plastic flow have high wear resistant to avoid wear and have good brittle fracture resistance to avoid chipping. To developed some mathematical models for cutting force, surface finish and tool life in terms of cutting speed, feed and depth of cut. The tests were earned out under dry conditions and he developed the following equations based on the experimental results (Murthy et al 2014).

2.3 Machinability

Machinability is defined in various ways which a work piece material is machined under a given set of cutting conditions .The term Machinability is used to refer to the ease with prior knowledge of a work piece material is important to the production engineer so that its processing can be planned efficiently "Good Machinability" can mean that less power is required or a higher tool life is achievable or a better surface finish can be obtained to machine that particular material .Moreover ease of chip disposal, cutting temperature, operator safety, etc are other criteria of Machinability one material may be better with respect to surface finish under a set of cutting conditions while Machinability of another material may be better with respect to tool life under a different set of cutting conditions (Murthy et al 2014).

2.3.1 Cutting speed and Tool Life

Cutting speed makes a significant different in production time with tool life. The cutting speed with feed rate are usually chosen to given an economical tool life. The speed needs to be adjusted to get a good-quality of cut. A cutting speed that is too slow or too high will cause cut quality problems.

2.4 Aluminum Machining Material

Aluminum alloy 6061 is soft to withstand wear, light metal, and tame the appearance of silvery to dull gray, depending on the surface roughness. Aluminum is nonmagnetic and does not trigger. It is also insoluble in alcohol, though it can be soluble in water in certain forms. Yield strength of pure aluminum is 7-11 Megapascals (MPa), while aluminum alloys have yield strengths of 200 MPa to 600 MPa. Aluminum has a density of one-third the density of steel or copper. It is ductile, and easily machined, cast, drawn and extruded. Table 2.1 Chemical composition for aluminum 6061. (Ranganath et al .,2014).

Table 2.1: Chemical composition for aluminum 6061

Weight (%)	Al 6061
Al	Bal
Si	0.41-0.83
Fe	0.74 max
Cu	0.15-1.3
Mn	0.2-0.8
Mg	0.8-1.3
Cr	0.05-0.035
Zn	0.25 max
Ti	0.16 max
Others each	0.05 max
Others each	0.16 max

2.4.1 Efficient Chip Removal Rates

Poor chip removal rates can be damaging to an aluminum precision machining production. For the Machine, Inc. maintains high cutting angles to create a clean cut in a relatively soft material and for accurate chip removal. Rake angles must be greater than 6° and angles are as much as 50% greater than traditional end fling chips away from the work piece. Zhu, (1982).can reach 12°. Gash angles are kept high to aid in pulling chips and prevent clogging. Helix (Ranganath et al., 2013)

2.5 CNC machine

CNC is Computer Numerical Control. This means a computer converts the design produced by Computer Aided Design software (CAD), into numbers. The numbers can be considered to be the coordinates of a graph and control the movement of the cutter. In this way the computer controls the cutting and shaping of the material. **C**omputer **N**umerical **C**ontrol (CNC) has been around since the early 1970's shown in (Figure 2.1). It was called NC, for **N**umerical **C**ontrol. (Nian et al.,2005) .

Figure 2.1: CNC machine using in manufacturing

2.6 Material Removal Rate

For material removal, it represent by Material Removal Rate (MRR). In term of CNC cutting material removal rate can be defined as the particle during the cutting process. If the amount of particle removed from work piece measured in gram ,the unit for MRR will be in (g/min) . In case of volumetric MRR the unit will be in mm^3 /min.

(Gupta et al .,2014)

The material removal rate, MRR can be defined as the volume of material removal divided by machining time. Another way to define MRR is to imagine an "instantaneous" material removal rate as the rate at which the cross-section area of material being removal moves through the works piece. Material Removal Rate (MRR) is defined by:

$$MRR = \frac{(\pi)\ (Davg)\ (d)\ (f)\ (N)V \quad [mm^3]}{T \quad [sec]} \qquad (2.0)$$

Where,

Davg: average diameter (mm)

2.7 Surface Roughness (Ra)

Surface Roughness measures if a good surface irregularities on the surface. This is a result of the process used to create the surface. Surface roughness (Ra) was rated as the arithmetic average deviation of the surface and the top of the Valley set in micro-or micrometer. ISO uses the term CLA (center line average). Both will be interpreted the same. (Davim et al.,2008)

2.8 Taguchi Approach and Design of Experiment (DOE)

DOE refers to the process of planning an experiment based on statistical practices. DOE consists of wide range of techniques such as fractional designs, response surface and methodology. By using DOE, several benefits will be determined like appropriate data can be collected and analyzed using statistical method, the analysis can often be done manually using graphs and simple calculations and the number of run for experiments can be minimized thereby minimizing the cost and time to conduct the experiments (Verma et al .,2012) .

2.8.1 Overview of Taguchi Method

Dr. Genichi Taguchi, who was developed a method for the application of designed experimental, DOE technique during late 1940s (Taguchi, 1990). This technique to improve quality of manufacturing products has been taken the design of experiments from the exclusively useful for the statistical and brought it more of technique into the world of manufacturing. His contribution is also making the practicing of work simple by advocate to use of lest experiment designs, and provide a clearer understanding of the variation nature and the economic consequence of quality engineering in the world of manufacturing. Taguchi method to introduces has approach, by using experimental design variable or factors are arranged in an Orthogonal Array (OA) (Nalbant et al ., 2007).

Several important contributions to industrial statistics problems have made consist to an emphasis orthogonal arrays and associated linear graphs for designing experiments (Chewaroungroaj et al .,2000).

- Design products/processes to make strong environmental condition.
- Design and develop products/processes to make strong component variation.
- Minimize variation around a goal value. (Nalbant et al ., 2007)

2.8.2 S/N Ratio

There are three categories of the quality characteristics in the analysis of the single to noise ratio (S/N ratio), i.e the smaller is better, bigger is better and nominal is the best. The S/N ratio for each level of process parameter is computed based on the S/N analysis. Regardless of the categories of the quality characteristics, a bigger S/N ratio corresponds to better quality. Therefore, the optimal level of the process parameters is the level with highest S/N ratio. (Sinha et al., 2013)

In Taguchi approach Design of Experiments the term Quality a characteristic (QC) is used to represent the objectives and it is divided as follow (Roy.,2001) .

a) QC = B: bigger is better. The total volume will be larger over the smaller set is the ones. Theoretically, there is no limit on the decision. In practice, few limits required for numerical accuracy. To achieve uniformity, average performances can be considered as the target (Roy.,2001) .

b) QC = S: smaller is better. Magnitude smaller than the results are always better than the other set. Goal theory is zero. Achieved the lowest practical value can provide some appropriate number (Roy.,2001).

c) QC = N: Nominal is the best. Value is always required. Level of achievement required a fixed-called target or nominal value. For purposes of comparison, a small deviation from the target value is taken into account only the magnitude (Roy.,2001).

Using one-factors –at-a-time experiments, the knowledge gathered is accurate when each factors behaves independently. But, most of the cases are not. The nature of influence factor between factors is known as the interaction effect. By utilizing appropriate methods of optimization such as Taguchi approach Design of Experiments, can get reproducible results.

The conclusions derived from an analysis measured performances on the experiments, such as observations and recommendations are possible for other people repeat the experiments other times and get the similar outcome. Design decisions can be made by finding from experiments (Rachayya et al., 2012).

However more desirable those results of experiments are reproducible when tested under similar conditions by others at different time. In other word, results of the experiments are valid and useful only when they are reproducible. In the book Design of Experiments Using the Taguchi Approach written by (Roy., 2001).Taguchi approach design of the experiments technique is a good way to keep the number of experiments small while increasing reproducibility. For this field of study, the L-9 (3^3) arrays are used. The total combination of experiments need is nine (9) compared to full factorial experiment that is 81. The experiments need to be replicated three (3) times, so the total experiments are twenty-seven. (27) (Roy., 2001).