DESIGN OF EXPERIMENT (DOE) BASED APPROACH IN OPTIMIZING FINISHING PARAMETERS OF CNC MACHINING TOWARD SURFACE ROUGHNESS.

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B071610023

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
2019

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Faculty of Mechanical and Manufacturing Engineering Technology

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Bachelor of Manufacturing Engineering Technology (Product Design)

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A thesis submitted
in fulfillment of the requirements for the degree of Process Technology
in Mechanical and Manufacturing Engineering

Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

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DEDICATION

I would like to dedicate this thesis to my parents whose untiring support for my study and assistance have made possible the fruition of our efforts. I would like to dedicate this thesis to my supervisor TS. Muhammad Syafik Bin Jumali for his guidance on providing me so much useful knowledge and provide guidance or supports for me along the way of my final year project. Furthermore, I would like to dedicate this project to technicians En. Azimin and Pn Nor Zalipah binti Sulaiman, who provide me a great assist and guidance on fabricating my project's prototype.

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ABSTRACT

Taguchi Method is an effective tool introduced for the optimization of the product or process quality. Aluminum 3003 is a commercially pure, manganese-added aluminum. Because of its excellent characteristics, 3003 is the most widely used aluminum alloy and its surface roughness varies with the changes of the process parameters of the machine such as layer spindle speed, feed rate, depth of cut and others. The combinations of different sets of the parameters will definitely produce parts with different specifications, thus the study of the suitable combination of parameters is necessary for optimum output is carried out. In order to achieve the optimum performance of the machined sample, the Taguchi method was employed because it is a simplified yet powerful method for experimental design using the orthogonal array method. In this study, an orthogonal array of L_9 (3^3) was used and nine pieces of samples were determined for 3 parameters that namely are spindle speed, feed rate and finishing tolerance with three levels each. The samples for machining was designed using SolidWorks, coded using Siemens Sinumerik and machined by DMU eVo 6 milling machine for the nine samples. The results were obtained and data was analyzed. The data of confirmation test shows that the samples with optimum parameters was a combination of spindle speed (14000 rpm), feed rate (900m/min) and finishing tolerance of 0.635 with a percentage difference of 7% from the prediction data. From the analyzed data from the Signal to noise, ranked 1 is feed rate than followed by spindle speed, and finishing tolerance respectively. Thus, this result shows that the surface roughness of a sample produced using DMU eVo 6 machine with different combination of process parameters and the Taguchi Method provides the solution of determining the optimum surface roughness of combination parameter with minimum number of experiment.

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ABSTRAK

Kaedah Taguchi adalah alat yang berkesan diperkenalkan bagi mengoptimumkan kualiti produk atau proses. Aluminium 3003 adalah aluminium yang dijual secara komersial tulen. Oleh kerana ciri-cirinya yg cemerlang, 3003 adalah aloi aluminium yang paling banyak digunakan dan kekasaran permukaannya berbeza-beza dengan perubahan parameter proses mesin seperti kelajuan gelendong lapisan, kadar suapan, kedalaman potongan dan lain-lain. Kombinasi pelbagai set parameter pasti akan menghasilkan permukaan dengan spesifikasi yang berbeza. Oleh itu kajian kombinasi parameter yang sesuai adalah perlu untuk menghasilkan output yang optimum. Dalam usaha untuk mencapai prestasi optimum bagi sampel yang dihasilkan, kaedah Taguchi telah dilaksanakan kerana ia merupakan kaedah yang mudah tetapi berkuasa untuk reka bentuk uji kaji menggunakan kaedah orthogonal array. Dalam kajian ini, orthogonal array L_9 (3^3) telah digunakan dan sembilan keping sampel ditentukan untuk 3 parameter iaitu kelajuan gelendong, kadar suapan dan toleransi kedalaman potongan akhir dengan tiga peringkat setiap parameter. Sampel untuk pemesinan direka menggunakan SolidWorks, dikodkan menggunakan Siemens Sinumerik dan dimesin oleh mesin pengilangan DMU eVo 6 untuk sembilan sampel tersebut. Keputusan diperoleh dan data dianalisis. Data ujian pengesahan menunjukkan bahawa sampel yang mempunyai parameter optimum ialah gabungan kelajuan gelendong (14000 rpm), laju suapan (900m / min) dan toleransi kedalaman potongan akhir sebanyak 0.635 dengan peratusan perbezaan 7% daripada data ramalan. Daripada data yang dianalisis, kedudukan pertama adalah kadar suapan diikuti dengan kelajuan gelendong, dan akhir sekali toleransi kedalaman potongan akhir. Oleh itu, hasil ini menunjukkan bahawa keadaan permukaan sesuatu sampel yang dihasilkan menggunakan mesin DMU eVo 6 dengan gabungan parameter proses adalah berbeza dan kaedah Taguchi memberikan penyelesaian untuk menentukan kekasaran permukaan optimum parameter gabungan dengan bilangan eksperimen minimum.

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ACKNOWLEDGEMENT

Firstly, I would like to express my gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for providing me an opportunity to become a student to gain precious knowledge from both academy and practical in my study life. I would also like to give a great thank to my final year project supervisor, TS En Muhammad Syafik bin Jumali for guiding me along the way of the project and giving me a guidance on studying the suitable of surface roughness parameter type of DMU eVo 6 CNC milling machine. Lastly, I want to deliver a lot of thank to all my friends and family for lending me your arms from obstacles that I had encountered throughout my study life and giving me a great support along the way of my life.

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LIST OF ABBREVIATIONS

DOE	Design of Experiment
OA	Orthogonal Array
RSM	Response Surface Methodology
UTeM	Universiti Teknikal Malaysia Melaka
CNC	Computer Numerical Control
ANFIS	Adaptive Neuro Fuzzy Inference System
ASFS	Automated Surface Finishing System
S/N	Signal to Noise
ANOVA	Analysis of Variance
ADOC	Axial depth of cut
RDOC	Radial depth of cut
TM	Taguchi Methodology
MQL	Minimum Quantity Lubrication
LCD	Liquid Crystal Display

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LIST OF SYMBOLS

$\mathbf{V_c}$	Spindle Speed
$\mathbf{f_z}$	Feed Per Tooth
$\mathbf{a_c}$	Depth Of Cut
$\mathbf{R_a}$	Arithmetic Mean Value
$\mathbf{R_q}$	Root Mean Square
$\mathbf{R_y}$	Maximum Roughness Height
$\mathbf{R_z}$	Ten Point Height of Irregularities

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CHAPTER 1

INTRODUCTION

1.0 Introduction

In this chapter, this paper introduces the project and briefly describe the background study, problem statement, objectives and also the scopes. This chapter will also give an overview on the implementation of the project.

1.1 Background

This study emphasizing on the machining parameter of a CNC milling machine toward surface roughness of a material through both predictive simulation of Taguchi's design of experiment method and refined via either response surface method or genetic algorithm. There is a wider optimization method that can be used such as Adaptive Neuro Fuzzy Inference System (ANFIS), evolutionary programming method, grey rational analysis, grey fuzzy logic, automated surface finishing system (ASFS) and others. However, consideration towards time constraint and cost for each iteration of model is also taken into account. DOE techniques, for example, factorial design, response surface methodology (RSM) and Taguchi strategies are currently generally utilized instead of one-factor at any given moment test approach, which is tedious and over the top in expense, (Montgomery, 2017).

Design of experiment or also known as DOE, are strategies that are utilized to change over the standard plan into a robust one. These strategies empower designer to give a knowledge into the communication factors that may influence the yield. As mentioned by

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(Ramu, Srinivas, & Vekatesh, 2018), Taguchi's technique utilizes orthogonal array experiment (OA). OA will give a lot of adjusted and least number of analyses. There is some standard all around characterized symmetrical clusters. Each of these exhibits are intended for a particular number of independent plan levels and factors. With the utilization of OA, the quantity of preliminary or investigations can be radically decreased. By applying this technique, the time required for experimental investigation can be significantly reduced and the influence of individual factors can be studied to determine which factor has more influence and which has less.

Component of Taguchi's DOE are standard Signal to Noise (S/N Ratio), Analysis of Variance (ANOVA) and Taguchi's own Orthogonal Array. For example, ANOVA is an instrument by which we can think about methods for at least two group. This procedure is valuable in various regions of research to be specific financial matters, psychological and in a few distinct controls. Examination of change is a method used to part the total inconstancy present inside the information into two variables. They are orderly and arbitrary elements. F-test will be utilized in ANOVA to check the speculation. Details on methodology will be explained in detail in chapter 3 later.

In manufacturing industry, surface roughness estimation is one of the most critical prerequisites in many engineering applications, as it is viewed as a vital file of item quality (Sarikaya & Güllü, 2014). Quality and productivity can be upgraded through procedure parameter streamlining or optimization. There are number of research works identified with different milling parameters improvement for accomplishing the better execution qualities. Among these are material removal rate and surface roughness which are both critical procedure parameters. In machining of parts, surface quality is a standout amongst the most determined client prerequisites where significant sign of surface quality on machined parts is the surface roughness esteem as said in (Xavior & Adithan, 2009).

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Milling is a much of the time utilized customary machining technique for both common and top of the line applications concerning material removal and machining of complex structures just as completing of machined parts. A workpiece surface can be effectively machined into a level surface by methods for plain and end machining. According to (Montgomery, 2017), in machinability considers, factual structure of analyses is utilized very extensively. Statistical structure of examinations alludes to the way toward arranging the investigation with the goal that the proper information can be dissected by measurable techniques, bringing about legitimate and target ends. Literature shows that complete examinations must be performed so as to decide the productive procedure parameters for acquiring progressively viable and condition environment-friendly machinability states of the materials.

For this study, L_9 orthogonal array is used for conducting this experiment. Signal-to-noise ratios (S/N) and main effect graphs of means analysis are carried out to obtain significant parameters influencing on surface roughness. After the desired result is obtained, the parameter is then optimized through Taguchi optimization where the cutting conditions are encoded to apply in optimization of machining parameters.

1.2 Problem Statement

Traditionally, hands-down value that are ambiguous in term of origin, effectiveness and practicality were given as a rule of thumb in machining but this study is to verify those concepts while providing a fixed value of parameter for a required surface finish in UTeM. During my experience working with a mold and die company, I observed the same trend where finishing parameter always inherit from some unknown source and sometime prove impractical where machining time can be reduced, cost can be saved and workforce can be reduced.

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Hence, a design of experiment (DOE) will be planned and executed in varying value of parameter of feed, speed, depth of cut and finishing allowance in testing the surface finish of a product through Taguchi L_9 orthogonal array and further optimized with Taguchi optimization. Confirmation experiment will be done to validate the prediction made through this study. This will in turn be used in predicting the surface roughness depending on the parameters involved through CNC machining.

In addition, this predictive value/function will be use as a framework that can develop for the intended parameter with different setting as a method of conservation in time, cost while improving efficiency.

1.3 Objective

The primary objective this study is:

- To optimize milling machining parameters such as spindle speed, feed rate and finishing tolerance by using Taguchi orthogonal array methodology.
- To design a simulated experiment and validate prediction through confirmation actual machining on aluminum alloy 3003.
- To verify and validate prediction with optimized parameter of machining.

1.4 Scope

The main focus of this study is to determine the optimum finishing parameter of CNC milling machine on surface roughness in UTeM. Taguchi design of experiment with L_9 orthogonal array will be used to design the experiment as Signal to Noise ratio will be used to compute the result predicted. Finishing parameters include feed rate, spindle speed, depth of cut and finishing tolerance, and machining is done on aluminum alloy 3003-H12 with HSS end mill cutter of diameter 20. This study limit to DMU eVo 5-axis machining, which

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those parameters will suffice for prediction as it does not account radial movement of the spindle head as compared to 5-axis machining.

Optimization through Taguchi optimization model through randomized runs in simulated environment will be done before comparison to the actual machining result were made. Some calculations, assumptions, and selections were made as a consideration of a proper and realistic design.

1.5 Summary

This chapter has covered the background of the project, problem statement, objectives and scope of the project. The background of this project is about optimization of finishing parameter in CNC milling machine toward surface roughness. This project is designed to predict surface roughness through Taguchi orthogonal array with the validation on S/N ratio with further optimization through Taguchi's. The objective had been explained briefly and the scope of study had explained the focus and limitation of this study in solving the problem intended in this study.

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CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Literature review is an evaluative report of data found in the writing that relates to the field of study. The purpose of a literature review is to describe or set up the field of studies in the chosen point. Literature review may consist of books, journal, article, thesis, website or some other resources. Particularly, this study is strongly assigned to the computer numerical control fields and in order to compose this literature review, the journal needs to be interpreted with all of the references that relates to the project. The purpose of this chapter are to clarify the historical backdrop of computer numerical control, operational parameter of machining and finishing tolerance of vertical milling machine. In addition, this section will clarify all the theory and execution of the research in regards to the project to accomplish the project objective in detail. The reference sources for this literature review are ScienceDirect, Google Scholar, academia.edu and lecturer's slide.

2.1 Machining

Machining is a procedure in which a bit of crude material is cut into an ideal last shape and size by a controlled material-removal process. The procedures that have this regular concept, controlled material expulsion, are today on the whole known as subtractive assembling, in refinement from procedures of controlled material expansion, which are known as additive manufacturing. Precisely what the "controlled" some portion of the

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