

# UNIVERSITI MALAYSIA PAHANG

## BORANG PENGESAHAN STATUS TESIS ♦

**JUDUL:** MATHEMATICAL MODELING TO PREDICT SURFACE ROUGHNESS IN MILLING PROCESS

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MATHEMATICAL MODELING TO PREDICT SURFACE ROUGHNESS IN  
MILLING PROCESS

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**LIST OF ABBREVIATIONS & SYMBOLS**

ANOVA	Analysis of Variance
CNC	Computer Numerical Control
$\beta$	Regression coefficients
$\phi i_i$	Percentage deviation
$\bar{\phi}$	Average percentage deviation
$\hat{\mu}_{y/x}$	Estimate of the mean of $y$ for any given $x$



## ABSTRACT

Surface roughness (Ra) is one of the most important requirements in machining process. In order to obtain better surface roughness, the proper setting of cutting parameters is crucial before the process take place. This research presents the development of mathematical model for surface roughness prediction before milling process in order to evaluate the fitness of machining parameters; spindle speed, feed rate and depth of cut. 84 samples were run in this study by using FANUC CNC Milling  $\alpha$ -T14iE. Those samples were randomly divided into two data sets- the training sets (m=60) and testing sets(m=24). ANOVA analysis showed that at least one of the population regression coefficients was not zero. Multiple Regression Method was used to determine the correlation between a criterion variable and a combination of predictor variables. It was established that the surface roughness is most influenced by the feed rate. By using Multiple Regression Method equation, the average percentage deviation of the testing set was 9.8% and 9.7% for training data set. This showed that the statistical model could predict the surface roughness with about 90.2% accuracy of the testing data set and 90.3% accuracy of the training data set.

## ABSTRAK

Kekasaran permukaan merupakan keperluan yang paling penting bagi penggunaan mesin. Bagi mendapatkan kekasaran permukaan yang baik, parameter mesin yang sesuai adalah sangat penting sebelum menjalankan sebarang proses. Tujuan kajian ini adalah untuk menghasilkan satu persamaan matematik yang dapat meramalkan kekasaran permukaan sebelum proses penggilingan. Kelajuan mata alat, kadar dan kedalaman pemotongan bahan merupakan pembolehubah dalam kajian ini. 84 sampel telah dijalankan dalam kajian ini dengan menggunakan FANUC CNC Milling  $\alpha$ -T14tE. Sampel tersebut telah diagih secara rawak kepada 2 set data, iaitu set latihan( $m=60$ ) dan set ujian( $m=24$ ). Analysis ANOVA menunjukkan bahawa sekurang-kurangnya satu koefisien regresi daripada populasi bukan sifar. Kaedah regresi berganda digunakan untuk menentukan hubung kait diantara satu pembolehubah dengan kombinasi pembolehubah yang lain. Kaedah tersebut telah menunjukkan bahawa kadar pemotongan adalah pembolehubah yang paling mempengaruhi kekasaran permukaan. Dari persamaan yang dihasilkan oleh kaedah regresi berganda, purata peratusan ketidaktepatan bagi set ujian adalah 9.8% dan 9.7% untuk set latihan. Ini menunjukkan bahawa model statistik dapat meramalkan kekasaran permukaan set ujian dengan 90.2% ketepatan dan 90.3% ketepatan untuk set latihan.

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 INTRODUCTION ON THE RESEARCH**

To realize full automation in machining, computer numerically controlled (CNC) machine tools have been implemented during the past decades. CNC machine tools require less operator input, provide greater improvements in productivity, and increase the quality of the machined part. End milling is the most common metal removal operation encountered. It is widely used to mate with other part in die, aerospace, automotive, and machinery design as well as in manufacturing industries (Julie Z.Zhang et al., 2006).

Surface roughness is an important measure of the technological quality of a product and a factor that greatly influences manufacturing cost. The quality of the surface plays a very important role in the performance of milling as a good-quality milled surface significantly improves fatigue strength, corrosion resistance, or creep life. (Dr. Mike S.Lou et al., 1999) In addition, surface roughness also affects surface friction, light reflection, ability of holding a lubricant, electrical and thermal contact resistance. Consequently, the desired surface roughness value is usually specified for an individual part, and specific processes are selected in order to achieve the specified finish. Surface specification can also be a good reference point in determining the stability of a production process, because the stability of the machine is contingent on the quality of the operating part (Oğuz çolak et al., 2005).

This research investigates to predicting surface roughness by using multiple regression prediction models. Three milling parameters have been selected, spindle speed, feed rate and depth of cut.

## **1.2 PROBLEM STATEMENT**

In manufacturing industries, manufacturers focused on the quality and productivity of the product. To increase the productivity of the product, computer numerically machine tools have been implemented during the past decades. Surface roughness is one of the most important parameters to determine the quality of product. The mechanism behind the formation of surface roughness is very dynamic, complicated, and process dependent. Several factors will influence the final surface roughness in a CNC milling operations such as controllable factors (spindle speed, feed rate and depth of cut) and uncontrollable factors (tool geometry and material properties of both tool and workiepce). Some of the machine operator using ‘trial and error’ method to set-up milling machine cutting conditions (Julie Z.Zhang et al., 2006). This method is not effective and efficient and the achievement of a desirable value is a repetitive and empirical process that can be very time consuming.

In order to solve the problem, develop one surface prediction technique which is termed the multiple regression prediction models to optimize the cutting conditions. This method can find the best conditions required for the machining independent variables such as speed, feed and depth of cut that would result in the best machining response. Thus, manufacturers can improve the quality and productivity of the product with minimum cost and time.

### 1.3 OBJECTIVES

The objectives of this study are to:

- (i) Develop a mathematical model for predicted surface roughness in milling process.
- (ii) Compare the predicted surface roughness and the actual surface roughness. (Average percentage deviation less than 10%)

### 1.4 SCOPE OF PROJECT

The experiment is performed by using a FANUC CNC Milling  $\alpha$ -T14tE. The workpiece tested is 6061 Aluminum 400mmx100mmx50mm. The end-milling and four-flute high speed steel is chosen as the machining operation and cutting tool. The diameter of the tool is  $D=10$ mm. 84 specimens are run in this experiment. 60 specimens are used to build a prediction model and the testing set contains 24 specimens. Spindle speed, feed rate and depth of cut are selected as considered parameters. Four levels of spindle speed- 750, 1000, 1250, and 1500 revolutions per minute (rpm), seven levels of feed rate- 152, 229, 305, 380, 457, 515, 588 millimeter per minute (mmpm), and three levels of depth of cut – 0.25, 0.76, 1.27 millimeter (mm) are determined.

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