Faculty of Manufacturing Engineering

OPTIMIZATION OF TURNING PROCESS PARAMETERS OF STAINLESS-STEEL USING BOX-BEHNKEN METHOD

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Master of Manufacturing Engineering
(Industrial Engineering)

2023

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Manufacturing Engineering in Industrial Engineering

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this thesis entitled "Optimization of turning process parameters of stainless-steel using Box-Behnken Method" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Industrial Engineering in Manufacturing Engineering.

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DEDICATION

A gratitude to:

My Heaven on Earth

Hj. Ahmad Rozelan bin Hj. Yunus

Hjh. Rokiah binti M. Jahi

for the perfect living and endless love

My Love-Hate Relationship Siblings

Syazwani Nadiah

Late sister Mimi Fariha

Aimi Fatihah

as shoulders to cry on and my stress relievers

My Energetic Supervisor

Profesor Madya Ir. Dr. Mohd Amran bin Md Ali

for the ideas, encouragements, motivations and keeping trust on me

and lastly

the pure heart, my fiancé

Muhammad Syakir bin Mohd Sufi

During the highest and lowest points of this journey.

ABSTRACT

This project focuses on the simulation of the turning process by using the finite element analysis (FEA) processing Deform 3D software based on the Box-Behnken of Response Surface Method (RSM) experimental matrix. Based on the Box-Behnken design matrix, 15 simulation runs were performed with a centre point to analyse the influence of cutting parameters on the turning process output responses such as cutting temperature, effective stress and material removal rate. The cutting parameters chosen in this turning simulation of 7075 stainless steel were cutting speed (100 m/min - 140 m/min), feed rate (0.5 mm/rev - 1.5 mm/rev) and depth of cut (0.5 mm - 2.0 mm). Analysis of variance (ANOVA) was used to determine the most influential cutting parameters on the results. The Box-Behnken response surface method was used to investigate the interactions between the cutting parameters on the initial responses and to optimise the setting of the cutting parameters for the turning process. From the results, the feed rate is the most influential cutting parameter on the cutting temperature. Meanwhile, the depth of cut is the most important cutting parameter for the effective stress. For the metal removal rate, the cutting speed is the most influential cutting parameter. Furthermore, the interaction between cutting speed and feed rate is the predominant interaction that has a significant effect on the cutting temperature, which shows that the downward saddle shape. Meanwhile, the relationship between cutting speed and depth of cut is the main relationship that has the greatest influence on the effective stress, when shows the upward saddle shape. The interaction between cutting speed and feed rate, which shows that the upward saddle shape. Additionally, the cutting temperature yields a minimum value of 926°C. Furthermore, the minimum value of 577.5 MPa is provided by the effective stress. The maximum value for the material removal rate is 2.45 m3/s. Overall, this project was effective in achieving all of its objectives. As a result, the defect of the wear on the cutting tool can be minimised by a decrease in both the cutting temperature and effective stress with an increase in material removal rate.

PENGOPTIMALKAN PARAMETER PROSES MEMILIH KELULI TAHAN KARAT MENGGUNAKAN KAEDAH BOX-BEHNKEN

ABSTRAK

Projek ini memfokuskan kepada simulasi proses pemusingan dengan menggunakan perisian analisis elemen terhingga (FEA) Deform 3D berdasarkan matriks eksperimen Box-Behnken of Response Surface Method (RSM). Berdasarkan matriks reka bentuk Box-Behnken, 15 larian simulasi telah dilakukan dengan titik tengah untuk menganalisis pengaruh parameter pemotongan terhadap tindak balas keluaran proses pusingan seperti suhu pemotongan, tegasan berkesan dan kadar penyingkiran bahan. Parameter pemotongan yang dipilih dalam simulasi pusingan keluli tahan karat ini ialah kelajuan pemotongan (100 m/min - 140 m/min), kadar suapan (0.5 mm/putaran - 1.5 mm/pulangan) dan kedalaman potong (0.5 mm - 2.0 mm).). Analisis varians (ANOVA) digunakan untuk menentukan parameter pemotongan yang paling berpengaruh pada keputusan. Kaedah permukaan tindak balas Box-Behnken digunakan untuk menyiasat interaksi antara parameter pemotongan pada tindak balas awal dan untuk mengoptimumkan penetapan parameter pemotongan untuk proses membelok. Daripada keputusan, kadar suapan adalah parameter pemotongan yang paling berpengaruh pada suhu pemotongan. Sementara itu, kedalaman potongan adalah parameter pemotongan yang paling penting untuk tegasan berkesan. Untuk kadar penyingkiran logam, kelajuan pemotongan adalah parameter pemotongan yang paling berpengaruh. Tambahan pula, interaksi antara kelajuan pemotongan dan kadar suapan adalah interaksi utama yang mempunyai kesan yang signifikan terhadap suhu pemotongan, yang menunjukkan bahawa bentuk pelana ke bawah. Sementara itu, hubungan antara kelajuan pemotongan dan kedalaman potong adalah hubungan utama yang mempunyai pengaruh paling besar terhadap tegasan berkesan, apabila menunjukkan bentuk pelana ke atas. Interaksi antara kelajuan pemotongan dan kadar suapan, yang menunjukkan bahawa bentuk pelana ke atas. Selain itu, suhu pemotongan menghasilkan nilai minimum 926°C. Tambahan pula, nilai minimum 577.5 MPa disediakan oleh tegasan berkesan. Nilai maksimum untuk kadar penyingkiran bahan ialah 2.45 m3/s. Secara keseluruhannya, projek ini berkesan dalam mencapai semua objektifnya. Akibatnya, kecacatan haus pada alat pemotong boleh diminimumkan dengan penurunan dalam kedua-dua suhu pemotongan dan tegasan berkesan dengan peningkatan kadar penyingkiran bahan.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Profesor Madya Ir. Dr. Mohd Amran bin Md Ali from the Faculty of Manufacturing Engineering Universiti Teknikal Malaysia Melaka (UTeM) for her essential supervision, support, and encouragement towards the completion of this thesis.

I would also like to express my greatest gratitude to my one and only best friend, my partner in crime, Muhammad Syakir bin Mohd Sufi who helped me to complete this thesis theoretically even emotionally, and always being there for me throughout this journey, especially for his never-ending encouragement, his valuable scientific advice, and his endless moral support.

Special thanks to all my peers, my beloved mother and father, and also my siblings for their moral support in completing this degree. Lastly, thank you to everyone who has been to the crucial parts of realization of this project.

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LIST OF ABBREVIATIONS

AISI	-	American Iron and Steel Institute
ANOVA	-	Analysis of Variance
BBD	-	Box-Behnken Designs
CCD	-	Central Composite Design
Cr	-	Chromium
FEA	-	Finite Element Analysis
IPM	-	Feed Rate in inches per minute
MRR	-	Material Removal Rate
RPM	-	Revolutions per minute
RSM	-	Response Surface Methodology
SEM	-	Scanning Electron Microscope

LIST OF SYMBOLS

°C	-	Degree Celsius
%	-	Percentage
v	-	Cutting Speed
min	-	Minute
mm	-	Millimeter
m	-	Meter
m/s	-	Meter per second
rev	-	Revolution
N	-	Number
D	-	Depth
W	-	Width
F	-	Feed Rate
K	-	Independent Variables
SS_T	-	Squared Deviations
y_j	-	Mean Grey Relational Grade

CHAPTER 1

INTRODUCTION

1.0 Background

Globally, the manufacturing industry has been experiencing turbulence because of increased competition in the market. Large emerging economies propelled themselves into the top tier of manufacturing nations, a severe recession stifled demand, and manufacturing jobs in established economies plunged. Nevertheless, both the developed and developing worlds continue to depend on manufacturing.

Today, manufacturing encompasses more than just creating goods. The way businesses work has undergone a significant transformation because of changes in consumer demand, product design, the industrial economy, and supply chain economics. Since this distinction between the manufacturer and the user is becoming more indistinct, customers are seeking personalization and customization.

Different industry sectors have shown interest in the hard-turning method for hard material finishing activities. The study of parameter optimization in turning operations in regard to a choice of circumstances for diverse materials by using different methodologies and explored by a range of researchers.

The use of statistical methods is another option for obtaining the optimum machining process parameters analysis. The Response Surface Method Box Behnken Design is one of them (BBD). The Response Surface Method is a collection of statistical and mathematical tools that are particularly beneficial for modelling applications where the goal is to maximize some variables' and responses' the output response. The Box Behnken Method is a set of experimental designs usable for factors from 3 to 12 and 16 respectively, of two-level factorial and incomplete box design. In BBD, it is possible to mix several repetitions against all factor levels.

Based on research that has been done, some findings can be concluded that Response Surface Method Box Behnken Design can be used to optimize parameters by using three variables. So, in this research Box Behnken Design is used to determine the optimum parameters on stainless steel rotary turning process. The aim of this study is to focus on cutting parameters (cutting speed, feed, and depth of cut) and how they affect the output response.

1.1 Statement of the Purpose

The purpose of the research is to investigate the optimum parameters for stainless-steel material in terms of the velocity, stress, temperature, and material removal rate by comparing the output in Deform 3D and output from previous research.

1.2 Problem Statement

Nowadays, DEFORM 3D software is hardly ever used. There is a lack of data regarding the characteristics of stainless steel available from industrial studies. Over the past few decades, simulation involving computer software has been adopted to improve the product's quality and production. In this study, the development of a simulation model of the turning machining process was the best way to handle the issue. The DEFORM 3D software is used to pinpoint important elements.

Furthermore, minimizing cutting parameter inaccuracy during the turning machining process is another consideration. One of the most crucial features for assessing the product's quality is the cutting parameters. The best cutting tools may be prepared for production with the use of Response Surface Methodology (RSM). Umar (2015) states that RSM has seen widespread use in model updating because of its simplicity and ability to do quick optimization according to smooth gradients, which minimizes the convergence issue. For better damage localization, RSM presented a damage detection method.

1.3 Objectives of Study

To perform this project smoothly, several objectives are aimed to achieve its goals. The objectives of this study are as follows:

a) To study the previous parameters of stainless-steel for implementing in Finite Element Analysis (FEA).

b) To simulate the turning machining analysis of stainless-steel using Box-Behnken's Response Surface Method (RSM).

c) To validate the previous cutting parameters with the new output found by FEA.

1.4 Scope of Study

The scope of this research is to study the cutting parameters of stainless steel and how it affects the output response which includes velocity, stress, temperature, and rate of material removal (MRR) to fully optimize in turning machining process. As a result, analytical methods have been utilized to simulate turning machining analysis. Later, the turning machining data are analyzed using Box Behnken's Response Surface Method (RSM) to provide higher order response surfaces for stainless steel material of turning process with fewer required runs than a typical factorial technique. In addition, this turning machining simulation process is to show the validation of cutting parameters and simulate turning machining analysis for stainless steel.

1.5 Significance of Study

The significant are detailed as follows:

1. Provide machining process industry with better solutions to provide higher order response surfaces.
2. To generate scientific information and deep understanding on the use of Response Surface Method (RSM) methodology. Useful findings of the turning machining analysis can be gathered later.
3. To gain new knowledge behind the simulation research by utilizing Deform 3D and Minitab software and lift machining process industry to higher level.
4. To develop an increasing machine utilization and decrease production cost in simulation analysis manufacturing environment.

1.6 Project Report Structure

Chapter 1 describes the research background, the problem, the objectives, the scope of the research and the general project structure. This chapter describes the importance of simulation using the software DEFORM 3D, which will facilitate the researcher's work. This chapter facilitates the researcher's work in machining stainless steel using the turning process. Chapter 2, Literature Review, contains previous studies on Deform 3D software, FEA, turning machining process, properties of stainless steel and standard cutting parameters for stainless steel. Chapter 3, Methodology, details the simulation process using the Deform 3D software. The Box-Behnken-Diagram (BBD) was used to design the experimental matrix. The result and discussion chapter of Chapter 4 provides into further detail regarding the results of utilising the DEFORM 3D and Minitab software. The end result consists of mathematical models, significant values for each output response, and single- and multi-response optimisation. Finally, in Chapter 5, there are sections under "Conclusions and Recommendations" that summarise the general objectives of the project and provide recommendations for future study approaches.

CHAPTER 2

LITERATURE REVIEW

The theory and research that have been defined and conducted by numerous researchers over the years are mainly described in this chapter. Based on their research into the turning machining process, DEFORM 3D Software, response surface method, tools, mechanical, and other physical properties, related information from previous studies is extracted as references and discussion.

2.1 Turning Machining Process

The purpose of the research is to investigate the effect of fiber treatment on the mechanical properties such as tensile, flexural and impact properties and water absorption of kenaf/polyester composite. The turning process is widely used in workshop practice for applications carried out in conventional machine tools, as well as in NC and CNC machine tools, machining centers and related manufacturing systems.

Using a lathe, turning is generally used to create conical and cylindrical pieces. A lathe can be used to produce flat faces, curved surfaces, grinding, and boring with the help of typical components. Therefore, through optimization research, it is beneficial to extend tool life, enhance surface accuracy, decrease primary cutting force, feed force, and machining zone temperatures (chip-tool interface temperature) in turning operations. Cutting fluids are frequently utilized in the machining process to minimize wear and friction and enhance tool life and surface quality.