DESIGN ANALYSIS OF THE X-AXIS ASSEMBLY OF A NEWLY DEVELOPED 3D ROUTER MACHINE USING FINITE ELEMENT ANALYSIS

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BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PRODUCT DESIGN) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical and Manufacturing Engineering Technology (Product Design) with Honours.

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DEDICATION

All praises to Allah and His blessing for the completion of this study. Throughout this journey, He has been the source of my strength, and I have only flown on His wings. I also devote my dissertation effort to my family and numerous friends. Next, Mr. Mat Rozi bin Che Leh and Mrs. Sharifah Hemamaleny binti Syed Mustahar, my loving parents, whose words of encouragement and push for tenacity still ring in my ears. My siblings Ibnur Huzairiel and Nur Ariesha have never left my side and are very precious to me. Not to mention, I dedicate my effort and express my gratitude to my supervisor, Ts. Dr. Hambali bin Boejang, for being there for me throughout the entire project. Without their encouragement and support, I may not be able to go as far as I could.

ABSTRACT

The main objective of this research is to design and analyze a newly developed Computer Numerical Control (CNC) three-dimensional (3D) router machine. Six students are involved in the project, and each student is responsible for handling a certain aim related to product distribution. However, this study focuses on designing and applied static analysis on X-axis assembly or stucture using Finite Element Analysis (FEA). The research problem statement was built on ideas from the Ministry of Higher Education and industry opinions. The current market benchmark price of CNC routers made the existing machine incredibly expensive for several colleagues and students attending schools. Following that, one of the concepts in this study that can tackle the issues of expensive 3D router prices on the open market is the new design of a CNC 3D router machine. The development of this machine will solve the issues of cost, availability, and exposure for a 3D router machine for educational purposes. However, in order to succeed in the develop of this machine, research must be conducted so that issues with machine durability may be tackled and the machine can endure a long time. The design of X-axis and static analysis in 3D routers machine is the focus of this research. The research starts with the benchmarking of the selected router machine and generating the engineering design specification in the formulation stage. After that, the sub-function of the X-axis structure concept was generated by using the table of combinations. The final specification of the X-axis assembly was developed using the weighted rating approach after the number of potential concepts was obtained from the table of combinations and one of them was chosen in the concept selection phase. Using the SolidWorks 3D Computer-Aided Design (CAD) software, the final specification produced the special purpose component part, and the detailed design drawing was released. The CAD design was then imported into Solidwork Simulation which is one of FEA software to perform static analysis using three different load of 5 kg, 10 kg, and 15 kg. The outcomes were validated using comparisons with experimental testing. According to the collected data, load less than 10 kg is the maximum load that this structure's X-axis design can support. This means that redesign should be done to meet higher load criteria if the load is over 10 kg. Finally, applying a load more than 10 kg to the X-axis structure is not advised since the results of the static analysis indicate that there is a significant risk of failure or fracture. Overall, we conclude that the load of the Z-axis, which is attached to the X-axis structure, cannot be greater than 10 kg. This is because experimental testing and static analysis results show that the applied load are predicted to be positive.

ABSTRAK

Objektif utama penyelidikan ini adalah untuk mereka bentuk dan menganalisis mesin penghala tiga dimensi (3D) Computer Numerical Control (CNC) yang baru dibangunkan. Enam pelajar terlibat dalam projek ini, dan setiap pelajar bertanggungjawab untuk mengendalikan matlamat tertentu yang berkaitan dengan pengedaran produk. Walau bagaimanapun, kajian ini memfokuskan kepada mereka bentuk dan menggunakan analisis statik pada pemasangan atau struktur paksi X menggunakan Analisis Elemen Terhad (FEA). Pernyataan masalah penyelidikan dibina atas idea daripada Kementerian Pengajian Tinggi dan pendapat industri. Harga penanda aras pasaran semasa penghala CNC menjadikan mesin sedia ada sangat mahal untuk beberapa rakan sekerja dan pelajar yang menghadiri sekolah. Berikutan itu, salah satu konsep dalam kajian ini yang boleh menangani isu harga penghala 3D yang mahal di pasaran terbuka ialah reka bentuk baharu mesin penghala 3D CNC. Pembangunan mesin ini akan menyelesaikan isu kos, ketersediaan dan pendedahan untuk mesin penghala 3D untuk tujuan pendidikan. Walau bagaimanapun, untuk menjayakan pembangunan mesin ini, kajian mesti dijalankan supaya masalah dengan ketahanan mesin dapat ditangani dan mesin boleh bertahan lama. Reka bentuk paksi-X dan analisis statik dalam mesin penghala 3D adalah fokus kajian ini. Penyelidikan bermula dengan penandaarasan mesin penghala yang dipilih dan menjana spesifikasi reka bentuk kejuruteraan dalam peringkat penggubalan. Selepas itu, sub-fungsi konsep struktur paksi-X dijana dengan menggunakan jadual gabungan. Spesifikasi akhir pemasangan paksi-X dibangunkan menggunakan pendekatan penarafan wajaran selepas bilangan konsep berpotensi diperoleh daripada jadual gabungan dan salah satu daripadanya dipilih dalam fasa pemilihan konsep. Menggunakan perisian SolidWorks 3D Computer-Aided Design (CAD), spesifikasi akhir menghasilkan bahagian komponen tujuan khas, dan lukisan reka bentuk terperinci dikeluarkan. Reka bentuk CAD kemudiannya diimport ke dalam Solidwork Simulation yang merupakan salah satu perisian FEA untuk melakukan analisis statik menggunakan tiga beban berbeza iaitu 5 kg, 10 kg, dan 15 kg. Hasilnya telah disahkan menggunakan perbandingan dengan ujian eksperimen. Menurut data yang dikumpul, beban kurang daripada 10 kg ialah beban maksimum yang boleh disokong oleh reka bentuk paksi X struktur ini. Ini bermakna reka bentuk semula perlu dilakukan untuk memenuhi kriteria beban yang lebih tinggi jika beban melebihi 10 kg. Akhir sekali, mengenakan beban lebih daripada 10 kg pada struktur paksi-X tidak digalakkan kerana keputusan analisis statik menunjukkan bahawa terdapat risiko kegagalan atau patah tulang yang ketara. Secara keseluruhannya, kami menyimpulkan bahawa beban paksi-Z, yang dilekatkan pada struktur paksi-X, tidak boleh melebihi 10 kg. Ini kerana keputusan ujian eksperimen dan analisis statik menunjukkan beban yang dikenakan diramalkan positif.

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LIST OF SYMBOLS AND ABBREVIATIONS

FTKMP	-	Faculty of Mechanical and Manufacturing Engineering Technology
TDP	-	Talent Development Program
CNC	-	Computerized Numerical Control
3D	-	Three-Dimensional
NPD	-	New Development Process
CAPEX	-	Capital Expenditures
OPEX	-	Operating Expenses
EDP	-	Engineering Design Process
DFA	-	Design for Assembly
DFM	-	Design for Manufacturing
CAD	-	Computer-Aided Design
CAM	-	Computer-Aided Manufacturing
CAE	-	Computer-Aided Engineering
FEA	-	Finite Element Analysis
B.O.M	-	Bill of Materials

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides background information on the project title, as well as an explanation of the newly developed three-dimensional (3D) router machine especially on the X-axis structure. Next, the new program which is Talent Development Program (TDP) engaged in this research project and the problem statement are described. Two objectives have been set based on the problem statement that must be fulfilled. The research's scope is also outlined in this chapter.

1.2 Project Background

Talent Development Program: Developing Tomorrow's Engineering Expertise (TDP) is a program where the students are grouped under one organization or group and invent a large-scale project called Computerized Numerical Control (CNC) 3-Dimensional (3D) router machines. The goal of this TDP program is to expose students to real-world situations before the students enter the workforce. Fundamentally, this is the first program that was developed with the Dean of the Faculty of Mechanical and Manufacturing Engineering Technology (FTKMP) and other department heads' support. This is due to the fact that this program can also provide students with real-world experience in learning something outside their specific fields. The group's organizational structure is similar to that of the professional world that includes investors which is Ts. Dr. Hambali b. Boejang, and

it is led by project managers and other department heads. The logo of the TDP program selected for this time is shown in Figure 1.1.

Figure 1.1 Logo for Talent Development Program (Ibnur, 2021)

The phrase Computer Numerical Control refers to plotters, vinyl cutters, 3D printers, milling machines, and other devices. CNC simply implies that the actual movements of the machine are controlled by instructions generated by a computer, such as coordinate positions. The phrase "CNC Machine" usually refers to a device that cuts or carves pieces out of various materials using a rotating cutting tool that travels in three (X, Y, and Z) or more axis (Vectric Ltd., 2013). Figure 1.2 shows the basic 3-axis of the CNC router machine. A computer determines the position of the router by telling the motors on each axis how much to move in each direction. Any place within the machine's work area (envelope) can be defined and the router moved within that space using this method of positioning. The operator utilizes a software application to draw the shapes they want to cut and create the path that the machine will follow, as the machine is controlled by a computer.

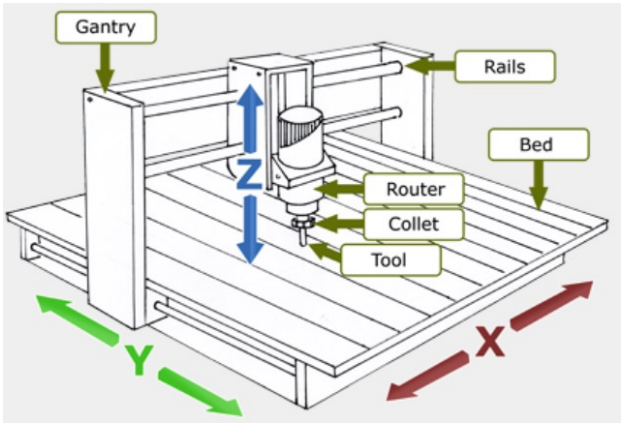

Figure 1.2 Example of 3-Axis Movement CNC Router Machine (Vectric Ltd., 2013)

A separate programme uploads coordinates into the machine controller. CNC routers are frequently used with two software applications: one for designing using Computer-Aided Design (CAD) and another for translating those designs into a Geometry (G)-code or Machine (M)-code programme of machine instructions using Computer-Aided Manufacturing (CAM) in vertical, horizontal, and perpendicular coordinates. CNC routers, like CNC milling machines, can be controlled directly by manual programming, but CAD/CAM opens up more contouring options, speeds up the programming process, and in certain circumstances allows for the creation of programmes that would be difficult to programme manually. G-code can be loaded as a vector file on the router control panel on some controllers. Using CAD software, a vector file can be produced from a picture file.

Eventhough the new product develoment (NPD) offers wide research area, this study is conducted based on a design analysis of a 3D router sub-assembly (x-axis) structure, which requires the use of Computer-Aided Engineering (CAE) computer software to simulate the performance of the sub-assembly part at the 3D router in order to improve the design and solve the problem.

1.3 Problem Statement

The Ministry of Education's primary goal is to establish a higher education system that is among the best in the world and that allows Malaysia to compete in the global economy (Malaysia Education Blueprint, 2021). As a result, the TDP programme was formed to give chances for students who need additional skills and experience, in accordance with the government's objectives under the first shift, which include improving the student learning experiences (Boejang H., 2021). Next, the cost of CNC 3D router machines on the market is extremely high, creating a barrier for those who run a small business and do not have the financial capability to purchase 3D routers on the market. Also that, the purpose of this machine issued is for education purposes. At an affordable cost, polytechnics, vocational schools, skills schools, and secondary schools that take design and technology courses can buy this machine. Lastly, in designing the x-axis structure of 3D Router, it is very important to know the durability of the structure when it has a load during operation. Because this research is based on new product development and there is no outcome yet regarding this CNC 3D router machine, design analysis needs to be done. Therefore, the problem that arises is whether the structure built is able to withstand the load to ensure the durability of this product in the future. In this case, the result for this case using Finite Element Analysis (FEA) in SolidWork 2021 is unknown. Therefore, the research objective is produced based on the problem.

1.4 Research Objectives

The following is the conclusion of this research project's objective:

a) To design X-axis structure of a low-cost newly developed 3D router machine.

b) To analyze the static load on X-axis using Finite Element Analysis (FEA) and compare with experimental testing.

1.5 Scope of Research

In this project, the research study is based on the research scope as follow:

- To do literature review on the design of scope study
- To understand the mechanisms and sturucture of x-axis at 3D router
- To design the sub-assembly of 3D router
- To find the static load occur at x-axis at 3D router during analysis

1.6 Summary

In conclusion, the background of the project is explained in this chapter. The problem statement was then provided, followed by the development of two objectives. The scope of research has been defined in order to obtain information about the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The researcher focuses on the analysis of the X-axis on the machines in this comprehensive literature review. The researcher also discovered several publications, such as thesis, journal articles, websites, and books. This chapter provides a literature review of ideas and approaches for better understanding of New Product Development (NPD), Engineering Design Process (EDP), and Finite Element Analysis (FEA). An explanation of the conceptual analysis that represents hypotheses generated.

2.2 Computerized Numerical Control Router

A Computer Numerical Control (CNC) router is a computer-controlled cutting machine that commonly uses a hand-held router as a spindle to cut materials like wood, composites, metals, plastics, glass, and foams. Many carpentry shop machines, such as the panel saw, spindle moulder, and boring machine, can be replaced by routers. It can also cut mortises and tenons. A CNC router is similar to a CNC milling machine in concept. Instead of routing by manually, computer numerical control is used to control tool routes. The CNC router is one of many CNC-enabled tools. Figure 2.1 shows the VHF 3-axis CNC milling machine classic series as the examples of the CNC router that available on the market.