UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN OF PORTABLE HANDHELD GRASS CUTTER USING PUGH'S METHOD (PHGC)

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE) WITH HONOURS

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Bachelor of Mechanical Engineering Technology (Automotive) with Honours

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A thesis submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (Automotive) with Honours

Faculty of Mechanical Technology and Engineering

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DECLARATION

I declare that this thesis research project of title. entitled “DESIGN OF PORTABLE HANDHELD GRASS CUTTER MACHINE USING PUGH’S METHOD” is the result of my own research except as cited in the references. The research project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : *YUMNI RUZAINI BIN AHMAD*

Date : 11 JANUARI 2025

APPROVAL

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 Automotive Engineering Technology with Honours.

Signature : .....

Supervisor Name : *PROFESOR MADYA TS. DR. MUHAMMAD ZAHIR BIN HASSAN*

Date : 11 JANUARY 2025

DEDICATION

This final year project is dedicated to my parents, Siti Aminah binti Ahmad and Ahmad bin Nawang, whose steadfast support, sacrifices, and encouragement have been the foundation of my success at this university. Their unending love and belief in my ability has motivated me to overcome several obstacles and strive for perfection. I am also grateful to my siblings for their crucial advise, financial assistance, and emotional support, all of which helped me create this report. Their consistent encouragement and conviction in my abilities have kept me going throughout this journey. Furthermore, I express my profound gratitude to my friends, whose unwavering support and camaraderie have given me the strength to persist. Their willingness to assist, whether through collaboration, idea exchange, or moral support, has been critical to the success of our initiative. Finally, I want to thank my supervisor, Professor Madya Ts. Dr. Muhammad Zahir Bin Hassan, for his excellent guidance, mentorship, and persistent commitment to my academic and personal development. His thoughts, counsel, and constructive input were critical to the project's success. This effort is a testament to all these incredible people's cumulative support and encouragement, for which I am extremely grateful.

ABSTRACT

In recent years, the need for efficient and environmentally friendly gardening tools has increased, encouraging innovation in handheld grass cutters. This project investigates the design, development, and optimization of a handheld grass cutter with the goal of improving user comfort, lowering environmental impact, and increasing cutting performance. The proposed device combines a lightweight, ergonomic design with sophisticated battery technology and precise cutting mechanics. A high-torque, low-noise engine, customizable cutting heights, and a blade system with improved safety are among the key characteristics. The project takes a user-cantered design approach, incorporating feedback from extensive field testing, to guarantee that the cutter fulfils the different demands of both household and professional users. The final prototype improves efficiency, durability, and user happiness significantly thanks to a combination of technical research, material selection, and sustainable production processes. This handheld grass cutter concept not only advances garden maintenance tools, but it also promotes sustainable practices by reducing carbon emissions and energy use.

ABSTRAK

Dalam beberapa tahun kebelakangan ini, keperluan untuk alat berkebun yang cekap dan mesra alam telah meningkat, menggalakkan inovasi dalam pemotong rumput pegang tangan. Projek ini menyiasat reka bentuk, pembangunan dan mengoptimumkan pemotong rumput pegang tangan dengan matlamat untuk meningkatkan keselesaan pengguna, mengurangkan kesan alam sekitar dan meningkatkan prestasi pemotongan. Peranti yang dicadangkan menggabungkan reka bentuk yang ringan dan ergonomik dengan teknologi bateri yang canggih dan mekanik pemotongan yang tepat. Enjin tork tinggi, bunyi rendah, ketinggian pemotongan yang boleh disesuaikan, dan sistem bilah dengan keselamatan yang dipertingkatkan adalah antara ciri utama. Projek ini mengambil pendekatan reka bentuk mengikut pengguna, menggabungkan maklum balas daripada ujian lapangan yang meluas, untuk menjamin bahawa pemotong memenuhi permintaan berbeza bagi pengguna isi rumah dan profesional. Prototaip terakhir meningkatkan kecekapan, ketahanan dan kegembiraan pengguna dengan ketara berkat gabungan penyelidikan teknikal, pemilihan bahan dan proses pengeluaran yang mampan. Konsep pemotong rumput pegang tangan ini bukan sahaja memajukan alat penyelenggaraan taman, tetapi ia juga menggalakkan amalan mampan dengan mengurangkan pelepasan karbon dan penggunaan tenaga.

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My deepest gratitude goes out to my academic mentors, Associate Professor Ts. Dr. Muhammad Zahir Hassan, for their unparalleled leadership, knowledgeable counsel, and assistance during this study. I am especially grateful to the technical team for their helpful suggestions on experimental work throughout the project duration, as well as for their excellent sense of humour and technical and laboratory support. I am also appreciative of my classmate's assistance and encouragement BMMA S1/1

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LIST OF SYMBOLS AND ABBREVIATIONS

CAD	-	Computer Aided Design
CATIA	-	Computer Aided Three-Dimensional Interactive Application
FEA	-	Finite Element Analysis
DC	-	Direct Current
3-D	-	3 Dimensional
2-D	-	2 Dimensional
HAV	-	Hand Arm Vibration
GMAW	-	Gas Metal Arc Welding
MIG	-	Metal Inert Gas Arc
TIG	-	Tungsten Inert Gas
PHGC	-	Portable Handheld Grass Cutter
NFCs	-	Natural Fibre Composites
HSS	-	High strength steel
RPM	-	Revolutions per minute
API	-	Application Programming Interface

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CHAPTER 1

INTRODUCTION

1.1 Overview

Nowadays, fuel and electricity are used to power lawn cutting equipment, which is expensive and requires a lot of maintenance. As a result, a hand-held device for cutting grass was created in this study utilizing components that could be found locally. For improved performance characteristics, key factors like strength, durability, and low weight were considered during the design process. A 12V/1.35A rechargeable battery that powers the DC motor of the lawnmower allows it to spin at 19,300 RPM. For effective grass cutting, the torque that is produced will be passed to the cutting head mechanism. A bicycle frame and a set of wheels were used to attach the wooden foundation to which the entire configuration setup was fixed. (Afan et al., 2020).

The goal of this project is to create a lightweight, portable lawn cutter. Unlike push-button and manual mowing techniques, this equipment saves time and energy, allowing for more flexible and increased mobility. (Mhamunkar et al., 2020) Here, the aim of this study is to modify the traditional hand grass cutter by providing wheel supports and rod support at the front end and middle of the cutter. The study must carry out with approaches the Pugh's method to compares and evaluates several design alternatives for the best design propose.

The analysis suggests a novel multi-axial vibration absorber to lessen the grass trimmer's handle vibration caused by a gasoline engine. Dunkerley's equation is used in the design of the suggested vibration absorber, which is then constructed for testing. To determine the resonance frequencies of the absorber and to confirm the conclusions of the equations, an experimental modal analysis of the absorber is carried out. To determine how

well an absorber reduces hand-arm vibrations in the x, y, and z directions, experimental tests are conducted on a grass trimmer with an absorber attached close to the handle location. The findings showed that attaching a multi-axial vibration absorber significantly lowers the overall vibration value recorded at the grass trimmer's handle. (Patil, 2019)

A portable grass cutter machine is a compact, handheld, or wheeled equipment that efficiently cuts grass and other vegetation in residential, commercial, or agricultural environments. Hence, in this study, a handheld operated machine for grass cutting was designed and fabricated by using locally available materials. Important aspects such as durability, strength, and light weight were taken into design considerations for better performance characteristics. Here's the **Figure 1.1** below show the target actual product in this thesis that available in the market.

Figure 1.1: Actual product of handheld grass cutter (Source: made-in-china, 2024)

1.2 Problem Statement

The durability of the old traditional machine grass cutter was heavy and need a more human effort. One major disadvantage of traditional grass cutters is their lack of human-energy efficiency, especially with manual scythes and reel mowers. Their limited acceptance due to this inefficiency presents difficulties for users. Important problems linked to conventional lawn cutters' low human-energy efficiency include:

i. Time-Consuming: The manual operation of traditional grass cutters is time-consuming, especially for larger lawn areas or thick grass, requiring repetitive motions and extended periods to achieve satisfactory results.

ii. Inefficient Use of Resources: Grass cutters that are low in human energy consumption led to inefficient lawn management practices since users must spend more time and effort than necessary to get the desired cutting results.

iii. Physical exertion: Using manual scythes and reel mowers requires a lot of physical effort from the user, which can be taxing and result in strain or injury, especially for those with weak or restricted strength.

1.3 Aim

Develop a user-friendly design must be achieve in this PHGC project that makes maintenance, operation, and assembly simple. Provide an enhanced mobility and less operator fatigue grass cutter design. This grass cutter also must ensure a good of lightweight and durable for prolonged use.

Functional prerequisites:

1. Supporting wheel: Include a robust wheel that makes it easier to move the trimmer across rough ground and eases operator fatigue.

2. Ergonomic handles that may be modified to suit a variety of user heights and preferences should be designed.

3. Power source: To supply enough energy for extended use, use a dependable power system, such as an electric cord or rechargeable battery.

1.4 Research Objective

This research is to provide an enhanced mobility and less operator fatigue grass cutter design by applying the Pugh's method as a structure. Specifically, the objectives are as follows:

a) To create design a light flexible of handle grass cutter machine using Pugh's method.

b) To analyze the developed design using finite element analysis.

c) To conduct experimental testing of the developed prototype.

1.5 Scope of Research

This thesis approaches a Pugh's method also known as the Pugh matrix or Pugh analysis, is a process in engineering and decision-making that compares and evaluates several design alternatives or concepts against a set of criteria. Engineers and designers frequently apply Pugh's technique to compare and assess several design proposals for new products. They can evaluate cost, performance, manufacturability, and user happiness to establish the best design direction.

This project focuses on designing, developing, and optimizing a handheld grass cutter with advanced interactive tools such as SolidWorks and CATIA (Computer Aided Three-Dimensional Interactive Application). The goal is to develop an efficient, user-friendly, and environmentally responsible gardening equipment that can meet the needs of both home and professional users. The project uses SolidWorks and CATIA's powerful modelling capabilities to develop the cutter's design through thorough 3-D modelling, simulation, and analysis.

To create a strength analysis model using Finite Element Analysis (FEA) in SimSolid software, first load your grass cutter CAD model and define material attributes. Use SimSolid's meshless FEA approach while specifying mesh parameters for accuracy, add boundary conditions to simulate how the grass cutter is supported during operation, and determine the loads acting on its components. Run the analysis to get findings like stress distributions and displacements, then evaluate them to find likely failure locations.

1.6 Organization Thesis

These four additional chapters, which make up the remainder of the thesis, are outlined below:

Chapter 2: A survey of the literature that is pertinent to the current investigation, including the needs of people's demand with the portable grass cutter.

Chapter 3: This project will provide an explanation of the present methodology that has been suggested via the process of discussing the procedures involved.

Chapter 4: The design of strength analysis will be test using Finite Element Analysis (FEA). The product is then will be manufactured using a fabrication technique.

Chapter 5: Conclusions are based on the research's general findings, as well as recommendations for further investigation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The performance of grass cutter machines during periodic maintenance has been the subject of a significant amount of literature, which has led to the formulation of multiple theories to explain the workings of the machines. Scheduled and unplanned maintenance are the two main research topics in studies on the effectiveness of lawn cutter machines.

This chapter begins with an overview of the grass cutter machine's components and functions. The many categories of grass cutter machine performance are provided in the frequency range in which they occur. A study of grass cutter machine literature is then presented, explaining the functioning of the grass cutter machine during planned maintenance. The Pugh's method is used to group the findings into simulation and experimental ways to solve and assess the old grass cutter machine issues. The next part outlines the experimental studies that must be carried out to solve grass cutter machine difficulties. Finally, a study review article on grass cutter machine planned maintenance is offered, as well as an overview of existing methodologies and their limitations for resolving grass cutter machine problems. **Figure 2.1** displays the chapter's structure.

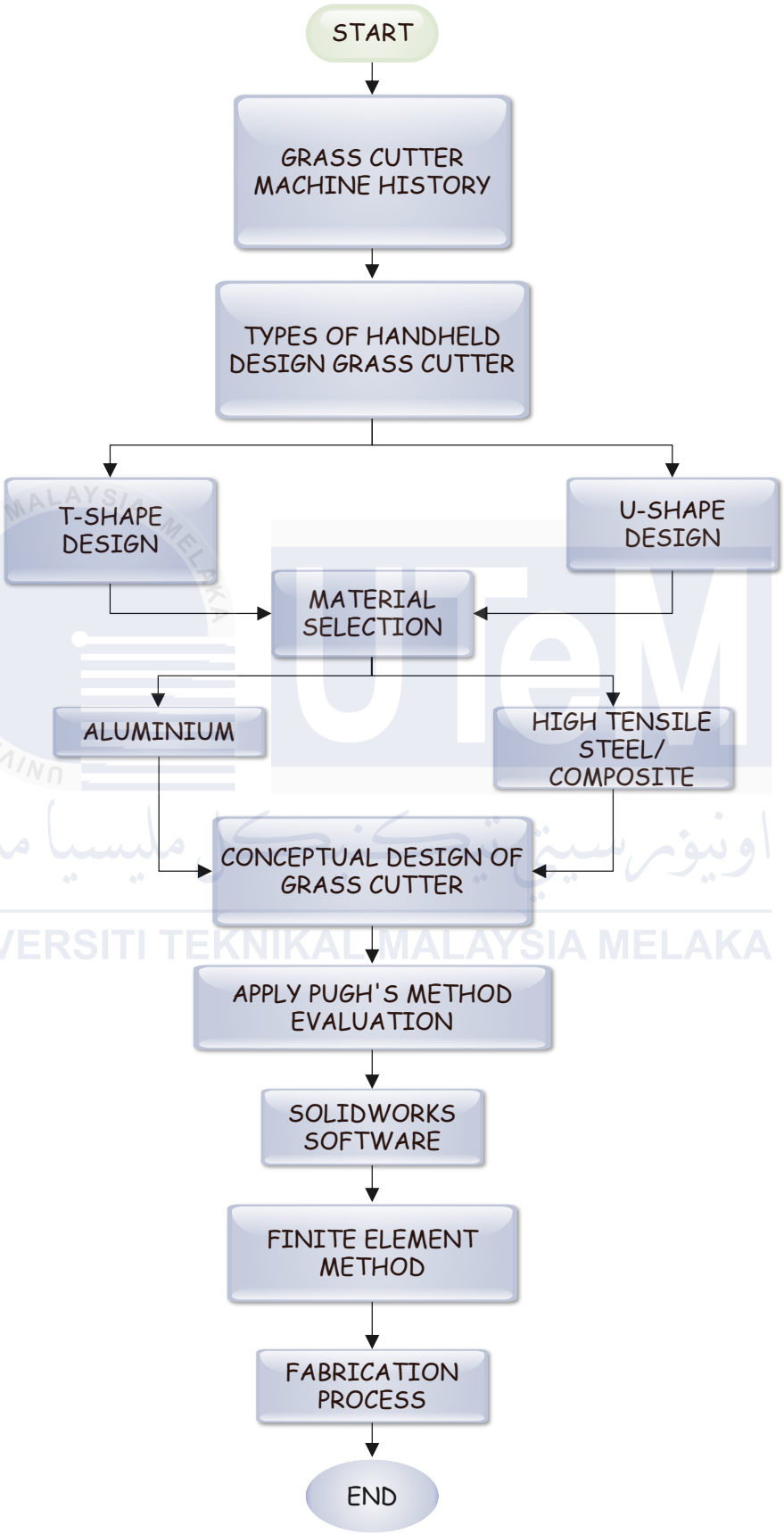


Figure 2.1: Overview of Literature Review

2.2 Grass Cutter Machine History

Today, grass cutting is still a necessary duty in agriculture, gardening, and grounds management. Modern grass cutting equipment encompasses a wide range of gadgets, from simple hand-held devices to sophisticated riding mowers and robotic lawn mowers. These methods have evolved over millennia to satisfy people demands for grass and vegetation management for practical, aesthetic, and recreational reasons.

The practice of cutting grass dates to ancient times when early humans began to reside in agricultural settlements. However, the earliest grass cutting tools were most likely basic hand-held instruments such as sickles or scythe. These instruments were used to manually cut grass and other vegetation for a variety of purposes, including agricultural field clearing, livestock feeding, and landscape maintenance.

However, there are no standardized methods for HAV exposure assessment. Many studies traditionally have measured acceleration values directly from tools by mounting an accelerometer on the tool handle. Most recently, vibration dosimeters integrated with hand adapters are available which enable to obtain daily exposure dose while minimizing interference with job activities. (Oh. J, 2022)

Familiarity with backpack brush cutters, as well as shoulder and other models of mowers on the market; today, there is another type of mower on the market called backpack mowers, which are designed so that they can be installed in the form of backpacks behind the operators, allowing them to be used easily and without difficulty on farmland.

Backpack brush trimmer are primarily distinguished by their structure, which is positioned behind the operator in the form of a backpack. This allows the operator to guide the gasoline engine's rotational power toward the blade using a spring and lack of human energy as shown in **Figure 2.2** below.

Figure 2.2: Backpack brush cutter
(Knight Auto Sdn Bhd, 2024)

Backpack lawn trimmers provide comfort and power for longer usage, but they also have several downsides. Their heavy weight and thickness can be inconvenient, especially in small settings. They contain more components than portable devices, which increases maintenance complexity and the possibility of mechanical failure. The engine's closeness to the operator's back exposes him to more noise and vibration, which might cause pain and health problems.

Furthermore, backpack trimmers are often more expensive, which may be a deterrent for budget-conscious shoppers. Their bigger size complicates transportation and storage, and they may require more fuel, resulting in higher operational costs and emissions. Using them efficiently necessitates more expertise and training. In conclusion, while backpack trimmers give power and comfort, they are heavier, more complicated, louder, more expensive, and difficult to transport and store.

2.3 Types of Handle Design Grass Cutter

Handheld grass cutters are available in T-shaped and U-shaped forms, with each having distinct advantages. The T-shaped cutter, which has a straight handle and a perpendicular crossbar, offers outstanding accuracy and control, making it perfect for meticulous trimming and edging of small grass areas. It is lightweight and provides a solid, two-handed grip. In contrast, the U-shaped cutter has a loop-like grip that improves comfort and decreases wrist strain, making it suited for long-term usage. Its design enhances stability and leverage, making it ideal for cutting thicker grass and wider lawn spaces. Both forms meet distinct gardening demands, with the T-shape being better for precise work and the U-shape excelling at comfort and cutting through harder plants. Following this, the details of these two types of designs are discussed. **Figure 2.3** and **Figure 2.4** below shows the two types of handle grass cutter.

Figure 2.3: T-Shape design of handle grass cutter
(Source: Machine Wales, 2024)

Figure 2.4: U-Shape design of handle grass cutter
(Source: EEC Hardware, 2024)

2.4 Material Selection for Handheld Grass Cutter

The study aims to determine the optimal material for a handheld grass cutter design, focusing on mild steel, composite, and aluminium, to ensure durability and withstand the load during the cutting process.

2.4.1 High Tensile Steel or Composite

Natural fibre composites, also known as bio composites, are an alternative to the synthetic fibre composites that are currently in use. These bio composites have several advantages over synthetic fibre composites, including being abundant in nature, lightweight, strong-to-weight ratio, and most importantly, environmentally friendly qualities like biodegradability, renewability, recyclability, and sustainability. To determine the dependability and accessibility of NFC for use in airplanes, automobiles, boats, sports equipment, and other engineering domains, researchers are delving deeply into the characteristics of NFC. One useful technique that helps to improve the performance and design of natural fibre composites is modelling and simulation (M&S) of NFCs. Finite element analysis has been used recently by several academics to examine the properties of NFCs. (Alhijazi et al., 2020). The yield and ultimate strength of high-strength steel (HSS) are superior to those of mild steel. Between mild steel and HSS, there is not much of a variation in elastic modulus. It should be observed that the stress-strain curve for mild steel clearly shows a yield plateau. However, the stress-strain curve of the HSS does not show a yield plateau. Furthermore, HSS has a worse ductile characteristic when compared to mild steel. **Table 2.1** illustrates the better material performance of HSS, which has led to its widespread application in constructions recently, despite certain drawbacks. (Xue et al., 2022)

Table 2.1: Difference properties between mild steel and high strength steel (Source: differencebetween.com, 2019)

	Mild Steel	High Tensile Steel
Definition	Mild steel is a very common type of carbon steel, which has low amount of carbon weight	High tensile steel is a type of mild carbon steel which has high yield strength and tensile strength
Carbon content	Moderate	Higher than other mild steel forms
Tensile strength	Comparatively low	Very high
Plastic ductility	Comparatively high	Comparatively low
Brittle fracture	High	Low
Application	For structural part in constructions	Mainly for reinforcement purpose, as automobile parts, weapon production, etc.

2.4.2 Aluminum

Aluminium metal and its alloys are used in the majority, if not all, of modern industrial processes due to their widespread availability and numerous applications. An alloy is a metal formed by mixing two or more metallic components to improve its qualities. Alloying is the process of putting certain metallic "alloying" elements into a base metal to give it special features such as improved strength, corrosion resistance, conductivity, toughness, or a desirable mix of these traits.

While alloys with higher percentages (up to 22%) are classified as cast alloys and are usually brittle, alloys with lower percentages (less than 4%), also known as wrought alloys, are thought to be workable. The Aluminium Association (AA Inc.), the foremost authority on aluminium alloys, has developed a four-digit naming scheme to distinguish various wrought alloys from one another according to their main alloying elements. (Christian Cavallo, 2023).

Aluminium's physical, chemical, and mechanical characteristics are similar to those of steel, brass, copper, zinc, lead, or titanium. Like these metals, it transfers electric currents and may be melted, cast, moulded, and machined. Equipment and methods used in steel manufacture are often the same. (Liji Thomas, 2019).

In industry, aluminium is used more often for a few primary reasons. To begin with, aluminium is one of the lightest metals produced in the world, thus its use is limited to construction. As seen in Figure 2.5, its density of 2660 (kg/m^2) is roughly one-third that of copper or steel. After steel, aluminium is the second most utilized metal worldwide. Aluminium's primary benefit for commercial development is frequently its light weight, which accounts for its widespread usage in shipbuilding, aircraft, and land transportation. This is also the reason aluminium is presently attracting a lot of interest from the car industry: lightweight is starting to matter. Aluminium's resistance to corrosion is its second benefit. This clarifies its significance in the fields of building, civil engineering, transportation, heat exchangers, etc. (LEGRAND, 2004).

Property	Symbol	Material	
		Aluminum Alloy	Mild Steel
Density (kg/m^3)	ϱ	2660	7850
Elastic Modulus (MPa)	E	70,300	210,000
Poisson's Ratio	ν	0.3	0.3
Yield Stress (MPa)	R_y	125	250
Ultimate Strength (MPa)	R_u	275	360
Design Stress (MPa) [26]	σ_d	93.75	176.25
Weldment Strength (MPa)	σ_{weld}	100	200
Weldment Design Strength (MPa) [26]	$\sigma_{d,weld}$	75	141

Figure 2.5: Physical and mechanical properties of aluminum alloy and mild steel.

2.5 Apply Pugh's Method Evaluation

Pugh's concept evaluation methods, the concept comparison and evaluation matrix, and the rating/weighting method are popular perception-based methods (Takai and Ishii, 2004). For a portable grass cutter, each design concept is evaluated against these criteria in comparison to a baseline, indicating whether it performs better, worse, or the same.

This method makes it simple to determine which design offers the most benefits overall. For example, one design may be very efficient and long-lasting but heavy and expensive, whereas another may be simple to use and safe yet less powerful. Designers can choose the finest overall design or mix the best features from multiple designs to create a better portable lawn cutter.

The Pugh's selection and assessment is evaluated by summation of '+' and '-' that indicates the element presented in the criteria. The '+' will be multiplied by weighing that assesses for every criterion before been total up and the result is present using Pugh method. Embodiment design is well known in product development. The main principles are minimum manufacturing costs, minimum requirements, minimum of weights,

minimum losses, and optimal handling ("Design of Smart Packaging Machine Liquid Soap Using Pugh's Method," 2020). This is sample of table evaluation six criteria of concern to be evaluate for the best selection of conceptual design as shown in **Table 2.2**.

Table 2.2: Sample Pugh's selection method for this study

Criteria	**Weight**	**Design 1**	**Design 2**	**Design 3**
Description	(1-10)	Concept 1	Concept 2	Concept
Easy to build		+	-	-
Cost		+	+	-
Lightweight		-	-	+
Low maintenance		+	-	+
Minimal component		-	+	-
Easy to be operate		+	-	-
Σ(+)				
Σ(-)				
TOTAL				

2.6 SolidWorks Software

Technical drawings are commonly used to clarify instructions and point out specifics to a group of people creating something to explain how it works or how to design and put together things. We compare the most well-known CAD programs in this study. Based on the unique profile of students undergoing instruction, the selection of CAD Software is limited to the most often used in this field: AutoCAD and SolidWorks. AutoCAD is an Autodesk computer modelling tool that allows you to generate 3D and 2D models of parts. (Hussien Mohamad & Alfuraih, 2019)

It is the most widely used CAD program in the world. In fact, it is the program most often associated with the notion of CAD (Computer-Aided Design) for students in high schools, colleges, and universities. AutoCAD is the most popular application for drawing two-dimensional designs, although it is not as widely used in solid modelling as SolidWorks.

SolidWorks is a CAD program that runs on Microsoft Windows. Dassault Systems publishes SolidWorks. SolidWorks assigns parametric characteristics to model construction. It means that designers develop models with engineering forms like cams, holes, and slots rather than geometric terminology. Keywords: automotive, design, AutoCAD, SolidWorks, 2D, 3D, modelling (Hussien Mohamad & Alfuraih, 2019). **Figure 2.6** show example design of SolidWorks software.

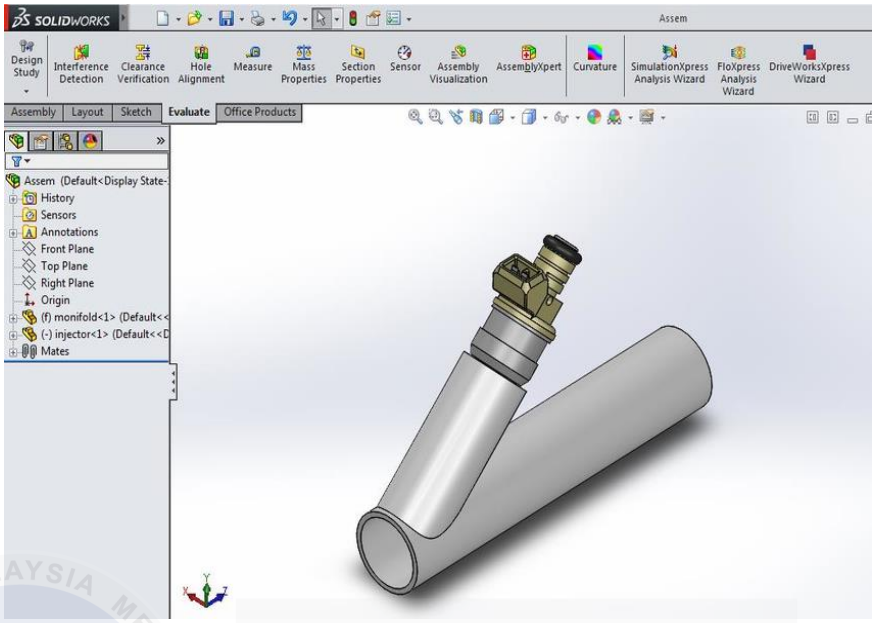


Figure 2.6: SolidWorks Software
(Source: SolidWorks Corp., Dassault Systemes)

2.6.1 SolidWorks Modelling

Stress analysis with SolidWorks Simulation is an effective technique for predicting the behaviour of components and structures under different loading circumstances. The process includes generating a 3D model of the component, assigning material attributes, specifying boundary constraints, meshing, configuring the analysis, and analysing the findings. SolidWorks Simulation supports a variety of analysis types, including static, dynamic, and thermal, as well as a full set of tools for visualizing and analysing findings. **Figure 2.7** shows SolidWorks part design in the software.

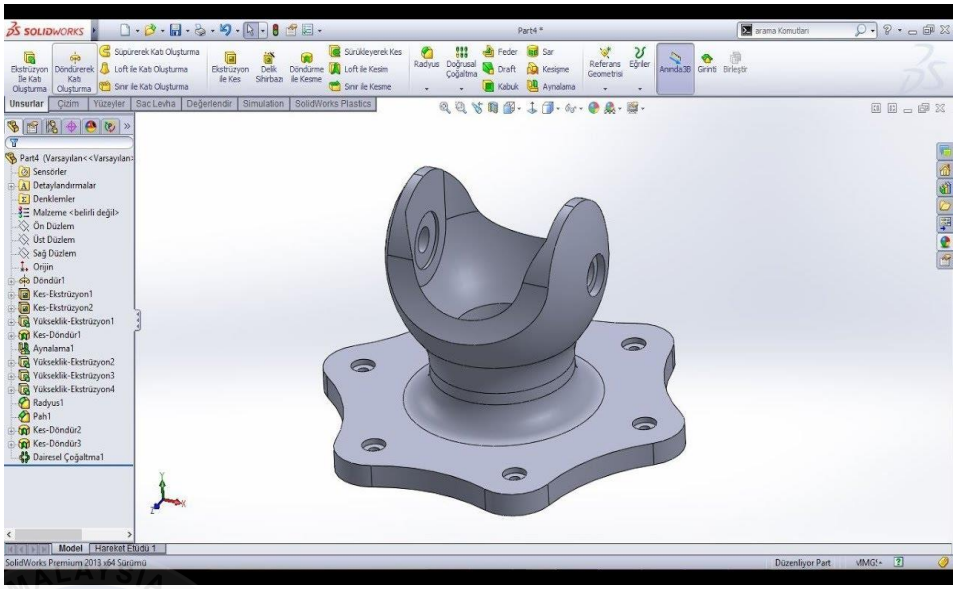


Figure 2.7: SolidWorks part design
(Source: Youtube, 2017)

2.6.2 SolidWorks Assembly Modelling

SolidWorks API (Application Programming Interface) capabilities were used to manage SolidWorks instructions and assembly procedures. An ActiveX DLL project was written in VB 6, and a plug-in file in.dll format was produced. The result was the creation of additional menus in the SolidWorks environment for choosing, inserting, and assembling MF parts. The method was used for both a side clamping process and a semi-circular workpiece.

Modular fixtures (MFs) are crucial in manufacturing processes because they save costs and production time. The authors of this research present an automated technique to MF design and assembly. This technique is based on the secondary development of SolidWorks and its integration with the Visual Basic (VB) 6 programming language (Farhan et al., 2012). **Figure 2.8** shows the SolidWorks assembly modelling.

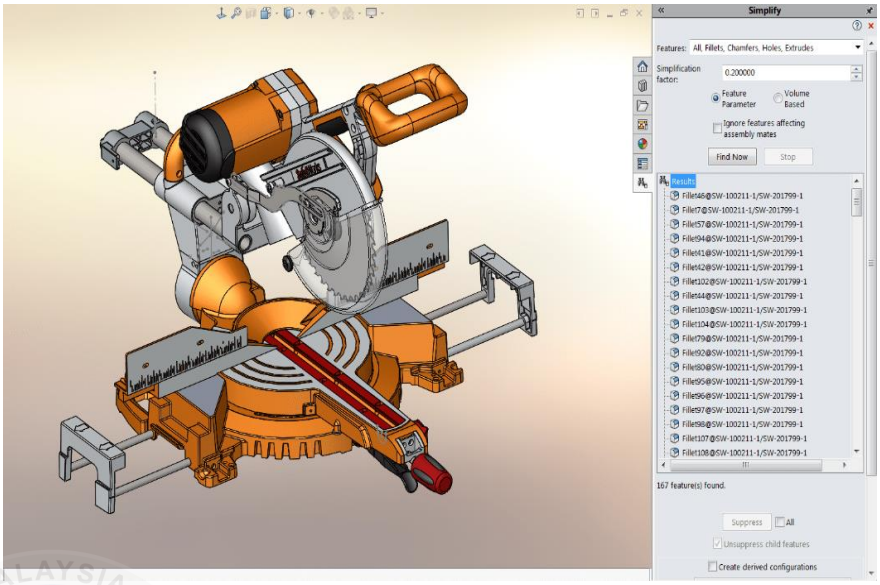


Figure 2.8: SolidWorks Assembly Modelling
(Source: hawkridgesys.com, 2017)

2.7 Finite Element Analysis (FEA)

Finite element analysis is a computer approach that predicts how different materials will respond when various forces are applied. In orthopaedics, this approach is mostly utilized for implant design and testing. As technology advances, more clinical applications are being explored, which hold promise in the areas of surgical planning and the ability to adapt implants to unique patient features. This page describes the many preclinical mechanical testing available and provides a brief explanation of finite element analysis technology (Welch-Phillips et al., 2020). **Figure 2.9** shows Finite element analysis in SimSolids software.

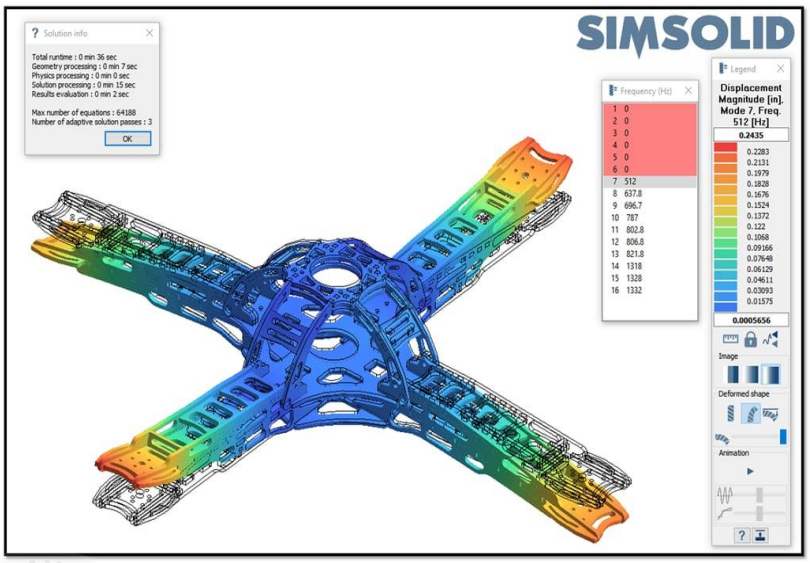


Figure 2.9: Finite Element Analysis
(Source: Fastway Engineering, 2019)

The FEA is a M&S tool widely used in academia and industry, as any material model, boundary conditions, and complex shape structures can be solved by FEA easily. Highly accurate and optimized results can be obtained by conducting several iterations, so that the product development down time will be reduced and its lifetime will be enhanced (Alhijazi et al., 2020). To determine the maximum strength, stress, and critical point of the structure, the design of the grass cutter project will be developed using the FEA approach, which will analyse the design's entire composition. The three main steps of this approach are pre-processing, analysis, and postprocessing, which will be covered in more detail in the upcoming chapter.

2.8 Fabrication

Fabrication refers to two main concepts: manufacturing, which is the process of constructing products by cutting, shaping, and assembling raw materials, as seen in industries such as metalworking, textiles, and electronics; and deception, which is the creation of false information or stories with the intent to deceive, such as inventing data in research or fabricating an alibi. Both uses entail the manufacture of something, whether it is concrete items in industrial situations or immaterial lies in deception scenarios. The repercussions of fabrication differ tremendously depending on whether it involves honest workmanship or immoral deception.

2.8.1 Welding

Welding is a fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. Welding is usually used on metals and thermoplastics but can also be used on wood. The completed welded joint may be referred to as a weldment (TWI, 2020). A welding joint refers to the specific location or boundary where two or more pieces of metal or plastic are interconnected. They are created through the process of joining two or more work components (made of metal or plastic) together based on a specific geometric configuration using welding. The strength of these joints is important in today's world, as they play a crucial role in the development of structures and machine parts. The strength of these joints and the quality of welding determine the lifespan of these structures, preventing any form of loss, whether it be human, economic, or otherwise. This chapter provides a detailed discussion on various topics related to welding. It covers the concept of welding and weldability, arc welding and its equipment, electrodes, gas welding and the different types of flames, gas welding equipment, resistance welding, design considerations for weld joints such as butt

joints and fillet joints. It also includes information on allied processes like soldering and brazing, as well as special welding processes like plasma arc welding, metal inert gas arc welding (MIG), and TIG welding. Additionally, it explores the automotive applications of welding and the welding procedures used in automotive manufacturing (Awari et al., 2023). Welding can be categorized into two types: pressure welding, also known as plastic welding, and non-pressure welding, also known as fusion welding. Gas Metal Arc Welding (GMAW) is a widely used method of arc welding as shown in **Figure 2.10.** A welding cannon supplies a continuous and consumable wire electrode and a shielding gas, usually argon and carbon dioxide. Gas combustion creates a focused, high-temperature flame that fuses the workpieces and filler. The most common gas welding method is oxygen-fuel welding, which uses acetylene in oxygen.

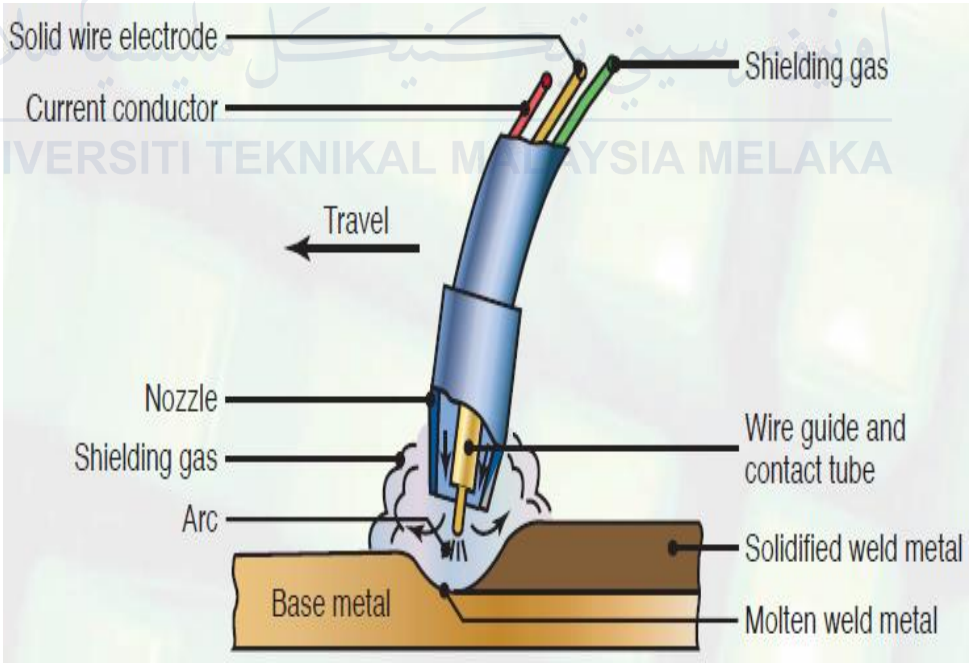


Figure 2.10: Gas Metal Arc Welding (GMAW)
(Source: Weld-Guru, 2024)

2.8.2 Grinding

Grinding is a highly prevalent technique for removing material that is commonly employed at the conclusion of many process sequences. The grinding force is interconnected with nearly all grinding parameters and significantly impacts the material removal rate, dimensional and shape correctness, surface and subsurface integrity, thermodynamics, dynamics, wheel durability, and deformation of the machining system (MENG et al., 2023). Grinding is essential in the production process, resulting in a finished product. Industrial power tools having abrasive wheels are called grinders. Revolving abrasive wheels cut metal from the workpiece. Grinding provides a precise finish with good surface quality, shape, and dimension. Grinding is categorised as rough and precision grinding based on the accuracy of the work. **Figure 2.11** illustrates harsh grinding.

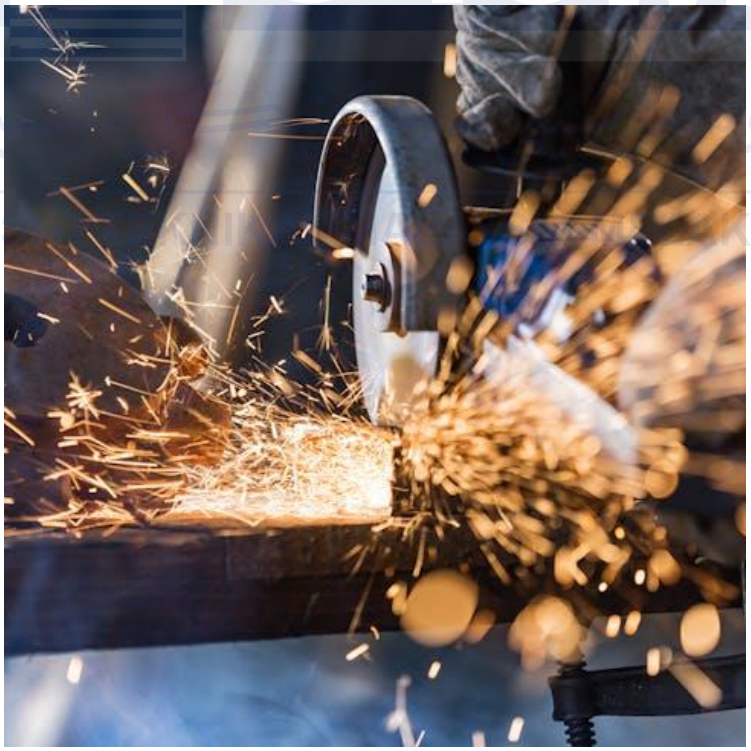


Figure 2.11: Hand Grinding Machine
(Source: Machine Design by Xometry, 2023)

2.8.3 Drilling

The optimum drilling parameters (drill geometry, speed, feed, and depth of cut) selection for the specific materials is good to achieve effective drilling performance and better surface quality of the holes (Jagadeesh et al., 2023). Drilled holes are distinguished by their keen edge on the side of entry and the existence of burrs on the side of exit. In addition, the interior of the hole typically exhibits helical feed marks. Drilling can affect the mechanical properties of a workpiece by creating low residual stresses near the hole and a thin layer of highly stressed and disturbed material on the newly created surface. Consequently, the workpiece becomes more susceptible to corrosion and the propagation of cracks on the surface under stress. To mitigate these unfavourable circumstances, one may opt to carry out a concluding operation.

2.9 Summary or Research Gap

In conclusion, this chapter provides a summary of the information gathered from the literature study completed during this research. The first component of the literature study examines the historical background of grass cutters and explores the distinctive features of portable grass cutter design. At that juncture, it became imperative to construct a redesigned handheld grass cutter that would enhance the quality of labour. Moreover, it is imperative to examine the material used in the design of the handheld grass cutter to determine the most suitable material for manufacturing the parts. This chapter provides a detailed description of the design of handheld grass cutters that are already available on the market. It highlights the specific features of well-known handheld grass cutters manufactured by different companies, which are designed to suit the efficiency requirements of users throughout the grass cutting process. Therefore, several designs of portable grass cutters have been examined using Pugh's method to determine the optimal design based on

variables such as effectiveness, cost, and future design considerations. The forthcoming chapter will elucidate the approach used to discuss the processes entailed in this project. The chapter will be structured in accordance with the sequence of activities.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will outline the technique used to finish this project. This chapter goes into detail about the technique utilized for this project. First, as shown in **Figure 3.1**, the procedure was split into two phases: Phase 1 and Phase 2. Phase 1 focused on gathering as many design ideas as possible from various sources and contrasting them with the product that was already on the market.

After that, the product development process proceeded to Phase 2, during which the information obtained in Phase 1 was used to build the prototype computer assisted design (CAD) model. A more thorough examination of the process for producing the CAD model that was intended based on the design inputs will be provided later. Before going on to the product production process, the CAD model was first submitted to FEA using SimSolids software to determine the model's strength, yield stress, and other analyses for better understanding of the model.

3.2 Proposed Methodology

This section explains how to apply Pugh's technique to determine the optimal design for a lawn cutter machine and provides a detailed design process. **Figure 3.1** depicts a flow chart of the product development process that will be employed in this project.

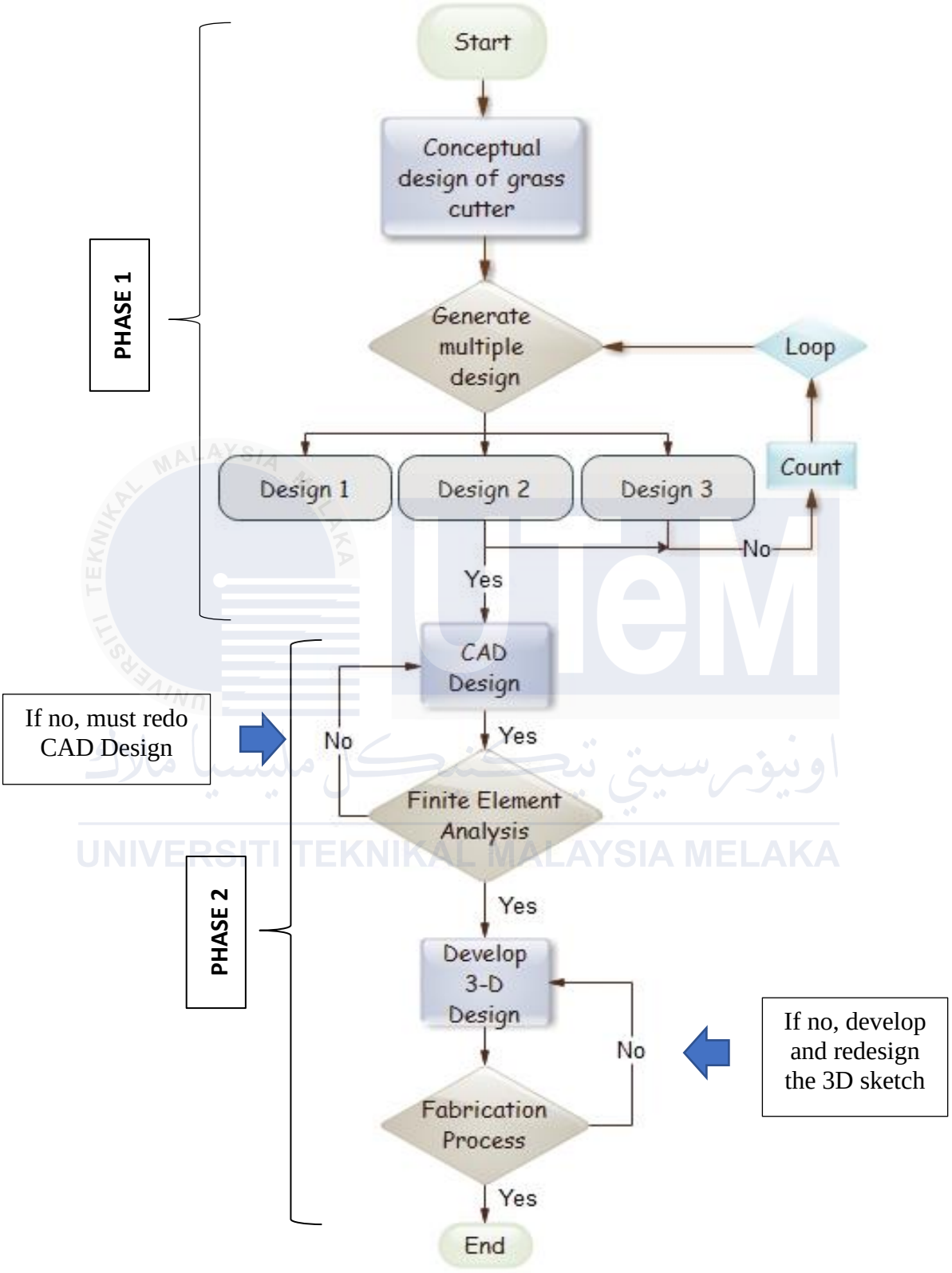


Figure 3.1: Product Development Process

Every component that has been designed must undergo the Finite Element Analysis (FEA) step. This phase will assess each component to ensure its suitability and ability to sustain the applied force throughout the design process of a handheld lawn cutter. This technique will additionally examine each component using various material qualities to investigate its strength and durability. The materials utilized in this investigation consist of mild steel and aluminium. The material exhibits unique features that allow for visualization of its shape when subjected to a specific applied force, based on the material used in the analysis. This analysis allows for the observation of the weak component, as well as other relevant information such as strength and deformation. The process flow is depicted in **Figure 3.2**.

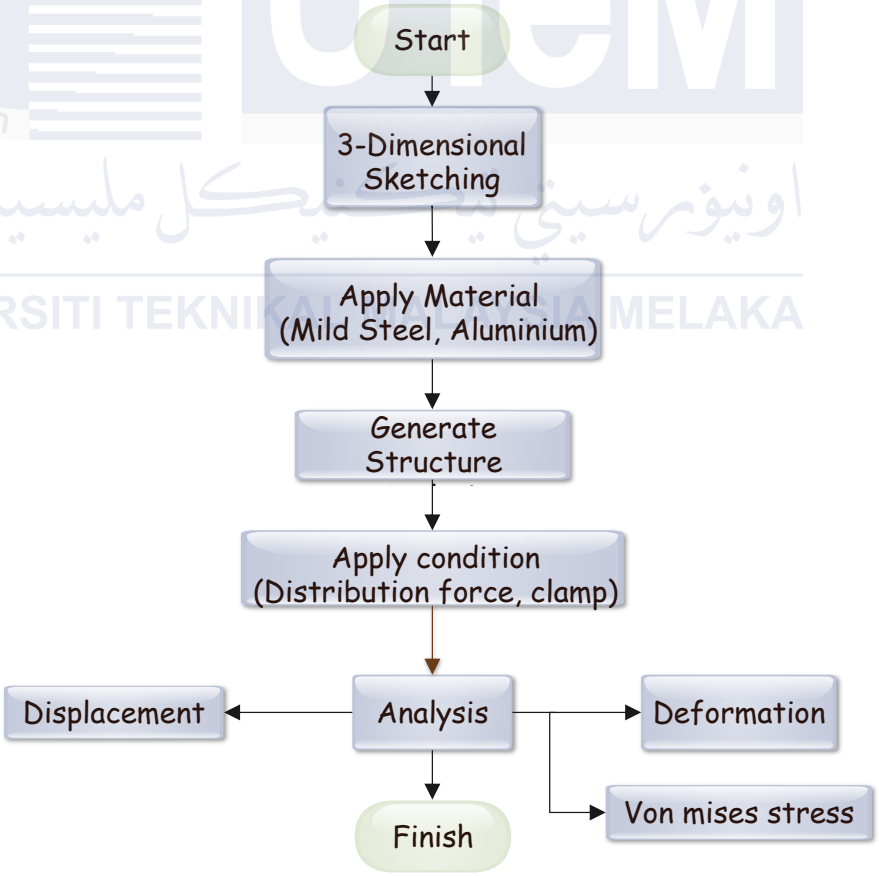


Figure 3.2: Flow Process 3-D Model

3.3 Product Benchmarking

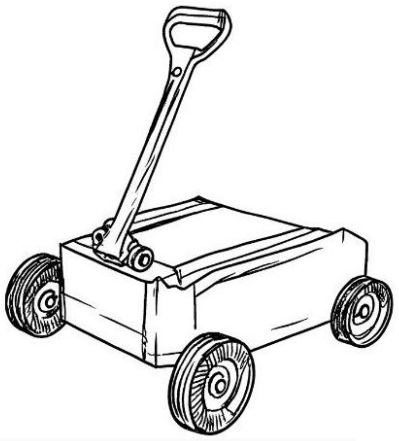
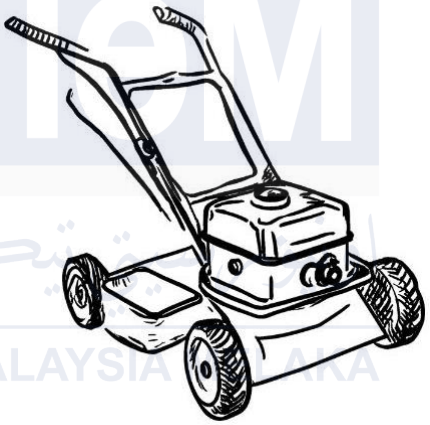
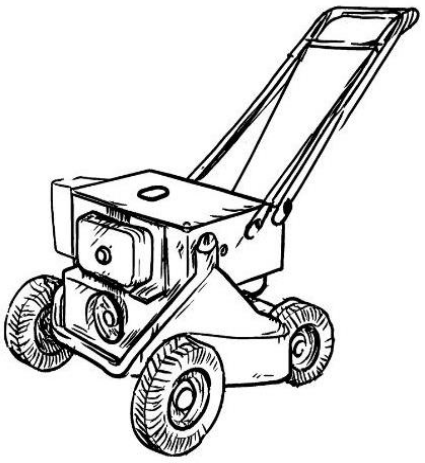
The product benchmarking technique aimed to identify current designs and characteristics of portable handheld grass cutters, as well as explore potential designs for this project. A literature review and a market survey were utilized to evaluate the product. Extensive research led to the discovery of patents for handle lawn cutters. These designs served as inspiration and will be enhanced for the future product.

The concept of the model and the use of suitable materials were also considered. These techniques were also applied to stimulate the development of novel material designs that would contribute to the enhancement of the product's overall robustness. In order to choose the appropriate product to employ for the PHGC being created in this project, a more thorough and complete viewpoint is provided by the larger amount of data obtained throughout literature studies.

Based on the information obtained throughout the literature study and idea design processes, 3 concept designs were generated. These concept concepts were all created in accordance with the criteria for design components, the materials that were utilized, and several other factors that were covered in the Pugh's method evaluation.

This approach results in a better design creation process in the process of creating the design. Moreover, all the important factors for choosing a strong design concept were considered throughout the brainstorming phase. The process continued until the best possible design idea was identified, at which point it was decided to move on to the following step, the product development phase, where all further development was predicated on the chosen design and analysis. Three design concepts for PHGC are shown in **Table 3.1**.

Table 3.1: Design Concept of PHGC

Design Concept	Image
Design 1	
Design 2	
Design 3	

3.4 Pugh's Method Evaluation

As was already indicated in section 2.5, by creating a process for selecting the design, this strategy assists consumers in reaching a selection among several designs. This approach allows the best design to be chosen from the collection of several designs. The approach started with the creation of an online survey using a Google Form, as shown in **Figure 3.3**, to gather community input and gauge preferences for design elements.

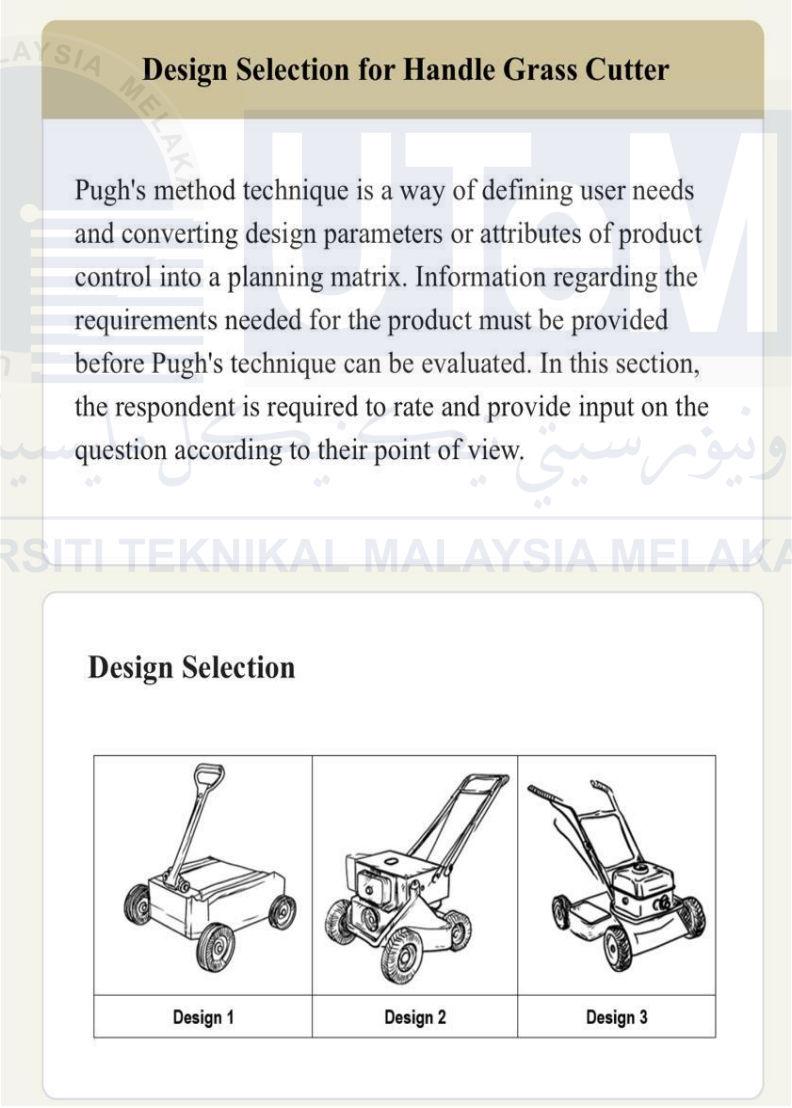


Figure 3.3: Method of Survey Evaluation

From 1 to 5, with 5 representing the highest importance and 1 the least, each trait will be rated according to their point of view. The characteristic rating online survey question is displayed in **Figure 3.4**. The next step in the process is a technical measure that ensures that technical specifications or product needs reflect community feedback. Additionally, they can recommend improvements or point out where the trait is at.

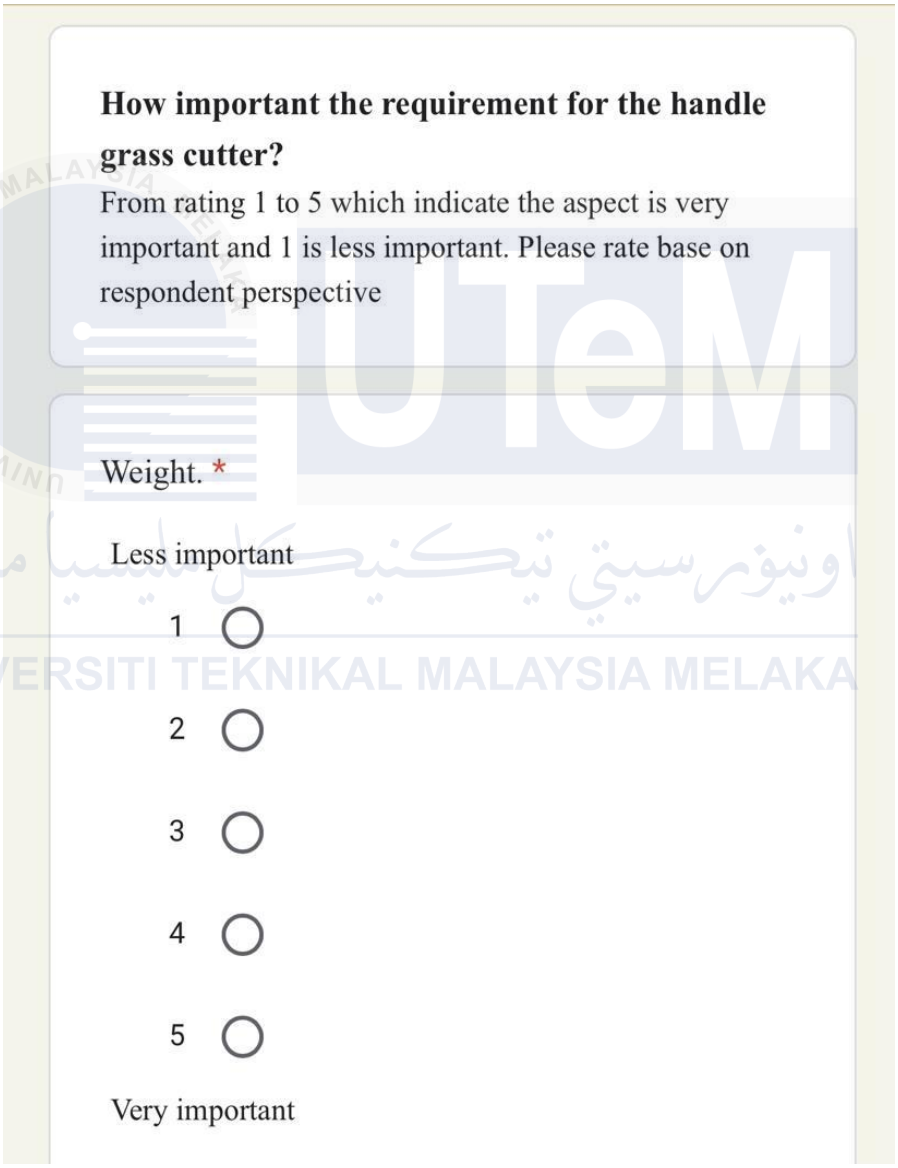


Figure 3.4: Grass Cutter Handle Requirement

Finding the relationship matrix that develops a correlation between the criteria or design attributes is the next step in the process. As previously explained in subchapter 2.5, the grade will range from weak to strong relationships. The survey next asks respondents to rate the 3 designs that have been presented considering all the requirements. A rating on a scale of 1 to 5, with 1 denoting extreme dissatisfaction and 5 denoting extreme satisfaction, is used. A design evaluation question is shown in **Figure 3.5**.

Figure 3.5: Design Evaluation for Grass Cutter Handle

The survey is divided into two sections: section 1 covers demographics with 2 questions and section 2 covers design requirements with 9 questions for respondents. The survey questions are listed in **Table 3.2** below.

Table 3.2: List of Question

SECTION 1

DESIGN SELECTION FOR PORTABLE HANDHELD GRASS CUTTER

Hello! I'm Yumni Ruzaini, a third-year BMKA student at Universiti Teknikal Malaysia Melaka (UTeM), studying in the Faculty of Mechanical Technology and Engineering (FTKM). In order to choose the ideal design for my FYP project, I'm running a survey.

Sign in to Google to save your progress. Learn more

* Indicates required question

Age *

- ○ Below 18 to 25
- ○ 26-30
- ○ 31-40
- ○ 40 & above

Gender *

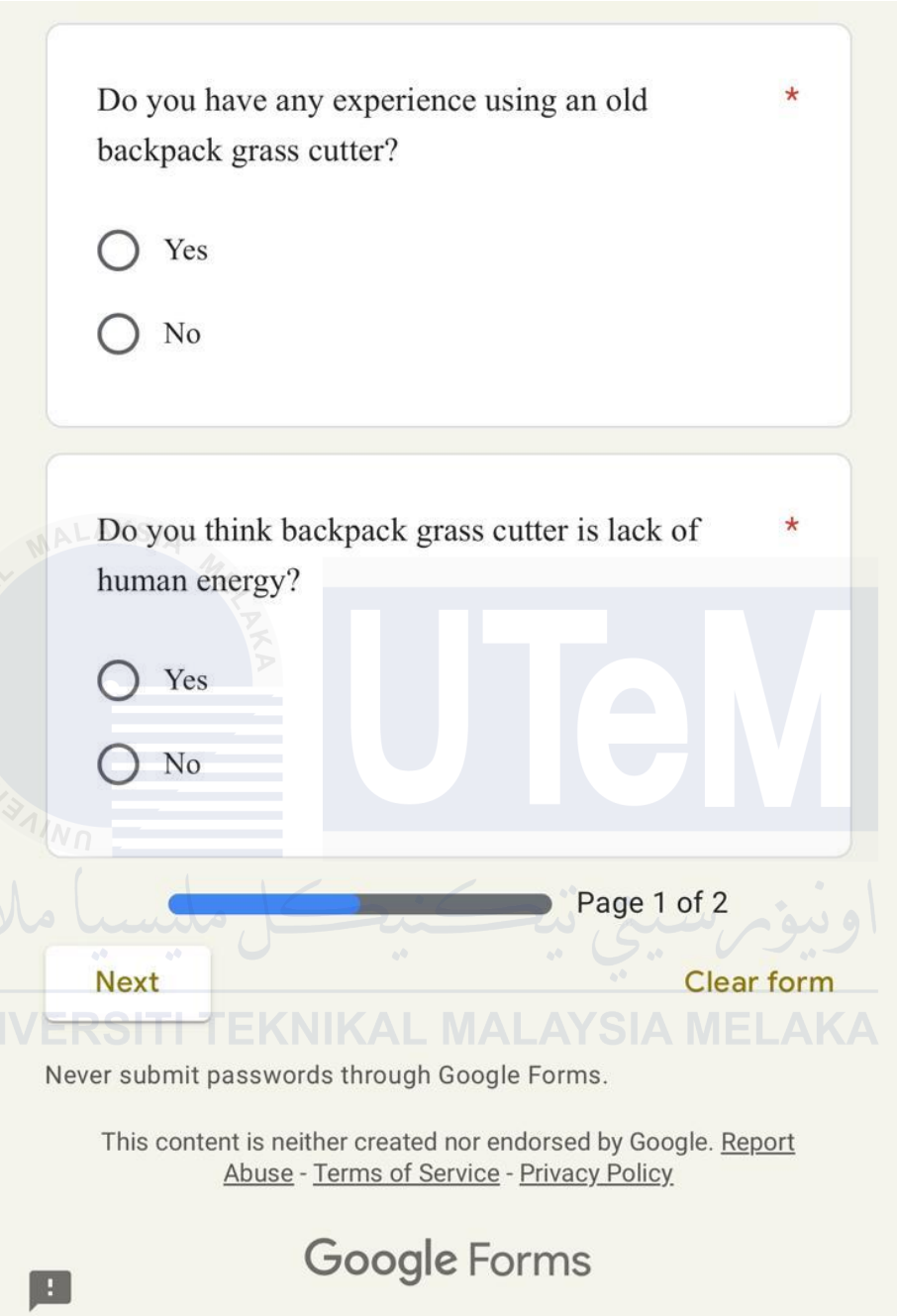
- ○ Male
- ○ Female

Do you have a problem using old backpack grass cutter? *

- ○ Yes
- ○ No

If yes, what kind of problem you faced?

Your answer

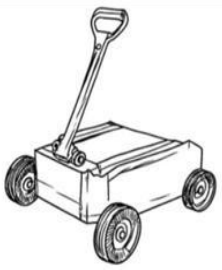
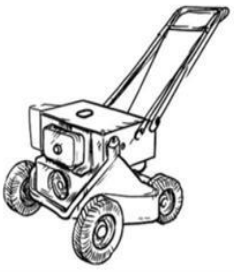


SECTION 2

Design Selection for Handle Grass Cutter

Pugh's method technique is a way of defining user needs and converting design parameters or attributes of product control into a planning matrix. Information regarding the requirements needed for the product must be provided before Pugh's technique can be evaluated. In this section, the respondent is required to rate and provide input on the question according to their point of view.

Design Selection

		
Design 1	Design 2	Design 3

In your opinion, what are the requirement for the handle grass cutter? You can choose more than answer. *

- [ ] Weight
- [ ] Durability
- [ ] Operating method
- [ ] Portability
- [ ] Material properties
- [ ] Cutting efficiency
- [ ] Safety features
- [ ] Other: _____

How important the requirement for the handle grass cutter?

From rating 1 to 5 which indicate the aspect is very important and 1 is less important. Please rate base on respondent perspective

Weight. *

Less important

1 ○

2 ○

3 ○

4 ○

5 ○

Very important

Operating method *

Less important

1 ○

2 ○

3 ○

4 ○

5 ○

Very important

Portability *

Less important

1 ○

2 ○

3 ○

4 ○

5 ○

Very important

Material properties *

Less important

1 ○

2 ○

3 ○

4 ○

5 ○

Very important

Cutting efficiency *

Less important

1 ○

2 ○

3 ○

4 ○

5 ○

Very important

Safety features *

Less important

1 ○

2 ○

3 ○

4 ○

5 ○

Very important

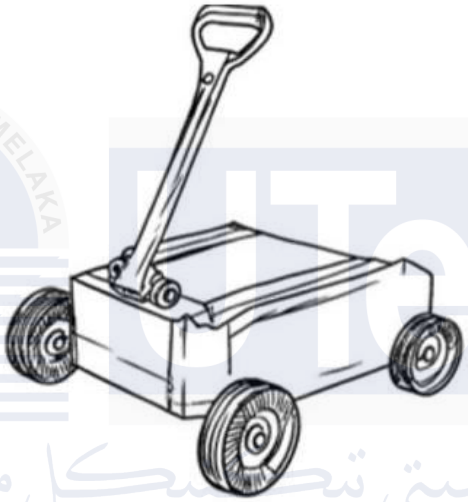
Which design elements did you anticipate seeing in the final product? More than 1 response can be selected. *

- [ ] Material usage
- [ ] Concept Design
- [ ] Adjustable part
- [ ] User friendly
- [ ] Light and portable
- [ ] Other: _____

Which of the 3 designs listed below best meets all of the requirements stated above?

From rating 1 to 5 which 5 indicate highly satisfied and 1 for highly dissatisfied.

Design 1 *



Highly dissatisfied

1 ○

2 ○

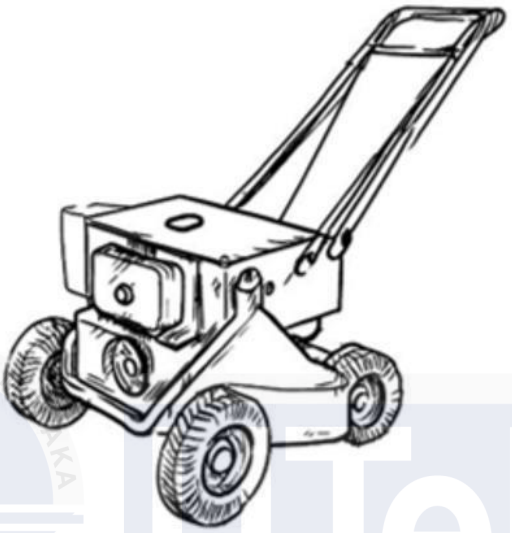
3 ○

4 ○

5 ○

Highly satisfied

Design 2



Highly dissatisfied

1 ○

2 ○

3 ○

4 ○

5 ○

Highly satisfied

Design 3 *

Highly dissatisfied

1 ○

2 ○

3 ○

4 ○

5 ○

Highly satisfied

Page 2 of 2

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3.5 SolidWorks Design

The best design was selected once Pugh's method had been applied, evaluating each criterion and characteristic in the survey. After that, CAD design can be created, ranging from 2-D sketching to 3-D components. In this thesis, the design will be created in SolidWorks software when the criteria and requirement of the mostly respondent design has been selected.

3.6 Finite Element Analysis

Project start and model preparation are the first steps in the planning flow for Finite Element Analysis (FEA) of the design of a portable handle lawn cutter. Weeks one through seven are dedicated to defining the project's goals, defining its scope and deliverables, and conducting a literature study to identify pertinent approaches. The required resources will be assigned, and comprehensive computer-aided design (CAD) models of the grass cutter's component parts will be then created. As mentioned in section **2.4**, material attributes and boundary conditions are defined to guarantee correct analysis.

During weeks 8–13, design suggestions to enhance the performance of the grass cutter will be produced, along with the creation of the FEA process documentation, which will include methodology and important findings. The results will then be given to interested parties for their comments and permission to go forward with the PSM 2 thesis project's next objectives.

3.7 Summary

To summarize, the project begins by implementing the provided approach to gather information on 3-D model and concept design from the literature on Handheld Grass Cutter Design. Product benchmarking was employed to confirm that the manufacturing of the model aligns with the project's objectives. The Pugh's method was employed to assess potential designs, considering multiple criteria, before reaching a final decision. The criteria were evaluated by performing an online survey using Google Forms and by conducting surveys with classmates, friends, and people within our target demographic. Subsequently, a three-dimensional model was constructed utilizing SolidWorks and CATIA V5R18 software, commencing with two-dimensional sketching and progressing to the development of a three-dimensional model. The structural integrity of the model was assessed through Finite Element Analysis (FEA) in SimSolids. The fabrication procedure was being conducted to produce the design of the Handheld Grass Cutter product. In the subsequent chapter, the outcomes derived from the methodology will be elaborated upon in greater depth.

CHAPTER 4

PRELIMINARY RESULTS

4.1 Introduction

In this chapter, the results and analysis of the model that was chosen are presented. This is followed by an analysis of the findings of the research in relation to each of the project's goals. The conversation is carried out in accordance with the procedures that were designed for this project, beginning with the design of the concept, moving on to the evaluation of the concept, developing the model, and finally moving on to the production of the final product. All the shortcomings that have been discovered throughout the course of this project will be discussed in this chapter for the purpose of further improvement.

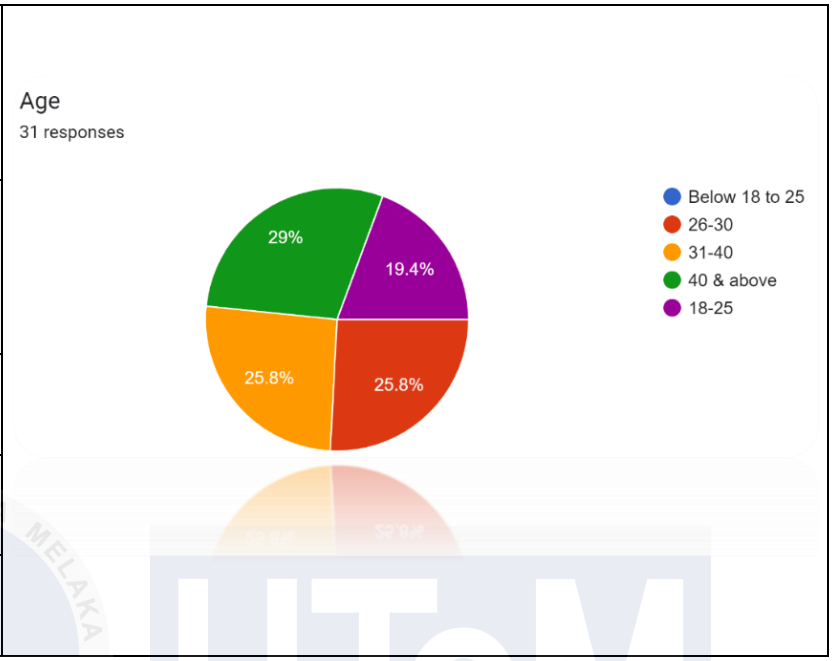
4.2 Results and Analysis

This phase gathers the data required for the evaluation of Pugh's technique using a Google Form results survey. This survey was generally sent to my classmates and the neighbourhood. Every outcome is determined by their viewpoint. Thirteen people in all have participated in this survey. We'll get into further detail information below. The respondent will be questioned on a total of eighteen questions.

The first question asks the respondent about their age with (29%) of responses, most respondents are over 40. **Table 4.1** displays the data that has been simplified.

Table 4.1: Question No.1 Data

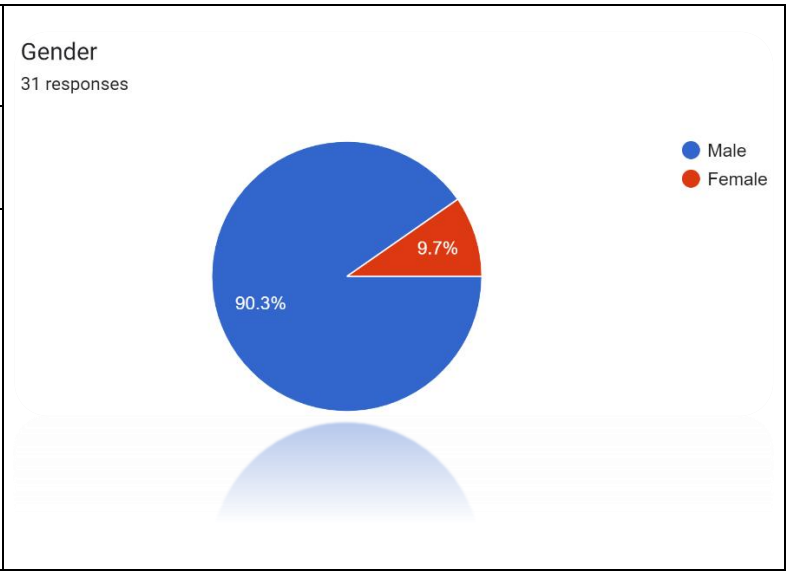
Age / years old	Percentage %
Below 18 to 25	19.4
26-30	25.8
31-40	25.8
40 >	29



For question number 2, the respondent was asked about their gender. Most respondents (90.3%) are male. The simplified data is provided in **Table 4.2**.

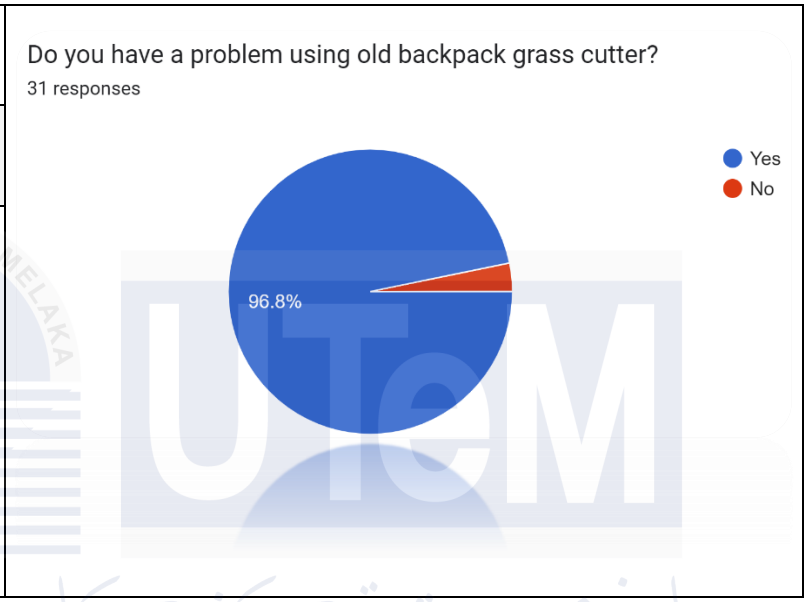
Table 4.2: Question No.2 Data

Gender	Percentage %
Male	90.3
Female	9.7



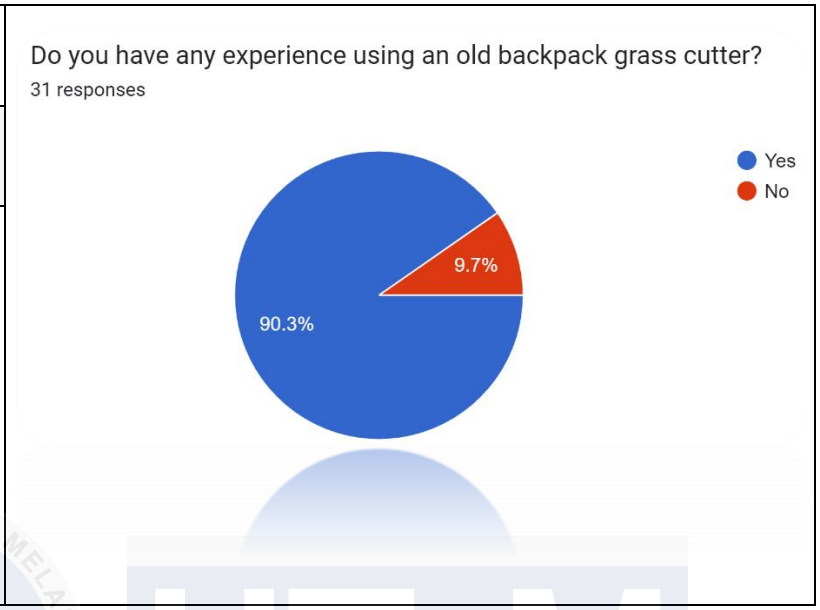
The respondent was questioned about a problem with a backpack lawn cutting machine in question number 3. Most of them are aware of the machine, which has a (96.8%) Yes response rate. **Table 4.3** below displays the data that has been simplified.

Table 4.3: Question No.3 Data

Problem	**Percentage %**	
Yes	96.8	
No	3.2	

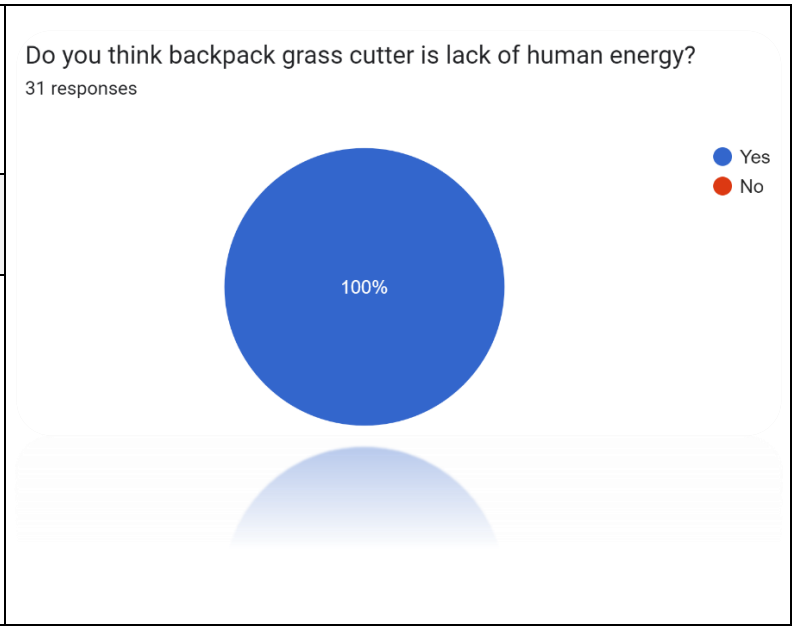
In response to question 5, the respondent was questioned about their experience with backpack grass cutters. Most of them are aware of the circumstance in which (90.3%) of respondents select "Yes.". **Table 4.4** below displays the data that has been simplified.

Table 4.4: Question No.5 Data

Experience	Percentage %	
Yes	90.3	
No	9.7	

For question 6, the respondent was asked about the disadvantages of utilizing a backpack lawn cutter, which is a loss of energy. Most of them agreed in this case, with the majority choosing Yes as their option. The simplified data is provided in **Table 4.5**.

Table 4.5: Question No.6 Data

Lack of human energy	Percentage %	
Yes	100	
No	0	

For question number three, as illustrated in **Figure 4.1**, respondents were asked about the problems that consumers encountered. This is not a mandatory question, but 14 respondents participated. **Table 4.6** illustrates the respondent's problem. The "none" response was removed from the table.

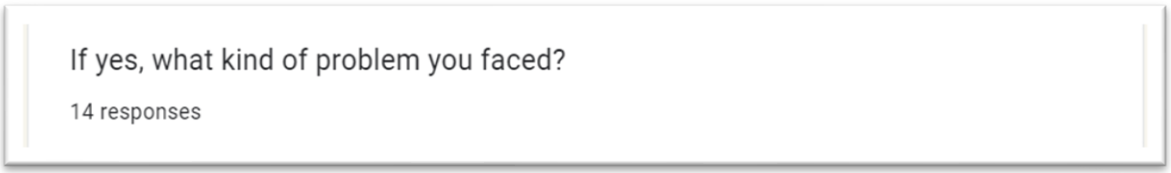


Figure 4.1: Respondent Problem on using backpack grass cutter

Table 4.6: Question No.4 Data

Respondent Problem
Sometimes, I faced my health weakness to bury the backpack grass trimmer and my back was in pain.
Lack of energy use and hurt pain sometimes
Facing myself hard to handle the vibration on my back
The backpack grass cutter was heavy and not comfortable sometime.
Sometimes it takes risk of health
The grass cutter on the backpack was very cumbersome and difficult to handle.
I have no experience to handle it.
Easy to handle but kindly hard sometime.
Difficult to handle and waste of energy.
Waste of human energy.
Not practical for users of advanced age.
Sometimes the vibration of the engine backpack grass cutter annoyed me, especially on my back.
My hand and my back get in pain with the vibration.
The vibration on the handle hurts my hand surface.

For question No 7 as shown in **Figure 4.2**, the respondent has been asked about requirement needed for PHGC. Majority of the respondent suggest that weight (31 responses), durability (31 responses), portability (28 responses) with 100% and safety features (30 responses) with 96.8% of the respondent choose it. The simplified data is as shown in **Table 4.7.**

Table 4.7: Question No.7 Data

Requirement	**Response**	**Percentage %**
Weight	**31**	**100**
Durability	**31**	**100**
Operating method	**28**	**90.3**
Portability	**31**	**100**
Material properties	**5**	**16.1**
Cutting efficiency	**16**	**51.6**
Safety features	**30**	**96.8**
Ad's requirement	**Response**	**Percentage %**
Reduce noise and vibration	**2**	**6.4**

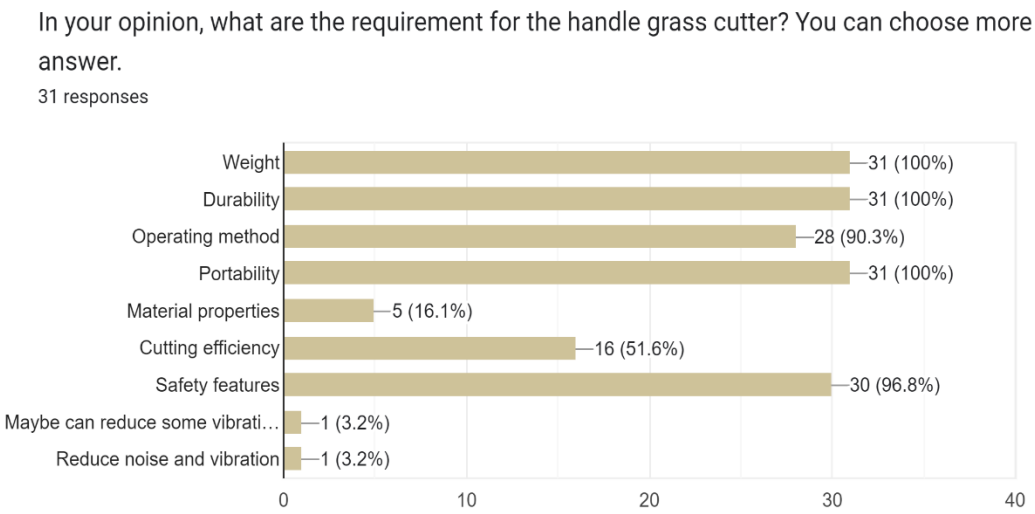


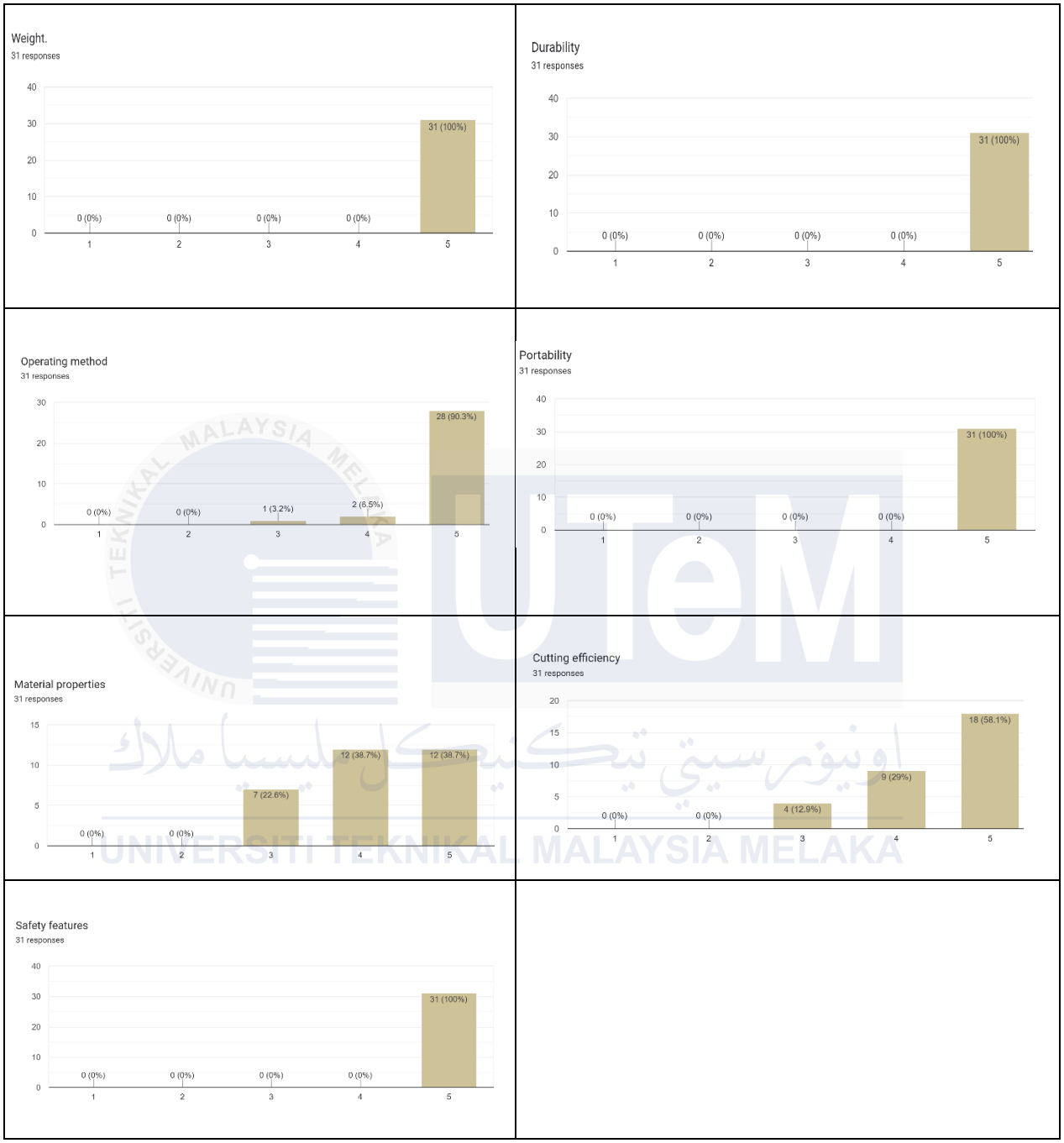
Figure 4.2: PHGC Requirement

In question No. 8, respondents were asked to rate the importance of each requirement on a scale of 1 to 5, with 5 being the most important and 1 being the least important. **Tables 4.8** and **4.9** show the simplified data and survey answer list, respectively. The highest rating for the requirement will be used to determine the rating result. Weight requirement has a rating of 5 from 100% of respondents, while material properties receive the same grade from 31%.

Table 4.8: Question No.8 Data

Rating/requirement	1(%)	2(%)	3(%)	4(%)	5(%)
Weight	0	0	0	0	100
Durability	0	0	0	0	100
Operating method	0	0	3.2	6.5	90.3
Portability	0	0	0	0	100
Material properties	0	0	22.6	38.7	38.7
Cutting efficiency	0	0	12.9	29	58.1
Safety features	0	0	0	0	100

Table 4.9: List of Survey Answer



In **Figure 4.3**, Question No. 9 asks respondents about their expected design characteristics for the product. With 31 respondents (100%), most respondents chose user-friendliness and portability as the design characteristics they are looking for. This means that both are extremely crucial to the product. **Table 4.10** shows the simplified data.

Table 4.10: Question No.9 Data

Characteristics	Responses	Percentage (%)
Material usage	14	45.2
Concept design	20	64.5
Adjustable part	29	93.5
User friendly	31	100
Light and portable	31	100

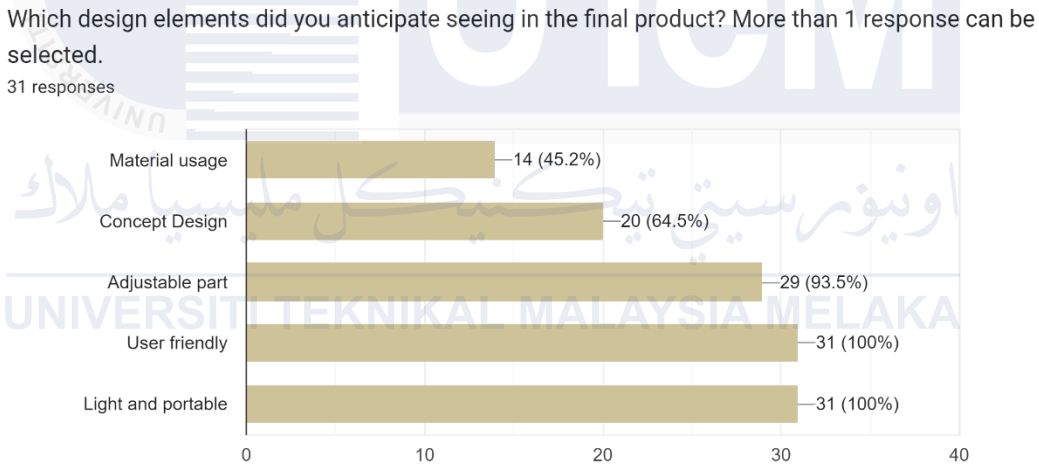


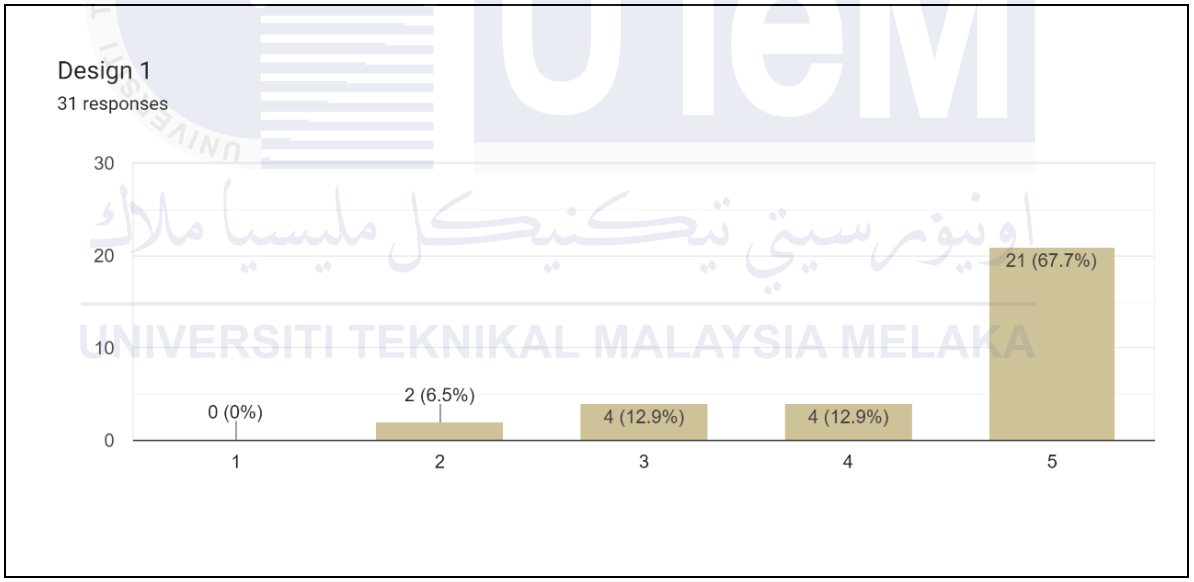
Figure 4.3: Predicted feature of design

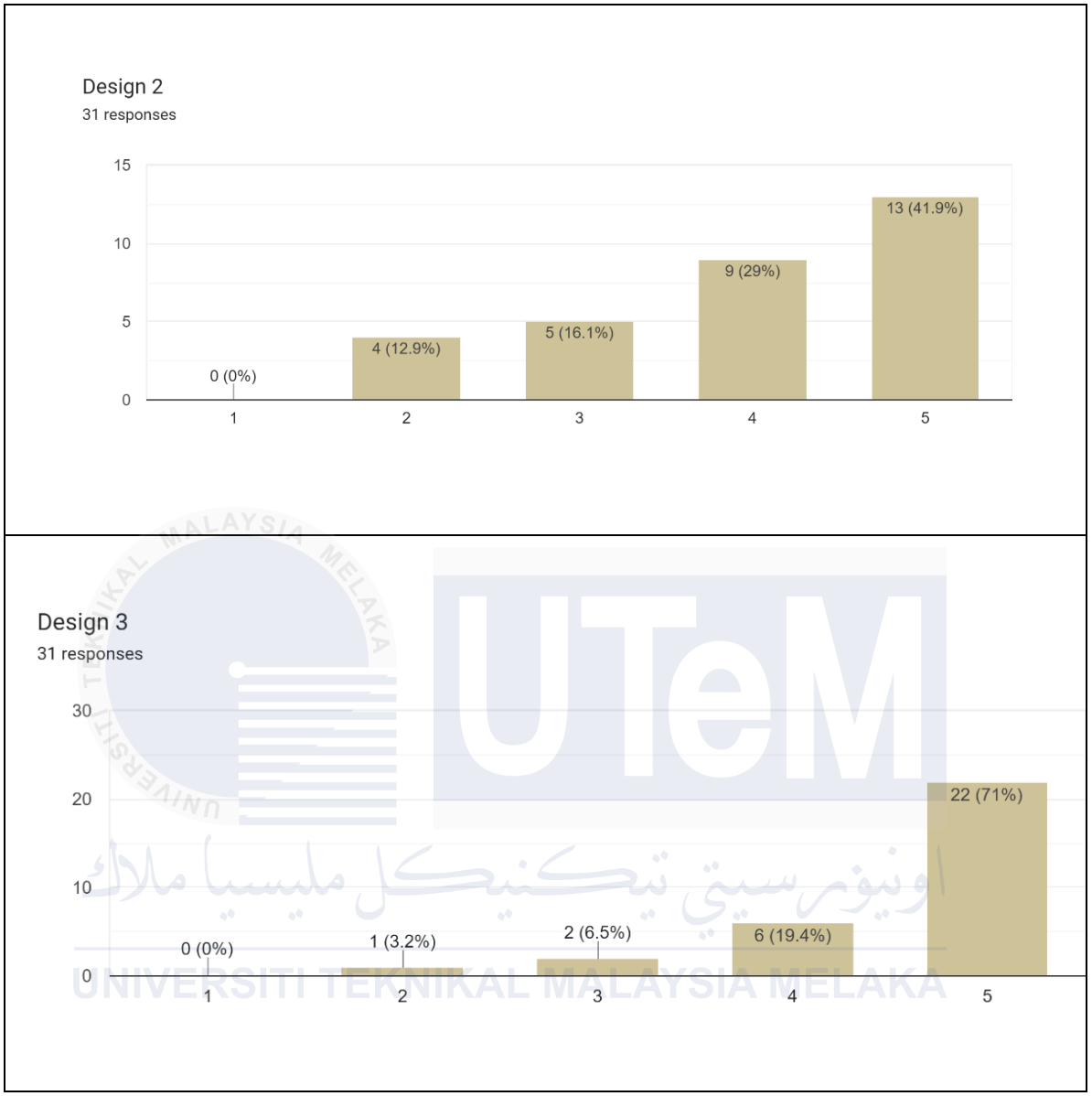
In question 10, respondents were asked to choose the best design from three options. The design will be chosen using all the criteria specified in the survey. In this question, the highest vote for rating 5 of the design will be used to determine the rating outcome. **Tables 4.11** and **4.12** reveal that design No.3 received a 71% vote and will move on to model development.

Table 4.11: Question No.10 Data

Rating/Design	1(%)	2(%)	3(%)	4(%)	5(%)
Design 1	0	6.5	12.9	12.9	67.7
Design 2	0	12.9	16.1	29	41.9
Design 3	0	3.2	6.5	19.4	71

Table 4.12: List of Survey Answer





4.3 Pugh's Method Evaluation

The Pugh's matrix evaluation is then evaluated by rating which (0) is the baseline and "+1" is the concept that slightly better than baseline. Then for "+2" the concept is significantly better than the baseline and "-1" is the slightly worse than baseline and "-2" also for significantly worse than the baseline.

The data collected from respondents is evaluated using Pugh's approach. **Table 4.8** provides ratings for weight/importance, durability, operating method, portability, material

properties, cutting efficiency, and safety features. The overall improvement required is evaluated based on decreasing, maximizing, or reaching the aim. As demonstrated in the **table 4.13** Pugh approach below.

Table 4.13: Requirement Evaluation for Grass Cutter Handle

Criteria	Weight	Design 1	Design 2	Design 3
Description	(1-5)			
Weight	5	+2	-1	+1
Durability	5	-1	+1	+1
Operating method	4	+1	-1	-2
Portability	5	-1	+1	-1
Material properties	4	+2	-1	+2
Cutting efficiency	3	-1	+1	+1
Safety features	5	+2	-1	-1
Σ(+)		+7	+3	+5
Σ(-)		-3	-4	-4
TOTAL	31	19	-5	3

After that, the data gathered from respondents is analysed using Pugh's technique. **Table 4.10** shows ratings for material usage, concept design, adjustable part, user friendliness, and safety features. The overall improvement required is evaluated in terms of diminishing, maximizing, or achieving the goal as shown in **table 4.14** the Pugh technique below.

Table 4.14: Design Element Requirement Evaluation

Criteria	Weight	Design 1	Design 2	Design 3
Description	(1-5)			
Material usage	3	+2	-1	+1
Concept design	4	-1	+1	+1
Adjustable part	5	+1	-1	-2
User friendly	5	-1	+1	-1
Safety features	5	+2	-1	+2
Σ(+)		+5	+2	+4
Σ(-)		-2	-3	-3
TOTAL	19	12	-4	2

According to the Pugh's matrix evaluation method, "Design 1" has the highest overall score with the complete demand of a handle grass cutter and the design element is (+19) and (+12). It excels in movable parts and safety measures, making it an appealing option despite a minor rise in other criteria.

4.4 Gantt Chart of Thesis Workflow

The goals of the project, a review of the literature, and the development of a project plan are the first steps shown in the Gantt chart that listed in **Appendices** section for the thesis report on creating a portable handle lawn cutter, which is started in weeks 1-4. User needs are determined by surveys in weeks 5-8, and specifications are finalized through data analysis. Weeks nine through twelve are devoted to developing and accessing preliminary design concepts, from which the best idea is chosen. Following the inspection in the subsequent PSM 2 flow, detailed design drawings has been produced in weeks 13 and 14. Simulations and feasibility analyses will then be conducted to make any required design modifications.

4.5 Fabrication Process

The fabrication of a portable handheld grass cutter is the translation of a conceptual design into a working device through reasoned planning, selection of materials, and precise engineering. It constitutes several steps in designing the framework of the cutter, selection of light but strong materials, assembling components such as the blade, motor, and handle, and testing of all functionalities. The aim is to create a compact, efficient, and user-friendly device that eases grass cutting activities, mainly for places where larger equipment cannot be used. The manufacturing process ensures that the grass cutter meets modern user requirements while maintaining standards of safety and durability by focusing on portability and ease of operation.

The outcome of the fabrication process will be highlighted in this section. The product is composed of several parts with different materials utilized in their construction. For better understanding, the part is shown below in **Table 4.15**.

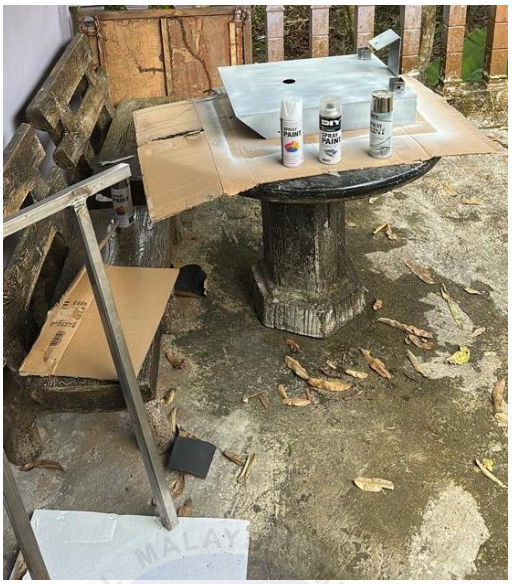
Table 4.15: PHGC Fabrication Process

Part	Process
 Plate fender (60 x 10 cm)	The part of fender household of body casing material that has been used is plain mild steel and cut into edge of 45° degree of angle.
 Custom rod (diameter 26 mm)	Custom the part of engine which is material rod is aluminum with the preferred length measured.

 Custom shaft rod (weld)	The material of shaft is steel and has been custom for proper length for the engine.
 The mount base for handle	The mount base of handle was measured in squared angle of size (1-1/4 x 1.6 mm) and has been weld properly
 Brush the mount of handle	The part of mount handle that has been weld is brush for a good surface of condition.

 Handlebar of grass cutter (1-1/4 x 1.6 mm)	The material that has been used is squared hollow mild steel with length of 3m and has been cut with machine cutter with proper measured length.
 Driller Machine	In this part, the mount of handle base was drilled with driller machine with a 38 mm diameter of hole for the knob.

 Metal Inert Gas (MIG) Welding	This the welding machine part that has been used for tapping the part of material on mount of handle to case body of engine grass cutter.
 Brush grinder for metal	The part that has been weld is brushed with the grinder for better surface of finishing.
 Part of handle and housing engine assembly	The handle was assembled with the housing engine and mount on the top of the housing engine.

 Repaint the part	Last part is the finishing process which is painting the handle bar and housing of the engine.

4.6 CATIA CAD Model

The CAD model was made during the development stage using the CATIA V5R21 CAD program. The motorbike wheel's measurements and the materials that would be utilized for design testing in the next phases were consulted when creating the CAD model. All of the model's dimensions are in millimeters (mm).

This assembly component of the handle was made with a specific purpose in mind. The parts affix to the engine grass cutter's shell body and are somewhat substantial, although they are nonetheless lightweight and portable. This assembly design may be folded into the shell body and is also made to be portable. The handle's assembly drawing portion is seen in **Figure 4.4** below.

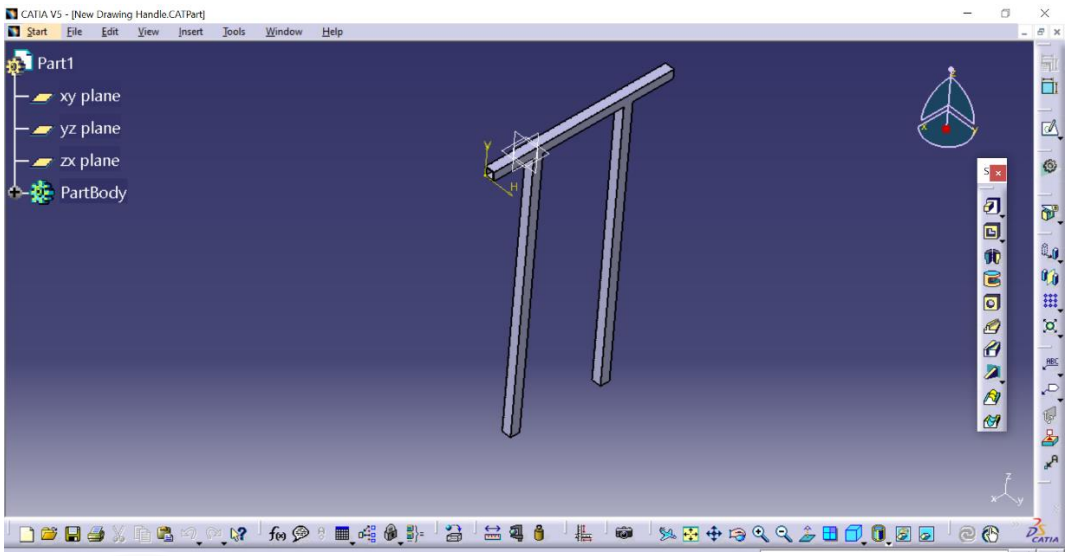
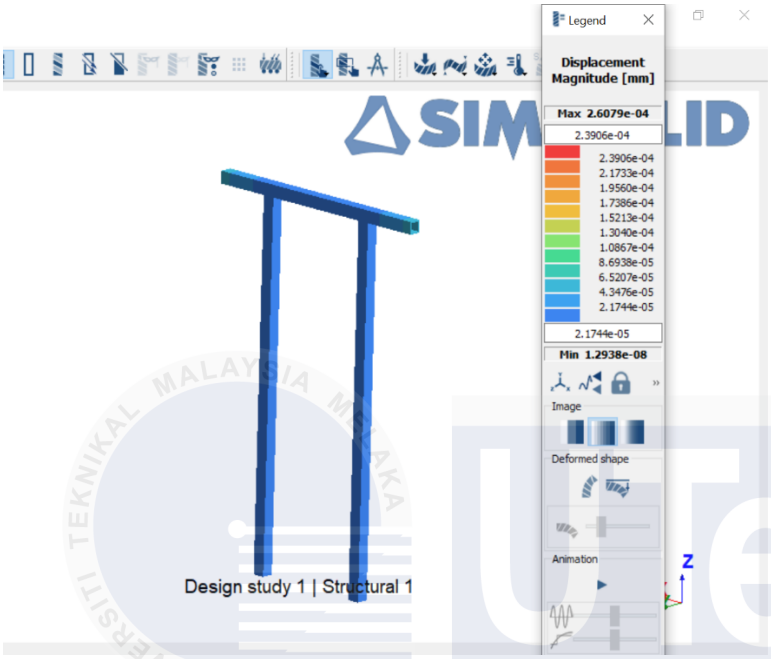
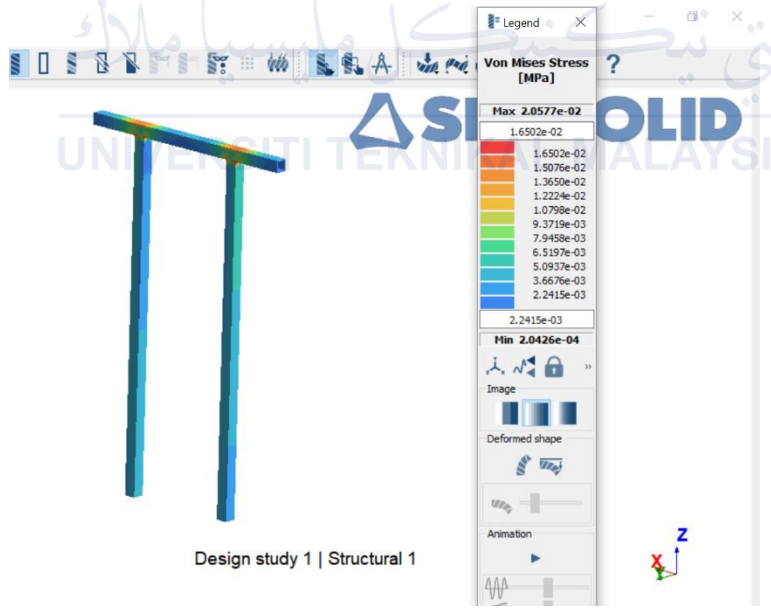


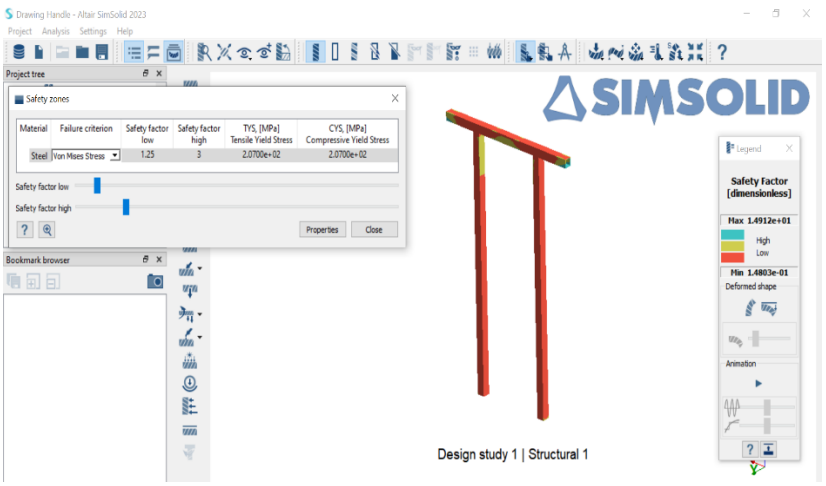
Figure 4.4: Drawing part of handle

4.7 Finite Element Analysis (FEA)

In the current project, FEA on a CAD model was performed using a simulation in the SimSolid software. The goal of this process was to monitor reaction and condition of the prototype when it was subjected to the pressure applied during a person holding the handle. The result of the simulation is given in **Table 4.16**. The model handle is being subjected to a force of 29.43 N. The FEA were ran with a person holding and gripping the handle. The run is based on the force applied to the Z-axis. This is due to the pressure applied by a person holding the grass cutter's handle.

Table 4.16: Finite Element Analysis

Force applied	Analysis Type
	This analysis focuses on the displacement magnitude (mm) using a force of 29.43N at the Z-axis. The highest displacement was 2.6079e-04.
	This research focuses on the Von Mises Stress (MPA) using a force of 29.43N at the Z-axis. The maximal Von Misses Stress is 2.0577 e-02.

	This study focuses on the Safety Factor (dimensionless) and applies a force of 29.43N at the Z-axis. The highest safety factor is 1.4912e+01 and the minimum is 1.4803e-01.

All support, force, and other conditions must be applied to the model before running the analysis. In the first trial, some errors made the software fail to run. After the guidance of the lecturer, the model is finally successful in running.

4.8 Summary

The purpose of this chapter is to provide a concise summary of the results that were obtained from the approach that was utilized. To continue with this thesis, the results of the online poll that was carried out using Google Form among the community to select the most suitable design with the evaluation of Pugh's approach are shown. After that, the procedure continues with the CAD model that has create using the software programs SolidWorks and CATIA. All the dimensions that are being referred to in this process are the actual dimensions of the actual backpack grass cutter. Immediately following that, the results of the finite element analysis (FEA) also defined in this chapter where it concludes three type of analysis which is displacement magnitude, von misses stress and the safety factor. During this process, the reaction on the model will be display, and it will be determined in which materials and components require improvement. The Handheld Grass Cutter Design is built in the fabrication process by adhering

to the Handheld Grass Cutter model that will developed in the software design. Several aspects of the product, including its shortcomings and potential for enhancement, were discussed in this chapter, including the operating mechanism and other aspects of the product.

CHAPTER 5

CONCLUSION

5.1 Project Highlight

This thesis explains the general issue that employees, including gardeners, encountered in the first chapter. The user reported feeling as like they are running out of energy when cutting the lawn. The thesis then goes on to discuss its goal, which is to offer the utmost ease when using the lawn cutter equipment. In this chapter, the goal, parameters, and summary of the research are also given.

The literature review is where the thesis begins in the second chapter. It explains the background of the lawnmower that is currently available for purchase. T-shaped and U-shaped portable lawn cutters are the two types of models that fall under this category. The material that was suggested to be used for the prototype and the strength of the material qualities for the portable lawn cutter are then explained in this chapter. This chapter also explains how to design a portable grass cutter using Pugh's technique, which is the best way to determine design in the product development process while considering all the requirements needed for customers.

5.2 Conclusion

To accomplish the initial goal of the research, the Pugh's technique was employed to assess all the necessary specifications for a handheld grass cutter design. This was achieved by collecting information from the community through online surveys conducted via Google Forms. Two designs have been introduced in this process, each possessing its own distinct merits. Following the completion of Pugh's approach evaluation procedure, design number 2 has been chosen to be developed using the CATIA V5R18 software.

Regarding the second objective, once a CAD model was created, a strength analysis of the model was conducted using the CATIA software. The generative structural analysis, namely the static analysis, was conducted to obtain objective results such as the von Mises stress, displacement, and deformation. These results is shown at the chapter 4.

In relation to the third aim, the fabrication process was underway to produce the handheld lawn cutter design. The production process was thoroughly discussed in chapter 3. The product has been tested to determine its efficiency. Consequently, the product was functioning optimally. However, there is still room for further refinement and enhancement of the product to enhance its quality.

5.3 Recommendations

In the design of a portable handheld grass cutter machine, Pugh's method will compare alternatives to certain criteria such as portability, ergonomic design, safety, power source, efficiency, durability, environmental impact, cost, and ease of maintenance. One might select a baseline design, against which a decision matrix with the remaining ideas (including battery-operated, gasoline-powered, manual, and hybrid versions) were compared to identify the best choice. The best possible balance between advantages and disadvantages from each of these alternatives would then be chosen to work around its negative areas. This structured process ensures the final design is efficient, user-friendly, and environmentally sustainable, meeting the target requirements effectively.

After this analysis, the outcome will clearly give the way to refine the selected design. The strengths and weaknesses will then be evident, therefore guiding the optimization process in the sense that any weaknesses will be worked on while the advantages are capitalized on. At the end, this approach leads to informed decision-making and a user-friendly, efficient, and environmentally responsive grass cutter design that meets the set objectives.

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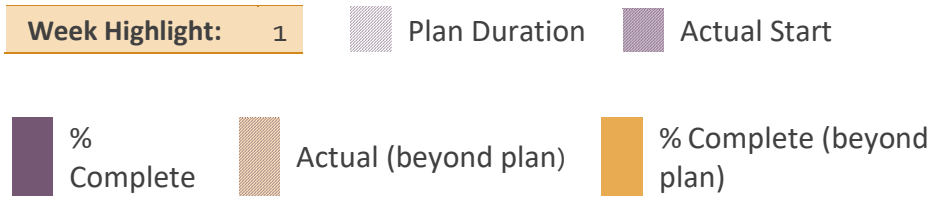
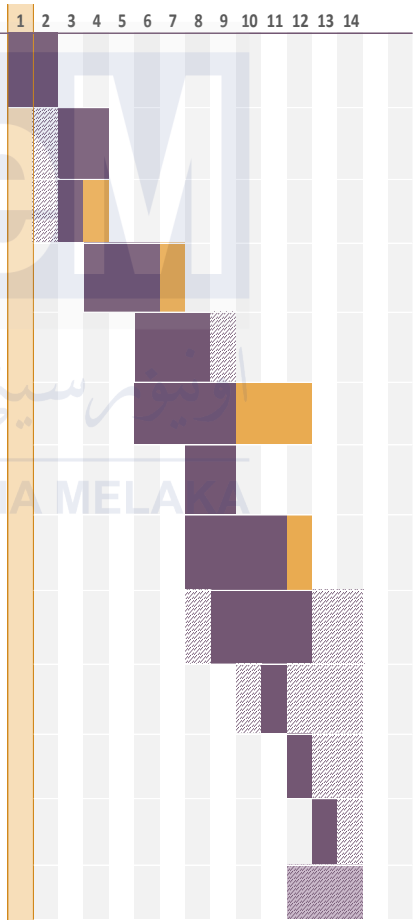
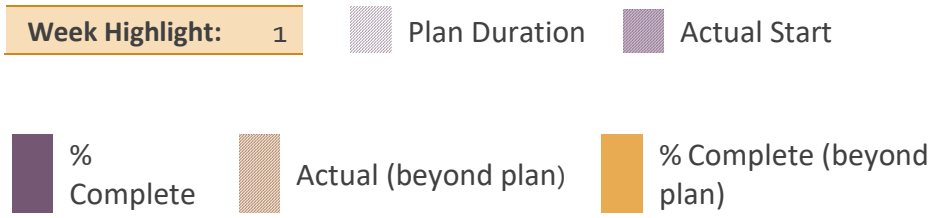
APPENDICES



APPENDIX A: Gantt Chart Workflow for PSM 1

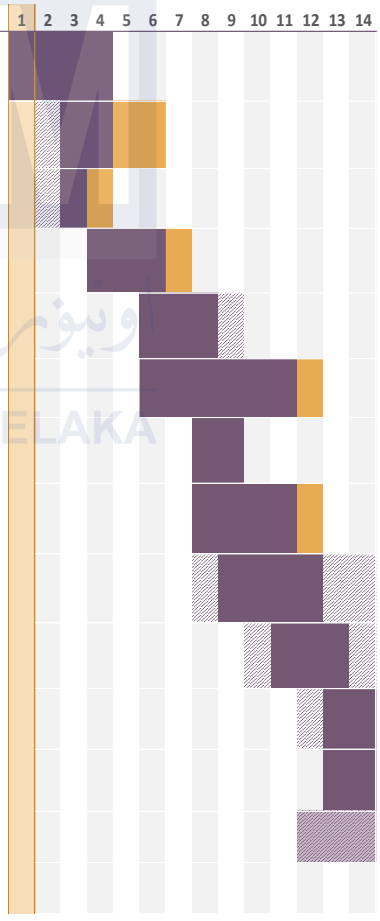
ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
SUPERVISOR SELECTION AND REGISTERED TITLE	1	2	1	2	100%
BRIEF AND PROJECT EXPLANATION BY SUPERVISOR	2	3	3	2	100%
MODULE 1 : RESEARCH DESIGN AND PLANNING	2	2	3	2	100%
DISCUSS PROBLEM STATEMENT AND OBJECTIVE FOR CHAPTER 1	4	3	4	4	100%
MODULE 2 : FINAL YEAR PROJECT LITERATURE REVIEW	6	4	6	3	100%
DRAFTING LITERATURE REVIEW AND WRITING UP CHAPTER 2	6	4	6	7	100%
DRAFTING SUBMISSION OF CHAPTER 2	8	2	8	2	100%
MODULE 3 : RESEARCH METHODOLOGY	8	4	8	5	100%
RESEARCH METHODOLOGY AND WRITING UP CHAPTER 3	8	8	9	4	100%
WRITING UP PRELIMINARY RESULT	10	10	11	1	100%
SUBMISSION OF FIRST DRAFT PSM 1	12	12	12	1	100%
SUBMISSION OF SECOND DRAFT PSM 1	13	13	13	1	70%
PREPARATION FOR PRESENTATION PSM 1	12	3	12	3	0%



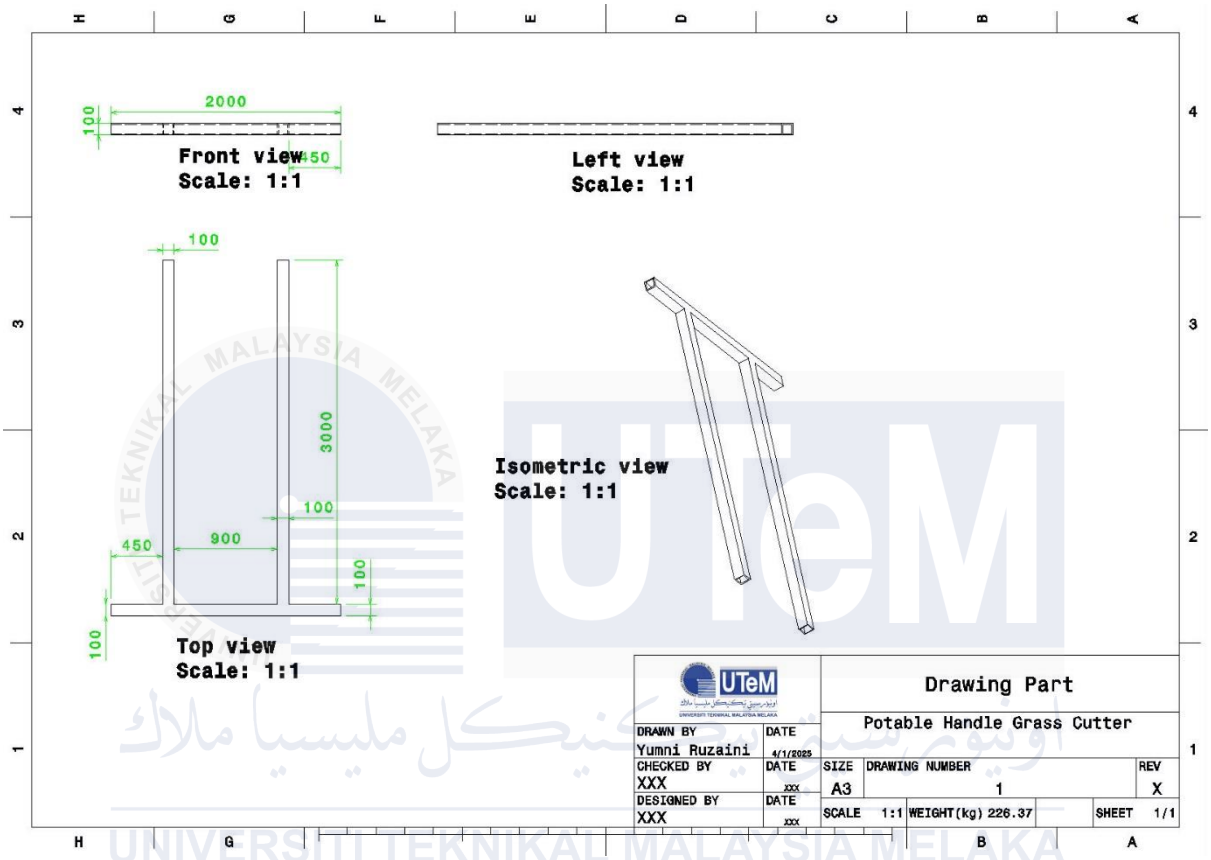


APPENDIX B: Gantt Chart Workflow for PSM 2

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
DESIGN THE PORTABLE HANDHELD GRASS CUTTER	1	4	1	4	100%
SELECTION OF MATERIAL THAT USED	2	3	3	4	100%
PROTOTYPE DEVELOPMENT	2	2	3	2	100%
ASSEMBLY OF PROTOTYPE	4	3	4	4	100%
DISCUSSION FOR FABRICATION PROCESS	6	4	6	3	100%
FABRICATION PROCESS (WELDING,GRINDING,DRILLING)	6	6	6	7	100%
DRAFTING REPORT CHAPTER 4	8	2	8	2	100%
MODULE 3 : RESEARCH METHODOLOGY	8	4	8	5	100%
TESTING PROTOTYPE FOR FINAL RESULT	8	8	9	4	100%
THESIS FINALIZE CHAPTER 4	10	10	11	3	100%
THESIS FINALIZE CHAPTER 5	12	13	13	2	70%
FINALIZE THESIS FOR SV CHECKING	13	13	13	3	0%
PREPARATION FOR PRESENTATION PSM 2	12	3	12	3	



APPENDIX C: Drawing of Handle



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