DESIGN AND CONSTRUCTION OF A PORTABLE ELV BATTERY REMOVAL TOOL

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BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE) WITH HONOURS

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DEDICATION

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ABSTRACT

The automotive industry has seen significant growth in recent years, leading to a higher number of vehicles on the road. However, as these vehicles reach the end of their life cycle, proper disposal of their components becomes crucial. Among these components, end-of-vehicle-life (ELV) batteries pose a challenge due to their hazardous materials like lead-acid electrolytes and heavy metals. Disassembling ELV batteries is essential to minimize environmental pollution and ensure safe handling of hazardous materials. However, the process faces challenges in terms of safety, efficiency, and compatibility with various battery types. To address these challenges, a project aims to develop a portable tool specifically designed for removing ELV batteries. This tool will be user-friendly, adhere to safety regulations, and work effectively with different battery types. The goal of the project is to create an innovative and efficient tool for ELV battery removal, contributing to sustainable practices in the automotive industry. By optimizing disassembly processes, the project aims to reduce environmental impact and enhance resource utilization. One obstacle to improving ELV management is the lack of specialized tools for efficient disassembly. While vehicle assembly has advanced with specialized tools, disassembly remains relatively simple, lacking tools to expedite the process. Developing a dedicated tool for vehicle disassembly can help reduce pollution caused by defunct vehicles. ELV batteries contain hazardous materials that can cause environmental pollution and safety hazards if mishandled. Current removal methods are labor-intensive and often inefficient, contributing to delays and increased costs. The lack of a dedicated, adaptable tool further complicates the process, increasing the risk of accidents and hindering efforts to streamline operations. Addressing these challenges requires innovation in battery removal and disposal methods. Developing specialized tools that can adapt to various battery designs and sizes will significantly improve the efficiency and safety of the removal process, contributing to a greener and more sustainable future. The primary objective of the project is to design and construct a portable tool for efficient ELV battery removal. This involves identifying design criteria, suggesting designs based on these criteria, and analyzing and fabricating the tools. The scope includes analyzing current challenges in the depollution process, identifying requirements for a portable and user-friendly tool, researching suitable materials, creating design prototypes, building a working prototype, and performing rigorous testing. Efficient ELV management is crucial for minimizing environmental impact, preserving resources, and promoting a circular economy in the automotive industry. Developing a portable battery removal tool for ELVs is a significant step in this direction, focusing on handling batteries in conventional internal combustion engine automobiles. By ensuring proper waste disposal and enhancing resource utilization, efficient ELV management supports environmental protection goals and fosters sustainable practices in the automotive industry.

ABSTRAK

Industri automotif telah mengalami pertumbuhan yang signifikan dalam beberapa tahun ini, menyebabkan peningkatan jumlah kenderaan di jalan raya. Namun, apabila kenderaan-kenderaan ini mencapai akhir hayat kitaran mereka, pembuangan yang sewajarnya terhadap komponen-komponen mereka adalah penting. Antara komponen-komponen ini, bateri akhir hayat kenderaan (ELV) merupakan cabaran kerana bahan-bahan berbahaya seperti elektrolit asid plumbum dan logam berat. Memecahkan bateri ELV adalah penting untuk mengurangkan pencemaran alam sekitar dan memastikan pengendalian yang selamat terhadap bahan-bahan berbahaya. Walau bagaimanapun, proses ini menghadapi cabaran dari segi keselamatan, kecekapan, dan keserasian dengan pelbagai jenis bateri. Bagi menangani cabaran ini, sebuah projek bertujuan untuk membangunkan alat mudah alih yang direka khas untuk membuang bateri ELV. Alat ini akan mesra pengguna, mematuhi peraturan keselamatan, dan berfungsi dengan berkesan dengan pelbagai jenis bateri. Matlamat projek ini adalah untuk mencipta alat yang inovatif dan cekap untuk penyingkiran bateri ELV, menyumbang kepada amalan yang berkesan dalam industri automotif. Dengan mengoptimumkan proses pembongkaran, projek ini bertujuan untuk mengurangkan impak alam sekitar dan meningkatkan penggunaan sumber. Salah satu halangan dalam meningkatkan pengurusan ELV adalah kekurangan alat khas untuk pembongkaran yang cekap. Manakala penyusunan kenderaan telah berkembang dengan alat-alat khas, pembongkaran masih relatif mudah, tiada alat untuk mempercepatkan proses. Membinakan alat khusus untuk pembongkaran kenderaan dapat membantu mengurangkan pencemaran yang disebabkan oleh kenderaan yang tidak berfungsi. Bateri ELV mengandungi bahan-bahan berbahaya yang boleh menyebabkan pencemaran alam sekitar dan bahaya keselamatan jika diendahkan. Kaedah penyingkiran semasa ini memerlukan tenaga buruh yang intensif dan seringkali tidak cekap, menyumbang kepada kelewatan dan peningkatan kos. Kekurangan alat yang khusus dan boleh disesuaikan semakin memperumit proses ini, meningkatkan risiko kemalangan dan menghalang usaha untuk mengoptimumkan operasi. Menangani cabaran ini memerlukan inovasi dalam penyingkiran bateri dan kaedah pembuangan. Membinakan alat khusus yang boleh menyesuaikan dengan pelbagai reka bentuk dan saiz bateri akan meningkatkan kecekapan dan keselamatan proses penyingkiran, menyumbang kepada masa depan yang lebih hijau dan mampan. Objektif utama projek adalah untuk mereka bentuk dan membina alat mudah alih untuk penyingkiran bateri ELV yang cekap. Ini melibatkan mengenal pasti kriteria reka bentuk, mencadangkan reka bentuk berdasarkan kriteria ini, dan menganalisis serta membina alat-alat tersebut. Skopnya termasuk menganalisis cabaran semasa dalam proses pembersihan, mengenal pasti keperluan untuk alat yang mudah alih dan mesra pengguna, meneliti bahan-bahan yang sesuai, mencipta prototaip reka bentuk, membina prototaip berfungsi, dan melakukan ujian yang ketat. Pengurusan ELV yang cekap adalah penting untuk mengurangkan impak alam sekitar, mengekalkan sumber, dan mempromosikan ekonomi berpusat. Membinakan alat penyingkiran bateri mudah alih untuk ELV adalah langkah penting dalam arah ini, memberi tumpuan kepada penanganan bateri dalam enjin dalaman pembakaran dalam kenderaan. Dengan memastikan pembuangan sisa yang betul dan meningkatkan penggunaan sumber, pengurusan ELV yang cekap menyokong matlamat perlindungan alam sekitar dan mendorong amalan yang efektif dalam industri automotif.

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LIST OF SYMBOLS AND ABBREVIATIONS

ELV	-	End-Of-Life Vehicle
ICE	-	Internal Combustion Engine
CAD	-	Computer Aided Design
CFCs	-	Chlorofluorocarbons
UV	-	Ultraviolet
ATFs	-	Authorized Treatment Facilities
EVs	-	Electric Vehicles
WSM	-	Weighted Sum Method
FEA	-	Finite Element Analysis
CFD	-	Computational Fluid Dynamics

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CHAPTER 1

INTRODUCTION

1.1 Background

Over the past few years, the automotive sector has experienced substantial expansion, resulting in a higher need for vehicles. When these vehicles approach the end of their useful life, it is extremely important to properly dispose of their components. Out of all these parts, end-of-vehicle-life (ELV) batteries provide distinct difficulties because of their dangerous substances and negative effects on the environment. ELV batteries, commonly found in internal combustion engine (ICE) vehicles, contain toxic substances such as lead-acid electrolytes and heavy metals. Efficient disassembly of these batteries is essential to minimize environmental pollution caused by metal ion leakage and to ensure the safe handling of hazardous materials. Proper disassembly also promotes green practices, reduces resource wastage, and contributes to sustainable waste management.

However, the process of dismantling ELV batteries encounters many challenges. Ensuring safety is of utmost importance when dealing with hazardous materials, as it needs the use of specific tools and procedures. Efficiency is essential because a rapid and efficient disassembly process reduces both expenses and environmental harm. Furthermore, the issue of compatibility is of great importance as ELV batteries come in different sizes, shapes, and designs, requiring versatile removal equipment. In order to tackle these difficulties, the objective of this project is to create and build a portable tool specifically designed for removing ELV batteries. Important factors to consider when designing the instrument are its ease of use, adherence to safety regulations, effectiveness, and ability to work with different types of batteries.

In summary, this project seeks to create an innovative, user-friendly, and efficient tool for ELV battery removal, contributing to sustainable practices in the automobile industry. By optimizing disassembly processes, the project aims to reduce environmental impact and enhance resource utilization, ultimately supporting broader environmental protection goals.(Zhan et al., 2023).

1.2 Project Motivation

One of the things slowing down the development of the process to appropriately manage the end-of-life vehicle (ELV) is the lack of tools. The process of constructing a car has already advanced to the point where some specialized tools have been created and manufactured to help with the process. However, the process of disassembling a car is still somewhat simple, and there aren't many specialized tools available to help speed up the process. Developing a tool to aid in the disassembly process of a car can be a first step toward elevating the process and ultimately lowering the pollution that the defunct vehicle causes.

1.3 Problem Statement

The increasing number of vehicles reaching the end of their operational life presents a significant environmental challenge, particularly with the disposal of end-of-life vehicle (ELV) batteries. These batteries, essential for vehicle operation, often contain hazardous materials such as lead acid electrolytes and heavy metals such as cadmium, nickel and lithium. Improper handling and disposal of these materials can cause severe environmental pollution, including soil and water pollution, and pose a significant safety hazard to workers and the public.

Current methods of battery removal from ELVs are fraught with inefficiencies. This process is usually labor intensive, requiring significant manual effort to remove the battery from the vehicle as shown in Figure 1.1 below. This manual extraction is often time-consuming, contributing to delays and increasing the overall cost of battery disposal. Additionally, the wide variety of battery designs and sizes across different vehicle makes and models adds complexity to the removal process. Standard tools and procedures often prove inadequate, unable to adapt to various ELV battery configurations.

Figure 1.1 Removing the Battery from The Vehicle
(Source: Wikepedia)

The lack of a dedicated tool that can be adapted for battery removal exacerbates this issue. Without tools specifically designed to address the unique challenges posed by different battery types and configurations, the process remains complex and error-prone. This not only increases the risk of accidents and injuries during removal but also hinders efforts to streamline operations and reduce costs. As a result, inefficiencies in the current disposal process hinder the adoption of green practices and sustainable waste management strategies.

Addressing this challenge requires innovation in battery removal and disposal methods. Developing specialized tools that can adapt to various battery designs and sizes will significantly increase the efficiency and safety of the removal process. By improving the battery disposal process, it is possible to address the environmental challenges posed by the increasing number of ELV batteries, thus contributing to a greener and more sustainable future.

1.4 Research Objective

The primary objective of this project is to design and construct a portable tool specifically for the efficient removal of end-of-vehicle-life (ELV) batteries, thereby enhancing depollution processes. The objective of this research are :

1) To identify design criteria for ELV batteries removal tools.
2) To suggest designs for ELV batteries removal tools based on criteria identified.
3) To analyze suggested design and fabricate ELV batteries removal tools.

1.5 Scope of Research

The scope of this research are as follows:

- Analyze current challenges and limitations in the depollution process of ELV batteries.
- Identify the requirements for a portable and user-friendly battery removal tool.
- Research suitable materials that ensure durability, safety, and lightweight characteristics for the tool.
- Create design prototypes using CAD software and other modeling tools.
- Build a working prototype based on the finalized design specifications.
- Perform rigorous testing of the prototype to evaluate its safety, efficiency, and compatibility with different battery types.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The study of end-of-life vehicles (ELVs) is crucial due to their significant environmental, economic, and societal impacts. Efficient management approaches are crucial in minimizing the environmental impact, preserving resources, and promoting a circular economy in the automobile industry when vehicles reach the end of their operating lives (Karagoz et al., 2020). Examining the evaluation of End-of-Life Vehicles (ELVs) depicted in Figure 2.1 enhances comprehension of the disassembly, depollution, and recycling methods for ELVs, resulting in decreased pollution levels. Additionally, this understanding encourages economic growth and encourages social accountability. Within this context, the development and fabrication of a portable battery removal tool for end-of-life vehicles (ELVs) emerges as a significant area of study, focusing on the specific procedures involved in handling batteries in conventional internal combustion engine automobiles.

Figure 2.1 The review of ELVs
(Source: Trinomics, 2019)

2.1.1 Definition End of Life Vehicle

An End of Life Vehicle (ELV) refers to a motor vehicle that has reached the end of its operational lifespan due to causes such as age, wear and tear, damage, or technological obsolescence. According to (Sulaiman et al., 2023), ELVs are often no longer considered suitable for use on the road or economically feasible to repair. Instead, they undergo a procedure called end-of-life vehicle management, which entails disassembling and recycling different components and materials to extract valuable resources and reduce environmental harm (Modoi & Mihai, 2022). The objective of ELV management techniques is to guarantee the secure disposal of dangerous compounds, encourage the sustainable utilization of resources, and adhere to applicable legislation for the management of automotive waste (Gerrard & Kandlikar, 2007; Karagoz et al., 2020).

2.1.2 Objective of End of Life Vehicle

The implementation of ELV management serves several goals, all of which aim to create a better future for civilization and the environment. The fundamental purpose of ELV management is to provide proper waste disposal of hazardous compounds found in vehicles (Wang et al., 2024). Refrigerants utilized in automobile air conditioning systems, such as chlorofluorocarbons (CFCs), have the potential to harm the ozone layer. The depletion of the ozone layer results in elevated amounts of ultraviolet (UV) radiation, which has a substantial influence on both human health and plant life. Inadequate management of materials such as plastic, rubber, and glass when disposed of in landfills can result in the release of hazardous compounds into the environment.

Another primary goal of ELV management is to enhance the recycling of automotive components. Although ELVs are commonly regarded as waste materials, several components and materials can still be effectively saved and recycled. Valuable components, such as engines and transmissions, can be removed and sold for the purpose of repairing or replacing them. Moreover, the materials employed in the fabrication of vehicles, such as metals, which account for more than 50% of a vehicle's mass, can be subjected to recycling processes. Recycled metals can be reused for a multitude of things, such as cookware and decoration.

ELV management also aims to assist authorities in reviewing policies and enforcing laws. These policies and regulations are designed to establish a proper system for recycling vehicle components to prevent greenhouse gas emissions and pollution. Their objective is to oversee the standard of recycling companies participating in ELV management (Raja Mamat et al., 2018). Nevertheless, in Malaysia, there is a relatively low level of interest among corporations in ELV management. Policymakers should actively seek input from industry stakeholders in order to develop the most efficient policies.

2.2 Process of End of Life Vehicle

End-of-life vehicle (ELV) management is a complex and sequential procedure aimed at disassembling, depolluting, and recycling the various parts and components of a vehicle in a responsible manner. The end-of-life vehicle (ELV) process involves several processes that try to recycle and responsibly dispose of cars that have reached the end of their useful lives. Vehicles are initially obtained from owners through various channels, such as government collection programs, authorized treatment facilities (ATFs), and scrapyards(Tian & Chen, 2014).

Once collected, the End-of-Life Vehicles (ELVs) undergo a depollution process, which entails the careful extraction of dangerous substances such as batteries, coolant, and oil, as well as other components, to prevent environmental contamination. After the process of depollution, the cars are dismantled and any salvageable components are extracted for reuse or sale.

After that, the leftover hulks are cut into smaller pieces and separated into materials such as plastics, glass, and ferrous and non-ferrous metals. Following that, these materials are recycled and used again in a variety of industries, supporting initiatives aimed at reducing waste and conserving resources (Al-Quradaghi et al., 2022). Minimal influence on the environment and human health is ensured throughout the process by following to environmental standards and regulations. Figure 2.2 shows the process recycling flow chart for end-of-life vehicles.

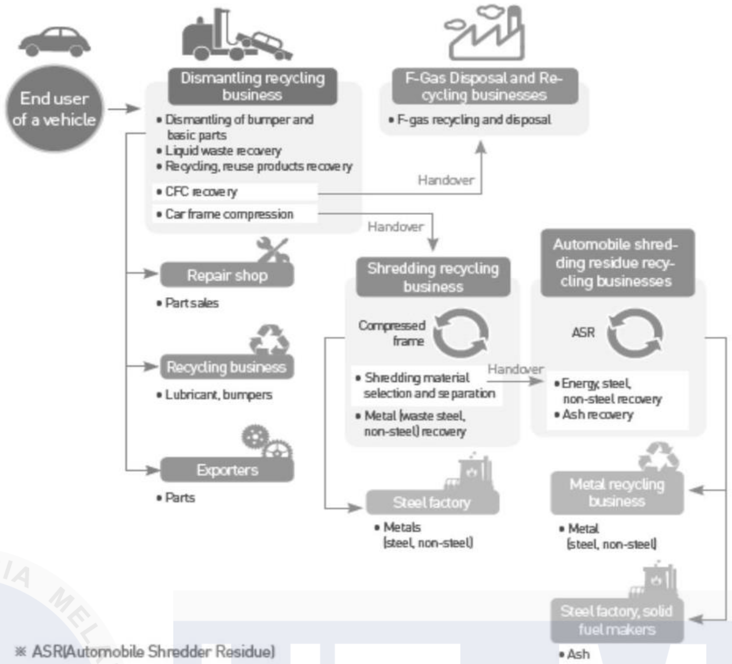


Figure 2.2 The process recycling flow chart for end-of-life vehicles

(Source: Research Gate)

2.3 Dismantling Process of ELV

The process of dismantling an End-of-Life Vehicle (ELV) is a meticulous method aimed at disassembling the vehicle into its individual components and materials for the purpose of reusing, recycling, or safely disposing of them. The process commences when the car is brought to an authorized treatment facility, where it gets a comprehensive inspection and documentation. The first stage entails removing all the fluids, such as oil, coolant, petrol, brake fluid, and refrigerants, in order to prevent any environmental pollution. Subsequently, these fluids are gathered for the purpose of recycling or appropriate disposal.

Afterwards, the battery of the vehicle is taken out since it poses a danger, and then the airbags and seatbelt pre-tensioners, which contain explosive substances, are removed (Zhan et al., 2023). Components of high value or demand, such as engines, transmissions, alternators, and electronic parts, are meticulously disassembled for resale or refurbishing. In addition, various components such as tires, glass, and catalytic converters are extracted at this phase.

Once the valuable and hazardous parts are extracted, the remaining vehicle body is shredded. This shredding process helps separate different materials like metals, plastics, and glass. Metals, which make up the bulk of the vehicle's weight, are further sorted into ferrous and non-ferrous categories using magnetic separation and eddy current techniques. Cars that have gone through the dismantling process are shown in Figure 2.3. These metals are then sent to recycling plants to be melted down and repurposed into new products.

The dismantling process not only enables the recovery of valuable materials but also ensures proper management of hazardous substances, thereby reducing the environmental impact of ELVs (Wang et al., 2024). This comprehensive and regulated procedure significantly contributes to the principles of the circular economy by promoting the reuse and recycling of automotive materials.

Figure 2.3 Cars that have gone through the dismantling process
(Source: Wikipedia)

2.4 Depollution Process of ELV

The depollution process of an End-of-Life Vehicle (ELV) is a vital step aimed at removing hazardous materials and pollutants from the vehicle before it undergoes dismantling for recycling. This process is essential to prevent environmental contamination during and after the disposal of the ELV. The process begins with the ELV being transported to an authorized treatment facility, where it is thoroughly documented and prepared for pollutant removal. First, all fluids are drained from the car. This comprises engine oil, coolant, brake fluid, gearbox fluid, petrol and air-conditioning refrigerants. These fluids are carefully collected and stored in appropriate containers for recycling or proper disposal, ensuring that they do not affect the environment.

The next step is to remove the battery, which contains toxic lead and acid. The battery is delivered to specialized recycling facilities, where its components are collected and repurposed. Following that, airbags and seatbelt pretensioners are retrieved because they contain explosive components that must be handled carefully to avoid accidental explosion and ensure safe recycling or disposal.

The catalytic converter is then removed since it includes valuable precious metals such as platinum, palladium, and rhodium, which can be recovered and recycled in a variety of industrial applications. Tires are also removed and recycled or repurposed, for example, to make rubberized asphalt for road building.

After all hazardous and valuable components are removed, the vehicle is considered depolluted. This ensures that the subsequent dismantling and recycling processes are conducted in an environmentally safe manner, significantly reducing potential pollution. The depollution process is crucial in the broader context of ELV management, aligning with environmental regulations and supporting the principles of the circular economy by ensuring proper management of hazardous substances and recovery of valuable materials.

2.5 Recycling Process of ELV

End of Life Vehicle (ELV) recycling entails the methodical disassembly of its parts and components to extract valuable materials for reuse in other industries. This process plays a crucial role in sustainable ELV management by reducing waste and conserving resources (Guo et al., 2022). The recycling process usually begins after the depollution and disassembly stages have been completed.

At first, the materials are separated by separating metals, plastics, glass, and rubber in order to make recycling activities more efficient. Afterward, these materials undergo several processing techniques to prepare them for reuse (Al-Quradaghi et al., 2022; Modoi & Mihai, 2022). Metals, which make up a substantial proportion of the vehicle's weight, are highly sought after for the purpose of recycling (Sainy et al., 2023).

Magnetic separation is a separation process that distinguishes between ferrous metals, such as steel and iron, and non-ferrous metals, such as aluminum, copper, and brass. The metal products from End-of-Life Vehicles (ELVs) are subjected to a recycling procedure as illustrated in Figure 2.4. Subsequently, these metals are subjected to the process of melting in order to be reconfigured into fresh commodities or employed as primary materials in the production industry(Arnold et al., 2021).

Plastics derived from End-of-Life Vehicles (ELVs) are classified according to their type, then purified and fragmented into smaller pieces (Sopher, 2009). Subsequently, these plastic fragments are either subjected to the process of melting and shaping to create new products or employed as additives in the fabrication of composite materials (Guo et al., 2022). The glass obtained from End-of-Life Vehicles (ELVs) is crushed into cullet, which can then be either melted down to create new glass goods or used as aggregate in construction projects. Rubber components such as tires, frequently undergo recycling procedures such as shredding and grinding, to produce crumb rubber. This crumb rubber is utilized in diverse industries, such as surface for recreational areas and as a component in road asphalt.

Stringent quality control protocols are upheld throughout the recycling process to guarantee adherence to industry standards and specifications, facilitating the smooth incorporation of recycled materials back into the manufacturing cycle. This promotes the establishment of a circular economy, thereby decreasing the dependence on new and unused resources (Liu et al., 2023). ELV management facilities play a crucial role in reducing the environmental impact of automotive waste by recycling car parts and components (Al-Quradaghi et al., 2022; Pan & Li, 2016). This helps to conserve natural resources in a significant way.

Figure 2.4 Metal items of ELVs undergo recycling process

(Source: My New Car Accessories, 2023)

2.6 Battery from ELV

A battery's worth increases when an end-of-life vehicle (ELV) is disassembled and salvaged. The battery is taken out early in the processes and put through a rigorous testing process to determine its current condition and remaining capacity. It may be refurbished, with parts changed and reconditioned to satisfy quality standards, if it is seen appropriate. Refurbished batteries prolong their useful life in automobiles or energy storage devices, which lowers the demand for new manufacturing. But in the event that the battery is no longer functional, recycling takes place. This involves dismantling the pack, separating materials like metals and plastics, and processing them for reuse. Recycling helps the automotive industry's sustainability efforts by reducing waste and recovering important materials like cobalt and lithium(Zhan et al., 2023). Recycling ELV batteries thus becomes essential to creating a circular economy, preserving resources, and minimizing environmental effect (Meegoda et al., 2022).

2.6.1 Issues with Battery from ELV

Mishandling end-of-life vehicle (ELV) batteries creates several safety and environmental concerns. ELV batteries frequently contain hazardous materials such as lead acid, lithium ion, nickel metal hydride, and other chemicals. If not properly handled, these materials have the potential to leak into the environment, contaminating soil, water supplies, and air quality(Wang et al., 2024). Lead and sulfuric acid, for example, are extremely toxic chemicals found in lead-acid batteries. Batteries that are not properly recycled or disposed of may end up in landfills, where their dangerous components may contaminate groundwater and soil, risking human and animal health (Meegoda et al., 2022).

In addition, ELV batteries contain precious metals such as copper, nickel, cobalt, and lithium. If these metals are not recovered by recycling, resources will be wasted, and additional mining will be required, further depleting natural resources and harming the environment. Furthermore, improper battery disposal can cause explosions and fires, especially in landfills where batteries may come into contact with other reactive materials or experience thermal runaway due to internal short circuits(Deng et al., 2020; Meegoda et al., 2022).

Furthermore, the substantial quantity of End-of-Life Vehicle (ELV) batteries manufactured globally worsens the gravity of the problem. Over the next few years, there is expected to be a significant rise in the number of batteries reaching the end of their lifespan as a result of the increasing popularity of electric cars (EVs). In the absence of an established infrastructure for the management and recycling of ELV batteries, the accumulation of these batteries will exacerbate the depletion of resources and environmental harm (Zhan et al., 2023).

In addition, mishandling of ELV batteries exacerbates the challenge of waste disposal as they have the potential to occupy landfills for thousands of years and could release dangerous compounds. Therefore, it is imperative to establish effective recycling and disposal protocols to minimize the adverse environmental impacts and promote sustainability in the automotive industry.

2.7 Current Jig use in Industry

Jigs are essential tools in modern manufacturing and machining operations, used to guide and hold workpieces in position. They are critical to maintaining precision, repeatability, and efficiency in a variety of industrial applications (Groover, 2010). This study looks at the numerous types of jigs that are regularly used in industry, the materials used to build them, and their unique applications in various industries.

There are various different types of jigs, each with a specific purpose. Drill jigs are among the most prevalent, and they are used to guide drills for precise hole placement. These include plate jigs for medium-sized batches, which provide stability and accuracy; template jigs for small batch production; angle plate jigs for drilling at particular angles; and box jigs, which enclose the workpiece to provide high stability for complex parts (Schmid et al., 2013). Fixture jigs are another type of jig that is used to keep workpieces steady during machining processes such as milling, grinding, and turning. Milling, grinding, and turning fixtures are examples of fixtures that ensure precise positioning for their respective operations (Susanto et al., 2019).

Welding jigs are crucial for keeping components aligned and positioned when welding. Standard welding jigs are used for fundamental jobs, modular welding jigs can be adjusted for different projects, and custom welding jigs are made for specific parts and assemblies (Schmid et al., 2013). Assembly jigs help to assemble components into finished products, with manual assembly jigs appropriate for low-volume manufacturing needing human interaction and automated assembly jigs linked into automated systems for high-volume production (Boothroyd et al., 2010).

Jigs are built of a variety of materials that are selected based on the task's specific requirements. Steel is a popular material, with tool steel offering great toughness and wear resistance, making it ideal for heavy-duty jigs, and mild steel being inexpensive and simple to make, making it acceptable for general-purpose jigs (Fentahun & Savas, 2018; Groover, 2010). Aluminum is another popular material, prized for its lightweight and corrosion-resistant properties, which are beneficial in applications where weight is an issue. Furthermore, aluminum is easier to produce than steel, reducing production time and costs (Black & Kohser, 2012; Schmid et al., 2013).

Polymer composites are also used, with materials like epoxy resin providing high precision and low weight, and carbon fiber offering a high strength-to-weight ratio, making them ideal for industries such as aerospace and automotive (Mikell P. Groover, 2020). Wood is used in simple, low-cost jigs for small-scale or prototype work, particularly in non-metallic machining processes. Titanium, with its high strength and low weight, is employed in specialized applications like aerospace, where resistance to high temperatures and corrosion is crucial (Boothroyd, 1994). Table 2.1 below shows the materials used for jigs and their descriptions.

Table 2.1 Materials used for jigs

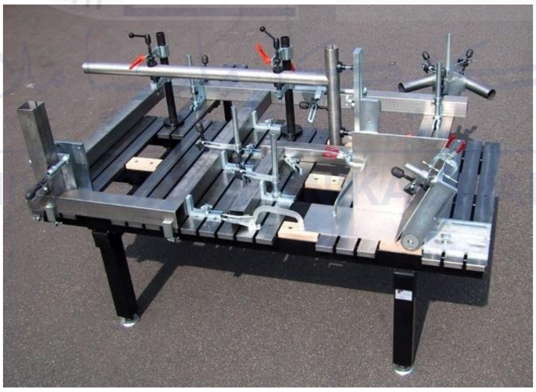
No	Material	Description
1	Steel	• Tool Steel: High durability and wear resistance, used for heavy-duty jigs. • Mild Steel: Cost-effective and easily machinable, suitable for general-purpose jigs.
2	Aluminum	• Lightweight and corrosion-resistant, used where weight is a concern. • Easier to machine, reducing production time and costs.
3	Polymer Composites	• Epoxy Resin: Used for high precision and lightweight applications. • Carbon Fiber: High strength-to-weight ratio, ideal for aerospace and automotive industries.
4	Wood	• Used for simple, low-cost jigs, often in small-scale or prototype work. • Suitable for non-metallic machining processes.
5	Titanium	• High strength and low weight, used in specialized applications like aerospace. • Resistant to high temperatures and corrosion, suitable for high-performance needs.

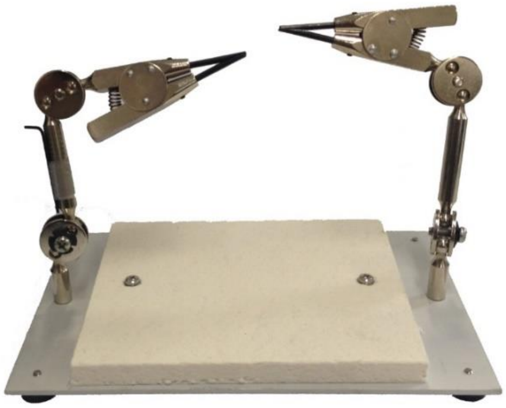
Jigs are used in a variety of sectors, each with specialized uses customized to their requirements. Assembly line jigs are used in the automotive industry to guarantee that parts fit precisely during high-volume production. While welding, jigs keep car frames and components aligned. Inspection jigs are used for quality control by verifying dimensions and tolerances (Peramanan et al., 2015). Drill jigs are used in the aerospace sector to accurately drill complex aircraft components, assembly jigs to precisely assemble aircraft parts, and composite material jigs to shape and assemble lightweight materials (Mangukia, 2017).

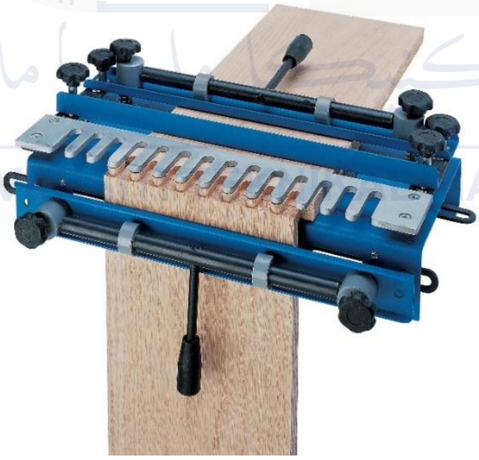
PCB assembly jigs are used in the electronics industry to assure precise positioning of components on printed circuit boards. Soldering jigs are used to hold components in place during automated soldering processes. Testing jigs are used to facilitate the testing of electronic devices to check their operation. Template jigs, joinery jigs, and assembly jigs are valuable tools in the woodworking industry. Template jigs help guide cutting tools for intricate designs and patterns, while joinery jigs ensure precise cuts for joints such as dovetails and mortise-and-tenon. Assembly jigs assist in the accurate assembly of wooden furniture and structures.

In the metalworking industry, drilling and boring jigs are used to ensure precise hole location and size. Milling jigs are used to hold workpieces steady during milling for accurate machining. Turning jigs are used to secure workpieces in lathes for precise turning process (Serope Kalpakjian, 2007). Table 2.2 below shows some examples of uses of jigs in various industries.

Table 2.2 Examples of jigs and their uses in industry

No	Name of Jig	Usage of jig
1	Assembly Line Jigs  (Source: Wikipedia)	• Use in automotive industry. • Ensure precise fitting of parts in high-volume production.
2	Welding Jigs  (Source: Wikipedia)	• Use in automotive industry. • Maintain alignment during welding of car frames and components.
3	Inspection Jigs	• Use in automotive industry. • Verify dimensions and tolerances for quality control.

	 (Source: Wikipedia)	
4	Drill Jigs  (Source: Wikipedia)	• Use in aerospace industry. • Ensure accurate drilling of complex aircraft components.
5	Soldering Jigs  (Source: Wikipedia)	• Use in electronics industry. • Hold components in place during automated soldering processes.

6	Milling Jigs  (Source: Wikipedia)	• Use in metalworking industry. • Hold workpieces steady during milling for precision machining.
7	Joinery Jigs  (Source: Wikipedia)	• Use in woodworking industry. • Ensure precise cuts for joints like dovetails and mortise-and-tenon.

Jigs play a crucial role in contemporary manufacturing by ensuring the accuracy, consistency, and effectiveness required for producing goods of superior quality. The wide range of jigs and the variety of materials used in their construction enable them to effectively cater to the individual requirements of various industries and applications. An in-depth comprehension of the proper utilization and choice of jigs is crucial for maximizing manufacturing processes and guaranteeing consistent product quality, thereby emphasizing their significance in the industrial sector.

CHAPTER 3

METHODOLOGY

3.1 Introduction

A product development has to undergo a proper development process in order to ensure workability, efficient and systematic approach to achieve the project's objectives. As for the battery removal tool, this tool is expected to meet the needs of portable and efficient depollution. This process encompasses several critical stages, each aimed at addressing specific aspects of the design and construction phases. During the design process, it considers the workability of the product and the efficiency in the current situation of the tool in the ELV industry and also the working principle of the product itself.

This structured approach ensures that the tool not only meets the technical requirements but also addresses safety, usability, and efficiency concerns. Multiple design concepts will be generated, focusing on portability, ease of use, and compatibility with various battery types and vehicle models. These concepts will be evaluated using a set of criteria including feasibility, cost-effectiveness, and potential impact on the depollution process.

3.2 Flow Chart

A flow chart for the product development process that will be used for this project is shown in Figure 3.1.

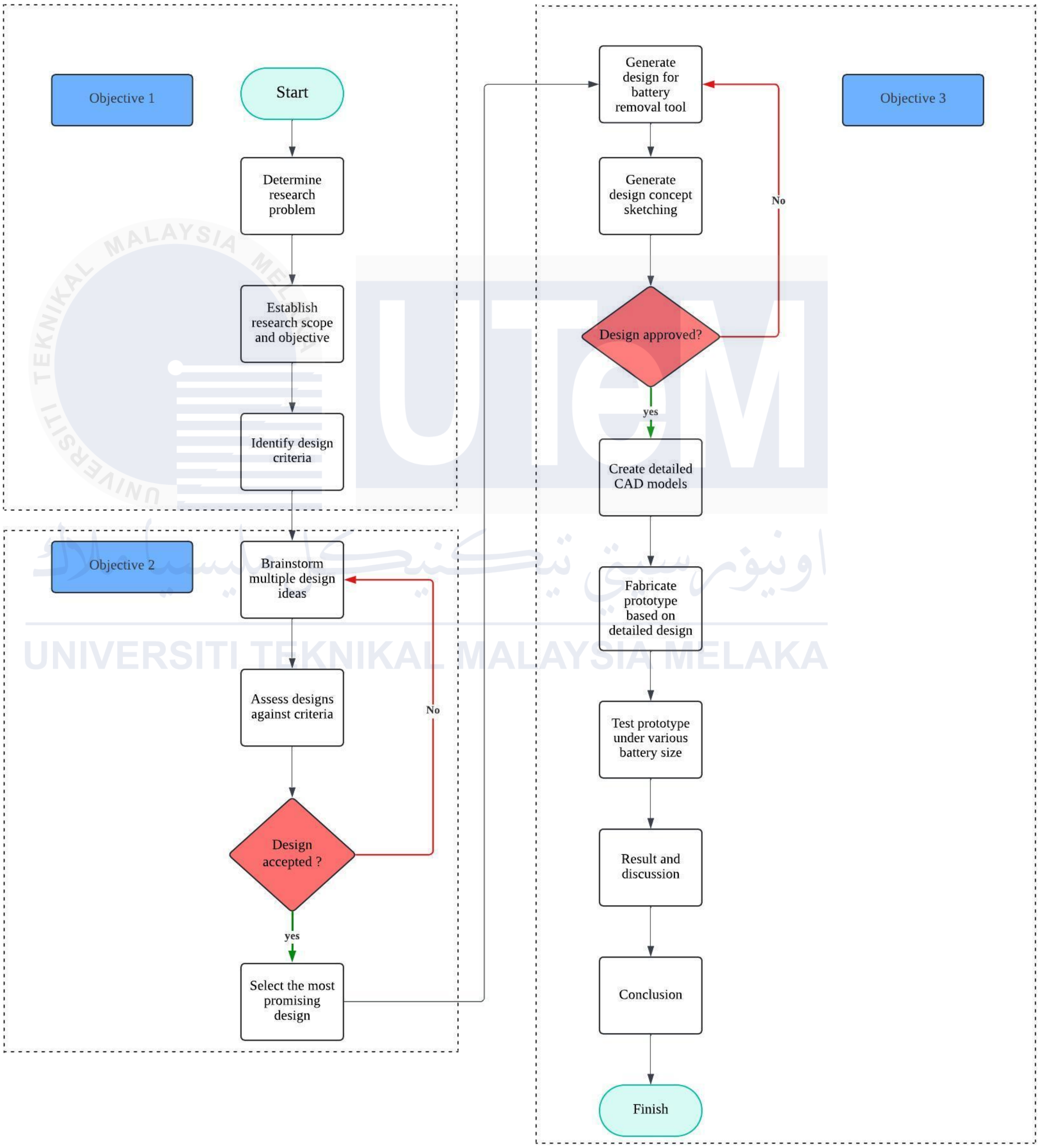


Figure 3.1 Process Development Flowchart

3.3 Design Selection

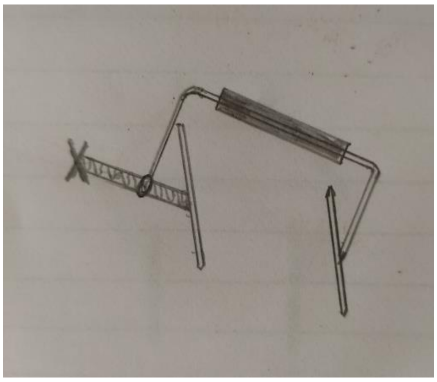
Design selection is a critical phase in project planning that involves evaluating various design alternatives to choose the most suitable option for a project. This process ensures that the chosen design aligns with the project's goals, budget, and timeline while meeting stakeholders' needs and preferences. By systematically comparing different designs, project teams can identify the option that best meets the project's objectives, whether enhancing user experience, improving functionality, or achieving aesthetic appeal. It also helps in managing costs by finding the most cost-efficient solution without compromising quality.

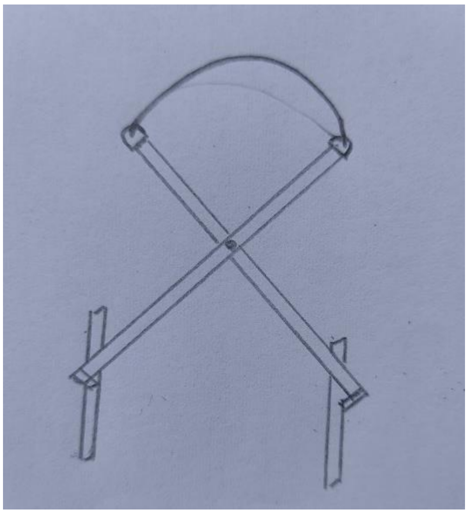
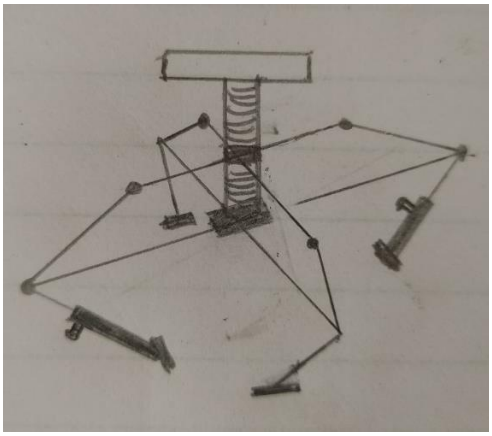
Additionally, design selection plays a vital role in risk management by identifying and mitigating potential risks early in the project. Furthermore, exploring multiple design options fosters innovation and creativity, encouraging unconventional solutions that may offer superior functionality or aesthetics. Ensuring regulatory compliance and assessing the feasibility and practicality of each design option are also crucial aspects of this phase. In conclusion, design selection is essential for delivering high-quality outcomes that meet or exceed project goals by ensuring the chosen design is cost-effective, feasible, innovative, and aligned with the project objective.

3.3.1 Concept Generation

The goal of the product benchmarking procedure was to find out about the most recent designs and features of existing portable battery removal, as well as to examine the designs that would be used in this project's design. After extensive research, several patents for battery removal tool have been found. The usage of appropriate materials and the model's idea were also taken into consideration. These strategies were also utilized to inspire the creation of new material designs that would help increase the overall strength of the product. Based on the brainstorming and concept design stages, four concept designs were developed. The process then proceeded until the most suitable design concept was determined and will move on to the next process that is product development phase where all the development is based on the selected design and analysis. Table 3.1 show concept design of battery removal tool.

Table 3.1 Concept Design of Battery Removal Tool

Design concept	Design Illustration
Design 1	

Design 2	
Design 3	
Design 4	

3.4 Weighted sum Method

The Weighted Sum Method (WSM) is a multi-criteria decision-making approach used to evaluate and compare different alternatives based on various criteria of the design. Each criterion is assigned a weight reflecting its relative importance. The performance of each alternative on each criterion is scored, and these scores are multiplied by the corresponding weights.

The weighted scores are then summed for each alternative. The alternative with the highest total score is considered the best option. This method helps choose the best design concept to be use according to certain important criteria to be implemented into the product. Table 3.2 show the layout weighted sum method to determine the best design selection for this project.

Table 3.2 Layout Weighted Sum Method for Design Selection

		Design alternatives							
		Design 1		Design 2		Design 3		Design 4	
Criteria	Importance Weight %	Rating (1-5)	Weighted Rating %	Rating (1-5)	Weighted Rating%	Rating (1-5)	Weighted Rating%	Rating (1-5)	Weighted Rating%
High efficiency	25	3	15	5	25	5	25	5	25
Less space consuming	25	4	20	4	20	4	20	3	15
Easy to maintain	20	3	12	5	20	4	16	3	12
Simplicity	15	5	15	5	15	5	15	3	9
Light weight	15	4	12	5	15	5	15	3	9
Total %	100	74		95		91		70	

After the evaluation of this method was made, then design 2 was selected for this product development. Design 2 obtained the highest percentage of criteria compared to other designs which is 95%. In the selection of this design, high efficiency and light weight are important to ensure high usability, the product is easy to use and portable.

3.5 Material Selection

Material selection is critical in product development, as it profoundly impacts performance, durability, cost and overall success. The chosen materials must withstand mechanical stresses to ensure the tool functions correctly under expected conditions. The strength of a material depends on various factors, including tensile strength, yield strength, and hardness. Durability and longevity are also essential, requiring materials that resist corrosion and wear. Cost efficiency is another crucial factor. Selecting cost-effective materials can keep our project within budget while reducing long-term maintenance expenses. Therefore, a systematic and holistic approach to material selection is essential to achieving a project's goals efficiently and sustainably. So, the weighted sum method has been chosen to determine the right material for this product show in Table 3.3.

Table 3.3 Layout Weighted Sum Method for Material Selection

		Material Selection							
		Stainless Steel		Aluminium		Cast Iron		Mildsteel	
Criteria	Importance Weight %	Rating (1-5)	Weighted Rating %	Rating (1-5)	Weighted Rating %	Rating (1-5)	Weighted Rating%	Rating (1-5)	Weighted Rating %
Strength	25	5	25	2	10	3	15	4	20
Durability	25	4	20	2	10	3	15	4	20
Machinability	20	2	8	5	20	3	12	4	16
Cost	15	2	6	3	9	4	12	5	15
Light weight	15	2	6	5	15	2	6	3	9
Total	100	65		64		60		80	

Based on the evaluation of each material, mild steel was selected for this development project by obtaining the highest criteria percentage of 80%. Cost and strength are important criteria in the selection of materials for this development product. Therefore, mild steel is a suitable material for this product.

3.6 Catia Computer Aided Design (CAD)

After completing the weighted sum method, which involved assigning ratings to all the criteria and characteristics in the poll, the best design was selected. CAD design can be generated by transitioning from 2-Dimensional sketching to 3-Dimensional parts using Catia V5. Catia V5 is a robust computer-aided design (CAD) program created by Dassault Systems. Due to its extensive capabilities and features, it is frequently utilized in diverse industries such as aerospace, automotive, and manufacturing.

Catia V5 is well regarded for design drawing because of its extensive range of tools and adaptable capabilities. Catia V5 provides a diverse range of tools that enable designers to create 2D sketches and detailed 3D models. This software allows designers to bring their ideas to life, whether they are working on basic sketches or elaborate surface modeling. The parametric modeling capabilities of this software are remarkable, as they allow designers to construct models that are influenced by parameters. This feature greatly simplifies the process of making alterations and updates to the design at any stage. This capability is extremely important when doing repeated design iterations and tweaks based on feedback.

In addition, Catia V5 demonstrates exceptional performance in assembly design, enabling users to create intricate assemblies of components, such as mechanisms and kinematic simulations, guaranteeing flawless operation of multi-component goods. Designers using Catia V5 have a wide range of analysis tools at their disposal, which allow for in-depth assessment of design performance and behavior. These tools encompass a wide range of studies that are essential for many engineering applications. Finite Element Analysis (FEA) enables the simulation and analysis of the structural integrity and behavior of components and assemblies under different loading circumstances.

It aids in the identification of regions with significant stress, deformation, and possible failure, allowing designers to enhance their designs for enhanced strength and durability. Computational Fluid Dynamics (CFD) enables the examination of fluid flow and heat transfer, which is crucial for enhancing aerodynamic forms and thermal management systems. Kinematic analysis allows for the evaluation of movement and space inside mechanical systems, guaranteeing correct operation and efficiency.

Thermal analysis is used to forecast the distribution of temperature and heat fluxes, which is essential for the design of effective cooling systems and electronic enclosures. Vibration analysis is a method used to assess the way mechanical vibrations affect the behavior of equipment and aeronautical structures. It helps to prevent failures in these systems. The analysis capabilities of Catia V5 enable designers to make well-informed decisions, optimize designs, and ensure the dependability and efficiency of their products in various sectors and applications.

The primary reason for using Catia V5 for design drawing is its extensive capabilities, including robust features for parametric modeling, analysis tools, and seamless connection with other software systems. Due to its adaptability, it is well-suited for various sectors and design applications. By selecting the Catia V5 program, the product can be designed and analyzed. The Finite Element Analysis (FEA) method will be employed to detect regions of elevated stress, deformation, and possible design failure.

3.7 Summary

Design selection is a vital phase in project planning that involves evaluating various possibilities to determine the best option. This method ensures that the design adheres to the project's objectives, costs, and schedule while also meeting the needs of all parties involved. It encourages innovation, lowers costs, and reduces risks. The Weighted Sum Method (WSM) was used in this study to identify the best design and material for a portable battery removal tool. The selection process includes selecting Design 3 for its remarkable efficiency and lightweight qualities, while iron was chosen for its cost-effectiveness and long-term durability. The design was created on CATIA V5, which is known for its powerful CAD capabilities, including 2D sketching, 3D modelling, parametric modelling, and assembly design tools. CATIA V5 has a number of analysis tools, including Finite Element Analysis (FEA), that can be used to optimize and ensure the dependability of the design.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter focuses on the thorough development of the product's design and operational principles to guarantee optimal functionality and successful attainment of project goals. This extensive phase encompasses multiple crucial processes, each playing a role in the overall success and sustainability of the product. The design that offers the highest level of efficiency is chosen initially after a thorough examination of the initial concept. The chosen design is then carefully elaborated and measured to ensure that all components fit together perfectly. Subsequently, an intricate and precise 3D representation of the product is created utilizing sophisticated computer-aided design (CAD) software. This involves constructing prototypes of different elements and combining them to verify their compatibility and incorporation. Initial simulations are performed to identify possible concerns, such as areas of high stress and the yield stresses. Detailed analysis is then performed to ensure that the product will perform as intended under various conditions. In this project, products are determined based on different battery sizes and weights. Structural analysis assesses strength and durability. The fabrication process is outlined starting with the selection of materials based on the analysis that has been made in the previous chapter. Manufacturing methods are determined for each component, and prototypes are made according to the selected design. Finally, this prototype will be tested in real conditions.

4.2 Prototype Sketching

The finalized prototype sketch is considered based on the design selection that has been made. This sketch is made as a preliminary step before making a more detailed drawing in computer-aided design (CAD) software. Prototype sketching of this product show in Figure 4.1.

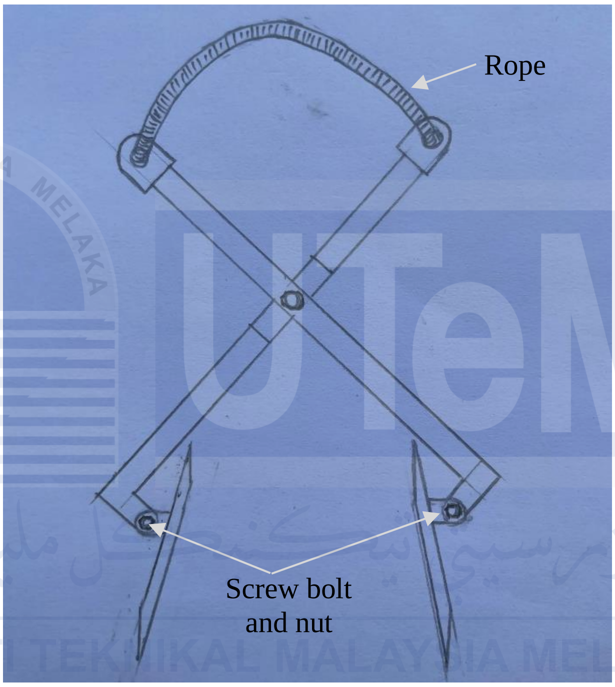


Figure 4.1 Prototype Sketching of The Product

4.3 Mild Steel Material for Product Development

A wide array of benefits come with using mild steel in development processes, which is mostly based on the quality and versatility that accompanies it as a material. Mild steel exhibits quite rounded properties, a blend of strength, flexibility and affordability that would be really desirable in applications that need strong and long-lasting material able to resist massive load stressors without suffering any damage. Figure 4.2 below shows the properties of the mild steel. It is one of the cost-effective materials because it has lower costs compared to stainless steel or aluminum metals. This makes it good for big projects or low-budget projects without necessarily compromising on the structural integrity.

Name	Mild Steel
Phase at STP	solid
Density	7850 kg/m3
Ultimate Tensile Strength	400-550 MPa
Yield Strength	250 MPa
Young's Modulus of Elasticity	200 GPa
Brinell Hardness	120 BHN
Melting Point	1450 °C
Thermal Conductivity	50 W/mK
Heat Capacity	510 J/g K

Figure 4.2 Mild Steel Properties
(Source: mild-steel-density-strength-hardness-melting-point)

Mild steel has a moderate level of tensile strength and hence can bear different kinds of loads and stresses in normal application in construction, machinery and parts of automobiles. Besides that, its ductility allows it to be easily shaped, bent or welded into complex structures, making it highly adaptable for different design requirements. Its adaptability is highly valued in various industries. Mild steel also has a number of types and shapes that we can use to develop any product in an industry. In this development of the project, the round bar and flat bar mild steel are used in the production of the product shown below in Figure 4.3.

Figure 4.3 Flat Bar and Round Bar Mild Steel

On aspects of durability, mild steel performs well in environments where moderate wear and tear are expected. While it is not naturally resistant to corrosion, such as stainless steel would be, mild steel can undergo additional treatment in the form of coatings or paints that protect it against conditions of corrosion. The versatility and adaptability of this material make mild steel practical for use in a broad range of applications, from the development of infrastructures to the making of tools. Its ease of handling and assured performance builds its reputation among the most usable materials within engineering and manufacturing.

4.4 Design Sketching in Catia V5 CAD

The design starts with 2-dimensional sketching, all dimensions are made based on measurements of car battery sizes available so that this tool can be used for all sizes of car batteries. The process started with opening new folder and select part design to load all the preference in the software. After exiting workbench in the 2-D sketching, the process goes to 3-D drawing. This process repeat for each part of the design before full model can be assembly. Several part of the design drawing, assembly design and the dimension show in figure below.

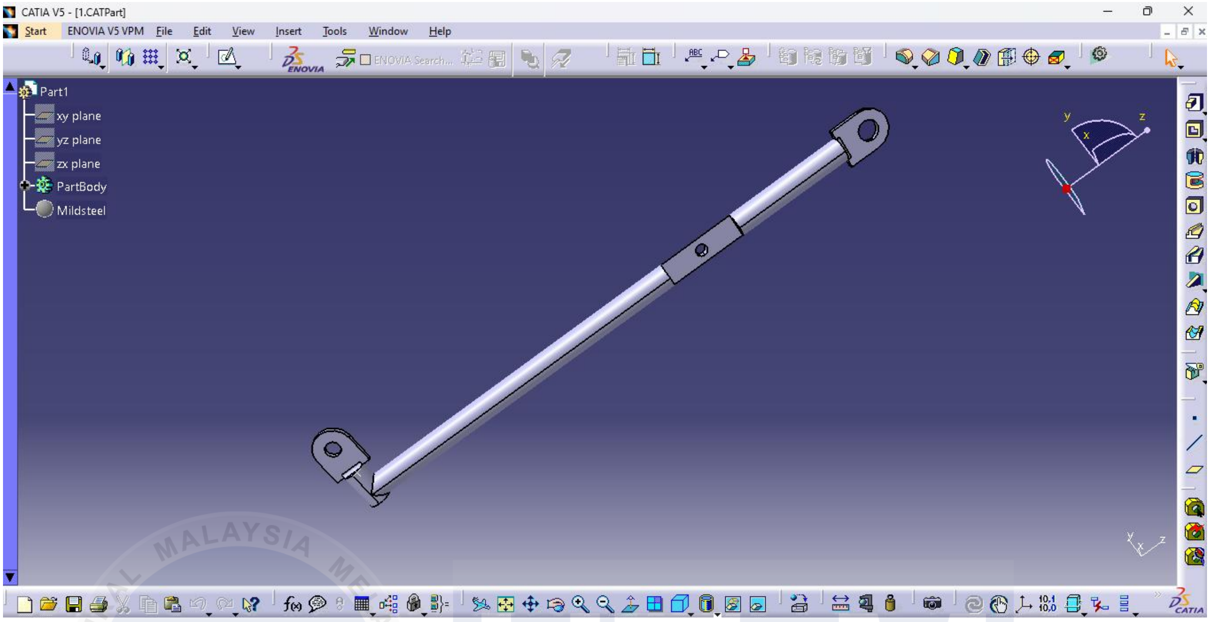


Figure 4.4 Design CAD Model Part 1

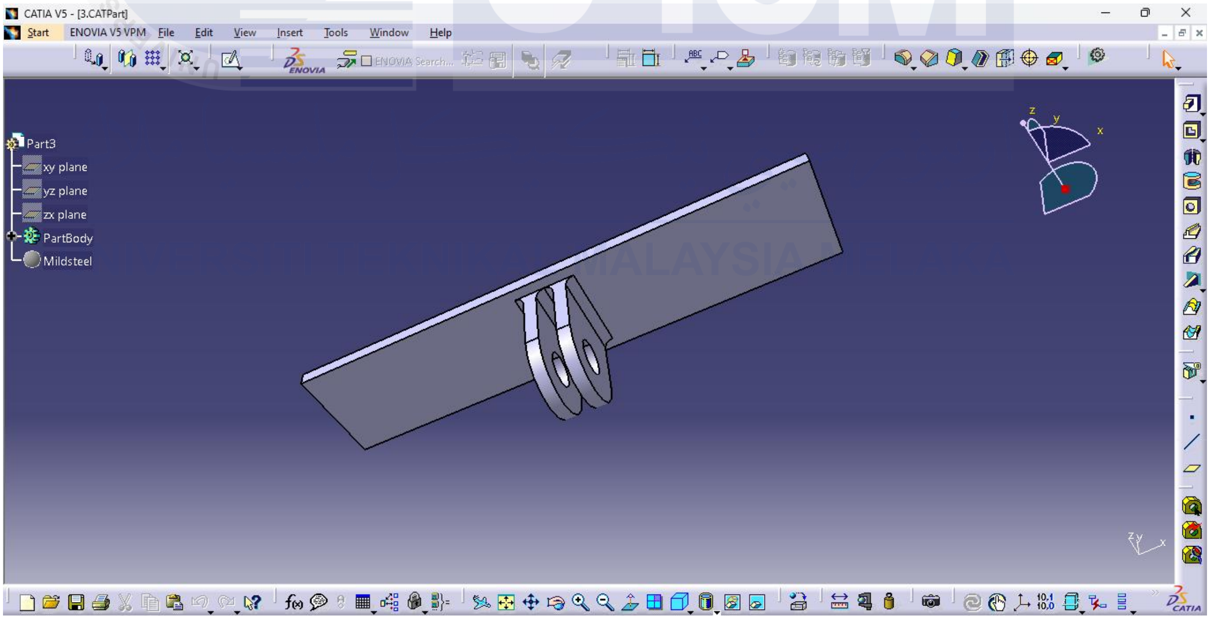


Figure 4.5 Design CAD Model Part 2

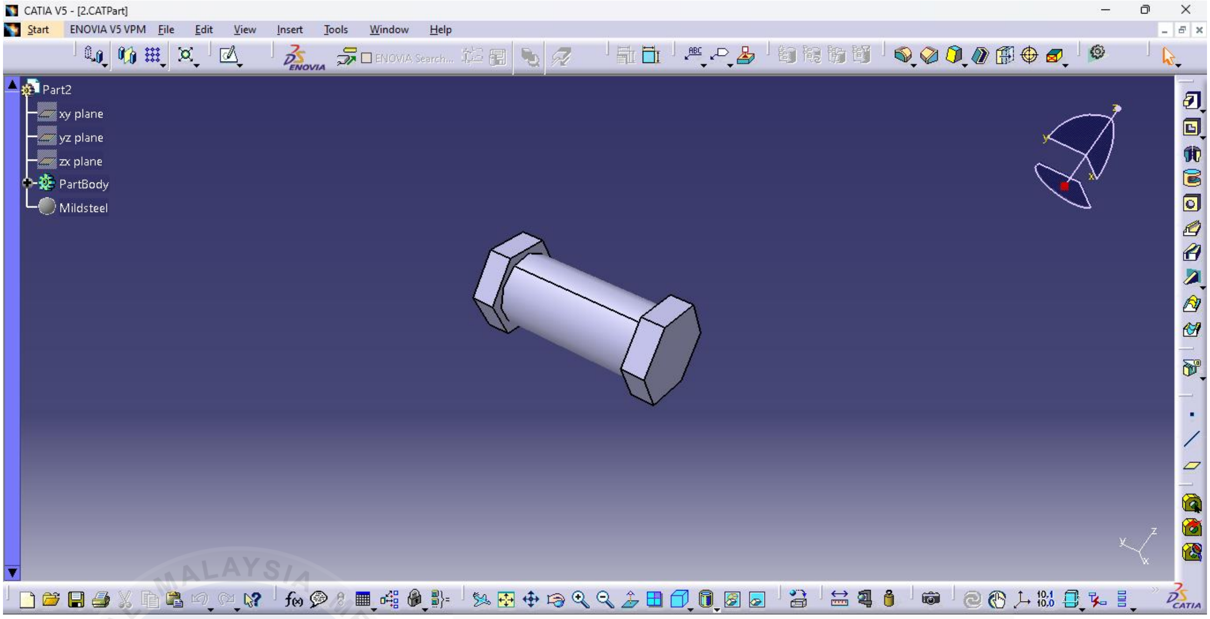


Figure 4.6 Design CAD Model Part 3

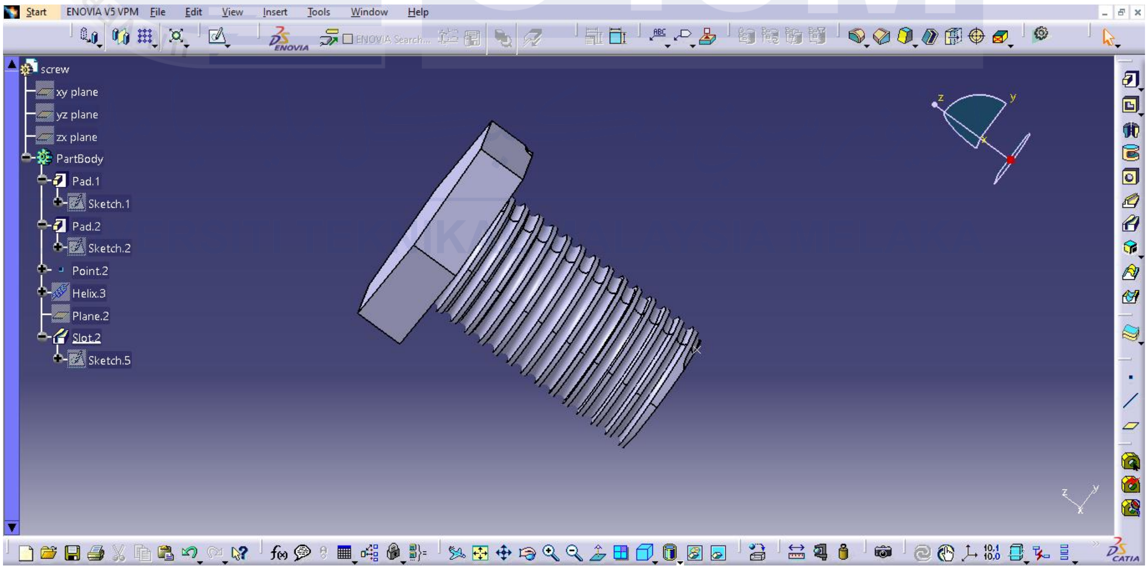


Figure 4.7 Design CAD Model Part 4

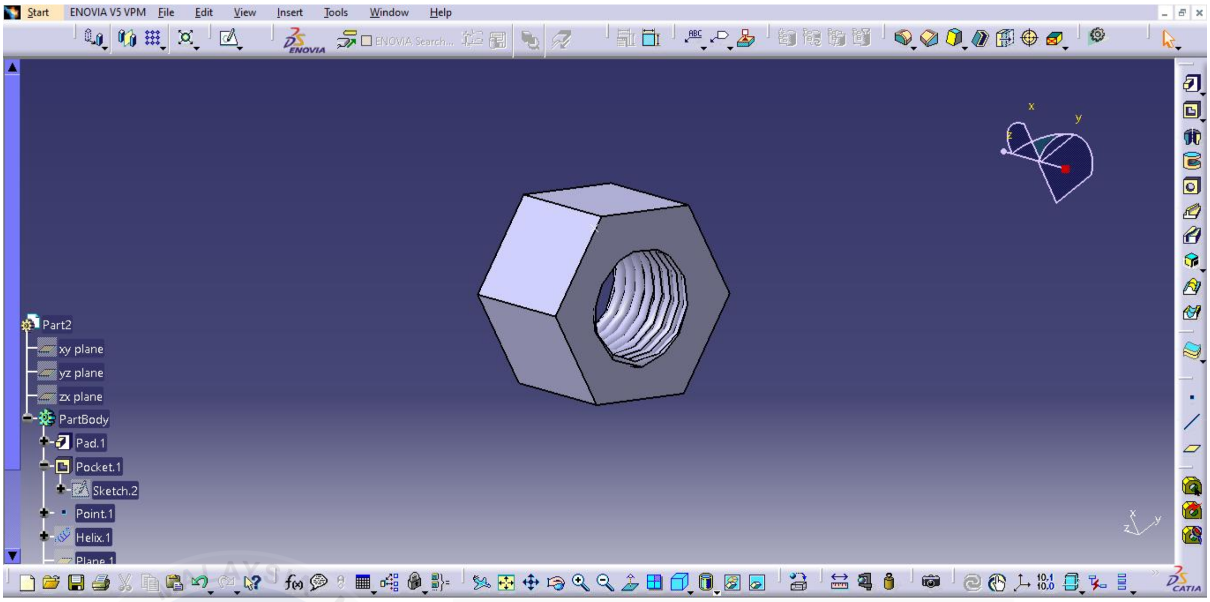


Figure 4.8 Design CAD Model Part 5

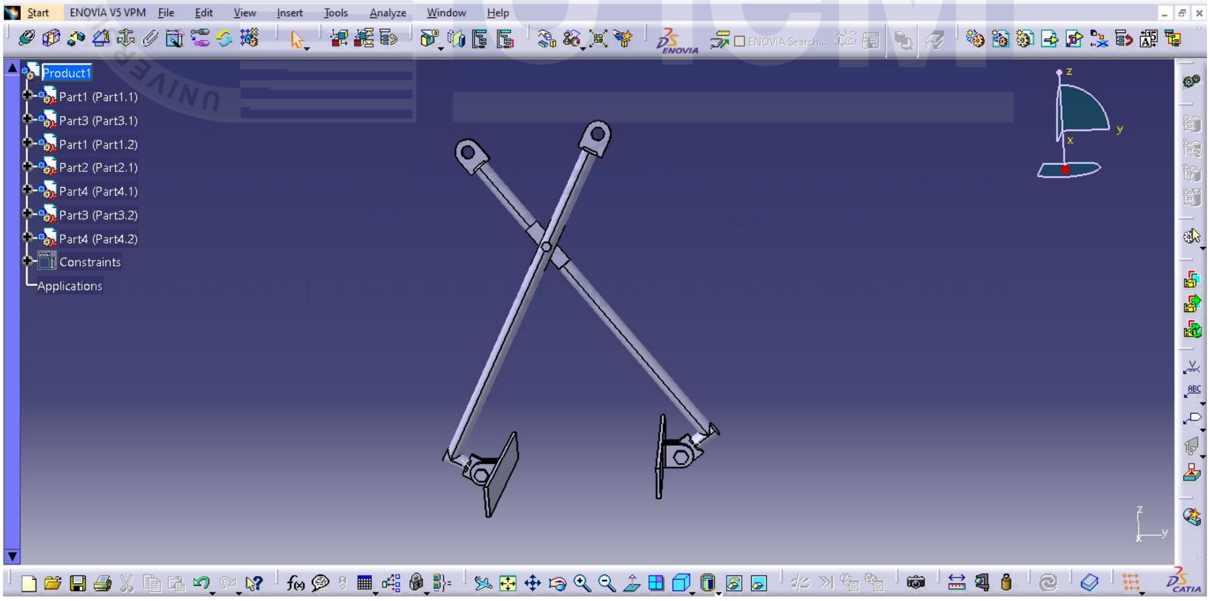


Figure 4.9 Front View Assembly Design CAD Model

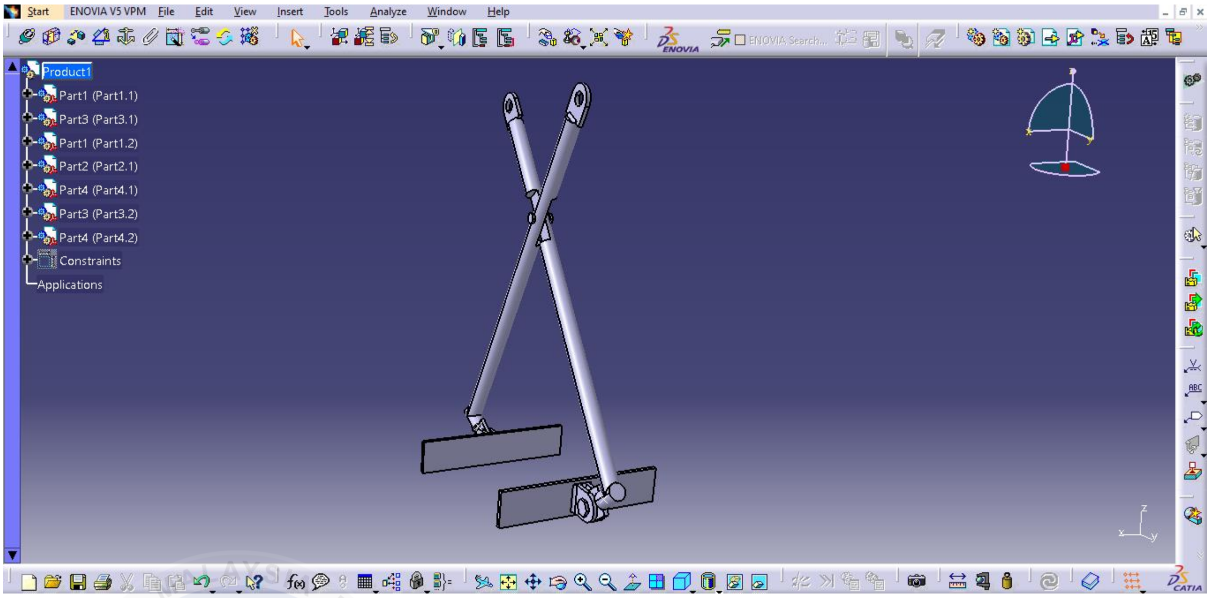


Figure 4.10 Side View Assembly Design CAD Model

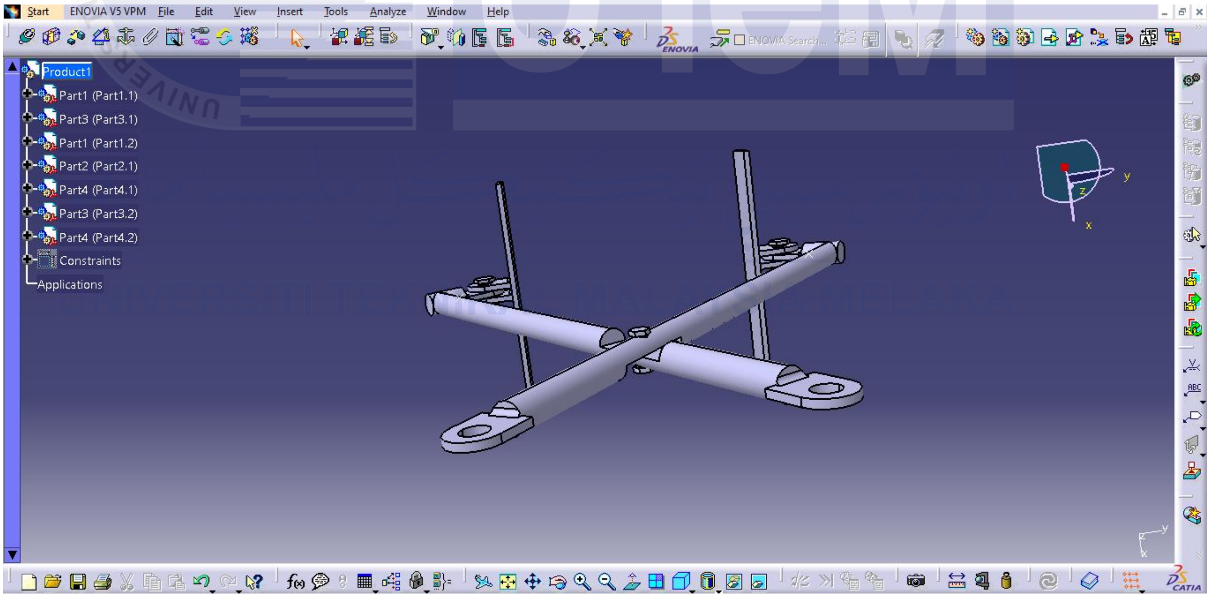


Figure 4.11 Top View Assembly Design CAD Model

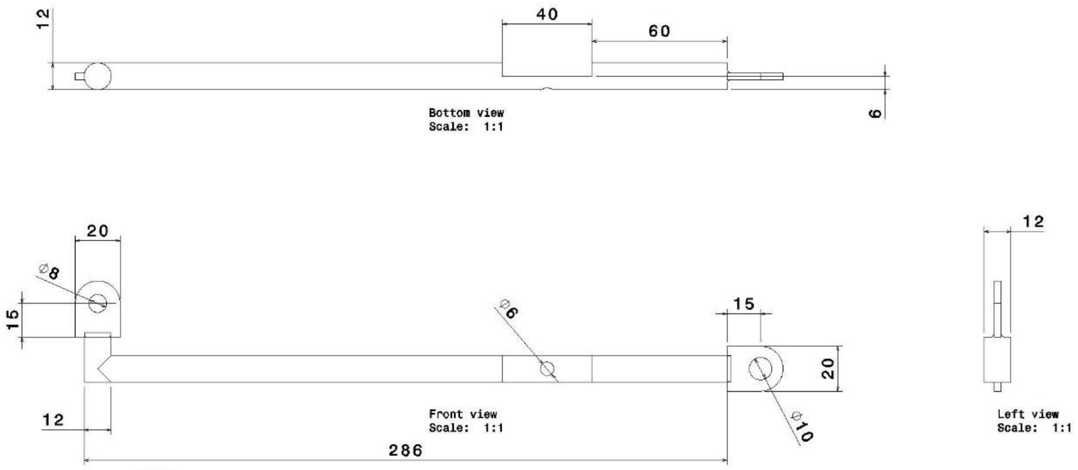


Figure 4.12 CAD Model Part 1 Dimension

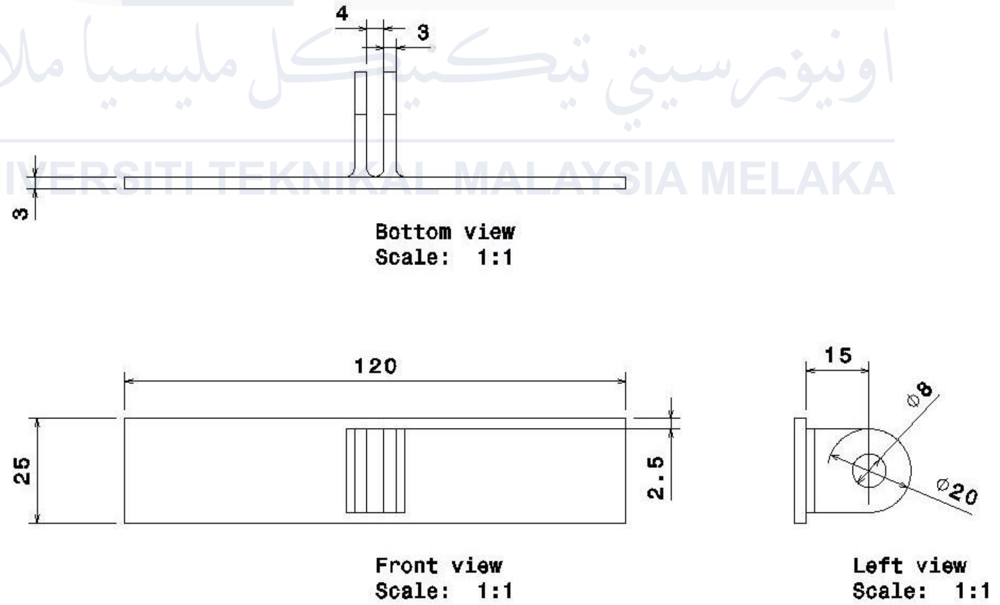


Figure 4.13 CAD Model Part 2 Dimension

4.5 Analysis

The analysis phase includes the performance and structural integrity evaluation of the design using the available analysis tools in CATIA V5. This will ensure that the design meets the required specification and is able to sustain real-world operating conditions. The process of doing this starts by importing the finalized 3D model into the Generative Structural Analysis workbench in CATIA V5, where appropriate material properties. For example, those for mild steel are assigned to the model based on the material chosen.

Next, boundary conditions such as fixed supports, loads and forces are applied to simulate the operational environment. Finite Element Analysis (FEA) is then performed to evaluate key parameters including stress distribution, deformation, displacement and safety factors. Analyzing results to find the weak points and spots where one may need a design modification is the next step. Iterative adjustments are done, if needed, for improvement. This analytical approach ascertains the reliability and strength of the product before final implementation.

4.5.1 Deformation Analysis

Based on the result of the deformation analysis, the structure can be assumed to respond to the applied load and should support the expected stresses without excessive deformation. The design model is further subjected to static loads according to conditions in reality using the Generative Structural Analysis workbench in CATIA V5. This simulation for the operational environment is created with boundary conditions like fixed constraints and distributions of forces. These deformations, represented in Figure 4.13, identify the maximum and minimum displacements due to the applied load.

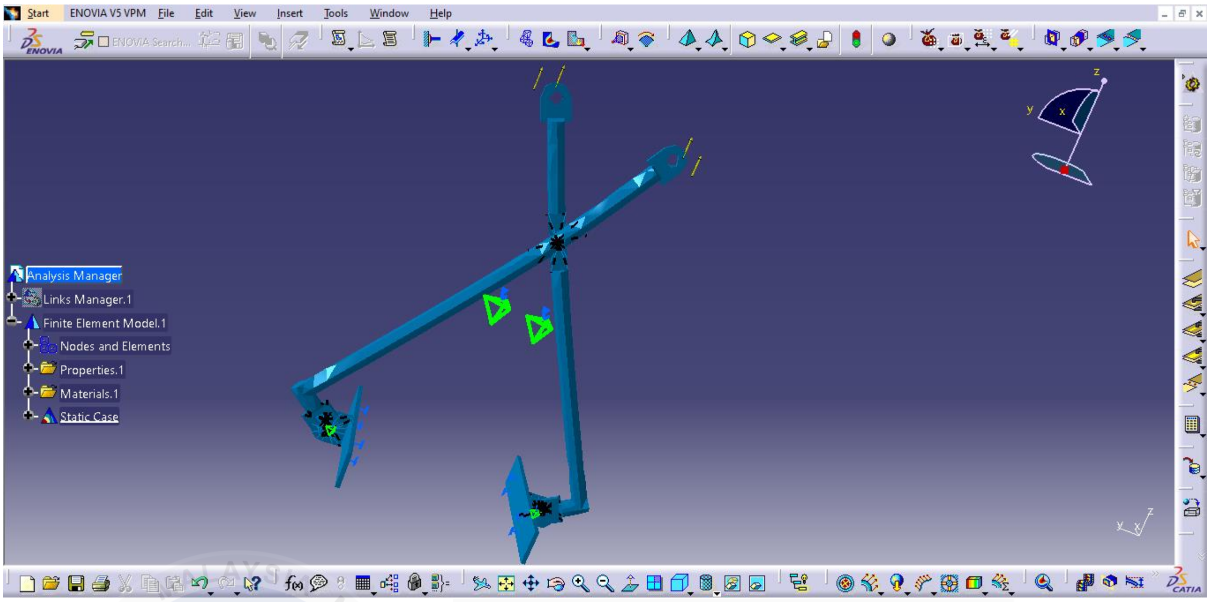


Figure 4.14 CAD Model Deformation Analysis

In such regard, this analysis is important to assure that any possible deformation will be maintained within acceptable limits and hence assures that the structure must be stable and reliable. It therefore becomes very important at this stage to find weaknesses in the designed structure and its behavior at specified operating conditions. In relation to the mentioned above, modification of design needed to go backward and modify any part, which has, or could eventually lead to improved structural integrity and stiffness.

4.5.2 Von Mises Stress Analysis

The Von Mises stress analysis is a critical evaluation to ensure the structural integrity of the design under the applied loading conditions. This analysis determines whether the material will remain within its elastic limit or yield under stress. For this design, a load of 300N was applied and the Von Mises stress distribution was analyzed using the Generative Structural Analysis workbench in CATIA V5. The results as shown in the Figure 4.15 below indicate that the maximum Von Mises stress experienced by the structure is approximately 1.16×10^8 N/m² (116 MPa). This stress occurs at points of maximum load concentration near joints or regions with high geometric complexity. The material used for the design is mild steel which the yield strength of this material is 2.5×10^8 N/m² (250 MPa).

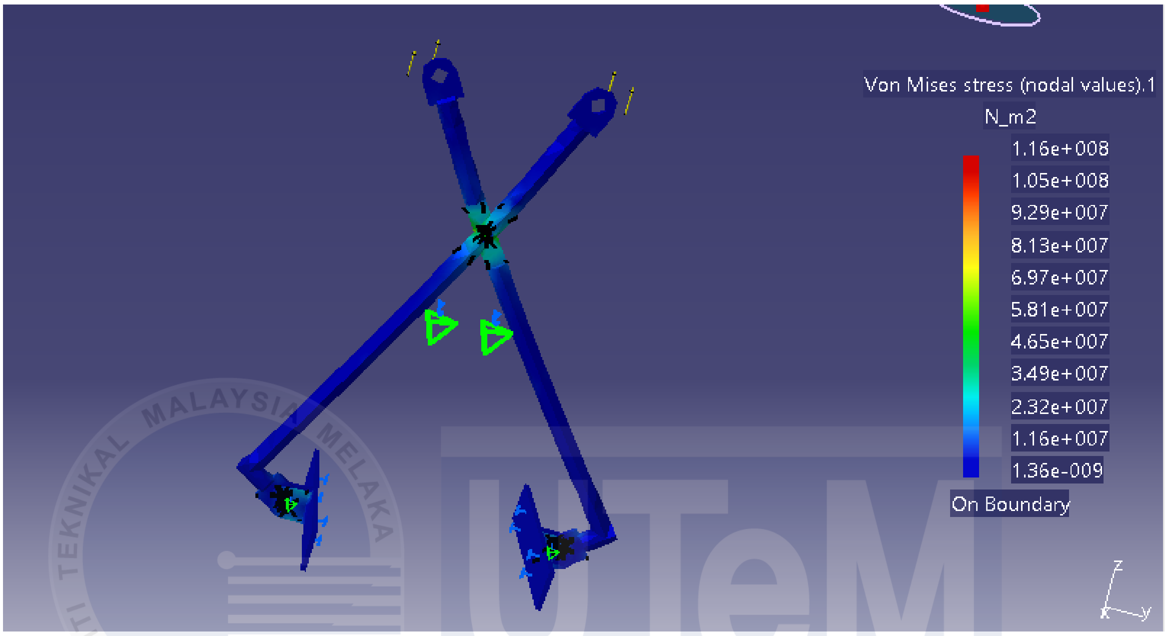


Figure 4.15 CAD Model Von Mises Stress Analysis

The Von Mises stress analysis confirms that the structure remains well within the elastic region of the material under the applied 300N load. No yielding or permanent deformation is expected under these conditions. Since the maximum stress value of 116 MPa is significantly lower than the yield strength (250 MPa) of the material, the design does not fail under the applied 300N load.

4.5.2.1 Safety Factor Evaluation

The safety factor (SF) is an essential metric used to assess how much stronger the design is compared to the applied load. It is calculated using the following formula:

$$Safety\ Factor\ (SF) = \frac{Material\ yield\ strength}{Maximum\ applied\ stress}$$

The safety factor is calculated as:

$$Safety\ Factor\ (SF) = \frac{250}{116} \approx 2.16$$

This safety factor of 2.16 indicates that the design is more than twice as strong as required to handle the applied load. A safety factor above 2 is generally acceptable in most engineering applications as it provides a sufficient margin of safety to account for unexpected stresses, material imperfections or additional loads. The safety factor further reinforces the reliability of the design, ensuring that it can safely operate under real-world conditions while maintaining a margin to withstand higher-than-anticipated stresses.

4.5.3 Translational Displacement Analysis

The translational displacement analysis provides the evaluation of how much a structure deforms and/or moves due to the applied load. This analysis is important in order to ensure that the displacements are within acceptable limits. Large displacements can affect the functionality, alignment, or stability of the structure. Figure 4.16 below shows that when a load of 300N was applied to the structure, the maximum translational displacement was about 0.267 mm shown in red in the displacement vector plot, while it diminishes towards blue areas showing the least movement or no movement at all. This result implies that deformation is concentrated at some regions, particularly where the points are under maximum stress or the structure is least rigid.

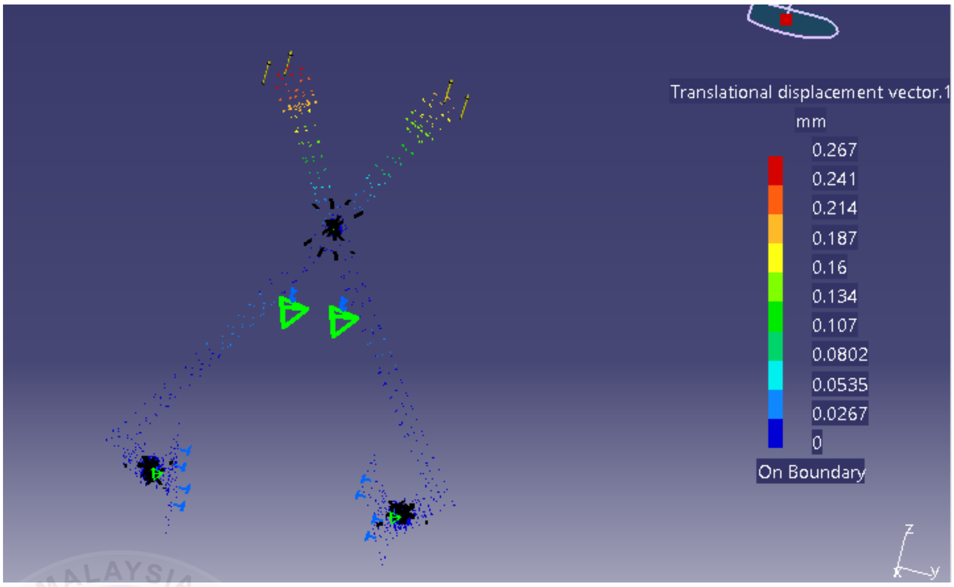


Figure 4.16 CAD Translational Displacement Analysis

The very small value of the displacement magnitude of 0.267 mm indicates high stiffness; hence, the structure can withstand a great amount of deformation due to the applied load. This very small magnitude of displacement ensures that the structure does not lose its dimensional accuracy and functional performance during operation. The displacement magnitude plot by translation confirms the design to be robust and with minimal deformation under the given loading conditions. This will keep the structure stable, reliable, and suitable for its application. Further optimization, if needed, could be done by design measures like reinforcement in weak areas or material property changes that reduce the displacement further.

4.6 Project Fabrication

The fabrication phase involves translating the finalized design from CAD models into a physical prototype. This process begins by selecting suitable materials based on the design requirements such as strength, durability and cost-efficiency. In this project, mild steel was chosen due to its excellent machinability, affordability and reliability for structural applications. Once the materials are procured, the fabrication process starts with measuring, cutting, shaping and welding the components as per the dimensions provided in the design.

Conventional methods such as drilling and grinding are employed for complete this project. The parts are assembled step-by-step to ensuring alignment and accuracy through frequent measurements and inspections. After the primary structure is completed, surface finishing techniques like sanding and painting are applied to enhance durability and prevent corrosion. This systematic approach ensures that the fabricated prototype meets the design specifications and functional requirements for the intended application. Several parts of the prototype fabrication show in Table 4.1 below.

Table 4.1 Parts of The Prototype Fabrication

No.	Picture	Explaination
1.		In this step, a solid rod is being measured and marked based on the design dimensions. This is the first step in the fabrication process where the raw material is prepared by accurately cutting it to the required length and shape.
2.		A mild steel plate was initially measured and marked according to the design specifications. It was then cut, shaped and finally drilled to create these functional components.
3.		Welding techniques were used to join several parts, creating a rigid and interconnected structure. After confirm the dimension and specification, these parts will move to next step (Finishing Process).
4.		This part have been fabricated using a welding process. A finishing process has been applied to enhance their performance and longevity. This processt includes sanding to achieve a smooth surface and painting to provide corrosion resistance.

No.	Picture	Explaination
5.		All individual parts have undergone a finishing process have been assembled and connected to create the final product.
6.		This is the completed product, resulting from the fabrication process based on a chosen design.

4.7 Test Result

The final phase of this project involved testing the fabricated portable ELV battery removal tool to evaluate its performance under real-world conditions. The test was conducted by using the tool to lift and dismantle an actual car battery weighing approximately 10 kg. The objective was to validate the tool's functionality, strength and usability in handling the removal process effectively. The tool successfully lifted and removed the battery without any structural failure or significant deformation as shown in

Figure 4.17 below. The ergonomic design facilitated easy handling and the tool's lightweight construction ensured that it could be maneuvered efficiently by a single operator. Additionally, the straightforward mechanism allowed the battery to be detached smoothly. It shows demonstrating the effectiveness of the design.

Figure 4.17 Product Test Under Real-World Conditions

The accurate test emphasizes the tool's dependability and strength. The selection of mild steel as the primary material contributed to the tool's strength and durability while the design ensured that it could handle the load comfortably. The tool's portability and simplicity further enhance its usability and making it a practical solution for dismantling ELV batteries. This test also validated the design criteria established during the initial phases of the project to confirming that the tool met the requirements for battery removal. The ability to lift and handle a 10 kg battery demonstrates that the tool is well-suited for its intended purpose and can be utilized effectively in real-world scenarios.

4.8 Bill of Material

The Bill of Material is a comprehensive list of all the part, raw materials and hardware required for the fabrication of this project. Table 4.2 below show the bill of material and total cost for this project.

Table 4.2 Bill of Material and Total Cost

No	Part Name	Description	Quantity	Price Per Unit	Total Cost
1	Solid Rod	Mild steel round bar 12mm x 1ft	2	Rm 7.00	Rm 14.00
2	Flat Bar	Mild steel flat bar 50mm x 3mm x 1ft	2	Rm 5.00	Rm 10.00
3	Screw bolt and nut	Screw bolt and nut M8 x 16mm	2	Rm 1.00	Rm 2.00
4	Screw bolt and nut	Screw bolt and nut M6 x 6mm	1	Rm 1.00	Rm 1.00
5	Paint	Samurai spray paint 30/109 black	1	Rm 10.00	Rm10.00
6	Rope	Poly rope 7m x 5mm	1	Rm 3.90	Rm 3.90
Total					Rm 40.90

4.9 Summary

The design, construction, analysis, and testing of the portable ELV battery removal tool was all covered in detail in this chapter. Design drawing was the first step in the development process. Using CATIA V5 CAD software, 2D and 3D models were made based on the measurements of several automobile batteries. Each component of the tool was designed individually and later assembled into a complete model. To validate the design performance a series of analyses were conducted in CATIA V5 including deformation, Von Mises stress and translational displacement analyses. The results indicated that the tool's design could withstand the applied load of 300 N with a sufficient safety factor and demonstrated minimal deformation under stress that confirming its structural integrity.

The fabrication process used readily available materials, mainly mild steel, which was chosen due to its strength and durability at low cost. Simple manufacturing techniques used included cutting, drilling and welding to ensure the tool is accessible and easy to produce. The bill of material was structured in such a way that every component was taken into consideration in order to keep costs efficient and standardized throughout the process. Finally, the tool was tested with a real car battery weighing 10 kg. The test went successfully, it efficiently lifted and dismantled the battery without failure or complications. Based on this, the practical test confirmed that the design could function properly and achieve its goals for this project which to provide an effective, portable and user-friendly solution for the removal of the battery in an ELV.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, this project has successfully achieved its objectives of identifying the design criteria, proposing designs, analyzing and fabricating a portable ELV battery removal tool. Through comprehensive research, design analysis and hands-on fabrication, the project has demonstrated the feasibility and practicality of the proposed tool in improving the efficiency and ease of removing ELV batteries. The findings reveal that integrating multiple simple mechanical principles, accessible materials and straightforward fabrication processes can result in a practical and efficient tool. The tool was constructed using readily available materials and basic fabrication techniques such as cutting, welding and assembly, making it cost-effective and easy to reproduce. Its portability adds to its convenience that allowing workers to operate in various conditions and locations without requiring heavy or specialized equipment.

The importance of this project lies in its potential to improve the efficiency of ELV dismantling operations, especially in battery removal. It is a critical step in recycling and reducing environmental hazards. As the number of end-of-life vehicles increases alongside advancements in electric and hybrid technologies, tools like this will become even more crucial for recycling industries. Overall, this project has been a valuable learning experience, fostering problem-solving skills, technical knowledge, and awareness of sustainable recycling practices. The development of this portable ELV battery removal tool serves as a stepping stone toward more efficient recycling processes and contributes to the ongoing effort to reduce waste and promote sustainability in the automotive industry.

5.2 Recommendation

To improve the functionality and reliability of the portable ELV battery removal tool, several recommendations are proposed for future enhancements that can elevate its utility and market appeal. Firstly, the current rope used as a holder should be replaced with a stronger material such as a chain or high-strength synthetic rope like nylon or polyester. These materials are capable of withstanding higher loads to ensuring durability and safety when handling heavy car batteries. A tensile strength analysis should be conducted to select a chain or rope that can accommodate at least 25–30 kg. This upgrade will significantly enhance the tool's load-carrying capability and reliability during operation.

Additionally, the slider mechanism connecting the two solid rods can be redesigned with adjustable screw bolts and nuts. This modification would allow users to tighten or loosen the connection as needed which can ensuring stability and preventing the tool from moving or shifting while carrying a battery. Furthermore, friction materials such as rubber or silicone should be added to the tool's arms that hold the battery. These materials will provide better grip that can reduce the risk of the battery slipping or falling during use. By securely attaching rubber pads or applying friction coatings to the inner surfaces of the arms, the tool's safety and effectiveness can be further enhanced. Overall, these modifications will improve the tool’s performance, ensuring it remains a practical and efficient solution for dismantling ELV batteries.

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APPENDICES

APPENDIX A Gantt Chart for PSM 1

Gantt Chart for PSM 1																
No	Task Project	Plan / Actual	Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	PSM title registration	Plan														
		Actual														
2	Project briefing with supervisor	Plan														
		Actual														
3	Research about this PSM title	Plan														
		Actual														
4	Introduction Chapter 1	Plan														
		Actual														
5	Literature review Chapter 2	Plan														
		Actual														
6	Design idea brainstorming	Plan														
		Actual														
7	Feature and function specification	Plan														
		Actual														
8	Methodology chapter 3	Plan														
		Actual														
9	Design Sketching	Plan														
		Actual														
10	Writing PSM report	Plan														
		Actual														
11	Sent full report to supervisor for checking	Plan														
		Actual														
12	Presentation PSM	Plan														
		Actual														

APPENDIX B Gantt Chart for PSM 2

Gantt Chart for PSM 2																	
No	Task Project	Plan / Actual	Week														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Prototype design generation	Plan														
		Actual														
2	CAD model development	Plan														
		Actual														
3	Prototype material finding	Plan														
		Actual														
4	Report writing chapter 4	Plan														
		Actual														
5	Prototype material processing	Plan														
		Actual														
6	Prototype assemble	Plan														
		Actual														
7	Report writing chapter 4	Plan														
		Actual														
8	Report writing chapter 5	Plan														
		Actual														
9	Finalize report and send to SV for checking	Plan														
		Actual														
10	Submission of PSM 2 report	Plan														
		Actual														
11	Presentation preparation	Plan														
		Actual														
12	Presentation PSM 2	Plan														
		Actual														