DESIGN AND FABRICATION OF A MANUAL ELV BRAKE PAD AND DISC SEPARATION DEVICE FOR END-OF-LIFE VEHICLE (ELV)

BUDRIZ BIN BERHAMAN

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (AUTOMOTIVE) WITH HONOURS

2025

FACULTY OF MECHANICAL TECHNOLOGY AND ENGINEERING

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

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DEDICATION

First and foremost, I want to thank Allah S.W.T for giving me the chance to be able to produce this thesis. Alhamdullilah.

I would like to thank my family for all the support they have given me, mentally and physically. If it wasn't for them. I wouldn't be able to finish this report.

I would like to extend my gratitude to my supervisor, for the endless support and guidance throughout the process of finishing this report.

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ABSTRACT

End-of-life vehicles (ELVs) pose substantial challenges in recycling due to hazardous materials and the complexities involved in disassembly, particularly with brake components. Brake disassembly is a critical yet risky process, requiring specialized tools and expertise to safely handle materials like asbestos and brake dust. This study aims to address these challenges through the design and fabrication of a manual brake pad and disc separation device specifically for ELVs. The device was developed with a focus on safety, efficiency, and environmental sustainability, featuring ergonomic design, durable materials, and cost-effective fabrication. By analysing existing disassembly methods, identifying risks, and optimizing design parameters, the resulting prototype ensures operational stability and adaptability across various vehicle types. Practical testing and simulations demonstrated its effectiveness in reducing manual labour, improving safety, and facilitating the recovery of recyclable materials. This tool enables safer handling of hazardous materials, reduces environmental impact, and promotes resource conservation by increasing the efficiency of material recovery. Its compact and versatile design makes it suitable for small- and medium-scale recycling facilities, addressing cost constraints and operational inefficiencies in the recycling industry. Furthermore, it supports the circular economy by enhancing the recycling of valuable brake materials while minimizing waste. The study concludes that this device offers a practical and scalable solution for advancing sustainable practices in ELV recycling. Recommendations for future development include the use of lightweight materials for increased portability, modular designs to accommodate a broader range of vehicle models, and semi-automation to further enhance efficiency and reduce labour dependency. By integrating such innovations, the device could significantly contribute to safer, more effective, and environmentally friendly automotive recycling processes, addressing critical gaps in current ELV management systems. This research lays the groundwork for future advancements in sustainable vehicle recycling technologies.

ABSTRAK

Kenderaan Tamat Hayat (End-of-Life Vehicles, ELV) menghadirkan cabaran besar dalam kitar semula disebabkan oleh bahan berbahaya dan kerumitan dalam proses pembongkaran, terutamanya komponen brek. Pembongkaran brek adalah proses kritikal tetapi berisiko, yang memerlukan alat khas dan kepakaran untuk mengendalikan bahan seperti asbestos dan habuk brek dengan selamat. Kajian ini bertujuan untuk mengatasi cabaran tersebut melalui reka bentuk dan pembuatan alat manual pemisah pad dan cakera brek khusus untuk ELV. Alat ini dibangunkan dengan penekanan pada keselamatan, kecekapan, dan kelestarian alam sekitar, menampilkan reka bentuk ergonomik, bahan tahan lama, dan kos pembuatan yang efektif. Dengan menganalisis kaedah pembongkaran sedia ada, mengenal pasti risiko, dan mengoptimumkan parameter reka bentuk, prototaip yang dihasilkan memastikan kestabilan operasi dan kemampuan menyesuaikan diri dengan pelbagai jenis kenderaan. Ujian praktikal dan simulasi menunjukkan keberkesanannya dalam mengurangkan tenaga kerja manual, meningkatkan keselamatan, dan memudahkan pemulihan bahan kitar semula. Alat ini membolehkan pengendalian bahan berbahaya dengan lebih selamat, mengurangkan impak alam sekitar, dan menyokong pemuliharaan sumber dengan meningkatkan kecekapan pemulihan bahan. Reka bentuknya yang padat dan serba guna menjadikannya sesuai untuk kemudahan kitar semula berskala kecil dan sederhana, menangani kekangan kos dan ketidakefisienan operasi dalam industri kitar semula. Tambahan pula, ia menyokong ekonomi kitaran dengan meningkatkan kitar semula bahan brek berharga sambil meminimumkan sisa. Kajian ini merumuskan bahawa alat ini menawarkan penyelesaian praktikal dan boleh skala untuk memajukan amalan lestari dalam kitar semula ELV. Cadangan untuk pembangunan masa depan termasuk penggunaan bahan ringan untuk meningkatkan mudah alih, reka bentuk modular untuk menampung pelbagai model kenderaan, dan separa automasi untuk meningkatkan lagi kecekapan serta mengurangkan kebergantungan pada tenaga kerja. Dengan mengintegrasikan inovasi ini, alat ini dapat menyumbang dengan ketara kepada proses kitar semula automotif yang lebih selamat, berkesan, dan mesra alam, mengatasi jurang kritikal dalam sistem pengurusan ELV semasa.

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LIST OF ABBREVIATIONS

ELV	-	End-of-Life Vehicle
NAP	-	National Automotive Policy
ARL	-	Automobile Recycle Law
EPR	-	Extended producer responsibility
RCRA	-	Resource Conservation and Recovery Act
NVMSRP	-	National Vehicle Mercury Switch Recovery Programme
EU	-	European Union
MAARA	-	Malaysian Automotive Recyclers Association
UTM	-	Universiti Teknologi Malaysia
ABS	-	Anti-lock Braking System
ESC	-	Electronic Stability Control
CAD	-	Computer-Aided Design
STL	-	Stereolithography

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CHAPTER 1

INTRODUCTION

1.1 Background

Given Malaysia's significant dependence on automobiles for transportation, it is evident that the quantity of cars on the road is substantial and continues to rise year. The prevailing belief among Malaysians is that driving is the most effective mode of transportation for travelling between different locations. This not only exacerbates pollution but also increases the volume of automobiles on the road.

In Malaysia, there is a noticeable pattern of people frequently replacing their cars. This behavior, if continued, will lead to increased pollution in the environment. Additionally, owners of these unused vehicles often choose not to sell or dispose of them. In the end, these cars that are not going to be used are going to take up spaces that are supposed to be used and it will create a problem in terms of waste disposal. This issue exists mainly because of the lack of recycling strategies and also the lack of law enforcement.

The improper techniques for the recycling and scrapping of the vehicles can bring to many effects especially to the environment. Dangerous substances, such as battery acid and oil from the engine and transmission can bring harm. The lack of agencies and organizations for the disposal of End-of-Life Vehicles (ELVs) in Malaysia are to blame for. Furthermore, the lack of knowledge of the public about the dangers are worrying. Further steps are to be taken to ensure that in the future, the disposal of End-of-Life Vehicles are handled properly and the materials that are retrieved are being recycled back.

1.2 Problem Statement

End-of-Life Vehicles (ELVs) disassembly process takes time and it also involves a heft amount of financial cost. This is because the process of removal is risky and hazardous materials are present and is requires heavy safety measures. Among the disassembly process in a vehicle, one of the notable components that needs skill and knowledge to disassemble is the brake components. The brake components that consist of the brake pads, disc, callipers are challenging because of their characteristics. Skilled workers are needed during this process and they should have the required knowledge of how to disassemble the brake models the correct way.

The disassembly of brake components requires a lot of attention to detail because of the complexity of the brake component. The correct tools and knowledge are needed for the process because the consequences of not using the right tools or not having enough knowledge can bring serious harm. The workers may get injured due to the improper handling. Lack of knowledge or experience may bring risk to the recycling of the component because the brake parts can be damaged and the potential of them being reused or recycled will significantly be reduced. Efficient process is crucial because it will deeply affect the operational cost and therefore making the cost of the disassembly much higher overall.

The impact on the environment as a result of managing and the recycling of brake parts also has massive effect. The lack of improper management can create a considerable number of consequences in term of ecological such as the brake pads that contain dangerous materials such as asbestos or heavy metals. It is important to dispose of the materials properly and recycles the ones that can be recycles in order to avoid the potential harming of the environment. To ensure these issues are avoided, proper training and tools are needed for the right job. Recycling of these materials that are obtained from the brake parts will help in conserving natural resources but it also reduces the burden of landfills by recycling the materials.

1.3 Research Objective

The main objective of this research is to design and fabrication of a manual ELV brake pad and disc separation device to

i. To identify current method of brake separation from End-of-Life Vehicles
ii. To propose and analyze design of tool for dismantling End-of-Life Vehicle brake assembly.
iii. To develop 3D printed prototype for dismantling of End-of-Life Vehicle brake assembly

1.4 Scope of Research

The scope of this project is as follow:

i. Study existing methods and tools used in dismantling of brake assembly from End-of-Life vehicles.
ii. Develop and create a prototype tool specifically designed for disassembling brake components.

iii. Perform a sequence of assessments to measure the effectiveness of the jig in practical disassembly situations.

iv. Establish clear design specifications and choose appropriate materials for disassembly of brake components.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

As of May 2022, Malaysia has 33 million registered vehicles and with 19 million of them being a decade old. This data alone shows that most Malaysians prefer to use cars as their main mode of transportation. This is highly due to the fact that other modes of transportation are not fully developed in Malaysia and thus people have the need to own vehicles in certain places. Public transportation is available in Malaysia but however they are frequently congested and have limited service that cannot accommodate to everyone. The lack of adequate public transportation in many smaller towns and rural areas makes owning a car as a necessary. **Figure 2.1** shows the detailed overview of the vehicle's lifecycle that consists of new or used caars and the end -of-life processes.

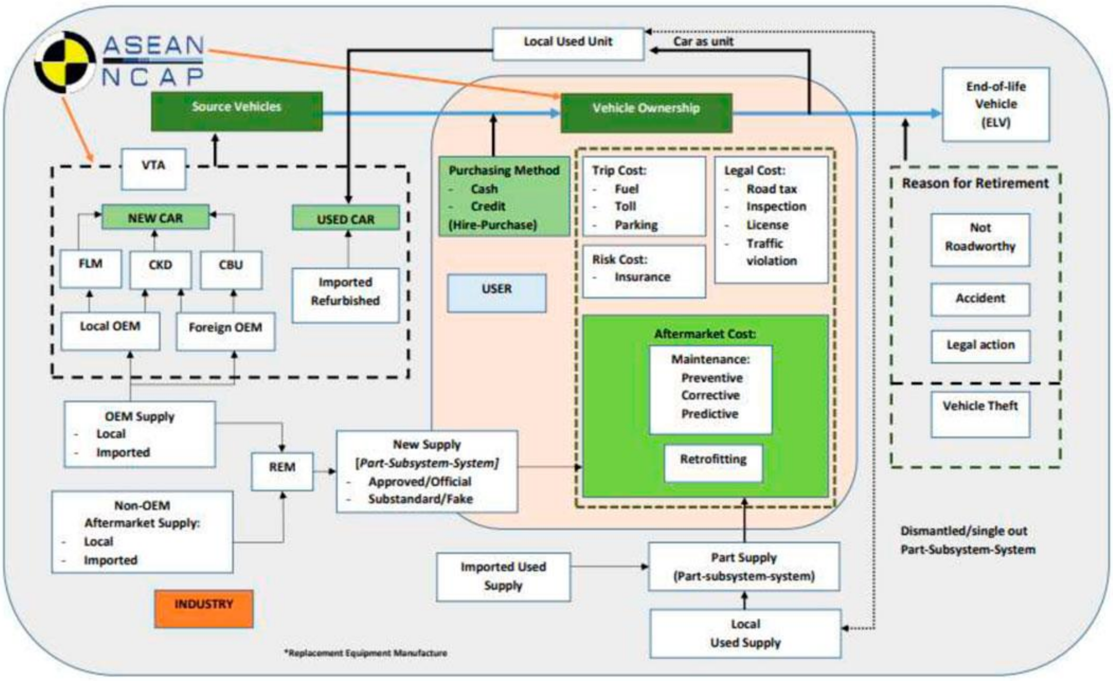


Figure 2.1 Automotive Ecosystem (*retrieved from ResearchGate.com, 2024*)

The ever-increasing ownership of cars in Malaysia means that new cars are coming in and old ones are being abandoned. This is a challenge to not only in Malaysia but to the whole world as the automotive sector generates about 5% of industrial waste in the entire world and older cars are left to deteriorate in places that are unsafe. The increase in ownership of vehicles also means that the number of vehicles that are being abandoned will also increase as some people may replace their car, but others will buy a better one without selling their old one, which will then be left behind.

2.1.1 Definition of ELV

End-of-Life Vehicles (ELVs) are vehicles that have been abandoned by their owners due to several factors. The vehicles could have been involved in accidents and in the end, it cannot be fixed or it can be too costly to fix. Other factors could include that the vehicle have been used for a long period of time and wear and tear have occurred. Finally, these vehicles are found to be parked in nearby neighborhoods and residents houses that could actually cause great harm to the environment and also the people nearby. ELVs are considered to be hazardous waste and there is a possibility that they may pollute the environment if appropriate steps are not taken properly (Simic, 2016). Vehicles that are left to be abandoned and parked, are considered to be very costly to repair or maybe the parts that are needed are not manufactured anymore.

Existing practices that are used currently in the processing and recycling of ELVs are considered to be insufficient to handle materials that are stored in these vehicles and thus they are deemed a threat. According to the study that is done by (Kumar & Sutherland, 2008), the leaching of these contaminants can have long term impact to the ecosystem and thus influence the health standard of the people living nearby. Leaching of contaminants such as oils, heavy metals and asbestos fibers. These pollutants can accumulate in the food chain and affect plants, animals and humans. Likewise, (Zhou et al., 2019a) argue in the Journal of Environmental Management that inadequate management of ELV materials is a factor that leads to environmental pollution in regards to recycling and disposal of the same materials (Zhou et al., 2019a). **Figure 2.2** shows an abandoned car in a residential parking lot, it is a clear sign of nelect from the owner and the vehicle is nearing the end of the lifecycle.

Figure 2.2 Abandoned vehicle near residences *(Retrieve from MediaMadani.com, 2025)*

2.1.2 Significant of ELV

End-of-Life Vehicles (ELVs) brings significant environmental benefits especially in preserving natural resources and reducing the greenhouse effect in the long term. Effective ELV practice will reduce the usage of materials such as steel. One primary advantage that can be seen is that the conservation of materials such as steel which is a significant component of a vehicle. Out of this conservation endeavor, much of the environmental costs such as habitat loss, water pollution and land degradation attributed to mining are offset (Jody et al, 2010). The recycling of metals from ELVs requires a considerably less amount of energy compared to that needed to extract metals from virgin materials, thus reducing overall emissions of greenhouse gases. Vehicles that have become ELVs should be disposed of accordingly to prevent environmental pollution and for the purpose of recycling useful materials, particularly metals (Harun et al., 2021).

Furthermore, ELV management reduces the release of hazardous substances into the environment. The proper disposal and reuse of these hazardous materials will prevent contamination of soil and water and thus protect the surrounding ecosystem and human health overall (GHK, 2006). ELVs not only have metals but they also have plastics, rubber, and glass. Plastics, rubber, and glass will take a long time to decompose in landfills, which in term will contribute to long term environmental pollution. The emergence of excessive water, air, and soil pollution has resulted in more attention being given to the ELV management problem in the latest Malaysian National Automotive Policy (NAP), introduced in January 2014 (Ministry of International Trade and Industry, 2014). This is why ELV management needs to be implemented globally, and it needs to be taken seriously for a better future.

2.1.3 Practice of ELV

The management of End-of-Life Vehicles (ELVs) is a critical aspect especially when it comes to environmental sustainability. It involves the recycling and disposal of vehicles that have reached the end of their operational life. There are various of practice around the world that examines the current practice and future prospects of ELV management especially in Malaysia, where ELV management is still yet to be further developed. The various practices that are conducted across countries are with variations in the extent of regulatory measures and industrial involvement. End-of-Life Vehicles (ELVs) are another important area as far as management is concerned, especially in relation to the topic of environmentalism. It is the process of managing the vehicles that have become scrap after the amount of time that they have been used. Different practices have been used all around the world and there are possibilities in where the ELV management will further improve. These practices are various in supervision and profession involvements (Nizam et al., n.d.)

In Malaysia, efforts are ongoing to develop a formulate an effective ELV policy and its operational framework that can fit into the larger national environmental management strategy (Harun et al., 2023). These measures are highlighting the importance of developing a viable and greener approach towards in managing ELVs. An example that can be seen and can be set as an example is from Japan. This is because Japan has an excellent example and they are stringent with the legal structures and also the support from the government that implements policies that ensures that ELVs have to be handled properly. Currently, Japan has an ELV management that is regulated by Automobile Recycle Law (ARL), that was enacted in the year 2005. It states that vehicles components have to be recycled and be reused to be recycled for further use, this included air conditioners and also airbags. According to the law that has been implemented, it has been established that the manufacturers of the vehicles have to be responsible for the recycling, collection, and disposal of the ELVs (Zhou et al., 2019b). This way, vehicles will be handled properly as new cars are produced and old ones have to be disposed of.

Furthermore, the Automobile Recycle Law (ARL) states that stakeholders must submit their recycling reports that states that they have done their recycling. The reports must be handed to the government in order to ensure the adherence to the law that is set and promote transparency. Not complying to this may bring consequences such as fines that can be taken and also temporary closure of the business. **Figure 2.3** shows a vehicle that is being towed away due to traffic violations because of it is improperly parked.

Figure 2.3 Vehicle being towed *(Retrieved from thesun.my, 2024)*

While there are countries that have enacted the ELV management laws at national level to cover for the management, recycling, and disposal of the ELVs, United State of America rely on a combination of voluntary measures, market mechanisms, and state laws. Some countries have implemented Extended Producer Responsibility (EPR) that requires manufacturers of automobiles to accept responsibility for effective disposal of their products at their end-of-life cycle. Hazardous wastes generated are disposed of in accordance with the statutory provision of Resource Conservation and Recovery Act (RCRA) to ensure that batteries and mercury switches among other are treated appropriately. The car industry, environmental non-governmental organizations, and the government cooperate in the entirety of voluntary initiatives such as the National Vehicle Mercury Switch Recovery Programme (NVMSRP) which entails in the removal of harmful parts from ELVs (U. S. Environmental Protection Agency, 2021). **Figure 2.4** shows a vehicle recycling center

Figure 2.4 Shredding process *(retrieved from RecyclingInside.com, 2024)*

One of the strictest and thorough End-of-Life Vehicle (ELV) management systems in the world has been put in place by the European Union. Directive 2000/53/EC, also referred to as the ELV Directive, sets forth the EU's strategy and attempts to reduce waste from automobiles while encouraging the collection, reuse, and recycling of its parts. The Directive mandates that 95% of the weight of ELV must be reused, recycled or recovered. The ambitious goal set by the European Parliament and Council Directive 2000/53/EC is to minimise the quantity of automotive waste that is disposed of in landfills (Arditi, 2023). By having this approach, it will promote the development of environmentally friendly automotive technologies and materials that will reduce the environmental footprint that is produced by the automotive industry. This directive will also ensure that that member state to establish collection systems for ELVs, ensuring that vehicles are processed in authorized treatment facilities. **Figure 2.5** shows the recycling process for End-of-Life Vehicle (ELVs) which highlights processes such as decontamination, sorting and recycling of materials which can minimize waste and support the sustainability for the automotive industry.

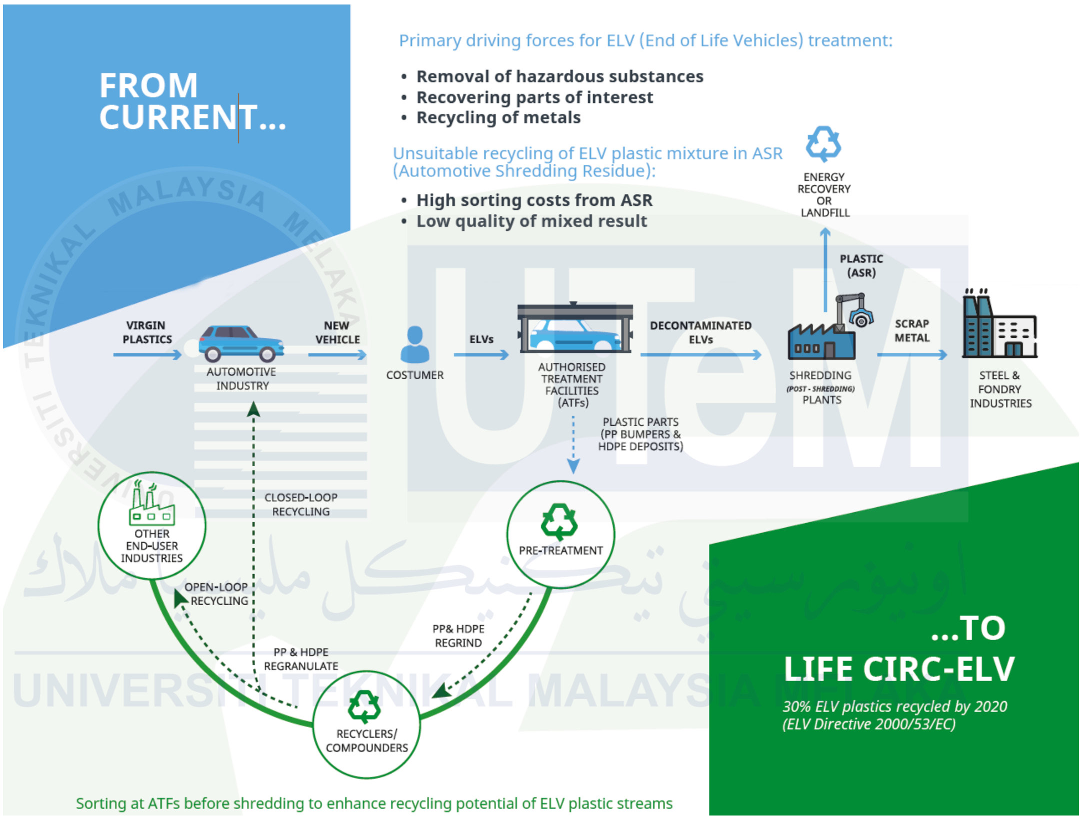


Figure 2.5 EU plans on ELV *(retrieved from Life Circ-ELV.com,2024)*

Malaysia is in the process of developing and enhancing the End-of-Life Vehicle (ELV) management system. There are several challenges in implementing the effectiveness of ELV management due to a lack of infrastructure, regulatory frameworks, and public awareness. Malaysia lacks infrastructure that is suitable for ELV recycling and therefore many vehicles are not processed in facilities that are not equipped to handle hazardous materials and recover valuable components (Molla, Moghtaderi, et al., 2023)

Recent studies and recommended policies propose the use of organized systems for End-of-Life Vehicle (ELV) management in Malaysia. These recommendations are influenced by successful models in nations such as Japan and the European Union. Policies such as the manufacturers should be responsible for the end-of-life management of their products. In Malaysia, the top manufacturers in the nation are Proton and Perodua. In the year 2023 alone, Proton and Perodua captured a combined market share of 66.9% in 2023 which is the highest level since the early 2000s. This shows that, more cars are going to be on the road and therefore older cars are eventually going to be classified and end-of-life vehicle. Therefore, manufacturers should figure out a way to manage the problem before it's too late (Jawi et al., 2016).

In the future, Malaysia aims to develop a cohesive ELV management policy by 2025, which ensures the focus on sustainability and environmental protection. This includes to improve recycling infrastructure to further improve the recycling process of materials and also to make the process more efficient and safer. Other than that, awareness among the public should be implemented nationwide on the environmental impacts of improper ELV disposal and the benefits of recycling (Sitinjak et al., 2022). Furthermore, steps are being made by the Malaysian Automotive Recyclers Association (MAARA) and with collaboration with Universiti Teknologi Malaysia (UTM) to develop an ELV blueprint by 2025 (*MAARA And UTM To Develop The End-of-Life Vehicle Blueprint By 2025 - Auto Recycling World*, n.d.)

2.2 Dismantling Practice of ELV

Managing End-of-Life Vehicles (ELVs) is a crucial component in working towards an environmental sustainability and resource conservation initiatives. As vehicles are left to be abandoned by their owners, overtime they will create unwanted pollution that will cause damage to nature and to the surrounding. To avoid contamination, the vehicles have to be brought to a place where it is suitable to tear the vehicle down piece by piece. This is because, most of the ELVs can be found in residences where their owners left the car to be parked for a long amount of time. The vehicles that are brought are deemed unsafe and therefore they cannot be used on the road anymore.

When a vehicle is deemed total lost, the cost of fixing the vehicle or returning the vehicle to its original state will not only be costly but it will also be time consuming. Therefore, the vehicle will be classified as an ELV. The vehicle will then be transported to a specialized facility where the vehicle will undergo a few steps to ensure the vehicle is disposed of in an environmentally responsible manner while maximizing the recovery value of the materials that are still salvageable to be used. Moreover, recycling and reusing parts from ELVs contribute to resource conservation, reducing the need for new raw materials and promoting a circular economy (Chong et al., 2023a)

The vehicle will undergo inspection at the specialized facility and the initial step is to safely remove the hazardous materials. This involves properly disposing of fluid that are contained in the car such as the engine oil, transmission fluid, coolant, brake fluid and also fuel. This is important because these fluids need to be disposed of properly because the elements in these fluids are hazardous and can cause significant environmental damage not only to the environment but also pose risk to the ecosystem and human health. In addition, the extraction of air conditioning refrigerants, batteries, and other dangerous components such as airbag units and mercury switches are carried out to prevent environmental contamination (Chong et al., 2023b; Fonseca et al., 2013)

Following the removal of hazardous materials from the vehicle, what's left is the materials that can be reused and recycle. Valuable components are carefully removed such as the engine, transmission, alternator and the starter motor and other electrical parts. These parts are often still functioning and can be refurbished so that it can be used again. These parts are often inspected, refurbished if necessary, and sold for reuse, which helps to conserve raw materials and reduce the demand for new parts (Xu et al., 2019). There is usually a good market for these refurbished components as they are cost effective to new parts for vehicle and upgrades especially towards classic cars collectors where components for their vehicle are not being produced anymore (Environmental Protection Agency, 2017).

After valuable components have been removed and all what's left is just the vehicle shell itself, the vehicle will undergo a shredding process. Recycling as mentioned above involves the act of cutting the vehicle into smaller parts where the constituent materials and components could be separated effortlessly. The resulting materials are also divided into various material categories including metals, plastics and glass materials. These materials can be recycled and utilized in producing other good products. For instance, it can be reused in manufacturing after being melted down and thus reduces the amount of raw material raw materials; the use of new metal and hence reduces the negative effects on environment when mining and processing new metals. This process not only helps to preserve the materials from natural resources but also the energy and greenhouse gas emissions lower more than the production of new metal production (Innovating Solution for the Material Recovery from End-of-Life Vehicle (ELV) Shredding Residues - RecyclingInside, n.d.).

Any leftover scrap which cannot be recycled is also disposed of in a pollution sensitive manner in accordance to the industry norms. This is to ensure that no materials are left that can be harmful to the environment and to the surrounding. Practices that are done the correct way will ensure that valuable materials can be recovered and hazardous materials can be safely managed. Recycling glass from ELVs, for example, involves environmental impact assessments to determine the best recycling practices (Manshoven et al., n.d.) During the process of dismantling, the tools used by the workers are tools that are suitable for the job and is appropriate. They are also trained to prevent any hazardous exposure to the surrounding and to dispose of hazardous materials properly. Safety is the main priority when it comes to the dismantling process and also the materials that are going to be salvaged. It is important to note that when dismantling, the materials that are going to be recycled and reused are going to be in a condition where they are reusable, meaning that the workers have to be precise when dismantling the materials from the vehicle.

2.2.1 Benefit of Dismantling ELV Part

Dismantling End-of-Life Vehicles (ELVs) provides numerous benefits across various dimension that includes the economy, social welfare and the environment. End-of-Life Vehicles (ELVs) are known to contain valuable materials such as metals, plastics and rare eat elements which can be recovered and also reintroduced.

The dismantling and recycling sector has substantial employment prospects, offering positions for proficient workers required to operate dismantling facilities, handle hazardous materials, and handle recyclable components (A Study of Current and Future Workforce Needs Recycling and Jobs in Massachusetts, n.d.). This not only creates employment opportunities but also bolsters local economies. Through the process of disassembling End-of-Life Vehicles

(ELVs), important resources including metals, polymers, and rare earth elements are extracted and can be reused in manufacturing, hence reducing the demand for new materials and decreasing production expenses (Petrauskienė et al., 2022). Moreover, intact components that have been disassembled and are still in excellent condition can be restored and marketed as used parts, so establishing a market for cost-effective car components that are advantageous for both consumers and automobile repair enterprises (Numfor et al., 2021). **Figure 2.6** shows a technician in protective gear removing hazardous materials at a certified recycling facility.

Figure 2.6 Worker working on vehicle *(retrieved from ELVTraining.com)*

When we look at it from a community angle, properly taking apart and disposing of dangerous substances in old vehicles like batteries, oils, and coolants helps cut down on pollution and health risks. This not only makes neighborhoods safer but also lightens the load on healthcare systems. Building dismantling and recycling centers can boost local economies by creating jobs and supporting small businesses. This leads to better infrastructure and services in these areas (Rovinaru et al., 2019). Plus, the need for skilled workers in the dismantling field pushes schools to offer specialized training, making the workforce more knowledgeable and encouraging lifelong learning.

From an environmental standpoint, breaking down old vehicles significantly reduces landfill waste. By recycling and reusing parts, we cut down on automotive waste, promoting a cleaner and more sustainable environment. This process also conserves natural resources by reducing the need for new raw materials, which often harm the environment. Reusing materials generally uses less energy than making new ones, thus lowering greenhouse gas emissions and helping fight climate change. Properly managing and recycling hazardous substances also prevents soil and water pollution, protecting ecosystems and ensuring that both animals and humans aren't exposed to harmful chemicals (Molla, Shams, et al., 2023).

2.2.2 Challenge in Dismantling Practice

The issue being faced in dismantling End-of-Life Vehicle (ELVs) is the dismantling process that is not being faced companies internationally. However there a lot of challenges that can hinder efficiency, safety and efficacy in the process of implementing this method. These concerns include and go as far as technical, regulatory, environmental and economical.

Overtime, vehicles have developed and have changed in a better wat compared to it was before. Disassembling a modern car can come with its difficulties due to the fact that the vehicles know heavily depend on electrical system and the use of sophisticated materials. Specific knowledge and tools are crucial in dismantling of the equipment from the ELVs because improper knowledge and tools will have a higher chance on destroying components that are valuable and that can be recycled (Barwood et al., 2015). The components that are found in ELVs are considered hazardous and having specialized tools and knowledge is not considered to be enough, having proper protective gear is crucial so that the worker is not exposed to the hazardous materials that are present during disassembling. Technologies play a big part in ensuring the high purity of materials that are recycled but they are costly and require high technical expertise (*End-of-Life Vehicles (ELVs) - EuRIC*, n.d.).

Pollution control throughout the dismantling process of components and materials is a big challenge from an environmental perspective. Contamination of the land and water can occur when dangerous liquids are unintentionally released or discharged. Strict pollution control measures need to be put in place and regularly monitored in order to minimize the impact on the environment). Furthermore, in order to minimize the amount of landfill space used and guarantee the environmentally responsible disposal of non-recyclable materials, it is imperative that non-recyclable trash generated during the deconstruction process be managed (Mensah et al., 2023).

Social and labor issues complicate the dismantling process even further. The specific knowledge required to handle dangerous materials, run complicated machinery, and adhere to safety protocols is lacking in the workforce. The effectiveness and security of disassembly procedures may be hampered by this deficiency. In addition, workers in dismantling facilities run the risk of suffering from a variety of health and safety hazards, including as ergonomic problems, exposure to dangerous substances, and physical injuries from machines. According to (*OSHA Worker Rights and Protections | Occupational Safety and Health Administration*, n.d.) maintaining a safe workplace necessitates continual training, using safety gear, and strictly adhering to safety rules. **Figure 2.7** shows the outline of end-of-life process for cars from the delivery of the cars to the recycling center and the process of dismantling and sorting.

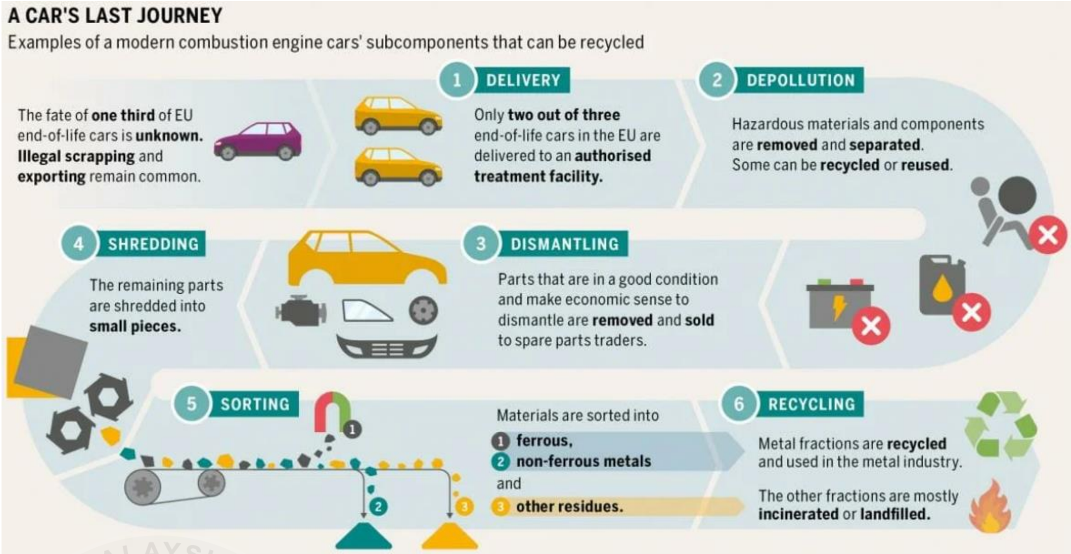


Figure 2.7 Infographic on A Car's Last Journey (*retrieved from projectdriven.eu,2024)*

The process of dismantling end-of-life vehicles (ELVs), which is crucial for promoting environmental sustainability and recovering valuable resources, encounters various obstacles in terms of technical, regulatory, environmental, economic, and social aspects (Wang et al., 2021). To tackle these difficulties, it is necessary to make substantial investments in technology and infrastructure, comply with strict rules, implement effective waste management techniques, and cultivate a highly skilled staff. By surmounting these challenges, the dismantling sector may enhance efficiency, safety, and environmental results, so contributing to a more sustainable future (Schmid et al., 2016a).

2.2.3 Technological Advances in ELV Dismantling

End-of-Life Vehicles (ELVs) have come a long way and since then, there have been a big significant improvement due to the technological advances over the years. From this, we can see that innovations have been made to enhance the efficiency of dismantling process of ELV. These advancements not only help the efficiency of dismantling the dismantling but only help to keep the safety of the workers as they are not exposed to dangerous and hazardous materials that could seriously bring harm to them.

One notable advancement that can be seen is that the development of a machine based dismantling process. This machine will help the dismantling of the vehicles and according to (El Halabi et al., 2015), machine-based dismantling has been proven to be an alternative to traditional manual dismantling, offering significant benefits in terms of labor safety and also the speed of processing the much-needed materials for recycling for the vehicles. This will be a much faster process. Besides that, by having machines doing the work less error will be present. **Figure 2.8** shows a robotic arm that handles especially electric vehicles batteries. Critical components like these must be carefully extracted for reuse and recycling.

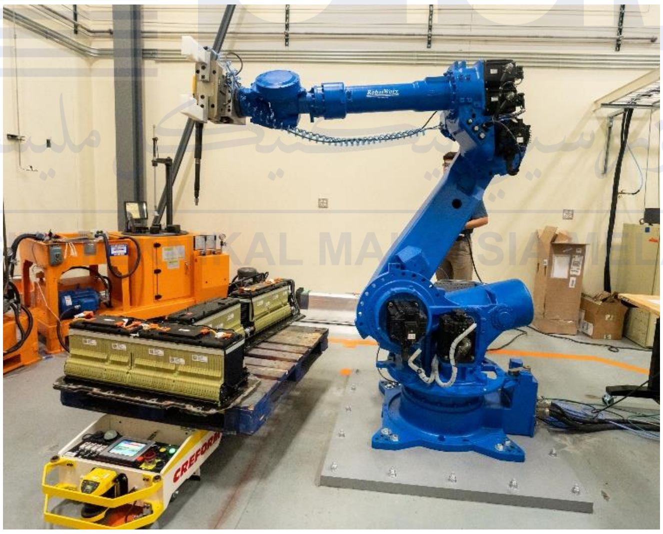


Figure 2.8 Robotic Disassembly Machine *(retrieved from BatteryPowerOnline.com,2024)*

Other than that, the advancement in the robotic technology field not only helps in the production of new vehicles that are coming out every year, but it also helps with the dismantling of much older vehicles that are no longer in service. (Tarrar et al., 2021) highlighted that by the integration of robotics in the dismantling process of End-of-Life Vehicles, there has been reduced human error and the recovery of materials and reusable components from the vehicle has increased which in turn, contribute to higher economic and environmental benefits.

Another notable improvement with the involvement of technology in the dismantling process of ELV is that the advance sorting technologies. The use of automated sorting system, with the help of sensors and also artificial intelligence can identify what type of materials are obtained from the vehicles. From there, it can be sorted into groups of the same material. This technology significantly enhances the recycling rates and also the purity of the recovered materials and thus increasing the sustainability of the dismantling process of ELV (Schmid et al., 2016b).

Technological advancement has made a big difference in the dismantling of ELVs, and making the process more efficient to obtain valuable materials that are going to be used for recycling. Other than that, by having machines do the dismantling, workers are at less risk of having to be exposed with dangerous and hazardous materials that could be present during the disassembly process. These improvements are essential for the advancing the recycling industry for ELV and also the contribution to a more sustainable future.

2.3 ELV Brake

The brake system of an End-of-Life Vehicle (ELV) is an essential component that necessitates careful handling during the disassembly and recycling procedure. Brakes consist of several elements, including metals, fluids, and potentially hazardous chemicals. Consequently, it is imperative to manage them appropriately in order to guarantee the preservation of the environment, the recovery of resources, and safety. This study explores the challenges associated with ELV brake systems and outlines the most effective approaches for recycling and managing of these components (Ng & Jönköping, 2018).

The intricate structure of ELV brake systems presents a significant challenge in their administration. Modern brake systems are composed of a variety of materials such as steel, cast iron, aluminium, copper, and various polymers. Furthermore, brake pads and shoes may contain perilous compounds such as asbestos, heavy metals, and other friction materials, which adds complexity to the process of dismantling and recycling. If not properly managed, the existence of dangerous substances, specifically asbestos found in older brake pads, presents substantial health hazards to workers. Asbestos is a well-established hazardous material, and its fibers can become airborne during the process of dismantling. Utilizing specialized equipment and strictly following rigorous safety protocols are necessary for this task (*Practitioner's Guideline on Depollution on End-Of-Life Vehicles: Depollution Guideline*, 2023).

Another obstacle is the gradual deterioration that brake components experience, leading to potential contamination from metal fragments, dust, and damaged friction compounds that could heavily affect the surroundings (Hagino, 2024). Effectively controlling these pollutants is essential to guarantee that recycled materials are devoid of impurities and appropriate for reutilization. Moreover, the introduction of sophisticated braking technology like anti-lock braking systems (ABS) and electronic stability control (ESC) has increased the intricacy of the disassembly procedure. These systems include electronic components that require careful handling and recycling (Moaref et al., 2024).

From an ecological standpoint, effectively managing pollution throughout the process of dismantling is a substantial obstacle. Discharges and releases of dangerous fluids such as brake fluid have the potential to pollute soil and water, requiring strict pollution control methods and monitoring to reduce environmental harm (Isabel Suárez Mayor et al., 2017). Furthermore, it is imperative to efficiently manage the non-recyclable waste generated during the deconstruction process to minimize the quantity of refuse transported to landfills and ensure the environmentally responsible disposal of non-recyclable materials.

Adhering strictly to legal regulations is of utmost importance when it comes to the elimination, packaging, and disposal of brake components that contain asbestos. In order to protect both the environment and workers from the release of asbestos fibers into the air, it is necessary to use specialized instruments and follow specific protocols (New Zealand, 2016). In addition, metals that have been recovered from brake systems can be recycled and reintroduced into the production process, hence reducing the need for raw materials. According to (Zupanc et al., 2023), the automotive industry can save money by using non-metal parts like brake drums and callipers that are reusable and refurbished.

It is important for dismantling facilities to keep up with technological improvements in brake systems, such as ABS and ESC. Ensuring that personnel are trained in the most up-to-date technologies and providing them with suitable tools and equipment for dismantling are crucial for optimizing recycling processes. Implementing these optimal methods allows for the successful resolution of the difficulties related to the management of ELV brake systems, guaranteeing safety, environmental preservation, and the conservation of resources (Restrepo et al., 2019).

2.3.1 Types of Brakes in ELVs

The automotive industry significantly impacts on the production of waste all around the world, especially in through the disposal of End-of-Life Vehicles (ELVs). The recycling of resources from End-of-Life Vehicles is crucial not only for the preservation of the environment but also the material that are retrieved which are valuable. Brakes are an essential component to a vehicle but it also poses a difficulty in the recycling procedure of it. There are various types of brakes that can be found in modern and older vehicles such as:

i. Disk brakes
ii. Drum Brakes
iii. Regenerative Brakes

Each of the brakes functions differently but they all serve the same function which is to slow down the vehicle when needed. Not only that, each of these brakes have their own way of recycling due to the complexity and also the types of material each of them is made from and this is a challenge in trying to recycle them.

The most widely used in modern vehicles are disc brakes. Disc brakes are widely used and are more favorable to be used by manufacturers due to their performance in stopping power and also the heat dissipation from it. Brakes are known to be hot especially during heavy use and disc brakes dissipate the heat efficiently. The disc brake consists of some key components such as the brake disc, brake pads, calliper and pistons. The material of the brake disc is usually made from cast iron or composite metals. Disc brakes frequently encounter problems such as the deterioration of brake pad and disc that is cause by heat and caliper malfunction. From a recycling point of view, it is important to classify metal components and non-metallic item such as brake pads that might contain dangerous compounds. The recycling of these components will result in the recovery of metals that can be used. **Figure 2.9** illustrates the components of the disc brake system that highlights the caliper assembly, brake pad and rotor.

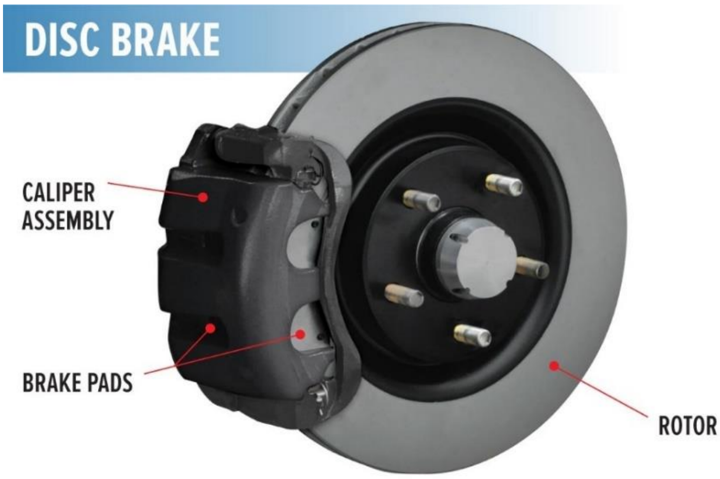


Figure 2.9 Disc Brake Components *(retrieved from WapCar.com,2024)*

Drum brakes are more applicable to older vehicles and heavy vehicles. This is because drum brakes are more prone to failure because of issues such as brake fade that is due to overheating and also the wear and tear of the shoes and drum over time. Under heavy braking, drum brakes are less effective and makes them more susceptible to overheating. They are suitable for heavy vehicles due to the cost and also the lower maintenance requirements. The recycling of drum brakes starts by separating the metallic drum from the brake lining. **Figure 2.10** illustrates the construction of the drum brake system which consist of several components.

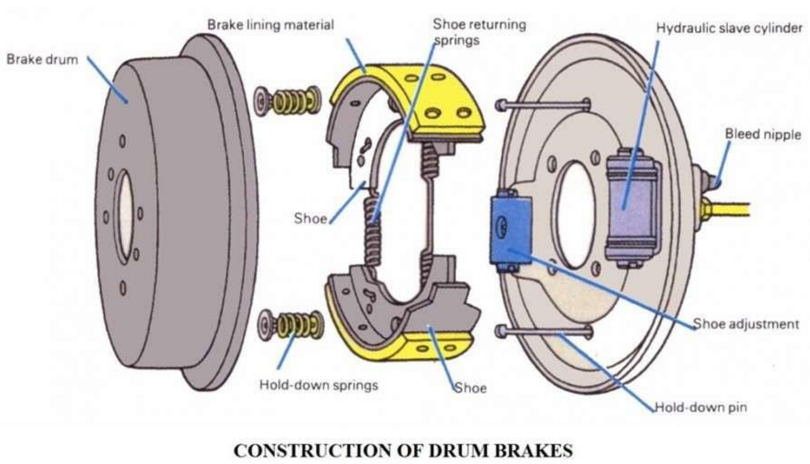


Figure 2.10 Components of Drum Brakes *(retrieved from armvperformance.com,2024)*

Regenerative braking is mostly found in electric and hybrid vehicles. This is because of the nature of regenerative braking that allows the conversion of kinetic energy into electrical during braking which in turn will be stored into the vehicle's battery. When braking, the motor will act as a generator, converting the kinetic energy that is produced into electricity. Regenerative braking systems faces a challenge of their components that consist of electrical components such as wear and tear and the efficiency lose because of the battery. The recycling of the regenerative batteries requires specialized handling due to the involvement of electrical system from the motor and valuable metals (Verma et al., 2021). **Figure 2.11** represents a hybrid or electric vehicles regenerative braking system which converts kinetic energy to electrical energy which then charges the battery.

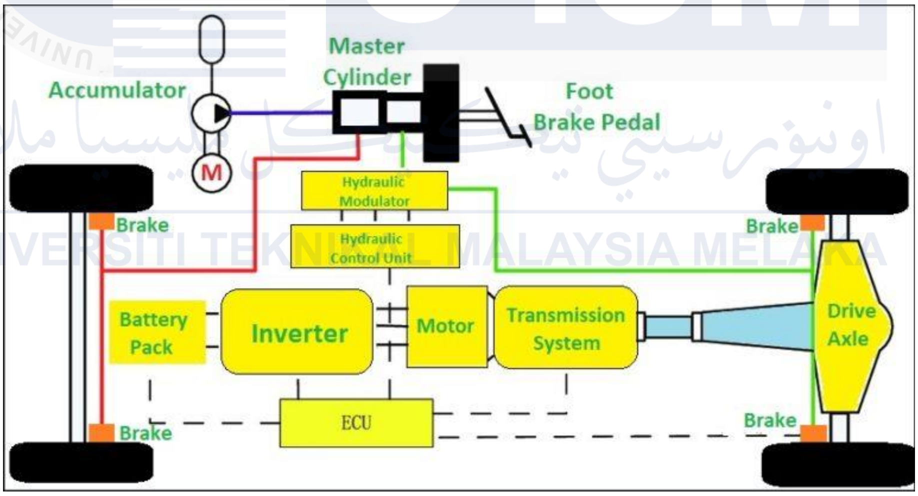


Figure 2.11 Infographic on How Regenerating Braking Works *(retrieved from mechanicalbasics.com, 2025)*

2.3.2 Application of Brake Pad and Disc Separation Tool

To effectively disassemble and recycle brake parts from old vehicles, a manual End-of-Life Vehicle (ELV) brake pad and disc separation system is necessary. This tool is specifically designed to enhance the safety, efficiency, and environmental responsibility of the process of separating the brake pad and disc. The main purposes and benefits of using this manual tool in automobile recycling operations is that we will do work much easier and faster.

The primary objective of the manual ELV brake pad and disc separation mechanism is to enhance the efficiency of the disassembly process. The tool is specifically engineered to apply precise force and leverage for the efficient removal of brake pads from discs. By utilizing this technology, personnel may execute the separation process with greater efficiency and precision compared to conventional manual methods, hence decreasing the time and labor needed for each car. Efficiency is essential in recycling processes with enormous volumes, because the rate at which materials are processed is a key element.

When dismantling and recycling ELVs, it is crucial to prioritize safety, especially when dealing with brake systems that may include hazardous compounds like asbestos or hydraulic fluids. The manual separation device is fitted with safety features that protect the operator from potential hazards. For instance, the gadget may incorporate shields and barriers to avert contact with brake dust and other fine particles. In addition, the inclusion of ergonomic handles and grips helps to mitigate the potential for repetitive strain injuries, so guaranteeing that workers can utilize the tool in a comfortable and secure manner for prolonged durations.

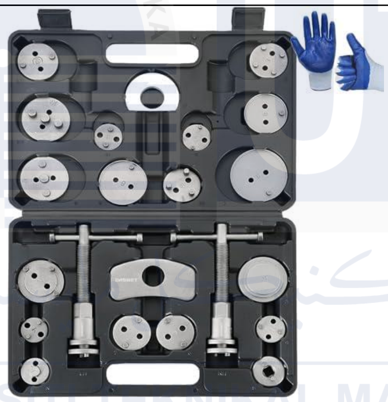
Implementing a manual ELV brake pad and disc separation tool can offer a cost-efficient resolution for recycling enterprises. The tool reduces the need for more expensive, automated technologies, making it a practical option for smaller institutions or businesses with limited budgets. The device improves the effectiveness and speed of the separation process, hence decreasing labor costs and increasing the overall productivity of the dismantling operation. Furthermore, the tool's robustness and dependability contribute to minimal requirements for maintenance and replacement, resulting in significant cost savings over the long term.

Using a manual ELV brake pad and disc separation device tool offers significant benefits in vehicle recycling procedures. This technology enhances the efficacy, security, and ecological accountability of the dismantling procedure, hence advancing sustainable practices and enhancing the overall efficiency and cost-efficiency of recycling operations. The tool's valuable attribute is in its versatility and adaptability, allowing it to successfully manage a wide range of brake systems. Moreover, its utilization also promotes training and skill enhancement among staff. The automobile recycling sector must integrate innovative equipment as it expands to meet the requirements of efficient and ecologically conscious vehicle dismantling.

2.3.3 Current Product of Brake Pad and Disc Separation Tool

A variety of specialized instruments are currently available on the market for the purpose of separating brake pads and discs from End-of-Life Vehicles (ELVs). Nevertheless, there is currently no globally acknowledged product that is explicitly promoted as a tool for separating brake pads and discs. However, there are several commonly used ways that effectively achieve this goal. **Table 2.1** showcases the tools that are used for the current dismantling o brake components for End-o-Lie Vehicles (ELVs).

Table 2.1 Current ELV Tool

No	Product Name	Usage
1		A simple hand-operated tool that is designed to spread brake pads
2		A comprehensive set including various adapters and tools for compressing caliper pistons and removing brake pads.
3		A quick-action tool designed to spread brake pads easily.

Although these tools are varied, they all aim at achieving the goal of efficiently and effectively expediting the removal of brake pads and discs from End-of-Life Vehicles (ELVs). Each of them is aimed at particular aspects of the disassembling process, but when used as a set, they enhance the process by making it faster and providing the safety standards compliance.

These tools decrease the effort that is required and thus enabling the mechanics to perform the work in the shortest time possible.

2.4 Design Parameter for A Manual ELV Brake Pad and Disc Separation Device

When designing a tool that is going to be used, many factors have to be taken into consideration so that when the final product is produced, it will be user friendly and most importantly that it meets its intended users. When designing a manual ELV brake pad and disc separation device, certain design parameters have to be followed to ensure the final product will be used as intended. Other than that, we have to make sure that when disassembly no risk is emerged that can heavily impact the workers safety.

With many dangers that are faced during disassembly such as, brake dust inhalation and sharp edges, these factors are taken into consideration to design a manual ELV brake pad and disc separation tool. This in turn will ensure the tool will work as planned.

2.4.1 Material Selection

When creating a manual device to separate brake pads and discs from End-of-Life Vehicles (ELVs), it is important to carefully select materials that will guarantee durability, safety, and efficacy. The device must possess the capability to withstand the mechanical forces associated with the separation process, while also demonstrating resistance to wear and corrosion.

For the frame and structural components, it is very advisable to use steel, particularly carbon steel or stainless steel, because of its outstanding strength, durability, and capacity to resist wear and damage. Steel is the best material for constructing the main framework, support structures, and appendages of the separation device because it provides a strong and stable framework that can withstand the forces produced during the separation process. Aluminum alloys are suitable for non-load-bearing components due to their favorable strength-to-weight ratio and corrosion resistance. This enhances the device's maneuverability and ease of handling without compromising its strength.

The components of the separating mechanism necessitate materials that possess exceptional hardness and resistance to wear. High-carbon steel is suitable for producing cutting blades or shearing components that will directly come into contact with brake pads and discs. This material ensures both efficient cutting and long-lasting performance. Tool steel, such as AISI D2, is well-suited for cutting and shearing parts due to its remarkable hardness, wear resistance, and ability to keep a sharp edge. This results in superior performance and durability, even under intense usage.

User comfort and safety should be the primary focus when designing handles and ergonomic components. Rubber or silicone materials are ideal for grips and handles because to their exceptional grip, comfortable handling, and ability to absorb shocks. This minimizes human exhaustion and improves device maneuverability during use. Plastic materials, such as polypropylene or nylon, are ideal for handles and ergonomic parts due to their lightweight nature, durability, and resistance to chemicals and wear. This feature facilitates their manipulation without significantly increasing their mass.

Fasteners and joints play a vital role in maintaining the structural integrity of the tool. It is recommended to use stainless steel bolts and nuts since they have outstanding corrosion resistance, strength, and durability. This ensures that the device remains rust-free and retains its structural integrity for a long time. High-strength alloy steel fasteners offer outstanding tensile strength and fatigue resistance, making them well-suited for critical joints and connections. This improves the durability and dependability of the gadget when exposed to repeated strain.

Applying protective coatings is essential to shield the item from environmental damage and deterioration. Powder coating provides a durable and excellent coating that exhibits exceptional resistance to scratches, abrasion, and corrosion. This greatly extends the longevity of the device while maintaining its aesthetic appeal and functionality. Furthermore, galvanization offers outstanding corrosion protection through the application of a zinc coating, rendering it suitable for steel components that are subjected to harsh environmental conditions. This protective coating provides resistance against corrosion and damage caused by the environment, ensuring exceptional endurance over time.

2.4.2 Comfort Design

Comfort Design plays a big role in the design of a manual ELV brake pad and disc separation tool as the user will be using the tool and this directly impacts the user comfort, efficiency, and safety. Some of the key factors that have to be taken into consideration are handle design, weight and balance, force distribution and adjustability. The handle of the tool should be designed so that it is comfortable when it is in use. It should also be able to be fit various hand sizes. Other than that, using materials that are lightweight are more favorable as the tool that is going to designed will be mostly handheld and this will ensure that the tool will be used in a more precise and controlled movement.

If the tool is not designed properly, it would heavily impact the working posture and thus will not be good to be used in a long amount of time. Other than that, the poor design will have a high chance in increasing the fatigue of the worker and thus will lead to higher error rates. Therefore, comfort design is a factor that should be taken heavily into consideration and not to be dismissed.

2.4.3 Safety Features

During the disassembly of the brake components, many precautions are to be taken. Several potential hazards. When designing a manual ELV brake pad and disc separation device, several safety features should be taken into consideration so that the tools is safe to be used by the user and that is minimizes the risk of injury while using the tool. A factor that should be looked at is that the tool does not have any sharp edges. Sharp edges could seriously injure the worker while working. It takes great force to decompress the brake caliper back into the housing, and while doing this the worker could injure themselves.

Other than that, clear visuals indicators and instructions will guide the worker on how to properly use the tool so that the worker can work efficiently. By addressing aspects such as these, the designed tool can be significantly reducing the risk that can emerge while using the tools.

2.4.4 Functionality and Versatility

Functionality refers to how well the manual ELV brake pad and disc separation device can perform its assigned duties. Main features of the equipment are its capacity to quickly and easily remove brake discs and pads from cars with little effort. The main factor in the design in that the tool can be used by someone that has little experience and with no skill whatsoever.

Meaning that the tool can be used by whoever, as long as the instructions are clear. The tool must also be durable so that it can be used over and over again without any failures or breakdowns.

CHAPTER 3

METHODOLOGY

3.1 Introduction

End-of-Life Vehicles are vehicles that have reached the end of their use and are usually left abandoned by their owners. These vehicles still have valuable materials that can be salvaged to be recycled and reused. One of the challenges in the dismantling process is the removal of the brake components which is an important component of the vehicle. The brake component consists of the brake pad, brake disc, callipers. The problem is that it is time consuming and specialized tools is needed to disassemble the brake assembly because proper extraction is need due to the complex design and the presence of hazardous material such as asbestos and also brake dust. By designing a manual brake pad and disc separation device, it would reduce time taken to remove the brake pad and disc and also be more efficient. Many factors have to be taken into consideration in order to create the best design of the product and the product's design will undergo multiple stages of selection to ensure that the final product will be the best design and will fulfil the expected results.

3.2 Flowchart

Figure 3.1 flowchart represents the workflows that will be done for both PSM 1and PSM 2. For PSM 1 the process starts by finding the problem based on the project title. After that, it will continue with the literature review. Literature review is where researching and studying articles and journals to gather information and identify related information based on the project. Next is examining the actual issue and from there solutions will be generated. If the solutions are viable, we will continue with the conceptual sketching of the design and one design will be chosen as the best one that complies with all the criteria.

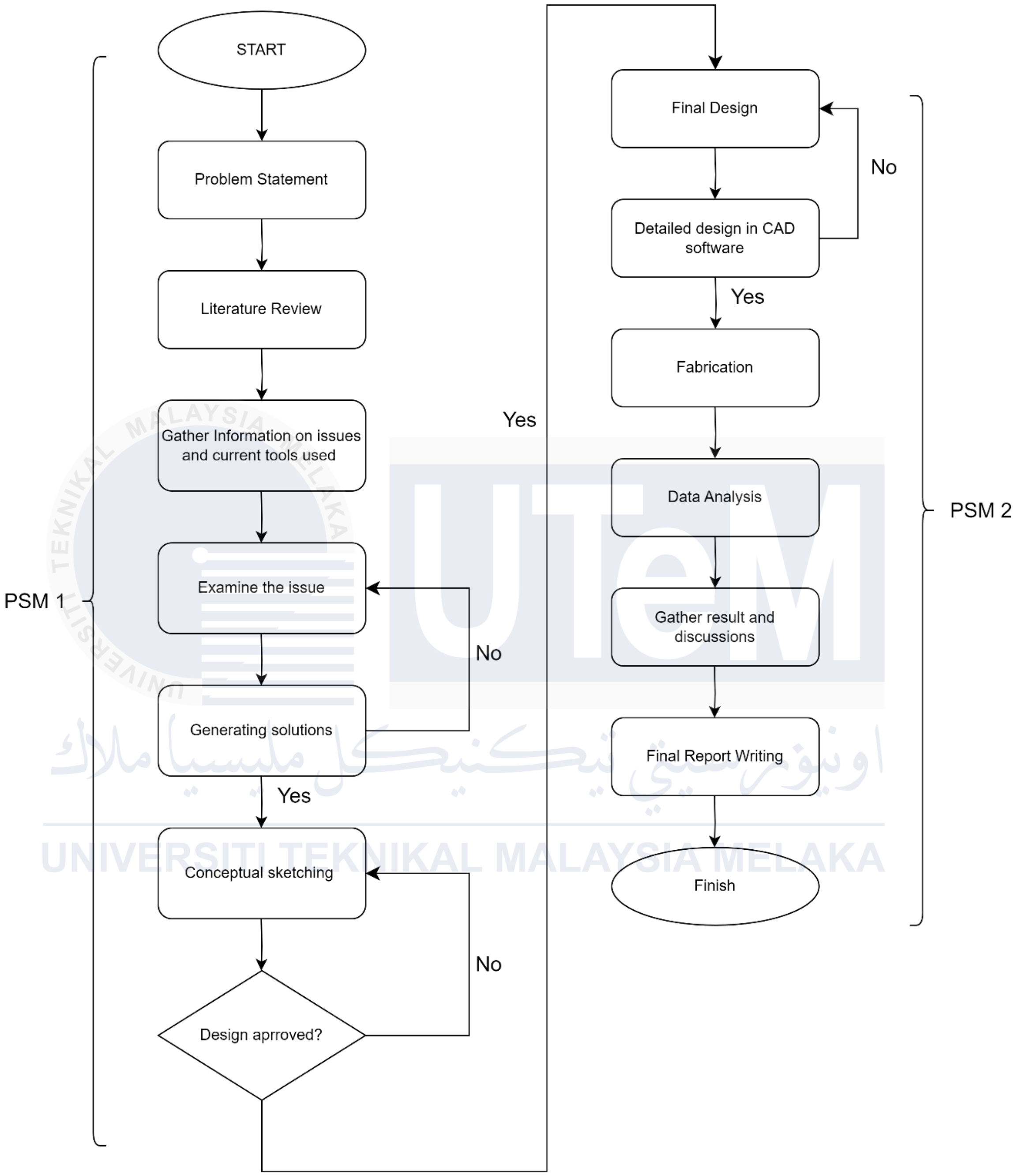


Figure 3.1 Flowchart

3.3 Gantt Chart

Table 3.1 and **Table 3.2** represents a Gantt chart which is a visual project management tool that displays tasks, timelines, and dependencies to help plan, track, and manage projects effectively. This Gantt Chart is or PSM 1 and PSM 2

Table 3.1 Gantt Chart for PSM 1

Gantt Chart for PSM 1																
			Week													
No	**Task Project**	**Plan/Actual**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
		Plan														
1	PSM title registration	Actual														
		Plan														
2	Project briefing with supervisor	Actual														
		Plan														
3	Research about title given	Actual														
		Plan														
4	Introduction	Actual														
		Plan														
5	Literature Review	Actual														
		Plan														
6	Design brainstorming	Actual														
		Plan														
7	Methodology	Actual														
		Plan														
8	Design Sketch	Actual														
		Plan														
9	Writing full report	Actual														
		Plan														
10	Submit draft	Actual														
		Plan														
11	Project presentation	Actual														

Table 3.2 Gantt Chart for PSM 2

Gannt 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	CAD model analysis	Plan														
		Actual														
4	Report writing Chapter 4	Plan														
		Actual														
5	Prototype printing	Plan														
		Actual														
6	Prototype Assembly	Plan														
		Actual														
7	Report writing Chapter 4	Plan														
		Actual														
8	Report writing Chapter 5	Plan														
		Actual														
9	Submit draft to supervisor	Plan														
		Actual														
10	Submission of PSM 2 report	Plan														
		Actual														
10	Presentation PSM 2	Plan														
		Actual														

3.4 Morphological Chart

Based on **Table 3.3**, the morphological chart illustrates the design concepts for each component utilized in the conceptual design of a manual ELV brake pad and disc separation tool. Various combinations of these components will be used to create three viable designs. Here are several potential components for the device have been identified, that can be used in designing the tool and can be combined in different ways to achieve the desired functionality.

Table 3.3 Morphological Chart

Function	Option 1	Option 2	Option 3
Frame material	High-strength steel	Aluminium alloy	Stainless steel
Handle	Ergonomic rubber grips	Textured plastic grips	Silicone coated handles
Assembly	Bolted together	Welded	
Separation Mechanism	Lever action	Screw mechanism	Hydaulic action
Portability	Compact design	Folding design	Lightweight construction
Ergonomics:	Basic		

3.5 Conceptual Design

A design has been made based on the morphological chart that has been obtained. Various functions have been combined to create three conceptual designs that will serve the purpose. Each design will have different features and combinations and they will then be evaluated using the wight sum method to determine which one is the most effective and suitable for the project. The selected design will then be refined and developed further to ensure it aligns with the project goals and parameters.

The **Figure 3.2** shows the first conceptual design for the brake pad and disc separator device. This tool will be bolted on onto the wheel hub using the lug nuts of the tires. It will also have hooks on each four side to clamp on to the brake disc for better stability. The tool will have one swinging arm that has a brake pad remover tool. This tool will be on the arm and will be in reach of the brake pad. It will be used as a tool that push the piston back into the calliper housing and thus easier brake disassembly.

<u>Conceptual Design 1</u>

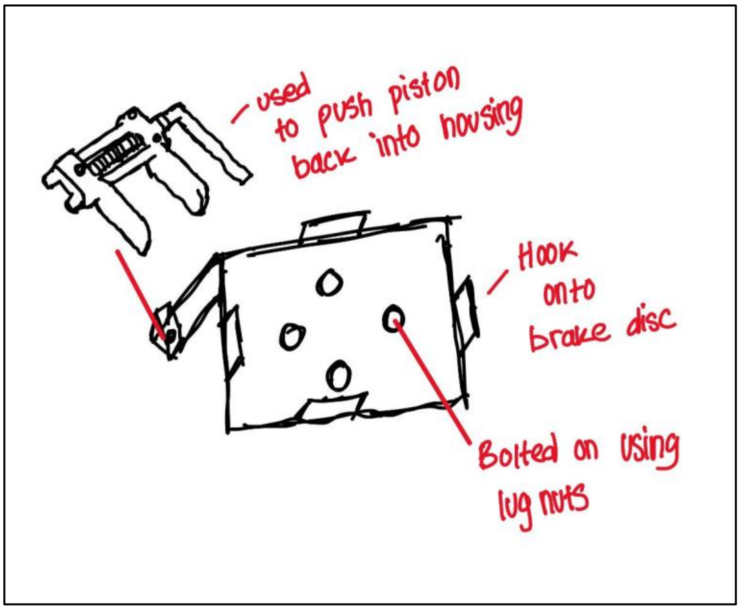


Figure 3.2 Conceptual Design 1

Conceptual Design 2

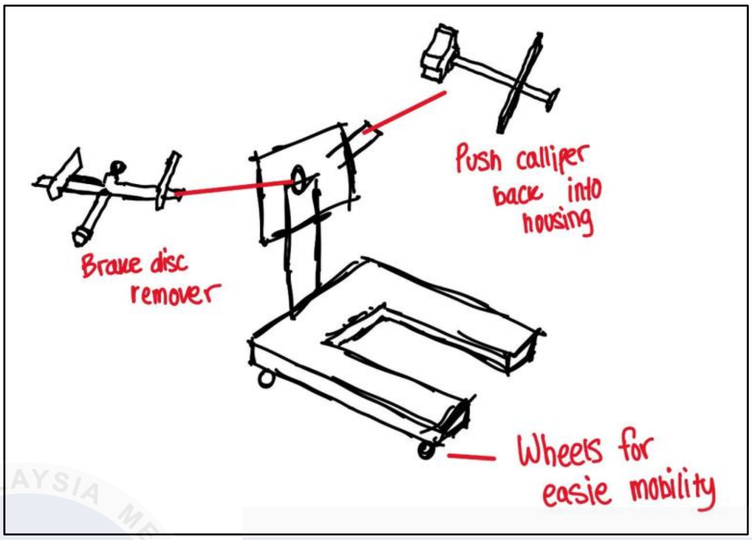


Figure 3.3 Conceptual Design 2

As for the design number two which can be seen in **Figure 3.3**, it has two legs that has wheels for easier mobility. Other than that, the centre of the design height can be adjusted according to the vehicle's height and the workers comfortability. In the middle, there is another tool that is added which is the brake disc remover. This tool will clamp onto the brake disc and apply even pressure to securely hold it in place which will allow for safe and efficient removal of disc and surrounding components. Another retractable arm will be found with a brake pad removal tool, which will help the separation of brake pad and disc.

Conceptual Design 3

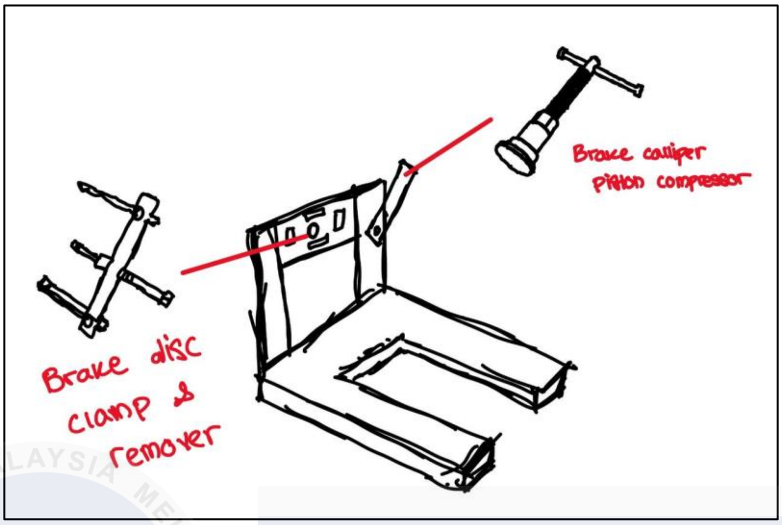


Figure 3.4 Conceptual Design 3

Figure 3.4 shows that the design will be stationary on the ground. It will have rubber grips on the bottom part of the structure so that it stays still while the process of dismantling happens. Other than that, this design will have 4 hooks on the middle part of the structure for the removal of the brake disc. These hooks will then be clamped onto the brake disc. It will have a retractable arm that will have a brake calliper piston compressor at the end of it.

3.6 Conceptual Design Selection

The weight sum method (WSM) is a popular multi criteria decision making technique that is used to evaluate and compare various alternatives based on multiple choices. It involves assigning weights to each criterion according to their importance. In this case, we are going to be giving weights to each of the design of the manual ELV brake pad and disc separation device based on that we have made.

Based on the weight sum method in **Table 3.4**, we have identified criteria that are crucial to the selection of the design. They are strength, weight, cost, safety, ease of use, and movability. These criteria will play a big part in helping us in choosing which one of the concepts is the best. Scores are given based on the weight factor, one being the worst and ten being the best.

Table 3.4 Weight Sum Method

	Weight Factor	Concept 1		Concept 2		Concept 3	
		Score	Rating	Score	Rating	Score	Rating
Strenght	0.25	6	1.5	9	2.25	7	1.75
Weight	0.15	8	1.2	8	1.2	8	1.2
Cost	0.20	6	1.2	8	1.6	7	1.4
Safety	0.20	7	1.4	8	1.6	8	1.6
Ease of Use	0.10	8	0.8	9	0.9	8	0.8
Movability	0.10	7	0.7	8	0.8	8	0.8

Following the weight sum method in **Table 3.5**, Concept 2 is the preferred design for the manual ELV brake pad and disc separation device., as it has the highest total weighted score. Concept 2 has an overall good score on every criterion and therefore the design will be suited. The weight sum method ensures a balanced evaluation of the design options.

Table 3.5 Weight Sum Method Results

Concept	Total Weighted Score
Concept 1	6.8
Concept 2	8.35
Concept 3	7.55

3.7 CAD Design Using CATIA

Having selected the proper design for the brake pad and disc separator device, the next step was to use a designing software called CATIA. CATIA was a software that was used to assist in designing, allowing users to create a more detailed version of the drawing they had in mind. CATIA was widely used in various industries, including automotive, aerospace, and industrial. The tools and features in the software made the designing and assembly process much easier.

The first steps that had to be taken in order for the design to be created involved analysing the individual parts that made up the device. In this case, the best conceptual design consisted of several components that made up the whole structure. It had a base that supported the weight of the tools attached to it. It also had a middle beam that held the base of the disc separator tool. By separating the design into several components, the design process became much smoother, and each component could be thoroughly designed to avoid any flaws.

During the designing process, the parts had to be defined with exact dimensions and shapes so that they resembled the concept. Additionally, the parts were designed properly and according to the given dimensions. This was because each of the individual parts would then be assembled together in the software itself. CATIA software allowed the assembly of the parts that had been created into one complete assembly design. This way, the design could be visualized, and the next steps could be taken.

3.8 Analysis

Once the assembly was completed overall, simulations were conducted to test the design's durability and functionality. This was to simulate how the device could actually perform if it were fabricated. By conducting these simulations, weaknesses or potential failures that might occur were identified. These simulations were done so that adjustments could be made to the design before fabricating the device, ensuring it was in the best possible design state before manufacturing.

Choosing the appropriate material was crucial because different materials had distinct properties with their own pros and cons. Properties such as tensile strength and hardness were essential requirements for making the brake pad and disc separator device. When selecting these materials, it was also important to consider factors such as cost and the availability of the chosen material.

Using the CATIA software, one of the tools provided was the Finite Element Analysis. This analysis was performed to observe the behaviour of the components under certain loads and stress. It demonstrated how the device would react under such conditions and whether it was strong enough. This simulation also illustrated how the device would function when fabricated. Additionally, studying the load distribution of the device helped identify any points prone to failure and deformation.

As a result of the analysis, the design that had been created often needed to be changed and modified based on the results. Changes such as altering the dimensions of the components and redesigning certain parts were made to increase the tool's durability and efficiency.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The innovative step for the improvement and enhancement of vehicle recycling is to design a brake pad and disc separation for the dismantling procedure of the ELV. This chapter describes the major results of the project by explaining the useful advantages ensured by the gadget, and discusses how it will affect user convenience, efficiency, and safety. The results are based on observations during the construction and first use of the prototype and data collected during the design, analysis, and testing phases.

This chapter assesses the effectiveness and performance of the device. It pinpoints those aspects where the prototype has met or exceeded expectations, indicating further areas for development. It further looks at the impacts of the device on wider implications within the ELV disassembly process, stressing how it enhances efficiency, reduces human labour, and simplifies operations. In this study, the separation of brake pad and disc is an effective and efficient solution for the automobile industry.

4.2 Prototype Sketching and Dimensioning

Finalised prototype sketching of the manual ELV brake pad and disc separation device is focused on a simple design in ease of operation and ease of being maintained whilst delivering its purpose functionality effectively. The sketching that has been done is going to be designed in CATIA V5 and analysis towards the design will be carried out. The design will have key features especially towards the user comfort.

Dimensioning of the device consists of calculating the distance of the ground to the centre of the brake disc. Other than that, the base is measured from the actual car of Proton Satria.

Measurement for base: Length: 50cm, Width: 60cm

Measurement for height: Height from ground to centre of disc: 30cm

These measurements were calculated to provide optimal functionality and compatibility. The base dimensions ensure the device remains stable and securely positioned during operation, while the height measurement aligns with the car's brake disc placement, allowing for seamless interaction with the braking system.

The initial sketching and dimensioning processes have laid a strong foundation for the prototype's development. By focusing on a simple yet effective design, the device will offer ease of operation and maintenance while meeting its functional requirements. The transition to CATIA V5 modelling and subsequent analysis will refine and validate the design further, ensuring it is ready for production and real-world application. This thoughtful approach ensures that the final product not only fulfils its intended purpose but also provides a practical and user-friendly solution for ELV brake pad and disc separation.

4.3 CAD Model Development

Figure 4.1 shows the CAD Model of Hook which will latch onto the brake disc. This hook will have a support bar inserted at the back for stability.

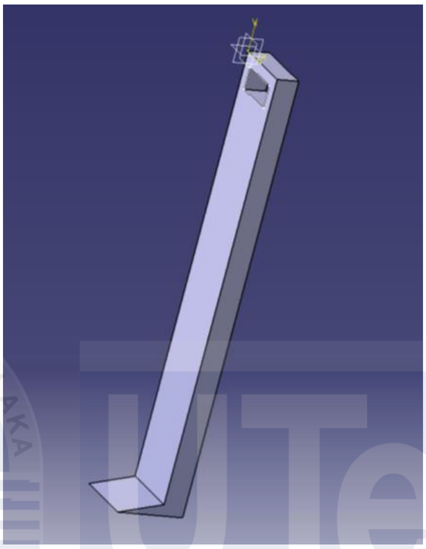


Figure 4.1 CAD Model of Hook

Figure 4.2 shows the CAD Model of Screw which will be inserted through a hole in the base and will be turned to force the brake disc to be removed.

Figure 4.2 CAD Model of Screw

Figure 4.3 shows the CAD Model of Support Bar which is going to help to stabilize the latching of hook with the brake disc

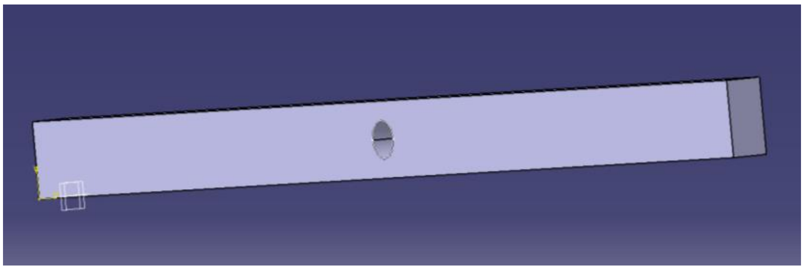


Figure 4.3 CAD Model of Support Bar

Figure 4.4 shows the CAD Model of Base which will be the main support of the product itself. By having a good structure, the base will be stable.

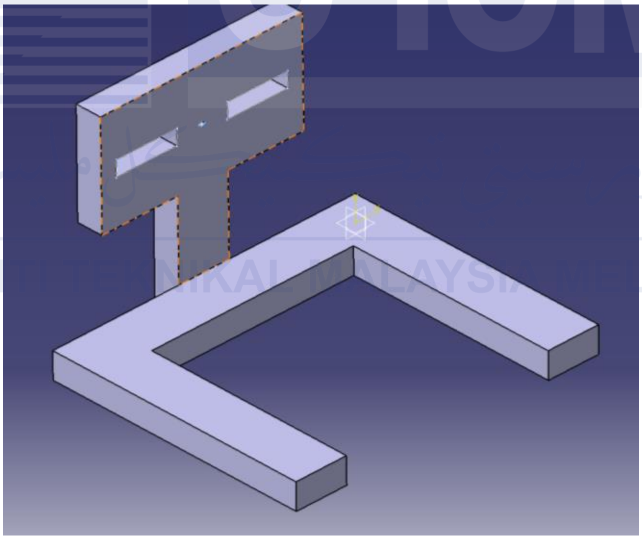


Figure 4.4 CAD Model of Base

Figure 4.5 shows a CAD Model of Calliper Holder which serves as the holder of the calliper during the process of disassembly.

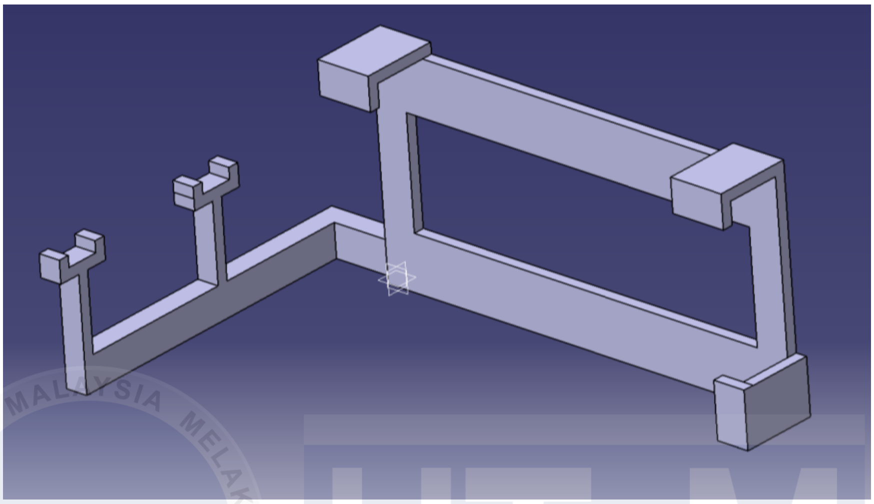


Figure 4.5 CAD Model of Calliper Holder

Figure 4.6 shows the CAD Model of Assembled Device. This device consists of several components that make up the device which will help the disassembly of brake components.

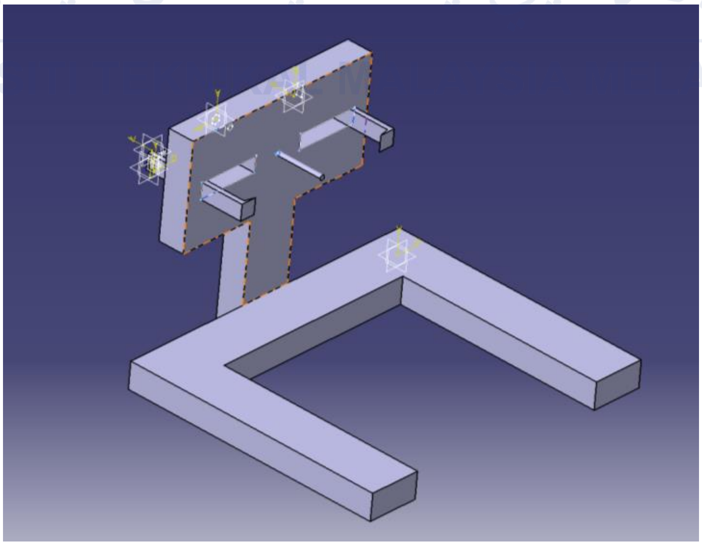


Figure 4.6 CAD Model of Assembled Device

4.4 Analysis

Analysis is a crucial phase in the design and development process or the manual brake pad and disc separation device. With the help of ANSYS, the components of the device can be evaluated first so that they can be evaluated to ensure that they meet the required performance such as their durability and stability. This analysis focuses on the static structural analysis which consist of total deformation, equivalent elastic strain, equivalent stress and the safety factor. The static structural analysis will be done on two components which are the disc brake remover and the brake calliper holder.

4.4.1 Static Structural Analysis

The static structural analysis for the disc brake remover will have the base as the fixed support while the forces are acting on the hooks that latch onto the disc brake. Static Structural Analysis is a method of analysis which is used to evaluate how the structures will respond to constant and changing loads. The analysis mainly focuses on main parameters such as stress, strain and deformation. It is widely used in engineering fields to ensure the mechanical components can withstand loads without failing.

4.4.2 Analysis of Disc Brake Remover

Figure 4.7 shows the Total Deformation analysis which shows the displacement of the component under the applied load. The results shows that the maximum deformation occurs near the upper section of the device especially near the hook that latch onto the brake disc with a value of 0.02975 mm. The deformation is at its minimum and its suggest that the device maintains its structural integrity under operational loads. The base that acts as the fixed support, shows that there is negligible deformation, primarily depicted in blue, indicating excellent stability and resistance to displacement.

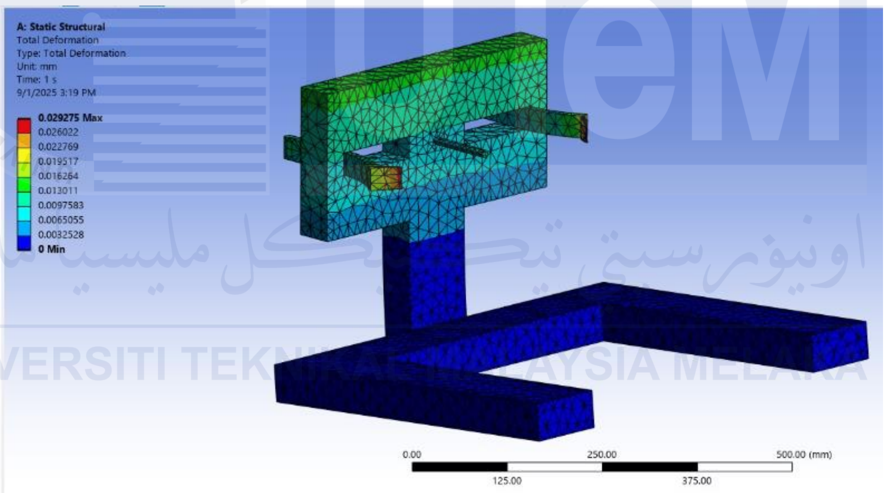


Figure 4.7 Total Deformation Analysis of Disc Brake Remover

Figure 4.8 shows The Equivalent Elastic Strain analysis which shows the maximum strain, 5.2692x10^{-5}, occurs near the stabilizer bar's connection points and hooks due to direct loading. The rest of the structure has very low strain, which indicates minimal elongation or deformation that can be seen by the blue region. This confirms the material's suitability for evenly distributing stress and preventing permanent deformation in critical areas.

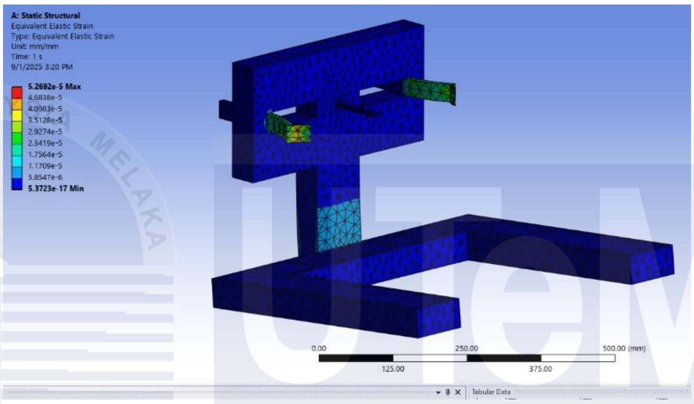


Figure 4.8 Equivalent Elastic Strain Analysis of Disc Brake Remover

Figure 4.9 shows the Equivalent (von-Mises Stress) which determines the stress that is distributed across the components under load. The maximum stress that is observed is 3.724 MPa which is located at the stabilizer's connection points that is near the hooks where force is concentrated the highest. This value offers enough safety margin to stop material failure since it is much below the yield strength of the employed component.

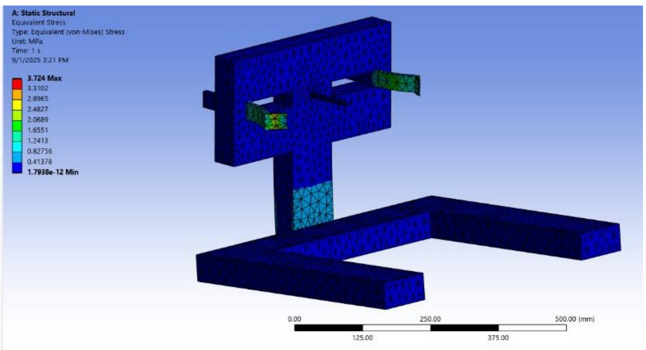


Figure 4.9 Equivalent (von-Mises) Stress Analysis of Disc Brake Remover

The analysis that has been done shows that disc brake remover is designed to withstand loads effectively, robust and durable. The results show that most of the stress values are well within the acceptable limits. The safety factor is high in value and thus provides confidence that the device will work as intended.

4.4.3 Analysis of Brake Calliper Holder

The static structural analysis for the brake calliper holder will have the hooks as the fixed support while the forces are acting on the holder that will hold on to the calliper.

Figure 4.10 shows the total deformation analysis looks at how much the brake calliper holder moves when it is under load. The highest movement measured is 0.4180 mm, which happens at the important connection point near the arm where the forces are strong. This amount of movement is quite small, showing that the brake calliper holder is stable and can handle the forces without much change. Most of the structure shows very little change, indicated by the blue areas, which proves that the design keeps it strong.

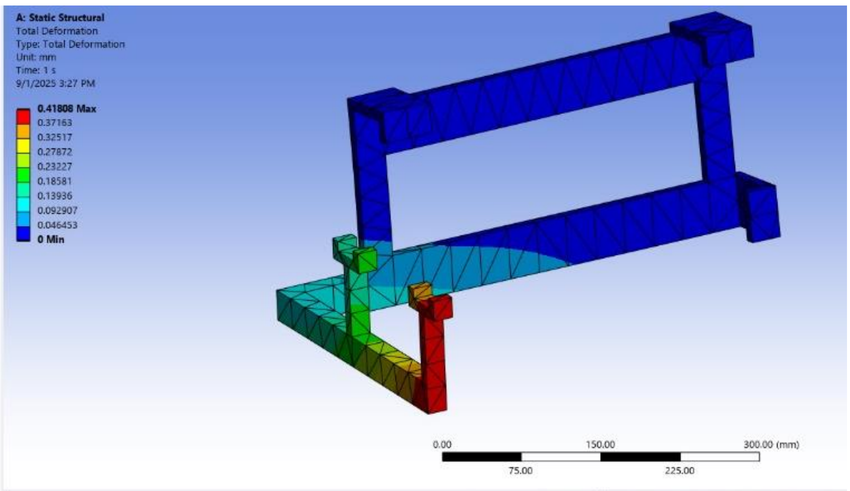


Figure 4.10 Total Deformation Analysis of Brake Calliper Holder

Figure 4.11 shows the Equivalent Elastic Strain which represents how much the material will stretch if it is under load. The maximum elastic strain that can be seen is 4.8591e-5, especially located near the arm areas which is where the load transfer will happen. The value of strain is well below the elastic limit. This means that the brake calliper holder does not leave the elastic range of deformation and therefore does not get damaged.

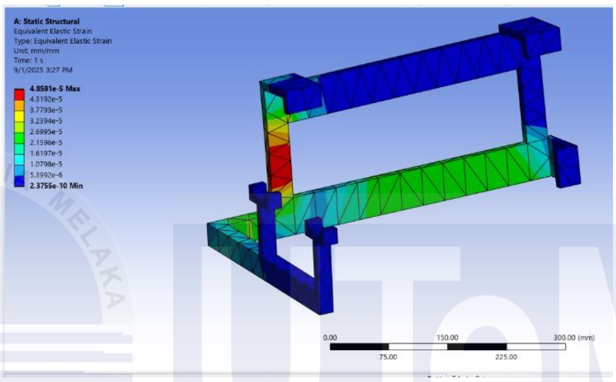


Figure 4.11 Equivalent Elastic Strain Analysis of Brake Calliper Holder

Figure 4.12 shows the equivalent stress (von-Mises Stress) analysis which shows how stress is spread in the brake calliper holder when it is loaded. The highest value of stress is 9.7164 MPa, located at the joints and arms, where the force is strongest. This stress is much lower than the yield strength of common high-strength steel, like 250 MPa, which gives a good safety margin.

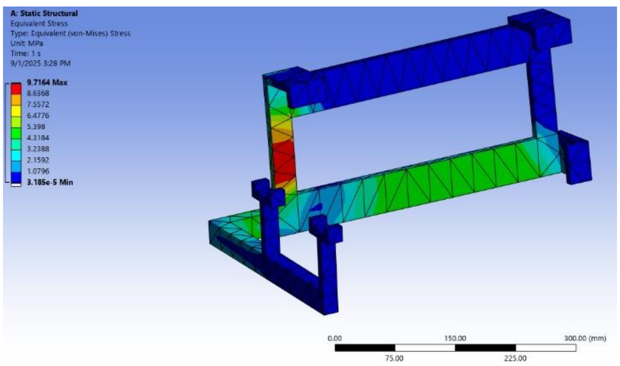


Figure 4.12 Equivalent (von-Mises) Stress Analysis of Brake Calliper Holder

4.5 Prototype Fabrication

The manual ELV brake pad and disc separation mechanism was made utilizing 3D printing technology because of its low cost, ease of use, and ability to build complex designs with great precision. This technology enabled rapid prototyping of the gadget, translating the digital design into a physical model without the need for traditional machining or manufacturing methods.

The 3D CAD model is sent part by part in STL file which will then be ready for printing. Before printing is done, the parts that has been designed is first assembled into Raise3D's ideaMaker which can be seen in **Figure 4.13** and **Figure 4.14**. This software is used to prepare the 3D printing machine on how to print the model appropriately by slicing the design into multiple layers and setting the printing parameters.

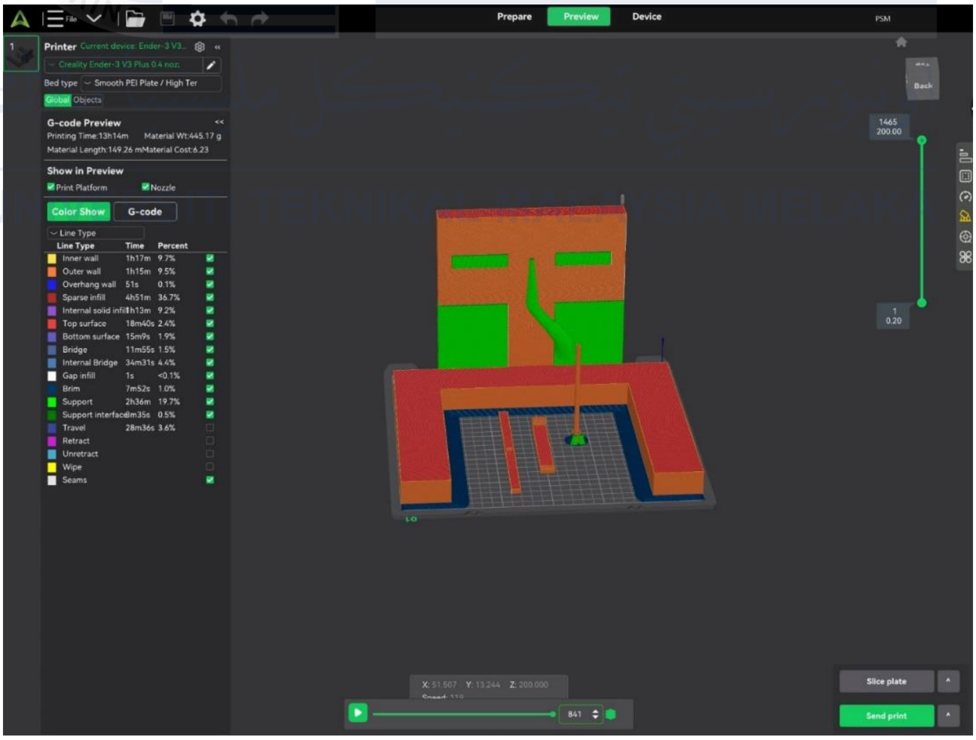


Figure 4.13 Setup For 3D Printing

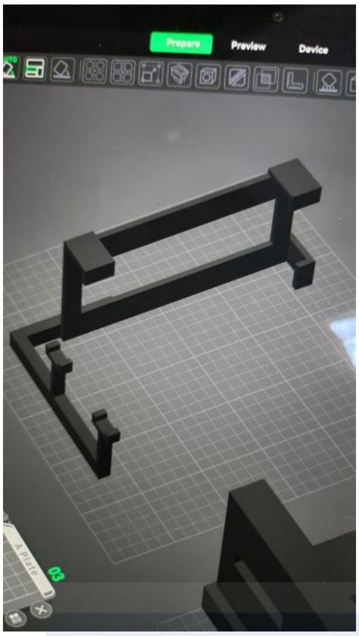


Figure 4.14 Setup For 3D Printing for Brake Calliper Holder

After the setup has been finalised and all the printing parameters has been set, it is time to print the design. By using a 3D printer, the finalized design will be printed accordingly. **Figure 4.15** shows the base that is being printed. The Creality 3D printer is used to print the design. Since the design is quite big in size, this particular printer has to be used.

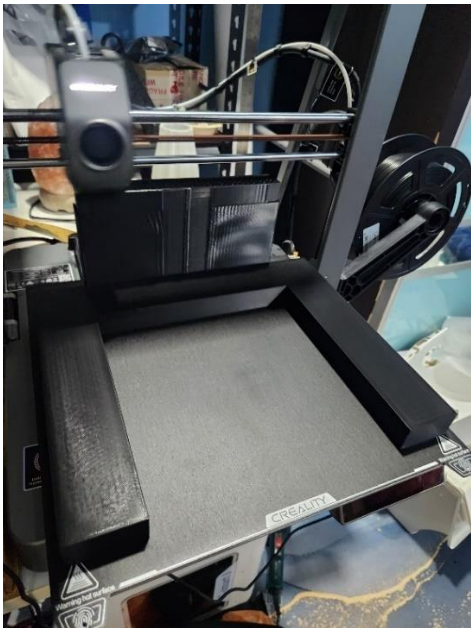


Figure 4.15 3D Printing Process Using Creality 3D Printer

For smaller objects that needs to be printed, a different printer will be used which is the Bambulab A1 AMS. This printer will be used to print smaller sized items such as the hooks and screw as can be seen in **Figure 4.16**.

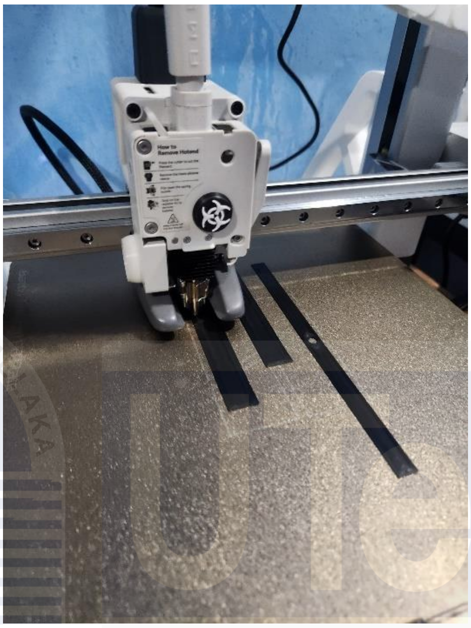


Figure 4.16 3D Printing Process using Bambulab A1 AMS

4.5.1 Prototype Final Design

The final design of the prototype marks the successful completion of the project’s design, fabrication, and testing efforts. The manual ELV brake pad and disc separation device is now a fully assembled, functional tool that effectively fulfils its intended purpose. The design prioritizes simplicity and user-friendliness, featuring an ergonomic structure that ensures minimal effort is required during operation. Built using durable materials like steel and aluminium, the prototype is designed for longevity and stability, with a sturdy base measuring 50 cm by 60 cm to prevent tipping or wobbling during use.

Figure 4.17 shows the front view of the product that has been printed. The base features a sturdy base that will be stable during the use of the product.

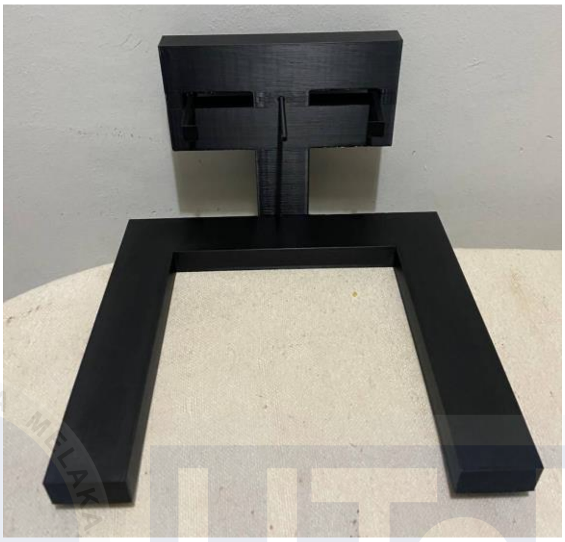


Figure 4.17 Front View of Actual Prototype

Figure 4.18 is the view from the side. It can be seen that the hooks and the stabilizer bar helps to stabilize the hook during disassembly process.

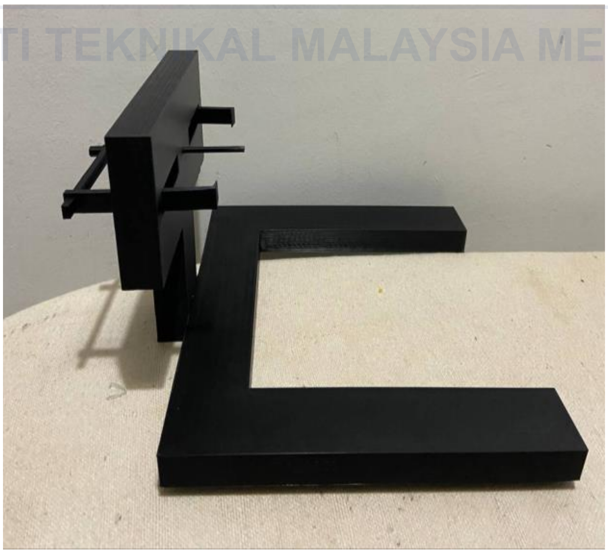


Figure 4.18 Side View of Actual Prototype

Figure 4.19 shows the back view of the actual prototype. Here it can be seen that the stabilizer bar and the hooks including the screw all come into place.

Figure 4.19 Back View of Actual Prototype

Figure 4.20 is the finished product of the Brake Calliper Holder. The brake calliper holder will be attached on to the base which in turn will hold the calliper during the disassembly process of the brake components.

Figure 4.20 Brake Calliper Holder of Actual Prototype

4.6 Summary

The evaluation of the manual brake pad and disc separation device proves that it can accomplish the design objectives such safety enhancement, efficiency improvement, and ease of use. The ANSYS based structural analysis of the device also aided in understanding the functionality of its major components, such as the disc brake remover and the brake caliper holder.

The findings exhibited a very low rate of deformation and low elastic strain, along with stress equivalent values considerably lower than the yield strength of the material thus, enabling the design to be reliable and durable. With a safety factor of 15, the stress on both components is extremely overestimated. Consequently, the device is significantly over-engineered, which further improves safety during operation. The safety provided by the device is considerable. Additionally, the functionality and practicality of the design were demonstrated by the 3D-printed prototype.

The usefulness of the device for its intended purpose is proved by the analysis and testing performed. Its sturdy construction makes it easy and safe to use for efficient and ergonomic disassembly of brake components further translating it into commercial potential. Further development may aim at material and design optimization in order to increase cost-effectiveness and scalability.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The manual ELV brake pad and disc separation mechanism was developed through a process that included conceptual design, prototyping, and analysis to provide a functional, safe, and user-friendly product. The research was done so that issues were addressed with and the device that has been developed is compatible with the real-world application. Hand-drawn sketches were used to depict the concept, which was then refined and validated through comprehensive 3D modelling and simulations in CATIA V5.

Strength analysis and accurate dimensioning guaranteed that the gadget met performance requirements while remaining stable and safe throughout operation. Selecting the right material was crucial in obtaining a balance of strength and utility to ensure that the device could withstand real-world conditions. The fabrication process was successfully turned into a design that is a workable prototype that met the project's goals. Overall, the project attained its goal of establishing a reliable and effective instrument for separating brake pads and discs, providing the groundwork for future research and commercialization.

5.2 Recommendation

There are various areas where work can be done for the device’s performance and versatility could increase. One of the steps that could be taken is to use lightweight materials that are durable which can maintain the device’s overall weight but still maintain its strength when using it. This improvement would increase mobility and convenience of use, especially for those who need to operate frequently.

Another area for improvement is the inclusion of adjustable components to meet a larger range of vehicle types and brake disc diameters. This would greatly expand the device's versatility and application. Getting consumer feedback is also essential to improving the device. By obtaining feedback on the device's overall ergonomics and operating efficiency, the design can be improved to better suit user needs and expectations. Additionally, improving safety measures, such as implementing locking mechanisms or anti-slip bases, would reduce dangers during operation and increase user confidence.

Another recommendation that can be suggested is that to consider semi-automatic or powered so that it can minimize the amount of manual labour that needs to be done Other than that, creating the product using eco-friendly materials can increase the marketability. Long-term durability testing under diverse environmental conditions should also be performed to ensure reliability over a longer operational lifespan. Finally, doing a market analysis to determine the target audience and price strategy would assist prepare the device for commercialization, potentially increasing production for wider use.

By implementing this advice, the manual ELV brake pad and disc separation mechanism can become a more adaptable, efficient, and marketable product. This study not only accomplishes its basic goals but also provides the framework for future advancements in brake system maintenance tools.

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