DESIGN AND DELEVOPMENT OF AIRBAG DEPLOYMENT TABLE FOR END-OF-LIFE VEHICLE (ELV)

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A thesis submitted
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DEDICATION

I would like to dedicate this project to my supervisor Mr. Mohd Khairul Nizam Bin Suhaimin whose guidance, support and expertise are extremely helpful as I completed this project. I couldn’t have done this without his insights, constructive feedback and encouragement.

I also am grateful to my parents and relatives who have always been there being source of in strength and encouragement. Without it I truly do not think I would have made it this far through these challenges. To be honest, their belief in me has been why I've achieved what I have.

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ABSTRACT

Airbags in End–of–life vehicles (ELVs) present a special safety challenge, as airbags must be removed from vehicles prior to recycling. The design, analysis, and development of an Airbag Deployment Table is the focus of this project to make airbag deployment more safe and operationally efficient in ELV handling. Using advanced tools, including CATIA for modelling and ANSYS for simulation, the project guarantees the table satisfies strict safety and durability requirements. To verify design concepts a scaled down 3D printed prototype was used. By using this approach, material waste was minimized, manufacturing proceeded much faster, and iterative improvement was possible based on testing results. Main features of the prototype include compatibility with many types of airbag systems, robust structural integrity via the use of SAE AISI 4140 steel, as well as safety enclosures made of polycarbonate for protection during deployment. The table resistance to dynamic force of section was confirmed by simulation results; it did not exceed the acceptable values of stress, strain, deformation, and a factor of safety. The final design improves operational efficiencies and safety of ELV dismantling operations towards a more sustainable recycling practice. Recommendations for future work include expanding the table's compatibility, automating its function, and testing the recommendations on a real-world case. This project provides a foundation for improving the recycling of ELVs, such that workers are safe, operational risks are mitigated, and environmentally responsible recycling can be supported in automotive recycling.

ABSTRAK

Beg udara dalam kenderaan yang mencapai akhir hayat (ELV) menghadirkan cabaran keselamatan khusus kerana beg udara mesti dikeluarkan daripada kenderaan sebelum proses kitar semula. Projek ini memberi tumpuan kepada reka bentuk, analisis, dan pembangunan Meja Pengaktifan Beg Udara untuk menjadikan pengaktifan beg udara lebih selamat dan cekap secara operasi dalam pengendalian ELV. Dengan menggunakan alat canggih seperti CATIA untuk pemodelan dan ANSYS untuk simulasi, projek ini memastikan meja tersebut memenuhi keperluan keselamatan dan ketahanan yang ketat. Untuk mengesahkan konsep reka bentuk, prototaip berskala kecil yang dicetak 3D telah digunakan. Pendekatan ini meminimumkan pembaziran bahan, mempercepatkan proses pembuatan, dan membolehkan penambahbaikan dilakukan berdasarkan hasil ujian. Ciri utama prototaip termasuk keupayaan untuk serasi dengan pelbagai jenis sistem beg udara, integriti struktur yang kukuh dengan menggunakan besi keluli SAE AISI 4140, serta penutup keselamatan yang diperbuat daripada polikarbonat untuk perlindungan semasa pengaktifan. Keupayaan meja untuk menahan daya dinamik telah disahkan melalui keputusan simulasi; nilai tekanan, regangan, ubah bentuk, dan faktor keselamatan tidak melebihi had yang dibenarkan. Reka bentuk akhir ini meningkatkan kecekapan operasi dan keselamatan dalam operasi pembongkaran ELV ke arah amalan kitar semula yang lebih mampan. Cadangan untuk kerja masa depan termasuk memperluaskan keserasian meja, mengautomasi fungsinya, dan menguji cadangan tersebut dalam kes dunia sebenar. Projek ini menyediakan asas untuk meningkatkan proses kitar semula ELV, memastikan keselamatan pekerja, mengurangkan risiko operasi, dan menyokong kitar semula yang bertanggungjawab terhadap alam sekitar dalam industri automotif.

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In the Name of Allah, the Most Gracious, the Most Merciful

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LIST OF SYMBOLS AND ABBREVIATIONS

ELV	-	End-Of-Life Vehicle
ACU	-	Airbag Control Unit
WSM	-	Weight Sum Method
CAD	-	Computer Aided Design
BOM	-	Bill of Materials
PLA	-	Polylactic Acid
2D	-	Two-dimensional
3D	-	Three-dimensional

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CHAPTER 1

INTRODUCTION

1.1 Background

End-of-Life Vehicles (ELVs) refer to vehicles that are no longer useful because it's have become too old or sustain critical damage or fail to meet current regulatory standards. The automobile industry evolution brings heightened requirements for ELV management to achieve efficient disposal methods alongside recycling benefits and protective environmental practices. The waste stream that comes from End-of-Life Vehicles (ELVs) unfolds as a complex mixture which combines different metals and plastics with fluids and hazardous materials. Successful management of ELVs needs full-scale plans that lower environmental harm while boosting recycled material returned to industrial use and protecting worker safety during dismantling and material recovery tasks.

End-of-Life Vehicles (ELVs) present safety problems for airbag systems during disassembly and deployment. Airbags protect passengers during vehicle operation yet represent part of the risks when equipment approaches ELV disassembly tasks. The inadvertent deployment of airbags threatens worker safety throughout airbag deployment procedures. Designing an Airbag Deployment Table for ELV processing stands out as a critical answer for existing safety problems.

Construction of the Airbag Deployment Table is the central goal of this project to enhance safety standards and streamline ELV disassembly tasks. The project plans to resolve safety threats while reducing airbag deployment duration and controlling End-of-Life Vehicles (ELVs) through special equipment. A fundamental progression was the creation of an Airbag Deployment Table which establishes a dedicated platform for securely managed airbag system operations.

The introduction points toward industry standards and best practices as reliant on close cooperation between automotive specialists together with engineers and regulatory agencies. The publication discusses the objectives, development methodology and potential benefits of designing and implementing this process.

The Airbag Deployment Table features a research-based comprehensive design to help ELV dismantlers solve major problems. Through this project researchers created sustainable automotive recycling methods and spotlighted better safety performance alongside enhanced operational efficiency and environmental accountability within dismantling facilities.

1.2 Problem Statement

When End-of-Life Vehicles (ELVs) are taken apart, there are special problems with the airbags. The systems that make airbags work might not do their job properly because they don't consider things like different temperatures, how the car crashes, or how old the car is. This could be dangerous for people who work on taking apart and recycling the cars. So, it's important to solve these problems in a careful and organized way.

When developing solid design rules engineers need to include assessments of structural integrity along with material durability plus compatibility across the various airbag systems. To develop an Airbag Deployment Table capable of enduring End-of-Life Vehicle (ELV) conditions while maintaining peak operational standards.

Purposeful evaluation of Airbag Deployment Table designs enables engineers to discover improvement areas alongside existing strengths and weaknesses. The analysis results will help choose the best design which solves all the specific problems encountered when working with End-of-Life Vehicles (ELV).

The move from design toward fabrication brings across challenges which become even more complex when it comes to ELVs. Fabrication operations should meet this phase requirements which demand effective assembly practices and appropriate material selection. The minimum standards of safety and reliability for Airbag Deployment Table production rely on optimized fabrication processes designed to match ELV specifications.

This study focuses on moving ELV safety frontiers ahead through the creation of effective Airbag Deployment Tables. Through improvements in ELV dismantling safety and efficiency this project seeks to minimize the risks of airbag deployment in older vehicles.

1.3 Research Objective

The primary objective of this research is to design and develop an Airbag Deployment Table optimized for End-of-Life Vehicles (ELVs). Specifically, the objectives are as follows:

i. To study design parameters for effective Airbag Deployment Table
ii. To compare and analyze designs for effective Airbag Deployment Table
iii. To fabricate prototype Airbag Deployment Table based on chosen design.

1.4 Scope of Research

The scope of this research are as belows:

1.4.1 Study of Design Parameters

The objective will be to perform an in-depth examination of the various design characteristics that are important for the creation of an efficient Airbag Deployment Table. This will require a thorough analysis of material characteristics, structural strength, measurements, and suitability with all types of airbags. The analysis will consider structural integrity to comprehend their influence on the effectiveness of the design. Moreover, the study will investigate the adaptability of the design to fit many vehicle airbags models. A thorough assessment of safety standards related to the design of Airbag Deployment Table will be carried out to guarantee safety according to industry rules.

1.4.2 Comparison and Analysis of Designs

This research will include detailed analysis of multiple Airbag Deployment Table design models have collected. Evaluate different design options through their speed of deployment implementation safety levels while ensuring they match End-of-Life Vehicle requirements. Researchers need to discover key design features which offer improved safety benefits together with better effectiveness for End-of-Life Vehicle systems. Evaluate which designs offer the best cost-efficiency outcomes for application in real-world environments.

1.4.3 Fabrication Process

The fabrication procedure for End-of-Life Vehicle Airbag Deployment Tables needs to very sceptical on the design choice selected. The solution demands new fabrication techniques that work alongside the existing materials and manufacturing processes found in End-of-Life Vehicles. Selecting appropriate materials stands as a crucial consideration by evaluating factors of material considering together with reliability standards and assembly simplicity. Implementation of specific fabrication methods will ensure high quality Airbag Deployment Tables for End-of-Life Vehicles.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Safety regulations along with environmental protection measures require automotive industries to manage End-of-Life Vehicles (ELVs) programs because it present opportunities for resource efficiencies. During ELV processing one needs to safely and efficiently disassemble vehicle parts while taking special care with systems such as airbags due to their problematic nature caused by both complexity and dangerous characteristics. The automotive industry investigates more creative strategies to improve ELV recycling by combining greener process methodologies with circular economy concepts. ELV disassembly's safe execution requires this project to design a specific Airbag Deployment Table for strategic reuse of resources. The project establishes conditions for ELV recycling advancement through state-of-the-art technology developments in materials science and automation to improve ecological sustainability alongside safety and performance. The present study investigates how innovative approaches to Airbag Deployment Table development can make it an essential ELV processing tool which supports responsible vehicle retirement strategies while driving sustainable automotive industry transformation.

2.2 End-of-Life Vehicle

End-of-Life Vehicles (ELVs) refer to vehicles which are no longer functional, or which have surpassed their expected service period. Both environmental and financial issues related to ELV disposal have brought their management and processing forward as essential concerns. This section presents key information about ELVs looking at their significance and enforcement frameworks for their treatment next to environmental factors and closure with recycling methods.

2.2.1 Definition of ELV

End-of-Life Vehicle (ELV) refers to the procedure of gathering, salvaging components, extracting valuable materials, and properly disposing of vehicles that have reached the end of their operational lifespan as in **Figure 2.1**. Research on ELV management is a crucial global topic of study, which includes estimating ELV quantities, developing recycling methods, and recovering materials such as lithium-ion batteries (Sato & Nakata, 2019). ELV recycling offers prospects for resource retrieval, including valuable metals, and closed-loop recycling to diminish the need for new materials (Tu & Hertwich, 2022). Furthermore, there is ongoing research on the integration of remanufacturing into ELV with the aim of improving sustainability (Paterson et al., 2018). Japan, China, and Malaysia have enacted legislation and regulations to tackle the management of end-of-life vehicles (ELVs), with a focus on promoting sustainable practices and circular economy efforts (Abu Kassim et al., 2020).

Figure 2.1 End-Of-Life Vehicles (*trinomics ,2019*)

2.2.3 Significant of ELV

The significance of End-of-Life Vehicles (ELVs) are their crucial contribution to environmental preservation, economy, and sustainable progress (Molla et al., 2023). Effective Efficient ELV management would save resources, minimize pollution, and promote environmentally friendly, sustainable development with low carbon in the global automobile industry. Efficient ELV recycling processes lead to significant conservation of energy and consequent environmental benefits (Abdullah, 2021). ELVs, in many countries, are considered a renewable resource with intensive economic and environmental value. Japan has become an example of ELV recycling, explained by extensive laws and regulations on the technical aspects of ELVs (J. Wang et al., 2021).

2.2.4 Practice of ELV

Proper management of end-of-life cars is a important component of the automotive industry as in **Figure 2.2**. The improper management of ELVs can lead to environmental and safety risks. Many nations have implemented legislation and requirements to guarantee the appropriate management and disposal of End-of-Life Vehicles (ELVs).

Figure 2.2 Practice of End-Of-Life Vehicles (*emrgroup, 2024*)

A common approach in ELV treatment is depollution, the removal of hazardous materials like batteries, lubricants, and fluids contained in vehicles before being destroyed or recycled. After removing its contaminants, the end-of-life vehicle (ELV) can be shredded and disassembled to recover valuable materials like steel, aluminium, and copper.

Automotive scrapyards must follow the regulatory regulations for End-of-Life Vehicle (ELV) management. Effective ELV management also helps the economy by facilitating the reuse and recycling of materials derived from end-of-life vehicles. Through the implementation of efficient End-of-Life Vehicle (ELV) management procedures, minimize the quantity of waste that is disposed of in landfills and encourage the responsible and sustainable utilization of resources. Through collaboration, manufacturers, dismantlers, recyclers, and government agencies may exchange knowledge and skills to enhance the efficiency and efficacy of ELV management, ultimately resulting in a more environmentally friendly and sustainable automobile industry. An effective method for managing ELVs is the implementation of the design for disassembly idea. The concept of design for disassembly focuses on facilitating the process of extracting and taking apart vehicle components during the end-of-life phase. This facilitates the effective recycling and reutilization of components, hence reducing the quantity of trash produced during the disposal procedure.

2.3 Airbag System

Airbag systems are now an important element of safety systems in cars and mechanism that works during car crash by instantaneously inflating of bags that acts as a cushion. This will be a general introduction meant to give a background on what airbag systems are all about – the parts that make up an airbag system, how the system works, different types of airbag systems available in the market today and the advantages of using airbag systems.

2.3.1 Introduction of airbag system

The applications of airbag systems in automobiles have been documented to enhance the safety of numberless passengers. An airbag is a component of passive safety systems whose purpose is to prevent the collision occupants during an accident (Kotiev et al., 2021). These systems have in development over time, and the initial commercial airbags were introduced into the North American motor vehicle fleet in 1986 (Kuk & Shkrum, 2018). In 1991, a law was ordered in the United States that required all passenger automobiles sold to have dual airbags. Progressive improvements resulted in the creation of second-generation airbags throughout the late 1990s and more advance airbag systems in the 2000s (Breen et al., 2021).

Apart from airbags, safety measures have revealed several systems backed by sensors in the automotive industry (Vyas et al., 2020). All these technological developments have been of great help in one way or another in improving the safety of vehicles in general. Also, the management and application of airbags have been adopted advanced technologies whereby the air restraint may modify the timing of an airbag's discharge based on the force of an impact and characteristics of the occupants (Nayak et al., 2013).

Airbags have contributed to an overall improvement in vehicle safety, along with the implementation of other safety measures such as seat belts, ABS, and driver assistance systems (El Youssfi & El Bachtiri, 2021). The implementation of these safety advancements has been helpful in mitigating the extent of injuries incurred in motor vehicle accidents (Majdan et al., 2014). Although airbags have proven to be efficient in reducing injuries, research has emphasized the need to consider variables such as the severity of the crash and the posture of the occupants to maximize their protective benefits (Zozulia, 2022).

In general, the development of airbag systems in automobiles have greatly enhanced passenger safety and mitigated the extent of injuries sustained in car accidents as in **Figure 2.3**. Airbags, when used to communicate with other safety systems, continue to have a crucial impact on improving overall vehicle safety standards.

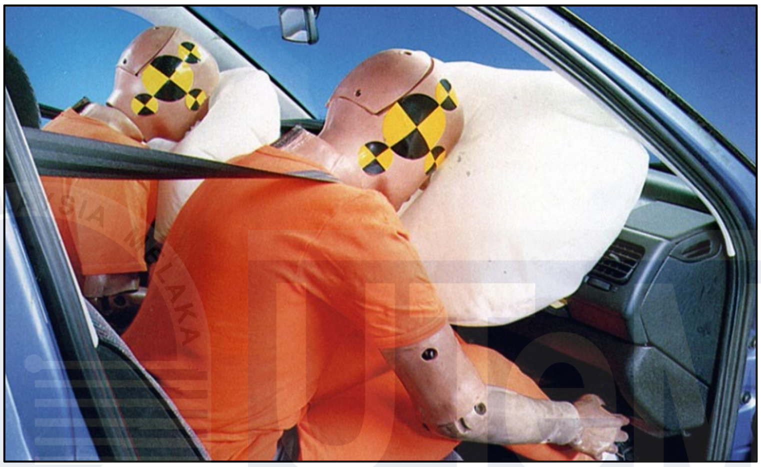


Figure 2.3 Airbags during deployment (*Mishra et al, 2015*)

2.3.2 How airbag system working/deploy in vehicles

Vehicle airbag systems are essential safety components that activate during a collision, effectively mitigating the severity of injuries (Haris et al., 2020). The crash triggers a series of carefully synchronized activities in their deployment process.

The airbag system in cars is powered by variety of sensors and control units (Suprapto et al., 2024). The strategically placed sensors within a vehicle detect the immediate deceleration or impact energy during a collision. Accelerometers and impact sensors, which measure the magnitude and orientation of the collision, are examples of these sensors. The sensors transmit an electrical signal to the airbag control unit (ACU) if they detect an accident that meets or exceeds the preset limit.

The central control unit (ACU) serves as the airbag system's central nervous system. By assessing the sensor data, the system determines if the severity of the crash warrants the activation of airbags. The airbag inflator units are activated by the ACU when the required conditions are met.

The inflator units are loaded with chemical propellant, typically sodium azide (NaN3) in older systems or a combination of other gases in more current versions. A minuscule igniter within the inflator unit initiates a rapid chemical reaction upon receiving a signal from the ACU. Upon initiation, this process promptly generates a substantial quantity of nitrogen gas (N2O) or other gases, resulting in the inflation of the airbag.

The airbag itself is made of a durable and lightweight material, usually nylon. The item can be folded and stored in several locations within the car, such as the dashboard, seats, side panels, and steering wheel. The airbag quickly breaks its cover when the inflator discharges gas, rapidly expanding to its full size in just 20 to 30 milliseconds—quicker than the average human blink.

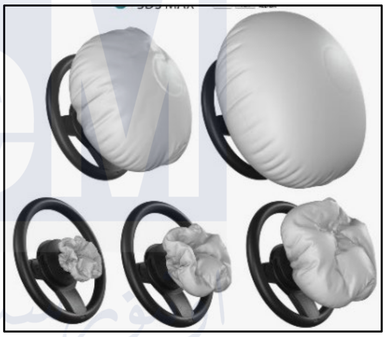
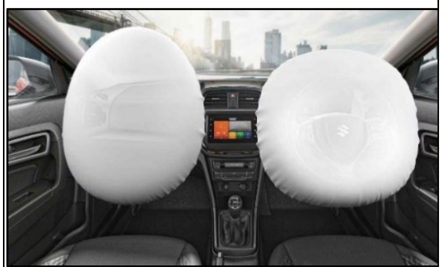
Upon activation, the airbag forms a safeguarding partition that separates the occupant from the car's dashboard, windows, and steering wheel. The cushioning's capacity to evenly distribute impact force over the occupant's body significantly reduces the likelihood of severe injuries.

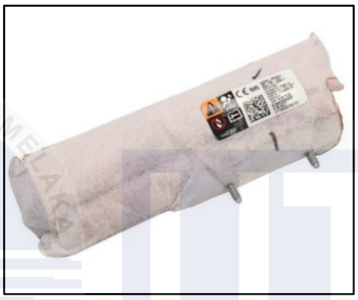
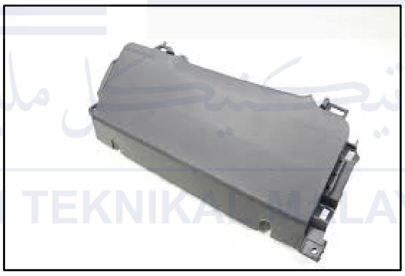
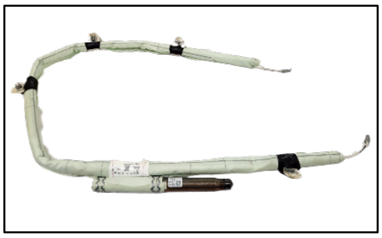
The airbag rapidly loses pressure and deflates once it has been deployed through small ventilation openings. The controlled deflation enables the occupant to maneuver and exit the car if needed. To provide maximum safety during the critical moments of a crash, the entire process of deploying and deflating the safety system is carefully designed to occur within a few seconds.

2.3.3 Types of airbag systems

Airbag systems have developed many types to fulfill the requirements for improved safety and protection in different situations. Recent advancements in airbag technology as in **Table 2.1** encompass the implementation of external airbags and autonomous emergency braking systems, with the primary objective of enhancing safety (Ju et al., 2023).

Table 2.1 Types of airbags and images

No.	Types of airbags	Part image	Deployed image
1	Driver airbag		
2	Front passenger airbag		

3	Centre airbag		
4	Side airbag		
5	Knee airbag		
6	Curtain airbag		

The placement of airbags in a vehicle is carefully designed to maximize occupant safety by providing protection in various types of collisions as in **Figure 2.4**. Each airbag is positioned to safeguard specific areas of the body, enhancing the overall effectiveness of the vehicle's safety system.

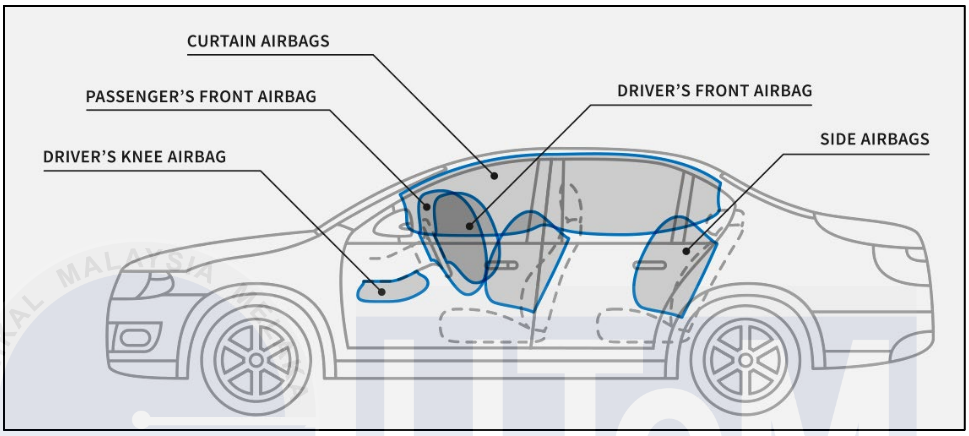


Figure 2.4 Different types of airbags and placement (*Ricks et al, 2019*)

2.3.4 Common issues and failures in airbag systems

Vehicle airbag systems can experience common problems and malfunctions that can drastically affect the safety of the vehicle. Studies have found that, in the event of airbags not deploying properly or functioning as designed, they can cause leg injuries, injuries to the chest area, traumatic brain injuries, and wounds (Wallis, 2002). Furthermore, a study conducted by (Shakouri & Mobini, 2019) has documented a variety of problems associated with airbag systems, including eye injuries, heat damage, and injuries to the upper extremities. This goes to show the few numbers of issues that can be created as an impact of airbags.

Moreover, researchers have looked into the impact of airbags and restraining devices on the types of facial injuries in car accidents (Murphy et al., 2000). Although airbags have been proven to decrease driver fatalities in head-on collisions, there have been documented instances of airbag misdeployment, heat damage, and injuries caused by airbag deployment

(Albalooshi et al., 2021). Other reports indicated that even more studies and development need to be carried out regarding safety issues, associated with occupant position sensing, thumb fracture due to airbags, and injuries to the knee due to airbags as well (Xu et al., 2024).

Airbag-related injuries have been associated with certain situations, such as chest wall burns caused by airbags indicating underlying ailments, and retinal detachment occurring due to airbag deployment (Yılmaz et al., 2023). Research has also investigated the improvement of airbag designs, such as the design of ejectors for driver airbags, to better their performance and safety characteristics (Yurchenko & Vynogradskyy, 2022). This research underscores the possibility of using creative solutions to reduce injuries in many situations (Tamura et al., 2009).

To add up vehicle safety and minimize the likelihood of occupant injuries in accidents, it is important to effectively take care of the problems and malfunctions in automotive airbag systems. Researchers and engineers can improve the effectiveness and dependability of airbag systems in protecting car occupants by studying the several aspects that can affect airbag performance and safety.

2.3.5 Safety risks associated with undeployed airbags in ELVs.

Undeployed airbags in End-of-Life Vehicles (ELVs) pose several critical safety risks during the dismantled, recycled, and disposed process. These are critical issues that need to be addressed since they can affect workers and environmental safety. The concern is the potential for accidental deployment. Undeployed airbags can deploy unexpectedly during the dismantling process, leading to severe injuries. The impact of airbag detonation is strong and is purposely designed to cushion an occupant during a collision and can result in physical injuries of workers within in range (Ashabyamin & Hamdamjo, 2021). The sudden explosion may also have an impact on the hearing since the sound is loud will damage if it reaches the ears (Pham et al., 2019).

Chemical hazards significant risk associated with undeployed airbags. Airbags contain chemical propellants, such as sodium azide. When handled in the wrong way, these chemicals in the propellants are hazardous (Mohd Yasin et al., 2023). They pose risks of toxic exposure through contact or inhalation of the chemicals released during accidental deployment. Additionally, some propellants are flammable and can therefore pose a fire risk if a source of heat is present, which can add another level of danger in handling.

Furthermore, improper handling and disposal may lead to environmental contamination with airbag chemicals. Long-term environmental damage occurs when airbag chemicals leach into soil and water. The improper methods used include burning, because if the process is uncontrolled, toxic fumes go into the atmosphere to add to the problem of air pollution.

Safety concerns related to undeployed airbags can lead to operational inefficiencies as well. The need for extra precautions to handle undeployed airbags can slow down the disassembly process, causing delays (Van Tilburg, 2021). Additionally, the requirement for additional safety measures and potential accident-related costs can increase overall operational expenses, impacting the efficiency and profitability of ELV disassembly operations (Li et al., 2022).

Dismantling facilities that mishandle undeployed airbags face penalties from regulatory authorities because their improper practices lead to regulatory noncompliance. Faulty airbag management which leads to injuries or environmental harm triggers legal lawsuits adding a legal liability risk to reuse processing environments.

2.3.6 Environmental impact of airbags in landfills

Much concern is raised about the effect of airbags in landfills on the environment due to the possible effect of airbag disposal. Airbags from ELVs can cause numerous problems for the environment once they find a way into landfills. The disposal of airbags in landfills could affect soil and the quality of groundwater as chemicals along with toxic elements get released into the environment (Preziosi et al., 2019). Moreover, the same source illustrates that based on (Kim et al., 2018), due to the airbag being at the landfill site since, because of it, landfill gas is minor that contains methane that effects climate change.

Furthermore, some of the waste that is non-biodegradable, for example, airbags tend to remain in the landfill for a long time tends to overstay in the landfill hence possibly causing long term environmental pollution. Research has previously indicated that landfills have an poor effect on the ecosystem by polluting different environmental elements, which thus calls for proper waste management techniques (Vaverková et al., 2018). For example, life cycle analyses have been conducted to determine the environmental effects of solid waste landfills on examining how often airbags are dispose of to understand the overall environmental effect of waste management methods (Sauve & Van Acker, 2020).

Landfill disposal of airbags results in potential environmental hazards, such as land contamination, greenhouse gas emissions, and the buildup of non-biodegradable elements. The extent of environmental damage that airbags in landfills cause can be reduced by proper safe disposal techniques and proper waste management techniques like recycling.

2.3.7 Environmental benefits and impacts of airbag disposal.

Airbag disposal is among waste disposal management strategies that must take care of the environment. Poorly disposed airbags may post health hazards and pollution. Research on efficient disposal techniques that lower environmental effects and improve sustainability is important.

With focus on the fundamental of harm reduction, resource efficiency, and the achievements of harmless, high temperature burn can be an effective method for disinfecting hospital trash (B. Wang et al., 2022). This method can be used for airbag disposal with the purpose of ensuring proper disinfection and reducing environmental risks linked to hazardous substances.

In other words, plastic utilizes waste materials for the purpose of general infrastructure construction, providing both waste management and sustainability. These measures can save the disposal cost of the waste materials in road construction, reduce pollution to the environment, and improve the efficiency of resource utilization (J. Wang et al., 2020). This technique may hold the potential to apply when constructing a new roadway, thus providing an environmentally friendly way of disposing of materials used in airbags.

The benefits and impacts of airbag disposal to the environment illustrate that the usage of suitable waste management methods is very important (Gidey et al., 2020). Some other efficient disposal methods can help reduce the environmental impacts that disposing of airbags causes while ensuring safety and a clean environment. These include high-temperature burn, the use of waste materials in infrastructural developments, and promoting proper disposal behavior.

2.3.8 Safety standards and guidelines

Airbags are crucial parts of car safety systems that quickly deploy when an impact occurs to protect passengers during collisions. The usefulness of airbags in lowering injuries and fatalities in auto accidents has been demonstrated by numerous research (Bhalla & Gleason, 2020). Airbag installation requirements in cars have greatly improved passenger safety (Gugliotta et al., 2024). It is imperative to recognise the many hazards linked to the deployment of airbags, including the possibility of harm resulting from the airbag itself.

The complex relationship between seatbelts, airbags, and occupant placement is shown by research showing that the deployment of airbags may raise the incidence of arm injuries (Kroeker & Siegmund, 2024). Furthermore, several important variables affect how well airbags protect occupants, including the fabric permeability, inflator mass-flow rate, and vent leakage coefficient. Technological developments in airbags, like the creation of nanobag systems, have the potential to provide multidirectional impact protection (Špička et al., 2021).

Ensuring the effectiveness of airbags requires the use of rigorous testing and evaluation procedures. To identify high-risk triggering items and improve system reliability, dynamic abuse testing of airbag systems under diverse scenarios is essential. Furthermore, the evaluation of injury rates and the efficiency of safety equipment such as seat belts in averting fatalities is made possible by numerical simulations of airbag interactions with anthropomorphic dummy models (Gonsales et al., 2022).

Airbags are still a vital component of car safety systems, and in order to enhance occupant protection and mitigate any hazards related to their activation, airbag technology must be continuously researched and developed.

2.3.9 Methods for safe airbag deployment during recycling

It is crucial to consider techniques and policies that might reduce potential dangers connected with handling airbag systems to guarantee safe airbag deployment during recycling processes. Although there aren't any direct references on safe airbag deployment during recycling, we can still learn from waste management and recycling procedures that are similar.

Safe handling of airbag components during recycling is an important factor to consider minimising unintentional deployments. The danger of unintentional deploys can be reduced by following correct dismantle procedures, which include removing the battery to unpowered the airbag system and waiting a predetermined amount of time before handling the airbag unit (Yi & Lee, 2022). Furthermore, it is imperative to guarantee that recycling establishments have staff members with airbag system knowledge and the right instruments for safe dismantling in order to avoid accidents during the recycling process.

Furthermore, using closed-loop recycling techniques, which have been shown to be effective in recycling clothing and other materials, can provide an environmentally friendly way to handle airbag components. Reusing materials within the same product lifespan minimises waste production, cuts down on the requirement for new raw materials, and closes the loop on recycling (Wiedemann et al., 2022). Manufacturers may guarantee that materials are securely and effectively reused without violating safety standards by putting in place closed-loop recycling systems for airbag components.

To sum up, although there are not many references on safe airbag deployment during recycling, methods for properly recycling airbag systems can be developed by taking cues from waste management plans, material flow analysis, and associated recycling practices. The recycling industry may improve safety standards in handling airbag components by placing appropriate dismantling methods to people and conducting material flow analysis.

2.4 Design and Development of the Airbag Deployment Table

The design and development of the airbag deployment table are crucial steps in enhancing vehicle safety through comprehensive testing and evaluation of airbag systems. An airbag deployment table is a specialized test apparatus used to simulate various crash scenarios and analyze the performance of airbag systems under controlled conditions. This introduction provides an overview of the significance, objectives, key components, and development considerations of an airbag deployment table.

2.4.1 Engineering requirements and material selection

Engineering requirements and material selection are important in the design and development process of an Airbag Deployment Table to ensure reliable and safe functioning. Engineering requirements for the Airbag Deployment Table are material properties like structural strength, impact-resistant features, rapidity in deploying, and airbag compatibility. It should have enough strength to withstand the deployment impact of the airbag and, at the same time, be lightweight and conveniently deployable.

Furthermore, (Blanco et al., 2021)offers valuable information about environmentally friendly methods used in the production of aluminium, steel, magnesium, and titanium alloys for the transportation industry. Therefore, since the ideal is lightweight materials with strength, the strength-to-weight ratio of advantage lends itself to choices of considering aluminum alloys for the making of the Airbag Deployment Table.

Polycarbonate is an acknowledged high-resistance and transparent material, allowing observation and protection but presently used to produce ballistic shields because of its nature of lightness, malleability, transparency, resistance, and well-established impact strength (Kumar et al., 2023). It is being considered as a possible material for use in protective window since it is lightweight and has good light transmittance, UV resistance, as well as stability, making it a material for multiple use, including window glass and structure(Antunes et al., 2022).

A new acrylic shield called "Endoshield" has been designed as a supplemental physical barrier equipment to increase protection for use in medical procedures, particularly in pediatric endoscopic settings. It is also commonly used in protective coatings because it adds value when compared with other materials, such as good stickiness and stability against degradation from light exposure(Rezaei Abadchi et al., 2022).

When designing and developing an Airbag Deployment Table, it is important to carefully consider engineering requirements such as the table's structural integrity and its ability to resist impact. Additionally, it is crucial to select suitable and good materials like impact-toughened composites, aluminium alloys, or innovative safety systems to ensure the table performs optimally and safely during airbag deployment scenarios.

2.5 Design parameters for Airbag Deployment Table

Automotive safety testing requires the construction of Airbag Deployment Tables as fundamental elements. A good constructed deployment table performs safe and consistent airbag testing while obtaining crucial data which helps to refine airbag technology thus improving total vehicle safety. This literature study surveys the essential design elements researchers should consider when constructing an optimal airbag deployment device. The study concentrates precisely on the structural strength aspects alongside safety protocols precision in measurement optimal material choices and ergonomic considerations.

2.5.1 Material and durability

The selection of suitable materials that match criteria is critical for the durability and long-term functionality of deployable tables. High-strength steel SAE AISI 4140 or aluminum alloys are chosen for the frame and support structures due to their outstanding ability to handle heavy loads. The materials used in the table can hold the pressures that come with several airbag deployment and guarantee the table's structural strength.

The table's top is made of strong materials like hardened steel or composite panels to resist damage caused by airbag deployments. Further, protective coatings, such as corrosion-resistant finishes, are applied to improve the durability of components that are exposed to outside conditions (Verho et al., 2011). These coatings prevent degradation and extend the lifespan of the table.

It is important to include wear-resistant materials in frequently used components, to warrant the great performance of the table in the long term (Cetin et al., 2022). The durability of the table can be enhanced further by using materials showing self-healing properties that could automatically fix minor flaws and so extend the lifespan of its components (Ionov & Synytska, 2012).

Further, the selection of materials with excellent durability is an important consideration in the optimization of table durability. Materials that incorporate self-healing aspects, featuring autonomous self-healing functions, can increase the mechanical durability of the table (Zhuo et al., 2018). Moreover, materials with excellent durability of the class imply that the long-lasting superhydrophobic materials result in the extended effective life of the table under various operational conditions (Nazifi et al., 2022).

Deployable tables can be optimised for performance and longevity by selecting materials such as high-strength steel or aluminium alloys for structural components, durable surface materials, protective coatings and wear-resistant materials.

2.5.2 Ergonomic

A table for the deployment of airbags in ELVs should consider ergonomic factors in respect to the posture and reach of an operator.

Ideal height for the Airbag Deployment Table that suitable for average human height. For standing work, the operator should be in an ideal position equivalent to approximately 90 cm to 110 cm (Pepin et al., 2024). Items and controls should be placed within easy reach to avoid stretching. The location for frequently used items and controls may lie within 25 cm to 45 cm from the operator. Those that are less used can be placed within 45 cm to 70 cm. Rarely used items may even be 100 cm away. This setup ensures efficiency and reduces physical strain (Babayigit & Sattuf, 2023).

Allow various posture changes to keep the body from static postures that may become painful. Workspaces should allow moving around the table with a change of angle of work surface to allow posture change.

By making a table height adjustable, making items easy to reach, encouraging movement, and making tools accessible, it is possible to design an ergonomic and user-friendly airbag deployment table. By such a design approach, comfort, performance, and safety in use are to be significantly improvent (Øksnebjerg et al., 2019).

2.5.3 Versatility

A modular design is essential in the manufacture of a flexible and interchangeable system that will serve in testing different types of airbags and different scenarios. This ensures that limited reconfiguration is enhanced with flexibility for varying test configurations, thereby increasing the functionality of the table (Jaśkiewicz et al., 2021). Adjustable height and angle should be applied in designing the table, where there is a need for accurate replication of various deployment scenarios, hence testing a variety of airbags, including front, side, and curtain airbags, under different conditions. (Hallman et al., 2010).

An adaptive deployment table that consists of interchangeable construction and customizable features with the added ability to replicate various airbag deployment events is important to safety testing. Combining the results from studies of airbag operation, crash conditions, and the safety tests themselves, this table will ensure that various airbag models are fully tested according to a variety of conditions, as a result improve the safety standards for automobiles.

2.5.4 Safety features

This is a very important factor when doing deployment activities since it involves people and equipment. The deployment table should be designed with some safety features to avoid any accidents during use. To improve safety, it is crucial to use protective shields composed of impact-resistant materials such as polycarbonate. These shields are important as they ensure that the worker is shielded from any debris and forces that may impact from the explosion (Singh et al., 2021). They control excellent impact durability, can see thru clarity, and high thermal stability and therefore, safety shields that are ideal for use against multiple threats.

Aside from safety shields, the addition of emergency stop devices is important in the design of the airbag deployment table. These methods allow for the sudden stop of the deployment process in the event of failures, hence preserving the safety of operators and averting potential mishaps (Oh et al., 2017). Applying emergency stop methods can greatly eliminate the potential for injuries and damage, hence improving overall operating safety.

Additionally, designs are essential in safely controlling and minimizing explosive forces during the testing processes. The designs reduce the effects of explosions on workers and components and minimizing the potential hazards (Andrews et al., 2020). Through effective measures of blast containment, the deployment table system can operate safely while minimizing the risks associated with explosions.

There is a need to apply the deployment table with protective shields, emergency stop mechanisms, and blast containment designs to increase safety during deployment operations. Protective measures that work all at once to ensure operator safety, equipment protection, and environmental safety will guarantee the safe, efficient, and risk-free execution of testing operations.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter commences with an explanation of the methodology of this project. It describes the project methodology for data collection and analysis. The chapter starts with the overview of the project methodology and the flowchart of the whole process of the project. The flowchart starts with the refinement of problem, literature review and data collection. Besides, the data analysis is also considered as an important aspect in this chapter. The design of the Airbag Deployment Table undergoes several selections to ensure the final design can deliver the expected results and meet the aesthetic value for the market. After several fine detailing of the product, the final design proceeds to prototype development and testing.

1.2 Flowchart

The development flowchart process of the Airbag Deployment Table for End-of-Life Vehicles (ELV) as Figure 3.1 follows a systematic approach to ensure efficiency, safety, and functionality. The process begins with identifying the need for an airbag deployment table specifically designed for ELV testing. This is followed by thorough research to recognize the required parts, methods, and materials. The objective at this stage is to gather insights from existing studies and standards to determine the best possible solutions.

After research are done, the conceptual designs become constructed. This design displays identical features alongside its purpose for use. The concept designs undergo approval evaluations to confirm they satisfy criteria related to function and safety as well as operational standards. Use the CATIA software to convert the conceptual design into CAD design.

After that, the process proceeds to material selection. Materials which deliver needed strength characteristics while follow durability limits for deployment tables with cost efficiency. Steel alloys and high-strength composites are suitable materials for airbag deployment systems because it can handle the force from the airbag deployment. The prototype enters structural and dynamic analyses through simulation using ANSYS after materials are chosen. The analysis process measures important design factors such as stress levels, strain responses, deformation with safety factors to confirm design performance.

If the analysis did not meet the criteria and the evaluation process is repeated until the requirements are met. Once all criteria are satisfied, the prototype is developed using methods like 3D printing or machining. This stage transforms the CAD design into a physical model that is ready for final testing. The last step involves fabricating the components and assembling the final product to confirm its functionality and safety.

By following this flowchart process, the development ensures the delivery of a reliable and efficient Airbag Deployment Table that meets the specific requirements for ELV airbag testing as in **Figure 3.1**.

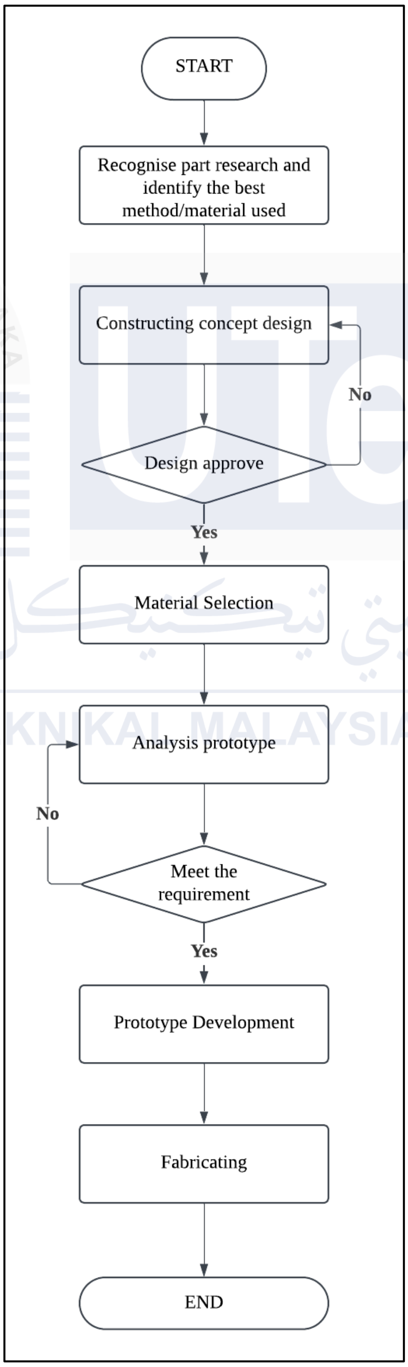


Figure 3.1 Flowchart for Airbag Deployment Table

1.3 Gantt chart

PSM 1 and 2 Gantt chart for Airbag Deployment Table as in **Figure 3.1**.

Table 3. 1 Gantt chart

Gannt 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 registraion	Plan														
		Actual														
2	Project breafing	Plan														
		Actual														
3	Research about the title	Plan														
		Actual														
4	Introduction (Chapter1)	Plan														
		Actual														
5	Literature review (Chapter 2)	Plan														
		Actual														
6	Conceptual design brainstroming	Plan														
		Actual														
7	Methodology (Chapter 3)	Plan														
		Actual														
8	Design sketching	Plan														
		Actual														
9	Writing full report	Plan														
		Actual														
10	Submit draft to supervisor	Plan														
		Actual														
11	Project presentation	Plan														
		Actual														

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	CAD model development	Plan														
		Actual														
2	CAD model analysis	Plan														
		Actual														
3	Report writing (Chapter 4)	Plan														
		Actual														
4	Prototype printing	Plan														
		Actual														
5	Prototype assembly	Plan														
		Actual														
6	Report writing (Chapter 4)	Plan														
		Actual														
7	Report writing (Chapter 5)	Plan														
		Actual														
8	Submit draft to supervisor	Plan														
		Actual														
9	Full report finalization	Plan														
		Actual														
10	Project presentation	Plan														
		Actual														

3.4 Conceptual Design

The conceptual design for the Design and Development of Airbag Deployment Table for End-of-Life Vehicle (ELV) involves creating innovative ideas and defining specific requirements. This includes creating initial sketches and models, as well as setting clear objectives for the project. It ensures that the design follows technical, safety, and functional standards to addressing potential challenges. This foundational work guides the detailed design and development stages, ensuring a well-planned approach to creating the airbag deployment table.

3.4.1 Conceptual Design 1

Conceptual design 1 in **Figure 3.2** is an open table only got safety display using polycarbonate or novel acrylic but no wall for both sides left and right and back. The body is made of steel or aluminium. It nuts and bolts are secured the table to the floor. For the table it has jig that can use clamp to secure the airbag during being deployed.

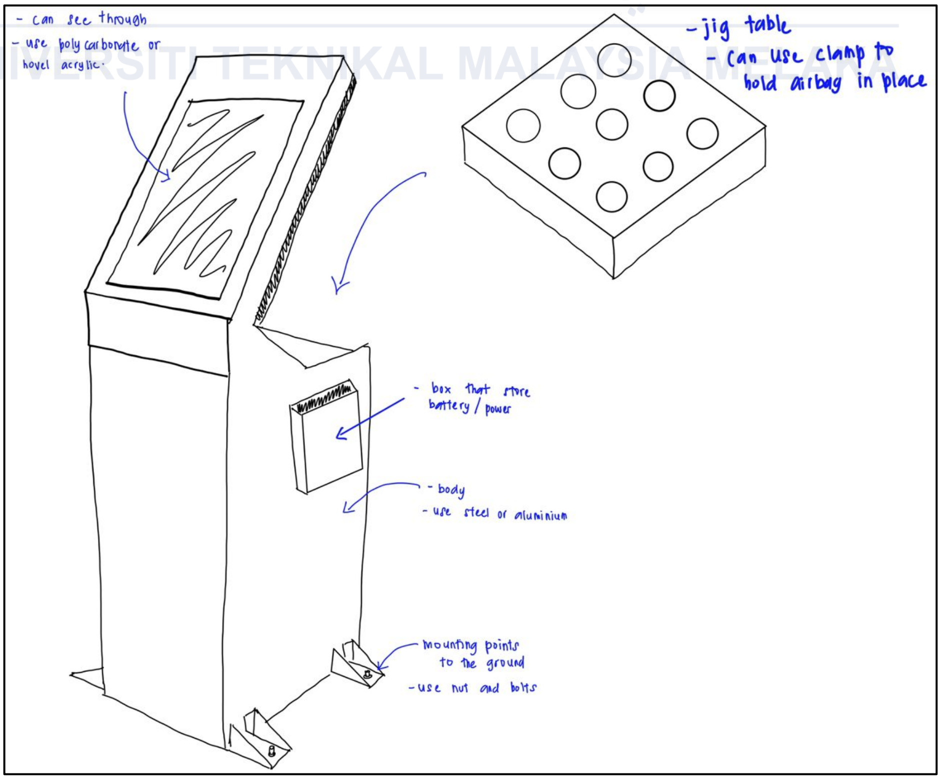


Figure 3.2 Conceptual Design 1

3.4.2 Conceptual Design 2

For conceptual design 2 in **Figure 3.3** is an enclosed table. It has a door at the front to have access to the table. For the table it has jig that can use clamp to secure the airbag during being deployed. The door has a window with iron wire mesh in the middle. At the side it got a box to store battery. The body is made of steel or aluminium.

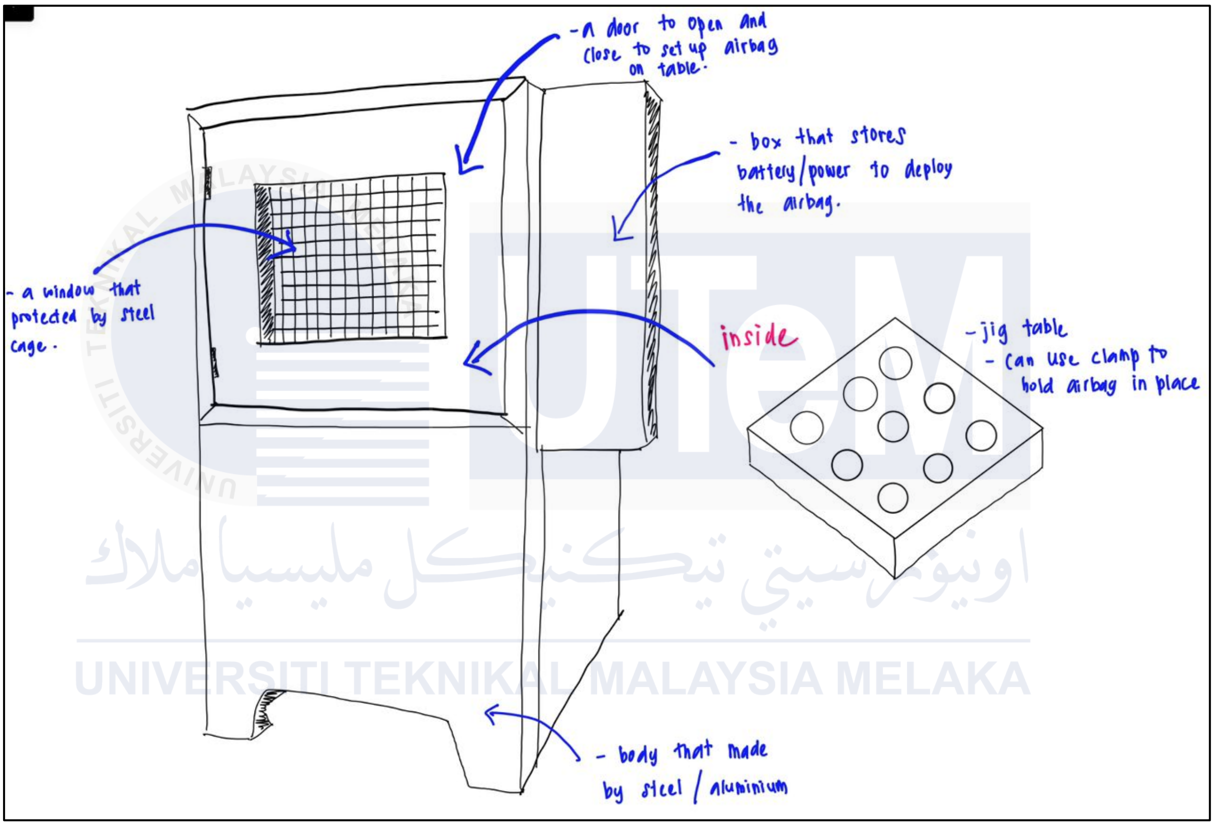


Figure 3.3 Conceptual Design 2

3.4.3 Conceptual Design 3

For conceptual design 3 in **Figure 3.4** is an enclosed table. It has 2 doors from the side and can be open from the top. The body will be made of steel SAE-4140. At the top it got safety display using polycarbonate that can see the airbag getting deploy. For the table it has jig that can use clamp to secure the airbag during being deployed. This concept got mounting points to the ground to secure the table using nuts and bolts.

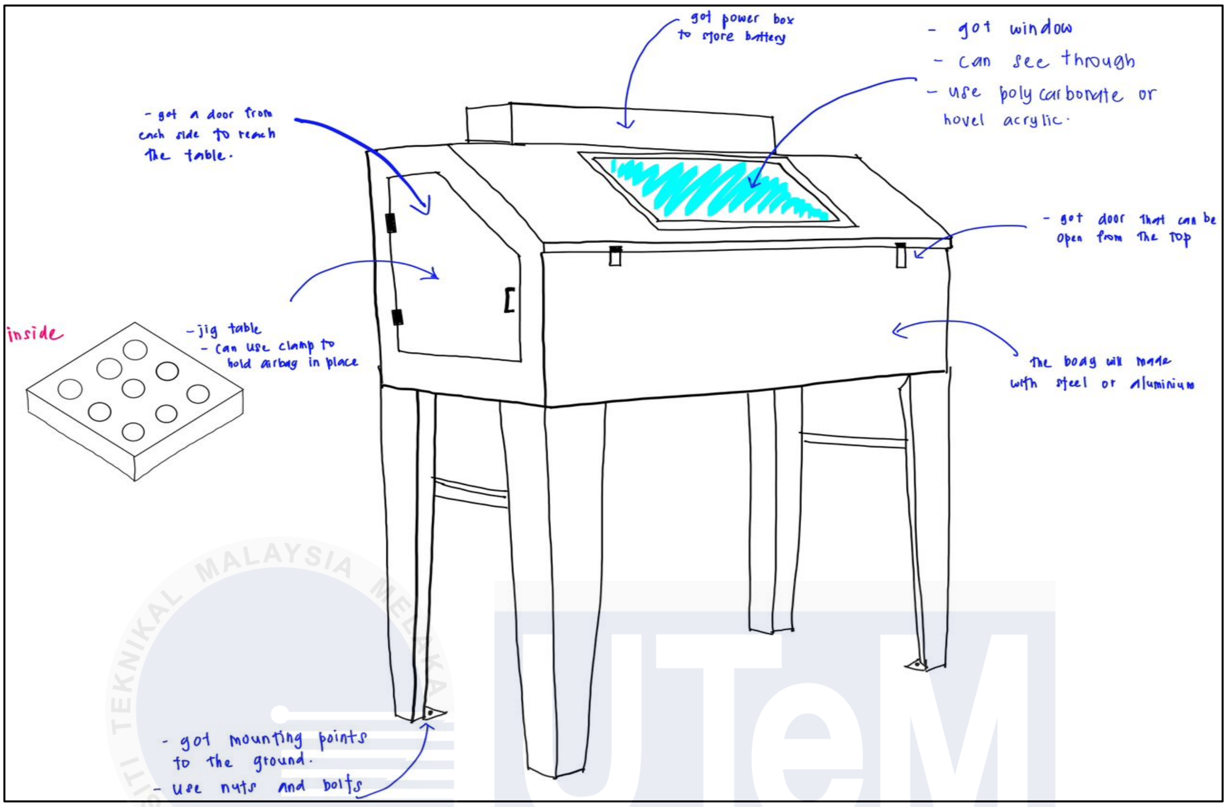


Figure 3.4 Conceptual Design 3

3.5 Steps on how to deploy an airbag

Deploying an airbag manually is a highly dangerous procedure and is typically not recommended for untrained individuals due to the risk of injury and potential damage.

Step 1: Prepare a Safe Deployment Area

i. Select specially designated tools for testing airbag deployments. Use the airbag deployment table.

ii. Secure the airbag module in a fixture designed using the jig and the clamp to hold it firmly during deployment. Airbag deployment table is specialized airbag deployment a sturdy, non-flammable surface that can withstand the force of the airbag.

Step 2: Connect Deployment Wires

Cut two long wires (red for power and black for ground for easy to recognize) and route the wires through hole the airbag deployment table to ensure can stand safely distance during deployment.

Step 3: Attach the Wires

Connect one end of each wire to the airbag's electrical connectors. Ensure a solid and secure connection.

Step 4: Set Up the Power Source

Use a 12-volt car battery or an appropriate 12-volt power supply.

Step 5: Prepare to Connect

Red wire should be connected to the positive terminal of the power source and the black to the negative terminal of the Arduino.

Step 6: Initiate Deployment

Quickly and securely connect the wires to the respective terminals on the power source. Press the push button, it will send the necessary current to the airbag, triggering its deployment.

Post-Deployment Procedures

i. After the airbag has deployed, wait a few minutes to ensure it has completely deflated and is safe to approach.
ii. Ensure the area is free of hazards, such as any fire or chemical fumes that might result from the deployment.

Dispose of the Airbag:

Follow local regulations for disposing of the deployed airbag. This involves taking it to a recycling centre that handles automotive waste.

3.6 Morphological chart

Creating a morphological chart for an airbag deployment table involves listing out different functions and possible solutions for each function as in **Table 3.2** Morphological charts aid in visualizing different design possibilities for the air bag deployment table, from which a combination of these solutions can be used to create an optimal design.

Table 3. 2 Morphological chart

Function	Conceptual design 1	Conceptual design 2	Conceptual design 3
Body Material	Stainless steel	Steel	Steel AISI 4140
Window material	Tempered Glass	Iron wire	Polycarbonate
Size	Small	Medium	Large
Ground mounting	Yes	No	Yes
Power source	Vehicle Battery	Vehicle Battery	Vehicle Battery
Airbag positioning	Fixed position	User-Configurable	User-Configurable
Cost	Economical	Medium cost	High cost
Type of airbag can be deployed	Small	Big	Big
Door	No door	1 door in front	3 doors. 1 from the top and 2 from side
An open and closed airbag deployment table	Open	Open	Closed

3.7 Weighted sum method

The Weighted Sum Method (WSM) is used for decision-making technique that helps in analyse various alternatives against a set of defined criteria. When developing an airbag deployment table for End-of-Life Vehicles (ELV), WSM can help compare different design options. This method systematically identifies the best solution using various performance metrics.

The reason for applying the Weighted Sum Method in this project is to ensure a comprehensive and balanced evaluation of all potential design alternatives. This method allows for the incorporation of various critical factors, such as safety, cost, ease of use, reliability and others, which are crucial for the successful development and of the airbag deployment table as in **Table 3.3**. By giving specific weights to each criteria according to their importance and scoring each alternative, WSM allows filtered and limited ranking and enables the decision-maker to make logical conclusion.

Table 3. 3 Weighted sum method

		Concept alternatives					
		Conceptual design 1		Conceptual design 2		Conceptual design 3	
Criteria	Importance weight (%)	Rating	Weighted rating	Rating	Weighted rating	Rating	Weighted rating
Safety	25	2	0.50	4	1.00	5	1.25
Cost	15	4	1.00	3	0.75	2	0.50
Ease of Use	25	4	1.00	3	0.75	3	0.75
Reliability	20	2	0.50	4	1.00	5	1.25
Easy to maintain	15	5	1.25	4	1.00	4	1.00
Total	100		4.25		4.5		4.75

3.8 CAD Design

CATIA, a widely used CAD software tool from Dassault Systems Limited, played a crucial role in the design and development of the Airbag Deployment Table for End-of-Life Vehicles (ELV). Its flexibility and comprehensive features made it an ideal choice for creating and analyzing the complex system required for this project. The software was utilized throughout various stages, including part design, assembly, simulation, and documentation, providing an integrated toolkit for engineers and designers.

During the development of the Airbag Deployment Table, CATIA's Part Design module was instrumental in creating detailed and precise 3D models of each component, such as the base structure, mounting frames, control systems, and safety enclosures. The software enabled the specification of dimensions, materials, and technical standards with accuracy, ensuring that all parts adhered to the required criteria.

Following the individual part design, the Assembly Design module was employed to integrate all components into a single cohesive system. This step allowed engineers to verify the proper fit and alignment of parts, ensuring that no interferences occurred between components. These checks were critical to confirm that the assembled deployment table would function as intended without any mechanical issues.

Furthermore, the Drafting module in CATIA facilitated the creation of detailed 2D drawings and manufacturing documentation. These engineering drawings included precise dimensions and material specifications, ensuring that the deployment table could be consistently fabricated to meet the project's standards.

Overall, CATIA provided a robust and integrated platform for designing and developing the airbag deployment table. Its precision, flexibility, and simulation tools contributed significantly to the project's success, ensuring that the final product met safety requirements, research objectives, and functional goals.

3.9 Analysis

The design analysis using ANSYS for developing the Airbag Deployment Table for ELVs consisted of several critical components to ensure the table could withstand the forces generated by airbag deployment. The CAD model, previously designed in CATIA, was imported into ANSYS Workbench. During this stage, the model was carefully examined for any errors that could affect the accuracy of the analysis.

Material properties were defined in ANSYS based on their real-world characteristics, such as density, elasticity, and strength. Specific properties of the selected materials, such as SAE AISI 4140, were input into the software to achieve accurate simulation results.

The model was then meshed, dividing it into small elements that ANSYS used for numerical calculations as this significantly influenced the accuracy of the stress and strain analysis.

A static structural analysis was performed to evaluate the table's response to applied loads, revealing areas of high stress, strain, and potential deformation. This included stress distribution and deformation plots to determine whether the table could safely withstand the forces. Additionally, a dynamic structural analysis was conducted to assess the table's behavior under rapid, time-varying loads characteristic of airbag deployment replicating the conditions during airbag deployment.

The results were processed to identify deformations, stress concentrations, and safety factors. These observations guided design improvements, such as geometry modifications, adding reinforcements to critical areas, or using alternative materials. Each design iteration was re-evaluated in ANSYS to verify that the modifications met the performance expectations.

Through this meticulous analysis process, the airbag deployment table was confirmed to be robust, safe, and capable of delivering reliable performance. This ensured the table met the project's requirements for testing airbags in End-of-Life Vehicles.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Results from the design and development with this Airbag Deployment Table that has been customized in its use for End-of Life Vehicles (ELV's). In this, vehicle data collected under testing test procedures are detailed analysed and the resulting data are critically reviewed in term of the implications and significance of the results in relationship to automotive safety. Airbag Deployment Table for End-of-life Vehicles (ELV) is a project to develop an environment for testing airbag deployment in controlled category. A scaled down prototype is being developed using 3D printing technology for this project. This approach results in a cost-effective and accurate way to see and test the integral design elements before constructing a complete model.

Through 3D printing, the prototype has the potential to be fabricated with a minimal amount of material waste, reduced manufacturing times, and increased flexibility during making design tolerance adjustments as based on test results. The scaled down version of this product will replicate the essential features of the final product so that the development process can be economical and is accessible for research for academic work.

4.2 Product Design Specification

First ensure that the product follows the criteria for the product design specification, such as usability and functionality, to deliver a safe, efficient, and multifunctional tool. Creating products that are high quality and usable is critical to achieving the projects goals. The materials and design of the product should meet the following requirements:

a) Proper Workability

i. The table should allow safe and convenient deployment of airbags, including easy setup and in use.

ii. It must be flexible to accept airbags from different vehicle models or type.

iii. Controllable workability should easily integrate with airbag deployment systems and operator controls.

b) Wear and Corrosion Resistance

i. Frequent use requires materials used in construction to be highly resistant to mechanical wear.

ii. Added durability can be achieved with coatings or surface treatments like powder coating or anodizing.

c) Sequence of Assembly

i. A modular deployment table design is what should be used in the deployment table to allow quick and systematic assembly and disassembly.

ii. The steps in the sequence must be logical — otherwise, some parts don’t get fixed securely and are left not ready for operation.

iii. To minimize setup time and minimize errors clear labelling and instructions for assembly should be provided.

d) Safety Requirements

i. With the reinforced enclosure walls of steel.

ii. Extra mechanism should also be included to provide locking during deployment to avoid any unauthorized access.

iii. An insulation needed to bring noise levels down to within safe hearing thresholds.

e) Design Parameters

i. Table size dimensions should be able to accommodate conventional passenger vehicle airbag modules.

ii. Table must be durable with respect to repeated use but not to structural integrity.

4.3 Design Drawing

Design drawings of the Airbag Deployment Table for End-of-Life Vehicle (ELV) give a comprehensive description of the proposed solution that guarantees safe and controlled airbag deployment from End-of-Life Vehicles (ELVs). These drawings contribute to the project, as they provide a step-by-step performance of the structure of the system and the functions of it.

4.3.1 CAD model development

CAD model development for the Airbag Deployment Table for End-of-Life Vehicles (ELV) is an important method to designing the product as in **Figures 4.1** to **4.11** below. CATIA's advanced tools allow to create precise 3D design and assemble and simulate complex assemblies and their real-world functionality. **Figures 4.12** and **4.13** shows the assembly for the product. A run through this process facilitates the conversion of conceptual ideas minimizing errors, while promoting iterative changes to physical prototyping. This already allows for accurate modelling, efficient use of resources, alignment with requirements in terms of function and safety and provides a good foundation for prototyping and fabrication.

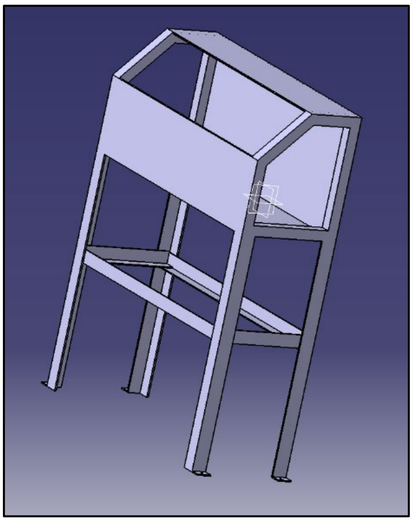


Figure 4. 1 Main body

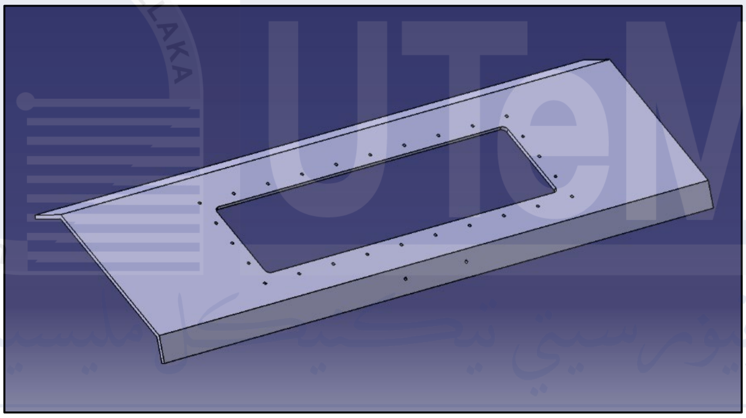


Figure 4. 2 Top door

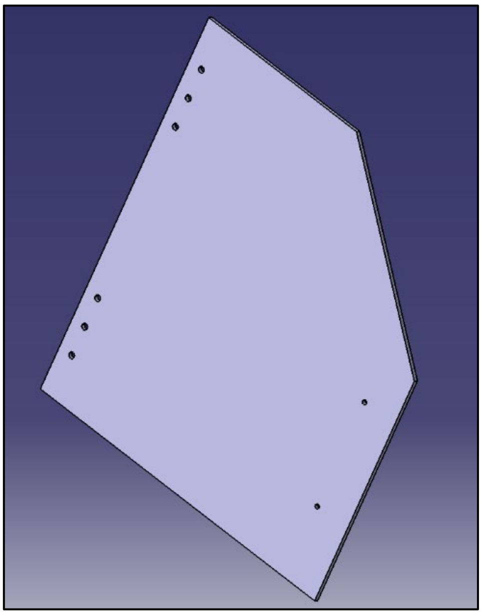


Figure 4. 3 Door

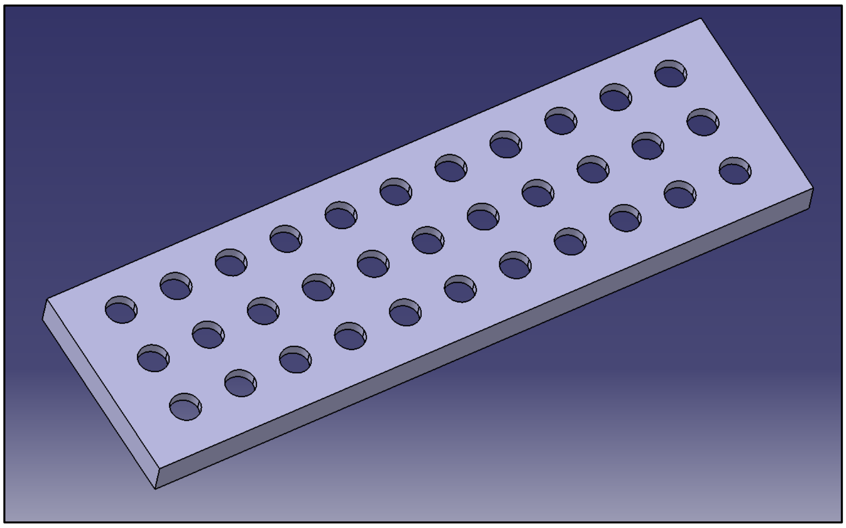


Figure 4. 4 Airbag Holder

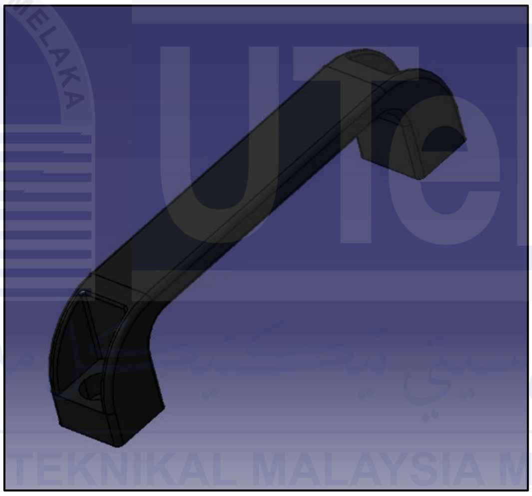


Figure 4. 5 Door handle

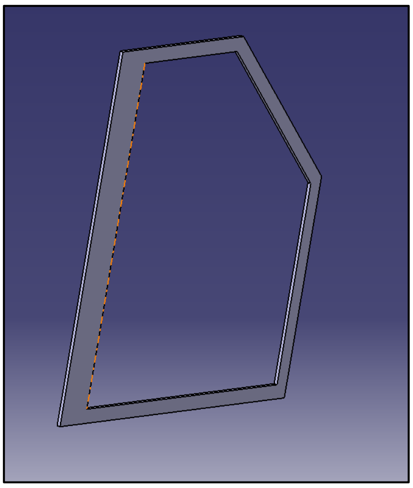


Figure 4. 6 Door Rubber

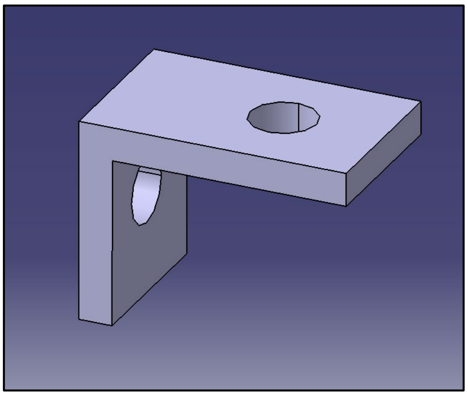


Figure 4. 7 L Bracket

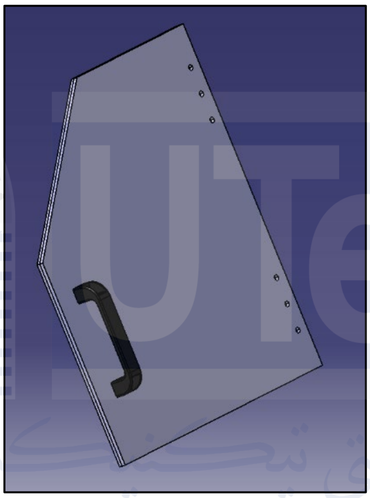


Figure 4. 8 Door Assembly

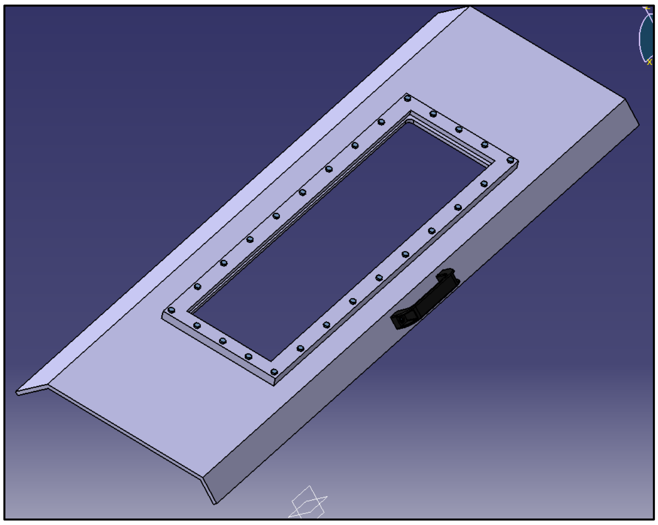


Figure 4. 9 Top door assembly

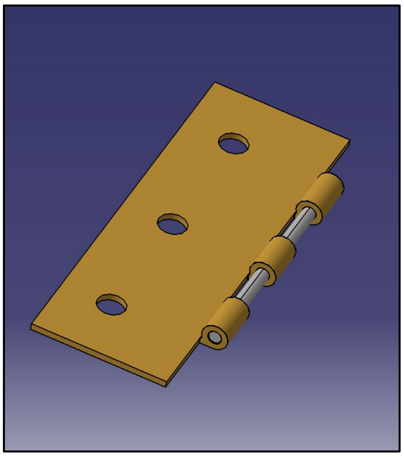


Figure 4. 10 Hinge

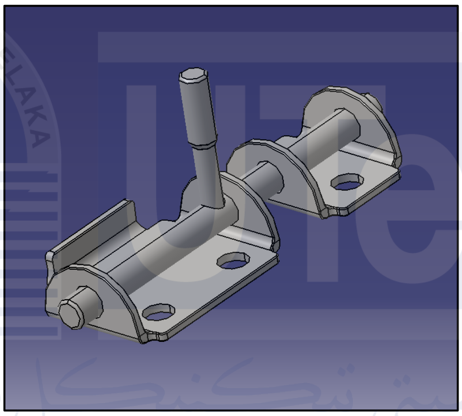


Figure 4. 11 Grandel Lock

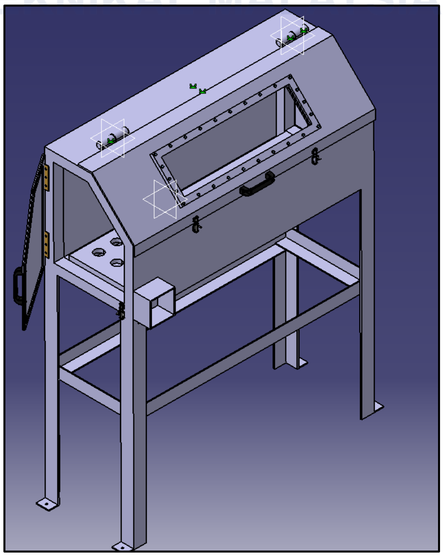


Figure 4. 12 Airbag Deployment Table Assembly

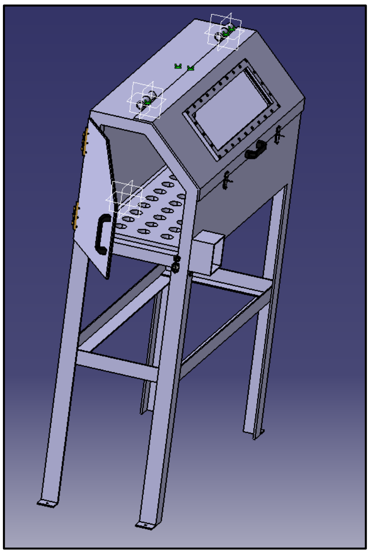


Figure 4. 13 Airbag Deployment Table Assembly side view

4.3.2 Model Drafting

Model drafting is an essential step in the design process, converting 3D CAD models into detailed 2D drawings for manufacturing and assembly. In drafting the Airbag Deployment Table for the End-of-Life Vehicles (ELV) as in **Figure 4.14** it provides precise dimensions and specifications for accurate production. It serves as a means of communicating design purpose, evaluating the product for potential problems and to close the gap between digital design and physical fabrication such that a product fulfils the performance and safety standards.

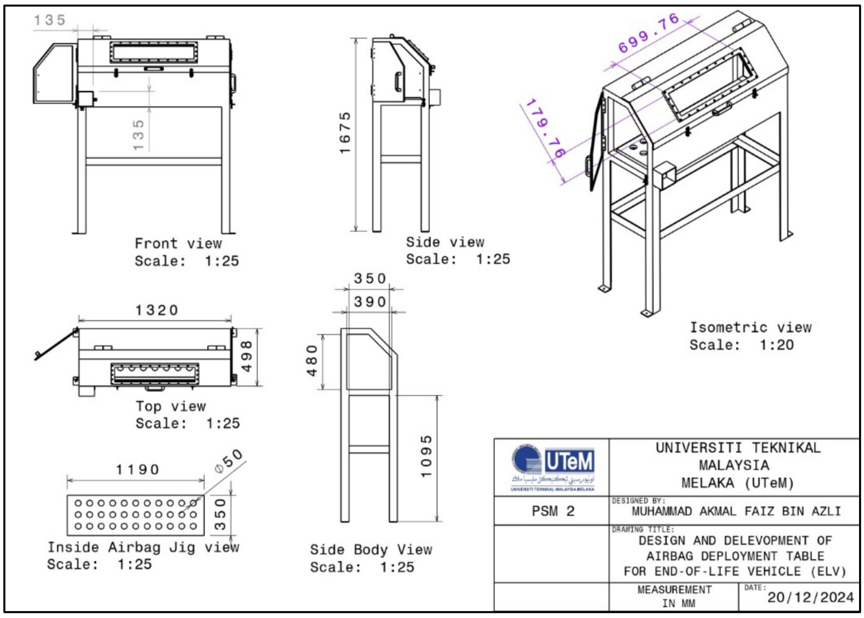


Figure 4. 14 Airbag Deployment Table CAD Drafting

4.4 Analysis

The performance of an Airbag Deployment Table for End-of-Life Vehicles (ELV) is analyzed using ANSYS software to confirm safety, proper performance and durability. Two types of analysis are conducted: Static Structural Analysis and Dynamic Analysis. Static analysis evaluates the table's response to steady forces, focusing on stress, strain, deformation, and the safety factor to ensure it operates within safe limits. Dynamic analysis looks at the table's behaviour under time dependent forces like an airbag deployment, impact resistance and structural integrity. These analyses lead to optimizing the design for safe operation.

4.4.1 Static Structural Analysis

Static structural analysis is a standard method of engineering to perform a static structural analysis — that is, analyze how a structure will behave when the table on constant loads. This analysis is performed of the Airbag Deployment Table for End-of-Life Vehicles (ELV) to determine the ability of the table to withstand forces caused by airbag activation. Stress, strain, deformation and safety factor are the selected parameters for examination.

This analysis can identify high stress areas, areas of potential deformation as well as weaknesses as in **Table 4.1** in the design which will make the table safe and stable when subject to maximum operational loads.

Table 4. 1 Results Static Structural

RESULTS STATIC STRUCTURAL				
Object Name	Equivalent Elastic Strain	Equivalent Stress	Total Deformation	Safety Factor
Minimum	1.3095×10^{-6} mm/mm	2.9769×10^{-3} MPa	0. mm	5.4317
Maximum	0.61508 mm/mm	353.98 MPa	9.8284 mm	15
Average	4.5614×10^{-3} mm/mm	36.271 MPa	0.91983 mm	14.811

The static structural analysis of the Airbag Deployment Table shows as in **Figure 4.15** that the design performs well under applied forces during airbag deployment.

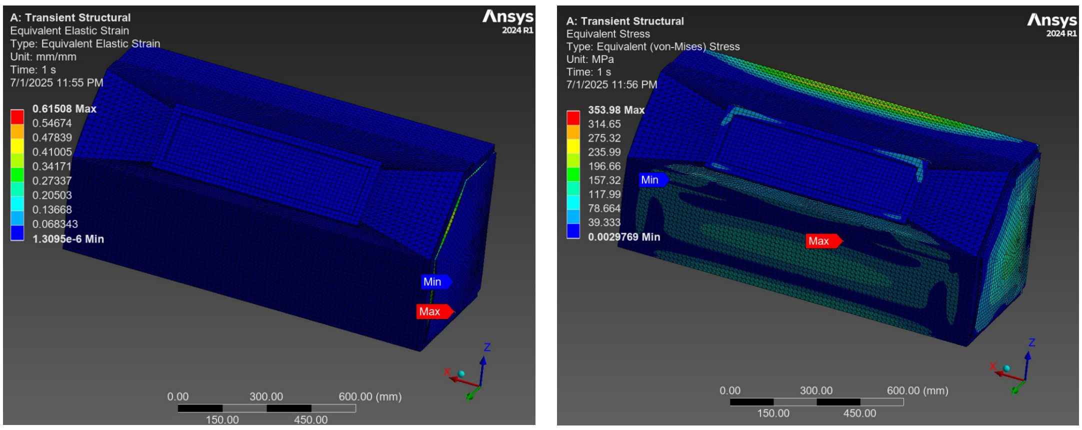
The Equivalent Elastic Strain shows in **Figure 4.15 (a)** how much the material stretches under load, with values ranging from 1.3095×10^{-6} mm/mm to 0.61508 mm/mm, and an average of 4.5614×10^{-3} mm/mm. The material stays within its elastic limit, meaning no permanent deformation happens.

The Equivalent Stress in **Figure 4.15 (b)** ranges from 2.9769×10^{-3} MPa to 353.98 MPa, with an average of 36.271 MPa. These stress values are within the material's safe limits, ensuring it can handle the applied forces.

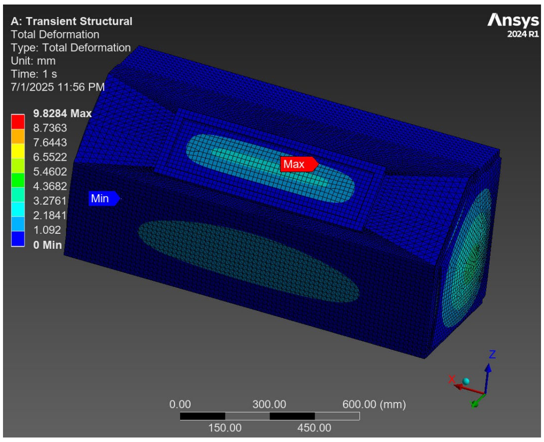
The Total Deformation is minimal, ranging from 0 mm to 9.8284mm, with an average of 0.91983mm, showing in **Figure 4.15 (c)** that the table maintains its structural integrity.

The Safety Factor ranges from 5.4317 to 15, with an average of 14.811, indicating a high margin of safety and ensuring the table can handle much greater forces than expected as in **Figure 4.10 (d).**

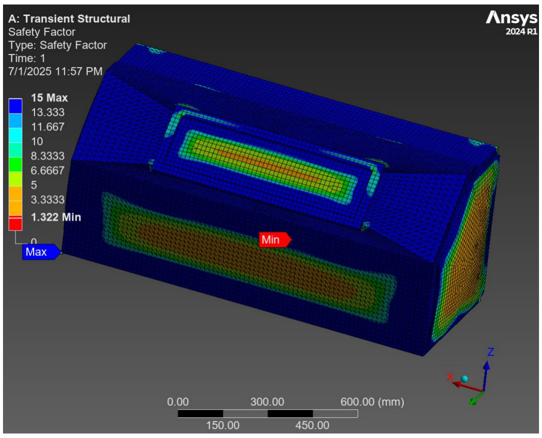
In summary, the table is strong, safe, and reliable for airbag deployment testing in End-of-Life Vehicles (ELV)



a) **b)**



c)



d)

Figure 4. 15 (a,b,c,d) Static Structural Analysis from Ansys

4.4.2 Dynamic Analysis

Dynamic structural analysis is a technique to evaluate the response of a structure to rapidly changing or time dependent forces. This analysis focuses on how the Airbag Deployment Table for End-of-Life Vehicles (ELV) behaves during airbag activation where very fast, high momentum forces act on it.

Impact resistance and structural integrity under transient conditions are investigated. The analysis then simulates these dynamic loads using ANSYS software to confirm the table can be subjected to real world forces without failure. This process optimizes the design for safety, reliability and long-term durability under operational conditions.

The graph and table illustrate the transient pressure applied over time, an important aspect of Dynamic Analysis in ANSYS. This analysis simulates how the Airbag Deployment Table for End-of-Life Vehicles (ELV) responds to the forces generated during airbag deployment.

The graph shows as in **Figure 4.16** a linear increase in pressure from 0 MPa to 0.086 MPa over a short time. At the start (0 seconds), there is no pressure, representing the initial state before airbag activation. By the end of the time step, the pressure reaches its peak value, simulating the maximum force from the inflating airbag. The table provides specific pressure values at different time steps, confirming this moderate increase.

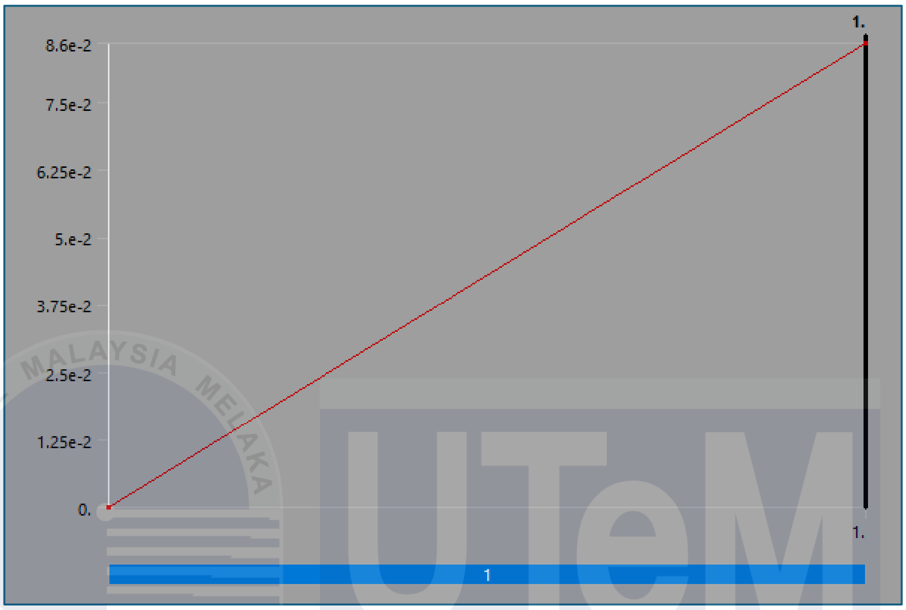


Figure 4. 16 Transient pressure over time for Dynamic Analysis

This analysis as in **Table 4.2** helps evaluate the table's performance under rapidly changing forces. By applying this pressure in the simulation, engineers can assess stress, deformation, and safety factors across the structure. This process ensures the airbag deployment table is strong, safe, and capable of withstanding real-world forces during airbag testing.

Table 4. 2 Transient pressure over time for Dynamic Analysis

Steps	Time [s]	Pressure [MPa]
1	0.	0.
	1.	$8.6x10^{-2}$

4.5 Prototyping Plan

An advanced 3D printing technology is used in the prototyping plan of the Airbag Deployment Table for End-of-Life Vehicle (ELV) to develop a scaled down. The ratio is 1:42. This approach enables an efficient, cost effective and accurate means of viewing and testing critical design elements prior to full scale production. The prototyping process utilizes 3D printing to minimize material waste, reduce manufacturing lead times, and the ability to iterate upon testing feedback improves the prototype to manufacture workflow.

4.5.1 List of Material/Apparatus

This project aims to develop a small-scale prototype for testing airbag deployment safely within the Airbag Deployment Table for End-of-Life Vehicles (ELV). This will be prototyped by 3D printing, which is cheaper, faster, and easier to redesign.

With the scaled down model, the main features of the full-scale design can be tested and improved, and the model can be inexpensive to build and relatively unaffected by mistakes made during manufacture. It describes the materials and tools as in **Table 4.3** needed to make the prototype, and simple, efficient ways for academic research.

Table 4. 3 List of Material

No.	Apparatus	Quantity
1.	PLA Filament (Grey)	988.3 grams
2.	Acrylic Sheets	1
3.	Plywood	1
4.	Epoxy Adhesive	1
5.	Sandpaper 800 grit	3
6.	Cleaning Alcohol (IPA)	1
7.	Cutter	1
8.	Flashforge Creator PRO 3D Printer	1

4.5.2 Prototyping Process Development Using 3D Printer

The 3D printing process connects material choice with final assembly to provide a continuous method for creating prototypes. The chapter presents essential phases in creating a successful prototyping method with 3D printing applications. This will guide the essential prototyping components that include CAD system compatibility while showing both printing methods and finishing processing techniques needed for high-quality print outcomes.

4.5.2.1 Material Selection

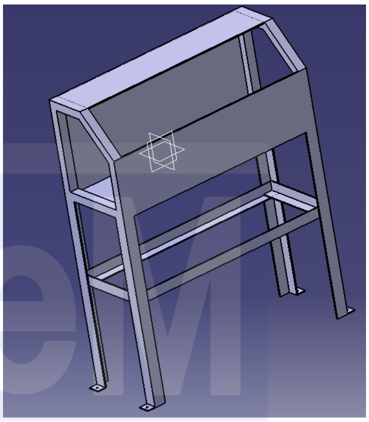
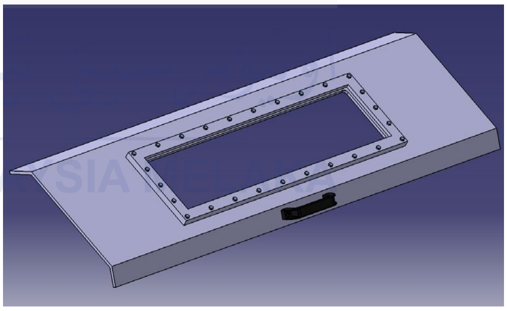
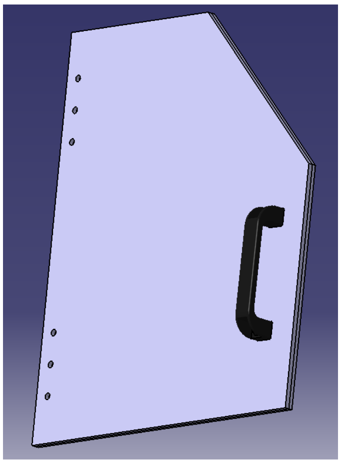
Selecting the perfect materials remains importance to product design because it affects both functionality and environmental impact together with total manufacturing cost. Use of the Material Library in CATIA as below in **Figure 4.17** enables simulation to evaluate material properties for application-based suitability assessment. SAE-AISI 4140 steel was chosen as the final material because its high strength and durability.

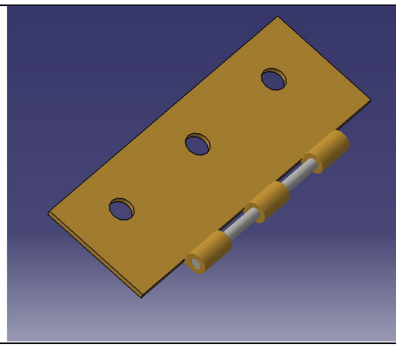
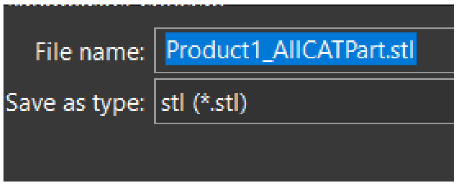
Figure 4. 17 Material Selection in CATIA

4.5.2.2 CAD Conversion

The sequence of transforming digital designs into printable physical forms requires CAD conversion when dealing with 3D printing applications. Below **Table 4.4** the conversion from a prototype design derived from CATIA software to an STL format usable for 3D print technology is documented. The design conversion process accurately retains all design details properly transforming them into the necessary file format for 3D printing.

Table 4. 4 CAD Conversion

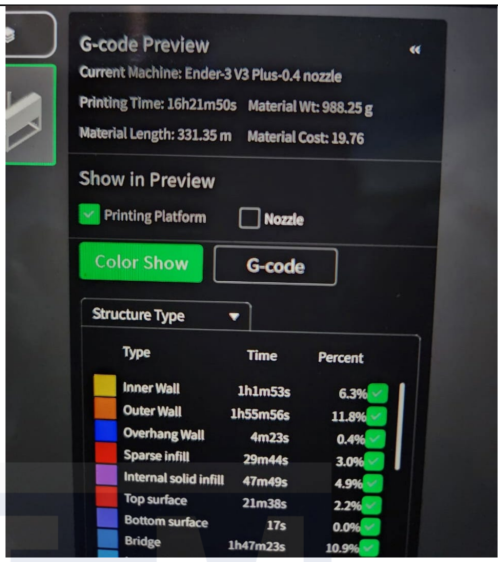
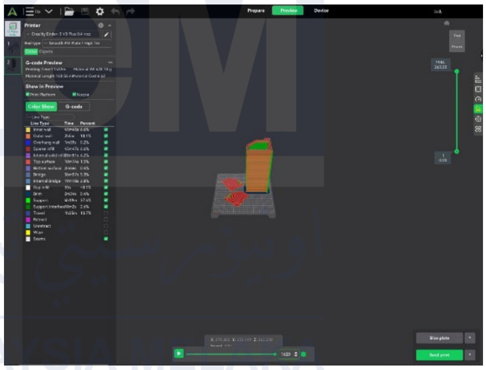
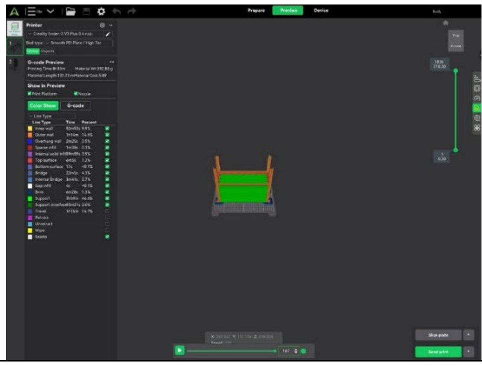
Process name	Explanation	Picture
Drawing Creation in CATIA	a) The prototype design is developed using CATIA software, where each component is modeled. b) The model is checked for accuracy, dimensions, and compatibility to ensure all parts fit together seamlessly.	  

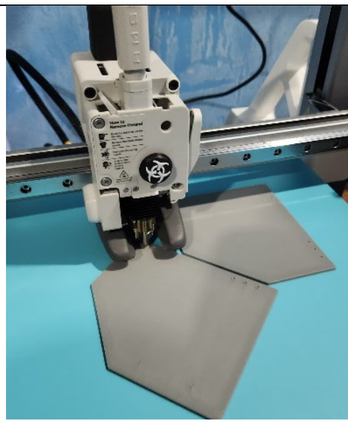
		
Conversion into STL File	a) Once the drawing is complete, the design is exported from CATIA as an STL (Stereolithography) file. b) The STL file contains all 3D geometry details required for the 3D printing process.	

4.5.2.3 3D Printing Process

The 3D printing process represents an important step as in **Table 4.5** below through which CAD design becomes a physical object. Examine each stage of the 3D printing sequence which begins with STL file setup within FLASHPRINT software. Through the configuration of printing parameters such as material type, layer height and print speed users can optimize both the quality and accuracy of printed prototypes. Next in 3D printing technology is the stage where the printer builds each section of the physical object one layer after another using the STL file specifications.

Table 4. 5 3D Printing Process

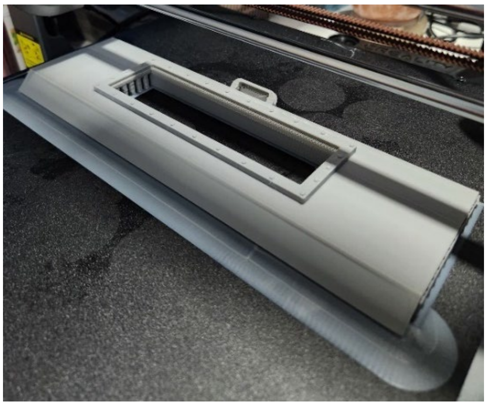
Process name	Explanation	Picture
3D Printing Setup	a) The STL file is imported into FLASHPRINT software, where the settings for 3D printing are configured: i. Material Type: PLA filament. ii. Layer Height: 0.2 mm for optimal detail. iii. Print Speed: Automated adjusted for accuracy. b) The software estimates material usage: i. Material length: 331.35m ii. Printing time: 16 hours 22 minutes	  
3D Printing Process	a) The 3D printer fabricates the parts layer by layer, following the design specifications in the STL file.	

	b) PLA filament is used due to its ease of use, affordability, and compatibility with scaled-down models.	 

4.5.2.4 Prototype Preparation and Assembly

Prototype development in 3D printing reaches completion through accurate preparation actions followed by assembly as in **Table 4.6** below. The section explains the vital post-processing techniques such as scraping and scrubbing with finishing to protect both the structure and functional capabilities of 3D printed components. By assembling separate elements as prescribed in design specifications technicians finalize a complete prototype.

Table 4. 6 Prototyping Process

Process name	Explanation	Picture
Scrapping the Prototype	a) Once printing is complete, a scraper is used to carefully remove the printed parts from the printer's platform. b) This step ensures that the parts remain intact and undamaged during removal.	
Scrubbing and Finishing	a) The printed components are sanded using fine-grit sandpaper to smooth the surfaces and remove imperfections. b) Residual material or supports from the 3D printing process are removed for a clean finish.	

Assembly Process	a) All components are assembled following the original design using screws and nuts. b) The assembly process is guided by the CATIA model to ensure precise alignment and functionality of the prototype.	 

4.5.3 Prototype Final Assembly

Using 3D printing technology, the first assembly stage of the prototype produces and combines individual components into a complete mechanical system. 3D printing represents a precise and efficient way to produce complex parts with high accuracy and few materials for the Airbag Deployment Table for End-of-Life Vehicles (ELV).

The product as in **Figure 4.18** below, printed by 3D technology using Bambulab A1 AMS printer are assembled in with the CAD model to assure they fit and are aligned properly. It adjusts and iteration improvements easy by allowing for easily created modifications and reprinting up new parts. This 3D printed prototype is a low cost and scalable solution for validation of design concepts and functionality prior to full production scale.

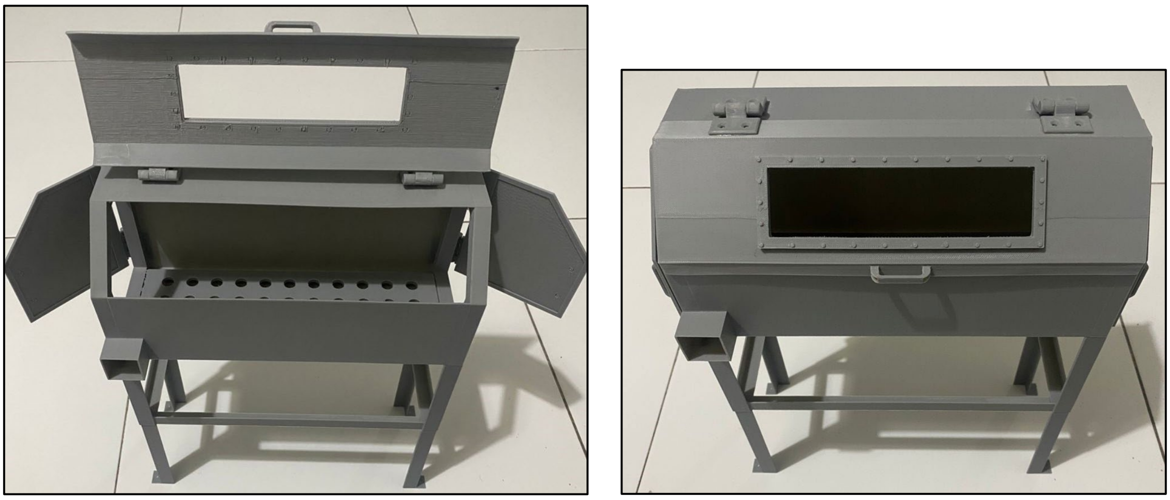
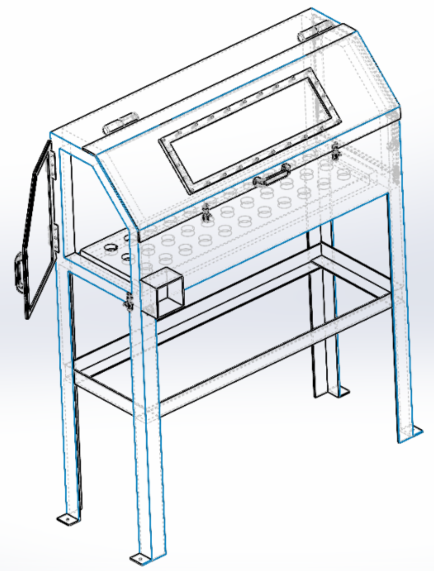


Figure 4. 18 Prototype final Assembly

4.6 Bill of Materials (BOM)

Important in development and manufacturing of the Airbag Deployment Table is a critical document known as the Bill of Materials (BOM). It is an inventory of all the parts, materials and sub-assemblies to make and assemble the deployment table like **Figure 4.19** below. Each item has detailed information available on its specifications and quantities to help positively accomplish a project as in **Table 4.7**.



ITEM NO.	PART NUMBER	QTY.
1	Main Body.CATPart	1
2	door.CATPart	2
3	Door Handle 165mm.CATPart	3
4	door rubber.CATPart	2
5	Part1.CATPart	4
6	Part2.CATPart	6
7	Pin.CATPart	4
8	Washer.CATPart	32
9	top door.CATPart	1
10	tempered glass.CATPart	1
11	glass cover.CATPart	1
12	ISO_4014_M6x35_STEEL_GRADE_A_HEXAGON_HEAD_BOLT.CATPart	26
13	ISO_4762_M6x12_STEEL_HEXAGON_SOCKET_HEAD_CAP_SCREW.CATPart	2
14	male.CATPart	2
15	female.CATPart	2
16	lock.CATPart	2
17	Shaft.CATPart	2
18	Part1_1.CATPart	2
19	Symmetry of lock.CATPart	2
20	Symmetry of Shaft.CATPart	2
21	Symmetry of Part1 1.CATPart	2
22	Symmetry of Part2.CATPart	2
23	airbag holder.CATPart	1
24	kotak.CATPart	1
25	L brakcet.CATPart	1

Figure 4. 19 Bill of Material

Table 4. 7 Bill of Material

No.	Parts Name	Quantity
1.	Main body	1
2.	Door	2
3.	Door Handle 165mm	3
4.	Door Rubber	2
5.	Door Hinge	4
6.	Pin	2
7.	Washer	32
8.	Top Door	1
9.	Tempered Glass	1
10.	Glass cover	1
11.	ISO 4014 Bolt M6x35 Steel	26
12.	ISO 4762 Screw M6x12 Steel	2
13.	Male	2
14.	Female	2
15.	Lock	2
16.	Shaft	2
17.	Part 1 Grandel	2
18.	Part 2 Grandel	2
19.	Symmetry of lock	2
20.	Symmetry of shaft	2
21.	Symmetry of Part 1 Grandel	2
22.	Symmetry of Part 2 Grandel	2
23.	Airbag Holder	1
24.	Box (for electronic)	1
25.	L bracket	2

4.7 Material Properties

The preferred material to produce the actual Airbag Deployment Table prototype components is SAE-AISI 4140 (Chromium Molybdenum Steel). Such high strength, toughness, and resistance to wear make this a very good material to use in an airbag deployment test, where it needs to last through large force and stress.

Whereas PLA (Polylactic Acid), a lightweight polymeric material, is used for prototyping because of its easy availability, low cost, and quick fabrication of complex geometries. But its lower strength and stiffness make it unsuitable for final component fabrication.

In this **Table 4.8**, compare the material properties of the used prototype's material (PLA) with the recommended material (SAE-AISI 4140):

Table 4. 8 Material Properties for Prototype and Actual (MatWeb. (n.d.). PLA (Polylactic Acid) and AISI 4140: Material properties. Retrieved from https://www.matweb.com)

Property	Prototype Material: PLA (Polylactic Acid)	Recommended Actual Material: AISI 4140
Model Type	Linear Elastic Isotropic	Linear Elastic Isotropic
Yield Strength	50 MPa	415-655 MPa
Tensile Strength	60 MPa	655-850 MPa
Elastic Modulus	3 GPa	200 GPa
Poisson's Ratio	0.35	0.30
Mass Density	1240 kg/m^3	7850 kg/m^3
Shear Modulus	1.1 GPa	80 GPa
Thermal Expansion Coefficient	7e-5 /Kelvin	1.13e-6 /Kelvin

The shift from PLA (Polylactic Acid) to SAE-AISI 4140 (Chromium-Molybdenum Steel) is crucial for the prototype's success. Its superior strength, toughness and resistance to wear make it better suited for stress application environments such as airbag deployment. This change will significantly improve the durability and reliability of the table and guarantee safe and accurate testing of End-of-Life Vehicles (ELV).

For window of the End-of-Life Vehicle Airbag Deployment Table (ELV), polycarbonate is an ideal material because of its high strength, impact resistance and high thermal stability. That means that the rapid forces that are generated during airbag deployment don't crack or break it, meaning that it can handle this critical part of the table well.

Polycarbonate is one significant application in deployment table consisting of safety enclosures. It's transparent enough that users can see what airbag deployment looks like, but users are protected from potential bits or debris. Furthermore, its excellent thermal stability allows it to withstand the heat generated during deployment without deforming, preventing the testing setup from deforming. Below in **Table 4.9** shows the properties of Polycarbonate.

Table 4. 9 Material Properties for Polycarbonate (Callister, W. D., & Rethwisch, D. G. (2020). Materials science and engineering: An introduction (10th ed.). Wiley.)

Property	Polycarbonate
Model Type	Linear Elastic Isotropic
Yield Strength	70 MPa
Tensile Strength	75 MPa
Elastic Modulus	2.4 GPa
Poisson's Ratio	0.37
Mass Density	1200 kg/m³
Shear Modulus	0.88 GPa
Thermal Expansion Coefficient	$7x10^{-5}$ /Kelvin

4.8 Simulation of Airbag Deployment

Another crucial step in the Airbag Deployment Table for End-of-Life Vehicles (ELV) functionality validation is simulation of Airbag Deployment System's deployment. The system duplicates the deployment mechanism in a controlled with Arduino and Tinkercad. This allows us to test and refine without having to build a full-size prototype, promoting safety, efficiency and precision in the development process. Airbag deployment is also simulated with a servo motor along with visual and audible alerts using led and buzzer. These elements combined provide an understanding of the operational behaviour of the designed system when it operates.

4.8.1 System Components

To replicate and analyze the performance of the simulation it is necessary to understand the components of the simulation. In this section introduce the hardware and software elements used and fabricating a functional prototype as in **Table 4.10** below. Integration of these components leads to a simulation that accurately models a portion of the entire airbag deployment system.

Table 4. 10 System Components

No.	Component	Quantity
1.	Arduino Uno R3	1
2.	Positional Micro Servo	1
3.	Pushbutton	1
4.	10 kΩ Resistor	1
5.	220 Ω Resistor	1
6.	Red LED	1
7.	Piezo Buzzer	1

4.8.2 Circuit Design

The simulation is built on the circuit design. This section describes the configuration of the components and explains the layout of the components so that they interact properly either inputs or outputs. The design of the system is proper to ensure the system functionality and to replicate the airbag deployment mechanism.

The controlled system for the airbag deployment mechanism is schematically shown below in **Figure 4.20**. It also includes the Arduino microcontroller, a push button as a trigger, a servo motor to actuate simulating airbag deployment, an LED and buzzer for feedback. Precise interaction of these components is ensured by the circuit, resulting in the simulation accurately replicating the real-world deployment process.

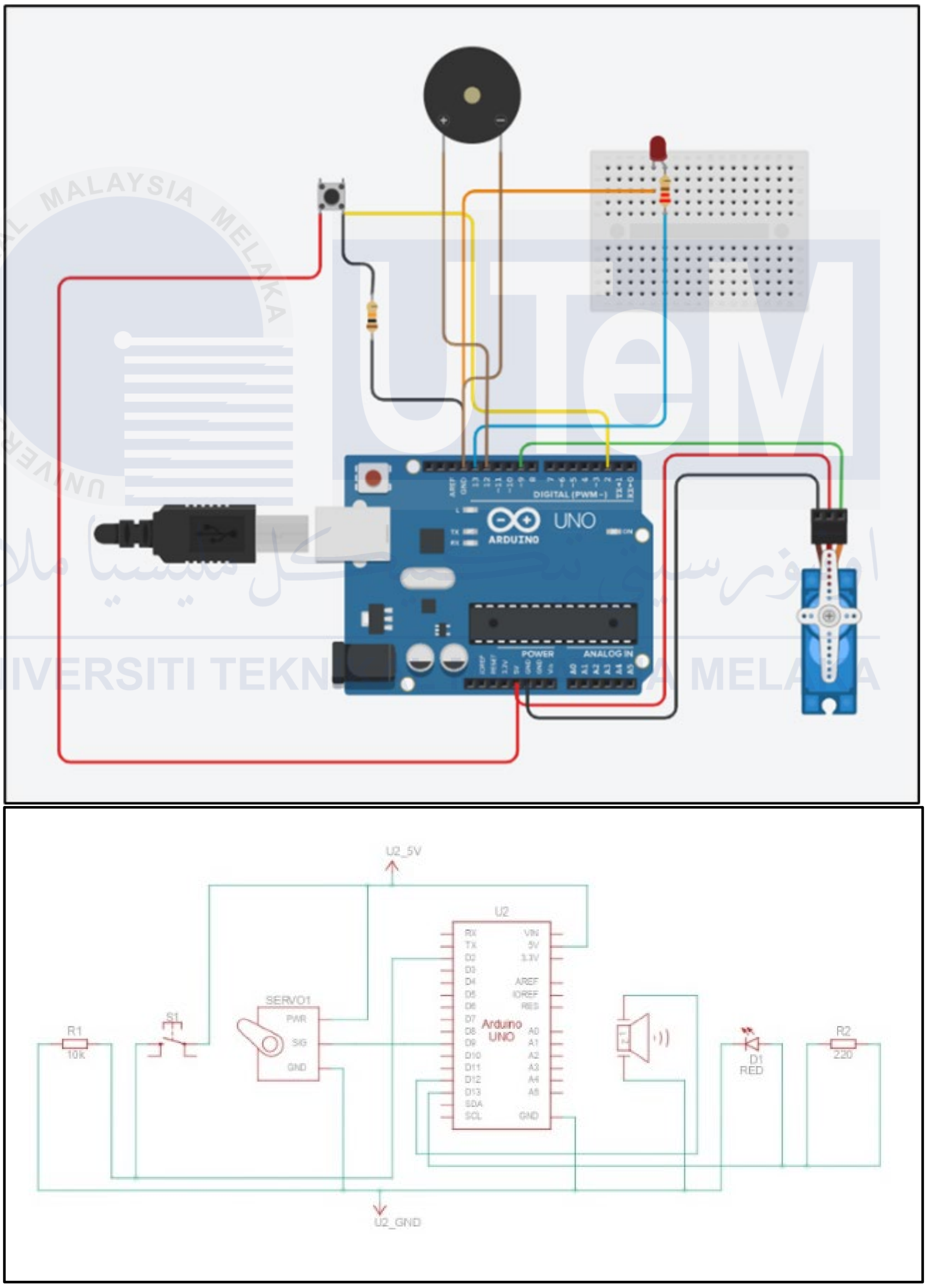


Figure 4. 20 Schematic Circuit

4.8.3 Coding for Arduino

Arduino is a microcontroller platform that is widely used for prototyping and developing electronic systems. It offers a friendly code writing, compiling, and upload interface for running code to communicate on hardware. In the simulation of the Airbag Deployment Table for End-of-Life Vehicles (ELV), Arduino is its control system.

To simulate airbag deployment scenarios, components, such as pressure sensor, LEDs, and relays can be interfaced to Arduino. In the Arduino Integrated Development Environment (IDE), the code is written which communicates to these components doing task such as trigger signal detection, airbag actuator activation and displaying the system status through LEDs.

For this project, the Arduino code is modified to deploy the airbag. Logic for detecting signals from input sensor, processing them, and executing commands for actuating the airbag system was included.

Have library inclusions and global variable declarations. In this code, include the Servo.h library to control the servo motor which serves as airbag deployment simulation as in **Figure 4.21**. The button, LED and buzzer are defined with pins and a variable to hold the button's state is defined. The first declarations map the hardware components to the Arduino, so they are usable in the program.

```
#include <Servo.h>

// Create a Servo object
Servo airbagServo;

// Define pin numbers
const int buttonPin = 2;    // Pin for the push button
const int ledPin = 13;      // Pin for the LED
const int buzzerPin = 12;   // Pin for the buzzer
int buttonState = 0;        // Variable to hold button state
```

Figure 4. 21 Variable Declarations

Where the system is initialized, is the setup function as in **Figure 4.22**. Attach the button as input, LED and buzzer as output, and the servo motor as pin 9. The system is designed such that when first powered on, the LED and buzzer are off so that the system starts in a neutral, safe state. With this setup, the basic operation of the simulation is prepared.

```
void setup() {
  // Attach the servo to pin 9
  airbagServo.attach(9);

  // Set the initial position of the servo
  airbagServo.write(0);  // 0 degrees (not deployed)

  // Configure the button, LED, and buzzer pins
  pinMode(buttonPin, INPUT);
  pinMode(ledPin, OUTPUT);
  pinMode(buzzerPin, OUTPUT);

  // Turn off the LED and buzzer initially
  digitalWrite(ledPin, LOW);
  digitalWrite(buzzerPin, LOW);
```

Figure 4. 22 Setup Function

DigitalRead() checks whether the button is off (high) or pressed (low), every loop of the main loop as in **Figure 4.23**. On button press the airbag deployment simulation is triggered. As airbag inflation, the servo motor rotates to mimics the inflation by turning 90 degrees, and LED lights up with a buzzer going off as a visual and audible feedback. To complete the simulation, keep the system active one second. Once that bit of control is triggered, the servo motor resets back to its starting position, the indicators turn off and the system is ready for the next activation.

```
void loop() {
  // Read the state of the button
  buttonState = digitalRead(buttonPin);

  if (buttonState == HIGH) {
    // Simulate airbag deployment
    airbagServo.write(90);      // Move servo to 90 degrees
    digitalWrite(ledPin, HIGH);  // Turn on the LED
    digitalWrite(buzzerPin, HIGH);  // Turn on the buzzer
    delay(1000);                // Keep deployed for 1 second

    // Reset
    airbagServo.write(0);       // Reset servo to 0 degrees
    digitalWrite(ledPin, LOW);   // Turn off the LED
    digitalWrite(buzzerPin, LOW);  // Turn off the buzzer
  }
}
```

Figure 4. 23 Main Loop

The entire code is written to effectively simulate airbags deployment by initializing the hardware, monitoring the input and execute the action. The code for each part is each important to know that it will run the airbag deployment table properly. Depending on the requirements of project you have or testing scenario, you can expand or modify these features.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Finally, this project successfully achieved these objectives while designing, analyzing and developing a prototype for the Airbag Deployment Table for End-of-Life Vehicles (ELV). Through deep research, material selection and design specification, the project pulled together the ability of deployment table to enable the accomplishment of airbag deployment testing for ELVs in a way that increases the safety, efficiency, and reliability of testing.

Demonstrate that combining practical mechanical principles, advanced materials like polycarbonate and SAE-AISI 4140 steel and easy manufacturing in the form of 3D printing and basic machining can give a functional and low-cost prototype. Deployment table simplicity of materials and assembling lends itself to the adoption of existing recycling ELV operations.

This project is important as it contributes to the still grow area of ELV recycling. Due to the large number of vehicles produced each year, this deployment table is a solid solution for the deployment of the airbag dismantling process to save time and to improve operational efficiency for recycling companies.

This project has been very rewarding as first learned the complex details regarding the intersection between engineering, sustainable practices and automotive recycling. This has led to problem solving skills and collaborations around in ELV recycling industry.

The final year project described here is a first step towards future tools for airbag deployment. Considering automotive transition to greener technology, innovations such as this deployment table will help the reduced environmental impact.

5.2 Recommendation

Some recommendations are proposed to improve the functionality and versatility of the Airbag Deployment Table for End-of-Life Vehicles (ELV).

To expand the material testing process to explore new advanced materials that may have better strength to weight ratios or better corrosion resistance. Light weight alloys or composite materials can be used to the table, and it can remain as portable as necessary without losing its strength or structural integrity.

Second, there is a need for increasing the compatibility of the deployment table. Airbags from a larger range of vehicle models like heavy vehicle, need to be taken into considerations in future designs. Such a table would become more adaptable and practical in multiple worldwide ELV recycling operations.

Third, the addition of automation will considerably enhance the table's efficiency and safety. Deployment process could be simplified by apply of such a programmable actuator, sensors, control systems, and would increase precision and decrease the need for manual intervention and consequently increase operator safety.

Furthermore, a modular design application is proposed for simplification of assembly, maintenance and scalability. Simply breaking the table down into small components would speed the process of adapting the table to other testing environments or allow quick repairs or upgrades when the need demands.

Finally, real world testing in ELV recycling facilities is considerable. This is very useful to get working information about the table at operational conditions and to find improving steps. Testing checks if the design is practical and satisfied the end users requirements.

By these recommendations, propose deploying an optimized ELV recycling operations table that would satisfy the requirements of a changing ELV while maintaining safety, efficiency and adaptability.

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Appendix B Static Structural Configuration Analysis in Ansys

Object Name	***Equivalent Elastic Strain***	***Equivalent Stress***	***Total Deformation***
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Equivalent Elastic Strain	Equivalent (von-Mises) Stress	Total Deformation
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier		mystress	
Suppressed	No		
Integration Point Results			
Display Option	Averaged		
Average Across Bodies	No		