# DESIGN SEATBELT ADJUSTER FOR CHILDREN BY USING INTEGRATED DESIGN METHOD

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# Faculty of Mechanical Technology and Engineering

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**Afiq Aiman Bin Ramlan**

**Bachelor of Mechanical Engineering Technology (Automotive Technology) with Honours**

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**AFIQ AIMAN BIN RAMLAN**

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

**Faculty of Mechanical Technology and Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2024**

## DECLARATION

I declare that this Choose an item. entitled " Design Seatbelt Adjuster for Children by Using Integrated Design Method" is the result of my research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature :

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**APPROVAL**

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

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|---|---|---|
| Signature | : | |
| Supervisor Name | : | DR NOOR SAFFREENA BT HAMDAN |
| Date | : | 12/1/2024 |

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# DEDICATION

I dedicate this final year paper to all the individuals who have played a significant role in my academic journey, supported me throughout this endeavor and inspire me to become excellence.

To my family, i am incredibly grateful to each every one of you for your unwavering support and encouragement during my academic career. You always been a pillar of support and inspiration in my life. I very grateful for your sacrifies and commitment for my education.

To my friends, i am deeply gratitude and heartfelt appreciation for your enduring friendship and support. Your unfliching faith in me, even though my worst day, has motivated my determination to succeed.

To my supervisors, who have shared their knowledge and skills with me, guiding me in my studies. Your guidance and encouragement have pushed me to reach new height and surpass my own expectations. Your insightful feedback, constructive critcism and assisted me in refine my ideas for producing high-quality work.

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To the many researchers, professors, and authors whose work has laid the groundwork for this study. Your commitment to furthering knowledge in your various discipline has served as an inspiration and guided me throughout my study process.

Finally, I dedicate this paper to myself, in recognition of my perseverance, determination, and numerous hours invested in this project. It shows my development, resilience, and dedication to lifelong learning. I hope this serves as a starting point to a future of ongoing growth and the study.

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## ABSTRACT

The purpose of this research paper is to report the findings of a research project into the design of a seatbelt adjuster for children that makes use of the design-integrated method. Seatbelt adjusters rarely work properly with automobile seats because of compatibility issues. There is also the possibility that some children will be persuaded to remove the seatbelt adjuster or otherwise tamper with it, which places their safety in jeopardy. The primary purpose of this investigation is to develop an idea for a child's seatbelt adjuster for the booster seat. The vehicle that is being proposed needs to be suitable for the design. The purpose of wearing a booster seat is to improve the safety of the vehicle's occupants and to provide protection if the vehicle is involved in a collision or accident. Laws requiring drivers and passengers to wear seatbelts have been introduced to encourage safe driving and to lessen the possibility of serious injuries and fatalities resulting from motor vehicle collisions. There are many types of restraints in the vehicles. The integrated design method is a collaboration between two methodologies such as TRIZ, Morphological Chart, Pugh Method, Dematel Method and AHP Method. This study makes use of applications of both The Inventive Thinking Process (TRIZ) and the morphological chart. Both of these are referred to as applications. At first, the TRIZ contradiction matrix was utilized to zero in on a primary solution. 40 various instruments in TRIZ that can also be utilized to solve problems with innovative principles. To build theoretical notions for the elements in a methodical manner, important solution parameters for specific design characteristics were refined, and morphological charts were used to display the results. The final conceptual design was produced based on two different design principles.

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# *ABSTRAK*

Tujuan kertas penyelidikan ini adalah untuk melaporkan penemuan projek penyelidikan ke dalam reka bentuk pelaras tali pinggang keledar untuk kanak-kanak yang menggunakan kaedah bersepadu reka bentuk. Pelaras tali pinggang keledar hampir tidak pernah berfungsi dengan betul dengan tempat duduk kereta kerana masalah keserasian. Terdapat juga kemungkinan bahawa sesetengah kanak-kanak akan dipujuk untuk menanggalkan pelaras tali pinggang keledar atau sebaliknya mengusiknya, yang meletakkan keselamatan mereka dalam bahaya. Tujuan utama penyiasatan ini adalah untuk membangunkan idea untuk pelaras tali pinggang keledar kanak-kanak serta reka bentuk. untuk salah satu penyelaras tersebut. Kenderaan yang dicadangkan perlu bersesuaian dengan reka bentuk. Tujuan pemakaian tali pinggang keledar adalah untuk meningkatkan keselamatan penumpang kenderaan dan memberi perlindungan sekiranya kenderaan terbabit dalam perlanggaran atau kemalangan. Undang-undang yang mewajibkan pemandu dan penumpang memakai tali pinggang keledar telah diperkenalkan untuk menggalakkan pemanduan yang selamat dan untuk mengurangkan kemungkinan kecederaan serius dan kematian akibat perlanggaran kenderaan bermotor. Terdapat banyak jenis sekatan di dalam kenderaan. Kaedah reka bentuk bersepadu adalah kerjasama antara dua metodologi seperti TRIZ, Carta Morfologi, Kaedah Pugh, Kaedah Dematel dan Kaedah AHP. Kajian ini menggunakan aplikasi kedua-dua Proses Pemikiran Inventif (TRIZ) dan carta morfologi. Kedua-dua ini dirujuk sebagai aplikasi. Pada mulanya, matriks percanggahan TRIZ digunakan kepada sifar pada penyelesaian utama. 40 pelbagai instrumen dalam TRIZ yang juga boleh digunakan untuk menyelesaikan masalah dengan prinsip inovatif. Untuk membina tanggapan teori bagi unsur-unsur secara berkaedah, parameter penyelesaian penting untuk ciri reka bentuk khusus telah diperhalusi, dan carta morfologi digunakan untuk memaparkan keputusan. Reka bentuk konsep akhir dihasilkan berdasarkan dua prinsip reka bentuk yang berbeza.

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## ACKNOWLEDGEMENTS

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

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my appreciation Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform. Thank you also to the Malaysian Ministry of Higher Education (MOHE) for the financial assistance.

I would like to express my heartfelt gratitude to those who gave me the opportunity to complete this report. A special thanks to my main supervisor, Dr. Noor Saffreena Bt Hamdan for providing me with the opportunity of working on this project. I am grateful to him for his suggestions, advice, assistance, and encouragement in making this research possible. His unwavering patience in guiding and providing invaluable knowledge will be remembered for the rest of my life.

Lastly, thanks to all my family, friends and people who give me support all the time throughout accomplishing this project.

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# LIST OF SYMBOLS AND ABBREVIATIONS

UN R – United Regulation
LATCH – Lower Anchor anf Tethers for Children
ISOFIX – Internationally standardised car ceat filling system
TRIZ – Theory of Inventive Problem Solving
AHP - Analytic Hierarchy Process
DEMATEL – Decision making trial and evaluation laboratory
EDM – Electrical discharge machining
CNC – Computer numerical control
ABS – Acrylonitrile butadiene styrene

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Nowadays, companies want to increase their productivity and sales and the product becomes more efficient. TRIZ is one of the methodologies that offer scientific and systematic approval to overcome contradictions with innovative solutions in any field of technology. Students are required to design a seatbelt adjuster for children. TRIZ is the Russian acronym for the “Theory of Inventive Problem Solving” that was developed by Genrich Altshuller and his colleagues from 1946 to 1985 in the former Union of Soviet Socialist Republics (USSR). It is a systematic problem-solving method based on logical data, not intuition or spontaneous creativity individuals or groups. TRIZ is built on the principle that “there is always scope for invention wherever there is a contradiction”. TRIZ eliminates design aspects that are incompatible by employing an important tool known as the TRIZ matrix and devising a method to apply existing solutions to the current challenge. TRIZ assumes that similar issues in other fields have already been resolved. The paper explains the development of seatbelt adjuster for children using the integration of theory of inventive problem solving (TRIZ), morphology chart and concept design selection. After that, the concept design was tested in the Catia V5. The design was analyzed to pick the best between two design. After that, the design was fabricate and slicing using 3D printing.

## 1.2 Problem Statement

The seatbelt adjuster is designed to keep the seatbelt tight and stop the movement of the passenger. A seatbelt adjuster also helps to improve the comfort of the passenger while wearing the seatbelt in the vehicle. However, there are flaws in the seatbelt adjuster while wearing it. First, incorrect positioning of the seatbelt adjuster on a booster seat and if the adjuster is not placed in the right position, it cannot hold the child safely in the seat. (WORLDWIDE, n.d.). Second, if the booster seat is not securely and tightly installed in the car, it might cause loose installation and the seatbelt adjuster may not work properly. (WORLDWIDE, n.d.).Then, some booster seats and seatbelt adjusters may not be compatible with certain car models. Therefore, there are many ways to improve the flaws of the seatbelt adjuster on the child seat to be used by children.

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## 1.3 Research Objective

a) To make a easy design seatbelt adjuster for children in booster seat using integrated design method.

b) To fabricate and produce a design of seatbelt adjuster compatible with the booster seat of the children.

## 1.4 Scope of Research

This study focuses on the design of seatbelt adjusters for children. The main part is to make a compatible seatbelt adjuster to the vehicle. The methodology that been used in this research is:

i) Theory Inventive of Problem Solving (TRIZ). This method is used to find and solve contradictions. It also gives a set of creative rules that can lead to new ways of making a seatbelt adjuster. TRIZ also gives you a set of tools to help you think of new ways to solve problems and come up with creative answers.

ii) Morphological Chart. This method use to analyze and identify different features or components that could enhance the design of seatbelt adjuster. This method also explore different combinations of option from each column to generate new ideas of seatbelt adjuster.

iii) Concept Design Selection. The idea design for a seatbelt adjuster was chosen, and there are many things to think about to make sure it works, is safe, and makes the user satisfaction. By thinking about these things, the idea design for a seatbelt adjuster was chosen to be made into a design.

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# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter conducts research using a range of sources, such as articles, book reviews, and journals. For the entire project, this chapter oversees conducting background research and a literature review. This chapter is concentrated on briefings about all kinds of seatbelts and methodologies for designing products. It would be much easier to understand the entire project with the help of a literature study. Furthermore, it will be able to get an extra understanding of the research and conduct project evaluations.

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### 2.1.1 Seatbelt

Edward J. Claghorn patented the first vehicular seat belt in New York City in 1885 (#312,085). Claghorn first wanted to protect tourists from slipping from vehicles while touring the city. When cars first appeared in America in the early 20th century, several passengers and drivers used Claghorn's approach to travel through unprepared terrain. The US National Safety Council reported 30,000 road fatalities per year in the mid-1920s as this private new means of transportation was employed more and more without safety precautions. In 1934, General Motors pioneers conducted the first barrier impact test amid rising car deaths. Preston Tucker developed the Tucker automobile with seat belts in 1946. Early Tuckers had seat belts, but the design eventually removed them out of concern that they would make the car appear less safe. In the 1950s, only race car drivers an activity that predated the automobile wore seat belts. The Society of Automotive Engineers of USA established the first Motor Vehicle Seatbelt Committee in the mid-1950s. California was the first state to mandate horizontal lap safety belts in new cars. Automobile researchers began investigating measures to reduce the "second collision" that occurs when riders crash into interiors. In Sweden, Vattenfall, the State Power Board, asked engineers to build automobiles with more safety features. Bengt Odelgard and Per-Olof Weman, two engineers, began investigating this scenario. A diagonal restraint 11 would be safer than a lap belt, they concluded. Vattenfall cars soon had two-point across-the-chest belts. In 1958, Volvo president Gunnar Engellau employed Nils Bohlin as the first safety engineer. Bohlin observed that horizontal-lap belts in cars caused more injuries than crashes. He discovered Vattenfall's seatbelt inclusion while researching automotive safety. The two-point belt's main flaws were that it didn't restrain the passenger's body, making them more susceptible to chest, head, and spinal injuries, and that it crushed internal organs on impact if not properly positioned. The first three-point seatbelt, which holds chest and hips, was developed by Bohlin's research. Volvo patented the idea in 1959 but granted free use to all automakers to improve safety.

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### 2.1.2 Behavior of Passenger

An enhanced Theory of Planned Behavior (TPB) is used to anticipate driver and passenger seatbelt use. Seatbelts are a top road safety measure. Seatbelts lower moderate-to-critical motor vehicle crash injuries by 50%. They prevent occupants from hitting items within the car, including other occupants, and from being ejected in a traffic crash. The Theory of Planned Behavior (TPB) has been used to explain road user behavior, including seatbelt wearing, according to the literature. The TPB states that behavior, normative, and control beliefs influence an individual's intention to undertake a behavior, with intention being the most proximal influence. Behavior beliefs link a behavior to a favorable or negative outcome, influencing attitudes toward it. Normative views influence subjective norms by predicting whether influential people will approve or disapprove of a behavior. Behavior control is based on control beliefs. Control barriers and control facilitators enhance or decrease the perceived difficulty of a behavior. (Matheesha Herath∗, 2020).

### 2.1.3 Important of Wearing Seatbelt

Every year, 1.4 million people die in road traffic accidents (RTA). Over many years, these were adapted for use in cars, and in 1959, a Volvo was the first car to have a three-point seatbelt. At the beginning of the 1970s, Australia passed laws that made it necessary to wear and install seat belts in a standard way. This, along with public education efforts, has led to a big drop in deaths and injuries caused by RTAs at this time.The force of slowing down is spread out over the clavicle, chest, and pelvis by 3-point harnesses. At first, it was thought that these restraints caused a cervicothoracic spine injury, a sternal fracture, and a pelvic fracture. Evidence showed that people who weren't buckled up in similar RTAs had much worse injuries and results. The "seat belt sign," which is the presence of soft tissue damage caused by a seat belt, is a sign of deeper organ damage and helps doctors figure out what's wrong. As we'll see in the next case, a seatbelt that isn't worn right can cause serious harm. In this case, the injuries caused by seat belt syndrome were made much worse by the way the seatbelt was worn. The patient's injuries left lower rib fractures, splenic laceration, gastroduodenal transection, transverse colonic injury, and liver laceration look like they were caused by fast deceleration forces caused by an improperly worn seatbelt. Seat belts are made to move these forces of slowing down to tougher parts of the body. They do not lessen the collision force. Most of the time, the sickness is caused by damage to soft tissues, but there have been rare reports of damage to the liver, spleen, colon, and stomach. Most of the time,

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these are used with lap car belts instead of modern 3-point harnesses. In this case, the injuries caused by seat belt syndrome were made much worse by the way the seatbelt was worn. (Matheesha Herat, 2020)

## 2.2 Child Restrain System


Figure 2.1 Certified stickers under United Regulation UN R44 and UN R129

A child restraint system (CRS) is a vehicle seat designed to keep children safe. When properly installed in the vehicle, the seat helps to protect children from serious injurries during accidents. The Road Transport Department (JPJ) in Malaysia has published the CRS regulation under the road Transport Act 1978 – Motor Vehicles (Safety Seat-belts)(Amendment) Rules 2019. The law for private vehicles went into operation January 1, 2020. According to the rules, CRS used in Malaysia must meet UNR standards (R44 or R129) and children must weight less than 36kg, be shorter than 136cm and be under age of 12. According to the MIROS obeservation research, the percentage of awareness among drivers has increased from 44% in 2019 to 50% in early 2020. (Malaysian Car Seat Law, 2023)

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### 2.2.1 Types of Child Car Seat

a) Rear – facing car seat. This car seat must face towards to the back of the car. Tihs car seat are not allowed to be installed in the front passenger seat if there is and active air bag present. (BUYING THE RIGHT CAR SEAT, n.d.)

b) Forward – facing car seat. This seat face towards the front of the car and hahs an inbuilt harness. Usually, this car seat are by children until they are 7 – 8 years old. (BUYING THE RIGHT CAR SEAT, n.d.)

c) Booster seat. This seat protect children who are too big for a car seat but too small for a seat belt. Children around 145cm and weight between 36kg to 45kg allowed to use booster seat. Booster seat can reduce the risk of serious injury by 45% compared to seatbelt alone. (BUYING THE RIGHT CAR SEAT, n.d.)

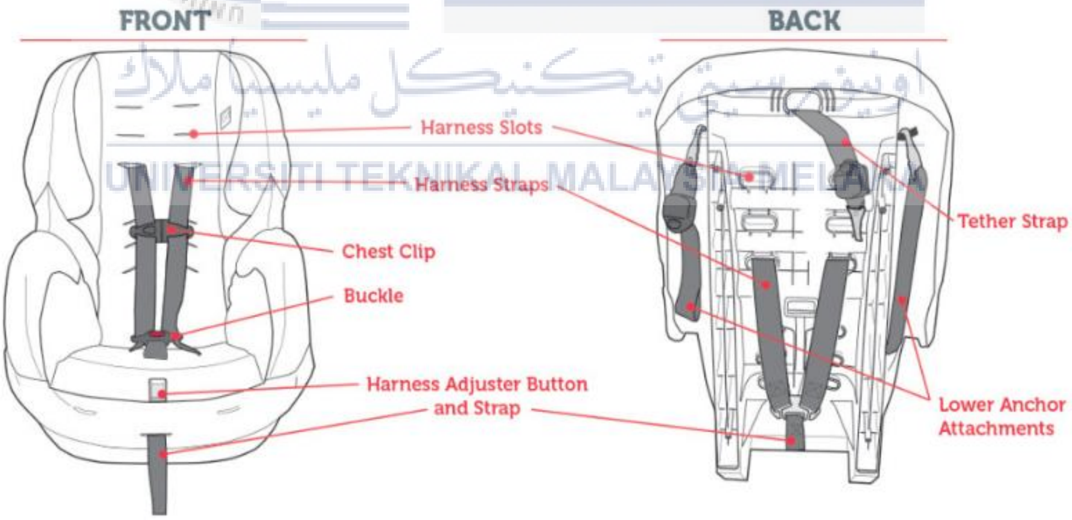


Figure 2.2.1 Basic Car Seat Parts

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### 2.2.2 LATCH System

Latch (Lower Anchors and Tethers for Children) Systems is a way to secure a child safety seat, rear facing or forward facing to the seat. Most child safty seats are manufactured after 1 Sept 2002 are required to have LATCH systems. This child safety seats have two attachments that connect to the lower anchorage points on the vehicle. All new vwhicles have top anchor points that connect to the top tether strap of a child safety seat. This system is made up of lower anchors and upper tethers. (Get the Facts About LATCH - Securing Child Safety Seats, n.d.)

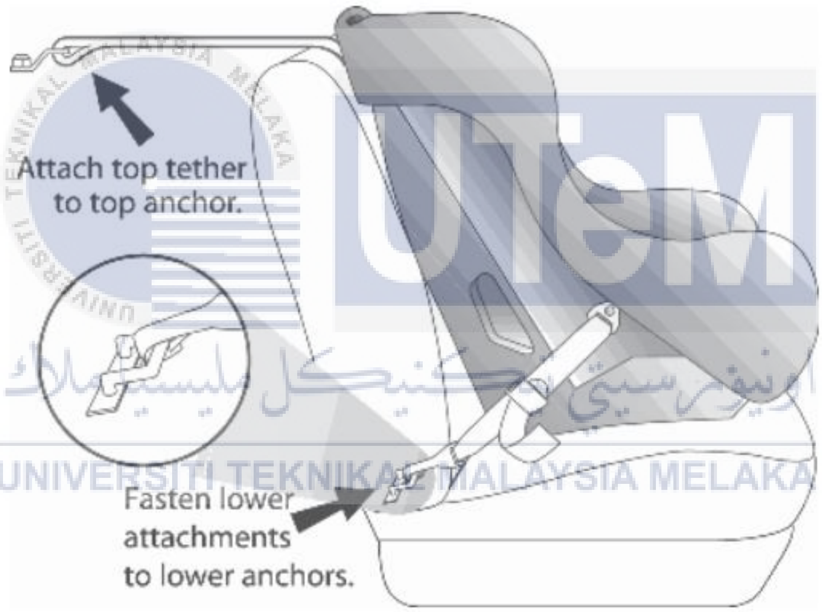


Figure 2.3 Latch Parts

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### 2.2.3 ISOFIX System

ISOFIX is an internationally standardised car seat fitting system. It automatically secures car seat or car seat base to two metal clips (ISOFIX fixing points) located between vehicle seats. There is no need to used the seatbelt. This system ensures for minimal risk of incorrect installation and a permanent connection between car seat and the vehicle,resulting in less force being applied to the children in the event of a sudden stop. It also provide quick installation and easy removal for baby car seats. (Amesar)


Figure 2.4 ISOFIX Part System

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## 2.3 Passive Restraint System

A "passive restraint" is a vehicle safety feature or system that deploys in the event of a collision or sudden stop to shield the occupant from harm. While other safety systems, such as anti-lock brakes and electronic stability control, strive to avoid accidents, passive restraints, also known as passive safety systems, operate to protect you in the case of an accident. Airbags and seat belts, sometimes known as safety belts, are the most popular passive restraint devices in automobiles today. The concept of a seat belt (sometimes known as a safety belt) is far from novel. Although they didn't make it into automobiles until much later, horse-drawn carriages had some type of safety belt or harness as early as the 1800s. Seat belts were primarily lap belts or two-point belt systems when vehicle manufacturers began to introduce them to some of their vehicles. It wasn't until 1959 that a Volvo engineer converted an aviation harness into the three-point, Y-shaped seat belt system we use today. Even after the three-point automotive harness was invented, it would take several years for it to become fully common in the industry. They were frequently offered as upgrades or modifications at gas stations and auto parts stores, although they were not legally needed. However, with the passage of the National Traffic and Motor Vehicle Safety Act in 1966, legislation requiring manufacturers to install safety belts in automobiles began to appear. Seat belts are meant to tense up when a sudden stopping force is applied; you may have seen this if you tried to take the belt out too quickly or if you braked unexpectedly. The most popular style of seat belt uses a basic mechanism to regulate slack in normal conditions while also keeping it tight in the case of a crash. A seat belt's slack is normally controlled by a spool and spring, allowing you to pull as much of the belt out as needed before reeling the rest in. A locking mechanism prevents the belt from extending any further when your car comes to a sudden stop or when it is wrenched too quickly.

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## 2.4 Restraint System

To find out how restraint systems can be made to fit a wide range of people and the changes in stance that active safety features can cause before a crash. By adding a knee airbag and making changes to the shoulder belt load limit, steering column force, and driver airbag features (tethers, inflation, and vent size) for each occupant model in a 56 km/h frontal crash, better restraint designs were made. The new shapes were then tried out in both positions before a crash. The chances of getting hurt in the head, neck, chest, and lower limbs were looked at. What happened The size and form of the people inside the car had the most effect on how badly they were hurt, while the way they were standing before the crash had the least effect. Some safety problems were seen with big passengers, like their heads hitting through the airbag or getting both head and chest injuries. These problems were lessened by a stiffer restraint system and a better-tuned driver's airbag. For women, chest injuries were a major safety issue. A softer seatbelt and smaller airbag near the chest helped reduce this risk. People who were overweight were more likely to get hurt in their legs, which showed that a knee brace was needed. There were fewer injuries with a variety of better restraint designs, which shows that restraints need to be able to adapt to different types of passengers. Pretensioners for seat belts In the event of a crash, these devices tighten the seat belts automatically, taking up any slack and keeping the people in the car securely in place.

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## 2.5 Type of Restraint

The term "restraint" is used to describe the various safety features and systems included in vehicles to keep passengers safe in the event of an accident or sudden deceleration. These devices are also referred to as car seat belts or seat belts. Restraints in vehicles serve to prevent serious injury or death by limiting passenger movement in the event of a collision. (Occupant Restraints System, 2021)

### 2.5.1 No Restraint

No restraining necessary. In some cases, as while traveling at slow speeds, this may be the best option. In situations where a collision or rollover is highly improbable and where the use of a safety belt could impair driving skills. Also, go-karts and similar lightweight vehicles without crushable constructions and rollover protection, in which the occupant is less likely to receive harm by being thrown clear in a situation. (Occupant Restraints System, 2021)

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### 2.5.2 Lap-sash belt

One end of a lap sash safety belt is fastened to the car below the driver's hips on one side, while the other end is fastened to the vehicle over the driver's shoulder on the same side. In use, it is joined to a second strap or a semi-rigid stalk through a sliding detachable buckle. This fastens to the car on the hip of the other passenger. This makes a lap belt that also provides diagonal chest support. This type of harness may feature an automated retraction and locking mechanism to accommodate passengers of varying heights and body shapes. A lap-sash belt is essential for everyone riding in the front seat of a car. (Restraint Systems for Occupants, 2021)

### 2.5.3 Two Point Belts and Three Point Belts

As shown in the image, a 2-point seat belt has attachments at both ends. This belt, which is typically worn around the lower waist, goes by another name: lap belt. The middle rear passenger seat of vintage vehicles typically has this sort of seatbelt. A 3-point seat belt consists of a lap belt, sash belt, and the connections between them, forming a Y. The energy of a collision is dispersed across the chest, pelvis, and shoulders thanks to the 3-point seat belt. The three-point belt was initially mass-produced by Volvo that same year (1959). In Malaysia, all newly certified models of passenger vehicles, including the center rear passenger seat, must be equipped with 3-point seat belts. All child restraints certified by the United Nations Economic Commission for Europe (UNECE) must be installed with a three-point seat belt. Installing a CRS requires reference to both the car owner's manual and the CRS manual.

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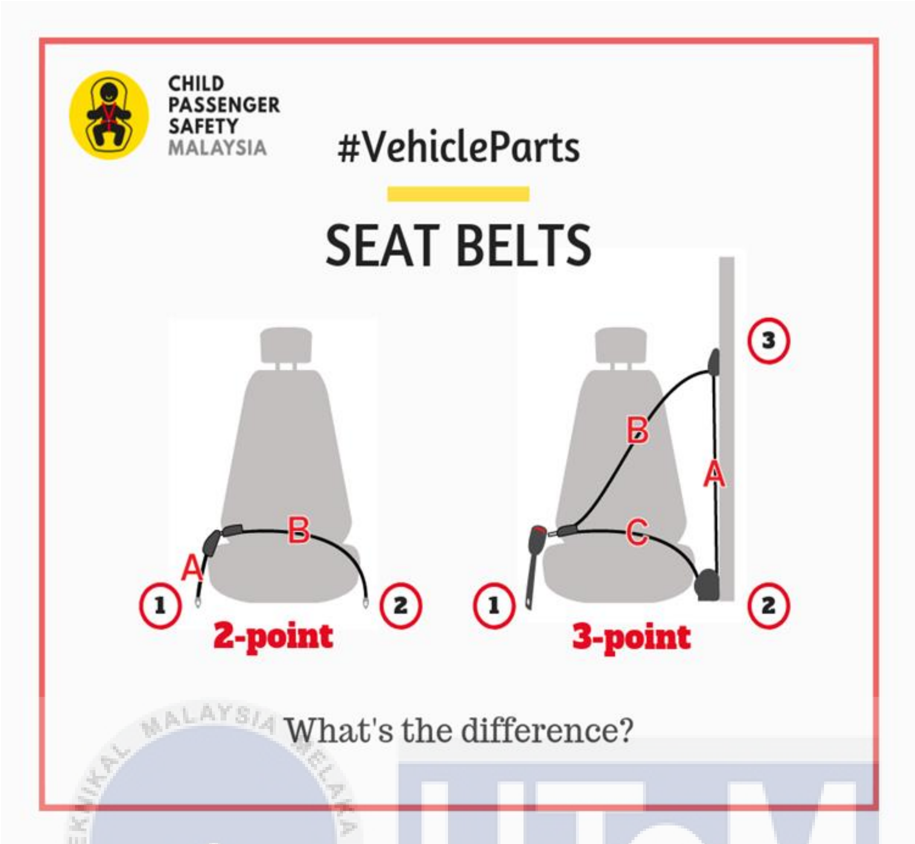


Figure 2.5 Difference Two Point Belts and Three Point Belts

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### 2.5.4 Four-strap harness

There are four straps in touch with the user's body in a four-strap harness. A lap belt is created by crossing two of these straps over the occupant's hips, and upper body restraint is provided by a strap crossing over each shoulder and extending down to the lap belt. The harness maker may chose to permanently join the shoulder straps to the appropriate lap belts, or they may provide separate straps that connect to a 4-way buckle assembly. When compared to a Lap-sash belt, the restraint capabilities of a four-strap harness are superior in forward and rollover accidents. The restraint's capacity to limit the effects of a side collision is also much improved. (Occupant Restraints System, 2021)

## 2.6 Integrated Design Method

The Integrated Design Method (IDM) is a design process that encourages collaboration among methodologies such as TRIZ, Morphological Chart, AHP Method, DEMATEL Method and Pugh Method. IDM aims to create sustainable, innovative, and user-focused solutions by considering the interconnections between various design areas and taking an integrated strategy. It focuses on systems thinking, user-centered design, sustainability, continuous improvement, visualization and prototyping, and decision-making frameworks. IDM enables thorough problem-solving and the creation of designs that effectively address complex challenges.

### 2.6.1 TRIZ Method

The Inventive of Problem Solving (TRIZ) was developed in 1946 by G. Altshuller of Russia. Excellent technical and scientific ideas can be attained with this strategy, which is particularly useful for getting to the bottom of a problem and discovering all your possible options. Engineers and scientists can reduce the potential for failure while designing new technologies and products by using the holistic approach provided by TRIZ. The contribution level of a challenge determines which of TRIZ's 39 engineering characteristics and 40 innovative principles will be most useful in arriving at a solution. The TRIZ technique shines most in its role as a diagnostic medium, from which a sequence of liberated, cutting-edge, and randomly determined actions can be derived for tackling problems. The material selection process was sped up, facilitated, and improved by using the expert system software. Using this method helps meet requirements and achieve objectives, leading to more effective product development. In addition, it offers a novel way to attack the issue by designing for it and a methodical approach to identifying opportunities. When trying to come up with solutions to problems, the TRIZ approach is helpful. Meanwhile, the morphological chart is one form of assessment used to refine TRIZ's creative ideas. (M.R.M. Asyrafa, 2019)

**Table 1 – Review of the application of TRIZ-Morphological Chart-ANP and related concurrent engineering approaches for product development.**

| Application of TRIZ | Product development example | References |
|---|---|---|
| TRIZ, Morphological Chart, AHP | Automotive parking brake lever | [35] |
| | Automobile engine rubber composite | [39] |
| | Automotive spoiler | [42] |
| TRIZ, Morphological Chart | Automotive door panel | [40] |
| | Composite shoe shelf | [43] |
| | Composite automotive anti-roll bar | [44] |
| TRIZ, ANP | Dual layer tread tire | [45] |
| | Automated communication connector | [46] |
| TRIZ, ANP, Eco-Design elements | Bottle casing | [36] |
| TRIZ, ANP, ECQFD | Overflow valve | [47] |

Figure 2.6 Review of application TRIZ-Morpholofical Chart-ANP

The research incorporated TRIZ, a morphological chart, and an ANP into the design process for the creep testing equipment. The technique was used throughout the conceptual design phase as a means of identifying a workable answer to the issue. In the hybrid strategy, the TRIZ methodology was used to help pinpoint issues and spark new ideas. Meanwhile, the morphological chart was set up to hone in on TRIZ-recommended improvements to the ideas that were developed. (M.R.M. Asyrafa, 2019)

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### 2.6.2 AHP Method

In the case of multi-criteria decision problems, the Analytic Hierarchy Process (AHP) is one of the statistical techniques that helps make optimal choices by breaking down the problem into a series of pairwise comparisons made by experts, allowing for a numerical measure of the values analyzed elements. In multi-level hierarchies, AHP compares factors in discrete and continuous ways to establish relative priority on absolute scales. Among discrete multi-criteria approaches, the AHP method stands out. It looks at the several pairs of criteria and compares them so that you can make an informed conclusion. This procedure generates a score that classifies choice alternatives as objects. Because the decision-maker evaluates the various selection options in terms of specific criteria on and influences the possibility of assessing the value of these criteria in terms of the goal according to his knowledge and discretion, AHP is a method that enables the selection of the best solution from among many variants. grounded in actual usage. As a multi-criteria decision-making technique, AHP can help you narrow down your options by organizing your goals, criteria, and potential solutions into a hierarchical framework. In AHP, the relative relevance of each variable is determined through pairwise comparisons at each level of the hierarchy, and the best decision is reached through an evaluation of the alternatives at the bottom of the hierarchy. When there is room for interpretation in a choice, AHP shines. It also excels at resolving issues in which the decision criteria can be organized hierarchically into sub-criteria. When multiple factors must be considered, AHP is frequently turned to as a reliable resource. AHP relies on breaking down criteria for assessment into tiers. In the AHP technique, the order of priorities is set in stone. The goal of the decision-making process drives the formulation of evaluation criteria and the selection of potential courses of action. Figure 3 depicts a decision-making process scheme.

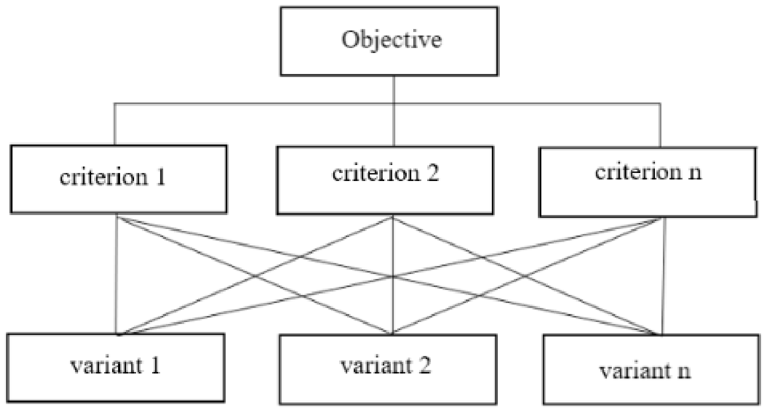


Figure 2.7 Diagram of the decision making process in AHP method

The AHP process consists mostly of the following steps:

The problem's hierarchy is defined at this stage, along with the people involved, the problem's scope, the primary objective, and the stakeholders' hopes and fears. Then, the problem is broken down into its component parts the overarching aim, the primary factors, the partial components, and the investigated variants each of which leads to a different amount of fulfillment of the objective functions.

The decision-maker compares each criterion in pairs with each other and with the overarching goal, and then decides which criterion, and to what extent, is more important.

• Establishing shared valuations (weights) for criteria and decision alternatives following the construction of a preference matrix. The matrix eigenvector is calculated by adding up the rows of the matrix after they have been normalized.

• Analyzing the outcomes that have been prioritized deciding on the most effective strategy that will lead to success.

### 2.6.3 Dematel Method

U.S. researchers from Battelle Laboratory presented their Decision Making Trial and Evaluation Laboratory (DEMATEL) technique at a Geneva conference in 1971. In addition to analyzing the system's direct and indirect relationships, this technique can also pinpoint where each factor stands within the system and is typically employed in the process of factor prioritization. DEMATEL has applications in many different areas, including supply chain management, waste management, and disaster risk assessment. To obtain the PSF weights, the input dependence data (relative relationship matrix of PSFs) is processed by DEMATEL. Next, a strategy is provided for adjusting the HEP in accordance with the PSFs' relative importance. (Yuan-Wei Du a, 2023)

### 2.6.4 Pugh Method

The Pugh matrix is a tool for evaluating potential solutions and deciding on the optimal one. During the product development process, it serves as a fundamental instrument for selecting the best concept to adopt. Pugh created it in 1990.Concepts should be listed in the columns of the Pugh Matrix, while criteria should be listed in the rows. The steps of Pugh Matrix Methods are as follows.

1) Pick a Base Year: -Determine what the bar must be in order to judge the idea. The rows of criteria you've entered should be measured against this floor. If the criteria exceed or fall short of the datum level, a plus, minus, or s symbol should be used. Put a plus sign in front of your criteria if they are higher than your datum level. If your standards fall below the datum line, you must indicate this. If it measures up to your standard.

2) Rating and evaluation: tally the number of "up" and "down" indicators in each column. Don't forget to tally up how many. After adding up the negative and positive signs, you can

make a call. If the results are favorable, the idea should be given more weight. If the result is + and -, the concept with the + sign is to be reselected; otherwise, the concept with the closer-to-zero number is to be chosen. In such a case, however, it is preferable to repeat the procedure. To further tailor the practice, we can also use ++ or - -.

Table 1 Illustration of Pugh Matrix Techniques

| Concept / Criteria | Relience-Jio | Idea | Vodafone | BSNL | AIRTL |
|---|---|---|---|---|---|
| Network | + | + | - | + | - |
| Datapack | ++ | + | + | - | - |
| Talk Time | ++ | ++ | ++ | + | + |
| Validity | +++ | ++ | + | - | + |
| Costing | ++ | ++ | + | - | - |
| | ∑+ signs+∑- signs | ∑+ signs+∑- signs | ∑+ signs+∑- signs | ∑+ signs+∑- signs | ∑+ signs+∑- signs |
| | 10 | 8 | 4 | -1 | -1 |

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### 2.6.5 Morphological Chart

The morphological chart is an analytical and systematic approach to brainstorming. In most cases, we begin by thinking about the product's functions. See 'Function Analysis' below for more on how to determine a product's many purposes. However, there is no assurance that all the necessary (sub) functions will be found through function analysis. These (sub)functions typically have multiple known solutions, in addition to the ones you come up with on your own. The morphological chart's components will be formulated from these answers. As a result, the morphological approach produces a matrix of roles and constituents. We list potential parts based on their roles. The parameters are concrete and detailed, outlining the elements that make up a given class. These parts are partially familiar from already implemented solutions: similar products. The columns represent the functions, and the rows represent the components used to implement those functions. Parameters are identified by zeroing in on component overlap and describing those shared features as those that a product should have, thus indicating what that product should be. The parameters are decoupled and abstract; they signify a class (but make no reference to concrete characteristics). The morphological diagram is used to decompose the product's function into its constituent (sub)functions. Ideas are generated for each of the (sub)functions, and then those ideas are combined to form a whole. An idea is formed by picking and putting together the right parts. This idea is the main solution, the result of deliberate selection of elements that work together to solve the problem conceptually.

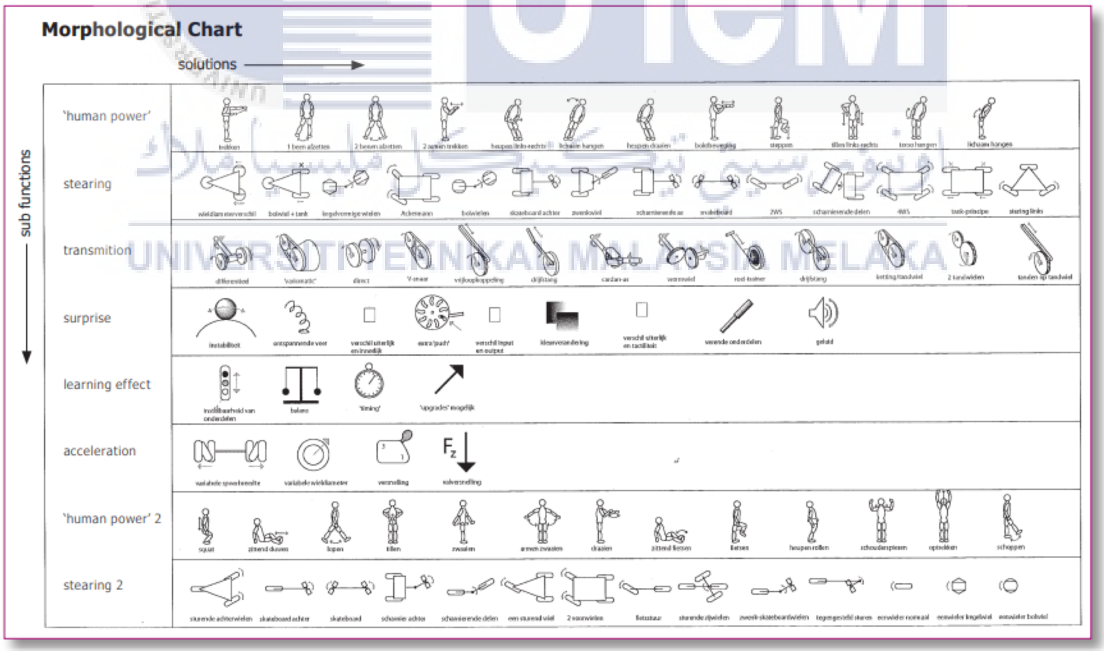


Figure 2.8 Morphological Chart

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Typically, the morphological chart is used at the beginning of the creative process. To get started, we use function analysis. The morphological approach is not always the best way to solve a design problem. For engineering design problems, the morphological chart has proven useful. Instructions for creating a morphological diagram. This year's morphological chart. Firstly, the problem to be solved must be formulated as accurately as possible. Then, determine all the possible solution parameters (i.e., functions and subfunctions). After that, build a morphological chart (a matrix) using the parameters as the rows. Then, in the rows, put the components that go with that criterion. Finding the right parts is as simple as comparing products with similar features or coming up with novel parameters (functions) design principles. To reduce the total number of primary solutions, it is recommended to use evaluation strategies (row analysis and parameter grouping). The sixth rule is to create principal solutions by combining at least one component from each parameter. Lastly, analyze and evaluate each solution considering the criteria (design requirements), and pick a small set of leading options (at least 3). The remaining steps of the design process can be used to flesh out the chosen principal solutions in greater depth.

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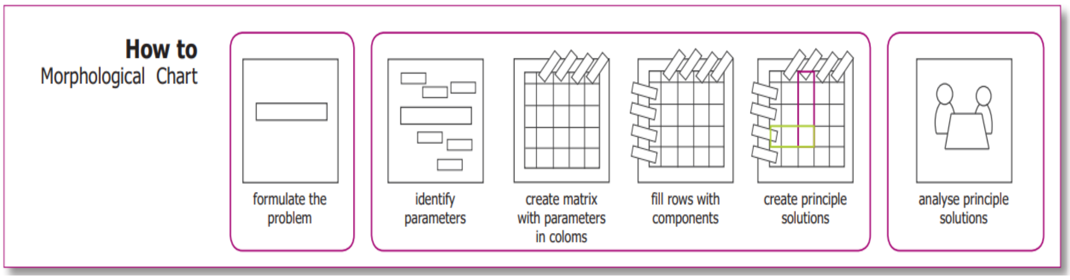


Figure 2.9 How to Morphological Chart

## 2.7 Product Manufacturing

Manufacturing is the production of transforming goods or raw materials into finished product through the use of machinery, tools, use of labour and chemical production. Raw materials are transform into final product through manufacturing engineering or the manufacturing process. This procedure begins with the design of the product and the selection of materials. To develop the finished product, the material are transformed during numerous production steps. After that, the finished products are sold to consumers, wholesaler, distributors, retailers or other manufacturers for further processing into more complicated products.

### 2.7.1 3D Printing

3D printing also known as additive manufacturing is swiftly transforming the product developement process, allowing companies to generate and develop prototypes more quickly and cost effectively than ever before. This technology use a layer-by-layer methodology to directly build actual products from digital designs, minimilazing the requirement for conventional manufacturing procedures that require costly tooling and production. There are many benefits of 3D printing in product development other than that this technology can reduce the costs of production and leads times. This technology also allows designers and engineers to experiment with more complex and complicated design that were previously impossible, resulting in innovative product offerings that better meet the need of the customers. 3D printing also use of various materials such as plastics, metals, ceramics and biomaterials. There are procedure for product development in 3D printing like generate the idea and design of 3D model. The next step after generates 3D model is preparation for 3D printing process such as slicing the model into layers and convert to suitable format that read by 3D printer. After 3d printing, fabricates the object layer by layer. Then, the product need to undergo checkup for specific requirements. Once completed the product can be scaled up for mass production using 3D printing technology. These are components of a 3D printer like extruder, bed, nozzle, filament and control software. Function of extruder is melts the material such as plastic or metal and applied layer by layer to build the product. Bed is the platform where the object is build. Nozzle is part of extruder to melts the material and it can be adjsuted. Filament is the material to build the object. Lastly, control software is used to ensure the object build according to the requirement. (Sunil Kumar Panda a)

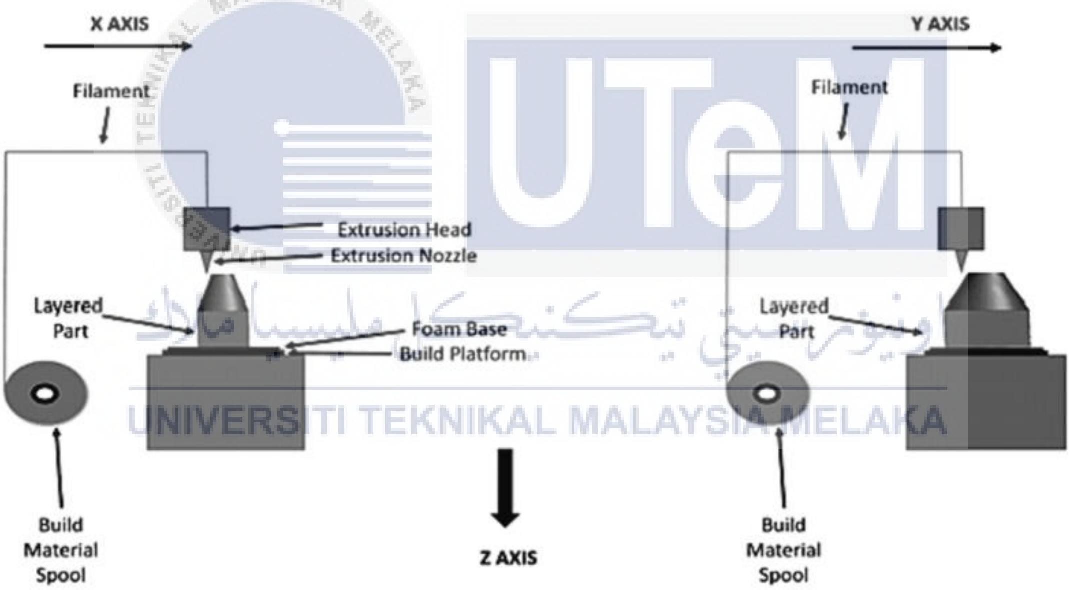

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Figure 2.10 Component of 3D printing

### 2.7.2 Wire-cut EDM

Wire-cut Electrical Discharge Machining (WEDM) is a well-known non conventional manufacturing process for machining harder materials and complex forms or shape that are difficult or impossible to machine using conventional machining methods. It is a thermo-eletrical process that removes material through a series of discrete electrical discharges between the work piece and the wire electrode. The dielectric fluid, usually deionized water, in which part and wire are submerged also served as a coolant and flushes away debris. Electrical conductivity is required for material to be machined. WEDM accuracy can be fully utilized only when the aspects of repeatability and high productivity can be built into mass manufacturing. The benefits of WEDM is to reduce the need for a highly skilled workforce and to avoid repetitive setting job for clamping and locating workpieces. (Juvenile, 2023)

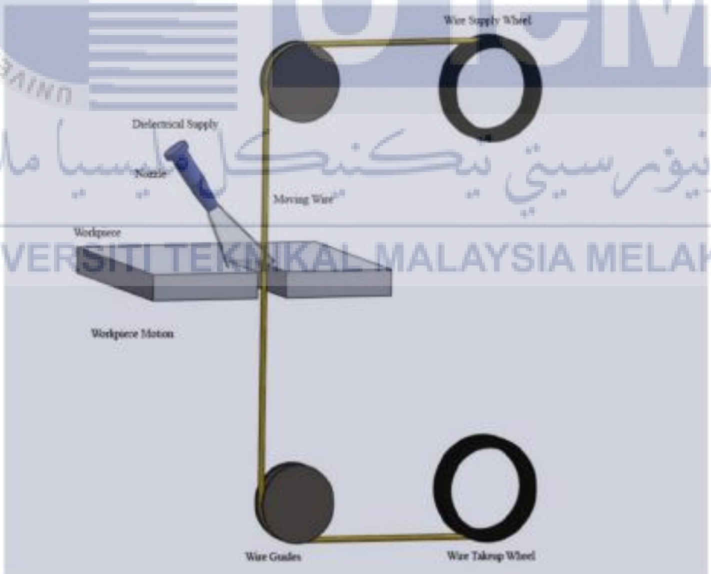


Figure 2.11 Working of wire-cut EDM process

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### 2.7.3 CNC Machining

CNC (Computer Numerical Control) machines are computer-controlled manufacturing tools that can perform a wide range of tasks such as cutting, milling, drilling and additive manufacturing(3D printing). This machine perform on a set of instruction that are programmed into a computer and control the movement and operation of the machine tools and components. There are many advantages of CNC machines such as their high precision and accuracy for the finished product. This machine also can produce complex shape and specific detail of the product. There are various of CNC machines like CNC milling, CNC Laser Cutters and CNC 3D Printer. CNC milling machine is used for cutting and shaping solid materials like metal or plastic.

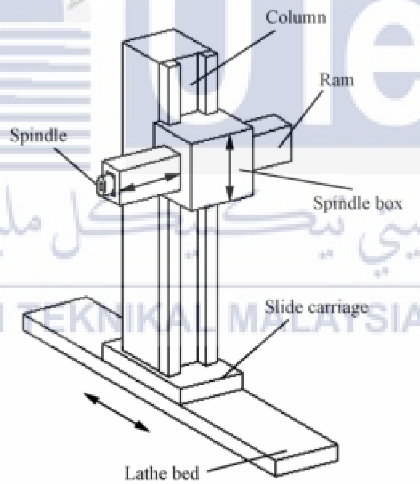


Figure 2.12 Components of milling machine

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# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

A children's seatbelt adjuster was developed using TRIZ together with a morphological chart for the purpose of this project. This methodology was used to investigate potential answers to the problem during the conceptual design phase of the project. The TRIZ methodology was applied to analyze the situation and identify potential solutions to the problem. After that, we utilized the morphological chart to zero in on the most effective solutions suggested by the generator and by TRIZ. Figure 3.1, which is a flowchart of the methodology, can be used to see that the final concept design included the selection and development of a variety of designs.

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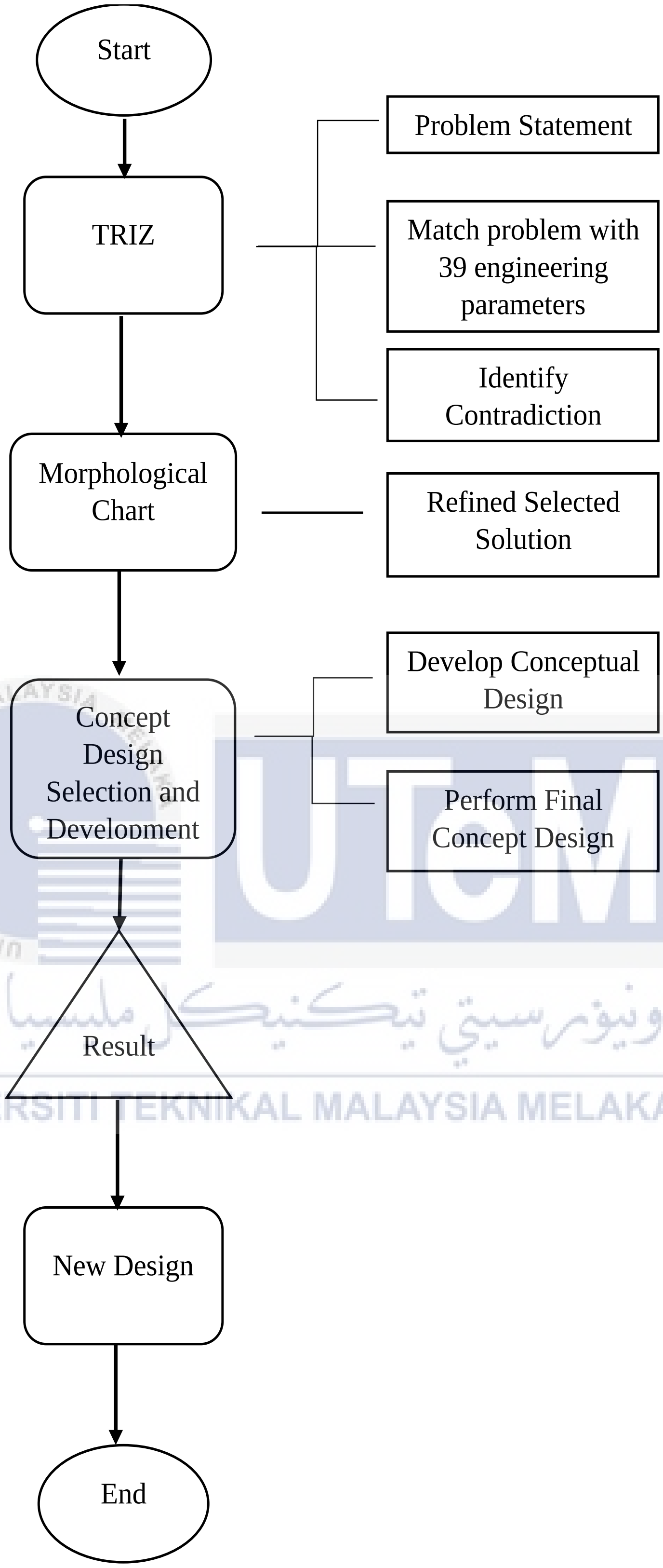

Figure 3.1 Methodology Flow Diagram

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## 3.2 TRIZ Method

The TRIZ technique was used to generate a fix after the issue was pinpointed. The engineering worsening problem and potential solutions were initially identified using the TRIZ contradiction matrix technique. Table 2 summarizes the resulting contradiction matrix, which was used to categorize the product that needs to be improved considering the deteriorating conditions. A child seatbelt adjuster's conceptual design was then matched with the most suitable TRIZ solution approach.

Table 2 – Contradiction matrix of TRIZ seatbelt adjuster design

| Improving Features | Worsening Features | TRIZ solution principles |
|---|---|---|
| 39 Engineering Parameters | 39 Engineering parameters | 40 inventive principles |
| #16 Durability of a non- moving object | #27 Reliability | #34 Discarding and recovering<br>#27 Cheap short-living objects<br>#6 Universality<br>#40 Composite material |
| | #32 Ease of manufacture | #35 Parameter changes<br>#10 Preliminary action |

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### 3.2.1 TRIZ Contradiction Matrix

Considering potential differences in the TRIZ 39 engineering parameters, the advantages and disadvantages of the current design are listed in Table 2 above. The purpose of this diagram is to provide a visual illustration of the contradiction matrix between the positive and negative characteristics. The most applicable principles are used to generate new ideas for seatbelt adjusters. To get an adaptable buckle for the safety belt without compromising on quality or making manufacturing more complicated. The outcomes of using the TRIZ 40 innovative principle technique to develop a new seatbelt adjuster are shown in the table below.

| Table 3 – Seatbelt adjuster design technique based on identified TRIZ solution concepts | | |
|---|---|---|
| TRIZ solution principles | Solution descriptions | Design descriptions |
| #6 Universality | Make a part or object perform multiple functions; eliminates the need for other parts. | Make use of the seatbelt adjuster and pillow simultaneously. |
| #40 Composite material | Change from uniform to composite (multiples) material. | Compose the material out of leather and combine it with ABS plastic to make it more effective and comfortable for kids. |
| #35 Parameter changes | Change the degree of flexibility. | Reduce it in size to amplify it. Seatbelts that can be adjusted easily |

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### 3.2.2 Specific Inventive Principle

A new child seatbelt adjuster was developed using Table 2's best principle as a benchmark. A new design, #6 universality, #40 composite material, and a different degree of flexibility in #35 parameter modifications should not compromise reliability. As a result, the TRIZ-derived design strategy is highlighted in Table 3.

## 3.3 Morphological Chart

Using the morphological chart method, the right TRIZ solution principles found earlier are now changed into useful alternative system elements. The morphological chart is a tool for clearly showing the design features of ideas during the brainstorming process and for helping designers find sub-solutions for each design sub-function, all of which are based on product functional analysis. Combining the morphological chart with TRIZ makes the TRIZ tool more useful and helps find out more about the unique design features of the answer given by TRIZ. As we saw in the last part, TRIZ gives specific rules for coming up with creative solutions to get to the root cause of a problem by getting rid of any contradictions that may come up during the problem-solving process. But the creative solutions are still very general, so the designer has to figure out how to turn the general answer into specific design features that can be used to make concept designs. So, in order for the TRIZ method to be used to make the concept design that is needed, the designer must be able to think of and develop the details of the solution principles that are given.

## 3.4 Concept Design Selection

For concept design selection, the elements from TRIZ and morphological chart was combined. The morphological chart was use to generate a broad range of concept variations and TRIZ principles was evaluate and refine the most promising ideas. From the table, there are 3 design concept that produced.

Table 4 Triz Morphological Chart

| TRIZ solution principle and strategy | Design features | Solutions | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| **#6 Universality**<br>Make use of the seatbelt adjuster easier to use | Easy Shape | Triangle | Square | Circle |
| **#40 Composite material**<br>Compose the material out of leather and combine it with ABS plastic to make it more effective and comfortable for kids. | Type of material | Zink alloy | Stainless Steel | ABS material |
| **#35 Parameter Changes**<br>Reduce it in size to amplify it. Seatbelts that can be adjusted easily | Support type | Circle support | Vertical Support | Horizontal Support |
| | Sectioning type | Symmetrical | Non-Symmetrical | |

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## 3.5 Comparison between design

| Feature | Design 1 | Design 2 | Design 3 |
|---|---|---|---|
| **Type of material** | Stainless Steel | ABS material | Zinc Alloy |
| **Shape design** | Circle | Rectangle | Square |
| **Comfortness** | Good | Low | Good |
| **Support type** | Vertical support | Vertical support | Horizontal support |
| **Sectioning type** | Symmetrical | Symmetrical | Symmetrical |
| **Overall Cost** | Affordable | Affordable | Affordable |

## 3.6 Generated design in Catia Software

Two new designs for seatbelt adjusters were created by employing a design method that was adapted from the TRIZ solution principles and the morphological chart, as shown in Figure 4. All of the concept designs were converted into two-dimensional computer-aided design (CAD) models at a scale of one to one so that the product design elements could be visualized more clearly. In general, every single one of the suggested designs for the concept shared numerous characteristics.

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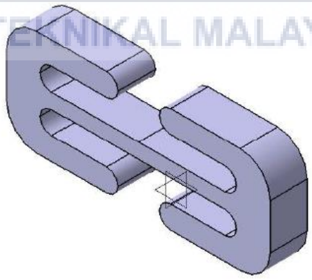

Figure 3.2 Concept Design 1

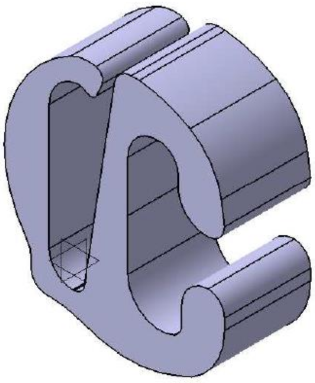

Figure 3.3 Concept Design 2

## 3.7 Selected Material

Material selection is a necessary aspect of product design and development. This part also involve choosing the correct material to suit the requirement of a particular application. This also include design requirement for set manufacturing process, material cost and material attributes. The material was discussed briefly in the Chapter 4. Stainless Steel, ABS material and Zinc Alloy were take into consideration.

### 3.7.1 Stainless Steel

Stainless steel is the generic name for a variety of steels that are primarily used for corrosion resistance. By minimum percentage (mass), stainless steel contains 10.5% chromium, less than 1.2% carbon, and other elements. This metal was added to improve corrosion resistance as well as mechanical properties.

Table 2 Material Properties of Stainless Steel

| **No** | **Properties** | **Value** |
|---|---|---|
| 1 | Density (g/cm3) | 7860 |
| 2 | Tensile strength (MPa) | 940 |
| 3 | Young modulus (N/m2) | $0.2\text{x}10^{3}$ |
| 4 | Elongation at break (%) | 26.5 |
| 5 | Strain at yield (%) | 22.7 |
| 6 | Poisson Ratio | 0.266 |
| 7 | Yield Strength (N/m2) | $2.5\text{x}10^{8}$ |
| 8 | Thermal Expansion (Kdeg) | $1.17\text{x}10^{-6}$ |

Advantage of Stainless Steel

1. High resistance to the corrosion resistance.

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2. High and low-temperature resistance.

3. Easy to fabricate.

4. Extremely tough and durable material with high impact resistance.

5. Highly sustainable choice.

6. Versatile material that can be used for other applications.

### 3.7.2 Zinc Alloy

Zinc alloy is a combination of at least two metals such as zinc and aluminium. The mixture of two metals has a different properties than a pure metal such as zinc.

Table 3 Material Properties of Zinc Alloy

| No | Properties | Value |
|---|---|---|
| 1 | Density (g/cm3) | $6.61x10^{6}$ |
| 2 | Tensile strength (MPa) | 259 |
| 3 | Young modulus (N/m2) | $8.32x10^{10}$ |
| 4 | Elongation at break (%) | 25.9 |
| 5 | Melting Point ($^{o}$C) | 424 |
| 6 | Poisson Ratio | 0.25 |
| 7 | Yield Strength (N/m2) | $1.4x10^{8}$ |
| 8 | Thermal Expansion (Kdeg) | $3.15x10^{-5}$ |

Advantages of Zinc Alloy

1. Good corrosion resistance
2. Has a relatively high melting point
3. Provides greater impact resistance
4. Low cost
5. Electrically and thermally conductive

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### 3.7.3 ABS Material

ABS, or Acrylonitrile butadiene stryene, is a thermoplastic polymer that is commonly used in injection molding applications. This material also used in engineering plastic and additive manufacturing processes due to its low production cost and the ease with which the material can be machined by manufacturer.

Table 4 Material Properties for ABS Material

| No | Properties | Value |
|---|---|---|
| 1 | Density (g/cm3) | 1.31 |
| 2 | Tensile strength (MPa) | 62.3 |
| 3 | Young modulus (N/m2) | $3.15\text{x}10^{6}$ |
| 4 | Elongation at break (%) | 4.82 |
| 5 | Melting Temperature ($^{o}$C) | 257 |
| 6 | Poisson Ratio | 0.353 |
| 7 | Yield Strength (N/m2) | $1.05\text{x}10^{7}$ |
| 8 | Thermal Expansion (Kdeg) | 0.12 |

Advantages of ABS Material

1. Excellent impact resistance
2. Versatile material that can be easily molded and shaped
3. Can be easily finished and post processes for a smooth surface
4. Good mechanical properties such as high strength and stiffness.
5. Good eletrical insulating properties.

## 3.8 Summary

Concept design in the chapter 3 was created on the methodology which is TRIZ method and morphological chart. The parameter of the each material is choose based on the method. Based on the proposed design and material, the testing analysis was conducted in chapter 4.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.1 Introduction

This chapter has an analysis on how the product which is seatbelt adjuster was formed and analyzed using software. There are many parts in this chapter such as 3D design in Catia V5, drafting isometric view, 3D printing process and product analysis in product fabrication segment.

### 4.1.1 3D Design in Catia V5

Cad model development is defined based on the conceptual on the morphological chart and TRIZ solution principles.

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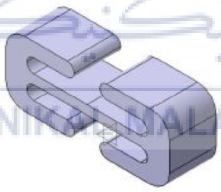

Figure 4.1 Isometric View (Design 1)

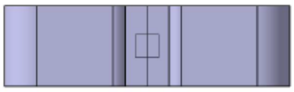

Figure 4.3 Top View (Design 1)

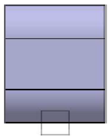

Figure 4.2 Right View (Design 1)

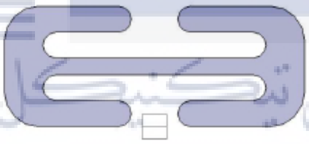

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Figure 4.4 Front View (Design 1)

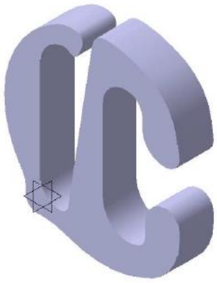

Figure 4.5 Isometric View (Design 2)

Figure 4.6 Front View (Design 2)

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Figure 4.7 Right View (Design 2)

Figure 4.8 Bottom View (Design 2)

### 4.1.2 Drafting Isometric View

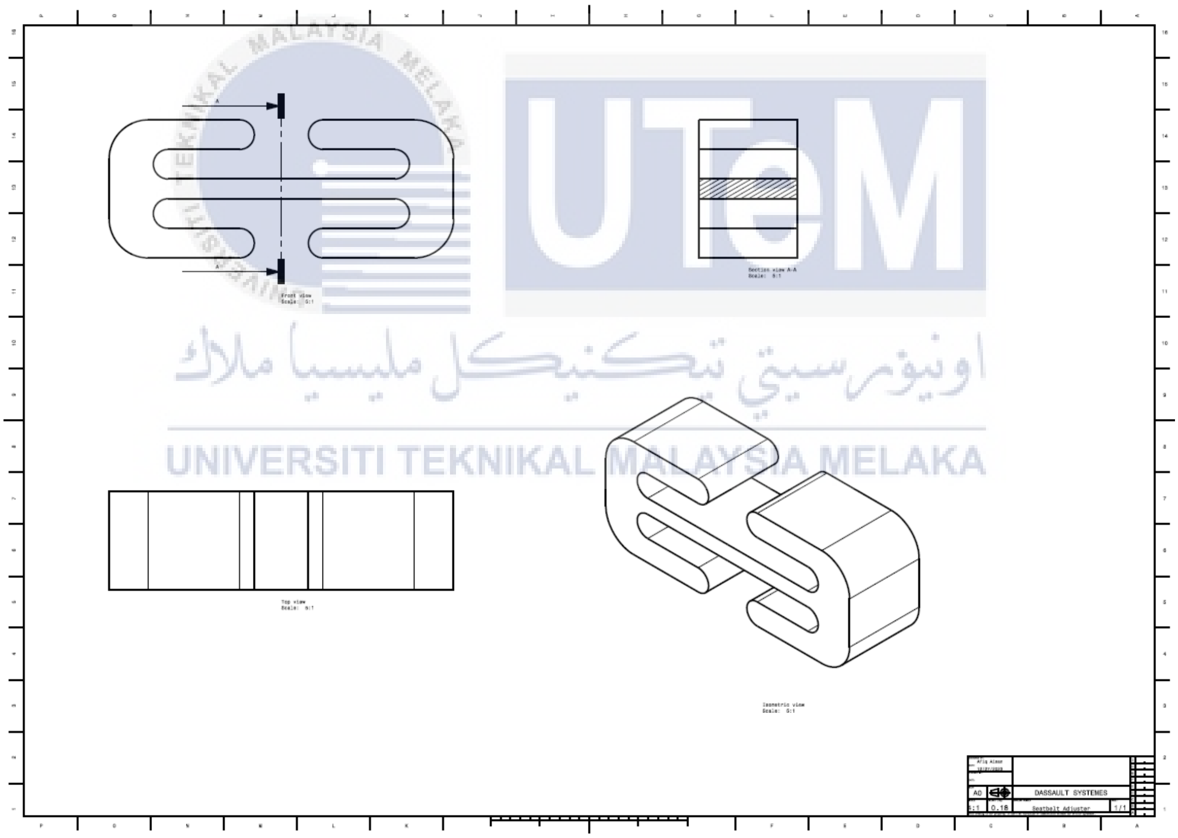


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Figure 4.9 Drafting View (Design 1)

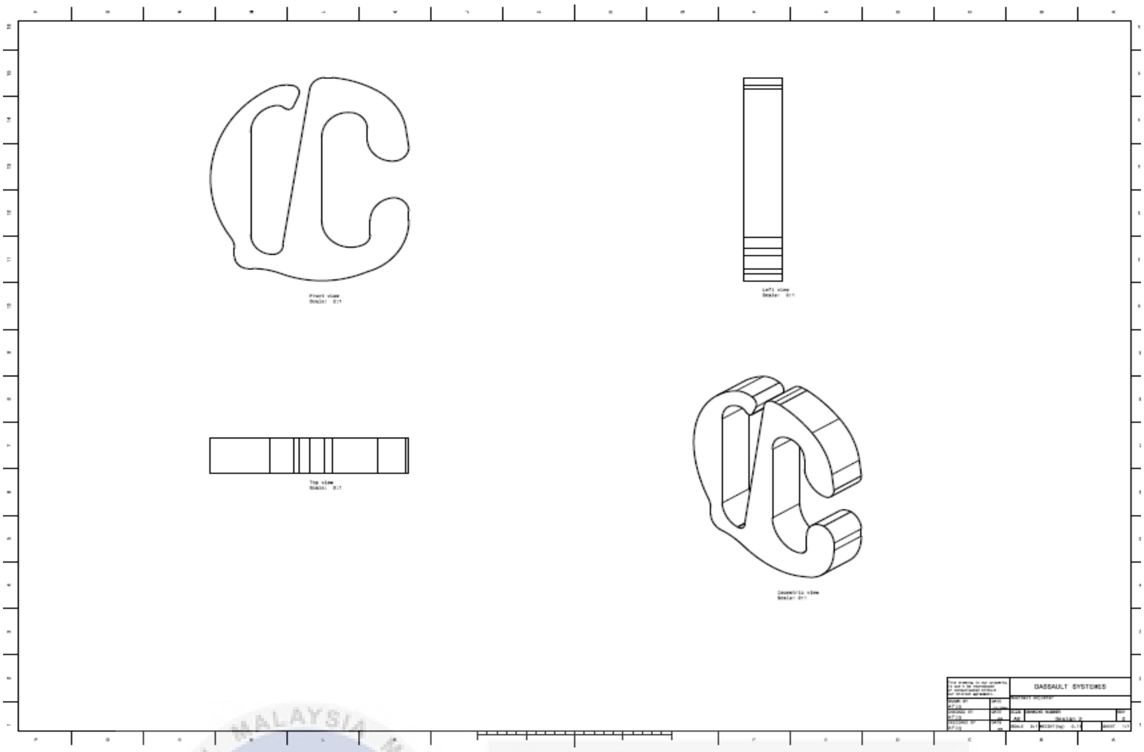


Figure 4.10 Drafting View (Design 2)

## 4.2 Product Analysis

This seatbelt adjuster was analyzed using Catia V5. The analysis determines how much force is needed to bend the seatbelt adjuster. The results of this analysis of test are used to choose materials for parts that can withstand more load. There is value in the analysis such as the Von Mises stress value, mass of the product, translational displacement magnitude and load force.

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The force of the pressure in the material is used by formula f =ma, which is m equivalent average mass of the children between 4 years old until 10 years old and a which is acceleration equal to 80m/s. The mass of the children is 30 kg which is average of the children who are between 4 years old until 10 years old.

f = ma

f = 30 (80)

240N

Safety factor = Ultimate Stress / Allowable Stress

$= 921 \times 10^{3} / 230.25 \times 10^{-3}$

= 4

When an object is given to a load of 240 N, it can deform in size or shape, as seen in figure 4.11. The Von Mises stress value helps us to decide whether the given material can yield or fracture under load. If the value of von Mises stress is equal to or greater than the yield limit of the same material under simple strain, the material will yield as shown in Figure 4.13 the value of translational displacement magnitude displays as shown in Figure 4.12 and the value of von misses as shown in Figure 41.3.

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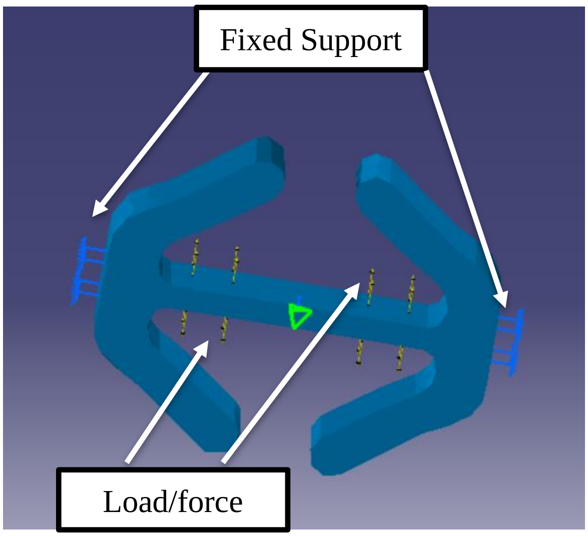


Figure 4.11 Deformation of product

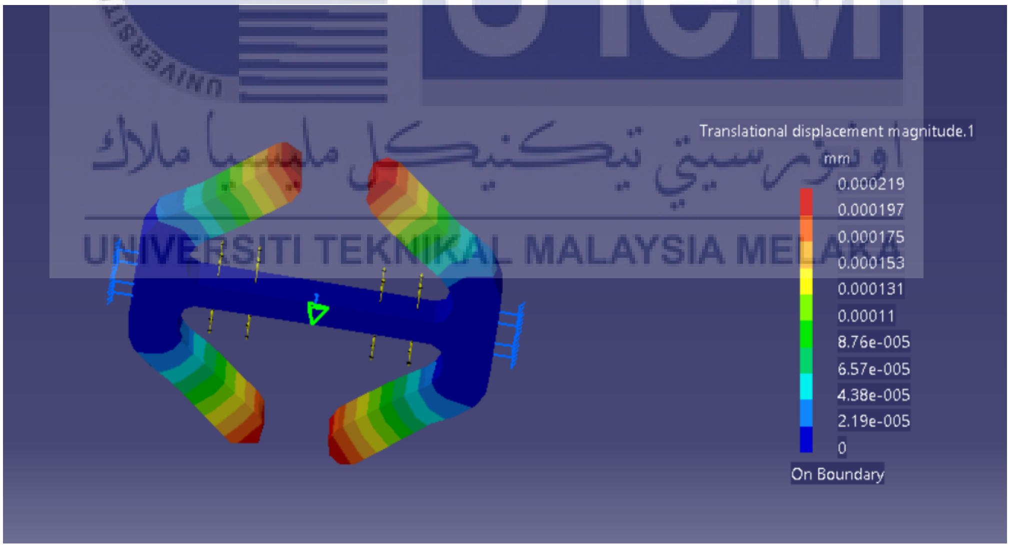


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Figure 4.12 Translational displacement magnitude value

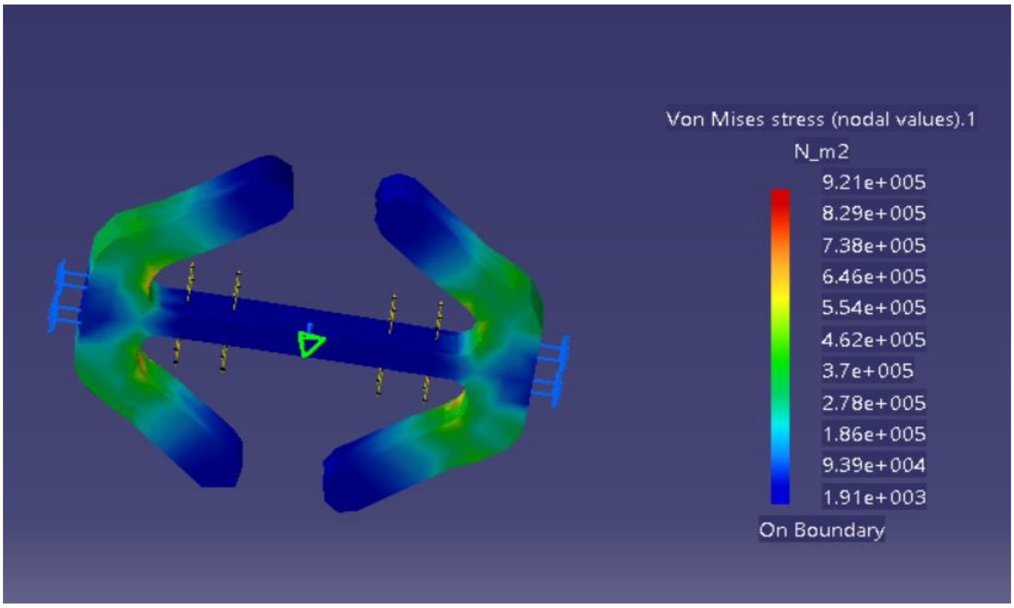


Figure 4.13 Von Mises stress value

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Figure 4.14 Deformation of product (Design 2)

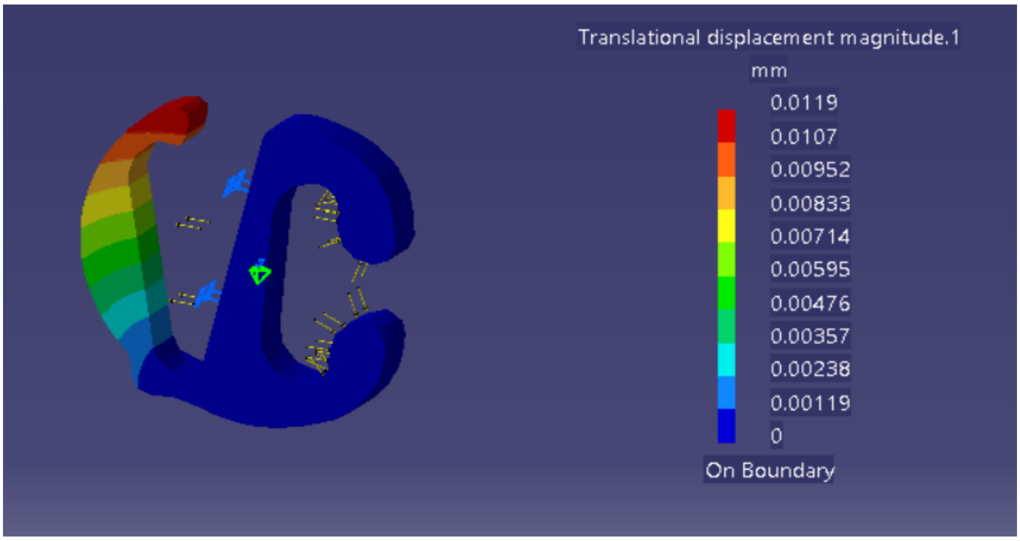


Figure 4.15 Translational displacement magnitude value (Design 2)


Figure 4.16 Von Mises stress value (Design 2)

For stainless steel, zinc alloy and ABS material this is the value of von mises stress and the translational displacement value as shown in Table 5, Table 6 and Table 7. Figure 24.1 shows the displacement of the material. In Figure 24.1, when the red part in the analysis means larger distance moved by the particles. The graph was created using the table of value von misses stress and the displacement for each material.

Table 5 Parameter stress versus displacement for seatbelt adjuster ( Stainless Steel)

| **Design 1** | |
|---|---|
| **Stress x $10^6$ N/$m^2$** | **Displacement (amplitude) mm** |
| 9.21 | 0.000219 |
| 8.29 | 0.000197 |
| 7.38 | 0.000175 |
| 6.46 | 0.000153 |
| 5.54 | 0.000131 |
| 4.62 | 0.00011 |
| 3.7 | 0.000088 |
| 2.78 | 0.000066 |
| 1.86 | 0.000044 |
| 0.94 | 0.000022 |
| 0.02 | 0 |

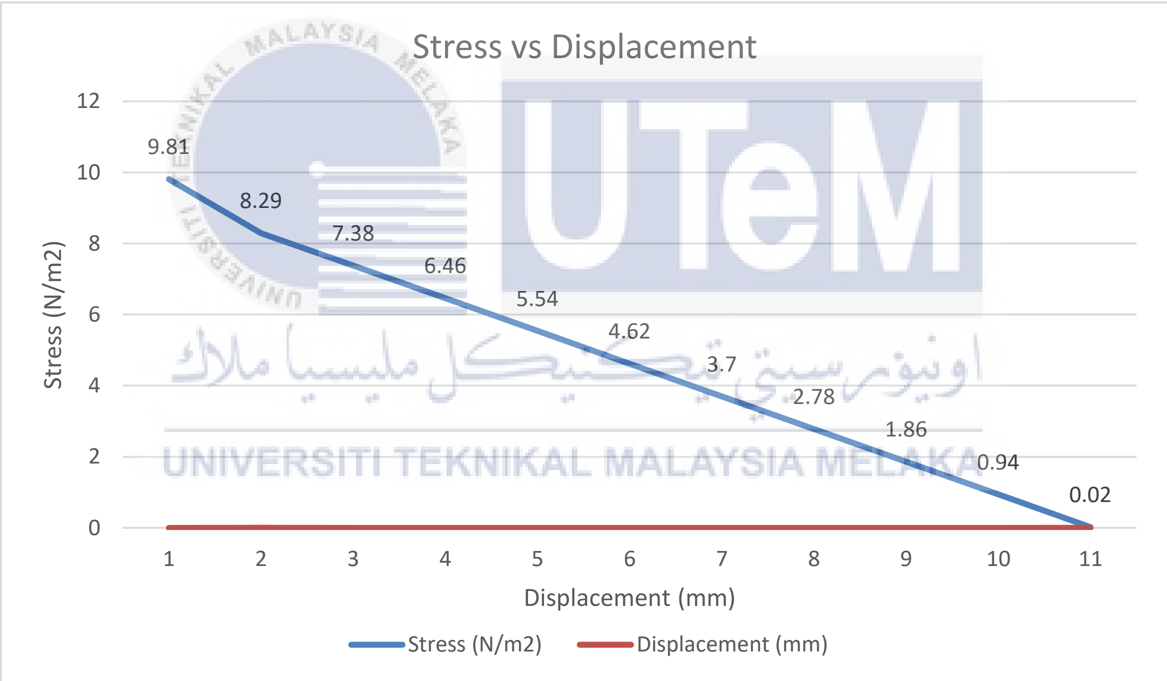


Figure 4.17 Graph stress vs displacement for design 1 (Stainless steel)

Table 6 Parameter of stress versus displacement for seatbelt adjuster ( Zinc Alloy)

| Design 1 | |
|---|---|
| **Stress x $10^5$ $N/m^2$** | **Displacement (amplitude) mm** |
| 9.24 | 0.000455 |
| 8.32 | 0.000409 |
| 7.39 | 0.000364 |
| 6.47 | 0.000318 |
| 5.55 | 0.000273 |
| 4.63 | 0.000227 |
| 3.71 | 0.000182 |
| 2.78 | 0.000136 |
| 1.86 | 0.000009 |
| 0.94 | 0.000045 |
| 0.02 | 0 |

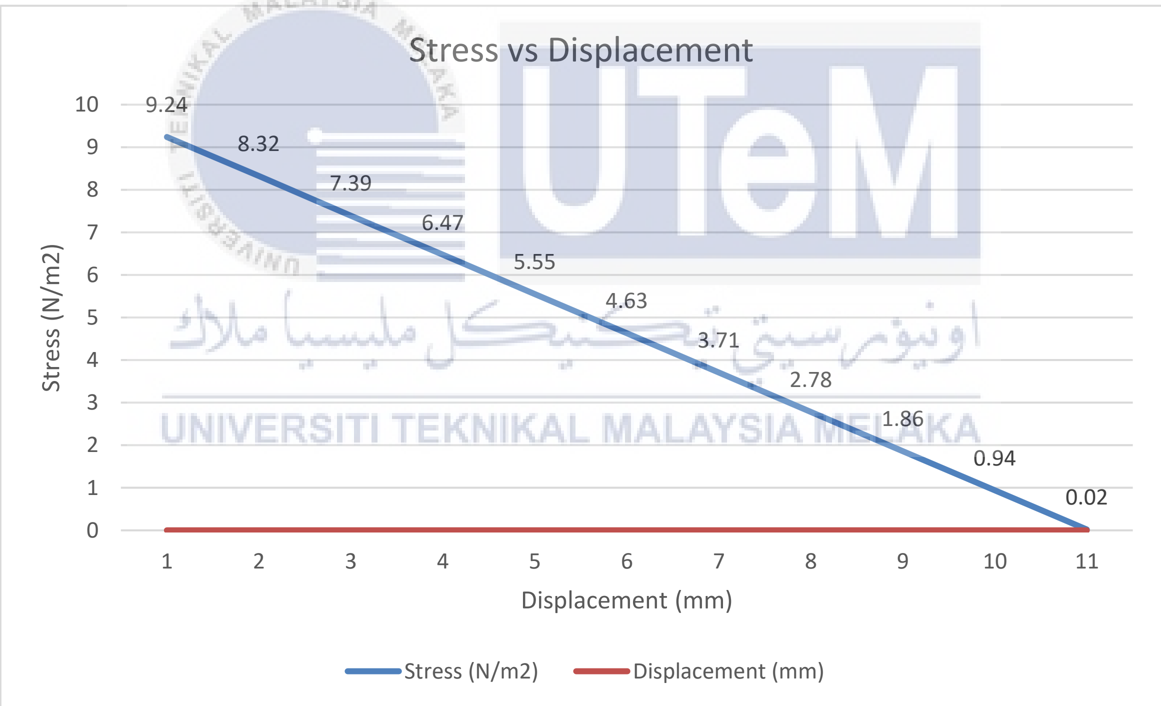


Figure 4.18 Graph stress vs displacement for design 1 (Zinc Alloy)

Table 7 Parameter of stress versus displacement for seatbelt adjuster (ABS Material)

| Design 1 | |
|---|---|
| **Stress x $10^5$ N/m$^2$** | **Displacement (amplitude) mm** |
| 9.11 | 13.3 |
| 8.20 | 12.0 |
| 7.29 | 10.7 |
| 6.38 | 9.33 |
| 5.47 | 7.99 |
| 4.57 | 6.66 |
| 3.66 | 5.33 |
| 2.75 | 4.00 |
| 1.84 | 2.66 |
| 0.94 | 1.33 |
| 0.03 | 0 |

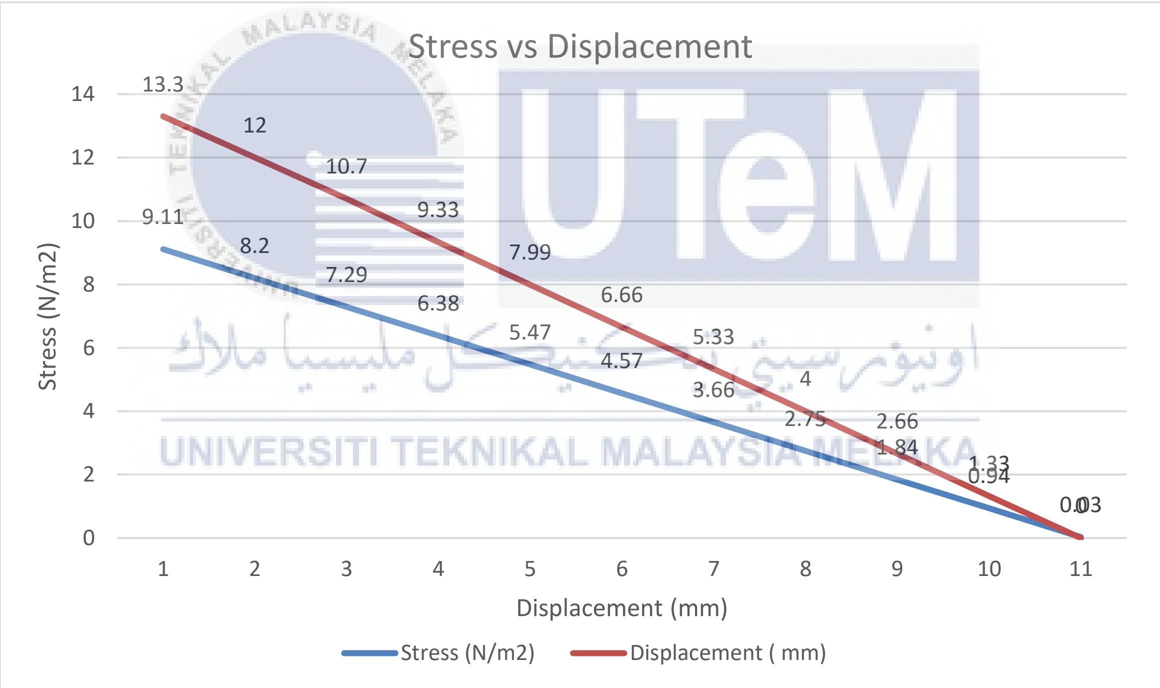


Figure 4.19 Graph stress vs displacement for design 1 (ABS Material)

The use of material on the product is based on the analysis in Catia V5. For design 1, stainless steel of the product has shown minimum, maximum and average value of von mises stress in $Nm^{-2}$ 1910, 921417.25 and 461663.63 respectively which is more than the zinc alloy and ABS material. Then, stainless steel has shown minimum, maximum and average value of magnitude displacement in mm is 0, 0.000219 and 0.0000110 respectively which is less than the zinc alloy and ABS.

Table 8 Average of Von Mises stress each material

| **Design 1** | | | |
|---|---|---|---|
| Von Mises stress of different materials | | | |
| Material | Minimum ($Nm^{-2}$) | Maximum ($Nm^{-2}$) | Average ($Nm^{-2}$) |
| Stainless Steel | 1910 | 921417.25 | 461663.63 |
| Zinc Alloy | 1520 | 923964 | 462742 |
| ABS | 2710 | 910507.5 | 456608.75 |

Table 9 Average of magnitude displacement each material

| **Design 1** | | | |
|---|---|---|---|
| Magnitude displacement shown by different materials | | | |
| Material | Minimum (mm) | Maximum (mm) | Average (mm) |
| Stainless Steel | 0 | 0.000219 | 0.0000110 |
| Zinc Alloy | 0 | 0.000045 | 0.0000225 |
| ABS | 0 | 13.323 | 6.6615 |

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Table 10 Parameter versus displacement for seatbelt adjuster (Stainless Steel)

| Design 2 | |
|---|---|
| **Stress x $10^6$ N/m$^2$** | **Displacement (amplitude) mm** |
| 3.9 | 0.0119 |
| 3.51 | 0.0107 |
| 3.12 | 0.0095 |
| 2.73 | 0.0083 |
| 2.34 | 0.0071 |
| 1.95 | 0.0060 |
| 1.56 | 0.0048 |
| 1.17 | 0.0036 |
| 0.08 | 0.0024 |
| 0.03 | 0.0012 |
| 0 | 0 |

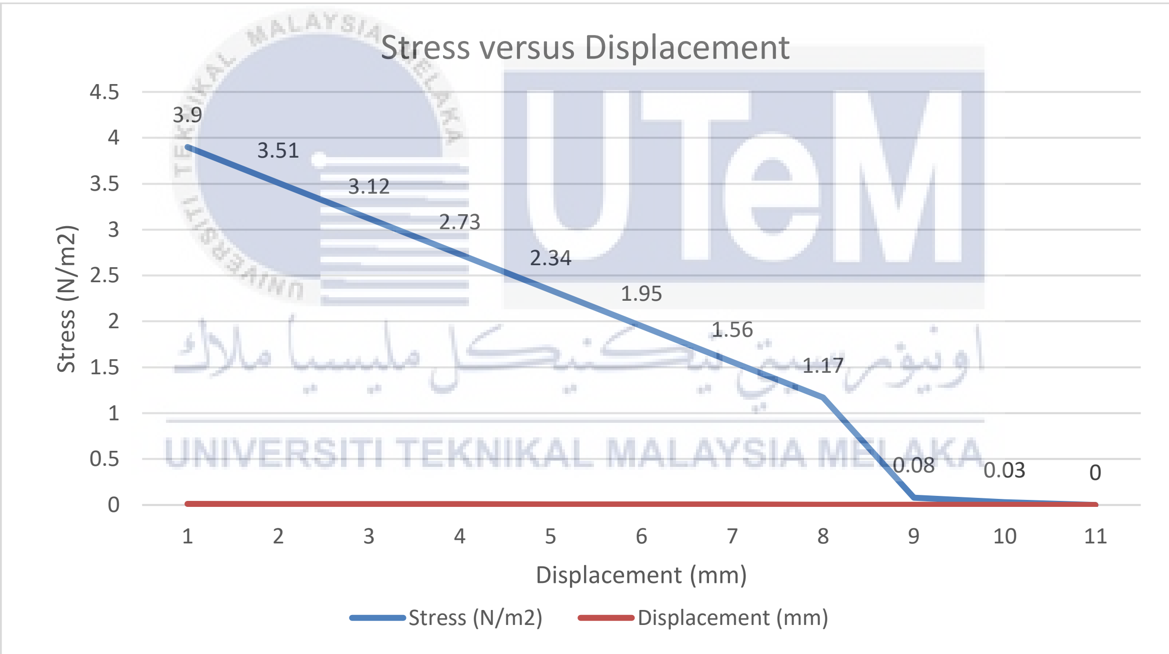

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Figure 4.20 Graph stress vs displacement for design 2 (Stainless Steel)

Table 11 Parameter stress versus displacement for seatbelt adjuster (Zinc Alloy)

| Design 2 | |
|---|---|
| **Stress x $10^6$ $N/m^2$** | **Displacement (amplitude) mm** |
| 3.93 | 0.0246 |
| 3.53 | 0.0222 |
| 3.14 | 0.0197 |
| 2.75 | 0.0173 |
| 2.36 | 0.0148 |
| 1.96 | 0.0123 |
| 1.57 | 0.0099 |
| 1.18 | 0.0074 |
| 0.79 | 0.0050 |
| 0.40 | 0.0025 |
| 0 | 0 |

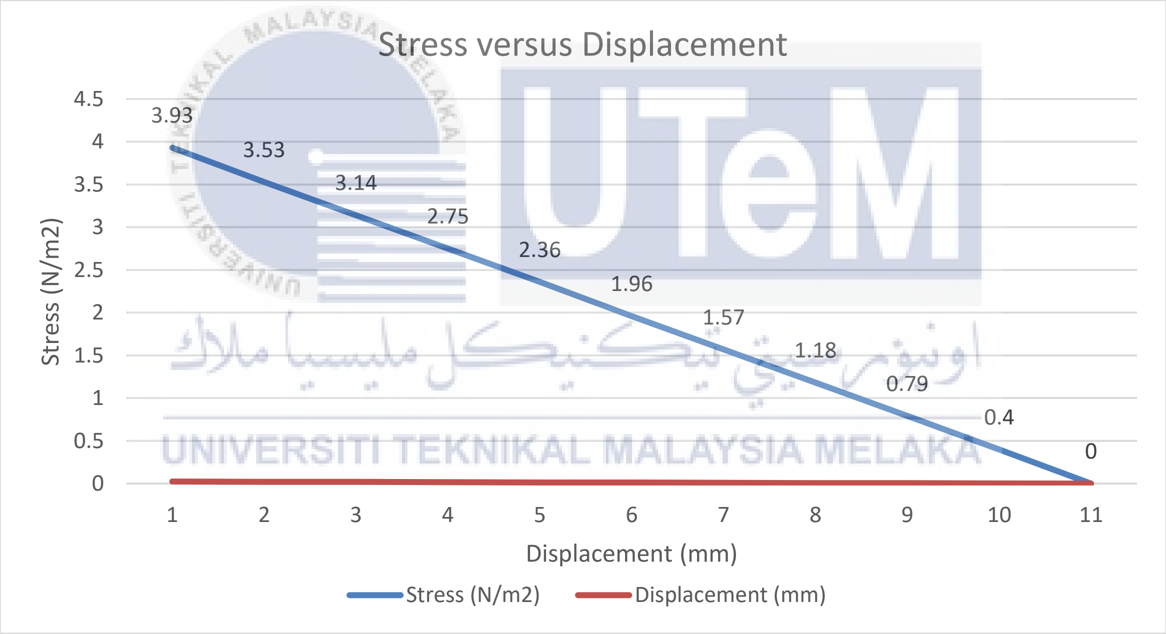

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Figure 4.21 Graph stress vs displacement for design 2 (Zinc Alloy)

Table 12 Parameter stress versus displacement for seatbelt adjuster (ABS Material)

| Design 2 | |
|---|---|
| Stress x $10^6$ $N/m^2$ | Displacement (amplitude) mm |
| 3.90 | 7.19 |
| 3.33 | 6.47 |
| 2.96 | 5.75 |
| 2.59 | 5.03 |
| 2.22 | 4.31 |
| 1.85 | 3.60 |
| 1.48 | 2.88 |
| 1.11 | 2.16 |
| 0.74 | 1.44 |
| 0.37 | 0.72 |
| 0 | 0 |

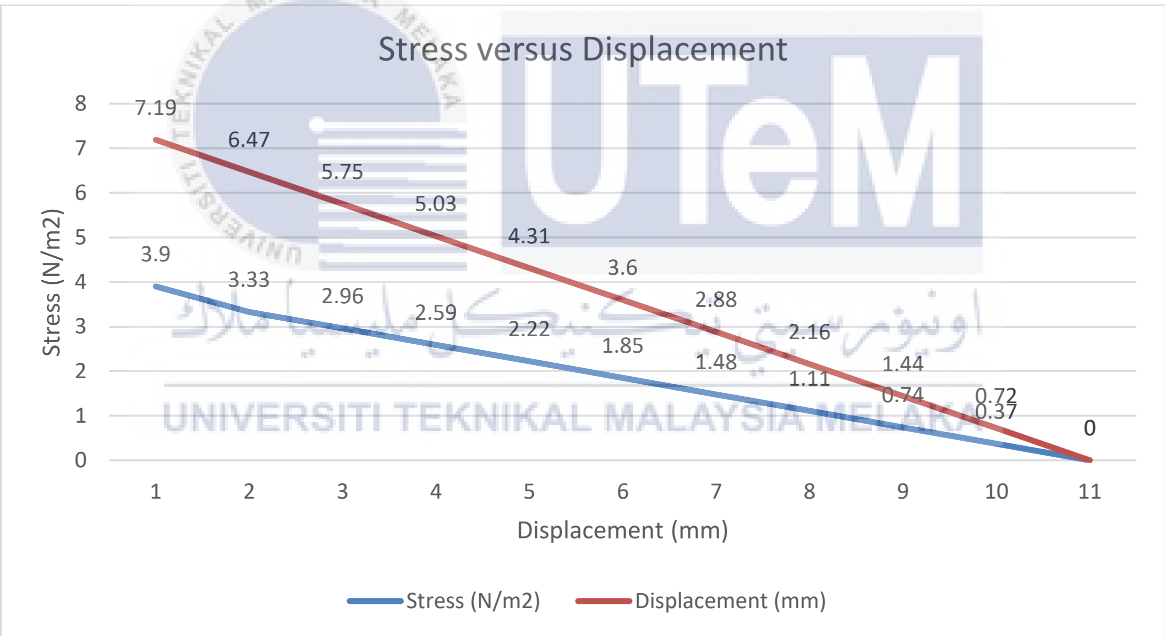


Figure 4.22 Graph stress vs displacement for design 2 (ABS Material)

For design 2, stainless steel of the product has shown minimum, maximum and average value of von mises stress in $Nm^{-2}$ 0, 3899000 and 1949500 respectively which is less than the zinc alloy and ABS material. Then, stainless steel has shown minimum, maximum and average value of magnitude displacement in mm is 0, 0.012 and 0.006 respectively which is less than the zinc alloy and ABS.

Table 13 Average of Von Mises stress each material

| **Design 2** | | | |
|---|---|---|---|
| Von Mises stress of different materials | | | |
| Material | Minimum ($Nm^{-2}$) | Maximum ($Nm^{-2}$) | Average ($Nm^{-2}$) |
| Stainless Steel | 0 | 3899000 | 1949500 |
| Zinc Alloy | 0 | 3928000 | 1964000 |
| ABS | 0 | 3902000 | 1951000 |

Table 14 Average of magnitude displacement each material

| **Design 2** | | | |
|---|---|---|---|
| Magnitude displacement shown by different materials | | | |
| Material | Minimum (mm) | Maximum (mm) | Average (mm) |
| Stainless Steel | 0 | 0.012 | 0.006 |
| Zinc Alloy | 0 | 0.025 | 0.013 |
| ABS | 0 | 7.19128 | 3.596 |

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The design was chosen based on the analysis in Chapter 4, which determined that the design is more durable and has greater tensile strength to withstand the weight of the children on the booster seat. Design 1 has a higher average von mises stress value than Design 2, which is 461663.63. It refers to a material's von mises stress under load being greater than its yield limit under simple tension. The stainless steel has the highest Von Mises stress value of any material. Furthermore, because the magnitude displacement of design 1 is less than that of design 2, it has less material deformation. Design 1 is chosen for product fabrication via 3D printing.

### 4.2.1 3D Printing Process

Fabrication is the construction of items from different parts using at least one of a range of processes and materials such as metals, wood and other solid surface materials. For this project, the processes are used of the computer aided designs (CAD) that can be programmed into machine 3D printing. The advantages of using 3D printing machines are reduces material waste, customization and personalization, low-volume production and rapid prototyping. The new product was a dummy because it was created by 3D printing. 3D printing or additive manufacturing is a process of making three dimensional objects or products from software such as Catia V5, AutoCAD and SolidWorks. There are many steps of the process when 3d printing. To print a model through 3D printing need to go through the following steps such as modelling, slicing, printing and post-processing.

| No | Process | Description | Picture |
|---|---|---|---|
| 1 | Modelling | Create the 3D model with 3D modeling software with Catia V5.<br>The STL files need to be used in a 3D printing machine like Creality. |  |

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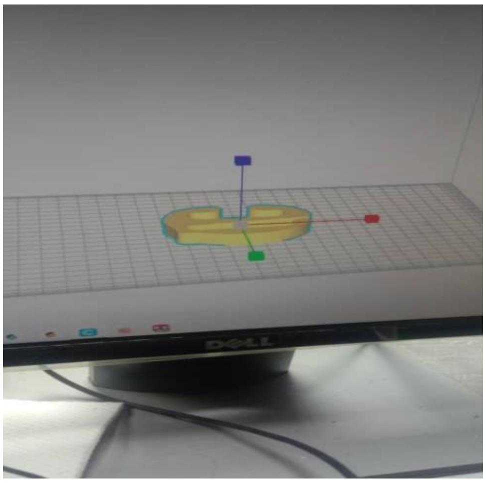
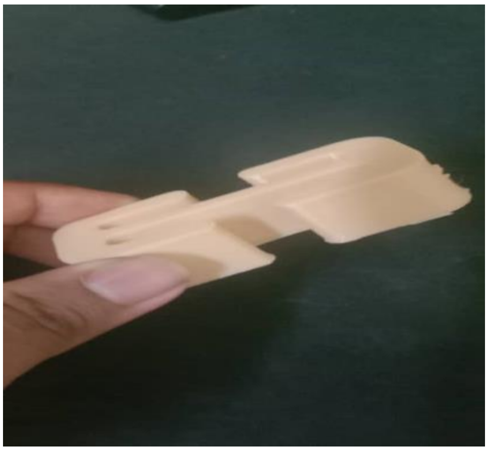
| | | | |
|---|---|---|---|
| 2 | Slicing | Use specific slicing software such as Creality.<br>The purpose of slicing is to allow the 3D printer to calculate the route and the amount of filament required. |  |
| 3 | Printing | The Creality will slice the file to the printer, product will be produced layer by layer. |  |
| 4 | Post - Processing | Removing support on the surface model. |  |

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# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

In conclusion, this project focused on design easy seatbelt adjuster for chidlren booster seat which is successfully acheived. Through many research, new design and the analysis of the product has been gathered to improve the seatbelt adjuster. The project began with a comprehensive literature review, using the principle of TRIZ method and morphological chart to determine the concept design of seatbelt adjuster. After the concept design has been develop in chapter 3 that where the concept desing has been analysis in Catia. The purpose of the analysis is to know which design is more durable and less deforming. The analysis shows that the stainless steel is the material that will longer live than the other material and has high durable between the other material. It has more live than the other material because of its less deformation and have high stress bearing capacity when force or load is loaded. The design of the seatbelt adjuster on the booster seat also simple and easy to use by the user.

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## 5.2 Recommendations

For future improvement, the design of seatbelt adjuster could be enhanced as follows:

i) Include study to find a better and accurate value of load and strength of material.

ii) Wider range of characteristic seatbelt adjuster such as customization features of seatbelt adjuster and the shape of seatbelt adjuster for comfort.

iii) Explore different adjustment mechanism for the seatbelt adjuster.

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# APPENDICES

Gantt Chart

| No | Task Weeks | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Find new Supervisor | | | | | | | | | | | | | | | |
| 2 | Write a comparison method between the best design | | | | | | | | | | | | | | | |
| 3 | Add more literature review based on design | | | | | | | | | | | | | | | |
| 4 | Update on method in Chapter 3 | | | | | | | | | | | | | | | |
| 5 | Submit an updated report to the SV | | | | | | | | | | | | | | | |
| 6 | Improve the design of the seatbelt adjuster | | | | | | | | | | | | | | | |
| 7 | Build a prototype of a seatbelt adjuster | | | | | | | | | | | | | | | |

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Gantt Chart

| No | Task Weeks | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | Complete Chapter 5 | | | | | | | | | | | | | | | |
| 9 | Submit a draft of the full report to the SV | | | | | | | | | | | | | | | |
| 10 | Correction of the report | | | | | | | | | | | | | | | |
| 11 | Submit a full report to the SV | | | | | | | | | | | | | | | |
| 12 | Preparation for the presentation of PSM | | | | | | | | | | | | | | | |
| 13 | Presentation PSM | | | | | | | | | | | | | | | |

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