A STUDY OF ALUMINUM HONEYCOMB IMPACT ATTENUATOR FOR NEIGHBORHOOD ELECTRIC VEHICLES

By

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FINAL PROJECT REPORT

Submitted to the Department of Mechanical Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Mr. Mohd Syaifuddin Bin Mohd
Project Supervisor

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June or December 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Muhammad Naim Al Amin Bin Saharudin

ABSTRACT

Vehicle safety is one of the major research areas in the field of automotive engineering. The car industry is developing new systems of passive and active safety and techniques to improve vehicle occupant safety. To reduce the cost of development and testing of new security architecture, it is recommended to use for the evaluation of simulation calculations accident early safety behavior under vehicle impact test. One of the devices are intended to reduce the damage done to the vehicle structure and possible injury to passengers as a result of the collision is the impact attenuator. The purpose of this project is to identify different materials and structural design for low cost impact attenuator design and perform crash simulation of impact attenuator in low speed impact. This requirement was completely satisfied with the final configuration of the impact attenuator. The main aspects of the research have been pointing out to find the optimal evolution of the kinetic energy during a front impact, with the lowest initial decline. In this report, the design concept of impact attenuator is discussed. The selection of impact attenuator as the platform to be develops largely due to less energy impact. The experiments were designed and performed to find the impact properties of honeycomb sandwich panels and to find the difference in properties of different design variations. Impact tests were performed on aluminum honeycomb sandwich panels of different thickness to investigate strength.

ACKNOWLEDGEMENTS

First and foremost I would like to thank god who made this project is possible, and I also would like to thank my direct supervisor for this project Mr. Mohd Syaifuddin Bin Mohd from Mechanical Engineering Faculty, for always supporting me throughout the project period and giving me a lot of new idea in term of improving the project development.

A special thanks to my university cliques, who have help in setup the experiment platform as well as during the experiment part. Apart from them, I would also like to thank everyone that I have worked with at this Honeycomb project as to their willingness to share valuable experience during the project period.

Next I would like to thank my technicians from the Mechanical Engineering Faculty for taking the time to monitor the development of this project and help in the fabrication part. Apart from that, I must thank UTP for providing me with a Final Year Project opportunity. With this opportunity, now I have broader my view in the mechanical field before going out to the industry world.

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CHAPTER 1
INTRODUCTION

An impact attenuator also called as a crash attenuator and crash cushion. Impact attenuator is designed to absorb impact energy, to minimize damage of the car frame and to protect the occupants. Usually the impact attenuators are placed in front and at the sides of the vehicles but in some other applications like railcar buffers it can be deployed on vehicle from behind.

Acceleration is based on the speed and mass of the car and speed and mass of the car when get crash also can be defined as deceleration. The initial force of the crash can be reduced by slowing down the deceleration. They are three method used to dissipate kinetic energy that is momentum transfer, material deformation and friction. The momentum transfer is transfer the energy to the sand or water and the speed of the impacting vehicle will be reduced. The material that is absorbing the energy from crash is called crumpled zone material. The last method is friction that is work by forcing a steel cable or strap through an angle slot.

1.1 Background of Study

There are a lot of things that need to be understood in order to complete this project. The impact attenuator design and construction is one of the areas that need to be researched thoroughly for the intended application. We must know about the strength and energy absorption of impact attenuator which is cores and some facing materials are directional with regard to mechanical properties and care must be taken to ensure that the materials are orientated in the panel to take the best advantage of this attribute. Besides that, the impact attenuator panels can provide a cost effective solution. Value analysis should include assessment of production and assembly costs and installation costs including supporting structure.

1.2 Problem Statement

A neighborhood electric vehicle is designed with sufficient protection for occupants to survive low speed accidents. A new modular, flat chassis platform type with lower center of gravity and separate body structure requires impact attenuator to provide good level of impact protection.

1.3 Objective and Scope Study

The main objectives of Front and Side Impact Attenuator for Flat Chassis Neighborhood Electric Vehicle (NEV) project are:

1. To identify different materials and structural design for low cost impact attenuator design.
2. To perform crash simulation of impact attenuator in low speed impact.
3. To fabricate and test performance of impact attenuator.

The scopes of study in this project are:

1. Design, modeling and impact simulation of the selected impact attenuator design for the intended neighborhood electric vehicle application. These will involve usage of computer aided tools such as CATIA for modeling and ANSYS for simulation.
2. Construction and testing of different materials samples for the impact attenuator.
3. Design and fabrication of the final design of the impact attenuator for the flat chassis neighborhood electric vehicle.

1.4 Relevancy of the Project

The project undertaken is relevant in the sense that it is compatible to the courses that I have taken in my university. The design using CATIA and ANSYS workbench software has been learned in the computer aided engineering design. This ANSYS software can be simulate to find the strength and deformation of impact attenuator. In the subject manufacturing of technology that gain me and skill using tools and machine such as lathe machine and milling machine. It also training me in hand works skill. Also got some knowledge using CNC machine and laser cutting machine.

In the mechanical and R&D aspects, the project exposed me to significant skills and knowledge in the mechanical and R&D field, which would make me more easily in the future.

1.5 The Feasibility of the Project within the scope and Time Frame

The project is executed within two semester time frame that is 8 month with limited budget given for this project. As a planned in Gantt chart the prototype of the impact attenuator will be able to complete.

a. Design concepts-preliminary specification impact attenuator with the following dimensions and target mass.

b. Simulation using software ANSYS to find strength and deformation of impact attenuator.

c. Fabrication with the cutting, milling and using laser cutting machine.

CHAPTER 2
LITERATURE REVIEW

2.1 Impact Attenuator Design

The impact attenuator designs in this project are:

2.1.1 Air Bag Design

The first design is a design that uses an air bag. This concept has scored well in terms of weight, reliability, security but was ranked lowest in terms of cost. Even though it is lighter and reliability, the cost will not be ignored. Costs are widely used in the necessary parts, while the replacement parts will be expensive. But the idea was reject after a more detailed analysis of the effect of pressure requirements and compare this to the limitations found in ordinary air bags [1].

2.1.2 Crimped Metal Lattice Design

Next, crimped metal lattice design has been investigated. This concept involves separating a few lines of a metal plate with crimped metal that will absorb a lot of energy by crushing when the effect. Lattice design scored quite well in almost every category without performing extraordinarily better or less in any one area. A major concern of the design is the ability to rebuild after the effects of intensive involvement in the fabrication time [1].

2.1.3 High Impact Foam Design

Impact absorbing foam effects are then evaluated in the design matrix. This is the second highest scoring design with good performance in every category. Compared with other materials, foam provides lightweight and cost-friendly materials for absorption effects. Foam was rated as one of the safest two concepts and the ability to easily manipulate in any size or shape to be made use of foam is perfect. As the use of foam is scored so it should look into more detail later in the design process [2].

2.1.4 Honeycomb Design

Furthermore, honeycomb structures were evaluated in the matrix. It scored the highest of all design. Lightweight and low prices make the material interesting because it has the ability to create a relatively cheap and easy to replace. Honeycomb also scored high in safety and reliability as the ability to reduce the impact will not change much because of the variance of the design and construction. This design was examined in greater detail in the design process [2].

2.1.5 Rubber Bumper Design

The rubber bumper then evaluated as a possible design solutions. Rubber scored well in terms of weight, cost, and the possibility that it is a common ingredient that can be made to fit into the correct dimensions. Problems were predicted with this material because its elasticity is small compared with other designs. Therefore, it will transfer too large amount of power to the car body itself rather than absorb [3].

2.2 Application of the Impact Attenuator

The impact attenuator, also called a crash attenuator or crash cushion, is an attenuation system for the roadway and highway. In accidental situations, these traffic safety impact attenuators absorb impact and minimize vehicle damage. There are impact attenuators that apply in several ways [2].

1. Racing car
2. Honeycomb Crash Cushion
3. Crash Attenuator
4. Black Box System for Crash Cushion
5. Line Barrier
6. Rolling Guard Barrier
7. Plastic Jersey barrier
8. Truck Mounted Attenuator

2.3 Manufacturing Process

There are two processes to manufactured honeycomb. There are expansion method and corrugated process. Honeycomb is made primarily by the expansion method. The corrugated process is most common for high density honeycomb materials.

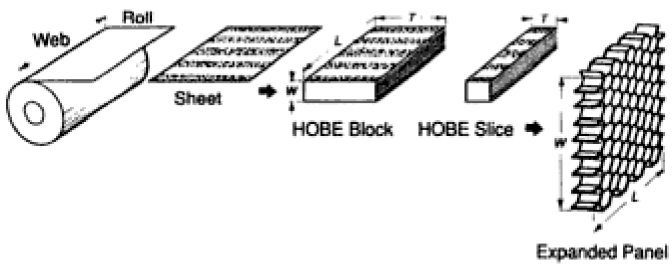

Figure 1: Expansion Method of Honeycomb

The honeycomb fabrication process by the expansion method begins with the stacking of sheets of the substrate material on which adhesive node lines have been printed (figure 1). The adhesive line is then cured to form a HOBE (Honeycomb before Expansion) block. The HOBE block may be expanded after curing to give an expanded block. Slice of the expanded block may then be cut to the desire T dimension. Alternately, HOBE slices can be cut from the HOBE block to the appropriate T dimension and subsequently expanded. The expanded sheets are trimmed to the desired L dimension (ribbon direction) and W dimension (transverse to the ribbon) [4].

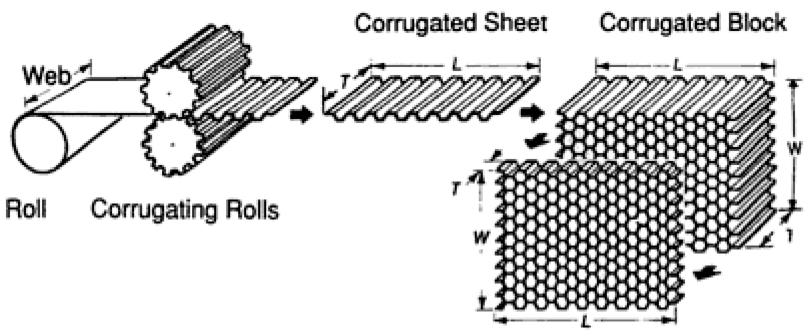

Figure 2: Corrugated Method of Honeycomb

The corrugated process of honeycomb manufacture is normally used to produce products in the higher density range (figure 2). In this process adhesive is applied to the corrugated nodes, the corrugated sheets are stacked into blocks, the node adhesive cured, and sheets are cut from these blocks to the required core thickness [5].

2.4 Material and Honeycomb Structure

There are several material and structure that apply in the honeycomb:

2.4.1 Aluminium Honeycomb

Aluminum honeycomb is one of the materials that have highest strength / weight ratios. There are many configuration of the bonding aluminum that can form in the multi-cell geometry usually hexagonal. Property is controlled by varying the thickness of the foil and the size of cell. Although the price is relatively low, aluminum honeycomb should be used with caution because of the potential to cause corrosion problems in salt water environments. Besides that, need to ensure that the honeycomb does not come into direct contact with the skin can exacerbate carbon for conductivity galvanic corrosion [6].

Figure 3: Aluminum Honeycomb

2.4.2 Nomex Honeycomb

It is made of Nomex paper ie paper based Kevlar instead of cellulose fibers. Initial paper honeycomb is usually dipped in phenolic resin to produce a strong and has good fire resistance. It is also widely used in the aircraft. Special grade for use in the application of fire retardant on public transport can also be made with a honeycomb cells filled with phenolic foam for added bond area and insulation. Nomex is becoming increasingly popular not because of good mechanical properties but low density and good long-term stability. As a result, Nomex be more expensive than the other core materials [7].

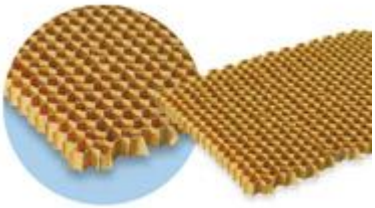

Figure 4: Nomex Honeycomb

2.4.3 Thermoplastic Honeycomb

Thermoplastic honeycomb is used in several sectors; the major fields of application are: refrigeration industry, production of composites panels like compartment, furniture, walls and car industry. Three main of thermoplastic polymers is polycarbonate, polypropylene and polyetherimide [8].

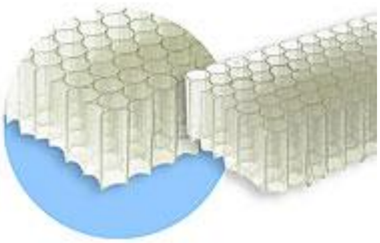

Figure 6: Polycarbonate

Figure 5: Polypropylene

2.4.4 Aluminium Foam

Metallic foams have great potential applications in light construction and create a relatively new class for high stiffness at low density. It is to absorb high amounts of energy in the relatively low impact and reduce vibration noise. Engineering properties of high metal foam of polymer foam, they are stable at high temperatures, has superior fire resistance, evolving toxic fumes in a fire and harder by an order of magnitude. Due to the melting temperature and low density primary attention paid to foam made of aluminum and alloys [9].

2.4.5 *Structural Foam*

Foam structure is functioning as a substitute for building materials such as metal, cement and wood. Foam begins as plastic compounds and mixed with chemicals or nitrogen gas. A mixture of both will make the plastic melting. Then be injected into the prepared mold. After that, the molten plastic expands towards the edge of the mold. The plastic that touches the inner walls was reacts and forms a hard shell, while the core of the foam remains porous [10].

2.5 Flat EV Chassis

Flat chassis architecture for electric vehicle is not an entirely new concept. The concept was first developed by General Motors for their future fuel cell vehicle prototypes such as the Autonomy and Hywire [11]. In these concepts, all the fuel cell components, fuel storage tanks and electric propulsion are mounted inside a 6 inch thick flat chassis. There are other prototypes of flat chassis developed by kit car manufacturer such as Trexa [12] and developed by research group such as the 8-wheel electric limousine Eliica [13]. However, all these concepts focus on highway worthy typical passenger vehicles, in which the costs of either the large battery pack or the large fuel cell components essentially prevent these prototypes from entering the market today.

An NEV is defined as lower speed vehicle (limited to a top speed of 48 km/h), limit for maximum weight (up to 3,000 lbs) and with sufficient safety features to be able to be operated on roads (headlights, signals, seat belts, etc) [14]. Most of these NEVs are marketed as urban transport, community transport, campus transport, industrial complex transport, tourist site transport and airport transport. There are several main functions such as people movers, security and to move goods. The existing niche market for NEVs is growing with new legislations being introduced in different parts of the world [15].

CHAPTER 3
METHODOLOGY

3.1 Procedure and Identification

The methodology on how the project was conducted is discussed in this chapter. In order to archive the objective of the project, research and experiment. The research will be done on some resources from the book, journal and any technical paper. This project was planned to be complete in two semesters, where the first semester was to concentrate on simulation work, crash and impact simulation using ANSYS workbench. Another semester will do in decision matrix, fabrication of manufacturing rig for sample site and sample testing.

After completing install all the hardware and software, the project will continue will field experiment, testing and be able to understand the characteristic of impact attenuator. Then, the sample will test using impact test machine.

3.2 Flow Chart of Project

The project methodology is summaries by the activities flow chart below. The most critical activity is the finite element analysis to optimize the impact attenuator strength and the actual fabrication in full scale of the NEV itself.

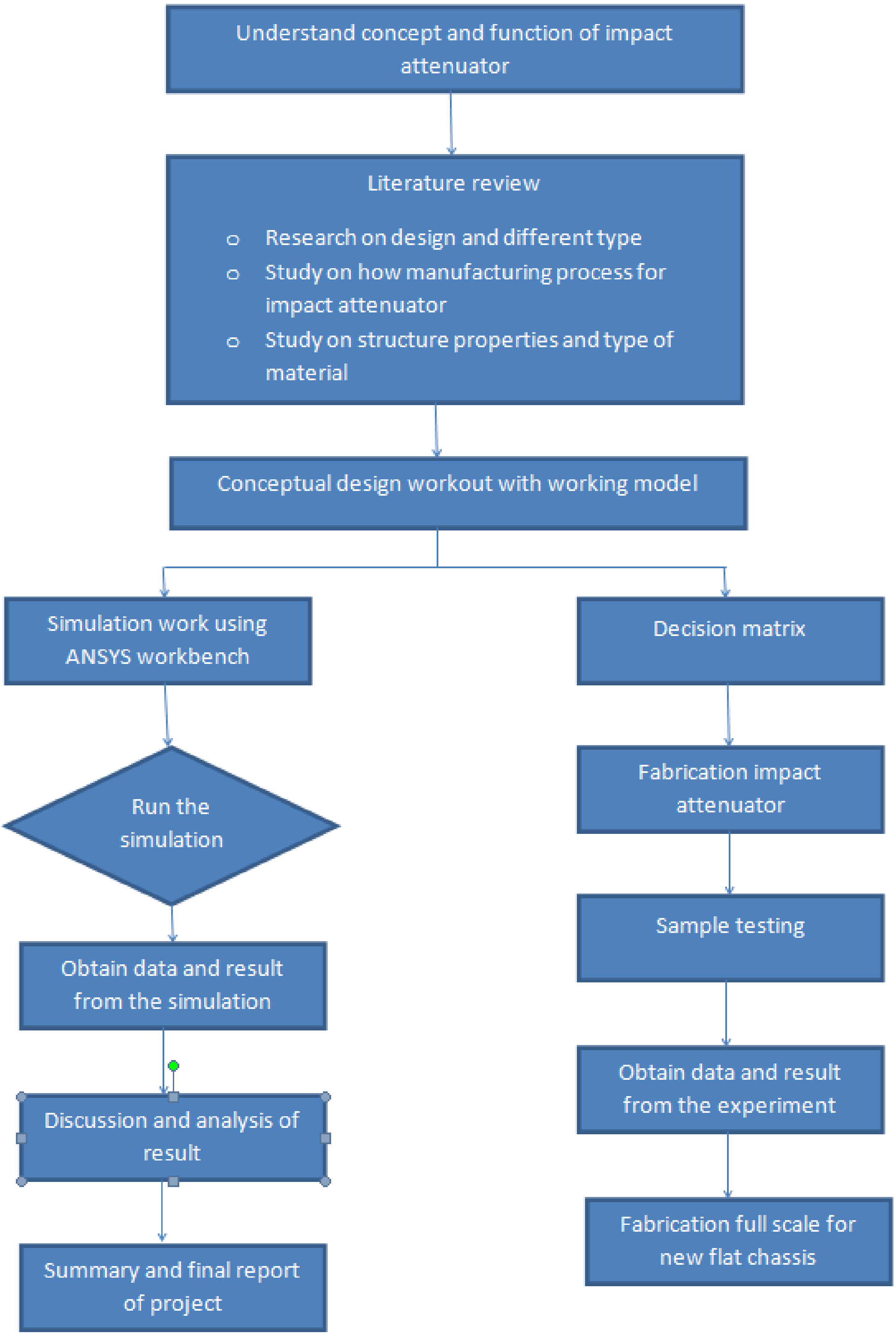

Figure 7: Flow chart

3.3 Tools and Equipment Required

Most of the tools required are identified at the secondary stage. Below are the hardware and software used for this project.

1. **Software Requirement**

- CATIA for design aluminum honeycomb
- ANSYS for impact simulation and crash simulation
- AUTOCAD for using EDM wire cut and save in DXF file

2. **Hardware Requirement**

- Aluminum plate 3mm
- Epoxy
- Prospect thickness 3mm
- Aluminum flat bar

3. **Machinery**

- Impact testing machine
- Compress machine
- Milling machine
- Laser cutting machine
- EDM wire cut

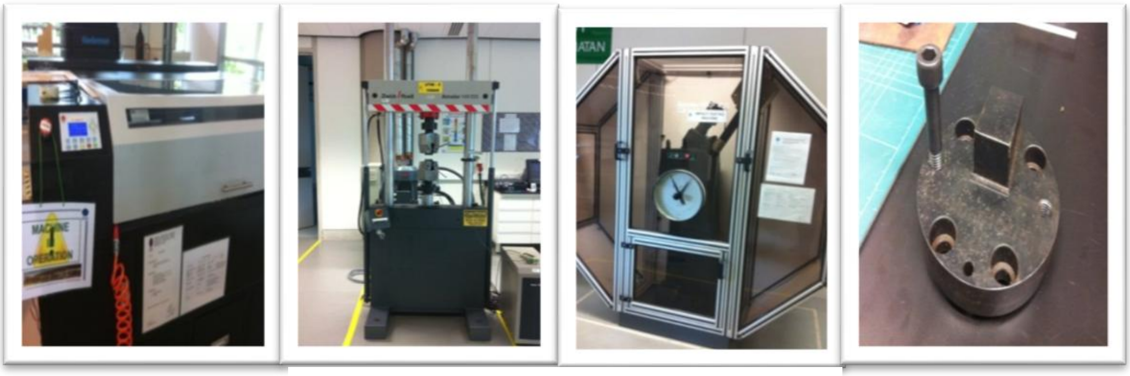

Figure 8: Equipment for Testing

3.4 Project Activities

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Work Stations block 17

- Impact testing using impact testing machine to find energy absorption.
- Compress testing using compress machine to find deflection

Work stations block 16

- Using laser cutting to make corrugating gear by using prospect.
- Using CNC machine for actual design for corrugating gear.

3.5 Key Milestone

Table 1: Milestone Table

		FYP1					FYP2				*Remarks*
		J	F	M	A	M	J	J	A	S	
i	FYP Title Selection	◆									Completion of the title selection
ii	Submission of FYP title proposal	◆									Completion of the title proposal
iii	Submission of Extended Proposal		◆								Completion of the Extended Proposal
iv	Submission of Draft Report				◆						Completion of draft report
v	Submission of Interim Report				◆						Completion of Interim report
vi	Decision Matrix (weighted score)					◆					Select Aluminum Honeycomb
vii	Fabrication of Manufacturing Rig						◆				Corrugating Gears Method
viii	Aluminum Honeycomb Sample					◆					Testing Aluminum Honeycomb
ix	Submission of Progress Report						◆				Completion of Progress Report
x	SEDEX							◆			Completion of SEDEX
xi	Submission of Draft Report							◆			Completion of Draft Report
xii	Submission of Technical Paper								◆		Completion of Technical Paper
xiii	Submission of Final Report									◆	Completion of Final Report

CHAPTER 4
DISCUSSION

4.1 Decision Making and Concept Selection

A decision matrix is a method of evaluating competing concepts by ranking the design concept with weighting factors and scoring the degree to which each design concepts meets the criteria. A brainstorming produced 5 basic concepts that could meet these needs. The factors that these were measured on were cost, weight, reliability, safety and feasibility. Weight is an important to maintain the lightweight not take away from its speed. Cost is also important because budget cannot pass the limit. Reliability is essential to how the design will perform and safety for taking the high impact forces and not threat to the driver. The last concept criteria is feasibility is needed to evaluate how like concepts could be implemented into attenuator.

Table 2: Design Concept

Design Concept	cost	weight	reliability	safety	feasibility	rank
weighting factor	0.35	0.25	0.2	0.15	0.3	
airbag	1	9	8	6	3	6
crimped metal lattice	6	6	5	5	6	7.2
foam	7	8	7	8	8	9.5
honeycomb	8	8	9	8	8	10.2
rubber bumper	7	7	6	7	7	8.6

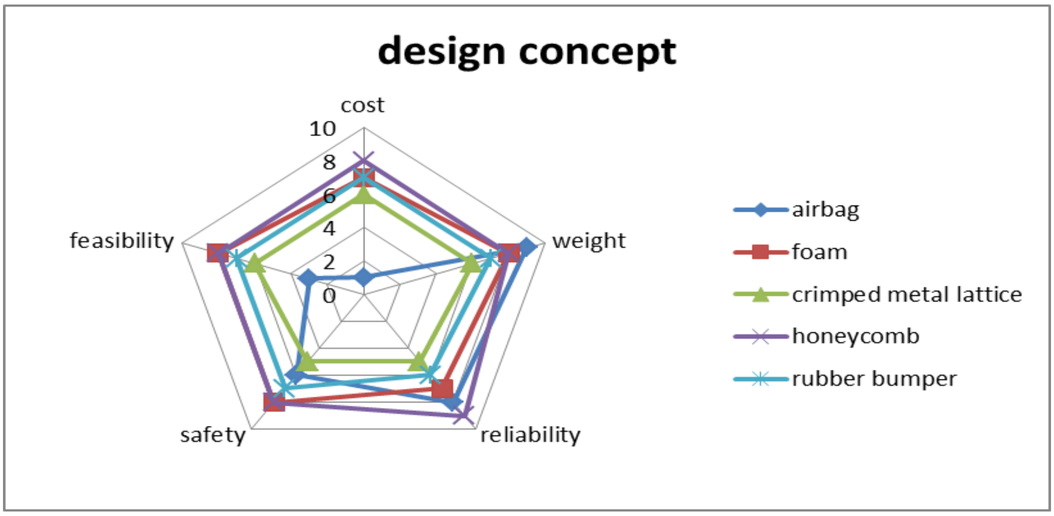

Figure 9: Design Concept

4.2 Current Design Flat Chassis Neighbourhood Electric Vehicle

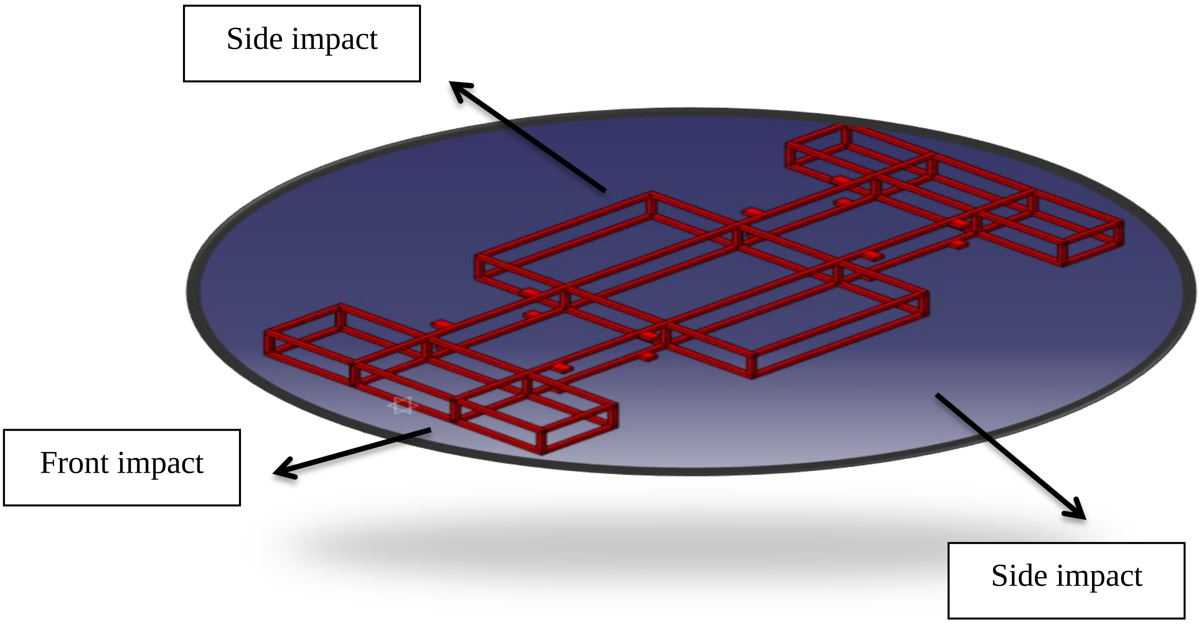

Figure 10: Design Flat Chassis NEV

The chassis proposed packaging diagram and the final design was developed using CATIA, a computer aided design software. The chassis is designed as a two layer ladder type chassis with all components housed in between the two layers. The battery pack, which is the heaviest component, is located at the center for optimum protection in case of vehicle impact as well as for perfect balance of the vehicle mass.

The motor controllers are located beside the motor controller together with the on-board charger and the custom electric air conditioner. The vehicle traction is provided by either 2 or 4 in-wheel motors housed inside the wheels.

In figure 10, the placement for front and side impact. It will place inside the body. The proposed design concept is a flat chassis NEV with modular interchangeable bodies, which can be replaced depending upon the requirements or functions desired. All the components; battery pack, motor controllers, on-board charger, solid state air-conditioner and even on-board generator are all installed inside the thin profiled flat chassis.

One major difference between this concept and the existing prototypes developed by various parties lies in the sizing of the battery pack. The proposed flat chassis NEV does not require large and expensive lithium polymer battery pack as it is lightweight and doesn't need to have large autonomous range on a single charge.

Therefore, even a cheaper and reliable nickel metal hydride battery pack or even a lead acid battery pack could be used in place of the lithium polymer battery pack. This significantly reduces the cost of the unit and would allow faster market penetration. However, as the cost of the lithium polymer battery pack is reduced, future models could include this type of battery as well to further reduce mass and improve energy efficiency. For the proof of concept prototype, fortunately an existing lithium polymer battery pack could be used during testing.

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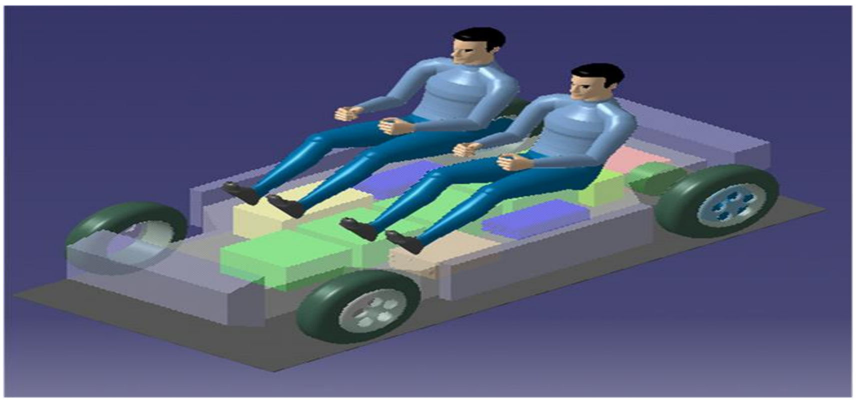


Figure 11: Design Concept with Impact Attenuator

First prototype flat chassis with the following dimension:

- Acceleration: 0 to 100 km/h less than 10 secs
- Top speed: 140 km/h
- Urban EV range (60 km/h speed): 130 km
- Highway EV range (100 km/h speed): 70 km
- Fuel tank capacity: 14 Liter
- Autonomy range (with on-board gen): 300 km
- Max wheel torque: 600 N.m (40 kW total)

4.3 Impact Attenuator Mathematical Model

Table 3: Formula

	Horizontal
Determine the stroke required to limit the G load to the allowable level.	$G = \frac{V^2}{2gs}$ Thus $s = \frac{V^2}{2gG}$
Determine the energy that must be absorbed.	$KE = \frac{1}{2} \frac{W}{g} V^2$
Determine the dynamic force, Fdyn = fcrAcr	$F_{dyn} = \frac{W(h+s)}{s}$
Determine impact velocity.	Given velocity

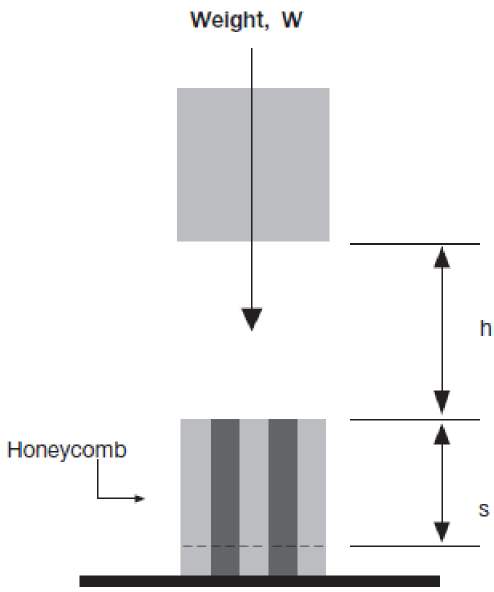
Determine total honeycomb thickness.

Use as example for formula Ks = stroke factor (assume 70%)

$$T = \frac{s\text{ (stroke required)} + \text{precrush}}{Ks} \qquad T = \frac{s\text{ (stroke required)} + \text{precrush}}{\text{stroke efficiency}}$$

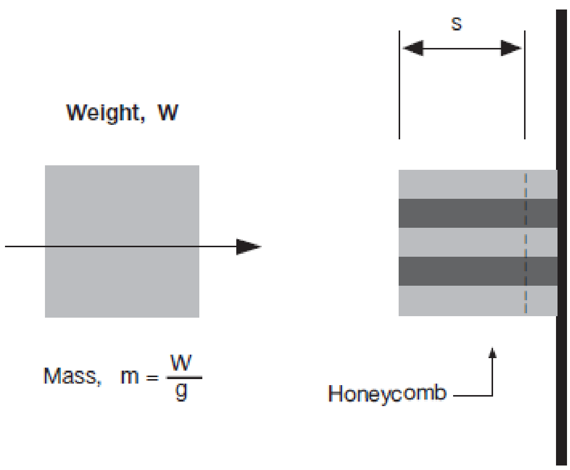
The designer must increase the static crush strength for the dynamic effect which is a function of aluminum honeycomb density and impact velocity to adjust the crush strength for temperature environment. Usually the thickness of honeycomb is about 1/8 to ¼ inch.

External Energy		Internal Energy
W (h+s)	=	$f_{cr}A_{cr}S$
"G" Load	=	$\frac{h+s}{s}$
$V_{AT\ IMPACT}$	=	$\sqrt{2gh}$



Vertical Drop Equations

External Energy		Internal Energy
$\frac{1}{2}m\,v^2$	=	fcrAcrS
"G" Load	=	$\frac{v^2}{2gs}$



Horizontal Motion Equations

Situation:

A 1000 pound object is traveling at 30 miles per hour and must be stopped.

Problem:

The object must not be subjected to more than 12 Gs.

Calculations: 30 mph x 1.467 = 44.0 fps

$G = \frac{V^2}{2gs}$ $s_{req'd} = \frac{(44.0)^2}{2(32.2)(12)} = 2.50 \text{ ft} = 30.0 \text{ in.}$

s = 70% Tc $T_{req'd} = \frac{30.0}{0.70} = 42.0$ in. (for stroke) + 0.25 in. (for precrush) = 43.15 in. (total)

Try ACG-3/8-3.3 fcr static = 120 psi fc dyn = (120)(1.10) = 132 psi

at 30 mph 10% increase

$\frac{1}{2}\frac{W}{G}V^2 = f_{cr}A_{cr}S$ $\frac{1}{2}\frac{(1000)}{(32.2)}(44.0)^2 = (132)(A_{cr})(2.50)$

A_{cr} req'd = 91.1 in² use 9.54 in. x 9.54 in.

Solution:

Use ACG-3/8-3.3 HexWeb® 9.54 in. L by 9.54 in. W by 43.15 in. T precrushed.

4.4 Finite Element Analysis

Finite element analysis (FEA) was conducted as the chassis evolved from the first concept to the final design as shown in Figure 12. This figure also shows the boundary conditions for the FEA analysis of torsional rigidity with the rear block supports being clamped and fully constrained and a distributed force of 10000 N.m applied at the front block.

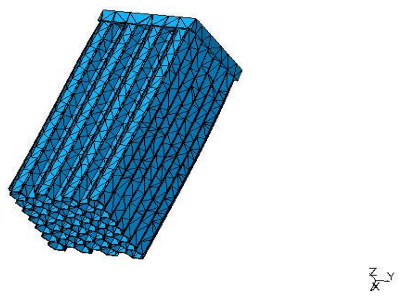


Figure 12: Boundary Condition- torsional rigidity

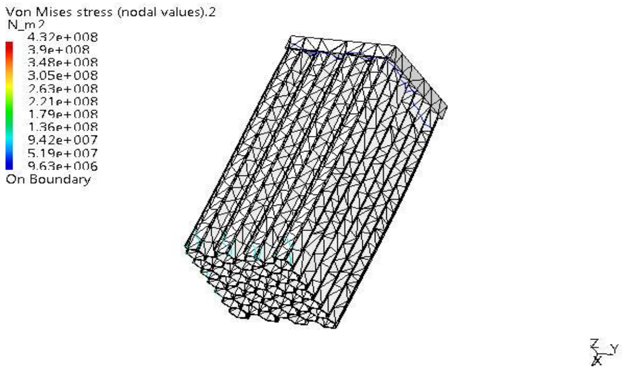


Figure 13: Von Mises Stress- torsional rigidity

The results show that a honeycomb rigidity of 10000 N.m/degree is possible with the design. The peak Von Mises stress is only 432 MPa, which is a lot less than the yield strength of aluminum at 600 MPa.

Figure 14 shows bending boundary conditions applied when the honeycomb is loaded with distributed force 50000 N.m. The honeycomb is clamped or fully constrained at all block back to honeycomb.

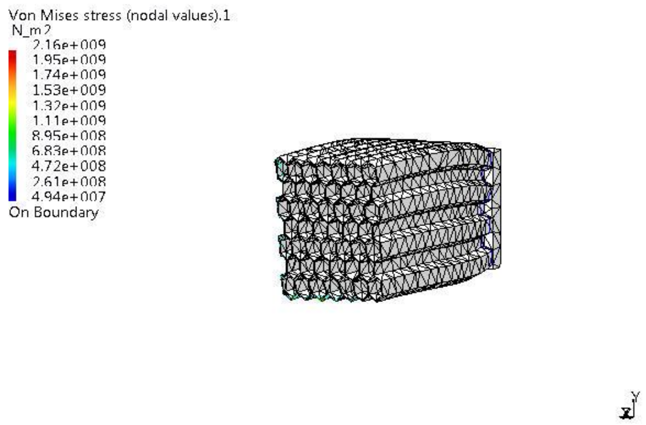


Figure 14: Boundary Condition- Bending

Finite element results of bending moment indicated the peak Von Mises stress of 2360 MPa, which is a lot lower than the yield strength of chassis material.

Other analysis performed is translational displacement simulation. It was discovered that the deformation is 0.475mm. Other static FEA stress analysis also exhibit lower Von Mises stress values compared with the two cases above.

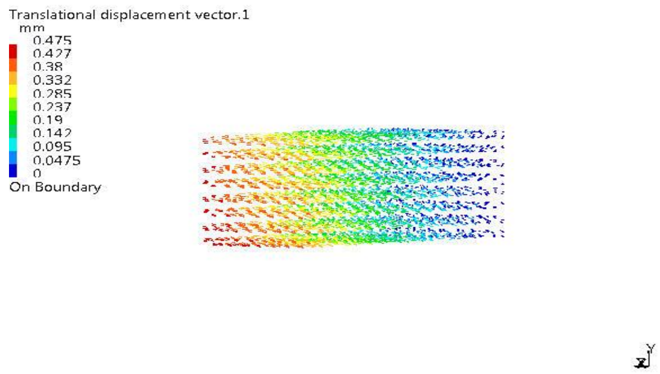


Figure 15: Translational displacement

4.5 Project Test Prototype

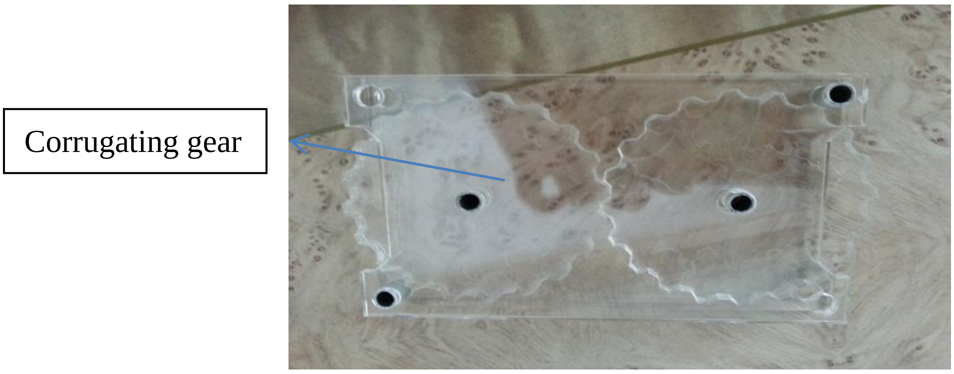


Figure 16: Sample of corrugating gear

For this semester, author has started work on the project prototype design and fabrication. The reason of preparing the project test bench is because wanted to make full scale of honeycomb and the material will change to steel. Figure 16 shows the selected manufacturing method of corrugating gear. The fabrication of this prototype is requiring to uses some of the mechanical machine such as laser cutting machine. Arrows indicate the gear cut using a laser cutting machine. The middle between the gears is the place to pass the aluminum sheet and will be produced aluminum hexagonal shape according to the gear teeth. Method was chosen because there is no limit for width. The thickness is according to gap between both teeth gear and the height is depending on the thickness of the gear.

Figure 17: Aluminum sheet through the teeth gear

4.6 Testing Honeycomb Using Impact Testing Machine

For this semester, author has started work on the testing specimen. The reason of preparing this testing is to get the value of AV and AVK. Every of force is the same which is 299.751J. The specimen is cutting a small scale which is suitable for platform of the impact testing machine. Figure 18 shows the specimen size for impact testing. The size is according to size platform and the thickness is according to the height of platform.

Figure 18: Specimen size for impact testing

Figure 19 show the result after the hammer impact the specimen. The specimen is split and the objective is achieved. The specimen is absorbing the energy impact by hammer.

Figure 19: Result after the hammer impact

Figure 20 show the energy absorption is 54.287J from the actual 299.751J. If the result goes to 0 degree it is mean no energy absorption.

Figure 20: Energy absorption

4.7 Design Corrugating Gear and Fabricated Using EDM Wire Cut

Start new design using CATIA for corrugating gear that has thickness 750mm. It is to make a bigger size for making the honeycomb.

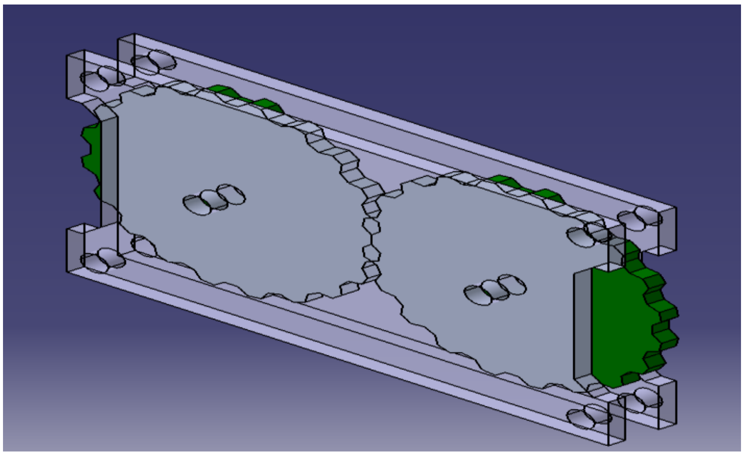


Figure 21: Assembly design

Figure 22 and figure 23 show the DXF drawing. The EDM wire cut machine need to setup and only allows DXF drawing to cording in this machine.

setup and only allows DXF drawing to cording in this machine.

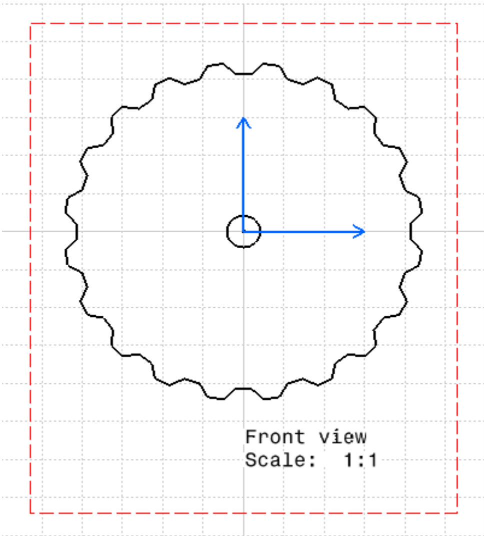


Figure 22: DXF drawing for corrugating gear

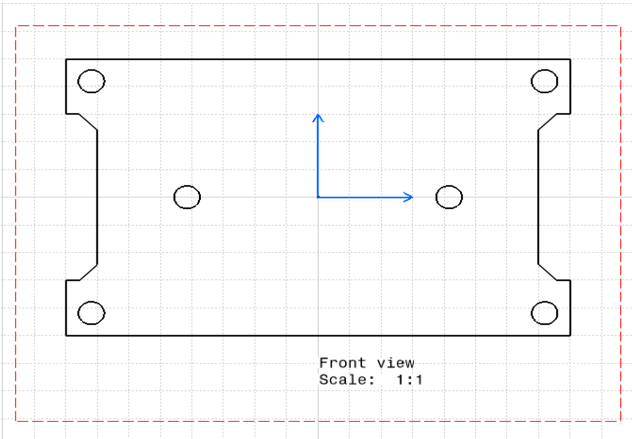


Figure 23: DXF drawing for corrugating gear holder

Figure 24 show the work piece for making the corrugating gear and holder. The work piece must have at least 1inch to holder the work piece at the machine.

Figure 24: Work piece before cutting using EDM wire cut

Figure 25 shows the EDM wire cut machine that using Brass wire of 0.2mm diameter to cut the work piece; we got the end product with the desire shape which is the shape above. This machine is fully automatic. Very fine holes can be easily drilled and a good surface finish can be obtained.

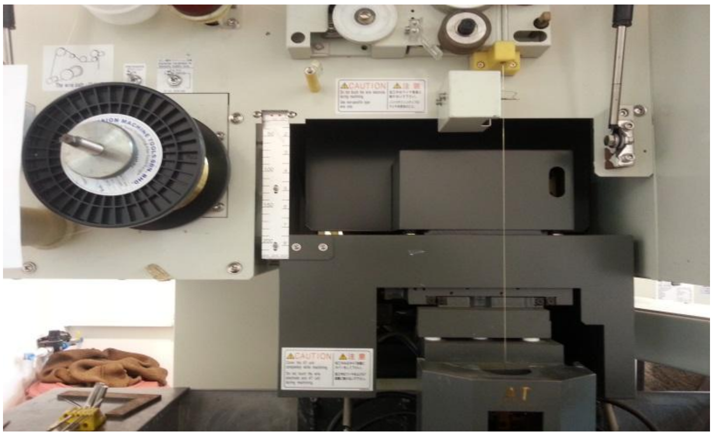


Figure 25: EDM wire cut machine

Figure 26: Controller

Figure 26 show the controller is to receive the programmed, check the simulation and setup wire cutting and machine parameter. The die fluid center usually controls the water pressure and automatic calibration.

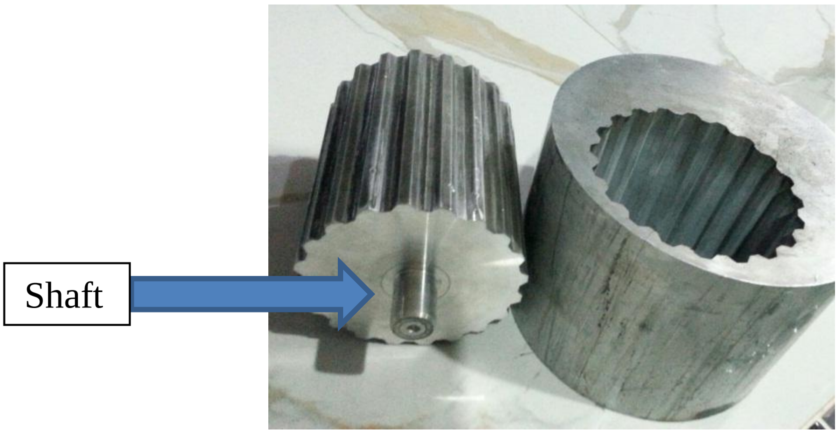


Figure 27: Making shaft

Figure 27 show the making of the shaft by using lathe machine. The aluminums roll bar has are mounted at the spindle. The spindle is rotating with an axis parallel and horizontal axle. By using the live center to making more stable and more force may be applied to the work piece. After the shaft is lathe by the dimension, the shaft is putting throw the hole of corrugating gear.

Figure 28: Holding for bearing

Figure 28 shows the process of making a hole for the bearing seat. Tapered roller bearing is used to ensure a smooth operation. By using drill machine and milling machine, the hole is drilled with the proper diameter at the center “through hole” as well as the counter-bore.

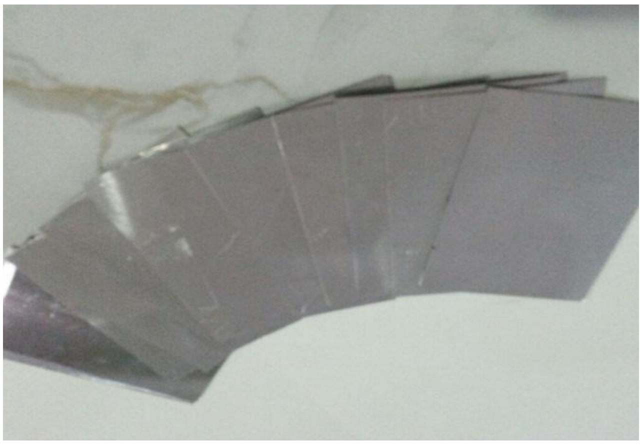


Figure 29: Cutting the work piece

Figure 29 shows the cutting of the work pieces to the required dimension of 100m x 75mm. The materials used are aluminum sheets with thickness of 0.03m. The cutting process is done using the cutting machine.

Figure 30: Roll the Aluminum Sheet

Figure 30 display the process of rolling the aluminum sheets. The corrugating gear is rolled by hand. The gap between the corrugating gears is ensuring to be suitable with the thickness of the aluminum sheet before rolling is done. The corrugated sheets are stacked into blocks.

Figure 31: Attaching it together

Figure 31 shows the process of attaching the aluminum sheets together on its surfaces by using superglue.

Figure 32: Paste the aluminum sheet

Figure 32 displays the aluminum sheets that is pasted together firmly.

Figure 33: The specimen ready for testing

Figure 33 displays the specimens that are ready for testing. These specimens are made in different design and thickness and are made with different types of materials which are either aluminum foils and/or aluminum sheets. The different designs are as below:

- First design

The first design was made with the size of 40mm in height, 90mm in width and thickness of 75mm.

- Second design

The second design was made with the size of 38mm in height, 92mm in width and thickness of 73mm. This design has aluminum sheet placed between the corrugated sheets.

- Third design

The third design was made with the size of 34mm in height, 86mm in width and thickness of 75mm. This design has an aluminum sheet covering around the specimen.

- Fourth design

The fourth design was made with the size of 22mm in height, 70mm in width and thickness of 75mm and it was made using aluminum foil.

- Fifth design

The fifth design was made with the size of 22mm in height, 70mm and thickness of 80mm which was different in dimension with the first design but it was made using the same material and method.

4.8 Impact Drop Testing

The drop test is done from a drop height range from 0.5m to 1.0m with an impact mass of 2kg, 9kg and 18kg. The weight blocks are used to provide different weight ranges for different impact mass. Vise is used to hold the specimen in place.

The blocks with different weight are step drop upon each different specimen at different height. The 2kg blocks are dropped at the heights of 0.5m as tested with specimen 9 and 10, whereas the 9kg weight blocks are used at the heights of 0.5m and 0.8m as tested with specimen 1 and 2, and the 18kg weight blocks are dropped at the heights of 0.5m, 0.8m and 1.0m as tested with specimen 3,4,5,6,7 and 8.

The deformation of the specimens after the impact of the mass is measured using the caliper. All the drop test data are recorded accordingly. The potential energy and impact energy absorption are then calculated using the specific formula.

Table 4: Data for Impact Drop Testing

Specimen	Area/m^2	Mass/ kg	Height /m	Deformation(s)	Potential Energy	k	Energy Absorbtion /J
1	0.0003	9	0.5	0.005	44.58645	3566916	17834.58
2	0.0004	9	0.8	0.007	71.25003	2908164.49	20357.15
3	0.0005	18	0.5	0.01	90.0558	1801116	18011.16
4	0.0006	18	0.8	0.015	143.9127	1279224	19188.36
5	0.0004	18	1	0.019	179.93502	996869.9169	18940.53
6	0.0036	18	1	0.007	177.8161	7257798.4	50804.59
7	0.0035	18	1	0.005	177.4629	14197032	70985.16
8	0.00292	18	1	0.005	177.4629	14197032	70985.16
9	0.00154	2	0.5	0.005	9.9081	792648	3963.24
10	0.00154	2	0.5	0.010	10.0062	200124	2001.24

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The impact attenuator is the important in the safety of the vehicle. The research and development that related on all safety have been emphasized in term of accident or crash from vehicle. In this paper, a detailed analysis of the crash behavior of the impact attenuator structure designed for flat chassis neighborhood electric vehicle. Simulations carried out by the finite element method revealed some very important facts that support the reliability of the numerical results.

First of all, obstacles and moving mass is simulated with solid elements and is also considered as a rigid body. Interface type 'node-to-surface' is used for the relationship between barriers and crash-box in effect. Besides the inner self and contacts the outer surface of the* crash-box has been imposed. All these results confirm that the structure is very well designed from the point of view of front impact, with good energy absorption impact. In addition, the pressure on absorbing structure is lower than in the case of independent attenuator.

In decision matrix author decide to use honeycomb for impact attenuator. It is because author considers with concepts criteria and gets the highest rank. A new finite elements method to model aluminum honeycomb structures based on size from flat chassis. FEA is conducted to find the von Mises stress and deformation for aluminum honeycomb. The methods of manufacturing aluminum honeycomb also decide to use corrugating method that no limitation width and length and thickness are depending on the gear’s thickness. Design and fabricated the corrugating gears mechanism to prepare the specimens of selected honeycomb design. Fabricated aluminum honeycomb specimens and tested the specimens for impact absorption energy capability.

The projects will achieved if designing, analyzing, simulating, fabrication and testing the aluminum honeycomb. Further works are necessary to complete the absorption of aluminum honeycomb.

5.2 Recommendation

The next order has to complete with testing, data collection, application at neighborhood electric vehicle. So this task will required a lot of experimentation and hand on work to be completed. The testing will include several design of honeycomb to select the best design. After the analysis of our data, the author has developed a set of recommendations to improve upon materials, design and testing. . These suggestions could help to create an optimal design for use in flat chassis NEV. Besides working with the honeycomb design also need to set up the experiment and the corrugating gear. The thickness of the aluminum sheet also must be considered in the testing time. We can change the thickness and collect the data to know the strength and energy absorption. Other than that it is also to make actual size for aluminum honeycomb to install at flat chassis. This kind research will be able to help us to keep improving the project in the future.

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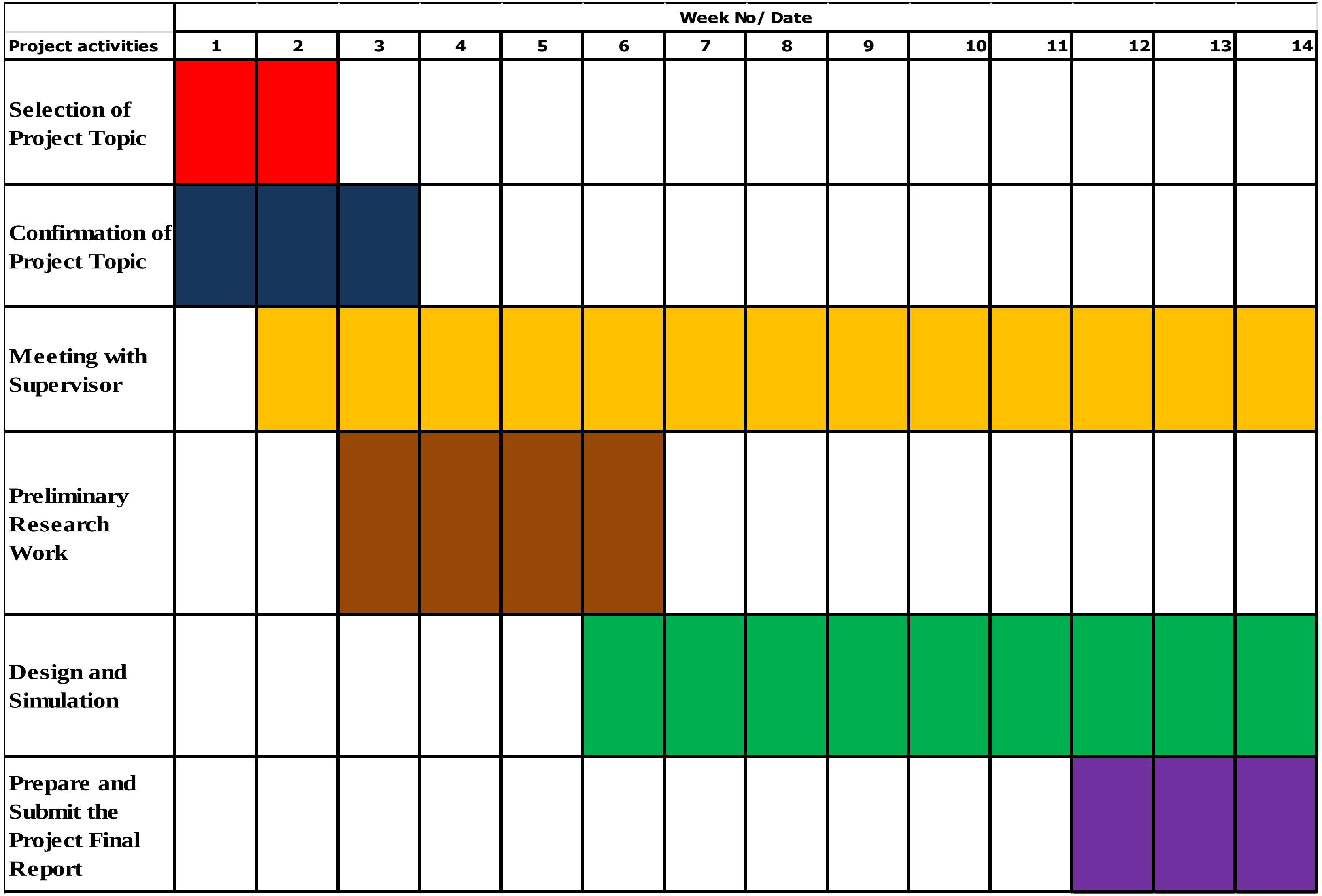
APPENDICES

APPENDIX A

FINAL YEAR PROJECT I GANTT CHART JAN 2013



APPENDIX B

FINAL YEAR PROJECT II GANTT CHART MAY 2013

	Week No/ Date													
Project activities	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Decision Matrix														
Fabrication of Manufacturing Rig														
Sample Testing														
Analysis and Discuss the Data From the Test Result														
Full Scale for Aluminum Honeycomb														
Prepare and Submit the Project Final Report														