# MODELLING AND ANALYSIS OF A CAR BUMPER

by

TAUFI QIL HAFIZ BIN MOHD TAHAR

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the requirements for the
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Unversiti Teknologi Petronas
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

# CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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in partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

_____

(Dr. Zainal Ambri Abdul Karim)

**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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TAUFI QIL HAFIZ BIN MOHD TAHAR

# ABSTRACT

Protecting vehicles is a demanding task. This is because vehicles are exposed to all kinds of harm almost all the time especially impact during accident. One of the devices that are capable of protecting a car is the car bumper. Since the bumpers are placed in front and in the rear of vehicles, they are able to withstand impact during collisions. In order to do that, the bumper must be strong enough and able to absorb the impact to reduce the damage on the vehicle.

There are few factors that lead to the failure of the bumper to perform as the bumper is intended for. This includes the material used for the bumper and the design of the bumper.

This report discusses the research undertaken to investigate the effect of impact damage to frontal bumper of a passenger vehicle. This research attempts to study the factor that must be taken into consideration when designing the bumper beam of a vehicle. This will be accomplished using simulation software such as CATIA to design and analyse the bumper. The simulation of the bumper was implemented by using difference types of material and with several designs. The results obtained from the simulation are used as a reference and a guide in improving the design of the frontal bumper. The findings of the project suggest a new design for the bumper and the best material that should be use to make the bumper

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# CHAPTER 1
# INTRODUCTION

## 1.0 INTRODUCTION

### 1.1 Problem Statement

The front bumper of a vehicle is more crucial part as compared to the rear bumper as it is confronted to damage since most collisions happen involves the vehicle's front part. It is therefore important to have a quality front bumper for the vehicle. During frontal accident, the impact usually happens at the corner of the bumper. The side’s corner of the car bumper is among the most effected area caused during frontal collision. A proper safety aspect and precaution should be put on it.

Bumper is used to absorb the impact during a crash and suffer the most damage as compared to the other parts of the car. This provides protection to the vehicle and its passengers by diverting all of the vehicle's momentum to the bumper with which it has collided. Although the bumper can reduce the damage, poor design leads to unnecessarily high levels of damage and repair costs for the vehicle and even in low speed impacts. The extend of damage and repaired cost contributed by the material and design of the bumper car might be high.

#### 1.1.1 Problem Identification

The main aim of this project is to identify the type of material to be used in making bumper beam and a bumper beam design that can decrease the impact during a crash. Therefore thorough research and analysis methods were done to identify the suitable materials for the bumper beam. In addition, research on the design of the bumper beam was

also done. This project aims to improve the existing bumper in order to maximize its function as one of the safety aspect in a vehicle.

### 1.1.2 Significance of Project

This project improves the safety aspect of a car and could reduce the number of death in an accident. It also provides a measure to reduce the cost to build a car.

## 1.2 Objectives and Scope of Study

The objectives of the project are:-

- To investigate the different design of bumper beam and how the bumper absorb energy during impact.
- To design bumper beam to reduce the damage effect during impact.

Part 1 of the project focused on collecting of data and information on the bumper beam. This was done by investigating the impact suffered at the front bumper beam of various bumper designs using software such as CATIA and ANSYS to do the analysis. The analyses also include the investigation of different types of material.

In part II of the project, one design was selected and continued to be analysed using the same design but focused on the investigation of different types of materials. Then the author focused on modification of bumper beam to meet good design and material requirement. In this chapter, the author will focus on the design and perform analysis for the best bumper beam design that can be used in future. The data analysis that the author have gather in the first chapter will be used as guidance during the design of the new bumper beam model.

### 1.2.1 Relevancy of Project

An approach on a design and material used in automotive engineering, providing an understanding of the scientific principles and technology of automotive as it applies to the development and production of new bumper beam for the safety of user and the car.

# CHAPTER 2
# LITERATURE REVIEW/THEORY

## 2.0 LITERATURE REVIEW/ THEORY

### 2.1 Bumper.

It is important to have a bumper that is made from good quality materials because bumper is used to absorb energy of impact and the prevention of the transmission of the crash to the occupants in the vehicle. The bumper is typically mounted to the car chassis with special impact absorbers. The absorption of the energy of the impact is a crucial aspect of the bumper and for this reason they are designed with a set of valves and air chambers [3].

The bumper's job is to minimize damage, primarily to the occupants of the vehicle and to the vehicle itself. Cars are required to pass special crash tests at various speeds. In order to pass these tests, the car's damage level during the crash must be below a standard that the country has stated. Sometimes bumpers are constructed with built-in "crumple zones" [3]. Crumple zones are designed to absorb impact. The crumple zone will allow the material to flex upon collision in order to absorb the impact and return to its original shape. As the metal flexes, the action of the bending metal converts the kinetic energy of the car into heat. Kinetic energy is the energy an object possesses while it is in motion. Beside that, some bumpers are attached with a hydraulic chamber. The valve openings absorb the energy from the collision and it will allow air and/or hydraulic fluid to pass through small openings.

### 2.2 Selecting Material.

Each material has its own characteristic, application, advantages, limitation and cost. Typical types of material used in the manufacturing industry include ferrous metal,

nonferrous metal, plastic, ceramic and etc. The selections of material become more challenging due to the new material being developed every day. Therefore the properties of every material must be considered when doing the selection. Beside that, cost, availability, appearance, service life and recycling also must be considered in selecting a material for any product [4].

**2.3 Properties of material.**

In real life we can observe many things are made from a variety of material. Why? This is because of the important consideration in material selection which is their physical properties. Each material has different type of physical properties such as density, fracture, melting point, specific heat, thermal conductivity, thermal expansion, corrosion and resistance to oxidation [4].

Some metals are hard while others are soft, some are brittle and some are ductile. This is due to the different arrangement of the atoms within the metal, known as atomic structure. When we want to make a selection on a specific application on a particular condition, an understanding of the structure of the metal is needed because it allows us to predict and evaluate its properties [4].

The three basic of atomic arrangements in metal are [4]:

- Body-centered cubid (BCC)
- Face-centered cubid (FCC)
- Hexagonal Closed-Packed (HCP)

In addition, there are also mechanical properties in a material such as strength, toughness, ductility, hardness elasticity, fatigue and creep [4]. For example the application of a stress to any solid will initially result in a reversible elastic strain that is followed by either fracture without plastic deformation [5]. When the mechanical and physical properties are combine the strength to weight and stiffness to weight ratio of material are equally important, particularly in aircraft structure and automotive application [4].

## 2.5 Examples of vehicle bumper

1) Nissan bumper:

- The bumper was designs not only directly intended to prevent injury during collision, but also design in order to protect the vehicle essential parts from damage and shock during the collision, this includes the various safety equipment installed in the vehicle.
- Nissan bumpers are made from a high quality and high performance materials and conform to the standard that have been indicates from federal regulation [6].
- There are many type of Nissan bumpers in the market now and the bumpers are manufactured using a variety of materials which are steel, plastic, aluminium, rubber and composite fibreglass. Most of these bumpers also contain polypropylene foam or plastic honeycomb as well as bracket and the energy absorbers to give the bumper better absorb shock during collisions [6].

Figure 1: Example of Nissan bumper model [6].

2) BMW Bumper.

- BMW has innovated new styles on their car bumper. Rubber bumper are being produce to absorb more distress and it helps in avoiding bigger damage.
- BMW has included the use of continuous fiber reinforced thermoplastic (CFRTP) material in the front bumper. This feature been intended for the M3 sport coupe because of its can increased energy absorption capability and also reduced the overall weight of the car. This type of bumper has been test and showed 60% improved crash performance. This bumper is fitted in the same space with similar attachment point used on the metal bumper [7].

Figure 2: Example of BMW bumper model [7].

3) Toyota bumper

- The Toyota bumper not typically designed just for the protection of occupants during the collision but also design to protect the other component in the car from suffering damages during collision. This is also to help in reducing the repair cost when collision happens [8].
- There are a lot of Toyota bumpers that are manufactured for vehicles and the bumpers are not only stylish but are also design to absorb as much of the collision impact as possible in order to minimize the damage to the vehicle [8].
- Beside that, the type of material used for the bumper helps in reducing the damage during the collision.

Figure 3: Example of Toyota bumper model [8]

## 2.6 Example Bumper Materials.

1) Urethane bumper

- The advantage of this bumper is that it is easy to accommodate the minor differences in the body panel alignment because this bumper has the ability to stretch and bend quite easily [9]. This will give huge advantage to the user when installing it onto the car.
- This bumper is made by using soft compound which can withstand very minor impact without noticeable damage [9].
- The weaknesses of this bumper are that it decomposes when expand to heat and age, causing the bumpers to ripple and shrink, and the paint to fade.

2) Fibreglass bumper

- This bumper is rigid and do not ripple or shrink. It will also not decompose when exposed to heat and age unlike urethane.
- This bumper provide an excellent surface to sand and paint but are sometimes very difficult to install because it cannot match the car shape [9].

3) Urethane and fiberglass bumpers

- This bumper is made by using a special formulated resin which links a urethane molecule to a stable polyester base material. This new formulated is both flexible and tough. The bumper is formed by using high fiberglass material [9].
- This bumper has been tested and showed that it is more flexible than fiberglass bumper and tougher than urethane bumper.
- This bumper is also easy to be repaired by using any common polyester resins or fillers [9].

# CHAPTER 3

# METHODOLOGY

## 3.0 METHODOLOGY

### 3.1 Project Identification

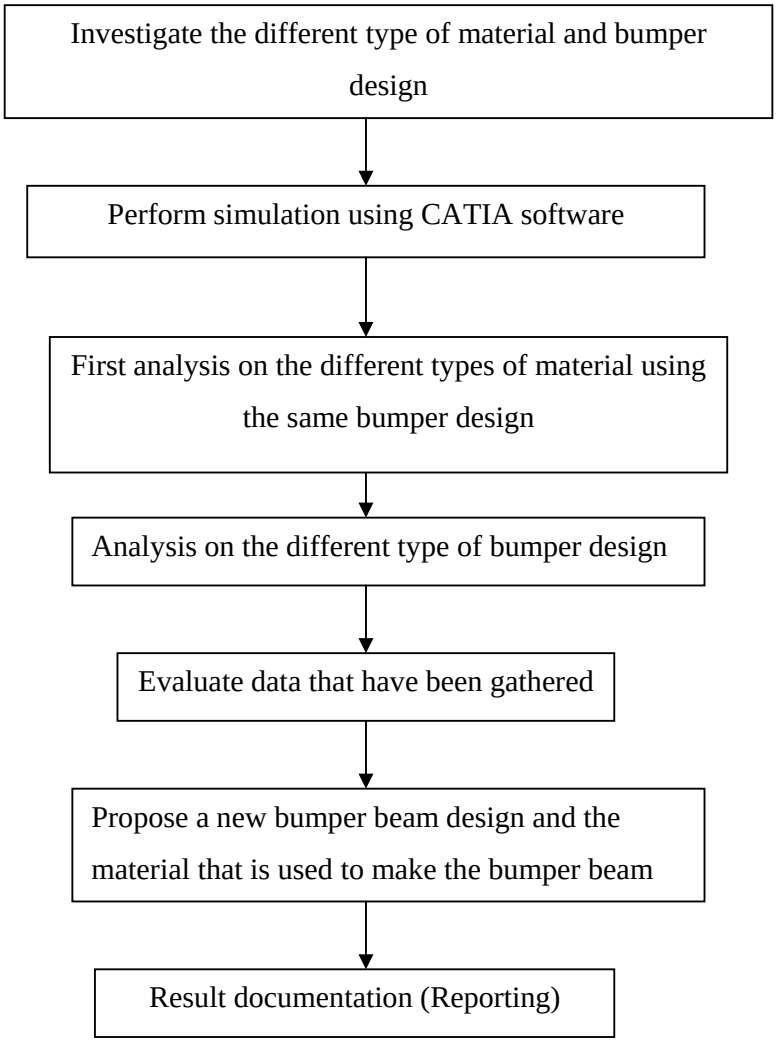


Figure 4: Process Flow Chart

### 3.2 Methodology

The project was started by finding the information about the bumper of a car. This include the necessary information such as different types of bumper design and also different types of material used in making the bumper.

The projects proceeded with learning about the computer software which is CATIA. This software is used to design the bumper and to do the analysis for the bumper. After selecting the bumper to be design and tested for the project, the author drew the 3D model of the bumper in the CATIA software.

The project continued with the analysis part. After the design was ready, materials for the bumper were selected and the simulation for the bumper was performed. The simulation is to analyse what will happen to the bumper after a specified amount of force applied to the bumper. After the analyses are completed, the gathered data was analyzed.

Upon analysis, the project continued by proposing a design for a new bumper and material according to the analysis that was made earlier. Then the bumper are analysed using CATIA for the final results.

# CHAPTER 4
# RESULT AND DISCUSSION

## 4.1 Design 1

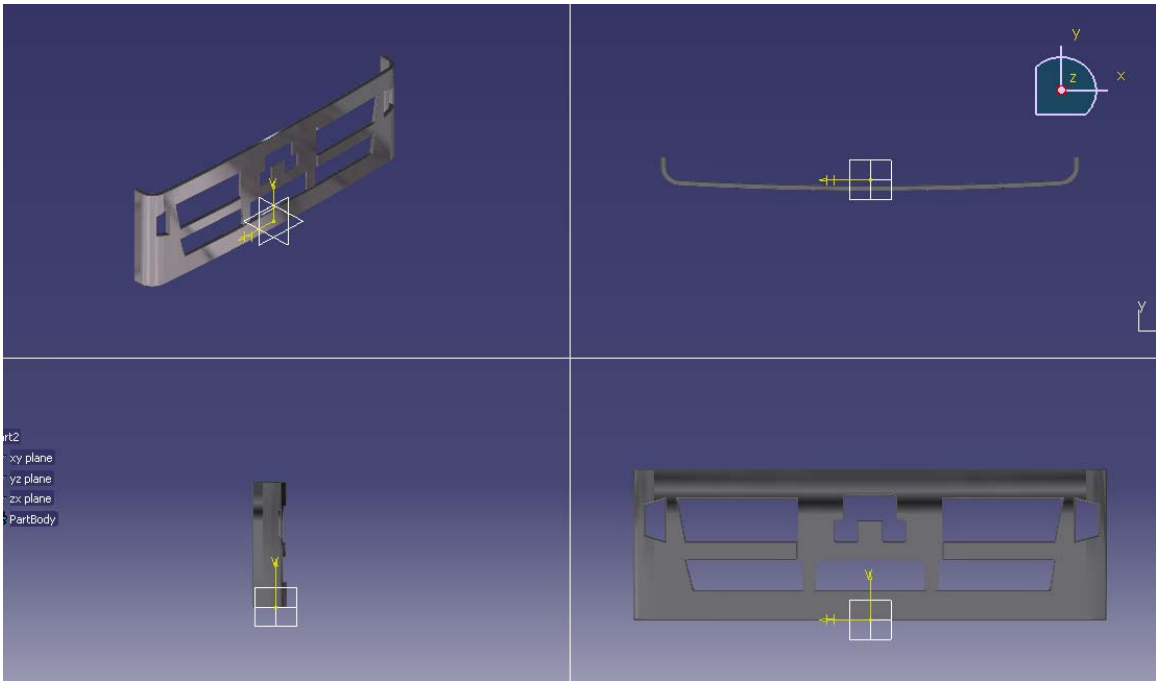


Figure 5: Bumper design 1

The author has chosen the design that the author wanted to draw a 3D drawing of the bumper and obtain the shape of the bumper. The bumper design used in the CATIA software was based on the study and the actual design in the market.

From this design, the distribution force analysis was done using CATIA software. For the first analysis, the material that was applied are aluminum and steel. The data gathered is shown in the following figures:-

4.1.1 Analysis

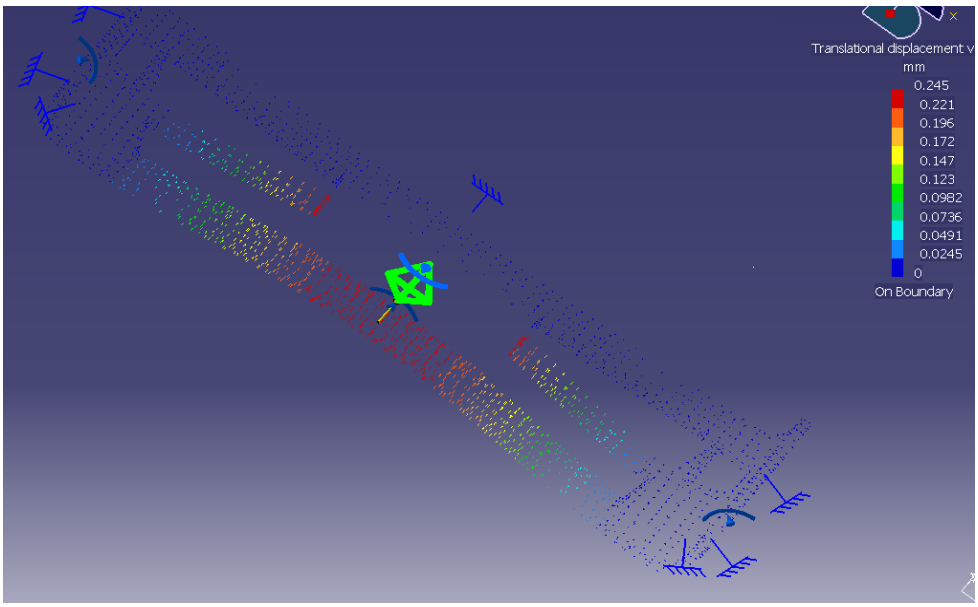


Figure 6: Translational displacement vector for aluminium

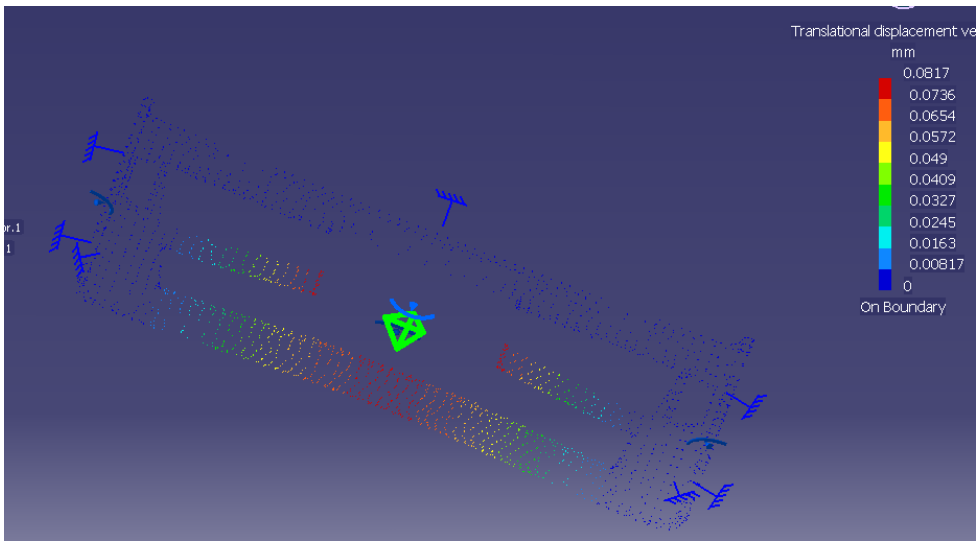


Figure 7: Translational displacement stress for steel

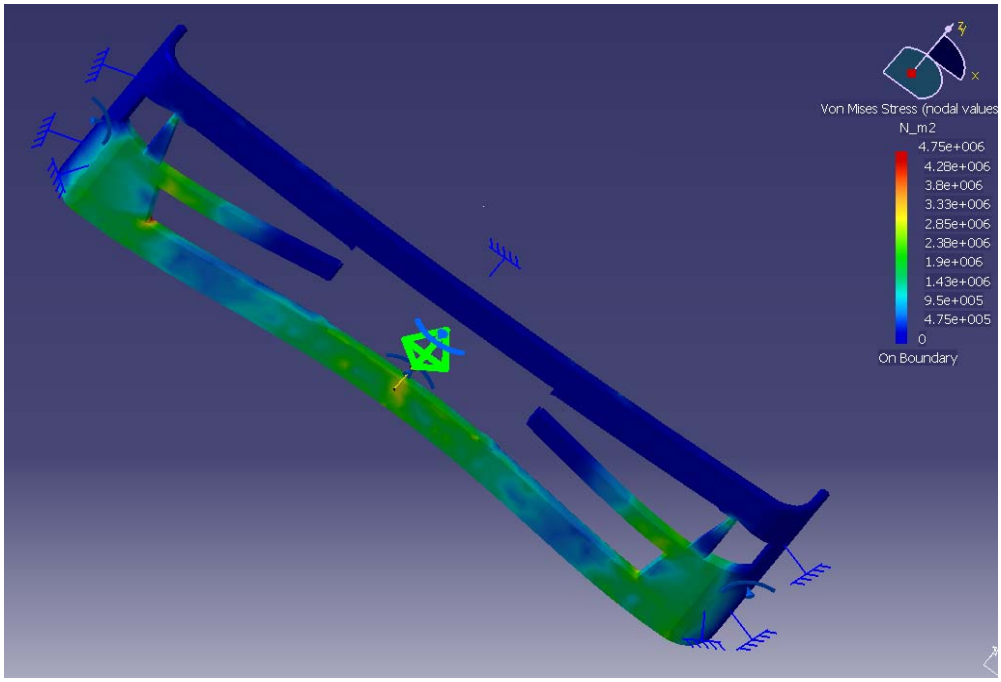


Figure 8: Von misses stress for aluminium

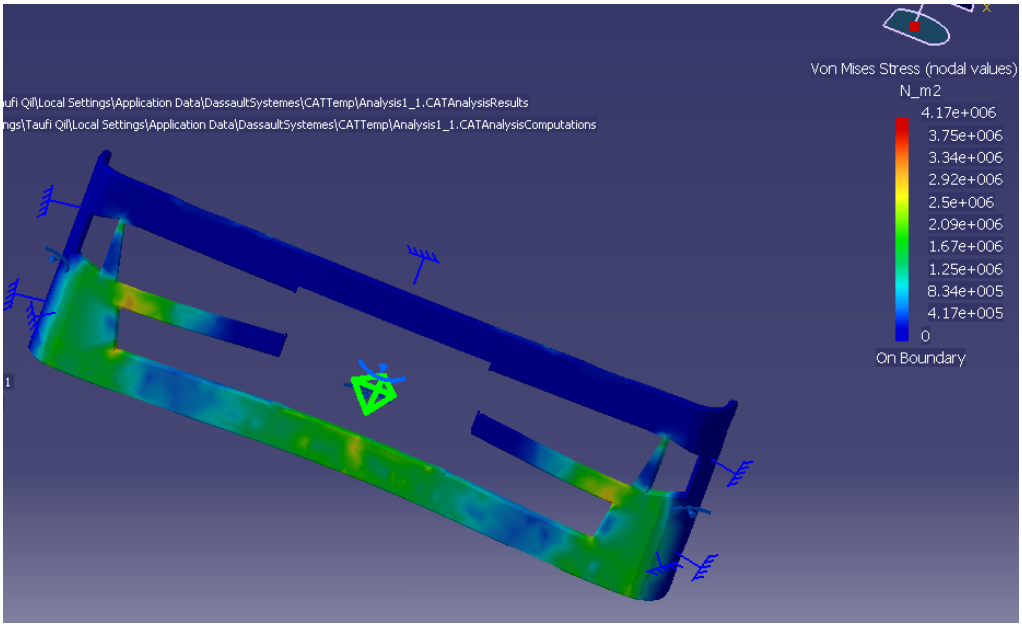


Figure 9: Von Misses Stress for steel

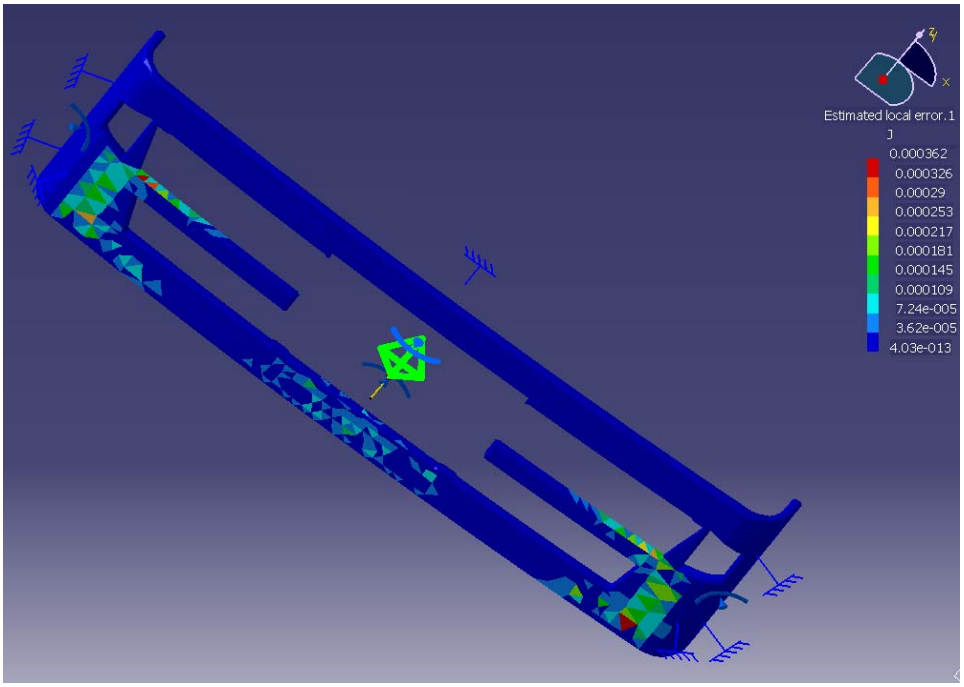


Figure 10: Precision of the estimated error for aluminium

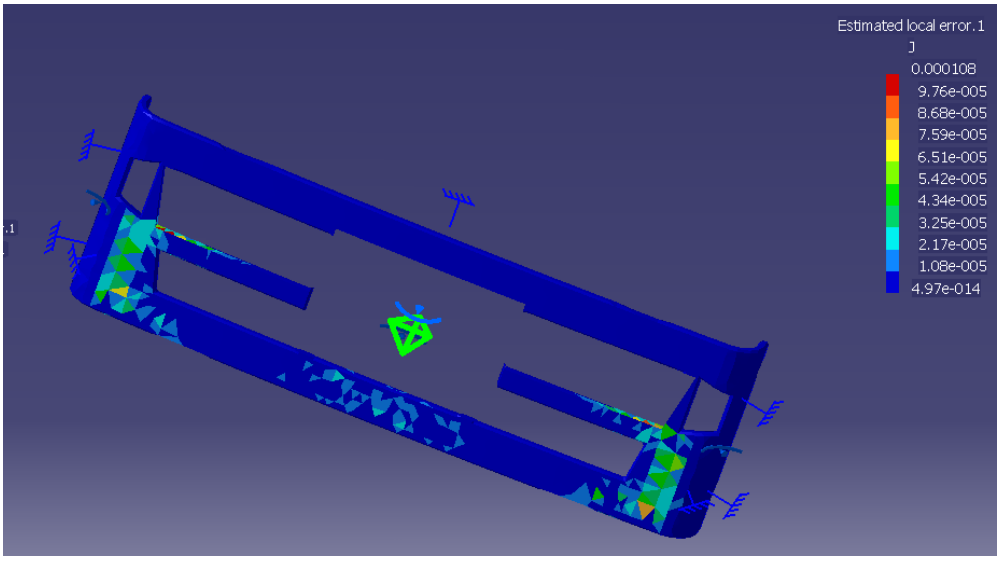


Figure 11: Precision of estimated local error for steel

From the figure of translational of displacement vector, it is shown that critical area of the bumper when the force 5000N are applied from the front of the bumper is in the red color. When the same force was applied to the bumper but with different material, it show that the critical area for the bumper are more wide for the steel as compared to aluminium.

From the figure of Von mises stress, it is shown that the bumper bending when the force of 5000N was applied to the bumper. From both figures, it is shown that, aluminium bends more than the steel. This shows that aluminium has more bending capability than steel. So that the time for impact can be reduce during the collision.

4.1 Design 2

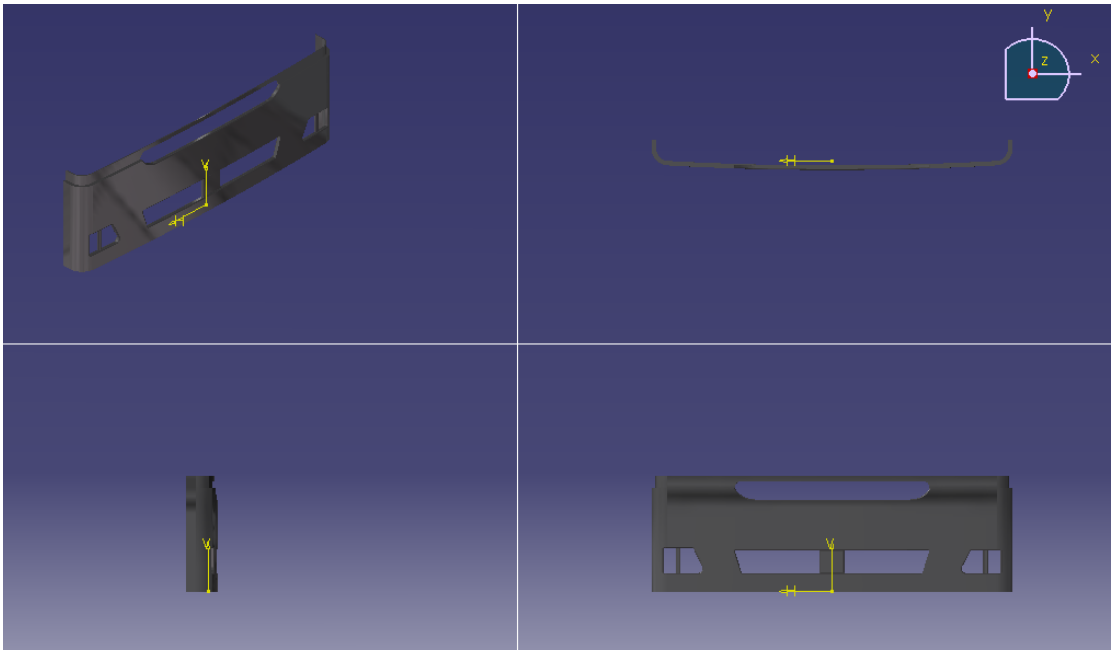


Figure 12: Bumper design 2

This design is the other design that the author have choose to make the comparison with the previous design. The design was choose because of the difference of the shape from the previous design. Unlike the previous bumper, this bumper has different arrangement of its holes. Beside that, the curvature of the bumper is unlike the previous bumper. This bumper also used more material compared to the previous bumper due to the number of holes the bumper have.

### 4.2.1 Analysis

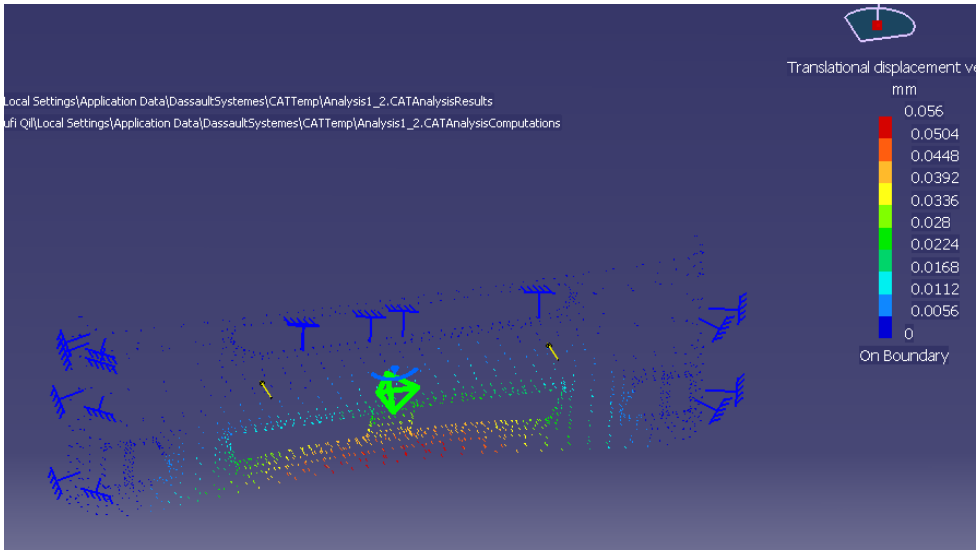


Figure 13: Translational displacement stress for aluminium

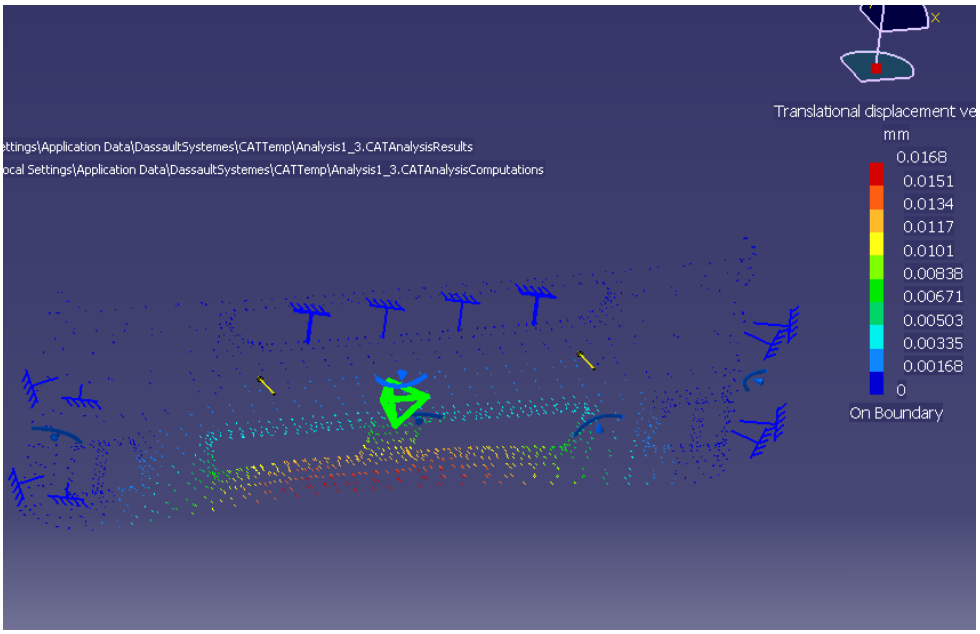


Figure 14: Translational displacement stress for steel

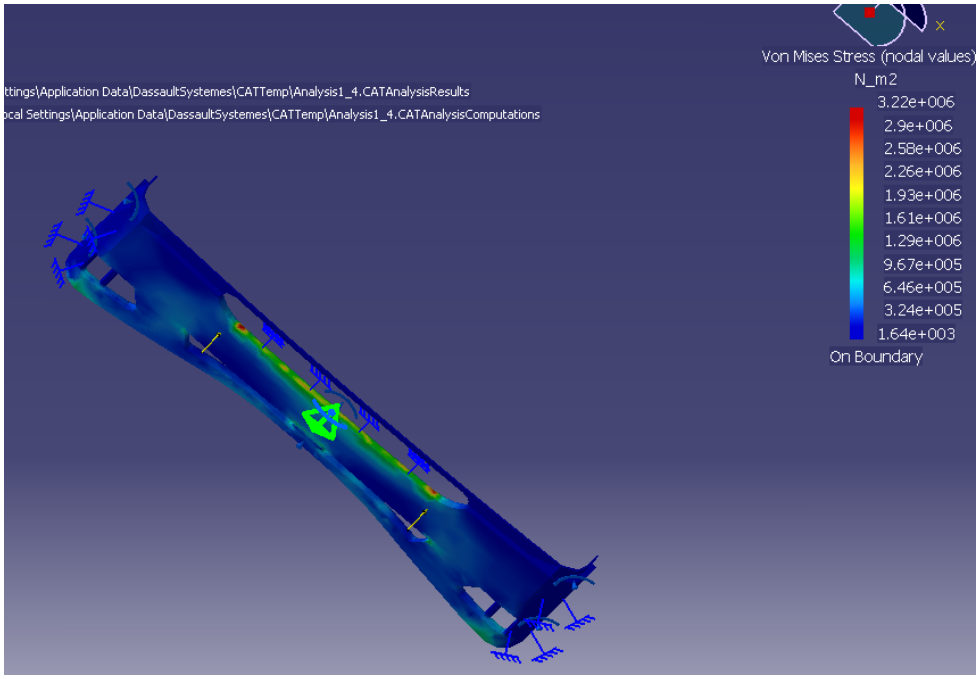


Figure 15: Von mises stress for aluminium

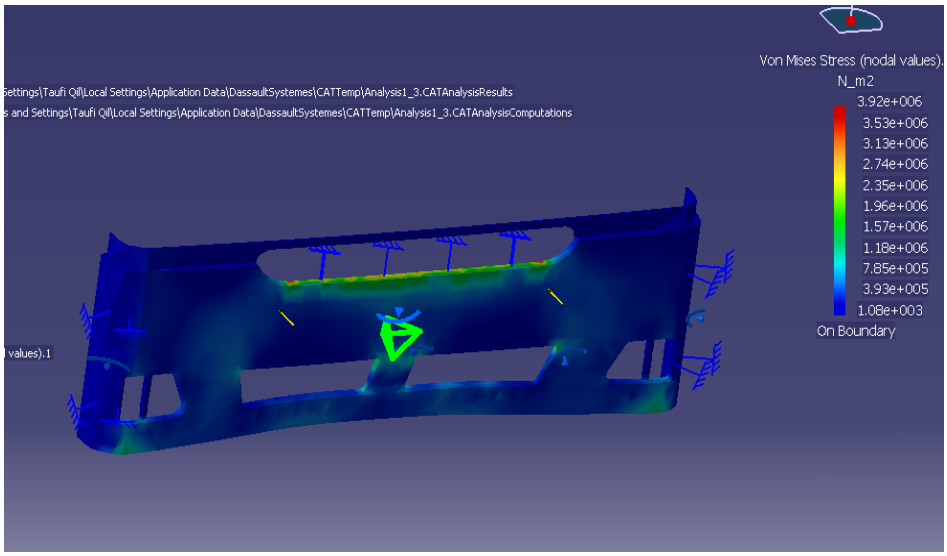


Figure 16: Von mises stress for steel

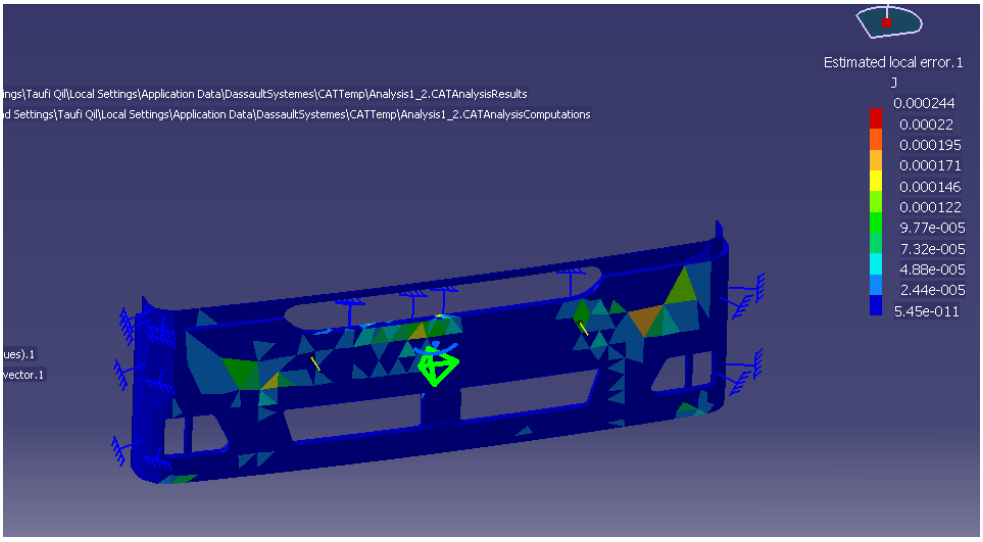


Figure 17: Estimation local error for aluminium

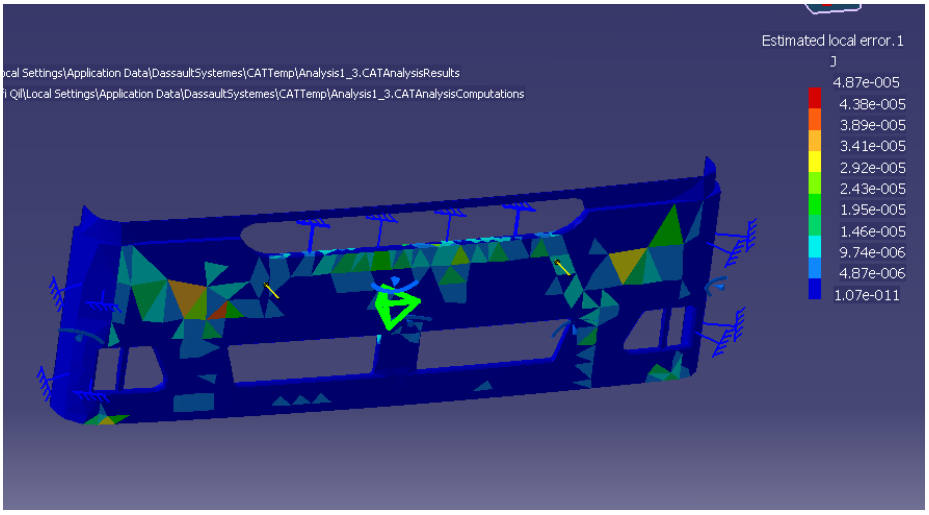


Figure 18: Estimation local error for steel

Using the design 2, the same analysis was performed to design 1 was applied to the second design and the results show in the above figures.

From the figures, Aluminium have greater translational displacement vector compare to the steel and for the bending it is shown that aluminium have greater bending capability than steel.

Therefore from the previous design and analysis, it is shown that the different design and material will cause different result to the bumper. A good design and correct selection of material will give better result when the collision happens. From the analysis, it is shown that aluminium is better that steel to be used for the bumper of a vehicle. The reason is aluminium has more bending capability than the steel. So it can reduce the impact during the collision by give more time before the impact occurs.

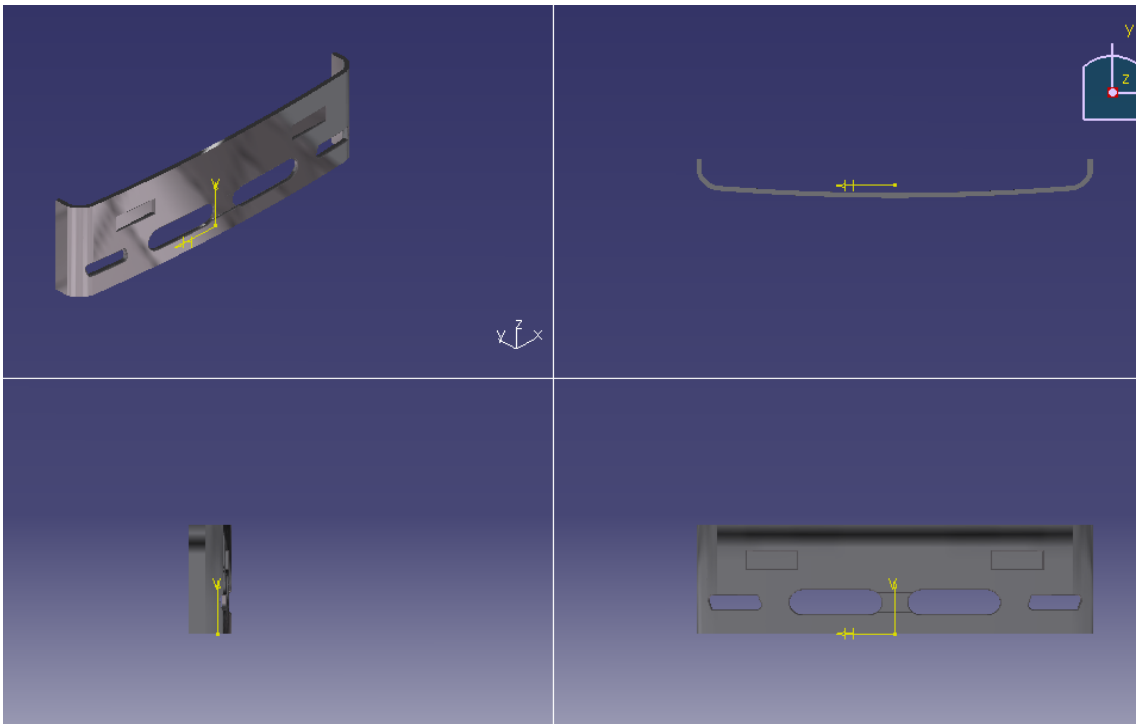

Figure 19: Recommended design

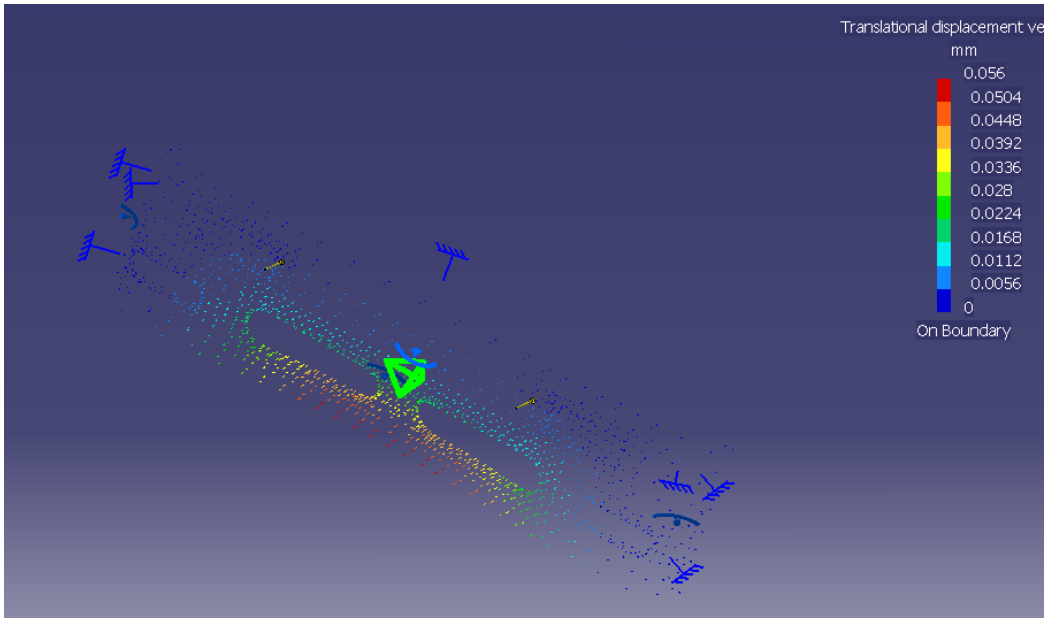


Figure 20: Translational displacement

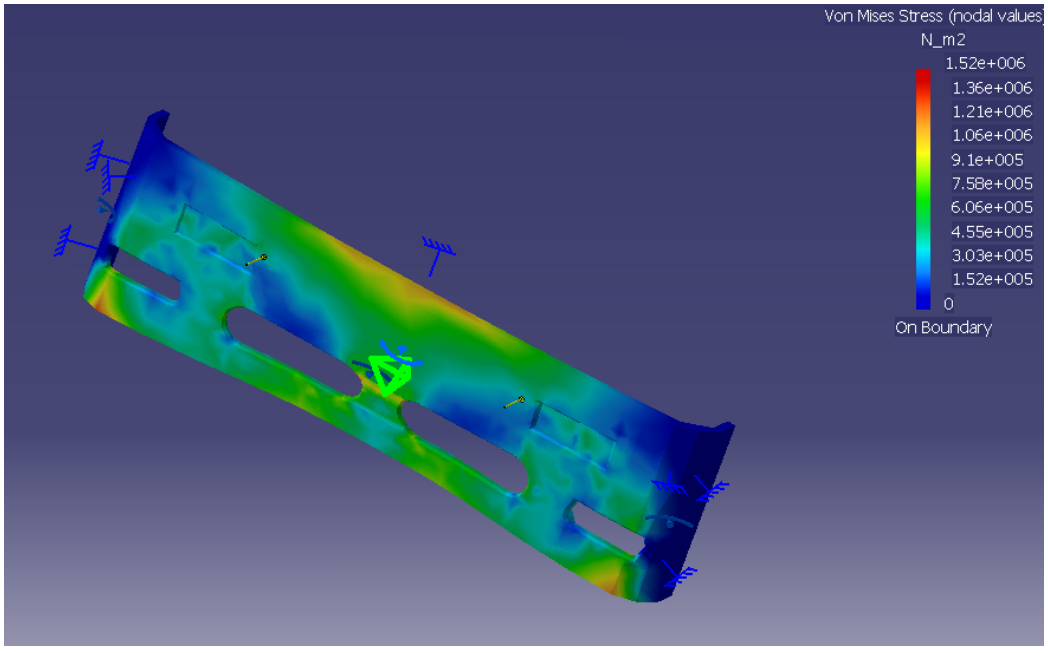


Figure 21: Von mises stress

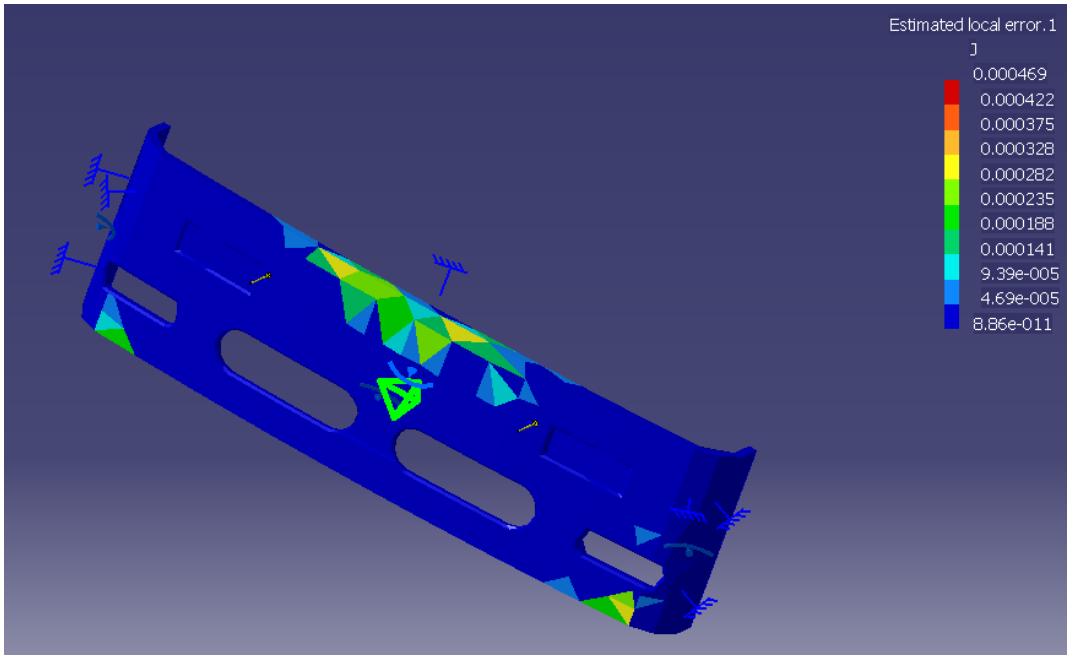


Figure 22: Estimated local error

# CHAPTER 5
# RECOMMENDATION AND CONCLUSION

## 5.1 Recommendation

This research attempts to investigate the improvement for a car bumper to reduce damage during impact.

This project basically used the method of simulation in CATIA software. The simulation of the project used two types of design and the models were analyzed by selecting different types of material. Than the information gathered was compared and an analysis was provided.

The findings of the simulation were used to suggest a new design to improve the bumper performance in order to reduce the damage to the vehicle during the collision.

## 5.2 Conclusion

Proper design of the bumper beam of a vehicle could effectively reduce the impact from a crash. The bumper beam will help to reduce the damage that will suffered by a vehicle during the impact. Beside that the material used in making the bumper beams is also a main factor in reducing the impact during a collision. Proper information on the material is needed in order to make the bumper beam useful as one of the safety feature on the vehicle. Therefore this project suggested a new design of bumper beam and best material for it. So that the function of the bumper can be maximize.

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