ANALYSIS OF PROTON PERSONA SIDE DOOR (DRIVER) USING SIMULATION TOOL

RAJA ASHRAFUZZAIM BIN RAJA ZOLKIPLY

UNIVERSITI MALAYSIA PAHANG

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ANALYSIS OF PROTON PERSONA SIDE DOOR (DRIVER) USING SIMULATION TOOL

RAJA ASHRAFUZZAIM BIN RAJA ZOLKIPLY

A report submitted in partial fulfillment
of the requirements for the award
of the degree of
Bachelor Of Mechanical Engineering

Faculty of Mechanical Engineering
University Malaysia Pahang

NOVEMBER 2008

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Automotive Engineering

Signature
Name of Supervisor: GAN LEONG MING
Position: LECTURER
Date: 14th NOVEMBER 2008

Signature
Name of Panel: MOHD FADZIL BIN ABDUL RAHIM
Position: LECTURER
Date: 14th NOVEMBER 2008

STUDENT,S DECLARATION

I declare that this entitle "*Analysis Of Proton persona Side Door (Driver) Using Simulation Tool.*" is the result of my own research expect as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature: …………………………..
Name: RAJA ASHRAFUZZAIM BIN RAJA ZOLKIPLY
ID Number: MH06001
Date: 14th NOVEMBER 2008

My beloved father, Mr. Raja Zolkiply Bin Raja Abdul Rahman

My loving mother Mrs. Esah Binti K.Moidu

My supervisor , Mr. Gan Leong Ming

Brothers and sister

All my friends

May Allah bless all of you

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ABSTRACT

Automobile safety is the avoidance of automobile accidents or the minimization of harmful effects of accidents, in particular as pertaining to human life and health. Numerous safety features have been built into cars for years. Safety is divided into two categories, active and passive. Active Safety is systems that use an understanding of the state of the vehicle to both avoid and minimize the effects of a crash. These include braking systems, like brake assist, traction control systems and electronic stability control systems to help the driver control the vehicle. Meanwhile, passive safety refers to built-in features of a vehicle that help reduce the effects of an accident, such as crumple zones, seatbelts, strong body structures and airbags . Impact test is conduct in 5 different ways such as side, front, pole rollover and offset. During side collision, physical event is a complicated transfer of momentum from striking car to struck car. This project consists of two steps. First is. to develop solid model by using 3D scanner and convert into simulation environment. Second is to do simulation which consists of setting the boundary condition for restraint, force and then meshing the model. The final result leads to finding that Proton Persona needs stiffer structure as unit body or by increase the numbers of impact bars. From simulation the numbers of impact bars differentiate the stress, strain and displacement result and the value clearly shown in chapter four. All result decreasing as numbers of bars added. The impact bars, outer panel and inner panel, is not enough to absorb the force applied .More on bars will reduce the stress, strain and displacement of the door.

ABSTRAK

Keselamatan pada sesebuah kenderaan adalah untuk mengelakkan kemalangan ataupun meminimakan kesan berbahaya akibat kemalangan yang menjurus kepada nyawa manusia dan kesihatan. Pelbagai ciri keselamatan telah dibina ke atas kenderaan dari masa ke semasa. Keselamatan terbahagi kepada dua iaitu aktif dan pasif. Keselamatan aktif menerangkan sistem yang digunakan untuk memahami keadaan kenderaan dimana pengelakkan dan meminimakan kesan pada pelanggaran. Ini merangkumi sistem hentian, contohnya hentian bantuan, sistem kawalan traktif dan sistem kawalan elektronik stabil,yang menganalisa signal dari pelbagai sensor untuk membantu pemandu mengawal kenderaan. Manakala, keselamatan pasif merujuk pada ciri-ciri binaan dalaman yang membantu mengurangkan kesan kemalangan seperti zon remuk, talipingang keselamatan, binaan badan yang teguh dan juga beg udara. Ujian dilakukan dalam lima bentuk cara iaitu impak dari sisi, hadapan, impak dengan tiang, golekan berulang dan impak sebelah bahagian. Ketika pelangggaran sisi, acara fizikal yang berlaku adalah peralihan momentum yang rumit dari kenderaan melanggar kepada kenderaan yang menanti. Projek ini merangkumi dua langkah utama.Pertamanya adalah untuk menghasilkan model menggunakan pengimbas tiga dimensi(3-D) dan menukarkan ke bentuk simulasi. Langkah kedua adalah untuk menjalankan simulasi yang merangkumi penetapan keadaan sempadan untuk kawalan,daya yang dikenakan dan penjaringan ke atas model.Keputusan akhir menjurus kepada penghasilan dimana Proton Persona memerlukan struktur yang lebih kuat sebagai sebuah unit badan lengkap dengan menambah bilangan palang impak.Dari simulasi,bilangan impak bar membezakan keputusan tegangan , regangan dan perubahan jarak boeh didapati dalam bab 4.Keputusan adalah menurun dengan penambahan palang. Semua struktur tidak mencukupi untukmenyerap daya diberikan.lebih banyak palang akan mengurangkan tegangan , regangan dan perubahan jarak pada pintu

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CHAPTER 1

INTRODUCTION

1.1 GENERAL OVERVIEW

1.1.1 History of Safety

The first motor cars began running in the 1880s, with primitive brakes, steering and tires, and with plate glass used for a windscreen. The potential for crashes and resulting injury was high. One of the earliest crashes resulting in fatal injury was recorded in a London newspaper in 1889 .The wooden spokes of the rear wheels fractured at the hub. All of the occupants were ejected, and the driver and a rear-seat occupant were killed [1]

The first barrier test was run by General Motors at the Milford Proving Ground in Michigan in 1934. At this time little was known of the cause of injury, and improvements in design were probably related more to reducing damage to vehicles than to reducing the risk of injury.

Automotive crash injury research was initiated by De Haven at Cornell University Medical College in New York in 1953[1] These studies identified the major sources of occupant injury as steering assembly, instrument panel, windshield and occupant ejection.

1.1.2 Improvement of Safety

In 1969, Holden established the first safety test laboratory in Australia, at the Lang Lang Proving Ground, and since that time has spent about $200M in testing, facilities and equipment to establish a world class safety test facility. General Motors has a long record of contributions to automobile safety, including such advances as safety glass, padded instrument panels, energy-absorbing steering columns [2] and infant seats. In 1977, GM developed the Hybrid III frontal test dummy, which has become the industry standard, and is universally used to evaluate the performance of restraint systems. The restraint system includes seat belts, airbag and seats. The system characteristics to be optimized include seat belt webbing stiffness, buckle pretension and webbing clamp characteristics, airbag deployment time, inflation rate, inflation pressure, airbag vent size, tether length, unfolding pattern, seat shape and stiffness, and anti-submarine ramp shape.

The first was a front structure developed to manage crash energy more efficiently, and to tailor the crash pulse to reduce loads on occupants. Following these leading front crash protection developments, in 1998 Holden was the first Australian maker to introduce side impact airbags. These side impact airbags were developed specifically to provide head and neck protection.

There are hundreds of other safety features, designs and devices that are helping preserve lives. Safety features such as energy absorbing front and side structures, air bags, seats with integrated seat belts, and various crash avoidance devices.

These are just some of the safety features offered as standard equipment on many vehicles. Future safety devices may include “smart” safety devices that would protect occupants based on age, gender, location in the vehicle, and crash severity.

The focus on vehicle safety, meaning structural crashworthiness and reduction in occupant fatalities and harm, will undoubtedly continue to sharpen during the next decades in response to consumer demands, increasing government regulation and globalization of the industry.

1.2 PROBLEM STATEMENT

Safety is always become major requirement or key part of today vehicle to minimize of harmful effect of accident especially from side impact. These forms of accident have a very significant of likelihood of fatality as cars don't have significant crumple zones to absorb the impact force before an occupant injured. From 1994 to 1997 there were 7676 fatalities per year for side impact accident estimated by National highway Traffic Safety Administration (NHTSA) [3]

Impact can be categorized from front, rear and side of car. Side impacts, especially lateral, comprise one of the most aggressive impact environment because of close proximity of occupant to the side structure which is small and occupant has very little protection from the striking vehicle [4]

Since 1985, Perusahaan Automobil Nasional (Proton) has produced several of models from Saga, Wira, Putra, Perdana, Waja and many more. The latest model is to launch is Proton Persona, upgraded from Gen-2 model as sedan model on 15 August 2007. [2]Since the first model until before Waja model there is no crash test were done. Since Malaysia regulation on crashworthiness not implement until now, all consumers are expose into danger level.

Proton Persona for Malaysian market also not meet the regulation either by NHTSA,or Euro NCAP.Many of lack in safety .Refer to figure 1.1**,**for base line ,there is no air bags at all and drum brake at rear with no antilock brake system (ABS).This will totally reduce the safety of the car. Even for the high line model, refer to figure 1.2, only front of driver and passenger airbags are installed as packages. Supposedly cars today must include all four side airbags as basic requirement with antilock brake system disc brake all wheel.

This is the problem when the accident occurs. The structure of door cannot overcome the impact from collision. Even though there is two impact bars installed in this model as in figure 1.3, it is not enough for the crashworthiness during accident. A side impact bars located inside of a vehicle door to improve the occupant's safety in the event of collision.

This project will deal with crashworthiness of driver side door of Proton Persona. Crashworthiness is the ability of the structure to absorb energy or impact and prevent occupant from severe injuries and fatality during the event of an accident. By doing the simulation, improvement can be done to the crashworthiness of the door. It implies four basic principles:

i. Limit impact focus on occupants to tolerate levels.
ii. Provide a means to manage the energy of collision, with adequate survival space for occupants.
iii. Contain occupants in survival space during collision or minimize ejection.
iv. Protect occupants from post crash hazard.

1.3 Objective

Objectives of the project are:

i. To modeling three dimensions (3-D) of door using 3-D scanner.
ii. To analysis driver side door stress/strain distribution through simulation method.

1.4 Scopes

The following studies are including in the study and analysis of the analysis of side door:-

i. Literature study on crashworthiness of side impact
ii. Tear off inside panel of the door
iii. 3-D scanning and inspection
iv. Conversion of 3-D model into simulation environment
v. Boundary condition setting
vi. Stress, strain and displacement simulation using Cosmos Works
vii. Analysis from result of stress, strain, and displacement
viii. Documentation

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Side impact accidents rank high in almost every country. Much research has focused on the development of countermeasures including the vehicle side structure energy absorption and human response in side impact events. New composite materials and structure optimization [4] have been widely used and some advanced methods have been developed to protect the occupants during side impact accidents. Tests and simulations similar to frontal impact safety tests are performed to evaluate a vehicle's side impact safety. [5]

Various side impact test methods exist and the moving deformable barrier (MDB) with pole side impact test are being used as the standard certified test on a car for side impact safety analysis. In China, the research focus is also switching from the frontal impact safety to side impact safety due to frequent occurrences of this type of accident. According to the Chinese road traffic accident statistics in 2002 [6] more than 33% of the accidents were side impacts. Furthermore, this led to high fatality rates for the small crash zone between occupants and vehicle structures. Starting in 2006, a side impact test, similar to the ECE R95, will be specified as the certified test for all new M1 class vehicles in China.

A typical midsized passenger car was selected to perform side impact simulations. According to the different characteristics of the impact modes, some suggestions are made for designing a safer car for side impacts.. In the year 2006, 445 died and about 4 000 were seriously injured at traffic accidents in Sweden (SRA). Those so many die and were seriously injured, depend to a great part of the shortcoming adaptation between the main components of the road transport system – man, vehicle and road. Those terrible figures render traffic to be one of the largest public health problems.

The most serious injuries occur at collisions against meeting or crossing vehicles and at single accidents against solid objects for example poles, trees and rocks on beside of the road. Even at legal speeds, such accidents can cause serious injuries or mortal outcome. Car safety can be divided in two respects, active safety known as driving safety and passive safety or crash safety. Active safety constitutes the qualities of the car, referring to avoid occurrence of an accident, (road holding, visibilities and brake system). Passive safety constitutes the qualities of the car, referring to protect the passengers at occurrence of a crash, (safety belts, airbags and head rests). The development is in progress for higher car safety in both respects.[7]

The European New Car Assessment Programme (Euro NCAP) is a European car safety performance assessment programme founded in 1997 by the Transport Research Laboratory for the UK Department for Transport. The organization is now backed by the European Commission, the governments of France, Germany, Sweden, The Netherlands and Spain, as well as motoring and consumer organizations in every EU country. Euro NCAP publishes safety reports on new cars, and awards 'star ratings' based on the performance of the vehicles in a variety of crash tests, including front, side and pole impacts, and impacts with pedestrians.[8]

2.1.1 Crash Test History

The roots of today's safety trend date back to the 1950s where such new car features as wrap-around windshields (elimination of distracting center dividers), padded dashboards and collapsible steering columns (shafts that collapse like a telescope in a collision). The crumple zone, safety steering column, steering wheel impact plate and side impact protection are examples of the pioneering inventions for which this first Mercedes safety engineer was responsible.

Automotive historians will remember the 1990's as the renaissance decade of automotive safety. During that decade occupant safety established itself as a leading marketing characteristic of motor vehicles. Vehicle crashworthiness as measured in standardized crash tests is currently ranked at equal level to quality, styling, ride and handling, and fuel economy

Safety features such as energy absorbing front and side structures, air bags, seats with integrated seat belts, and various crash avoidance devices are just some of the safety features offered as standard equipment on many vehicles. Future safety devices may include “smart” safety devices that would protect occupants based on age, gender, location in the vehicle, and crash severity. The focus on vehicle safety, meaning structural crashworthiness and reduction in occupant fatalities and harm, will undoubtedly continue to sharpen during the next decades in response to consumer demands, increasing government regulation and globalization of the industry.

i. **In the United States -** the National Highway Traffic Safety Administration (NHTSA) provides safety information through their New Car Assessment Program (US-NCAP), using crash-testing procedure of vehicles built after 1994. The Insurance Institute for Highway Safety (IIHS) does testing for the insurance industry, but data is only available for a few late-model vehicles.
ii. **In Europe -** the most popular models are crash-tested by the European NCAP, a consortium of governmental and auto clubs overseen by the FIA. Pedestrians and bicyclists are much more vulnerable than vehicle occupants when a crash occurs. The European NCAP's pedestrian evaluation tests the most hazardous areas of each model.

iii. **Germany's** Auto Motor und Sport magazine sponsors crash-tests of a small number of European cars but permits only subscribers to access the information.

iv. In Australia - the Australian NCAP (ANCAP) has recently adopted the Euro-NCAP testing procedures (they formerly used NHTSA test procedures).

v. **In Japan -** the National Organization for Automotive Safety & Victims' Aid (OSA) sponsors Japanese NCAP tests (full-frontal, frontal offset, and side impact) on the most popular Japanese home-market vehicles.[9]

2.1.1.2 Various Testing History

There is several testing from years o years to analyze crash test impact and severity to the occupants. Refer to **Table 2.1**; the 9 year of testing is done to implement the safety of a car.

Table 2.1 Testing made to improve the safety of a car.

1992	DaimlerChrysler Rear Entry (crash test and seat pull testing
1994	General Motors Transport Rear Entry (crash test and seat pull testing)
1994	DaimlerChrysler Side Entry (crash test and seat pull testing)
1995	Ford Windstar Rear and Side Entry (crash test, seat pull testing, brake test)
1996	DaimlerChrysler Rear Entry (crash test, seats, brakes, emissions, acoustic)
1999	Windstar Rear Entry (crash test, seat pull testing)
2001	DaimlerChrysler Rear Entry (crash test, fuel system integrity, seat pull testing)
2001	General Motors Venture Rear Entry (crash test, fuel system integrity, seat pull testing) [10]

2.1.2 Introduction To Proton Persona

Proton Persona also known as Proton Gen-2 Persona in United Kingdom and Indonesia is a national car that launch in year 2007. The Proton Persona is essentially a saloon based on the Gen-2 hatchback introduced in 2004. The most noticeable difference of the Persona from the Gen-2 is the separate, larger boot and less roofline slope.

This is a latest sedan family car with 1.6 liters (**Figure 2.1**) Campro four cylinder in-line engine which delivers a maximum output of 110bhp, 148Nm of torque and a top speed of 190km/h. From brochure stated in **Table 2.2**, it has 4477 mm length and 1725 width. Height from ground to top is 1438 mm. The horizontal distance from center of front wheel to the center of rear wheel is 2600 mm.

For high line, It comes with driver and passenger's dual airbags (**Figure 2.2**) with pretensioner seatbelt, antilock braking system, electronic brake distribution side impact protection bars, power assisted steering and reverse distance sensors all come as standard. The price is range between RM44,999 to RM55,800 is a competitive price and affordable for Malaysian citizen. With all the accessories and better finishing from previous model, Proton Persona demand continues to outstrip supply.

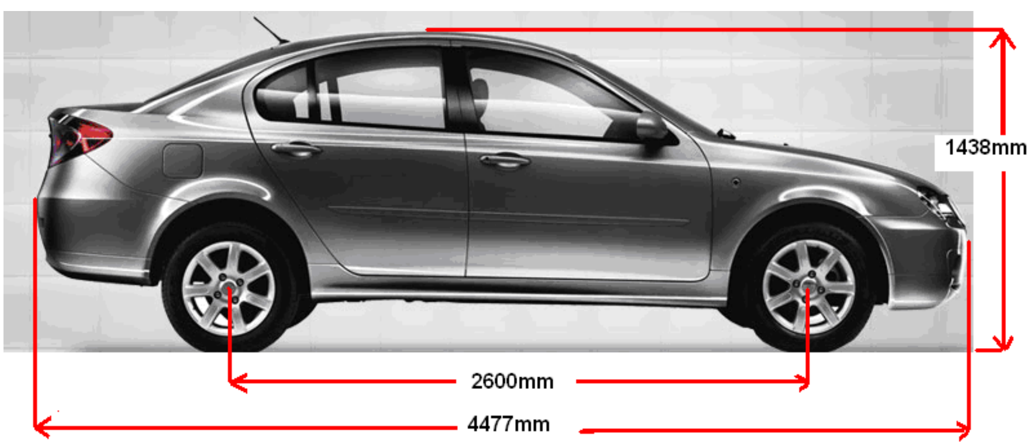


Figure 2.1 Proton Persona side view

Figure 2.2 Dual air bags for high line model

2.1.3 Door Components

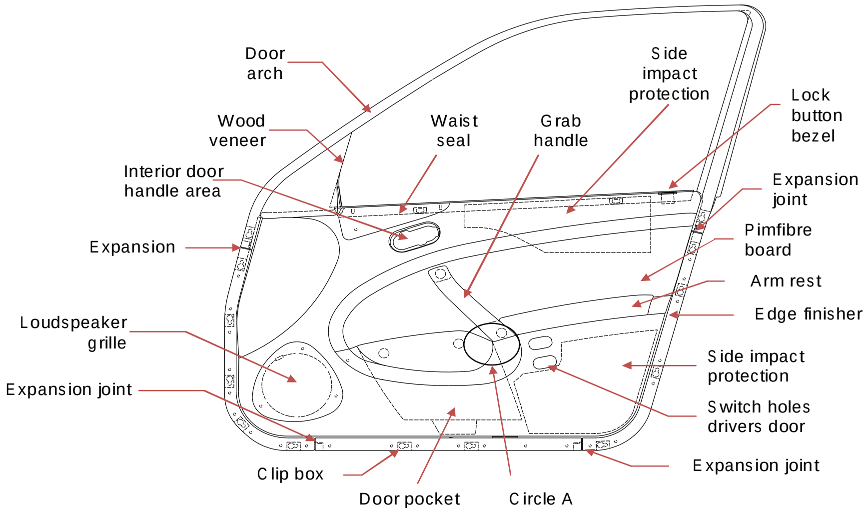


Figure 2.3: Front door trim assembly (Zamri Mohamed.2008)

The door is generally comprised of the outer (**Figure 2.5**) and inner panels. (**Figure 2.4**) usually made of sheet metal and the interior trim pane such as arm rest, grab handle and door pocket as seen on **Figure 2.3**. .The door frame is designed to resist collision forces and also serves to transmit crash loads from the region around the occupant to other vehicle structures during the mash. The outer panel (skin) is struck by the impactor (MDB) and moves together with the MDB almost immediately after contact. The impactor, after crushing the door panel, pickup the door sill, floor pan, rocker panel and B-pillar.

Thereafter, the door moves together with the rest of the vehicle structural components at a common velocity.

Figure 2.4: Original state door components

Door has to be clean and remove from dirt, dust and unfixed components such as wiring system and plastic cover.

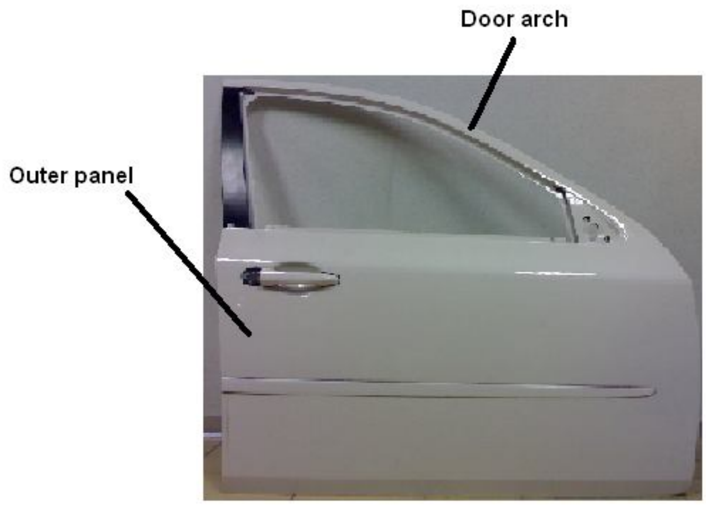


Figure 2.5: Proton Persona outer panel door

The outer panel after the cleaning process is ready for scanning process and solid modeling.

2.14 Type of Test

Crash testing of vehicles is a way to determine if best practice in terms of occupant protection for a new car. Euro NCAP is a crash test program, which was set up in 1996. Since that, 64 different car models have been tested and the results have been published. The cars are tested in a frontal collision and in a side collision. The possibility of adding a pole test has been introduced 2000.

Crash tests are conducted under rigorous scientific and safety standards. Each crash test is very expensive so the maximum amount of data must be extracted from each test. Usually, this requires the use of accelerometer with high-speed data-acquisition as shown in **Figure 2.6** and **Figure 2.7**, at least one triaxial accelerometer and a crash test dummy, but often includes more to calculate and record the deformation results. [8]

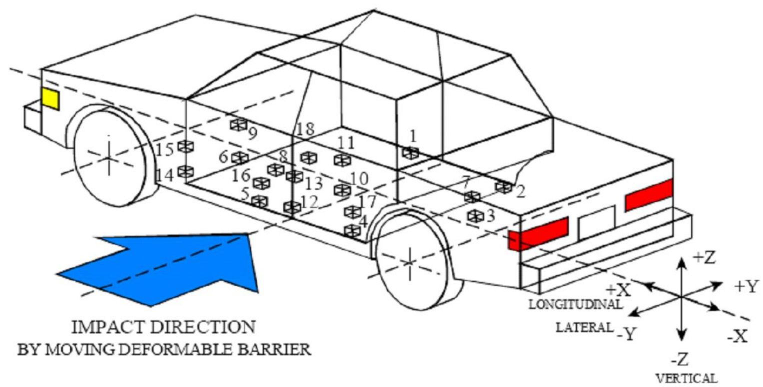


Figure 2.6: Location of accelerometer [9]

Location of accelerometer in a real world testing to measure the stress, strain and displacement of the structure.

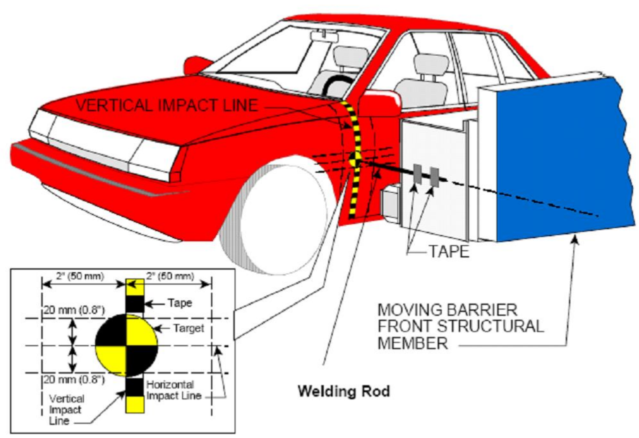


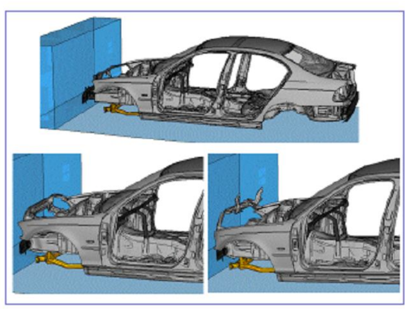
Figure 2.7: Point of impact [9]

Contact surface of barrier and struck car with its vertical line which illustrated in simulation mode.

Impact can be divided into several types. Namely, frontal impact, offsets impact, side impact, pole impact and roll over. Test for each of the impact criteria are:

i. Frontal impact
ii. Offset impact
iii. Roll over impact
iv. Pole impact
v. Side impact

Table 2.2: Categories of Impact Testing

1. Frontal-Impact  	These are usually impacts upon a solid concrete wall or barrier at a specified speed, but can also be vehicle-vehicle tests. The car is driven towards the barrier by a wire system. At 64 kph (40 mph) the car hits the deformable barrier with 40% of the width of the car. Both the driver and the passenger are belted in the front seat and the seats are adjusted to middle position. The crash test dummies (Hybrid III) used has the same height and weight as an average man [10]

2. Offset Tests 	Only part of the front of the car impacts with a barrier (vehicle). These are important, as impact forces) remain the same as with a frontal impact test, but a smaller fraction of the car is required to absorb all of the force. These tests are often realized by cars turning into oncoming traffic. In the U.S., this type of testing is done by the IIHS and EuroNCAP[10]
3. Roll-over 	A car's ability (specifically the pillars holding the roof) to support itself in a dynamic impact. More recently dynamic rollover tests have been proposed as opposed to static crush testing. [10]
4. Pole Impact 	The car is propelled sideways at 29 km/h (18 mph) into a rigid pole with a 254 mm diameter. The pole’s target area is the drivers head. The driver is belted in the front seat and the seat is adjusted to middle position. The crash test dummy (EuroSID-1) used has the same height and weight as an average man. [10]

5. Side-Impact  	Very significant likelihood of fatality, as cars don't have a significant crumple zone to absorb the impact forces before an occupant is injured. In a side crash test a trolley (width 150 cm and weight 950 kg) with a deformable front is towed into the driver's side of the car at 50 kph (30 mph). very significant likelihood of fatality, as cars don't have a significant crumple zone to absorb the impact forces before an occupant is injured. In a side crash test a trolley (width 150 cm and weight 950 kg) with a deformable front is towed into the driver's side of the car at 50 km/h (30 mph). [10]

2.2 SIDE IMPACT IDEOLOGY

A side impact defined as a collision in which the front or rear end of the striking vehicle contacts the struck vehicle in area of one or more of the vehicle structural pillars. An analysis of injury severity in the context of collision configuration expressed as a directional priority indicates the disproportionate occurrence of significant injuries in side impact collision.

Since 1997, the NHTSA has carried out forty-six full scale side impact tests under NCAP. Accelerometers were installed in various locations of the test vehicle including the door panels, A- and B-pillars, sills and floor, and vehicle center of gravity (CG). This information, combined with data recorded from occupants, is used in this study to investigate the differences in safety performance and identify design parameters that influence vehicle side crash protection. [11]

Based on the most harmful event, side impact accounts or 25 % of fatalities for passenger car and light truck crashes in the USA. For passenger cars, side impact accounts for approximately 30 percent of the fatalities in passenger car crashes[12] In comparison with frontal collisions, the space between the occupants and the intruding element in side crashes is extremely small. In addition, the side impact crash occurs much more rapidly. Consequently, occupant protection in side crashes presents a challenge to engineers designing a vehicle for safety. Side impact analysis indicates that side impact bar play an important role to reduce the risk of serious and fatal injury by minimizing and provide lateral stiffness of the side structure and get more human live space [13]

The door, mainly discretized is by the shell elements. During the analysis the door undergoes severe deformation normally leading to a failure of the modeled side window.

In car accidents, side impacts result in numerous injuries because the side structure of the car, including the occupant compartment, is crushed. During design, the strength of the door should be stressed for passenger safety. It is belief that improvements in the strength, numbers, and the configuration of the bar impact at door itself (refer to **Figure 2.8** and **Figure 2.9**) is quite effective for passenger safety, particularly in collisions from the oblique direction, or with fixed objects. That the reason of most racing car for example rally car have roll cage and cross type impact bars as seen in **Figure 2.10.**

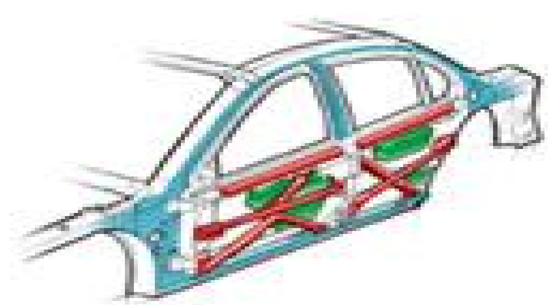


Figure 2.8: Side Bars Configuration

Figure 2.9: Door Reinforcement (side bar) and Padding

Figure 2.10: Racing Cross Type Side Bar

During a car-to-car side collision, the physical event is a complicated transfer of momentum from the striking car to the struck car. To a large extent he severity of the crash event, as seen by the occupant in the struck vehicle, is determined by the time rate of change for this momentum transfer. The time rate of momentum transfer, in turn, is dependent upon the relative structural stiffness and effective mass distribution, among other factors, of the individually struck cars. Because of their proximity to the impacting car and the occupant, the doors (front and rear) and the pillars (essentially the A- and B-pillars) of the struck vehicle are among the components that play a critical role in deciding how the momentum transfer is being carried out around the occupant.

The doors and the pillars use their energy absorbing capability and their material strength to channel the momentum transfer. In addition, the intruding door structure can provide an interior surface that crashes at a non-injurious level and acts to protect the occupant. The characteristics of the dynamic interaction between these components and the vehicle occupants (the SID test dummies) determine the effectiveness of the vehicle side crash protection performance.[14]

2.2 CURRENT U.S SIDE IMPACT STANDARD

On October 30, 1970, the Federal Motor Vehicle Safety Standards (FMVSS) were modified by the addition of Standard 214; Side Impact Strength - Passenger Cars. The standard went into effect on January 1, 1973[12]

The purpose of the standard was to enhance side door strength to minimize the safety hazards caused by intrusion into the passenger compartment during a side impact. The test procedure required "quasi-static" loading applied by a rigid steel cylinder or semi cylinder. Intermediate and peak crush force limits were established. This "quasi-static" requirement was extended to trucks, buses, and multipurpose passenger vehicles with a gross vehicle weight rating (GVWR) below 4,535 kg (10,000 lbs), effective September 1, 1993 [13]. The agency's 1982 evaluation of this "quasi-static" requirement indicated that the standard was effective in side impacts of single vehicles into fixed objects but provided little benefit for occupants in vehicle-to-vehicle collisions.

On October 30, 1990, a final rule was published adding a dynamic impact requirement for passenger cars to FMVSS 214; to address fatalities and injuries in vehicle-to-vehicle collisions. The requirement was phased-in such that all passenger cars made after September 1, 1996, had to comply. Subsequent to this action, a final rule was published requiring trucks, buses, and multipurpose passenger vehicles under 2,721 kg (6000 lbs) to meet the dynamic impact requirement by September 1, 1998 [15]

This is achieved by a moving deformable barrier (MDB), with all wheels rotated 27 degrees (crab angle) from the longitudinal axis, impacting a stationary test vehicle with a 54 km/h closing speed. For a typical passenger car, the left edge of the

MDB is 940 mm forward of the mid point of the struck vehicle wheel base. The MDB has a total mass of 1367 kg. The aluminum honeycomb of the barrier face is specified by design and its element.

The dimensions and material characteristics of the MDB face are shown in.**Figure 2.11** and **Figure 2.12**. This was initially derived from the weights of passenger cars and lights trucks in the U.S. fleet with a adjustment made assuming a downward trend in vehicle mass due to fuel economy needs [16]

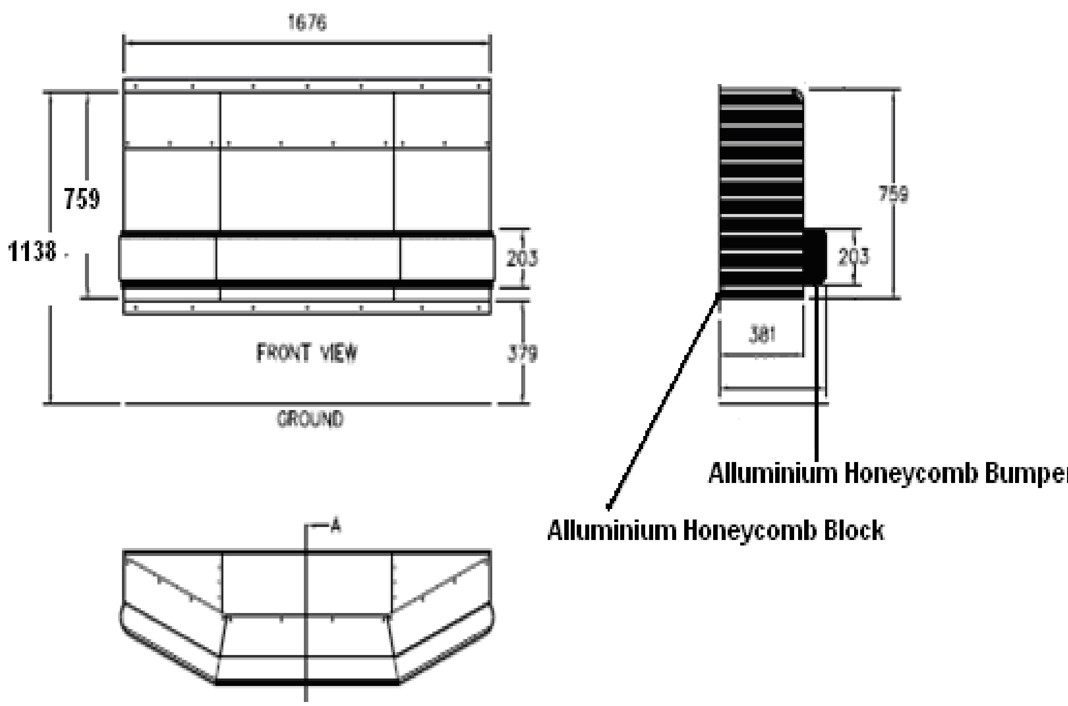


Figure 2.11 - FMVSS 214 Side Impact Deformable Barrier Element [17]

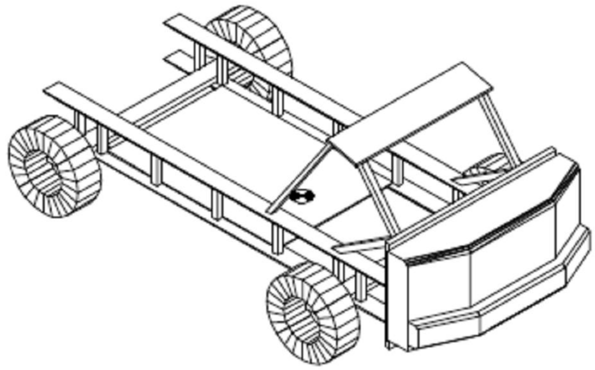


Figure 2.12 - FMVSS 214 Side Impact Deformable Barrier Face[17]

Side Impact Dummies (SID) are placed in front and rear occupant positions on the side of the vehicle which is being struck. The instrumented dummies must exhibit rib, spine and pelvic accelerations below specified thresholds in order to pass the test.

2.31 Crash Test Procedure

The vehicle impact tests that generated the data used in this analysis were conducted in accordance with the test procedure of the side impact NCAF'. The NCAP side impact test is based on the dynamic requirements of FMVSS No. 214, but is conducted at a higher speed. The NCAP tests, which simulate an intersection collision, were conducted with a moving deformable barrier (MDB), as the striking vehicle. The 1360 kg MDB was moving at a speed of 61 km/h and at an angle of 90 degrees off the perpendicular to impact a stationery vehicle,

Twenty or so accelerometers were installed at various locations of the test vehicle to monitor the motion of the test vehicle and its structural components. Since the vehicle side doors and the doorframes play an important role in side impact protection, special instrumentation used to capture the dynamic responses of these components. For the front door, three accelerometers were installed on the interior surface of the inner door panel. For the B-pillar, two accelerometers were mounted on the interior surface of the inner door panel.

The outer panel (skin) is struck by the impactor (MDB) and moves together with the MDB almost immediately after contact. Within 3 to 5 milliseconds, velocity of the inner panel (together with the interior trim panel) rises to the speed of the striking vehicle as it (the door) continuously undergoes deformation.

2.4 CORRELATION WITH REAL WORLD CRASHES

There is a need to relate crash test characteristics and outcomes with those of real world crashes. In this way better informed decisions can be made about the future direction of NCAP programs. Key issues that need to be addressed are types of tests to be conducted, test speeds and configurations, number and type of dummies, types of injuries to be assessed and, for the rating system, the relative weight given to various injuries and types of tests.

Several comparisons have been made between crash test results and injury outcomes in real world crashes. Hackney et al (1996) report on an analysis the impact speeds in real world crashes and a comparison of injury outcomes with those predicted from NCAP tests in the USA.

Newstead et al (1996) describe an assessment of the correlation between ANCAP results and real world crash data. This included an analysis of injury data from insurance records.

Whilst these comparisons are a good start they do not allow assessment of the predictive for specific injuries, such as say the head, chestor lower legs, for the different makes and models. Comparisons of this kind will require in-depth studies with good quality injury data.[18]

CHAPTER 3

METHODOLOGY

3.1 Project Methodology

In fulfillment of the project objective, there are two major important step in getting 3D model and simulation analysis. These including

i. Step 1: 3D Scanning and Solid Modeling
ii. Step 2: CAE Simulation

All of this stage should be followed to ensure that simulation analysis will perform successfully and without any error would occur. Solid modeling of door is get by using 3 Dimension Scanner. There is several steps and method to be done accordingly .First of all after removal of driver's side door; the cleaning process is done together with setup of 3 dimension scanner environment. Then, setup the scanner material before conversion of the model by using Polyworks software.

Second steps including of CAE Simulation.Model was imported into Cosmos works to setting the fix the force amount, restraint location, and meshing the model. Then run the simulation to get the result in html form or in motion scene. The stress, strain and displacement result is then documented.

Figure 3.1 shows the flow chart resemble the divisions of works and study have been made in all the way of achieve the objective of the project.

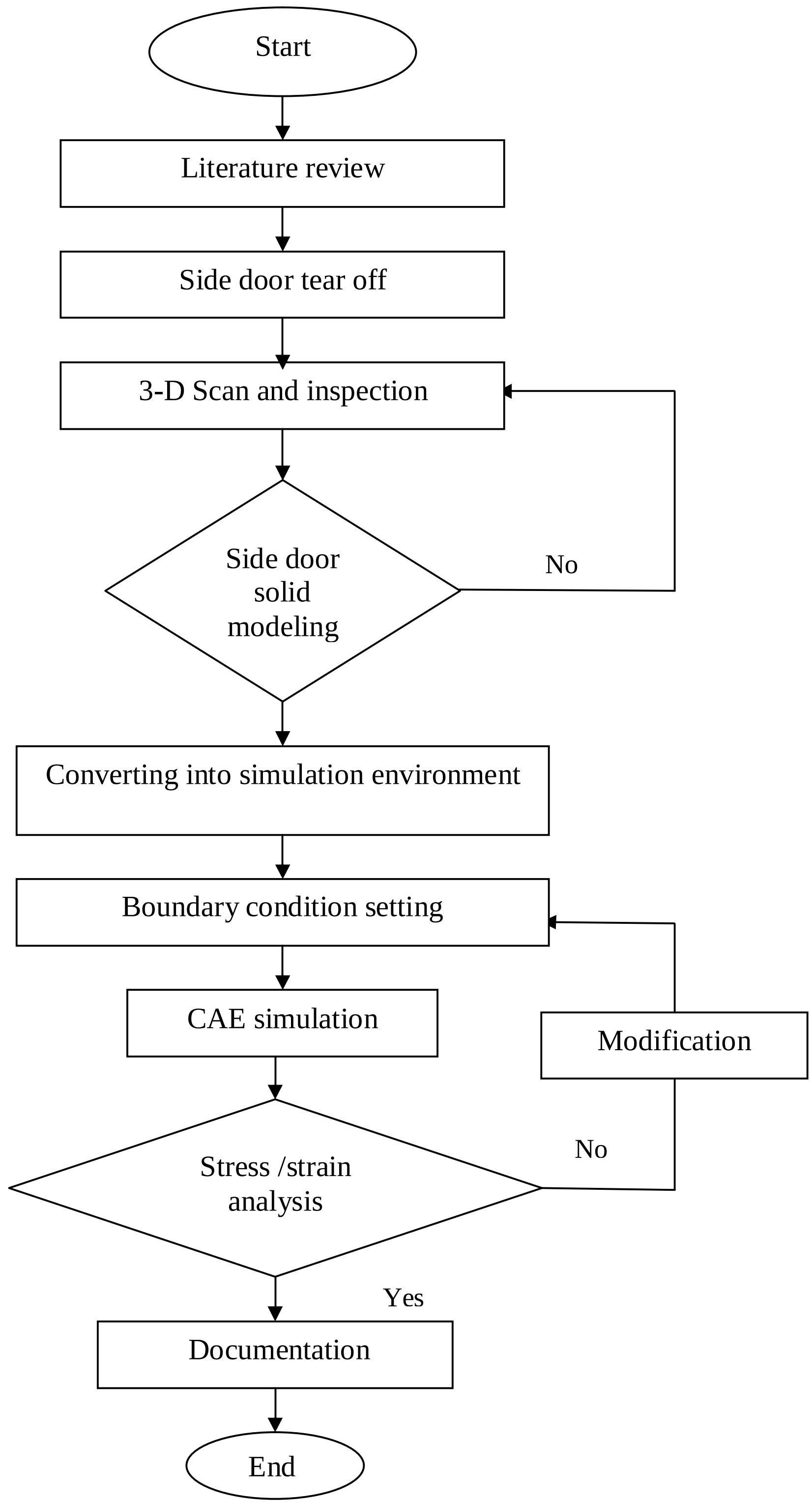


Figure 3.1 The division of work and study

3.2 Step1: 3D Scanning / Solid Work Modeling

3.2.1 Literature review about side door panel

Get some information from journal and books about impact of the car especially side impact and data available to set the boundary condition. The data is important to get correct analysis of stress/strain distribution. The speed of MDB (Moveable Deformable Barrier), distance, center of impact and element with properties of side bar is get from the literature review as a reference to set boundary setting in Cosmos Works later.

3.2.2 Tear off inside panel of the door

Tearing of work was started with removal of speaker system as shown in **Figure 3.2** and **Figure 3.3**.following with removal of side mirror (**Figure 3.4**) .Next, inside door panel which place the arm rest, power window console, and side mirror adjuster switch. After dissemble all wiring connector, plastic cover removed to allow removal of the power window rail, side mirror and window glass windscreen. Then minor components such as door locking mechanism. Finally, door is support using hydraulic floor jack to remove the door nut and hinge screw. Refer to Figure .3.5, hinge use to hold the door and support the weight overall of the door .Usually door has two hinges, upper and lower. Last mechanism not to forget is lock hinge that hold locking door to B-pillar.

3.2.3 Door surface cleaning

After removal the parts and place on the table, door goes through cleaning process. All the plastic cover glue as shown in **Figure 3.7** attaches to body must be clean. The cleaning process is using Diesel as solvent to remove all the rubber glue that hold plastic cover to body. As known diesel is a good erosion agent but not damage the surface of the door. So, it is suitable to use diesel to remove all glue and particles stick to door. All small particles and trim outer panel also must be removed by using detergent soak with water to get exactly only surface of inner and outer panel. Then door surface is drying using dry cloth and allow overnight before scanning process can be done. Refer to **Figure 3.8;** the door is completely free from dirt and glue shining as new and ready for scan process. Cleaning process is important as to get good similarity duplication door model in scanning process.

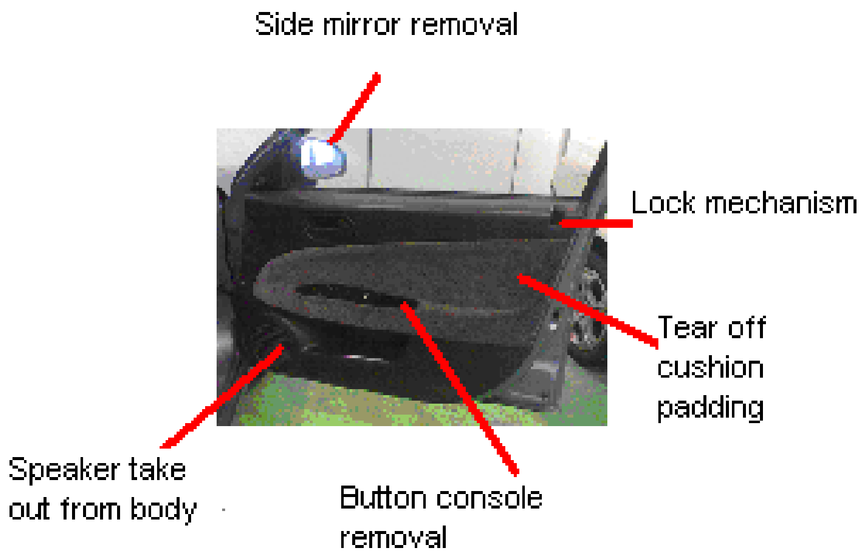


Figure 3.2 Component that need remove from side door

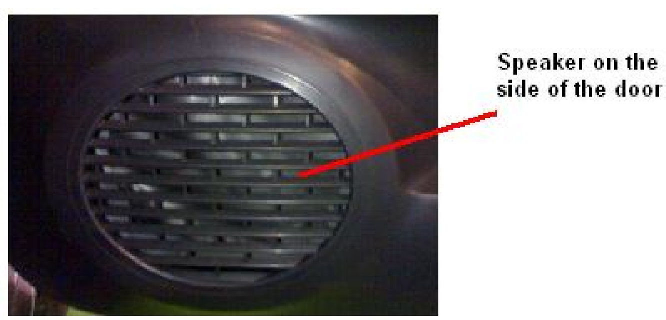


Figure 3.3 Parts of sound system Proton Persona

Figure 3.4 Side mirror needs to be removed

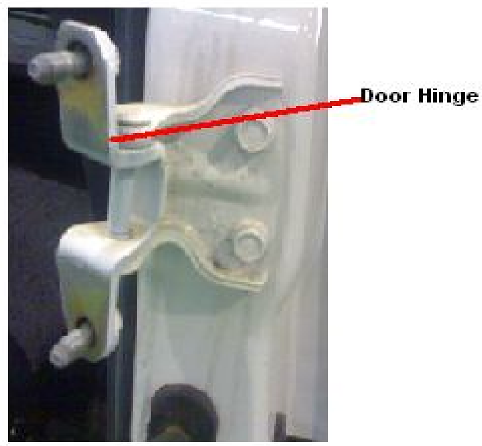


Figure 3.5 Hinge that hold and as supporter to the door

Figure 3.6 Lock hinge mechanism

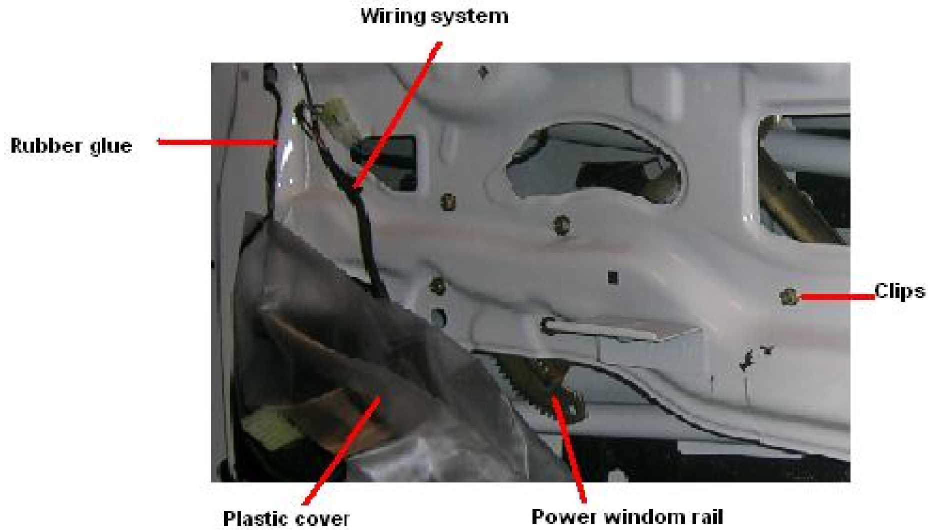


Figure 3.7 Inner part of panel removal items

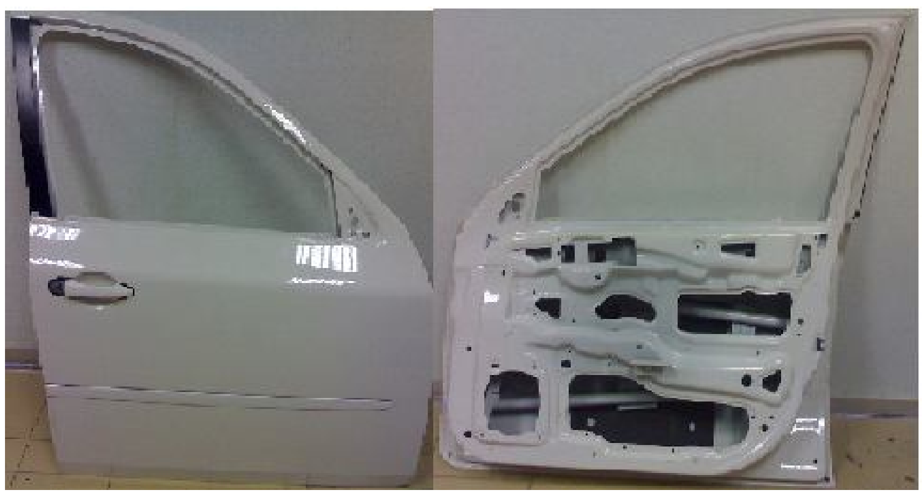


Figure 3.8 Inner and outer panel after cleaning process

3.2.4 Setup 3D scanning environment

Polyworks uses high-density point clouds and contact-probe datasets to control the quality of parts and tools at every phase of the manufacturing process. It provide Universal platform that supports high-density point cloud digitizers, arm-based and hand-held probing devices, photogrammetry-based devices and laser trackers for hybrid metrology applications. Besides, it also has features of powerful set of data-to-CAD alignment techniques that include constrained best-fit, feature-based, reference point, flush and gap. Finally, Polyworks is a comprehensive software solution for creating accurate and smooth polygonal models and NURBS surfaces from high-density point clouds.

3.2.5 Setup for scanning material

Door must be fixed at a place to reduce vibration while scanning process. First approach is using removal door and place at a table for reachable at all point.

3.2.6 Scanning and inspection using Polywork software

Instrument use in this project is a portable 7-axis 3-D scanner is used to get solid model of door from all angle. The image is saved in IMAlign and edited in IMEdit that available in Polywork software. Changes of angle are important in scanning process to eliminate uncovered scan image result.

3.2.7 Conversion of Model

Scanning and inspection process must be redoing if the solid model is not satisfied. Final step is import and save into IGES file.

3.2.8 Steps of 3-D scanning and solid modeling

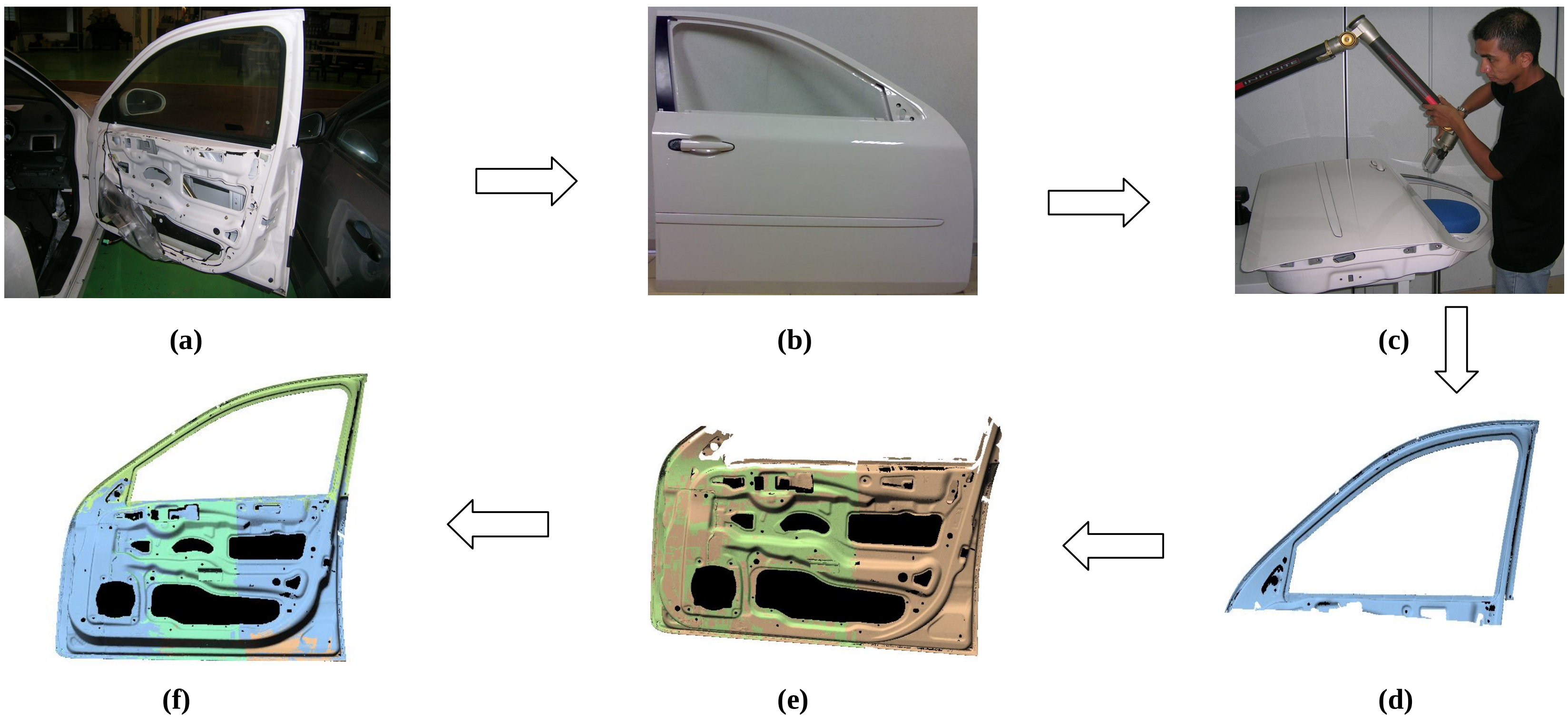


Figure 3.9 Steps of 3-D scanning and solid modeling

From **Figure 3.9**, steps of scanning and solid modeling can be illustrated from picture **(a)** to **(f).** Door is at the initial state and need to tear off and go through cleaning process. The entire unfixed item to the door is removed. Wiring system, window, and rubber seal is removed .Hinge of the door then removed and place at scanning table. Then door is ready for scanning process. After go through cleaning process to remove dust, dirt and accessories, door is ready to be scan. The scanning process to get 3D door model. The scanning process is a bit tough because of limited reach of simcore scanner arm Scanning process must be detail and work sheet must be fix along with scanner stand. Model arch image of scanning process. The first stage of the scanning process is to get the upper parts of the door. Then door is rotate to get the lower parts of the door .Lower parts of inner door panel. Image can be seen in two tones which referred to two group of scanning process. Last picture shows combination of inner door panel. The upper and lower parts are then aligned into single piece. A point is selected as reference point and both parts is combined..

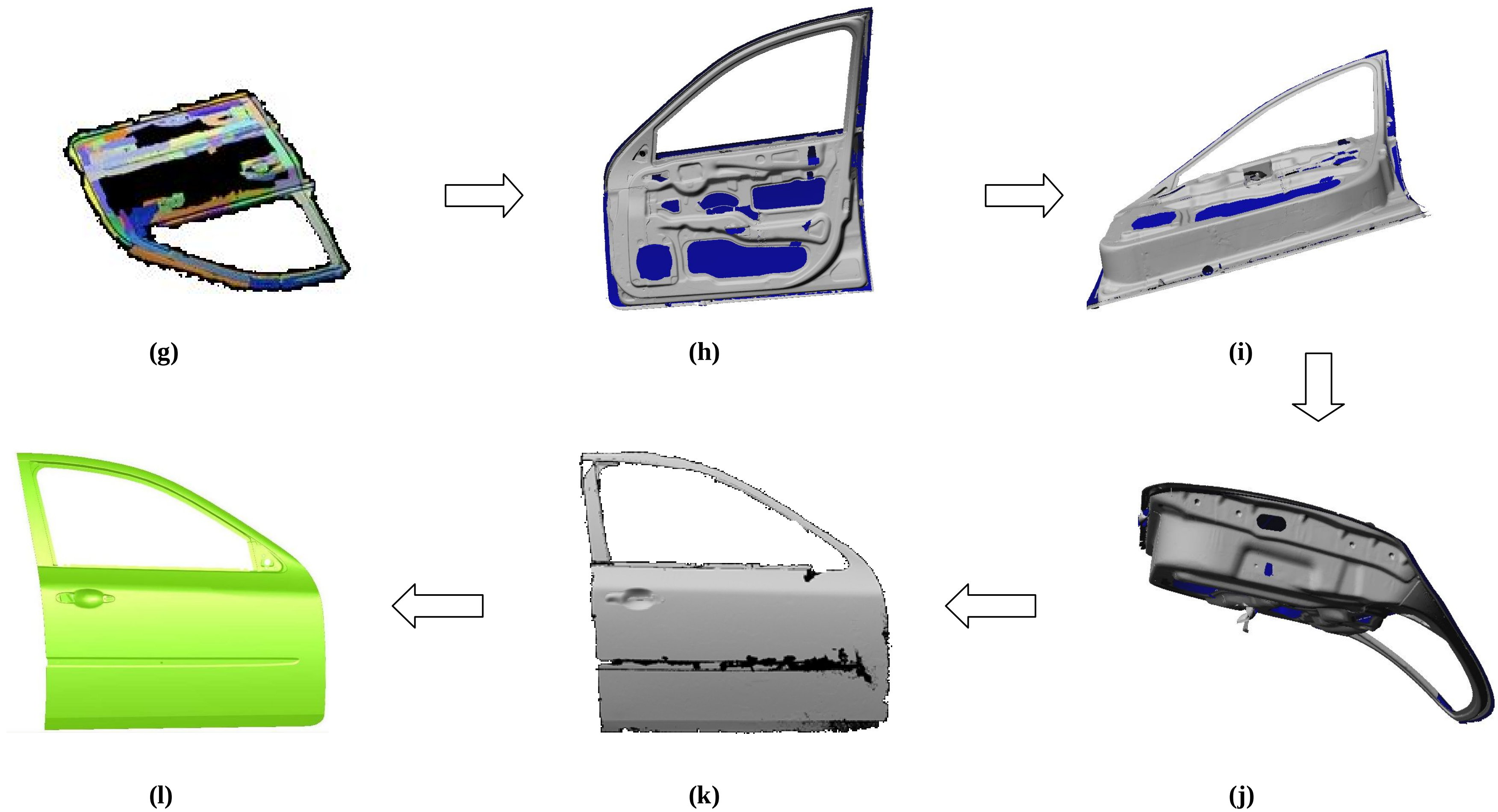


Figure 3.10 Continuation of steps of 3-D scanning and solid modeling

From **Figure 3.10**, picture **(g)** to **(l)** shows the continuation of progress. The outer panel needs to repair. Scanning process is redone at certain portion. The unwanted layer is cut and substitute with new scanning layers. Then inner and outer parts are align to get solid model and ready to merge. Next step is editing in IMEDIT. From main menu, IM Edit is selected and scanned model is import into IMEDIT. In this section, all the small holes can be fixed and fill to get the smooth surface. Go to bottom view, model is checked through all surfaces. The sharp corner is needed to be detail inspection as it will contribute to overall strength of the model. Right view, all angles is checked and original holes are maintiain.untouch. In IMEDIT, holes can be fill and edit to get a smooth surface. Final product is ready to converting into simulation environment. The model is saved in IGES file. Picture shows the outer panel of door with smooth surface, same in dimension and shape. Inner panel of door.-Door can be open in simulation tools namely Cosmos works. At this point, the first step which is to 3 D scanning and solid modeling is finished. and can be proceed with CAE simulation.

3.3 Step 2: CAE Simulation

In this section, the study is based on the structure failure due to stress, strain and displacement on the surface body and its member's component after given force. The focus is at the contact surface of moving deformable barrier with door outer shell. As the contact happen. the surface undergoes deformation and reach .plasticity region as they fail. Force per area is high enough to fail the structure of outer surface. As the impact forces reach the impact bars, it will slow the force and motion is separated to whole members of the door.

The analysis is done by give an impact force resemble of force from moving deformable barrier The force is sets to 100 kN and restrain is sets. Restrain means to moderate or limit the force, effect, and development. [21]

In doing this project, several factors must be considered to fulfill the objective of the project. The consideration is most important as the analysis can give various results and can be vary from one analysis to the next. The major factors include:

i. Converging the meshing output. The meshing must set at converged point by done analysis at several meshes level until the results reach its maximum. If the meshing level too low of high, analysis have big differences even though same other setting. The result will have too big value or too small value according to meshing level. So the main point is to done several analyses until result is converging.

ii. Outer body and inner body of door is clean and free from other accessories such as rubber seal, door knob, clips, mirror screen and others. These accessories will influent the result as scanner will detach as uniform body with door. So the exact dimension and figure is not same with original model.

iii. Restrain setting also will contribute to final result of the analysis. More on error will appear during analysis if wrong placing the restrain in setting boundary condition. These will consequence of failure in analysis process and restrain placement process must be done again.

iv. Force setting is not in critical factors as it set to whole surface contact with uniform distribution. So, the result is not depending on force setting point but the force value. The value is referred to journal as 100 kN.as maximum value to this project.

3.3.1 Converting solid model into simulation environment

After through the Polyworks inspection, model imported into solid work in IGS file. Then the side door solid model is converted into solid work and environment is completely ready for the simulation using the Cosmos Works. Cosmos Works capable to give fast, powerful, and accurate analysis within the same

Solid Works interface. It solves for linear stress, strain, displacement, thermal, design optimization, nonlinear, and much more. COSMOS Works has the ability to analyze shells using Solid Works surfaces and by extracting mid surfaces of thin walled structures. Then, define analysis inputs such as material, restraints, loads, mesh size, contact resistance, and geometric dimension as parameters or parametric equations. Parameters are defined at the model level and can be used in various studies.

Refer to **Figure 3.11**, after selecting specific name for the analysis and static type analysis with solid mesh for element type is used in simulation. Material were select from library is AISI 304(**Figure 3.12 and Figure 3.13**).The material is apply to all door components model.

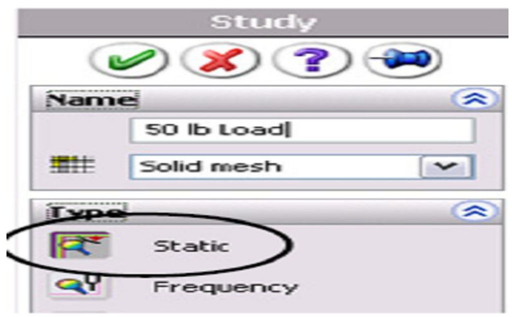


Figure 3.11 Study type and static analysis selection

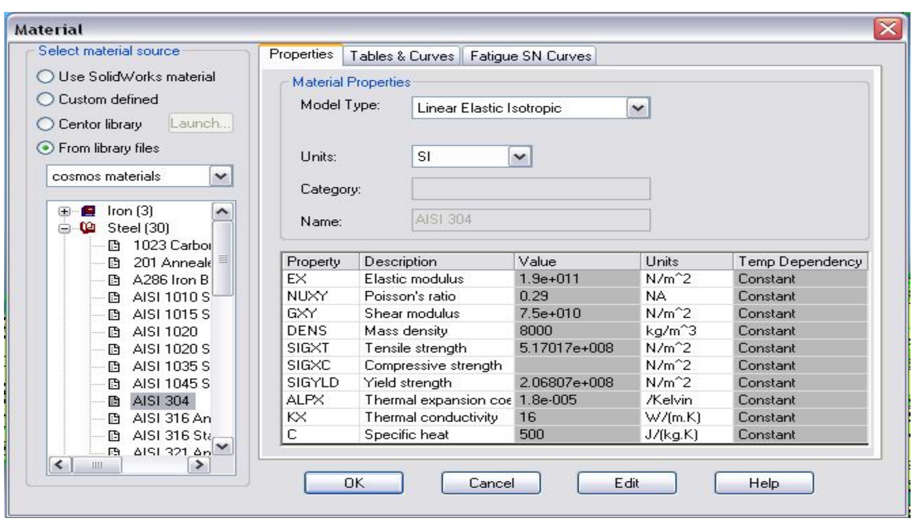


Figure 3.12 Material selection from library (source: Cosmos Works)

Internal and external trim (eg bumpers, door scuff plates, headlight bezels, etc)	Austenitic Ferritic	1.4301 (AISI 304) 1.4307 (AISI 304L) 1.4016 (AISI 430) 1.4113 (AISI 434) 1.4526 (AISI 436)

Figure 3.13 Material selection AISI 304

3.3.2 Boundary condition

Structural load and boundary conditions can be applied in global and arbitrary (local) directions. Uniform force is assumed at the contact surface of model and barrier. When a component is isolated for analysis, the way in which that component is attached to another must be simulated with boundary conditions. In this case, we have chosen a fixed restraint chosen. The choice of proper boundary conditions to simulate actual constraints is often one of the most important decisions to be made for an analysis.

From main menu(**Figure 3.14**) ,restraint is fixed type and applied to the face of hinge, lock point, and perimeter to the door which contact to the A-pillar and B-pillar as show in **Figure 3.15** with purple in color**.** Restrain use is six degree of freedom (6DOF) along the X, Y and Z axis and counter axis where restrain is fixed.

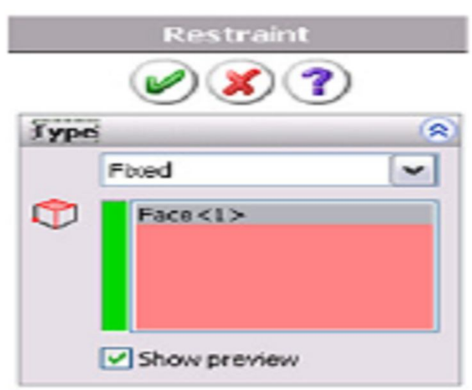


Figure 3.14 Fixed restraint type selection in main menu

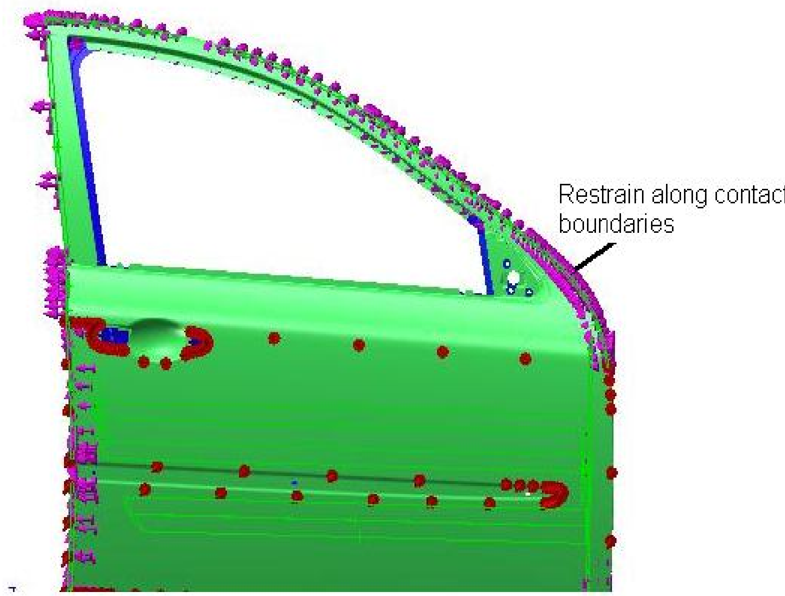


Figure 3.15 Restraint location of analysis

From main menu, load (force) is selected and attach to outer door panel with 100 kN. Range of load is referring to literature review in graph of force versus displacement. This is the most ideal value where door will fail after force is applied. Refer to **Figure 3.16**; force is applied along the contact point of moveable deformation barrier and surface of door. The red arrow in color showing the force given and the direction is 90 degrees to the door surface. The force is uniformly distributed, but the force point in Figure 3.14 only shows at the border of door and its center

Then mesh created in fine manner. A finer mesh, with more elements, will generally produce more accurate results at the expense of longer processing time. Mesh size can significantly impact processing time. While doing simulation the convergence value should be taken into consideration. This is to get value almost exact and stable example of meshing model is in **Figure3.17**. Final step is run the analysis. In analysis, the software computed the von-Mises equivalent stress, which can be compared to the material's yield strength to predict yielding of the part. After the analysis is complete, results can be viewed in report in menu.

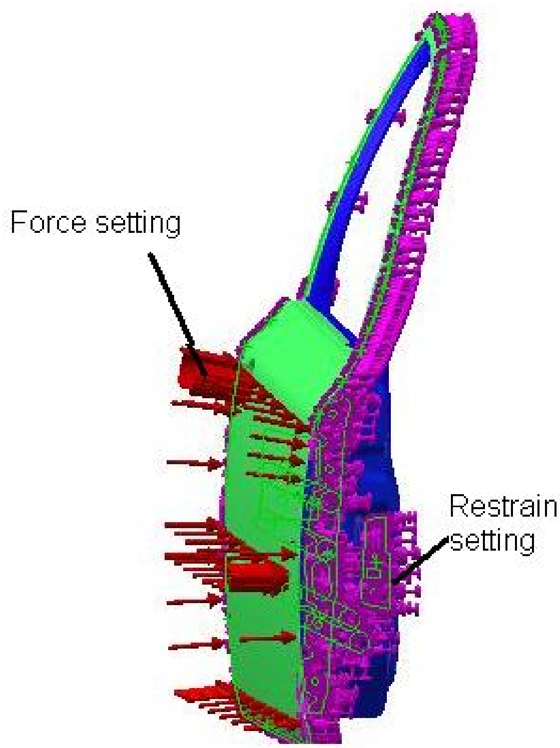


Figure 3.16 Force Location of analysis

Force is located along front panel surface and uniformly distributed. The direction is towards the body of car.

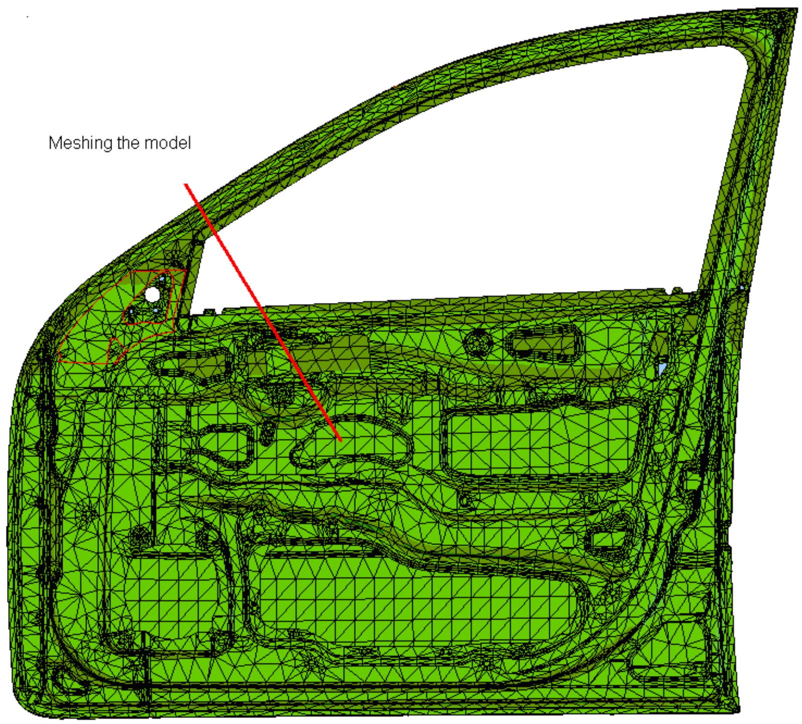


Figure 3.17 Meshing the model to analysis

Meshing have to be converge to get the valid result of simulation and not big in range different. Darker area in **Figure 3.17** is where meshing is high. This is due to more complex shape and around the corner needs more detail. The flat surface especially at the front panel are using lower meshing as detail are not needed to reduce time consumes in simulation phase.

3.3.3 CAE Simulation Steps

Firstly, restraint setting at hinge, lock, perimeter attach to A-pillar and B-pillar. Restrain is to limiting the force given and at these region where fixed point is attach to both side of door and body. Then, force is set up on surface outer panel of the door which facing to barrier applied. As the force applied is uniform, the load is selected to whole surface of outer door. The force is from out to in the car side directions. Model is mesh using finer size to get more accurate result especially at highest deflection region. Meshing level is important because it will influence the final result.

3.3.4 Documentation

Proper documentation of all steps and result is needed as the last step before the presentation to the panels. The result is display in html format or in jpeg format. Another is in motion form. Results of various numbers of bar were displayed on last of analysis process for the documentation.

3.4 3D Scanning Technologies

Scanning creates an organized digital representation of an object quickly and accurately. The file created is a cloud of points that represent the surfaces and characteristics of the object and can be used for reverse engineering, inspection, CAD comparison, prototyping and other applications. From initial design, through final inspection, 3D scanning solutions focus on accuracy, speed and portability acquiring more than 23,000 points/second, 3D Scanning simplifies complex projects without compromising accuracy [20].

3.4.1 Reverse Engineer to Design Intent

The restoration of classic automobiles has always been plagued with problems associated with formed sheet metal parts. Corrosion dents, and scratches are sometimes so severe that the original part cannot be repaired. 3D Laser scanning allows damaged parts to be modeled in the computer. Dents, scratches and corrosion can then be removed in the virtual model yielding a shape true to the original designer’s intent. This final model can then be used to fabricate new dies and parts.

3.4.2 Application

Applications for 3D scanning technology are growing daily and seem unlimited. The pressure to compress design and manufacturing time to a minimum and produce high quality items at low cost was never greater. The power to capture physical objects and turn them into digital assets for industrial design, engineering, manufacturing, quality control, inspection and other applications is built into 3D scanning solution.

In general, scan data collected using 3D scanning can be used for applications

Reverse Engineering

Produces a CAD model that describes a sample part. Reverse engineering software is used to import a scan cloud, and then mathematically smooth and combine the scan data until representative NURB surfaces are generated.

i. Copying

   Produce a duplicate of a sample part directly from the scan cloud data. CAM (Computer Aided Manufacturing) is used to read the scan cloud data.

ii. Rapid Prototyping

   Produce a duplicate of a sample part from a CAD representation of the part. This represents a combination of reverse engineering and copying.

iii. Inspection / Validation

   Check a manufactured part to ensure it conforms to the part's design intent. There are many different levels of checks that may be performed.

   a. Presence / Absence

      Ensure that an assembly contains all of the necessary parts. (hole, edge, slot, etc) and compare it to the designed nominal location.

   b. Contour Measurement

      Compare part contours to their corresponding CAD models. This comparison may be conducted as 2-D cross sectional cuts, or 3-D part topographical mapping.

   c. GD&T Analysis

      3D surface data allows complex GD&T analysis on parts with speed and ease.

3.4.3 Reverse Engineering Consideration

3D scanning and modeling is part of reverse engineering process. There are several factors to be considered to get exactly the needed model and valid for the conversion to simulation environment. The most important are:

i. Working area available is limited because of 3-d scanner is not portable compare to the size of door. The 3-D scanner must fix to the table to avoid scanner damage.
ii. Scanning process must be done more than once to get better image and because of lack of skills the scanning process takes time
iii. Surface of the model must be free from dirt as the scanner is sensitive and high accuracy that can affect the scanning result
iv. Material that shine and reflecting of light must be avoided as the scanner laser cannot detect the surface. The shining surface then covered with tape or temporary spray
v. Reflection of door surface with light from other sources makes the certain surface cannot be scan at certain angle. So scanning process must do at various angles to get the solid model.
vi. The model must be same in dimensions, gap and finishing so details were of utmost importance and 3D laser scan data is intrinsically very accurate and detailed. The subtleties were not lost in the CAD generated from the laser scan files
vii. Accuracy drops when measuring sharp discontinuities such as edges and holes.
viii. Choosing an optimal time and lighting condition are critical considerations for texture image

3.4.4 3D Scan Advantages

i. Quickly capture all of the physical measurements of any physical object
ii. Save time in design work
iii. Ensure parts will fit together on the first try
iv. Capture engineering optimizations inherent in manufactured parts
v. Utilize modern manufacturing on parts that originally manufactured before CAD
vi. Compare "as-designed" model to "as-built" condition [20]

CHAPTER 4

RESULT AND DISCUSSION

4.1 Overview of the result

In this project, stress, strain and displacement of the door are depending on the side impact bar. There is significant reduction of stress, strain and displacement value due to increment of value of bars added. The result will be discussed in this chapter after some modification in impact bars .The modification purpose to improve the crashworthiness of side impact. Besides, purpose of modification is to transmit and dampen the crash load from the region around the driver to vehicle structure.

4.2 Stage 1: Modeling 3-D Door Using Scanner

Fulfill the first objective which is to get the three dimensional door using scanner. In this project, Proton Persona driver door is used to get all the details and as well as the dimension. By help from Polyworks software, all the holes and unwanted crack can be edited in IMALIGN and in IMEDIT. Smooth and complete surface then converted to Solid work environment by import to IGES file. Advantages from using 3-D scanner are fast result, easy to edit, moveable, and accurate final result to produce. The disadvantage is 3D scanner has limited movement and cannot reach far object at same place.

4.2.1 Scanning result

Scanning result is based on the setting of the scanner and lighting source. The first phase of scanning is without the probe setting. The result of the scanning process is many of holes and unscans parts due to lighting reflection. Laser light cannot be reflected in some of angle as can seen in **Figure4.1.** After some adjustment and setting again the probe, the result of scanning is better.

Probe has to be adjusted to lighting of working environment. If scanning work is done in open area or in door with adequate light, the setting is different. The scanning works refer to **Figure 4.2** and **Figure 4.3** is totally different. As can be seen, **Figure 4.2 (a)** and **Figure 4.3(b)** shows the scanned result before the probe setting. The quality of scanning model is not good. Many of holes in the complex curve. The scanning process has to be done many times to cover the entire surface.

On the other hand, the outer panel also have similar problem especially at the center of door and around the door handle. Mean while, after the probe is set to more proper setting, Refer to **Figure 4.2 (b)** and **Figure 4.3 (b)**, after the probe setting changes have been made, final decision is satisfactory result with clean and without holes on the surface model.

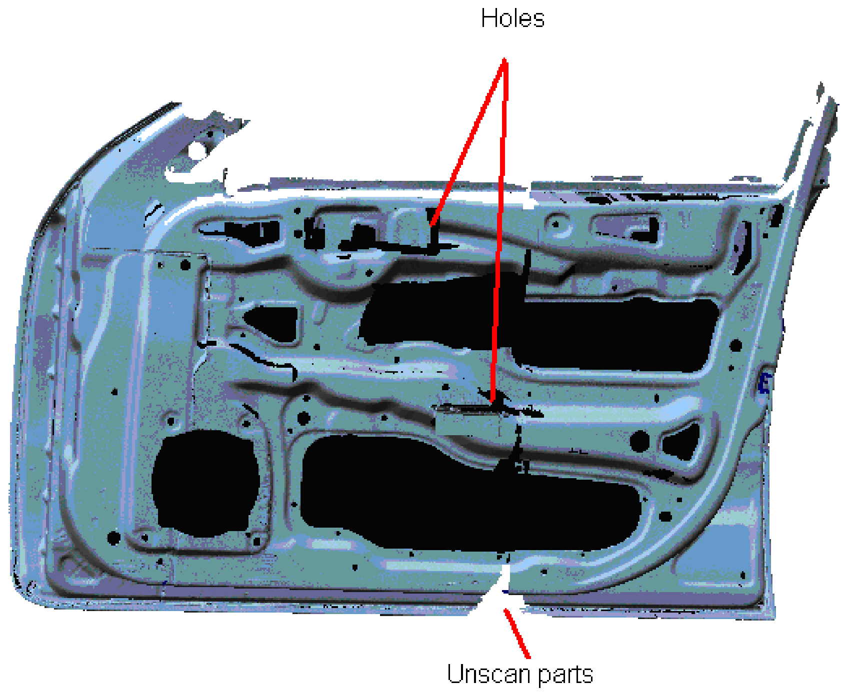


Figure 4.1 First phases in scanning model

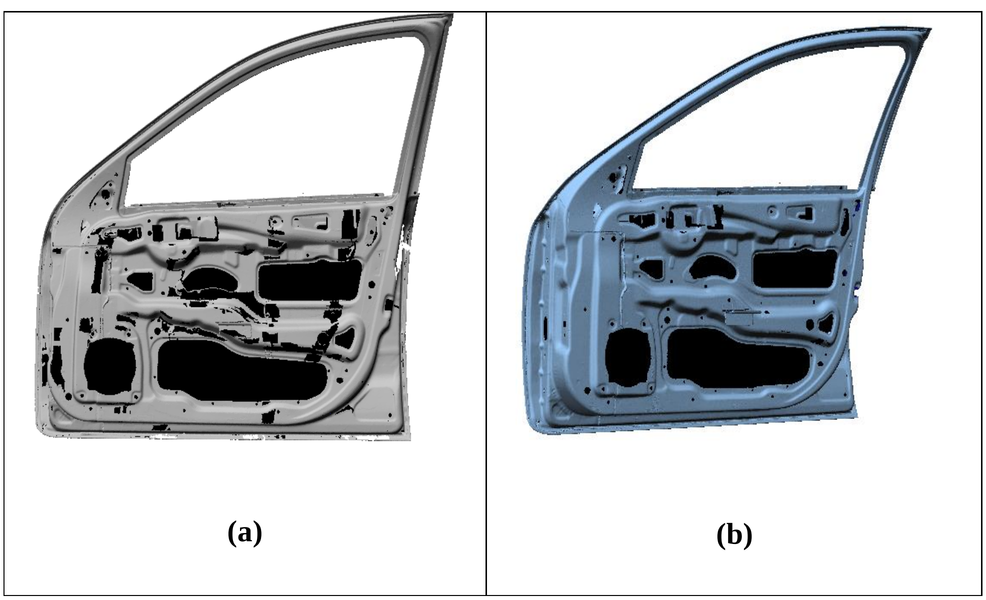


Figure 4.2 Inner panel of door before (a) and after (b) Probe setting

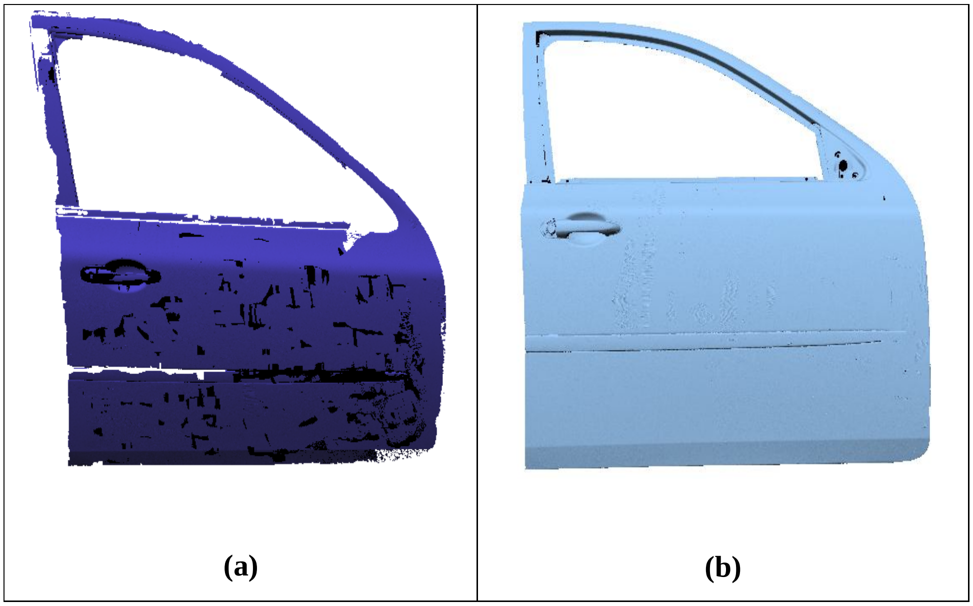


Figure 4.3 Before (a) and after (b) probe setting

4.2.2 Solid model editing result

Second phase of Solid modeling is using IM Edit. After done alignment and auto match reference point, the model have to be reduced its overlap before editing process. All small holes need to be clean and fill to get smooth surface is show in **Figure 4.4**. This is where advance triangle creation and editing play important role in filling the blank and clean the surface.

Figure 4.5 refer to surface that edited using unsetting probe. The surface is wavy and not smooth. Can be see that upper level is in form of wavy after filling holes and cleaning process and lower parts is seems like dented after reconstruct mesh. The wavy and dented scenario is due to vibration and a bit movement of door and scanner stand itself during scanning process.

Figure 4.6 shows zoom picture of door and can clearly seen the wavy surface. The wavy surface then goes process of reconstruction mesh to eliminate the wavy surface but the surface is become dented (**Figure 4.7**).Due to complex curve of the handle (**Figure 4.8**), the area is the worst among the others. So conclusion can be made that probe setting is the major factor to get the smooth and satisfied result. Besides that, scanned item and scanner stand should be fixing at a place during all time of scanning. The different of the final result of modeling can be seeing in **Figure 4.9**. As the consideration of probe calibration setting and fixed scanned model and scanner stand, the result is perfect refer to **Figure 4.10**, and the solid model can convert to simulation environment for stress strain analysis.

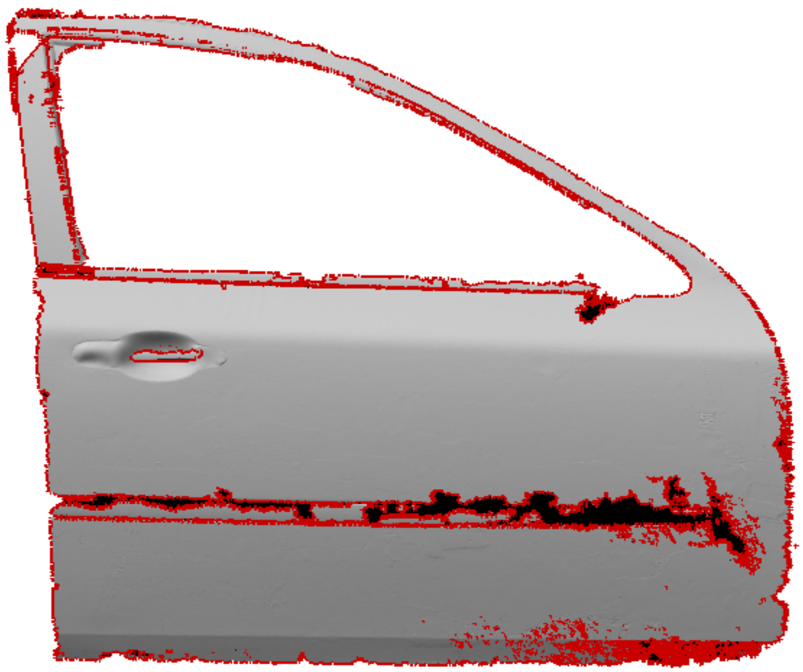


Figure 4.4 Second phase of solid modeling using IM EDIT.

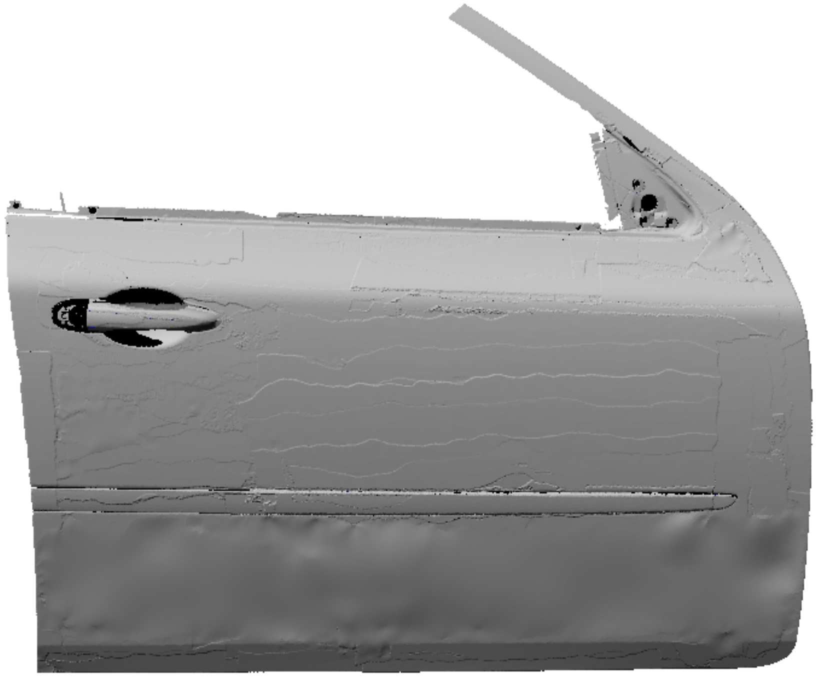


Figure 4.5 Editing processes using Advance Triangle Creation And editing

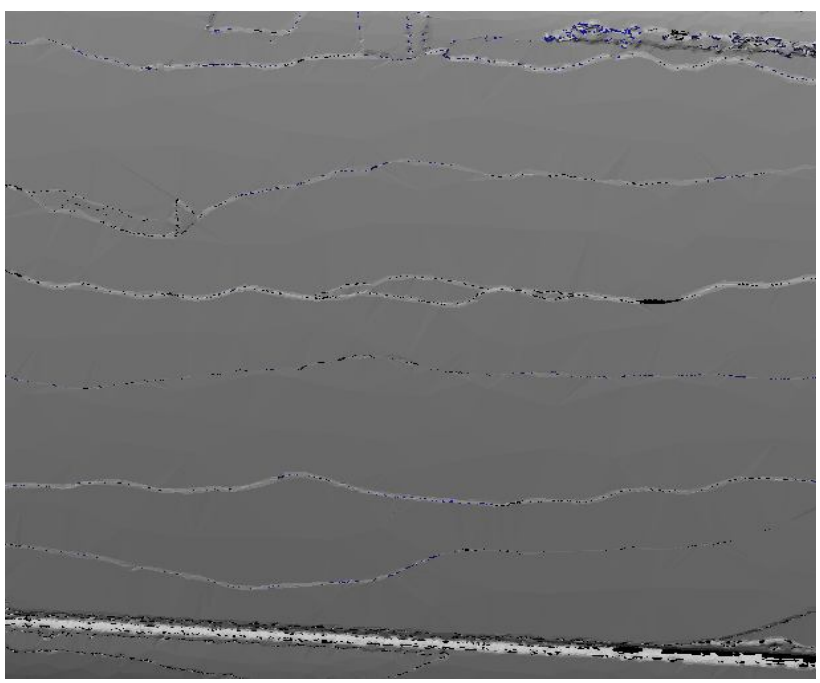


Figure 4.6 Surface of editing process

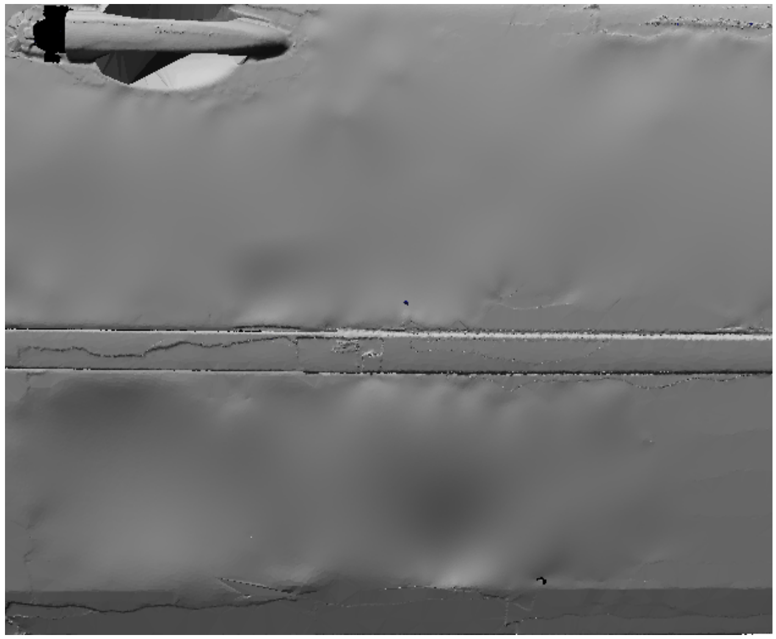


Figure 4.7 Surface after reconstruct mesh

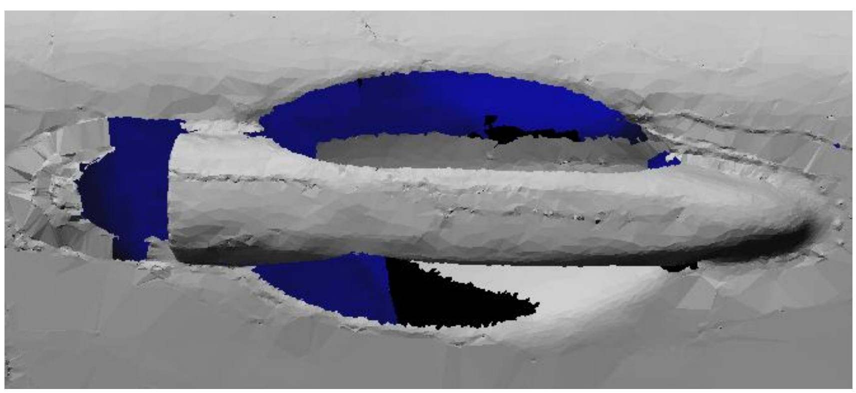


Figure 4.8 Door handle surface

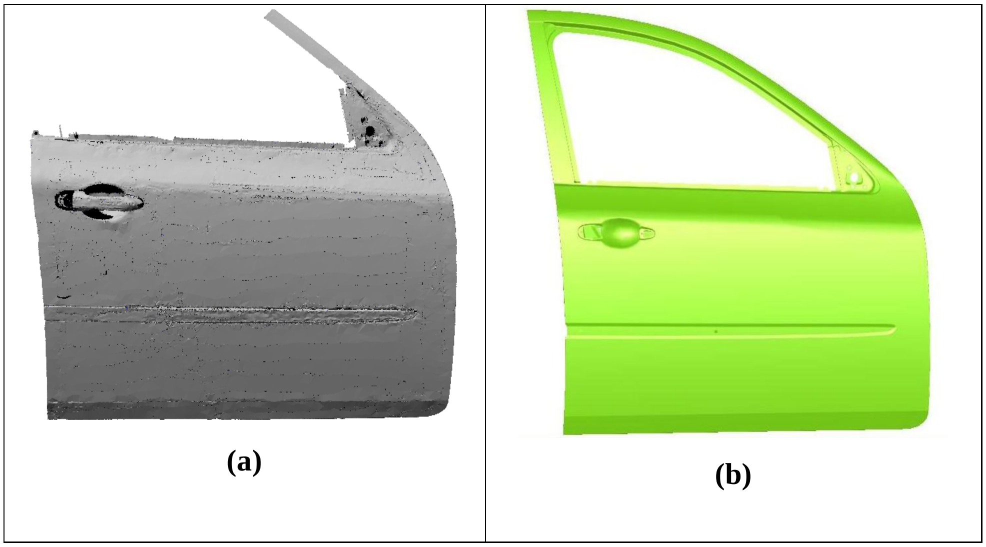


Figure 4.9 Editing in IM Edit result before (a) and after (b) probe setting

Figure 4.10 Perfect final result of scan door model after the probe calibration

4.3 ANALYSIS RESULT

After 3 D model is converted to simulation environment, analysis of stress strain can be done using Cosmos Works In the chapter three, the details of simulation process have been highlighted.

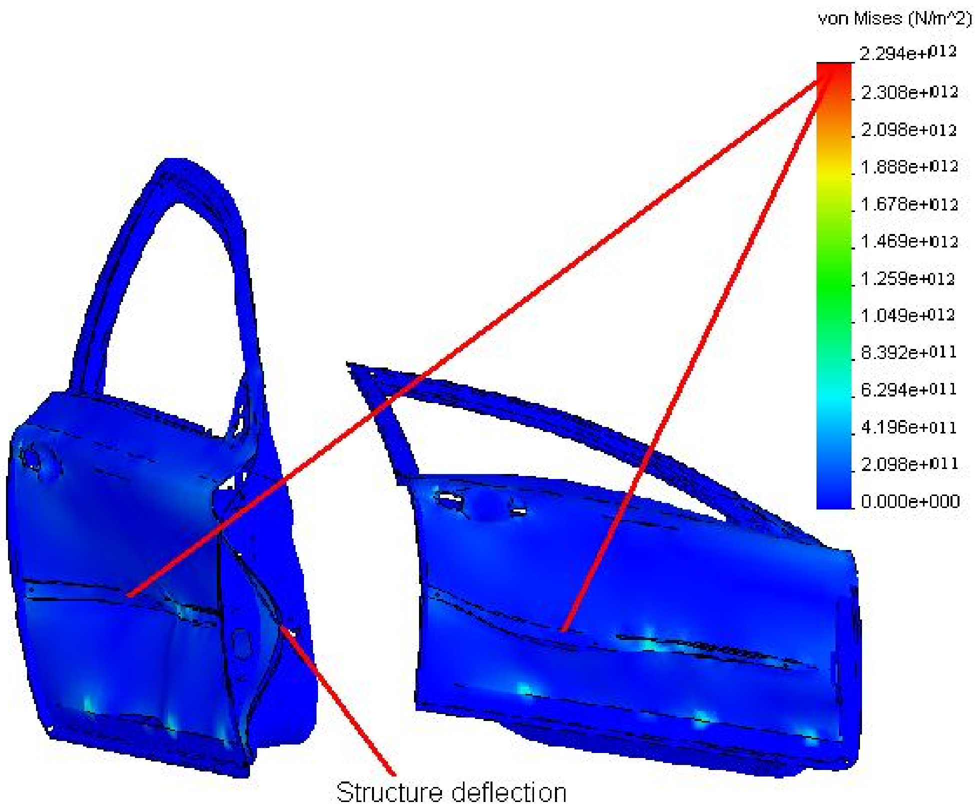


Figure 4.11 Von Mises result with two impact bar applied

Table 4.1 Table of minimum and maximum and location for von Mises stress (2 impact bar)

Type	Min	Location, mm	Max	Location, mm
VON: von Mises stress	0 N/m^2 Node: 56270	(1016.04, 717.082, 447.621)	2.29361e+12 N/m^2 Node: 11769	(452.193, 834.724, 119.035)

As two impact bars is applied, the result can be seen in the **Table 4.1**.Two impact bars is selected as base model because it is a standard requirement for latest car model and including Proton Persona in this project. The stress can be seen concentrated to middle of outer panel with maximum value 2.2936e^12 N/m^2 at node 11769 and the minimum Von Mises Stress occur at node 56270 at 0 N/m^2. These value is exceed than ultimate tensile stress (UTS) , that is 5.1708e+008 N/m^2.At these moment the structure is totally failure and break at the middle of door and towards the front of door. The breakage is due to welding point at the outer panel and inside frame of door. and welding of the impact bars attach to the frame. Among three simulations considered of two, three and four bars, the highest value of stress is using only two impact bars. Inadequate of bars to support the structure and medium to transfer the momentum of impact make the stress strain and displacement high at this time. Structure deflection is curvy shape as can be seen in side view. The structure is deflected in same direction of force .Meanwhile, the bars is bending at same shape of the structure outer panel.

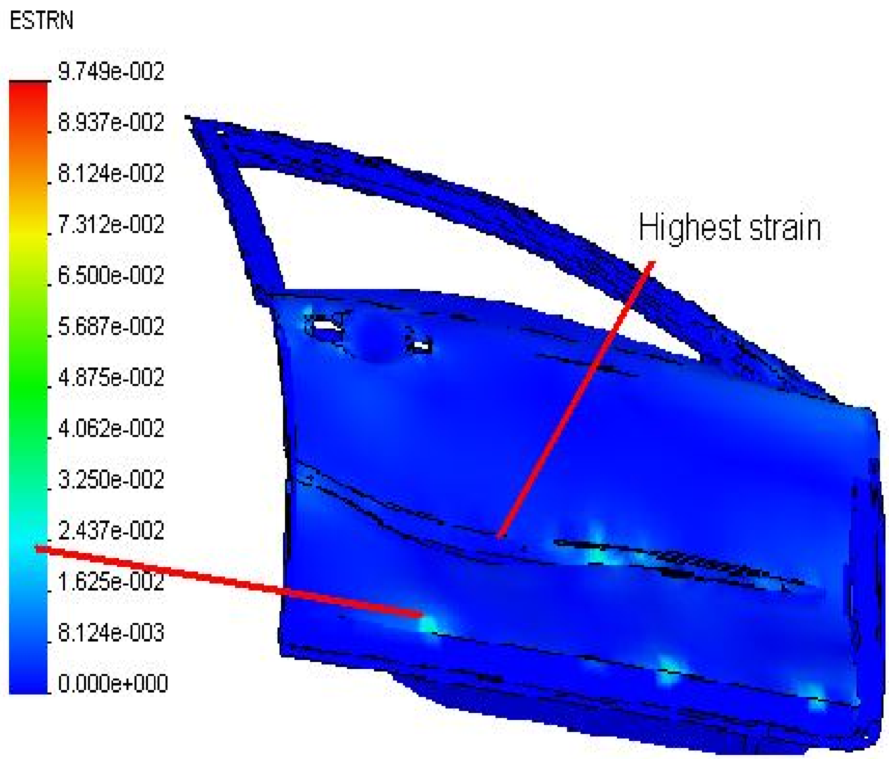


Figure 4.12 Strain result with two impact bar applied

Table 4.2 Table of minimum and maximum and location for equivalent strain (2 impact bar)

Type	Min	Location, mm	Max	Location, mm
ESTRN: Equivalent strain	0 Element: 573	(1625.01, 558.7, 1136.92)	0.0974932 Element: 4332	(1482.28, 840.512, 611.256)

Similarly to stress, the strain region is at same point with maximum value of 0.0974932 at the element 4332 and the minimum value is o at the element 573 as see in the **Table 4.2**. As 100 kN of force applied, the strain have same character deflection with stress. The region and shape of strain act is also same as stress.

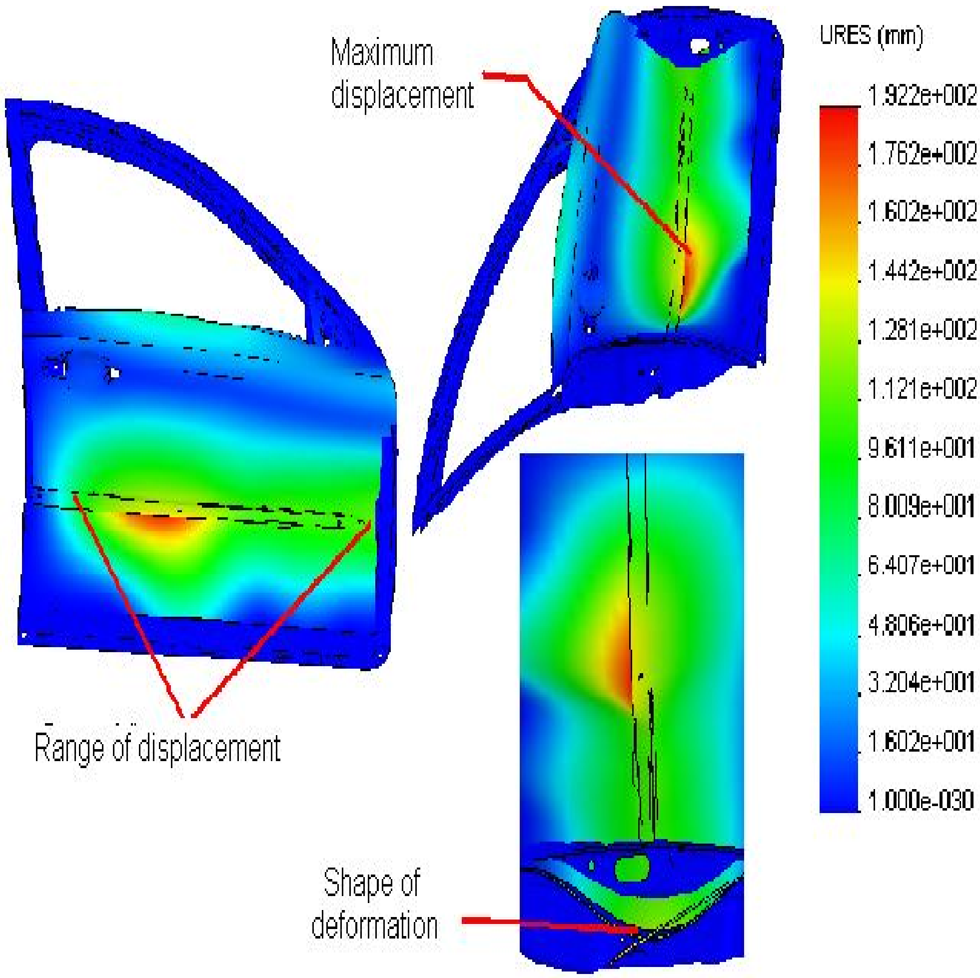


Figure 4.13 Displacement result with two impact bar applied

Table 4.3 Table of minimum and maximum and location for resultant displacement (2 impact bar)

Type	Min	Location, mm	Max	Location, mm
URES: Resultant displacement	0 mm Node: 25	(1627.23, 555.835, 1142.71)	192.222mm Node: 4434	(1136.62, 853.602, 338.86)

Refer to **Figure 4.13** displacements is highest at center of the door. The implement of only two impact bars cannot resist the force from the impact. The highest region is due to distance between two bar is large. The middle of the two bars distance is where the highest impact acting. The range of displacement is quite big, from front of the door to almost the end of door knob bar around 64 mm to 128 mm displacement. The highest value indicates the maximum value of 192.222mm (**Table 4.3**) from its origin surface as the force is applied. The momentum of the impact did not change the structure at the lowest value at door arch. This is because door arch is far from source of impact. The lowest value is 1.00e-03 and still has deformation even though in small scale. The vibration is still move towards all structure in contact with force given.

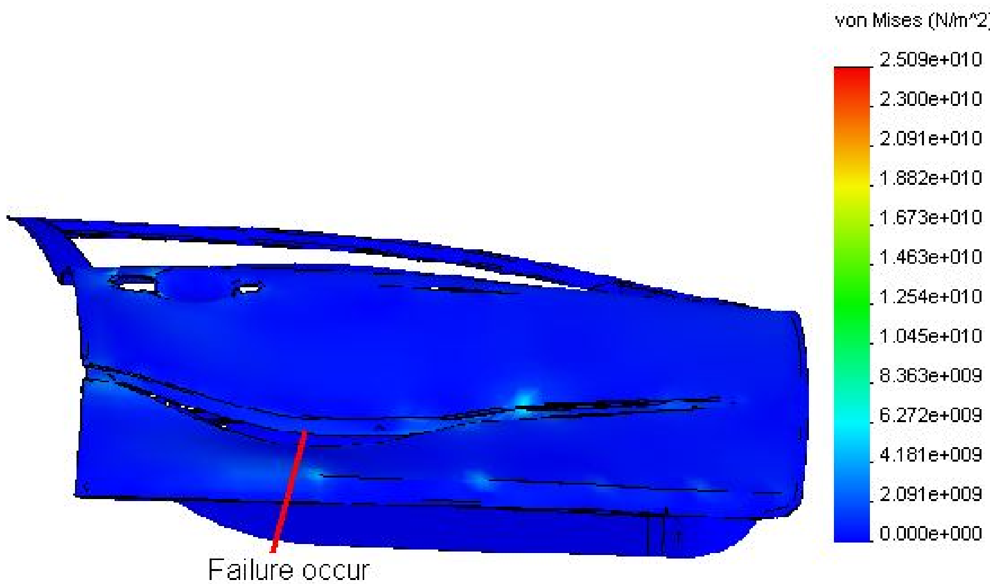


Figure 4.14 Von Mises result with three impact bar applied

Table 4.4 Table of minimum and maximum and location for von Mises Stress (3 impact bar)

Type	Min	Location, mm	Max	Location, mm
VON: von Mises stress	0 N/m^2 Node: 278	(1494.76, 557.136, 1114.57)	2.50878e+10 N/m^2 Node: 2064	(1417.65, 843.645, 604.077)

Von Mises stress for three impact bar is 2.50878e+10 N/m^2 which is maximum at node 2064 and the minimum is 0 N/m^2 at node 278.(**Table 4.4**) This reduction of the value for Von Mises stress from two impact bar to three impact bar occur because of the addition of the impact bar. The force is distributed to all members by the outer sheet metal and impact bars to all fame and other structure. The Von Mises stress is still higher compared to yield strength of AISI 304. That's why the surface break up can be seen in Figure 4.14 and noted as region where failure is occur. Refer to **Figure 4.15**; maximum strain is still at the center of the door where gap between impact bars is at the highest strain point**.** At the maximum strain point can see the outer surface is starting to break after plasticity deformation is reach to its limits.

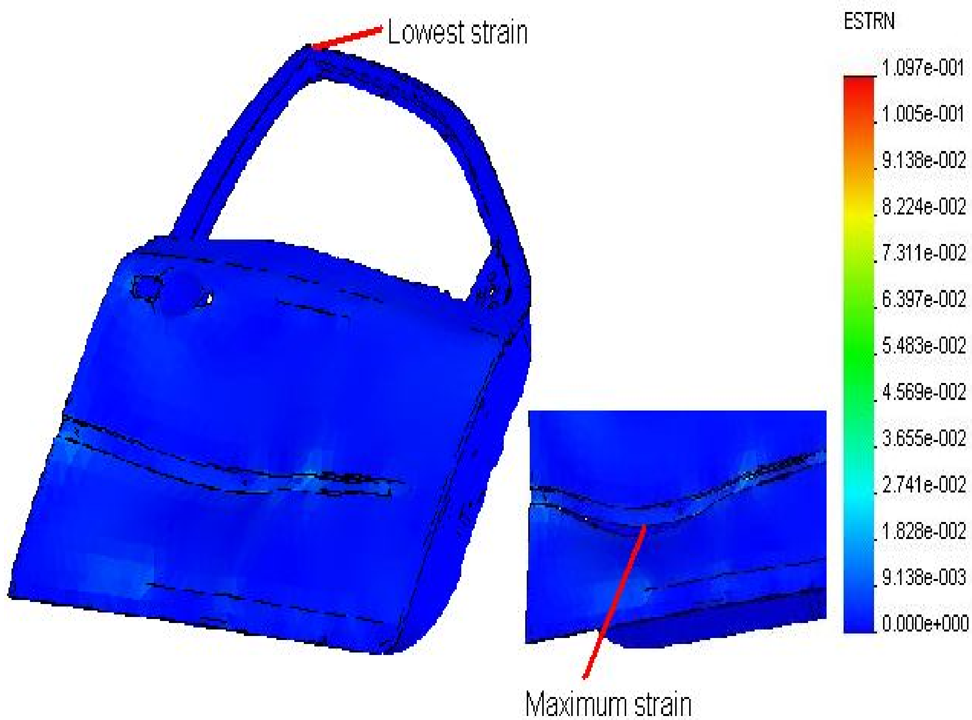


Figure 4.15 Strain result with three impact bar applied

Table 4.5 Table of minimum and maximum and location for equivalent strain (3 impact bar)

Type	Min	Location, mm	Max	Location, mm
ESTRN: Equivalent strain	0 Element: 385	(1501.55, 553.251, 1119.14)	0.109659 Element: 15483	(496.052, 833.533, 153.744)

A strain result show of maximum value is 0.109659 at the element 15483 and the minimum value is 0 at the element 385 as shown in **Table 4.5**.

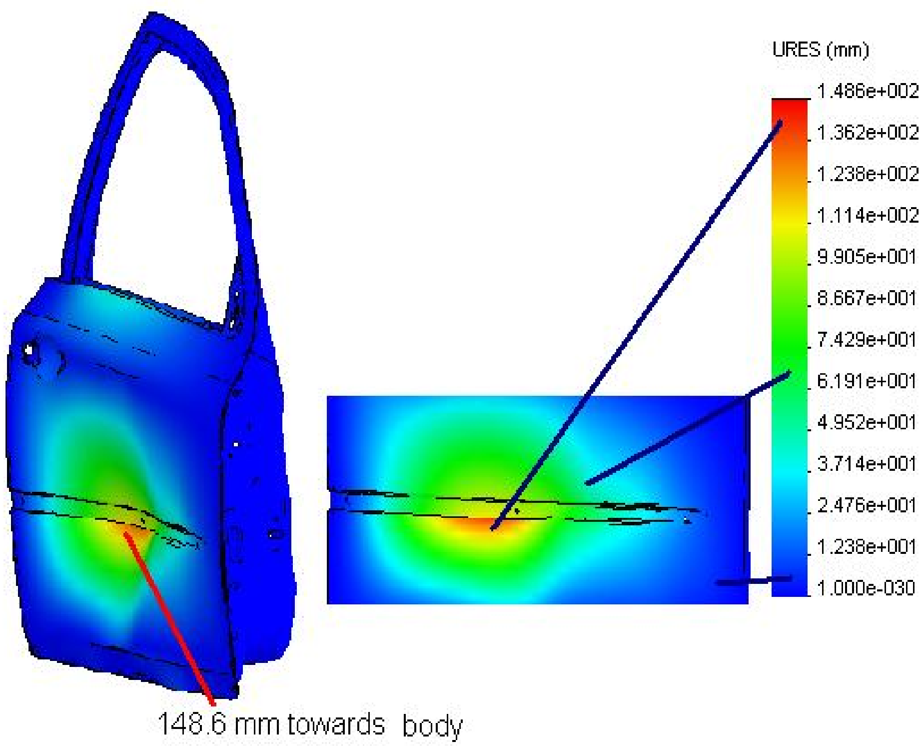


Figure 4.16 Displacement result with three impact bar applied

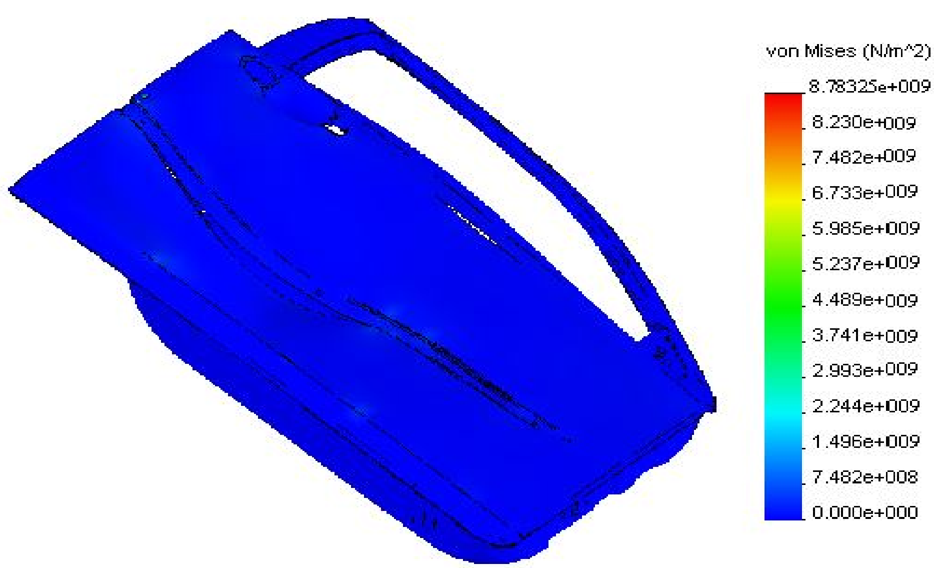
Table 4.6 Table of minimum and maximum and location for resultant displacement (3 bar impact)

Type	Min	Location, mm	Max	Location, mm
URES: Resultant displacement	0 mm Node: 26	(1493.93, 552.725, 1121.77)	148.572 mm Node: 2190	(1171.76, 859.494, 313.827)

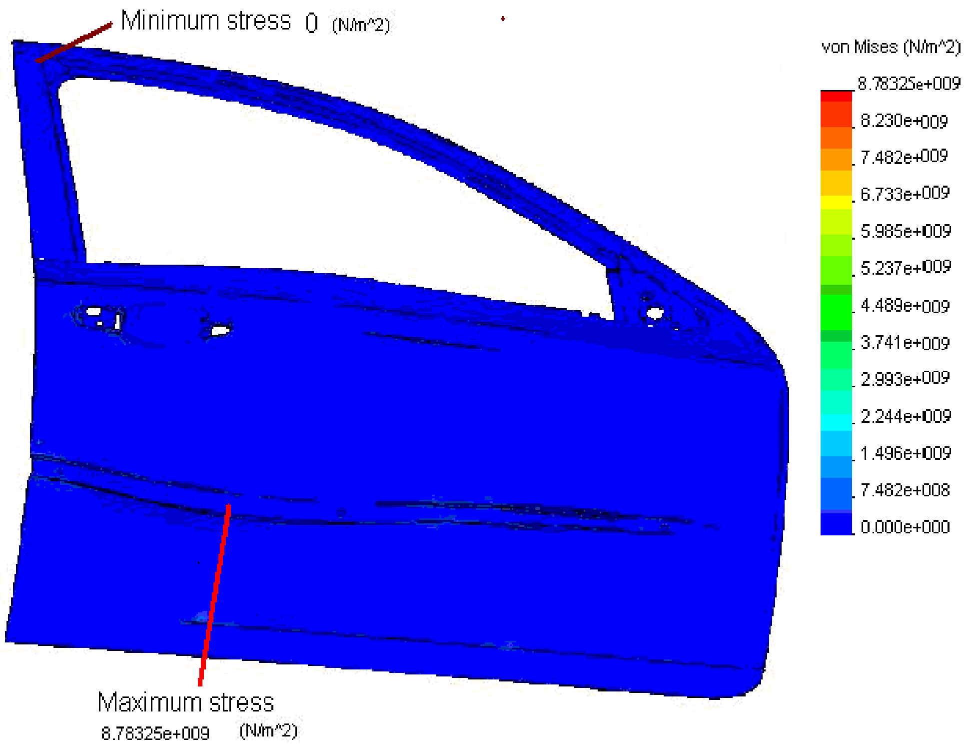
The value of displacement is reducing to 148.572mm at node 2190 at the maximum displacement for three impact bars. The region of affected force is also reduced to smaller scale. Higher displacement which is nodded as red and yellow areas seem to be smaller which means the force distribution is limited to highest region only and a bit to nearest members area. The movement is just 148.6 mm towards the body. But there is reduction compared to only two impact bars applied and as show in **Figure 4.16**, scattering of distribution is focus more on highest value of displacement.


von Mises (N/m^2)
8.78325e+009
8.230e+009
7.482e+009
6.733e+009
5.985e+009
5.237e+009
4.489e+009
3.741e+009
2.993e+009
2.244e+009
1.496e+009
7.482e+008
0.000e+000
Maximum area

(a)


von Mises (N/m^2)
8.78325e+009
8.230e+009
7.482e+009
6.733e+009
5.985e+009
5.237e+009
4.489e+009
3.741e+009
2.993e+009
2.244e+009
1.496e+009
7.482e+008
0.000e+000

(b)



(c)

Figure 4.17 Von Mises result with four impact bar applied in different view, **(a), (b), and (c)**

Table 4.7 Table of minimum and maximum and location for Von Mises Stress (4 impact bar)

Type	Min	Location, mm	Max	Location, mm
VON: von Mises stress	0 N/m^2 Node: 2111	(460.625, 831.698, 552.487)	8.78325e+09 N/m^2 Node: 2053	(868.067, 858.694, 338.773)

As four impact bars applied, the maximum value is again reduced to 8.78325e^09 N/m^2 at node 2053. The maximum point now is located to the center of door model. Majority is in low stress level due to compactness of supporting structure to the outer surface of door. Stress is still exist at the center of the door in smaller quantity yet still exceed the yield strength and tensile stress. So the door structure is break refer to **Figure 4.17 (b) .**The three impact bars only dampen a bit the stress but not to stop the failure from happen. Yet, bars are still done its work and as a result the door arch is at a lowest value of stress as shown in **Figure 4.17** (c) with 0 $N/m^{2.}$

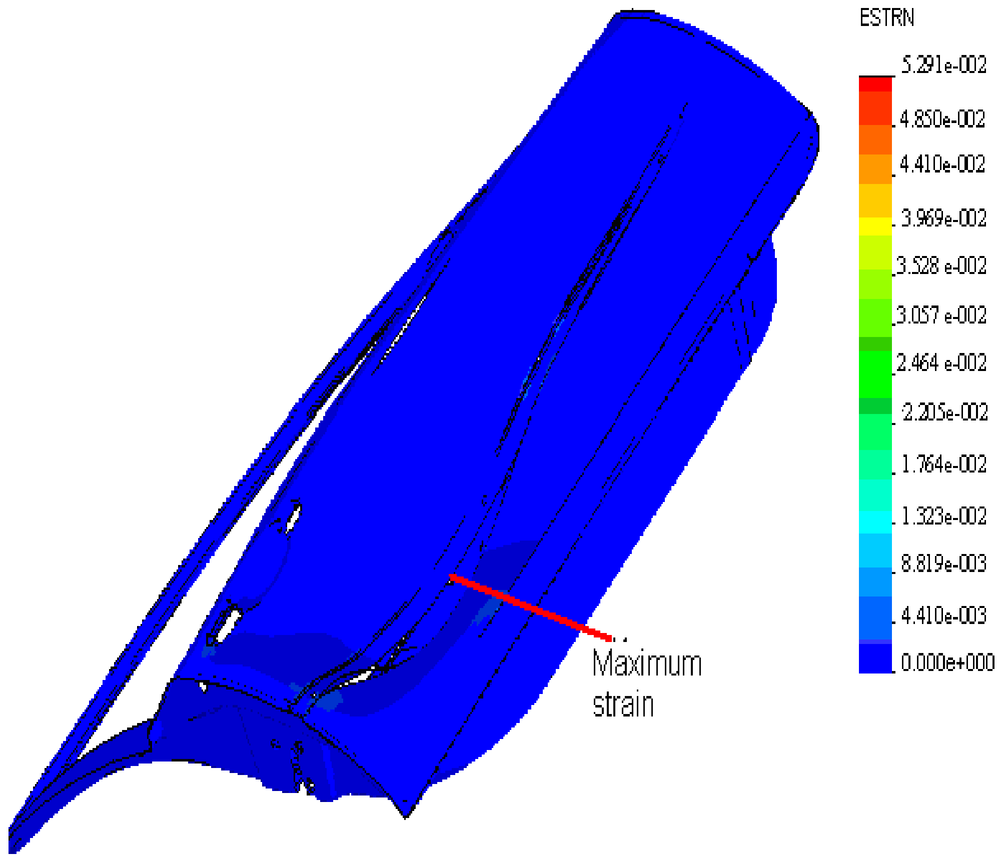


Figure 4.18 Strain result with four impact bar applied

Table 4.8 Table of minimum and maximum and location for equivalent strain (4 impact bar)

Type	Min	Location, mm	Max	Location, mm
ESTRN: Equivalent strain	0 Element: 3365	(459.458, 830.883, 560.163)	0.0529143 Element: 3536	(1525.33, 859.525, 321.187)

Strain result show the same scenario which is the value also decrease to 0.0529143 at the element 3536 as the maximum value and the minimum value is 0 at the element 3365(**Table 4.8**).The bar added did not made much of improvement for strain quality, even though decreasing in strain number .and similarly to stress condition in **Figure 4.18**, failure leads to breakage still occur but offset a bit towards back of the door from its maximum stress point.

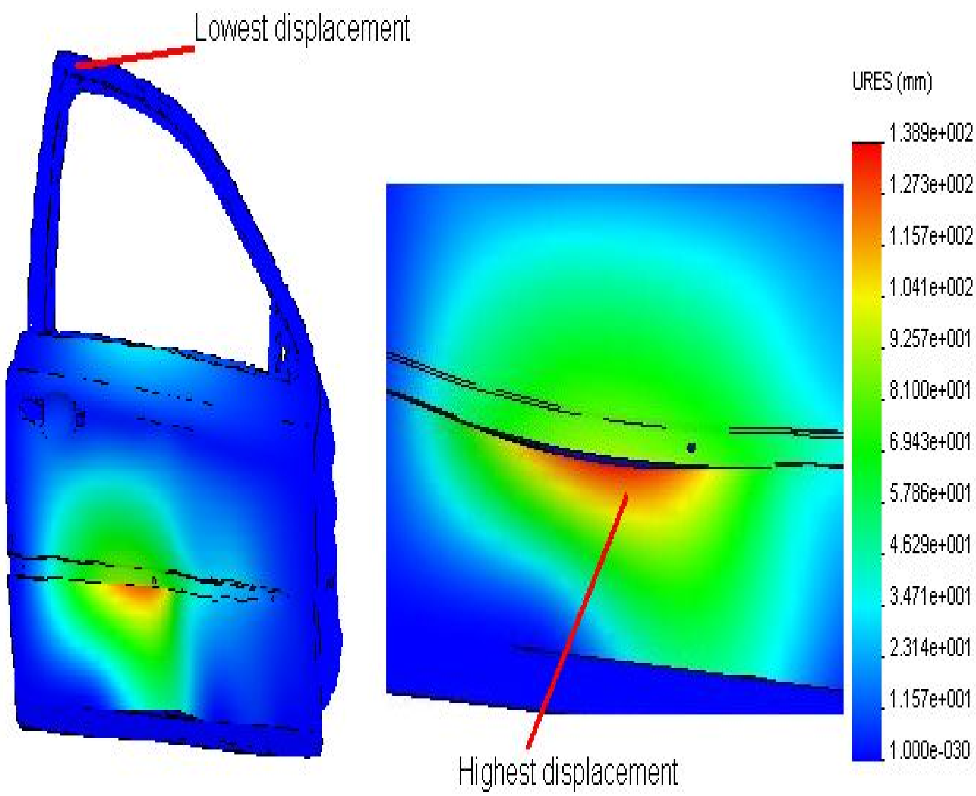


Figure 4.19 Displacement result with four impact bar applied

Table 4.9 Table of minimum and maximum and location for resultant displacement (4 impact bar)

Name	**Type**	**Min**	**Location, mm**	**Max**	**Location, mm**
Plot 1	URES: Resultant displacement	0 mm Node: 25	(1626.02, 561.551, 1117.01)	138.858 mm Node: 2440	(1177.32, 859.517, 313.933)

With 138.858 mm as the maximum value at the node 2440 for the displacement result in **Table 4.9**, it shows that the impact bars is help to reduce the impact action and controlled the maximum force area to the center of the door with the minimum value is 0 mm at the node 25.After analysis done of 100 kN and 90 degree of force impact to all three situations, for two, three and four impact bars, it is proven that impact bars help to dampen and absorbed all the force applied and distributed to side members of the door. Refer to **Figure 4.19;** the displacement is the lowest among 3 situations .The kinetic energy from source of impact has been absorb to all members and the area of displacement less than others. Four impact bars applied is not enough to counter the force given and resulting failure to structure at highest displacement. Even the failure is still occur, but there is reduction in analysis by analysis to the small portion only .The impact bars cannot be added more as consideration of space for glass window, power window motor, wiring system and many more other gadgets. The recommendation to in crashworthiness of the door by reduction in stress, strain and displacement is discuss in recommendation in chapter 5.

All of the analysis can be conclude into graphs to explain the indentation of bars.

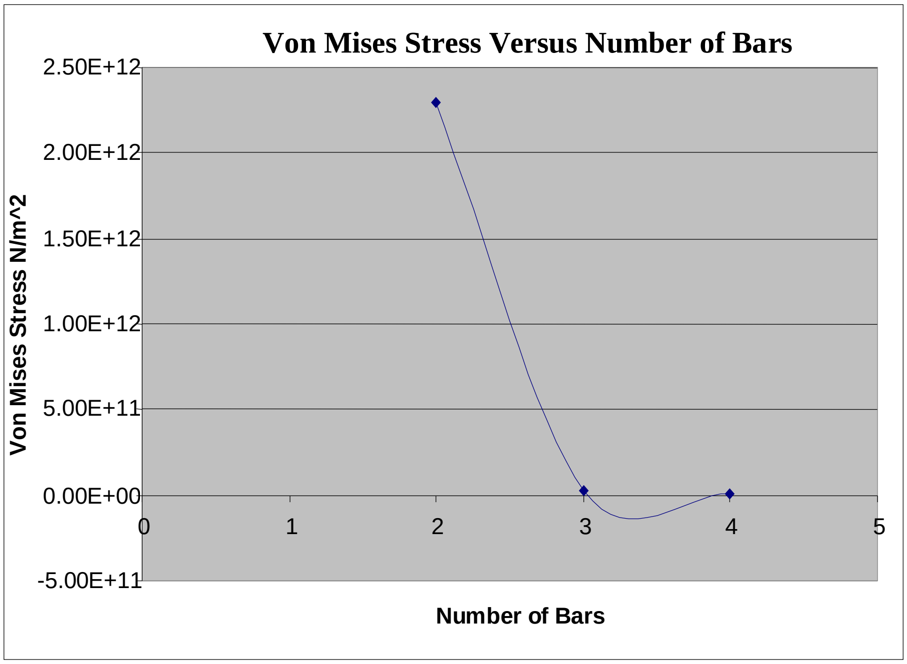


Figure 4.20 Graph of Von Mises stress versus number of bars install

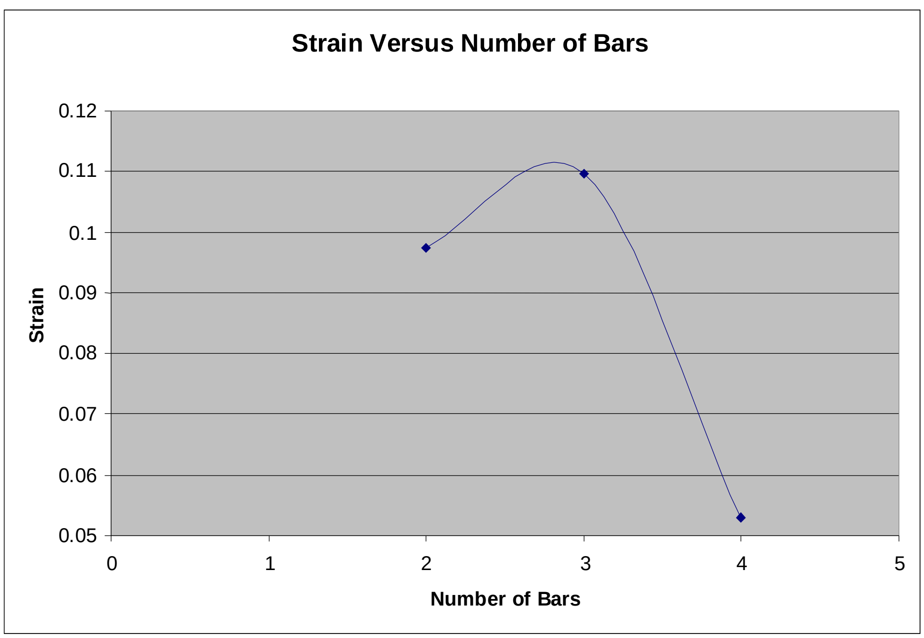


Figure 4.21 Graph of Strain versus number of bars install

Based on graph, the data shows that stresses that occur during impact force on the panel door have decrease when implementation of bars is added during the analysis. By using, two bars as initial point on the analysis, which is the standard design in Proton Persona door, stress starting to decrease gradually until three bars, is added. During this, stress is reaching negative value until reaching it minimum point and increase when four bars are implied. From three graphs above, the stress and strain shows the failure of material. From the property of AISI 304, the yield strength is 2.0681e+008 N/m^2 .The values of Von Mises stress is exceed the yield strength and ultimate tensile stress of the material use. So the structure is in plasticity region where it cannot form back into its shape after applied forces were removed and even the structure is said is fail due to force given per unit area.

Strain analysis is similar to the stress analysis for the location of acting. The different is on the values of strain. In strain analysis, implementation of using two bars causing strain of panel door structure increase until two bars is applied. The strain is having decrement gradually when adding the bars until three bars is used. Supposedly the graph is linearly decrease but after three impact bars applied, the strain value is increase a bit about 0.012166 and about 12.47 %. This is due to error on the analysis done perhaps. During this, the more bars is added meaning the better losses measure of given displacement differs locally from a rigid-body displacement.

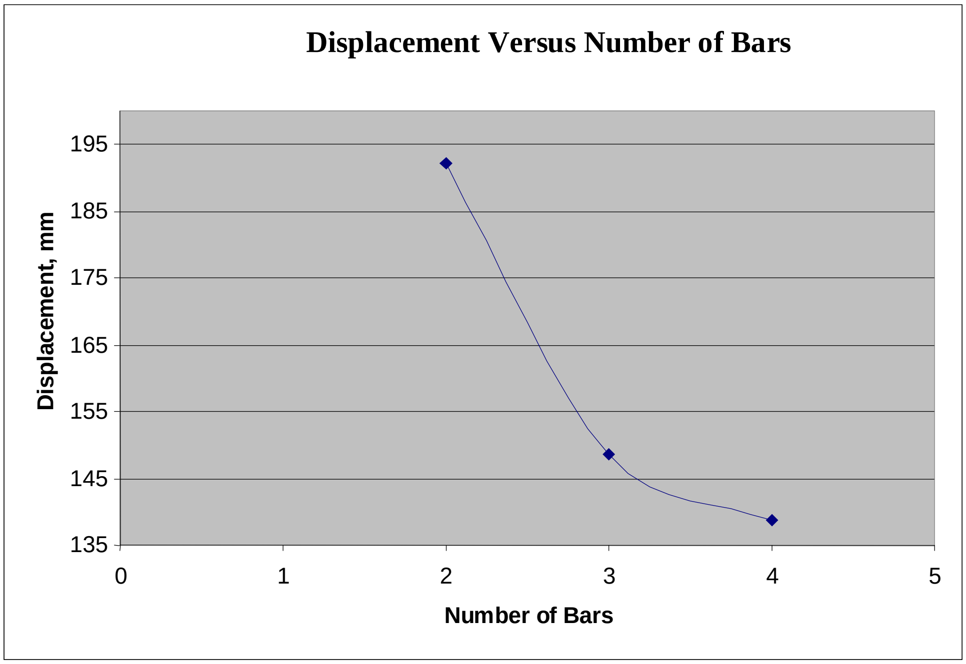


Figure 4.22 Graph of Displacement versus number of bars install

While for displacement analysis, deformation on the outer panel door that occur during adding the bars is decrease gradually from two bars until the four bars is used. The two impact bars give result of 192.222 mm while slightly reduction after three bars use. Reduction is to 148.572 mm or 22.7% decrement. Final analysis is using four bars in addition of two bars from base model. The final value of displacement is 138.858mm or 6.54% reduction indicates only small decrease in value This explain that implementation of bars is reducing the deflection occur during the impact force on the door. By having as much as minimum displacement of panel door during the impact is actually increase the safety features to the occupant. Impact force on the side car could be reducing because the bars generally stand the impact before the force could reach the occupant and absorb the energy transfer. The stiffness of overall door is increased due to absorption of impact load to the bars and member around. During time the impact occur, the load is carried in wave form. All contact members is start to vibrating and move the wave far away from source. Time dependent is important to the impact. The longer time, the smaller the effects of the impact and members around have enough time to absorb the energy transfer.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion of the project

For the conclusion, the stress, strain and the displacement of the Proton Persona Side door were analyzed with different numbers of bars. The final result can be expected to have same scenario which is decreasing after the impact bar addition.

The analysis of Proton persona side door impact using simulation tool is carried out in three cases where parameter to be considered is the numbers of the bar applied to the door. The analysis is done on base model for two impact bars, then addition to three impact bars and lastly four impact bars. The others parameter is fix which is force given is 100 kN at 90 degrees to the door surface and the material used is AISI 304 that have yield strength 2.06807e008 N/m^2.

Based on the simulation that have been done, the stress, strain and the displacement of Proton Persona door structure is proportional with numbers of impact bars which is in other words, the stress is reducing as the impact bars is increase. The impact bars function to dampen and reduce the force and momentum from the impact of crash.

The results only show the alternatives to increase the crashworthiness at the time vehicle takes a hit on the side impact. In real manufacturing industry, there is many of ways to improve crashworthiness such as interior padding, stronger steel beams for A-pillar, B-pillar and C-pillar. Besides, manufacturing also adding an anti lock braking system, air bags, and seat belt, and even Side Impact Protection System (SIPS). In a side impact these transverse rails allowed the seats to crush a reinforced center console during a side impact. The system is designed to more widely distribute the energy in a side impact across the whole side of the car rather than having the B-pillar absorb it all.

Although Malaysian regulation on crashworthiness not being implemented yet, it is a good start for the manufacturers to improve the active and passive safety. The standard safety requirements have to be following to reduce severe injury and death numbers on accident.

Finally, all of difficulties successfully overcome with any suitable way and initiative to get the results. Actually this is constitute the climax of this project after able to achieve the objective.

5.2 Recommendation

As the 3-D door model is already completed and almost perfect, there is some of room for improvement. In addition to the analysis that has been conducted, there are several steps and procedures that could have been taken to improve the result thus, obtaining more accurate and reliable data. The following are some recommendations that should be consider:

i. Include pillars (A, B and C) on 3-D scanning to made the analysis more perfect with include all the point of impact from moveable deformation barrier with side door
ii. Variable the configuration in terms of, numbers and shape for example beams can be use and thickness of impact bars. So, addition of the parameter will be more accurate.
iii. Use simulation tool that capable to give result in interval of time for example Virtual Proving Ground or LS-Dyna.

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Appendix A
Gantt Chart

	ACTIVITIES WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FYP – 1	1.0 Title Confirmation	1														
	0 2.0 Define Objective & Scope		1													
	2.1 Background Writing		1													
	2.2 Introduction Writing		1													
	2.3 Methodology Writing			5 WEEKS												
	3.0 Literature Review			11 WEEKS												
	4.0 Tear Off Side Door							2WEEKS								
	5.0 3-D Scanning and Inspection									5 WEEKS						
	6.0 Converting Into Simulation Environment													1		
	7.0 Submit Proposal														1	
	8.0 Presentation FYP1															1
FYP - 2	9.0 Boundary Condition Setting	2 WEEKS														
	10.0 Simulation			3 WEEKS												
	11.0 Analysis					4 WEEKS										
	12.0 Thesis Draft Writing					6 WEEKS										
	12.1 Final Presentation Preparation								4 WEEKS							
	12.2 Full Thesis Preparation											3 WEEKS				
	12.3 Thesis Correction														1	
	13.0 Submit Final Report															1

Appendix B

Material Properties (AISI 304)

Property Name	Value	Units	Value Type
Elastic modulus	1.9e+011	N/m^2	Constant
Poisson's ratio	0.29	NA	Constant
Shear modulus	7.5e+010	N/m^2	Constant
Mass density	8000	kg/m^3	Constant
Tensile strength	5.1702e+008	N/m^2	Constant
Yield strength	2.0681e+008	N/m^2	Constant
Thermal expansion coefficient	1.8e-005	/Kelvin	Constant
Thermal conductivity	16	W/(m.K)	Constant
Specific heat	500	J/(kg.K)	Constant

Appendix C

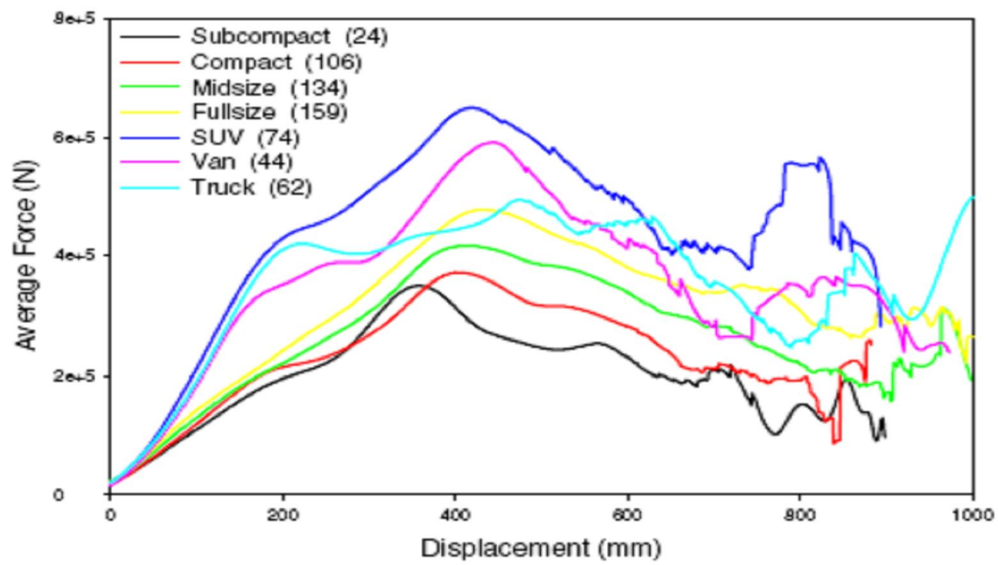
Mechanical Properties AISI 304

Mechanical Properties

Properties		Conditions	
		T (°C)	Treatment
Density (×1000 kg/m^3)	8	25	
Poisson's Ratio	0.27-0.30	25	
Elastic Modulus (GPa)	193	25	
Tensile Strength (Mpa)	515	25	hot finished and annealed (plate, sheet, strip)
Yield Strength (Mpa)	205		
Elongation (%)	40		
Reduction in Area (%)	50		
Hardness (HRB)	88	25	annealed (plate, sheet, strip)

Appendix D

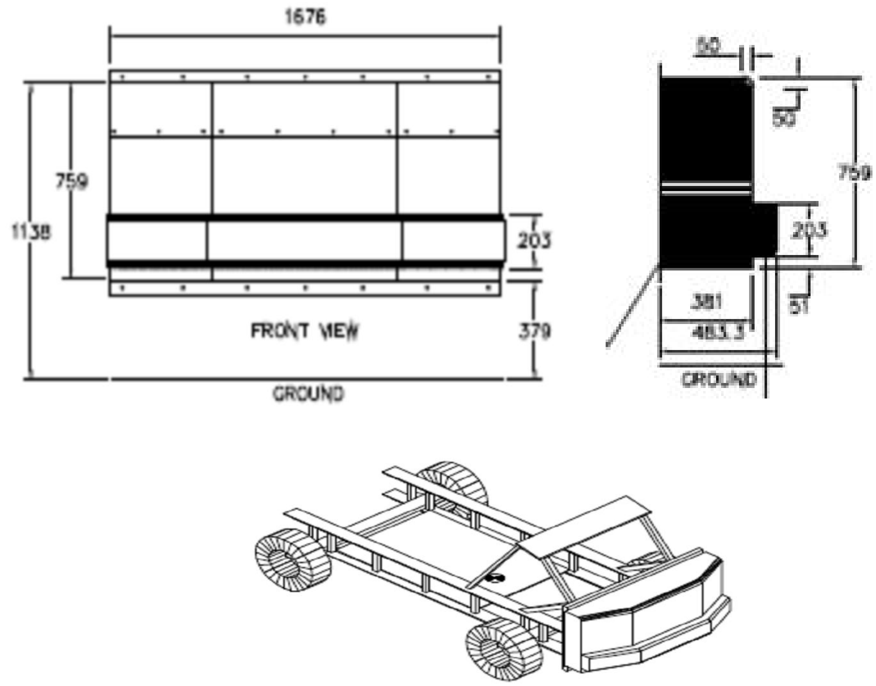
Displacement For Average Force Apply (benchmark)



Appendix E

Moveable Deformation Barrier Properties

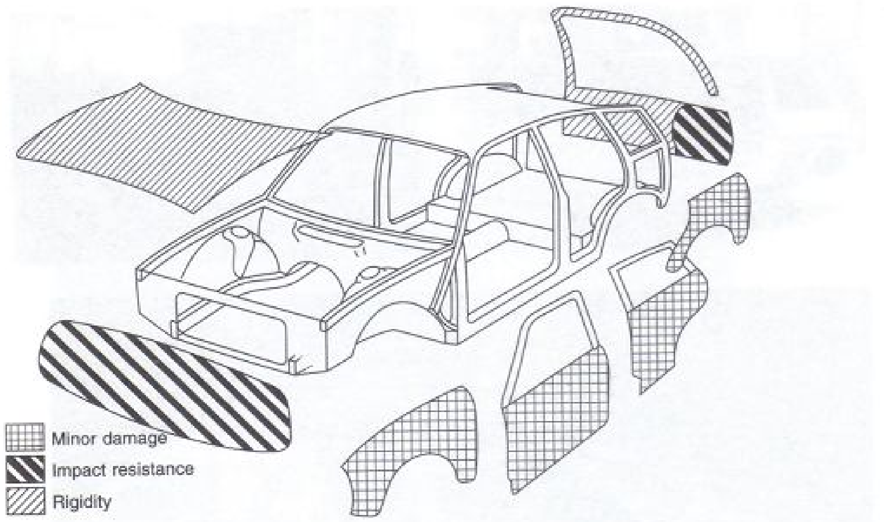
MDB Dimension



http://www.iihs.org/ratings/protocols/pdf/test_protocol_side.pdf

Appendix F

Various Sections With Material Use

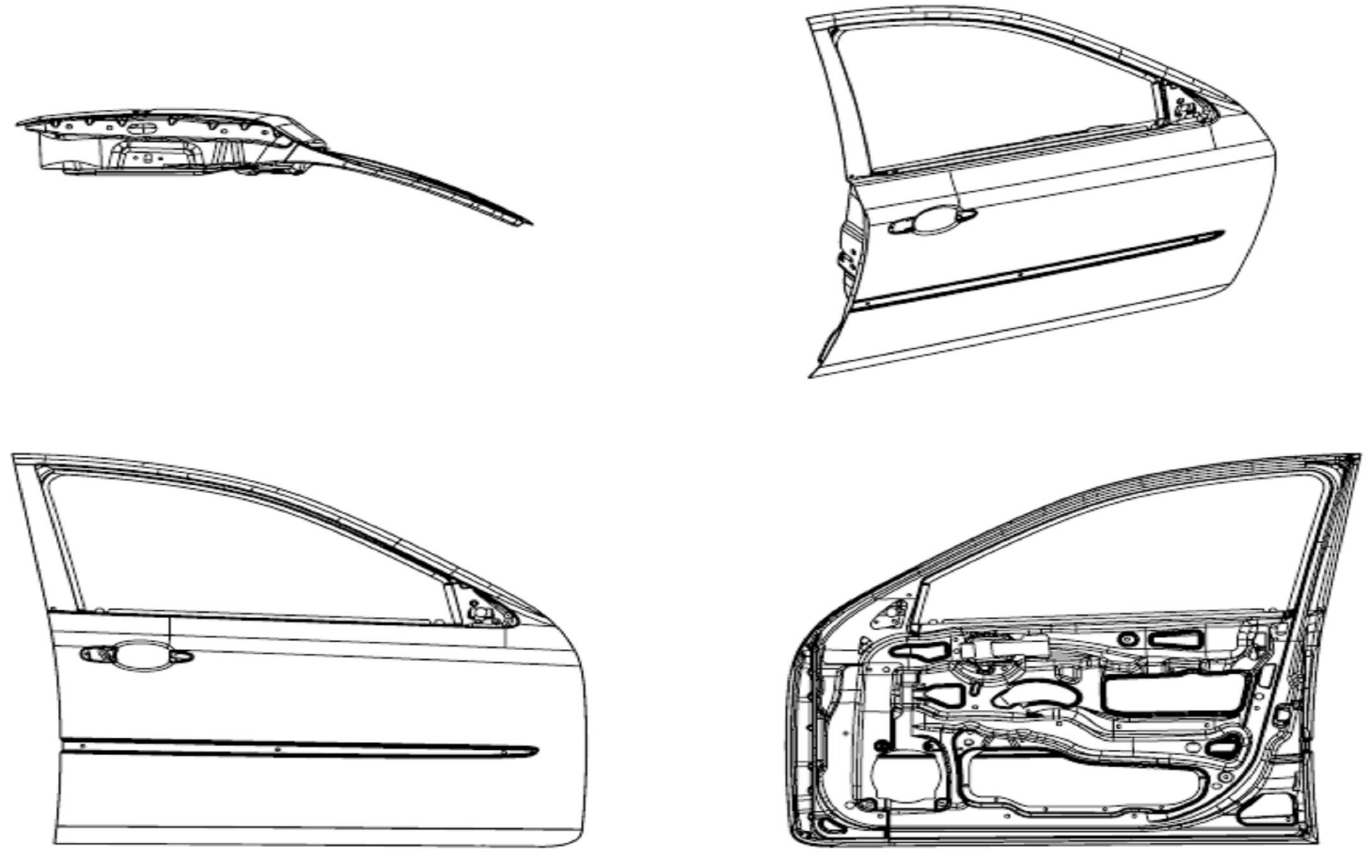


Skin panel material selection					
Property \ Material	Steel	Aluminium	PUR-RRIM	Sheet moulding compound	Polycarbonate
Useable thickness, mm	0.8	1.0	2.5	2.5	2.5
Damage resistance (elongation at yield) %	0.15	0.2	10	0.2	6
Weight/area	1	0.45	0.5	0.75	0.5
Cost/area	1	2.4	1.7	2.2	2.6
Corrosion resistance	X	✓	✓	✓	✓

Appendix G

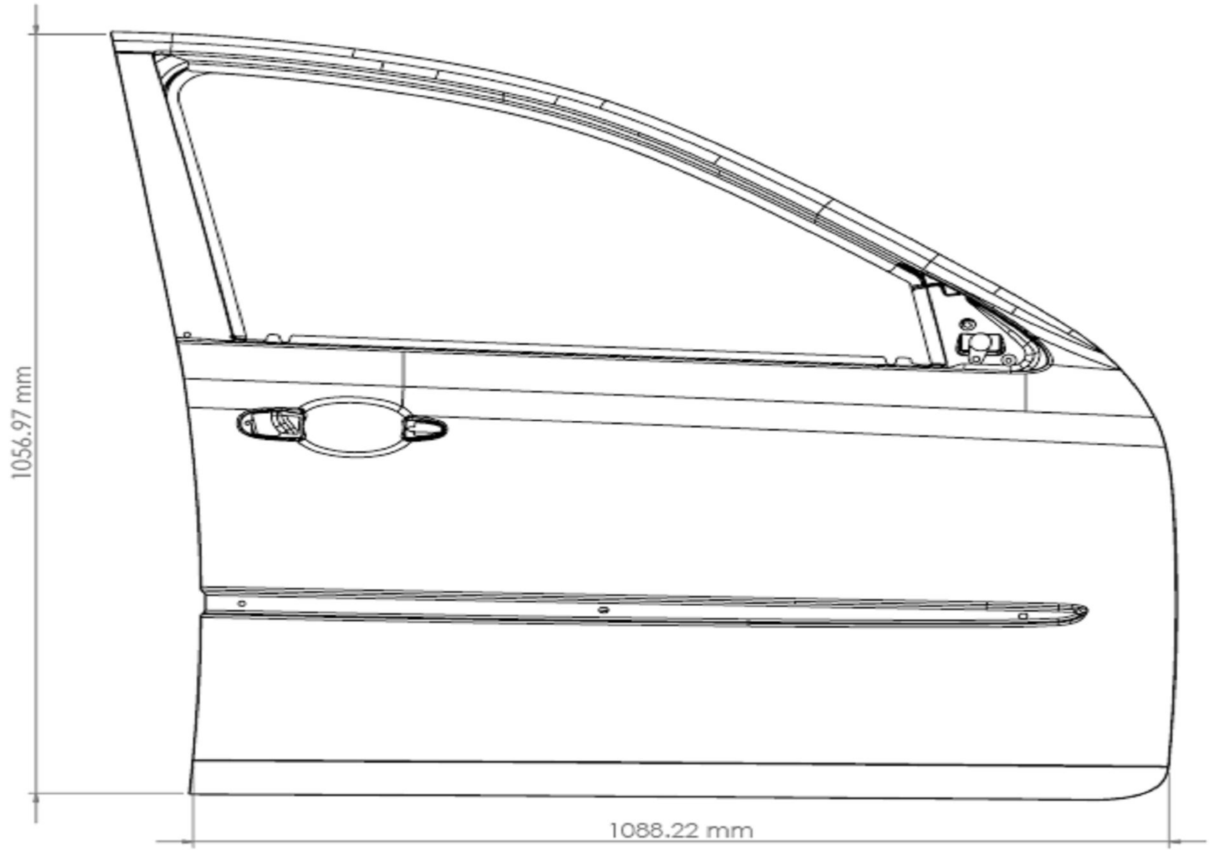
Proton Persona specifications

Model		1.6L Base		1.6L Med		1.6L High
Dimension and weight	Overall length(mm)	4477				
	Overall width (mm)	1725				
	Overall height (mm)	1438				
	Wheel base (mm)	2600				
	Kerb weight (kg)	1170	1195	1195	1220	1240
	Valve mechanism	16 –v DOHC				
	Displacement	1597 cc				
	Maximum Output	822kW/6000rpm				
	Maximum torque	148Nm/4000rpm				
	Fuel type	Petrol				
Performance	Acceleration 0-100 km/h	12.0	14.3	12.0	14.3	14.3



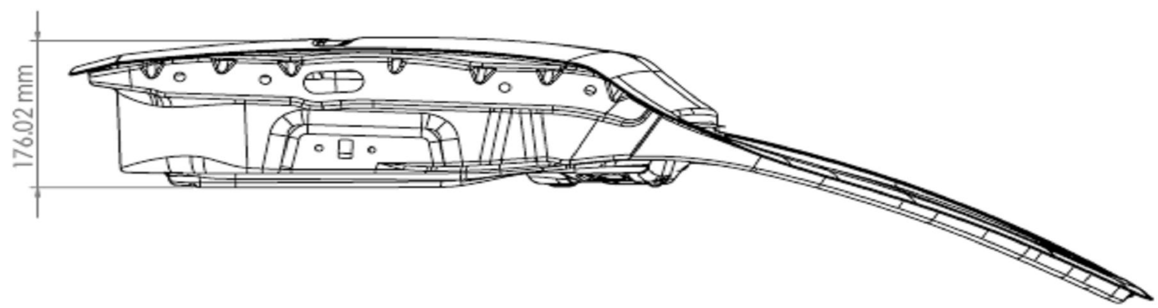
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS	DEBUR AND BREAK SHARP EDGES	WEIGHT:	TITLE: Proton Persona Door (Driver)	MATERIAL: AISI 304	DWG NO.	QTY:	SHEET 1 OF 1	SCALE 1:2
FINISH:	DO NOT SCALE DRAWING	SURFACE FINISH: TOLERANCE: (UNLESS SPECIFIED) LINEAR: ±0.1MM ANGULAR: ±0.1MM		REVISION:	UNIVERSITI MALAYSIA PAHANG Fakulti Kejuruteraan Mekanikal			A4

	NAME	SIGNATURE	DATE
DRAWN	RAJA ASHRAFUZZAIM ZOLKIPLY		
APPV'D	GAN LEONG MING		



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS	DEBUR AND BREAK SHARP EDGES	WEIGHT:	TITLE: Front View of Proton Persona Door (Driver)	MATERIAL: AISI 304	DWG NO.	QTY:	SHEET 1 OF 1	SCALE 1:2
FINISH:	DO NOT SCALE DRAWING	SURFACE FINISH: TOLERANCE: (UNLESS SPECIFIED) LINEAR: ±0.1MM ANGULAR: ±0.1MM		REVISION:	UNIVERSITI MALAYSIA PAHANG Fakulti Kejuruteraan Mekanikal			A4

	NAME	SIGNATURE	DATE
DRAWN	RAJA ASHRAFUZZAIM ZOLKIPLY		
APPV'D	GAN LEONG MING		



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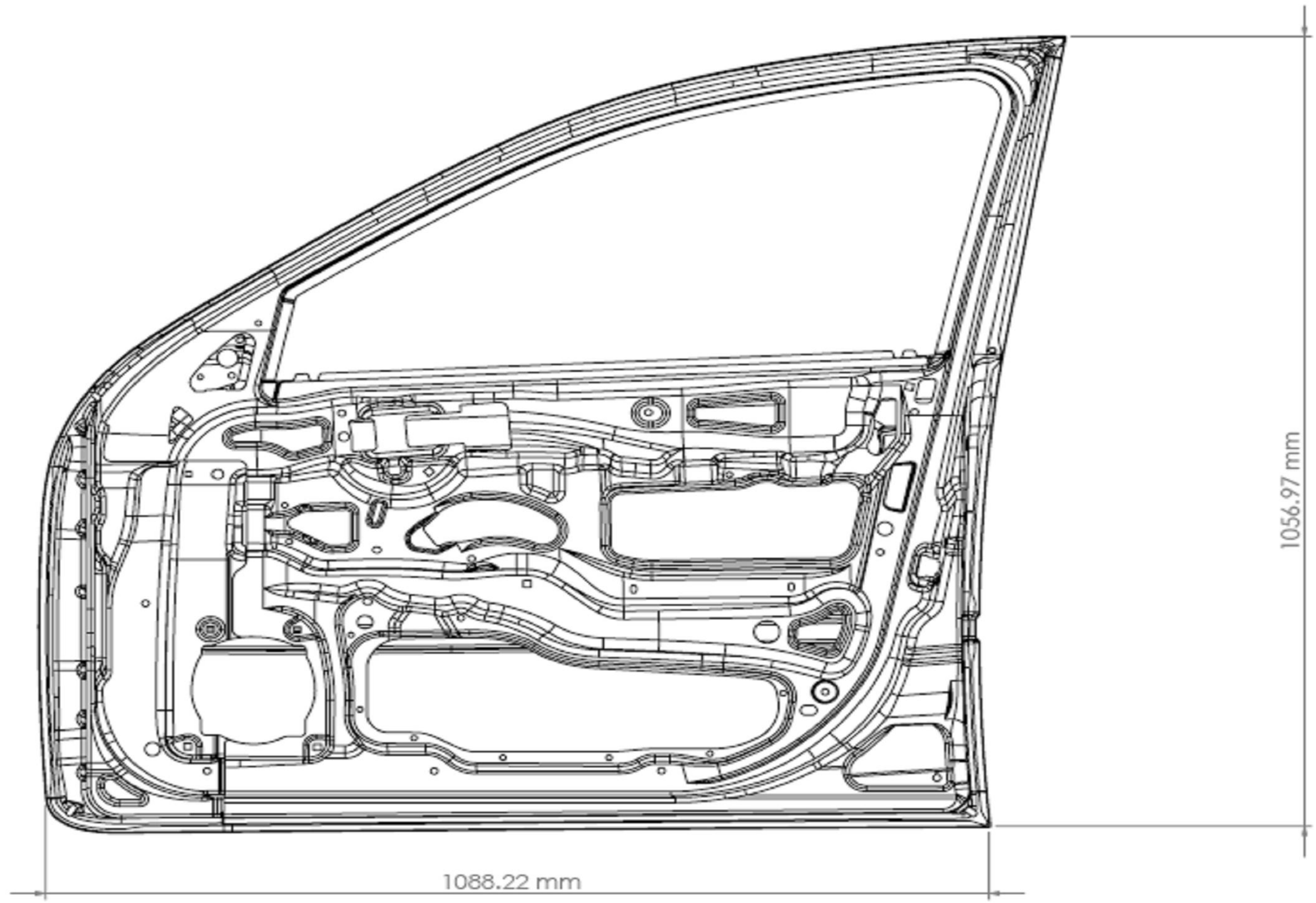
FINISH:	DO NOT SCALE DRAWING	SURFACE FINISH: TOLERANCE: (UNLESS SPECIFIED) LINEAR: ±0.1MM ANGULAR: ±0.1MM		REVISION:

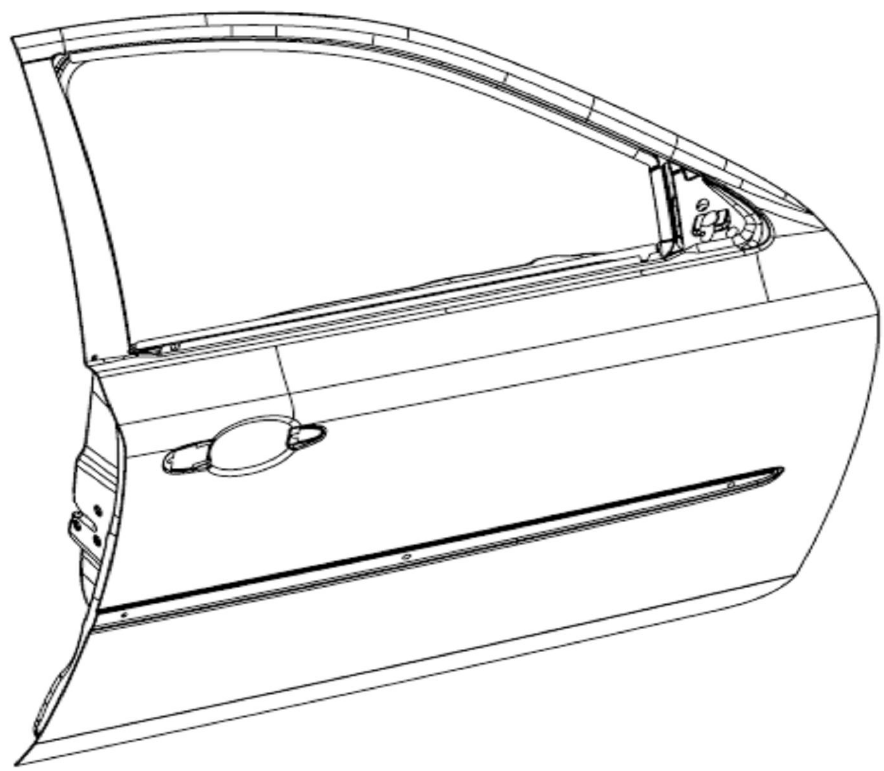
	NAME	SIGNATURE	DATE
DRAWN	RAJA ASHRAFUZZAIM ZOLKIPLY		
APPV'D	GAN LEONG MING		

DWG NO.	QTY:	SHEET 1 OF 1	SCALE 1:2
UNIVERSITI MALAYSIA PAHANG Fakulti Kejuruteraan Mekanikal			A4



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS	DEBUR AND BREAK SHARP EDGES	WEIGHT:	TITLE: Back View of Proton Persona Door (Driver)	MATERIAL: AISI 304	DWG NO.	QTY: / SHEET 1 OF 1 / SCALE 1:2
FINISH:	DO NOT SCALE DRAWING	SURFACE FINISH: TOLERANCE: (UNLESS SPECIFIED) LINEAR: ±0.1MM ANGULAR: ±0.1MM		REVISION:	UNIVERSITI MALAYSIA PAHANG Fakulti Kejuruteraan Mekanikal	A4

	NAME	SIGNATURE	DATE
DRAWN	RAJA ASHRAFUZZAIM ZOLKIPLY		
APPV'D	GAN LEONG MING		



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS	DEBUR AND BREAK SHARP EDGES	WEIGHT:	TITLE: Isometric View of Proton Persona Door (Driver)	MATERIAL: AISI 304	DWG NO.	QTY:	SHEET 1 OF 1
FINISH:	DO NOT SCALE DRAWING	SURFACE FINISH: TOLERANCE: (UNLESS SPECIFIED) LINEAR: ±0.1MM ANGULAR: ±0.1MM		REVISION:	UNIVERSITI MALAYSIA PAHANG Fakulti Kejuruteraan Mekanikal	SCALE 1:2	A4

	NAME	SIGNATURE	DATE
DRAWN	RAJA ASHRAFUZZAIM ZOLKIPLY		
APPV'D	GAN LEONG MING		