Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 03, March-2025

Construction, Development Vehicle Architecture and Enhancement of Crashworthiness Through Vehicle Simulation of an Automotive

A Thesis report submitted to

UKA TARSADIA UNIVERSITY
in Partial Fulfilment of the Requirements for the Degree of Bachelor of
Technology in Automobile Engineering

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ACKNOWLEDGMENT

This research work would not have been possible without the kind support of many people. We take this opportunity to acknowledge that who has been great sense of support and inspiration thought the research work successful.

There are lots of people who inspired me and helped, worked for our in every possible way to provide the details about various related topics thus making research and report work success. We are very grateful to Mr. Sachin Gupta (Assistant Professor) for all his diligence, guidance, encouragement and help throughout the period of research, which have enabled me to complete the research work in time. His constant inspiration and encouragement along with his valuable guidance has been instrumental in the successful completion of this Thesis . He has always been willingly present whenever we needed the slightest support from him. We also thank him for the time that he spared for me, from his extreme busy schedule.

We also express thanks to Mr. Darshan Kapadia (Head of Department of Automobile) in the Automobile Engineering Department, CGPIT for permitting me to use latest infrastructure and facility. This work is simply the reflection of their thoughts, ideas and concepts and about their efforts. Working under their guidance was a privilege and an excellent learning experience that we will 1cherish for life time.

ABSTRACT

Automobile safety is important and choosing a safer car is very important to help prevent crashes and accidents. Thus, a thorough crash-testing program is critical for the car makers and has contributed significantly to the improving safety of cars. The simulation of vehicle crashes by using computer software has become an indispensable tool for shortening automobile development time and lowering costs. It also has huge impact on the crashworthiness of an automobile. This Thesis is on the simulated crash test of an automobile and simulate a frontal impact crash of an automobile and validate the results. The aim is also to alter some of the materials of the components with a view to reduce the forces experienced during the crash. Computer models were used to test the crash characteristics of the vehicle in the crash. The model used here was that of a Chevrolet C1500 pick-up truck. The software used for the meshing the vehicle is HYPERMESH. Hyper-mesh a meshing software is widely use in industry to speeds up CAD to Finite Element Modelling (FEM) creation with the help of building tools. The software used for the simulation is LS-DYNA. It is widely used by the automotive industry to analyse vehicle designs. It accurately predicts a car's behaviour in a collision. The results obtained by the simulation were then validated by comparing it with the test results of the same test performed by the NCAC (National Crash Analysis Centre).

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1. INTRODUCTION

In modern engineering analysis it is rare to find a Thesis that does not require some type of simulation for analysing the behaviour of the model under certain specified conditions. The advantages of simulation are numerous and important. A new design concept may be modelled to determine its real world behaviour under various load, environments, and may therefore be refined prior to the creation of drawings, when few dollars have been committed and changes are inexpensive. Once a detailed CAD model has been developed, simulations can analyse the design in detail, saving time and money by reducing the number of prototypes required. An existing product which is experiencing a field problem, or is simply being improved, can be analysed to speed an engineering change and reduce its cost.
With the development of society, people have increasing demand of vehicles. Car accidents are happening every-day. Most drivers are convinced that they can avoid such troublesome situation. However, the statics shows that many are dead and thousands to millions are injured every year. Car body light weighting and crash-worthiness are two important aspects of design. During an automobile crash, some parts in the front of automobile body may have plastic deformation and absorb a lot of energy. Structural members of a vehicles are designed to increase this energy absorption efficiency and thus to enhance the safety and reliability of the vehicle. Hence, improvement of safety of automobile is must.

The finite element method is comprised of three major phases:

- pre-processing: In which the analyst develops a finite element mesh to divide the subject geometry into sub-domains for mathematical analysis, and applies material properties and boundary conditions,
- solution: During which the program derives the governing matrix equations from the model and solves for the primary quantities, and
- post-processing: In which the analyst checks the validity of the solution, examines the values of primary quantities (such as displacements and stresses), and derives and examines additional quantities (such as specialized stresses and error indicators).

1.1 CRASHWORTHINESS

First used in the aerospace industry in the early 1950’s, the term “crashworthiness” provided a measure of the ability of a structure and any of its components to protect the occupants in survivable crashes. Similarly, in the automotive industry, crashworthiness connotes a measure of the vehicle’s structural ability to plastically deform and yet maintain a sufficient survival space for its occupants in crashes involving reasonable deceleration loads. Restraint systems and occupant packaging can provide additional protection to reduce severe injuries and fatalities. Crashworthiness evaluation is ascertained by a combination of tests and analytical methods.

Crashworthiness is the ability of a structure to protect its occupants during an impact. This is commonly tested when investigating the safety of aircraft and vehicles. Depending on the nature of the impact and the vehicle involved, different criteria are used to determine the crashworthiness of the structure. Crashworthiness may be assessed either prospectively, using computer models or experiments, or retrospectively by analysing crash outcomes. Several criteria are used to assess crashworthiness prospectively, including the deformation patterns of the vehicle structure, the acceleration experienced by the vehicle during an impact, and the probability of injury predicted by human body models. ' The vehicle structure should be sufficiently stiff in bending and torsion for proper ride and handling.

1.2 CRASH-TEST

A crash-test is a form of destructive testing usually performed in order to ensure safe design standards in crashworthiness and crash compatibility for automobiles or related components. To test the cars safety performance under various conditions and during varied types of crashes, vehicle manufacturers crash test their cars from different angles, different sides and with different objects, including other vehicles. The most common types of crash tests are listed below.

- Front impact test
- Front offset crash test
- Side impact crash test
- Roll over test

1.2.1 Front impact crash test

To assess a vehicle's frontal impact crashworthiness an integrated set of test procedures is required that assesses both the car's self and partner (compatibility) protection. It has been recommended by the International Harmonisation of Research Activities (IHRA) frontal impact group that the set of test procedures should contain both full overlap and offset tests.

Figure 1.2.1 Frontal impact crash test

The European Enhanced Vehicle-safety Committee (EEVC) WG15 has helped coordinate work in Europe to understand and develop a set of test procedures to improve a vehicle's frontal impact crash performance. It has found that the main factors influencing a vehicle's compatibility are its structural interaction potential, its frontal force levels and its compartment integrity. In 2007, EEVC WG15 made a number of proposals for potential sets of test procedures, all of which contain both full width and offset tests. These were:

Set 1

- Full Width Deformable Barrier (FWDB) test to assess a vehicle's structural interaction potential and provide a high deceleration pulse to test the restraint system.
- Offset Deformable Barrier (ODB) test with EEVC barrier to assess a vehicle's compartment integrity and frontal force levels and also provide a softer deceleration pulse to test the restraint system.

Set 2

- Full Width Rigid Barrier (FWRB) test to provide a high deceleration pulse to test the restraint system.
- Progressive Deformable Barrier (PDB) test to assess a vehicle's structural interaction, frontal force levels and compartment integrity and also provide a softer deceleration pulse to test the restraint system.

Set 3

- Combination of FWDB and PDB

The aim was that this test would be suitable for regulatory implementation in the short term and also have potential for further development to include measures to assess and control compatibility in the longer term.

1.2.2 Front offset crash test

Crash tests are performed for a variety of reasons that include checking whether new designs meet engineering expectations and safety regulations, re-creating real-world crashes to study injury mechanisms, and comparing crashworthiness offered by different model designs. Because conducting a full-scale crash test is time consuming and costly, each of these endeavours relies on generalizing the results of a few tests, in many cases only one, to make inferences about other crashes under similar circumstances. Hence the issue of repeatability, or how closely the results of replicated tests resemble one another, is important.

Figure 1.2.2 Frontal offset crash test

Car Assessment Program (NCAP), the test vehicles were 1982 Chevrolet Citations identically equipped and built during the same shift at a single plant. The seats were welded in the correct adjustment position to minimize test setup differences. Head injury criterion (HIC) and chest acceleration were the two test results examined most closely.

The results of repeated crash tests of the same vehicle model were very similar in this study. Vehicle accelerations, and hence the forces acting upon the occupants, were highly replicable, as were the performances of airbag and belt systems. Measurements of intrusion, a primary focus of offset crashes, were especially repeatable. Differences between pairs of vehicles in repeated tests were much smaller than the range of intrusion measurements seen for different vehicles of the same class.

1.2.3 Side impact crash test

Side impact crash tests consist of a stationary test vehicle struck on the driver's side by a crash cart fitted with an IIHS deformable barrier element. The 1,500 kg moving deformable barrier (MDB) has an impact velocity of 50 km/h (31.1 mi/h) and strikes the vehicle on the driver's side at a 90-degree angle. The longitudinal impact point of the barrier on the side of the test vehicle is dependent on the vehicle's wheelbase. The impact reference distance (IRD) is defined as the distance rearward from the test vehicle's front axle to the closest edge of the deformable barrier when it first contacts the vehicle. Evaluation testing of the impact configuration has been previously reported. The MDB alignment calculation was configured to maximize loading to the occupant compartment and allow alignment of the driver dummy head with the flat portion of the barrier face. For most vehicles the MDB alignment also aligns the rear dummy head with some portion of the barrier. If the alignment calculation allows the flat portion of the MDB face to overlap either the front or rear tires, the impact alignment may be modified to prevent direct loading to these structures early in the crash. To date only one such vehicle has been tested by IIHS, the smart for two (186 cm wheelbase). Currently there is no set alignment rule for vehicles that fall into this category, therefore impact alignment will be determined on a case-by-case basis. Manufacturers may contact IIHS for impact point determination and/or confirmation of impact point during the vehicle development process.

Figure 1.2.3 Side impact crash test

IRD calculation:

-If wheelbase < 250 cm, then IRD = 61 cm

-If 250 cm ñ wheelbase ñ 290 cm, then IRD = (wheelbase - 2) —64 cm

-If wheelbase > 290 cm, then IRD = 81 cm

The MDB is accelerated by the propulsion system until it reaches the test speed (50 km/h) and then is released from the propulsion system 25 cm before the point of impact with the test vehicle. The impact point tolerance is 2.5 cm of the target in the horizontal and vertical axes. The impact speed tolerance is 50 - 1 km/h. The MDB braking system, which applies the test cart's service brakes on all four wheels, is activated 1.0 seconds after it is released from the propulsion system. The brakes on the test vehicle are not activated during the crash test.

The MDB consists of an IIHS deformable aluminium barrier and the cart to which it is attached. The crash cart is similar to the one used in Federal Motor Vehicle Safety Standard (FMVSS) 214 side impact testing but has several modifications. The wheels on the cart are aligned with the longitudinal axis of the cart (0 degrees) to allow for perpendicular impact.

1.2.4 Roll over test

A rollover test, particularly on road dynamic roller test, is conducted by the National Highway Traffic Safety Administration (NHTSA) essentially on SUVs, minivans and pickup trucks. Taller vehicle such as SUVs, pickup trucks and minivans are more likely to rollover after a collision or a sudden, curving movement then the usual car due to their high centre of gravity or because these kinds of vehicles are top heavy.

Figure 1.2.4 Rollover test

A rollover happens when there is dramatic effect on the vehicle balance after vehicle traverses a curve when eventually shifts the vehicle centre of gravity on one side.

Each car's reliability includes strength of the vehicle pillar holding the roof is determined in every rollover test. The pillars, as tested, should resist load they receive during the dynamic impacts or when the rolling after the severe turning manoeuvres.

1.3 METHOD OF ANALYSIS

Crash-testing requires a number of the test vehicle to be destroyed during the course of the tests and is also time consuming and uneconomical. One new recent trend that is gaining vast popularity is computer simulated crash-testing. Here instead of a real vehicle, a FE (Finite Element) model of the vehicle is generated and is used to carry out the different tests that were carried out before using actual vehicles.

There are several software packages that are equipped to handle the crash-testing of vehicles, but one of the most popular is from Livermore Software Technology Corporation called LS-DYNA.

With LS-DYNA, automotive companies and their suppliers can test car designs without having to tool or experimentally test a prototype, thus saving time and expense. While the package continues to contain more and more possibilities for the calculation of many complexes, real world problems, its origins and core-competency lie in highly nonlinear transient dynamic finite element analysis (FEA) using explicit time integration. The application of LS-DYNA covers a wide range of industries.

2. AIM AND OBJECTIVES

2.1 AIM

The aim of this Thesis is to increase the crashworthiness of a car and to reduce the effect on frontal part of a car.

2.2 OBJECTIVE

- Reduce the impact on vehicle during frontal crash test.
- To increase the toughness of the body parts and decrease the weight.
- Selection of material on the basis of strength.
- Minimizing the weight of the vehicle without compromising with safety.
- To reduce the cost for actual crash testing.
- Alternative materials in order to reduce impact shock.
- To ensure the safety of driver.
- Design optimization of the vehicle bumper to reduce the frontal impact.9

3. LITERATURE REVIEW

Simulated crash-testing is being increasingly by various institutes to study the outcome of a vehicular in various situations under different conditions. The advantage of simulation is that the FE models can be reused again and again and also the user has the freedom to change any of the parameters of the test and also the user can vary the material properties as well as the type of material of the parts in the vehicle.

The FE model was then used to simulate crash test. The FE software used here to carry out the simulation was LS-DYNA. One of the tests carried out was the Frontal-offset crash at 40 mph. Before the simulation could be carried out, several other preprocessing conditions have to be specified. The test results were verified using results from actual crash-test reports. Present runtimes on high-end workstations for LSDYNA vehicle models are still measured in days, while multi-body run-times are typically less than 1h, even for the most complex models.

Thacker et.al [1] conducted crash-testing simulation study of a 1997 Honda Accord. Originally, a real vehicle was obtained and then the vehicle was stripped down to its basic parts, each component was identified, labelled, and the material evaluated. Data that could be efficiently extrapolated from existing sources were collected.

A similar study was carried out by Cheng et.al [2], wherein the aim of the study was to reverse engineer a 1997 Honda Accord DX Sedan and to develop a FE model of the vehicle to be that can be successfully used in computational simulations of full frontal, offset frontal, side, and oblique car-to-car impact testing. The crashworthiness was then compared to existing physical data of a 2007 Jeep Wrangler that has been manufactured with all safety standards and technology. These comparisons were made to evaluate the crashworthiness of the pre safety standards.

Ibrahim KABADAYI, Bulent EKICI, Huseyin YALTRIK [3], ANCAP has recognised the global nature of the car manufacturing industry and developed a crash testing program to align with existing overseas programs. In addition to the full frontal test, an offset test using a deformable barrier was added in 1994. This test was developed for the European Experimental Vehicle Committee (EEVC) by the Transport Research Laboratory (TRL) in the UK. The test is recognised internationally and the barrier design is specified for both consumer crash test programs and for compliance with regulatory standards.

Each vehicle model tested in ANCAP undergoes a full. frontal crash test into a solid concrete barrier and an offset crash test into a barrier with a deformable aluminium face. The full frontal crash test simulates hitting a solid object or another vehicle exactly head-on and is conducted at a speed of 56 km/h. In this test the impact is spread evenly across the front of the vehicle. This test mainly evaluates the vehicle's restraint system. The offset crash test simulates hitting another car and is conducted at a speed of 64 km/h. Forty percent of the width of the car makes contact with the barrier. In this test the crash forces are concentrated on the driver's side of the vehicle. This test mainly evaluates the vehicle structure's resistance to intrusion.

The ANCAP ratings based on data provided by overseas organisations might differ from the ratings assigned by these organisations. In particular the ANCAP rating includes assessment of the results of full-frontal crash tests and takes into account the passenger injury measures and restraint performance in these tests. The ANCAP ratings also tend to place less emphasis on foot well intrusion and lower leg injury than IIHS ratings and more emphasis on structural performance than the Euro NCAP procedures. ANCAP consults with the automotive industry about the program through the Federal Chamber of Automotive Industries (FCAI), the group which represents the vehicle manufacturers and importers in Australia.

Representatives from the vehicle manufacturing companies are invited to attend the test of their products and are able to review the results before publication. ANCAP meets with the FCAI before each public launch and in early 1997 conducted a technical briefing for FCAI members on the new IIHS-style rating system. ANCAP is also working closely with the Federal Government through the Department of Transport's Federal Office of Road Safety (FORS) which administers the design standards for Australian vehicles.

Euro NCAP officially determines which car is tested in which laboratory. Governments as well as car manufacturers can suggest cars for testing. In the latter case, Euro NCAP will test three of the twenty vehicles (of the same model) that the manufacturer suggests as options. Euro NCAP groups the cars in various model classes, such as passenger car (‘small and large’), multiple purpose vehicle (MPV; ‘small and large’), SUV (‘small and large’), sports car and pick-up truck. Within these categories cars are only allowed to be compared with each other when they differ less than 150 kg in weight. By law, all new car models have to meet specific safety requirements (ECE regulations and EC directives) before they are allowed on the road. However, the European c.q. Dutch legislation only sets a number of minimum requirements that the secondary (crash) safety of new cars has to meet also known as passive safety or injury prevention). It is Euro NCAP's aim to encourage car manufacturers to exceed these minimum (crash) requirements in the interest of both the car occupants and the other traffic users, among whom pedestrians.

Early 2009, the Euro NCAP tests and assessment system were drastically revised. Gives an overview of the various Euro NCAP subtests, divided into four groups since 2009. Group 1 looks at secondary safety of adult occupants, group 2 at that of child occupants and group 3 at that of pedestrians as crash opponents of a car, and group 4 investigates the presence of a number of ‘intelligent’ safety devices. Besides seat belt reminders, these also include a number of primary safety devices, that is to say, for the prevention of crashes (earlier known as active safety). Prior to 2009, these types of safety devices were not part of the Euro NCAP assessment. The European car models have become much safer during the last few decades. Especially the stronger cage construction of European car models protects occupants increasingly better during a frontal collision. Nevertheless, there are limitations. At present, Euro NCAP does not allow for mutual mass differences in frontal car-car collisions (incompatibility), whereas this in particular is a very determining factor in the further outcome of a crash. Another phenomenon is that heavier cars have also become more unyielding (less shock absorbing) and therefore are at an advantage in a crash with a lighter car in terms of protection of the occupants. It is therefore important to set high requirements to the crash friendliness (energy absorption) of the fronts of cars and the strength and the design of cage constructions. Due to both mass and rigidity, safety for the occupants increases with vehicle mass, whereas safety for the occupants of the crash opponent car decreases with vehicle mass. As long as Euro NCAP does not test this incompatibility, the number of stars gives good insight into the safety within the same model and size class, but not between the various classes. The above incompatibility problem is all the more important because of the trend to make cars smaller and more lightweight for reasons of environmental targets. As a result, Euro NCAP and various other road safety organisations are now discussing how to deal with these differences in mass between cars. It is more effective for road safety to prevent crashes than to reduce the severity of injuries of car occupants in crashes. The attention paid by Euro NCAP to primary safety devices, such as an ESC-system, is therefore positive. It is, however, important to keep secondary safety at least the same level. The new Euro NCAP assessment now awards extra points when this kind of safety device is installed. However, until now no test methods have been available to determine the actual safe functioning, which is a limitation.

OSA has a Car Safety Assessment Committee with members from the Japan Automobile Research Institute (JARI) and Japan Automobile Manufacturers Association (JAMA). It also has regular discussions with JAMA members on NCAP related issues.

OSA conducts its full-frontal crash test program at JARI. The test is the same as for US NCAP. The numerical test results are not published as OSA believes they are of little interest to consumers. A four-category rating system (A/B/C/D) based on head injury criterion and chest acceleration is used. Recently the A category was split into A, AA and AAA levels to further discriminate vehicle safety performance.

The 1996 program tested the top selling nine vehicles across all classes and results were published early in 1997. A total of 18 models have now been reported on. OSA has tested 13 more passenger vehicles during 1997. Results were published in April 1998.

OSA believes its options to provide more vehicle safety data to consumers include:

- conduct more tests (subject to budget constraints);
- provide overseas NCAP data on vehicles which are sold in Japan; and/or - provide vehicle manufacturer test data.

OSA is reproducing US NCAP data on similar vehicles sold in Japan. OSA believes that left hand drive data can be used for right hand drive vehicles if the vehicle manufacturer agrees the vehicles are similar.

4. DESIGN AND ANALYSIS

4.1 OVERVIEW

Simulation a frontal impact crash-test of a vehicle model moving at a velocity of 15.65m/s or 35mph (≈56.3kmph) in to a rigid immovable barrier is to be carried out and analysed. It is assumed that the brakes are not applied during the crash event. The results obtained will then be validated and compared with the results of the same crash analysis performed by the NCAC (National Crash Analysis Centre). The reason for comparing with the NCAC is that the institute has already conducted the same test under the same conditions by using a physical test vehicle. Then developed a finite element model of the vehicle by the process of reverse engineering. Then again carried out the same test under the same test conditions on the finite element model and validated their results by comparing with the results obtained from the physical test.

	NCAC MODEL	TEST MODEL 1	TEST MODEL 2
Weight (Kg)	2013	1999	1843
Number of parts	251	187	187
Number of elements		60025	60025

Table 4.1 Comparison of NCAC model and Test Model

4.2 FINITE ELEMENT ANALYSIS

Finite element analysis is a numerical technique to handle complex geometry, any material properties, any boundary condition and any loading condition. Mathematical model of any geometric model describes the behaviour of geometry by differential equation and boundary condition. Mathematical model is dividing the object of interest into finite number of elements. The term degree of freedom is commonly used for physical object. If the number of degrees of freedom is finite, the model is called discrete and continuous.

When the physical object is divided into discrete parts, then the infinite degree of freedom is converted into finite degree of freedom. Each part of the discretized body called element. Every element has one or more nodes. Elements are connected to each other through these nodes. Displacement boundary conditions and surface loading conditions are the constraints.

4.3 VEHICLE MODEL

A 3D Computer Aided Design (CAD) model of the pickup truck Chevrolet C1500 was received. This CAD file was opened in NX. It was a huge assembly, which had many sub-assemblies like powertrain assembly, chassis assembly, etc.

The vehicle model assembly consisted of 187 components. Many parts in the chassis like nuts, bolts, name plate, etc were deleted as these parts do not add any significance to the study here. These parts do not contain any loads or any constraints. The deletion of these parts reduces the complexity in the chassis structure and also decreases the total simulation time.

After deleting the redundant parts, the thickness of all the remaining parts was measured and noted. The assembly was saved as a .step file format to be imported in Hyper-Mesh. These parts were all thin structures, i.e. the third dimension was very small compared to the other two dimensions.

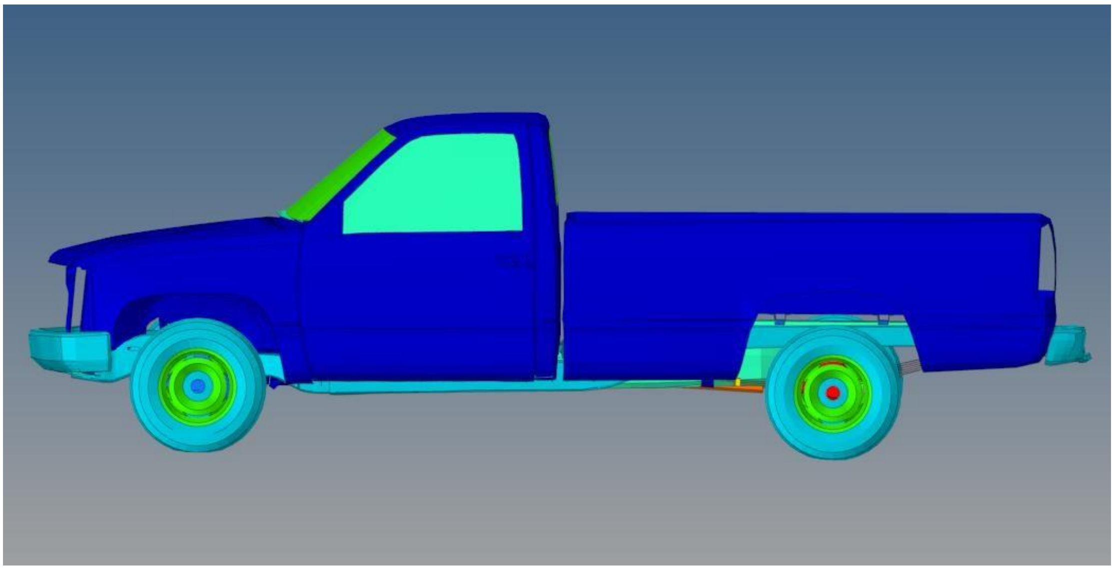

Figure 4.3.1 Vehicle CAD model

4.4 MESH GENERATION

After deleting the unnecessary parts, the CAD file was imported to Hyper-Mesh in step format. Hyper-Mesh automatically places each part in a collector called component. The component in Hyper-Mesh is an entity which contains the geometry and the mesh for a particular part. Every component is linked to a material and a property. Almost all the parts in the vehicle were thin structures. It is not advisable to mesh these parts with 3D elements because if we do so, we would need at least 3 to 4 elements across the thickness. This will increase the total number of elements, which in turn increases the simulation time drastically. For this reason, the decision to perform the 2D meshing for the chassis was taken. Whenever 2D mesh is done, Hyper-Mesh creates shell elements on the surface. Shell elements have no visual thickness representation. The user assigns a thickness to the shell elements. The software assigns this thickness symmetrically to the mesh, assuming that the mesh is at the mid plane of the component. For this reason, the first step in 2D meshing was to extract the mid-surface of all the components. The method of extracting mid surfaces has been discussed in Altair [8]. There is an auto- mid surface extraction option in Hyper-Mesh which extracts the mid surface. The mid surface of each part has been extracted and is saved in a separate component. After creating the mid-surfaces, a geometry clean-up was performed where any discrepancies in the CAD was corrected. Once the surfaces were checked, the 2D mesh was generated. Hyper-Mesh 2D Auto mesh option was used. In Auto mesh the user can select the surfaces to mesh and provide a target element size & type and the software meshes the part. There are two types of 2D shell elements in Hyper-Mesh, tries (3 node triangle element) and quads (4 node quadrilateral elements).

	TEST MODEL 1	TEST MODEL 2
Number of nodes	66636	66636
Number of elements	60025	60025

Table 4.4.1 Number of elements and nodes

All the surfaces are meshed with both types of elements. All the elements were first order elements. Some of the parts in the vehicle model have to mesh with 3D element because all the 3dimension are significant large. Parts like engine, transmission system have to mesh with 3D element. After meshing, all the components had to be connected. In reality most of the parts in the vehicle are welded. A similar thing was performed in FEA where all the components are connected together by weld connections. HyperMesh has a connector option, where the user can connect parts by weld. The nodes of the edge of a part are selected, and the parts to be welded are selected. A 1D element is created connecting the two nodes. There are many types of 1D elements which can be used for this function. As there was no data about the welds actually used, a Rigid element was used.

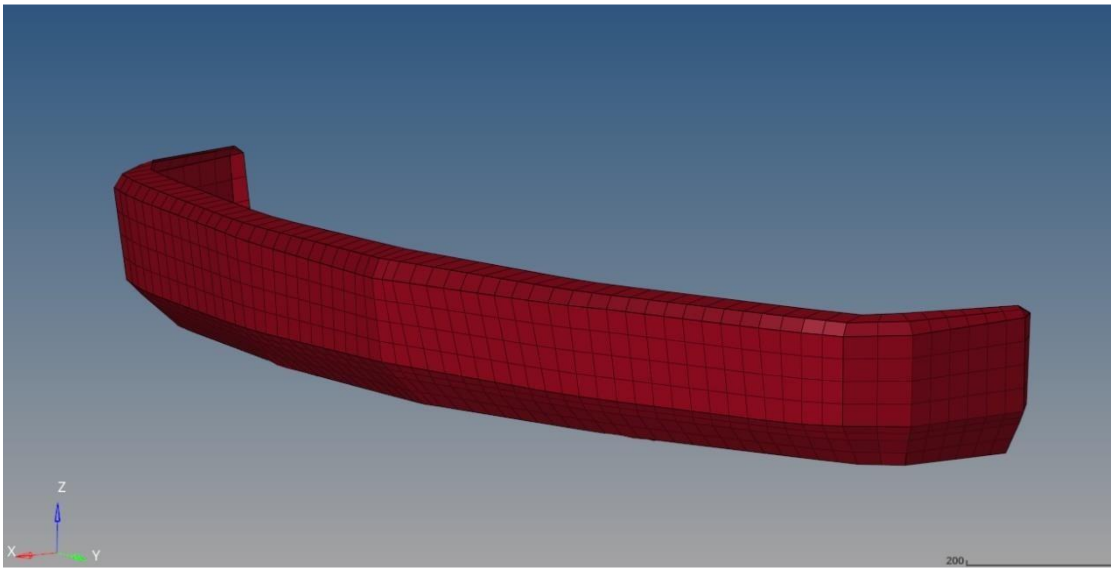

Figure 4.4.1 Bumper 2D mesh

Figure 4.4.2 Door 2D mesh

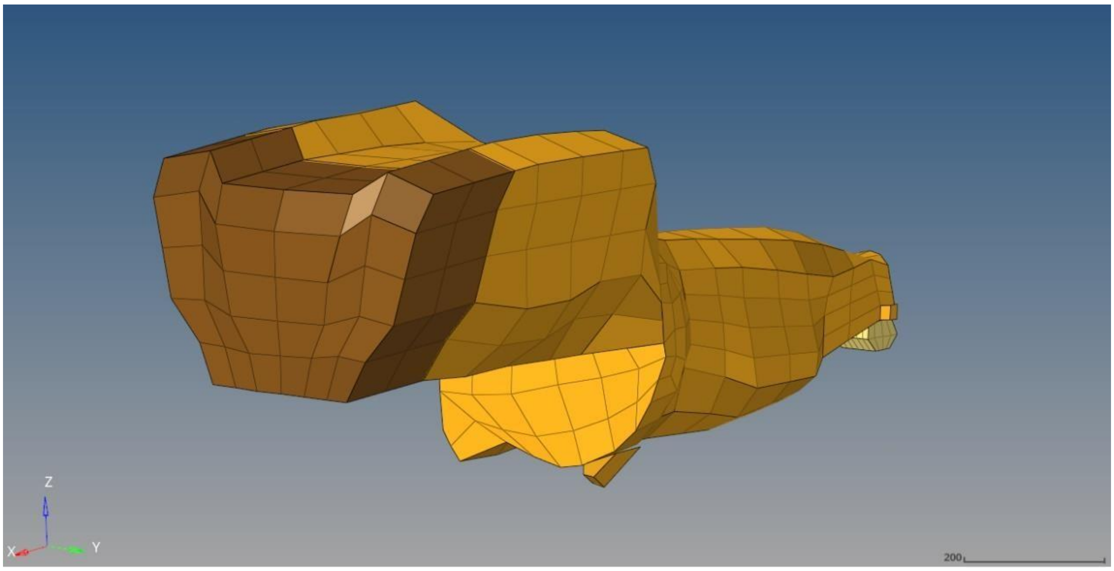

Figure 4.4.3 Engine 3D mesh

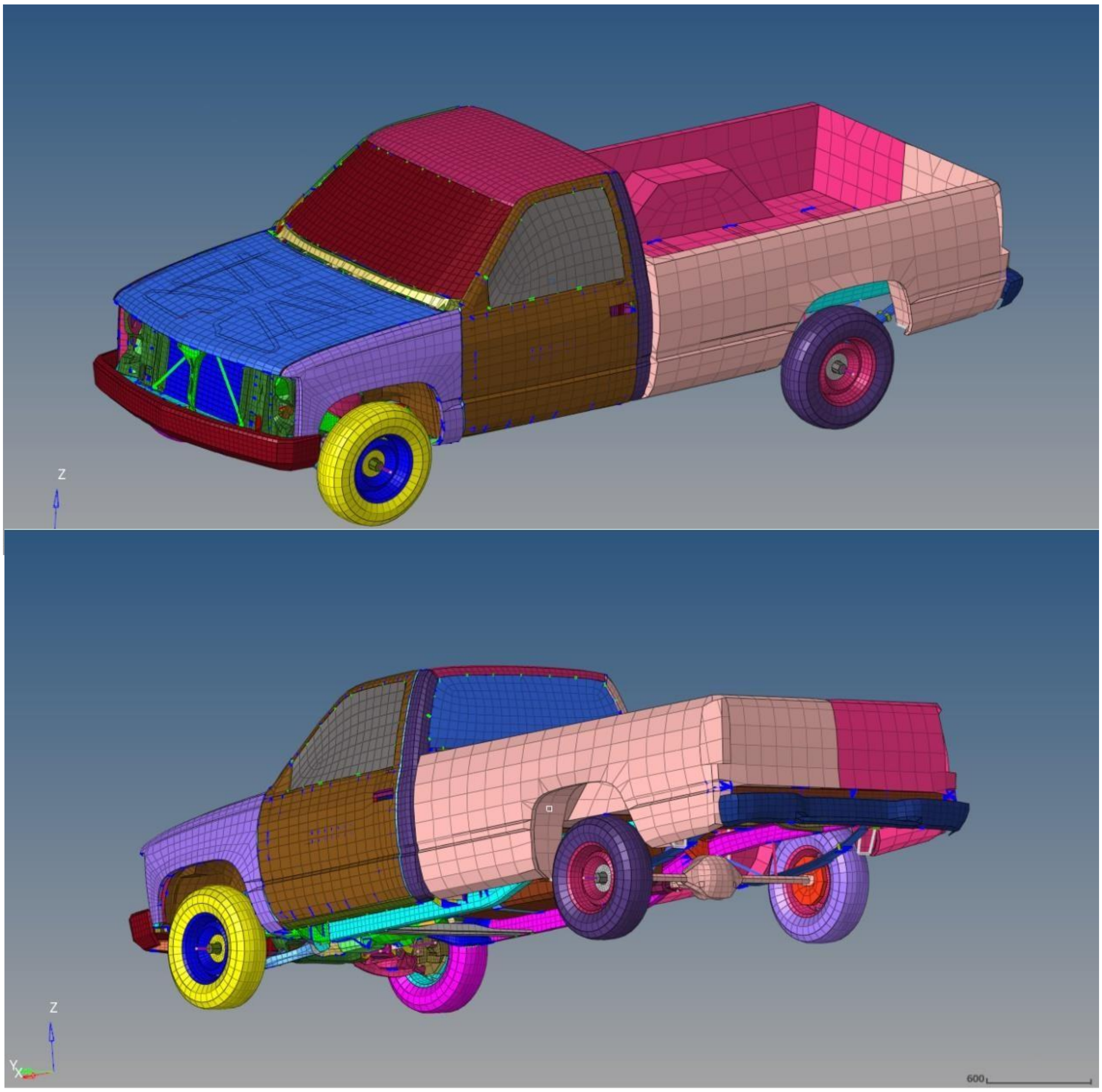

Figure 4.4.4 FE model of a Chevrolet C-1500

Quality Parameters	Requirement of entity unit quality
Aspect ratio	> 5.000
Warpage angle	> 5.000
Skew angle	> 60.00
Jacobian	< 0.700
Maximum Quad angle	> 135.00
Minimum Quad angle	< 45.00
Maximum Triangle angle	> 120.00
Minimum Triangle angle	< 20.00

Table 4.4.2 Statistics of mesh quality

4.5 METHODOLOGY

The frontal-impact crash-testing is conducted using a Chevrolet C1500 as the test FE model. The vehicle has an initial velocity of 35 mph (approx. 56 kmph) before it impacts the wall. The simulation is given a termination time of 0.15secs. The reason for termination time is that for rigid barriers, deceleration rates are very high. Numerous instrumental tests carried out in the past show that most energy transfer in a head-on or frontal vehicle impact with a rigid barrier occurs within 0.2 seconds and can be as short as 0.07 to 0.02 seconds.

To the generated model simulation is done in 3 steps:

1. Pre processing
2. Solver
3. Post processing

4.5.1 Element Formation

The completed model contains approximately 187 parts, 61 materials and 60025 elements and 66636 nodes. Structural components and specific element types used in the model include:

- Solid elements
- Bialystok - say shell element
- Hughes-Liu beam element

4.5.2 Alternative Material

Due to the age of the vehicle, the majority of the components were constructed of mild steel. However, in light of recent developments in manufacturing processes, the use of lighter substitutes to steel in the construction of the vehicle components has been steadily increasing. One of the most widely substitutes for steel is aluminium. In considering the total life-cycle of an automobile covering four stages (premanufacturing, manufacturing, use, and post-use), it is apparent that during the operational stage of a vehicle, aluminium is proven to be a reliable alternative for traditional materials currently used in automotive body structures largely due to its cost effectiveness and superior performance due to light weight.

In Test model 1, the materials used are the original materials that were used to manufacture the vehicle. However, in Test model 2, the materials used were updated in relation to the increased use of lighter alloy metals for manufacturing automobiles. The materials that were used in the two test models are:

- AA 3005
- AA 5182
- AA 5454
- A 319

MATERIAL	**PROPERTY**
AA5182	Density - 2.65 g/cm^3 Elastic modulus - 69.6 GPa Poisons ratio - 0.33 Yield strength - 130 MPa
AA5454	Density - 2.8 g/cm^3 Elastic modulus – 80 GPa Poisons ratio - 0.33 Yield strength - 180 MPa
A314	Density - 2.79 g/cm^3 Elastic modulus – 80 GPa Poisons ratio - 0.33 Yield strength - 130 MPa
AA3005	Density - 2.73 g/cm^3 Elastic modulus – 69 GPa Poisons ratio - 0.3 Yield strength - 165 MPa

Table **4.5.2.1** Material properties

Material		**Test model 2**
Aluminium	AA 3005	Radiator
	AA 5182	Door, Hood, Fonder, Wheel housing, Bumper
	AA 5454	Tire rim
	A 319	Engine

Table **4.5.2.2** Material used in Test model 2

4.5.3 Boundary Conditions

A boundary condition is a place on a structure where either the external force or the displacement are known at the start of the analysis. In this way, boundary conditions are where the structure interacts with the environment either through the application of an external force or through some restraint that is imposing a displacement. For a structural analysis problem to be solvable, every location on the boundary of our structure must have a known boundary condition, either a known force or a known displacement. The known force or displacement may have some magnitude or it may be zero. For example, we may know that there are locations on our structure that have no external force. This would be a zero-force boundary condition. A displacement boundary condition that is zero is equivalent to the structure being held in place at that location.

The function of the boundary conditions is to create and define constraints and loads on finite element models. To simulate a full vehicle car crash, all loads and boundary conditions that occur in the actual crash event need to be modelled. Just as a car is subjected to gravitational loads in real life, the simulated model should have a representative gravity force applied. Friction forces between the tires and the road surface play an important role in how the vehicle behaves on impact, so these have to be accounted for in the simulation. The tires in real life are filled with air and will affect the severity of the impact. Modelling of the tires has to be able to simulate the interaction of the tires upon impact. A velocity has to be applied to the vehicle in a manner as to not impart any unrealistic acceleration or cause the simulation to run for an extended amount of time. Fortunately, Ls-Dyna provides methods to simulate all of these requirements.

5. RESULT & DISCUSSION

Two simulations were carried out for the frontal impact; the Test model 1 had the same materials as the NCAC model while in the Test model 2, newer materials for the parts were employed. The results obtained were then validated with the results obtained of similar simulations performed by the NCAC.

The sequence of images shown below is the image of the vehicle before and after it impacts the rigid wall with the specified velocity of 35mph (≈56kmph). A collection of images showing the impact of the Test model 1 as it impacts the wall from time t=0 to t=0.15secs at time intervals 0, 0.05, 0.10 and 0.15sec.

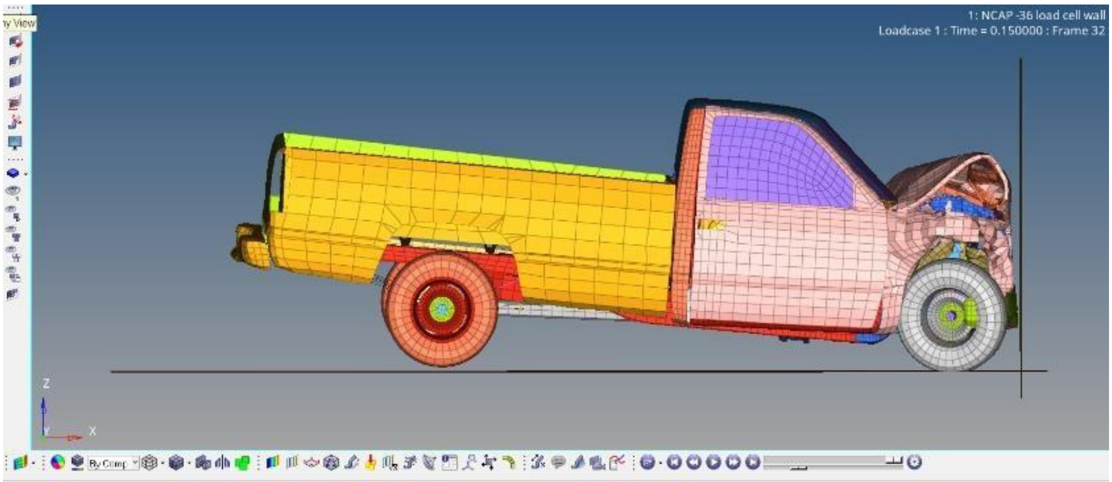

Figure 5.1 Crash sequence of test model 1 in time interval 0.0 to 0.05

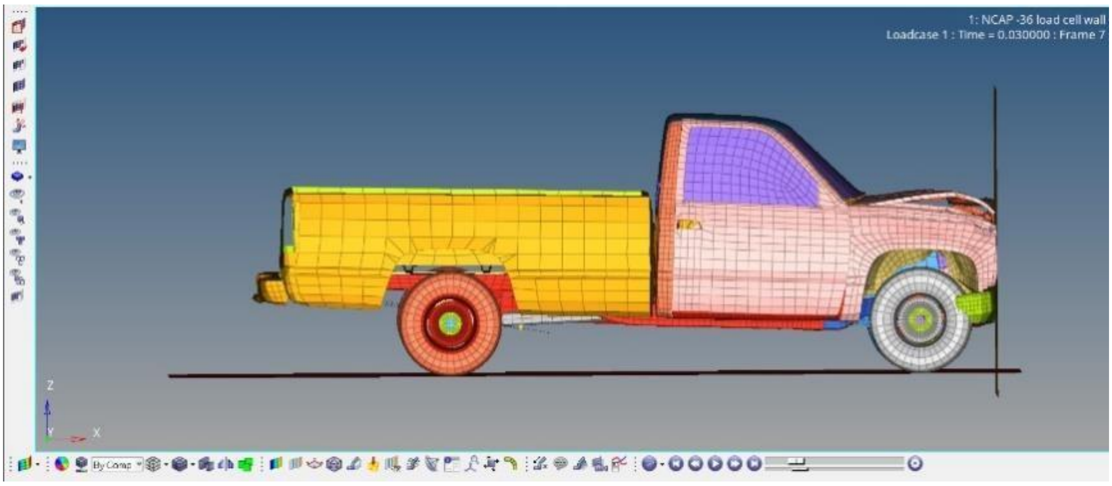

Figure 5.2 Crash sequence of test model 1 in time interval 0.05 to 0.10

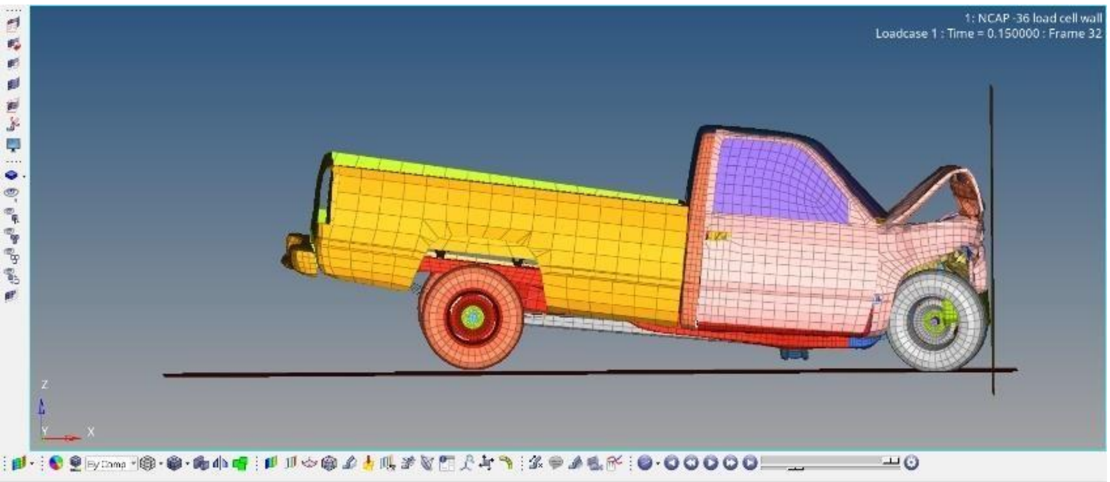

Figure 5.3 Crash sequence of test model 1 in time interval 0.10 to 0.15

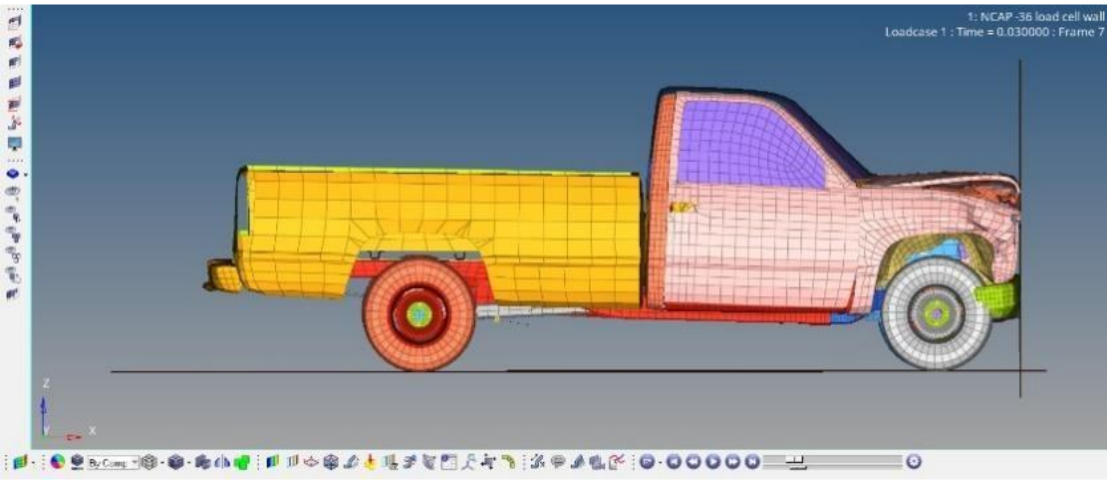

Figure 5.4 Crash sequence of test model 2 in time interval 0.0 to 0.05

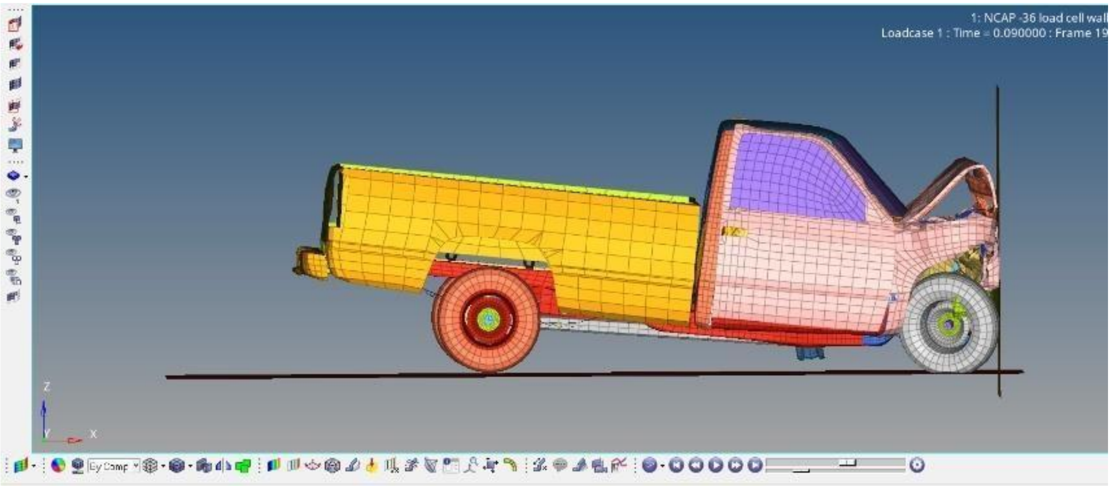

Figure 5.5 Crash sequence of test model 2 in time interval 0.05 to 0.10

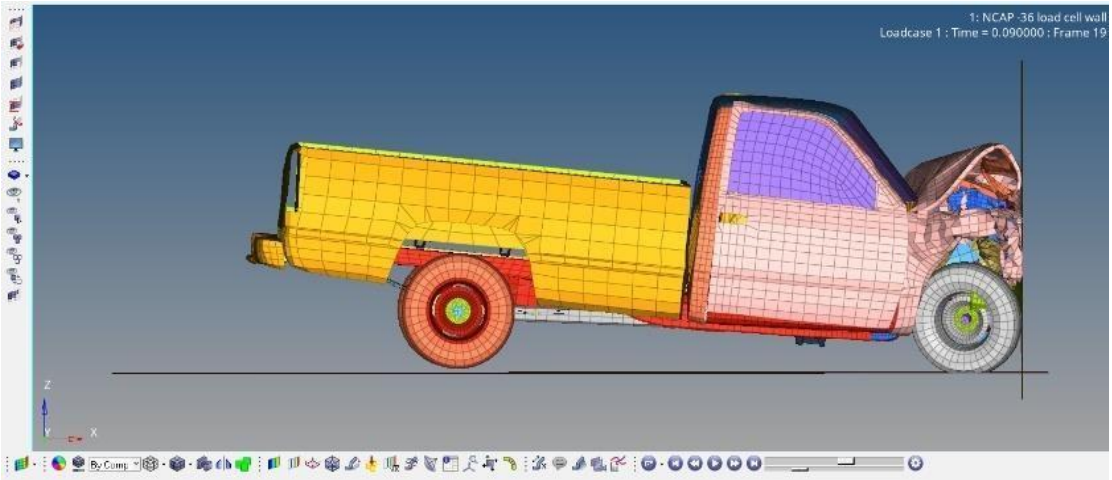

Figure 5.6 Crash sequence of test model 2 in time interval 0.10 to 0.15

5.1 ENERGY BALANCE GRAPHS

First of all, the energy balance graphs between the Test model 1 and Test mode 2 are compared to comprehend the performance of Test model 2 with respect to Test model 1.

Graphs showing the Kinetic energy, Internal energy and the Total energy Vs Time obtained after the simulation are displayed for both the simulations and also for the NCAC test.

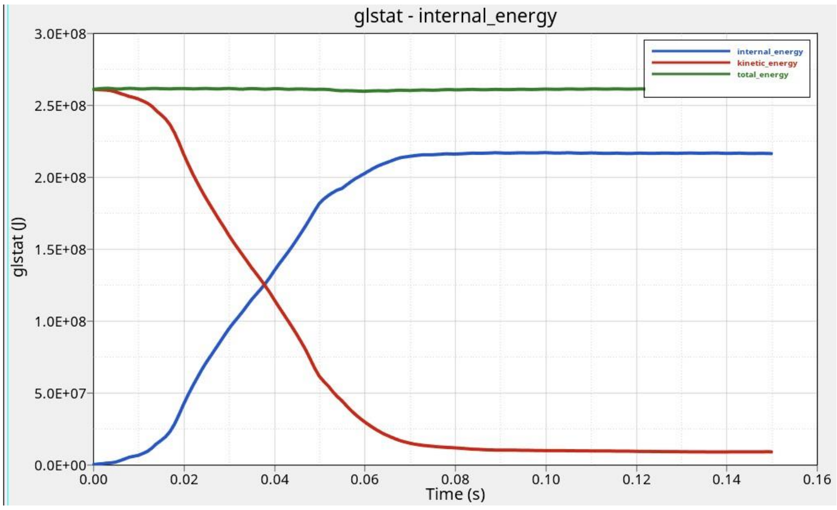

Figure 5.1.1 Energy graph of test model 1

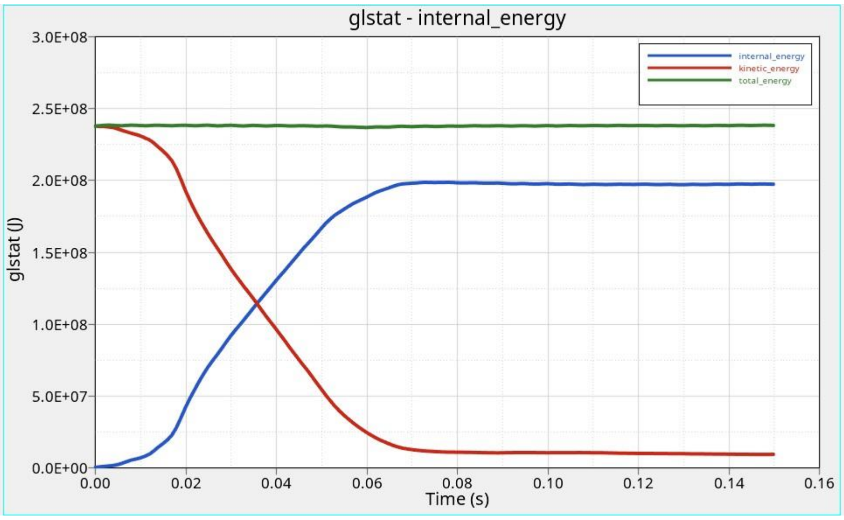

Figure 5.1.2 Energy graph of test model 2

As observed, the most of the energy of the impact is absorbed by the bumper, radiator, engine and the rails. These components absorb most of the energy of the crash before the tires impacts the wall. The maximum values of kinetic energy of the Test model 1 and Test model 2 are 239.126kJ and 208.301kJ respectively. For the Test model 2, whose main purpose was the reduction of the weight of the vehicle, the lower values of the results are not unexpected. The Test model 2 will experience lower forces as a result of its lower weight.

5.2 VELOCITY VS TIME GRAPH

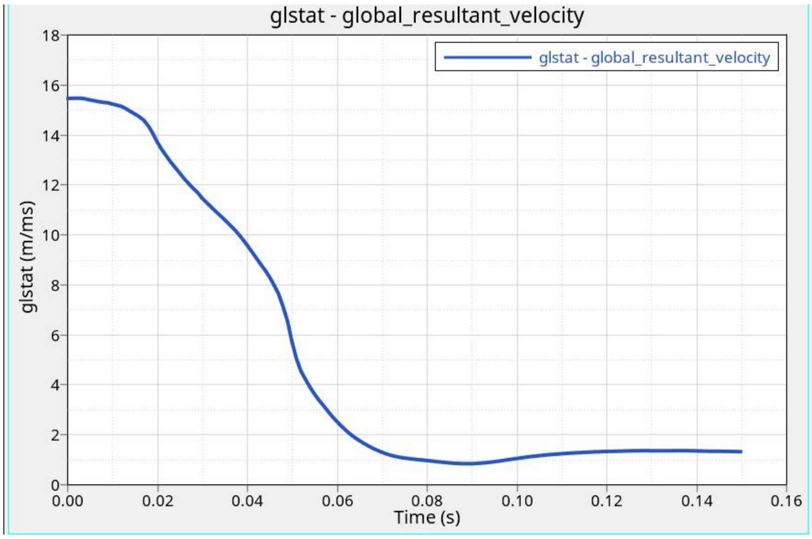

Figure 5.2.1 Velocity vs time graph of Test model 1

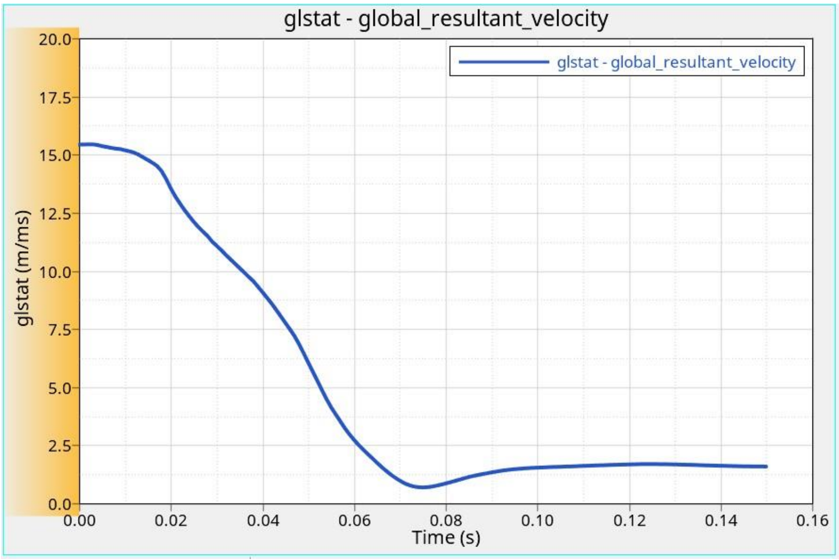

Figure 5.2.2 Velocity vs time graph of Test model 2

As can be seen from the graph, the velocity profiles of both the Test models follow very similar profiles. Here also there is the presence of a small negative velocity towards the end of the crash event. This is caused as a result of the forces generated due to the impact of the vehicle against the wall.

6. CONCLUSION

The overall objective of the report was to simulate a Frontal crash-test, validate the results of the simulations obtained from the crash-test and improving crash worthiness of a vehicle. Simulation was performed using the LS-DYNA software package.

1. The results of the simulations were validated by comparing with the results of the NCAC model simulation.
2. As was observed, the bumper, engine and the rails absorb most of the energy before the wheel impacts the wall. Almost half of the energy of the crash is absorbed by these components after about 0.04sec of the crash initiation.
3. It has been observed that there is minimum deformation of the cabin and also there was minimum intrusion of the components into the cabin. Therefore, it can be assumed that the occupants in the cabin would not be caused any injury by a component intruding into the cabin in the event of the crash.
4. The graphical results obtained all showed that the test models 1 behaviour were similar to that of the NCAC model throughout the crash event.
5. The slightly different behaviour of the Test model 2 can be attributed to the fact the material of the components were changed which had change the some of the outcome of the simulation.
6. The Energy Absorption of the vehicles frontal body components is more in the test model 2 compared with test model 1, because of the material change in the test model2. 7. Due to the reduction of the weight of the Test model 2, will experience lower valve of forces. We can say that the force experience by the occupants will be lower than Test model 1, hence improving the crash worthiness of the vehicle.

7. REFERENCES

[1] J.G. Thacker, S.W. Reagan, J.A. Pellettiere, et.al, “Experiences during development of a dynamic crash response automobile model”, Journal of Finite Element Analysis and Design 30 (1998) 279-295.

[2] Z.Q. Chenga, J.G. Thackera, W.D. Pilkeya, W.T. Hollowellb, et.al, “Experiences in reverse-engineering of a finite element automobile crash model”, Journal of Finite Elements in Analysis and Design 37 (2001) 843–860.

[3] Abdullatif K. Zaouk, Nabih E. Bedewi, Cing-Dao Kan, et.al, “Validation of a nonlinear finite element vehicle model using multiple impact data”, The George Washington University FHWA/NHTSA National Crash Analysis Center.

[4] M.A. Virginia, “Crashworthiness of a Pre-NCAP Safety Standard Light Truck and Corresponding Suspension Analysis”, Wichita State University (2001).

[5] Gary R. Consolazio, Jae H. Chung, Kurtis R. Gurley, “Impact simulation and full scale crash testing of a low profile concrete work zone barrier”, Journal of Computers and Structures 81 (2003) 1359–1374.

[6] S. W. Kirkpatrick, “Development and Validation of High-Fidelity Vehicle Crash Simulation Models”, SAE Publications, Presented at the 2000 International Congress and Exposition (2000) SAE Paper No. 00PC-248.

[7] Geoff Davis, “Materials for Automobile Bodies”, Elsevier, U. K. (2003) 10-60.

[8] J.O. Hallquist, “LS-DYNA Keyword User Manual”, Livermore Software Technology Corporation (1997).

[9] Zhipeng Zeng, Yanshu Zhang,Yi Zhouc, et.al, “Superplastic Forming of Aluminum Alloy Car Body Panels”, Materials Science Forum 475-479 (2005) 3025-3028.

[10]U.N. Gandhi and S. J. Hu, “Data-Based Approach in Modeling Automobile Crash”, Jouranal of Impact Engineering 16 (1995) 95-118.

[11]A. Deba, M.S. Mahendrakumara, C. Chavan, J. Karve, D. Blankenburg, S. Storenb, “Design of an Aluminium-Based Vehicle Platform For Front Impact Safety”, Journal of Impact Engineering 30 (2004) 1055–1079.

[12]THE OFFSET CRASH TEST -A COMPARATIVE ANALYSIS OF TEST METHODS (Tomiji Sugimoto, Yoshiji Kadotani, Shigeru Ohmura Honda R&D Co., Ltd., Japan M. Young, The Technical Writer’s Handbook. Mill Valley, CA: University Science, 1989.

[13]Convergence ergence of finite elements (Prof. J. Chessa, University Texas; http://youtu.be/YRJ0c8uO8iU)

[14]COMPARISON OF UNIVERSITY OF MICHIGAN CIREN CASES TO EXISTING TYPES OF CRASH TESTS (Bridget O’Brien-Mitchell, Kacy Bailey, Daniel Faust, Jack Jensen, Julie Kleinert, Christine Wodzinski, Stewart Wang. University of Michigan Program for Injury Research and Education United States).

[15]PASSENGER VEHICLE CRASH TEST PROCEDURE DEVELOPMENTS IN THE VC-COMPAT THESIS Robert Thomson Chalmers University of Technology Sweden Mervyn Edwards TRL, Limited (Transport Research Laboratory) United Kingdom.