KAUNAS UNIVERSITY OF TECHNOLOGY

MECHANICAL AND DESIGN FACULTY

Karthik Babu Sugumaran

CRASH TEST ON BUMPER

Final project for Master degree

Supervisor
Assoc. Prof. Dr.Valdas Eidukynas

KAUNAS, 2016

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Final project for Master degree
Mechanical Engineering (code ME-M3/2)

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KAUNAS, 2016

KAUNAS UNIVERSITY OF TECHNOLOGY

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Mechanical Engineering ME M3/2
(Title and code of study programme)

"Crash Test on Bumper"

DECLARATION OF ACADEMIC HONESTY

13 January 2016
Kaunas

I confirm that a final project by me, **Karthik Babu Sugumaran**, on the subject "Crash Test on Bumper" is written completely by myself; all provided data and research results are correct and obtained honestly. None of the parts of this thesis have been plagiarized from any printed or Internet sources, all direct and indirect quotations from other resources are indicated in literature references. No monetary amounts not provided for by law have been paid to anyone for this thesis.

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KAUNAS UN IVERSITY OF TECHNOLOGY
FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:
Head of Mechanical Engineering Department

______________________ *(Signature, date)*

Vytautas Grigas
(Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme MECHANICAL ENGINERING

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Crash Test On Bumper

Approved by the Dean 20__ y. _________________ m.__ d. _ Order No. ______________

2. Aim of the project

To model and analyze a better material for bumper in order to withstand impact.

3. Structure of the project

1. To model a bumper using CATIA V5
2. To conduct simulation of crash test on bumper with different materials using ANSYS 14.5.
3. To obtain the results of deformation and stress distribution over the bumper during impact.
4. To calculate Factor of Safety from the obtained stress values.
5. To analyze and propose a better material for bumper to withstand impact.

4. Requirements and conditions

ANSYS 14.5 for analysis and CATIA V5 for modelling.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2016 January 14th.

Given to the student

____

Task Assignment received ______________________ ______________________
(*Name, Surname of the Student*) (*Signature, date*)

Supervisor ______________________ ______________________
(*Position, Name, Surname*) (*Signature, date*)

Contents

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Kaunas, 2016.54p.

SANTRAUKA

Automobiliai paprastai turi priekinį ir galinį bamperius kurie avarijos (smūgio) metu pirmiausiai ir yra deformuojami. Taigi jie skirti apsaugoti kitas automobilio dalis nuo pažeidimų. Jie taip pat sugeria smūgio energiją ir paskirsto ją automobilio rėmui ar korpusui. Taigi šiame darbo siekiama padidinti bamperio smūginį stiprumą naudojant efektyvesnes medžiagas ar modifikuojant jo konstrukciją.

Šiame darbe tiriamas ir modifikuojamas siekiant gauti tvirtesnį smūginiam stiprumui lengvojo automobilio bamperis. Bamperio geometrinis modelis kurtas integruota erdvinio modeliavimo sistema CATIA V5, o smūginė stiprumo analizė atlikta universalia baigtinių elementų sistema ANSYS 14.5. Skaitinė bamperio analizė atlikta naudojant jo gamybai skirtingas medžiagas siekiant surasti labiausiai tinkamą.

Atliekant skaitinę bamperio smūgio į kliūtį analizę modelio kraštinės sąlygos, kaip pavyzdžiui, pradinis greitis, bamperio storis, atstumas iki kliūties visais tirtais atvejais parinktas pastovus. Taip padaryta siekiant korektiškai palyginti gautus skaičiavimo rezultatus. Tyrimai atlikti kai bamperio medžiaga plienas, aliuminis, Plastikas ABS, Polipropilenas (PP), poli karbonatas (PC), 30% stiklo pluoštu užpildytas ABS, 30% stiklo pluoštu užpildytas PP, 30% stiklo pluoštu užpildytas PC ir ABS su plieninėmis standumo briaunomis.

Skaitinė analizė atlikta esant smūgiui kai pradinis greitis mažas – 4 m/s arba 25,2 km/h. Taigi šiame darbe nagrinėtas tik atvejis bamperis deformuojasi nežymiai, nepaliesdamas bamperio nešančiojo deformacinio rėmo. Tikslas, kad esant nedideliam smūgiui bamperio dekoratyvinė dalis liktų galimai mažiau pažeista ir nereikalautų remonto po nežymaus smūgio.

Bamperis konstrukcija atitinka Jungtinių tautų nuostatų šių dienų sportinio lengvojo automobilio. Bamperio analizė atlikta baigtinių elementų metodu (ANSYS 14.5 programine įranga) ir gauti skaičiavimų rezultatai įgalina pateikti rekomendacija parenkant medžiagą tokio tipo bamperiui.

Raktiniai žodžiai

CATIA V5, ANSYS, bamperis, smūgio analizė, įtempiai, deformacijos, sustiprinimas stiklo pluoštu

SUMMARY

A bumper forms the front and the rear most part of any vehicle thus any impact on the vehicle should be sustained by these bumpers initially. A very good bumper safeguards other parts of the vehicle including the occupants of the vehicle. It absorbs energy during the impact and dissipates it to the frame and vehicle body. Hence researchers focus on increasing the impact strength of these bumpers either by using efficient materials or by improving the design of the bumper.

In the present work, a bumper of a passenger car is designed, modified and analyzed for impact strength. The bumper is designed using CATIA V5 and analyzed using ANSYS 14.5. Analysis of the bumper is carried out by using different materials in order to study the material behavior during the impact.

During this analysis process all the boundary conditions like the velocity of the bumper, wall thickness of the bumper, distance of the bumper from the wall are maintained to be constant. It is done so in order to compare the effects of the material during the crash .The materials studied are Steel, Aluminium,AcrylonitrileButadiene Styrene(ABS), Polypropylene(PP) , Polycarbonate(PC), 30% Glass Filled ABS, 30% Glass Filled PP , 30% Glass Filled PC and ABS with steel ribs .

All these bumpers are tested for low velocity impact at 7 m/sec or 25.2 Km/hr . Only low velocity impact is considered, as energy absorption and dissipation can be clearly studied during low velocity impact whereas in high velocity impact these studies is not so clear due to the crash of the bumper in a short time. This could improve the overall crashworthiness design of the car.

The bumper is modeled according to the United Nation Regulations as the modeled bumper is referred for dimensions from a present day running Sports Utility Vehicle .This bumper after analyzing through the Finite Element software (Ansys 14.5) produces the results and these results are further compared in order to conclude a better material for the car bumper.

KEYWORDS

CATIA V5, ANSYS, STRESS, DEFORMATION, GLASS FIBRE REINFORCEMENT.

INTRODUCTION

Car bumper is the front most part or rear most part. It is designed to sustain the impact loads without affecting other parts of the car. Car accidents are becoming common in the present day roads. Due to high discipline in traffic regulation the drivers are confident in avoiding accidents. But the statistics shows that ten thousand dead and hundreds of thousands to million wounded every year. Hence, improvement in the automobile safety structure is a prerequisite to decrease the numbers of accidents. One of the main key system in a automobile is the bumper system. Bumper systems are designed in such a way it reduces or prevents physical damage to the front or rear ends of passenger in motor vehicles in a sudden impact condition. A bumper provides protection to the hood, trunk, grill, fuel, exhaust and cooling system and also to the safety related equipment such as parking lights, headlamps and taillights. A car bumper is said to be good in design only when it protects the passengers and also light in weight for a better fuel efficiency.

An International standard is being followed all over the world for the bumper except North America .In this standard a bumper has to qualify a straight impact at a speed of 4 km/h (2.5 mph) to the front and the rear, and to the corners of front and rear bumper it is 2.5 km/h (1.6 mph) at 45.5 cm (18 in) above the ground with the vehicle loaded or unloaded. In North America they follow a standard namely FMSS: Federal Motor Vehicle Safety Standards and in Canada CMVSS: Canadian Motor Vehicle Safety Standards.

A better performance of a bumper is achieved by a combination of careful design and material selection and a particular balance of stiffness, strength and energy absorption can be achieved. Stiffness and Energy absorption are essential criteria in designing a bumper. Stiffness is important because vehicle design consideration limits the packaging space for the bumper design to deform under load and Energy absorption is important because bumper must withstand the impact force thus transmitting very less energy to the surrounding rails and vehicle frame so that the other parts are safeguarded. Automotive bumper plays a very important role in absorbing impact energy and also for aesthetic purpose. Now a day's automotive industry concentrates on optimization of weight and safety. This paper has considered the low velocity impact with different types of materials.

AIM

The aim of the thesis is to simulate crash test analysis on bumper using different materials and to analyze the material best suited for bumper.

TASKS

1. To model a bumper with standard size and shape which follows the international regulation using CATIA V5.
2. To simulate crash test of the modeled bumper in Ansys14.5. for steel, Aluminium, ABS, PP, PC, 30% glass filled Reinforced ABS, 30% glass filled reinforced PP, 30% Glass filled reinforced PC and ABS Bumper with steel ribs.
3. To obtain the results of deformation and stress using Ansys.
4. To calculate factor of safety from the obtained values of deformation and stress plots from the analysis software.
5. To compare and analyze the results of stress,deformation and factor of safety for the considered materials.
6. To propose the materials in an order according to the ability to withstand impact during a crash.

1 LITERATURE REVIEW

There is a standard maintained internationally for the dimensions and also the strength of the bumper materials to withstand the low velocity impact. A Light Motor Vehicle and a SUV has different standards to be maintained for the purpose of human safety.

Considering the bumper, The UN Standards have two types of tests to be passed in order to check the impact strength of the bumper. [1]

1. The Longitudinal Impact Test
   i. Unladen Weight test
   ii. Laden Weight Test
2. Corner Impact Test
   i. Unladen Weight test
   ii. Laden Weight Test

1.1 International Standards for Bumpers

The purpose of these tests is to check the speed impact conditions on the front and rear bumpers of the vehicles. These tests confirm whether the protective devices (front and rear bumper) of the vehicle meet the requirements of the regulations. [1]

1.1.1 Unladen Weight Test

The Weight of the vehicle is in running order ,unoccupied and unladen but complete with fuel, coolant lubricant, tools and a spare wheel(if provided as standard equipment by the vehicle manufacturer).

1.1.2 Laden Weight Test

The weight of the vehicle is in running order complete with fuel, coolant, lubricant, tools, and spare wheel and also includes the passenger.

1.1.3 The Longitudinal Impact Test

In this test the front and rear bumpers are made to collide on a straight impact at a speed of 4km/hr and is checked for its deformation. If the bumper sustains the impact then it is said to have sufficient strength according to the regulations.

1.1.4 Corner Impact Test

In this test the corners of the front and rear bumpers are tested by collision of the bumpers at an angle of 60 degree with a speed of 2.5km/hr. If the bumper corners sustain the impact at these parameters it is said to have sufficient strength according to the regulations. [1]

1.2 CATIA V5

CATIA –Computer Aided Three Dimensional Interactive Application is a multi-platform CAD/CAM/CAE software being used worldwide for many industries and for many tasks. The first release of CATIA was on 1977 by Dassault Systems. [2]

As products are increasing in complexity, performance and quality targets are becoming more demanding, CATIA overcomes this challenge, enabling rapid development of high quality mechanical products.

Mechanical engineers equipped with CATIA 3D Modeling tools can gain insight into key factors of quality and performance early in the product development phase. Digital prototyping, combined with digital analysis and simulation, allows product development teams to virtually create and analyze a mechanical product in its operating environment. [2]

CATIA delivers a unique, open and extensible development platform. It provides the engineers to integrate on a wide range of products. From product to transportation industries the design and the style plays the major role for success in the marketing of the product. Develop shape and material creativity ,reaches it heights and surface sophistications and providing the right tools for design are the key points to develop CATIA.

From 3D sketching, surface, Class-A modeling to 3D printing, reverse engineering, visualization and experience, CATIA Design provides all the solutions for Design Creativity, Surface excellence and Product experience.

Most of the Boeing and Automobile industries all over the world use CATIA for modeling as it has several workbenches and several ways to model a structure or product. And it is best used for surfacing because of its easy tools on surfacing.

Taking benefits of two best 3D tools "CATIA and ICEM", it provides the most advanced mathematic and comprehensive suite of tools to reach the highest quality of surface, by integrating the ICEM technology in CATIA. This allows creating, editing and analyzing complex, ergonomically and aesthetical shapes to the highest Class-A surface quality.

ICEM surfacing is the world leading software solution used for Class A surface modeling, Surface analysis and design visualization. ICEM fulfills the engineer's total needs and expectations throughout the digital surface design development process.

ICEM brings the power of CATIA within a 3D experience platform and allows 3D data to be shared with other application and then streamline design and engineering collaboration. Starting from basic inputs such as design sketches or point clouds from physical prototypes, it brings the design to class A surface quality and ready for manufacturing.

CATIA Icem covers the entire development process chain, allowing software based development to minimize the reliance on physical prototype and standalone renderers in the early development phases.CATIA Icem is the ultimate surface modeling platform combining the pricision and quality of class A surface design with the power of CATIA. It has a unified modeling environment and it is the alchemy of class A surface design.[2]

1.3 ANSYS

Ansys is a Mechanical software used as Finite Element Analysis tool for structural analysis, including linear ,non-linear and dynamic studies. It provides a complete set of element behavior, material models and equation solvers for a wide range of mechanical design problems. It also provides thermal analysis, fluid dynamics and also coupled physics capabilities involving acoustics, piezoelectric, thermal structural and thermal electric analysis. [3]

1.3.1 Superior CAD Interface and Meshing

The existing CAD geometry can be used with the same formats of CAD without any translation of formats. Ansys provides native bidirectional integration with the popular CAD systems. Integration with the CAD menu bar makes it easier   to launch world class simulation directly from a CAD system. Since the ansys geometry import mechanism is common to all CAD systems, the user has the flexibility to work within a single common simulation environment while using multiple CAD packages.

In addition, Ansys also supports neutral format files like IGES, Para solid and STEP. This enables the use of any CAD system and also export capability to any of these formats.

Ansys provides a wide range of highly robust automated meshing tools from tetrahedral meshes to pure hexahedral meshes, inflation layer and high quality shell meshes. Mesh settings like the size of edge meshes and surface meshes, sphere of influence, defeaturing tolerances and more can be set by the user.

1.3.2 Auto Contact Detection

On importing an assembly to the ANSYS workbench it automatically detects for contacts or joints between parts .Also the contact settings option can be modified and additional manual contact definitions can be added. Joints of flexible and rigid dynamics are automatically detected. Each contact or joints are easily identified using the graphical tools provided in the environment. [3]

1.3.3 Comprehensive Element Technology

Ansys element technologies provide rich functionality with a consistent theoretical foundation coupled with the most advanced algorithm. A large library of elements such as pipes, beam, shells, solids, 2D planar/axisymmetric and 3D axisymmetric elements which have wide applicability that includes composites, buckling and collapse analysis, dynamic analysis and nonlinear applications are also provided. It also includes special purpose elements like gaskets, joints, interface elements and layered elements for composites structures.

Solid Elements used are 2D-quad/tri, 3D hexa/tetra/wedge/pyramid, Layered solids, Solid shell and 4-node tetra (stabilized) .Shell Elements used are Lower/higher order and layered shells. Beam Elements used are Multi material beam analysis and Beam cross section definition Special element used are rebar/reinforcements, Links/pipes/elbow, Springs/joints, cohesive zone, Gaskets and user elements.

1.3.4 Extensive Library of Material Tools

It is very important to assign the exact material conditions during designing or analyzing an engineering application. Ansys provides a vast library of mathematical material models which aids the engineers to simulate the various kinds of material behavior, such as elasticity, visco elasticity , plasticity, visco plasticity ,cast iron plasticity, creep, hyper elasticity, gaskets and an isotropy .These models can be used to simulate various kinds of materials like metals , rubber, plastics, glass, foam, concrete, bio tissues and special alloys.It also makes it easy to find the parameters for these material models using a curve fitting tool. [3]

1.3.5 Powerful Solver Capabilities

ANSYS structural analysis software offers a large library of out of the box equation solvers. The library contains the sparse direct solver, preconditioned conjugate gradient (PCG) iterative solver, Jacobi conjugate gradient (JCG) solution and more. In addition, the distributed versions of PCG, JCG, and sparse solvers are available for use in large-scale computing via parallel processing. By combining the parallel algorithms with the power of GPUs, you can further reduce the solution time required for large models.

Variational technology from ANSYS allows accelerating computation of normal modes for cyclic structures, especially when a large number of harmonic indexes are required. Frequency sweeps such as those found in harmonic analyses benefit from variational technology as well. Typical speedup factors range from three to 10 times. Transient thermal runs and certain classes of nonlinear structural transient problems are computed in a shorter time using these same principles.

1.3.6 Advanced Post Processing

Ansys provides an efficient way to display the results on the model like the minimum and maximum values and the locations. Slicing Techniques of the model is more powerful and intuitive that the user gets more detail results of the analyzed geometry. The results can be exported as text data or spread sheet for calculations. In addition animations are provided for all type of analysis for better understanding of the analysis. Automatic reporting facilities are also provided which make the work of the user easy to study the entire analysis. [3]

1.4 Design and fabrication of Composite Bumpers

In the International Journal of Modern Engineering Research, S.Prabhakaran has published his analysis with composite bumpers under the title of Design and Fabrication of Composite Bumper for Light passenger Vehicles. In this paper he has compared the steel bumpers with the composite bumpers and analyzed the strength of both the materials. [4]

They have changed the steel bumpers in the passenger cars by the composite materials. They have used glass epoxy composites in order to reduce the weight of the bumper without compromising the strength of the bumper. Their main objective is to compare the stress, weight and cost between the composite bumpers and steel bumpers. They have used this idea of changing the material only to increase the fuel efficiency by reducing the weight of the vehicle. Reducing the weight of each and every part in the vehicle will automatically reduce its own weight so that we can reduce the use fuel which saves our natural resources.In this paper they have tried to reduce the weight of the bumper by removing the steel bumper and using a glass filled composite and the analysis is carried out.

1.4.1 Advantages of composite bumpers

- Reduction in weight
- Collision energy absorption is more
- Excellent corrosion resistance
- Impact strength is high
- Composite bumper properties allows rapid response to induced or release stress.

1.4.2 Glass Fibre

Glass fibers reinforced plastic combine the stiffness and strength of fibrous materials. This has a good mold ability which makes it easier for manufacturing. The majority of reinforced plastics produced today are from glass fiber reinforced epoxy or polyester resins .Glass fibers are also used with phenolics,silicones,polystyrene and polyvinyl chloride. [4]

1.4.3 Advantages of glass fiber

- Molten glass easily drawn into high strength fibers
- Readily available and easy to fabricate
- Relatively strong fibres produce very high strength in composite form
- Chemically can be inserted in plastics

Glass fibers are limited to low temperature applications like boat hulls , flooring works and automobile bodies. These properties of glass fibers has made them to choose this material for reinforcement in bumpers.

1.4.4 Epoxy Resin

It is a low molecular weight organic liquid containing epoxide groups. Epichlorohydrin react with phenols or aromatic amines to produce most of the epoxies.Epoxy is a costlier than other polymer matrices but still being used vastly as a PMC Matrix.Two third of the polymer matrices used in aerospace application is epoxy based.

- They have a good compatibility with Glass fiber
- Higher Strength
- Low viscosity and low flow rates allows good wetting and misalignment of fibers during processing.
- Low shrink rates reduce the tendency of gaining large shear stresses of the bond between epoxy and its reinforcement.
- It is available in 20grades to meet specific property and processing requirements.

These properties of epoxies have made them to choose epoxy for glass reinforcement in bumpers. [4]

1.4.5 Charpy Impact Test

In this paper the researcher has analyzed the impact strength of the composite material and the steel using charpy impact test. It is also known as charpy V-notch test, is a standard test for determining the amount of energy absorbed by a material during fracture. The absorbed energy gives the measure of the tested material's toughness.

A sample for both the materials steel and composite are tested using this charpy impact test. Then both the results of composite materials and steel are analyzed in order to study those materials.

It has been concluded that the weight of the bumper is reduced from 5.15kg to 2.38 kg. According to their tests the steel bumper has an impact strength of 3.25J/mm2 whereas composite bumper has 7.35J/mm^2 . This shows that composite bumpers are 53.8% less in weight when compared to steel bumpers .The author has analyzed the materials also using Ansys10.0 in which he has observed Factor of safety of composites to be 64% higher than the steel bumpers. [4]

1.5 Impact Experimental Analysis and Computer Simulation

In the paper of impact experimental analysis and computer simulation by Yucheng Liu has conducted impact tests on bumper both experimentally and through computer simulation and compared the results .He has considered three different types of tests which are as follows.

1. Experimental analysis on a bumper
2. FEA Simulation of the same Bumper
3. Theoretical calculations by modelling the bumper system as a spring damping system.

The main objective of the project is to verify the efficiency of computer model and computer simulation and to prove that a computer model always existed that can be used to simulate for any impact cases. Also the behavior of the bumper system during the impact process is studied and how the impact forces are transmitted to the joints and how the impact forces are transferred from the bumper to the frame. [5]

1.5.1 Exerimental Analysis

A 1980 volkswagen bumper is used for this analysis. A iron bar of 10.5" and 8.4lb iron bar with nylon string tied on its end is used to hit the bumper. In order to control the iron bar's initial position marking at different locations such as 3",4"etc., is being made. Also a long steel pipe is held vertically to serve as a guide for the iron bar during the impact on the bumper. The reaction forces at the end of the two shocks are measured, and the displacements at the connection between the shocks and the bumper are recorded either. The bars initial velocity when it hits on the bumper is determined using V2=2gh.

Two dynamic load transducers are fixed at the end of the shocks and the other end is connected to the bottom plate ,208 A03 type of transducers are used for this purpose and limit of the transducer is around 800lb .A sensitive displacement sensor (DVRT) is fixed for capturing the displacements at the connections between the bumper and the shocks. The tip of the sensor just contacts the bumper's surface in order to measure the bumper displacement and the other end is glued to the surface using epoxy in order to avoid the movement of the sensor during the impact process. All the transducers are connected to an amplifier and the output signal is obtained in the form of voltage.

The iron bar is dropped from three different heights 3",4" and 6" on the bumper surface and the reaction forces are measured. Different heights are chosen in this test in order to study the impact of initial velocities on the bumper.After measuring the reaction forces the force transducers are removed and DVRT installed. The displacement is measured in different areas of the bumper surface by installing DVRT. Thus different readings are obtained for displacement analysis and reaction force analysis.

The bumper system is a symmetric system and so the reaction forces on both ends should be the same . So the readings from one end of the shock is considered in this analysis.We have reaction force plots for three height conditions 3",4" and 6".From these reaction force plots it is observed that the time of peak values and the shape of the force curves are similar except the peak value differs with respect to the initial velocities.

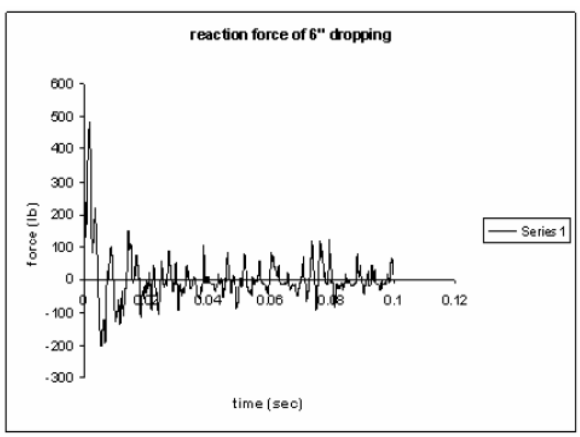


Figure 1: Reaction force curve for 6″ dropping[5]

Table 1: The effects of initial positions on the reaction forces (average value listed) [5]

Initial position (in)	Initial velocity (in/sec)	Peak force (lb)	Time (sec)
3	48.12	311.69	0.0017
4	55.57	370.72	0.0020
6	68.06	483.15	0.0020

The displacement results are produced in the form of a graph and analyzed.It is observed that the first peak displacement is 0.0178" that happened at 0.0046 sec and the second peak displacement is 0.0026" that happened at 0.0466 second. The big variation along the two peak values makes it clear that the bumper system has a large damping ratio value. [5]

1.5.2 Computer Simulation

A CAD model of the bumper similar to the tested one in dimensions and shape is modeled using IDEAS.This bumper model is exported in IGES format and imported in ANSYS environment to provide the original geometric information for the new finite element model.The material used for bumper is aluminium and the impact bar material is steel .

The whole impact analysis is simulated on a computer by running a transient analysis. The initial velocity of the impact bar is is 68.16in/sec,and acceleration 386in/sec^2 is applied on the entire environment to simulate the gravity.The solution time is set to 0.04 sec according to the sampling time so that the results are comparable. Similar boundary conditions as used in the experimental set up is used to measure the displacement except the initial velocity is provided as 87.86in/sec to simulate the effect of 10" high dropping.The analysis report is provided as graphs below.

1.5.3 Comparison of Experimental Analysis and FEM Simulation

First the reaction forces of 6" dropping of experiment and simulation are compared . The computer analysis yield the maximum force 468lb that appears at 0.002 and this matches the experimental results very well. The comparison proves that the computer model can predict the peak force value and the time it occurs accurately which makes the study of impact force transfer from the bumper to the other parts of the body meaningful. The displacement measurement using simulation shows a value of 1.33e-4 inches at 0.0035 second which significantly differs from what has been obtained in the experiment 0.0178".This difference is due to the way of measuring displacement in the experimental setup. The placement of sensors and improper measurement during the impact. [5]

1.5.4 Theoretical Analysis

The whole bumper system is considered as a spring damping system with stiffness of 4203.52 lb/in and the impact problem is solved.

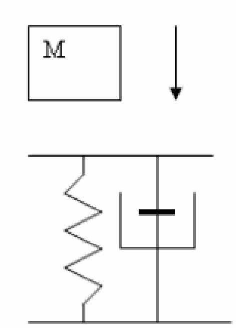


Figure 2:Equivalent spring damping system[5]

The governing equation is

$m\ddot{x} + c\dot{x} + kx = W$

W is the weight of the impact bar and the bumper itself, which is 24.4lb .The theoretical values for reaction force is found to be 317.01lb for 3" and 373.96 for 4" and 456.46 for 6".All the results of the three methods are shown below in the tabular form.

Table 2: The Theoretical results and the experimental results for reaction force [5]

Initial position (in)	Peak force (lb)			Time (sec)	
	Experimental	Theoretical	Error (%)	Experimental	Theoretical
3	311.69	317.01	1.7	0.0017	0.003
4	370.72	373.96	0.9	0.002	0.003
6	483.15	456.46	5.5	0.002	0.003

From the above analysis they have concluded that the computer model can correctly predict the reaction force in nondestructive impact test.The above table clearly shows that the experiment and computer model yield very close results including the force and time. [5]

1.6 Automobile Bumpers

The bumper design should mainly concentrate on providing safety for the passengers and stay intact at low speeds than being stiff enough to dissipate the kinetic energy at higher speeds. Steel was the material used for automobile bumpers in 1980’s.

But steel is known for its weight and its rigid support to the vehicle but the main work of the bumper is to absorb the energy and should be stiff for passenger safety. Theoretical part of steel is that it is the alloy of iron with carbon which is contributing 2.1% of its weight carbon. Other elements and inclusions within iron act as hardening agents that prevent the movement of dislocations that are naturally present in the iron atom lattice. The varying amount of alloying elements retards the movement of dislocations which in turn controls the tensile strength. [6]

The automobile industry was interested in an alternate for steel bumpers in order to reduce the weight of the vehicle and also with good impact strength. Plastics was the effective alternate for these steel bumpers as it has very low weight and also high impact strength. Other advantage of plastics is the ease of manufacturing through injection molding process and a bumper can be shaped to any form by this process.

The majority of modern plastic car bumpers and interiors are made of thermoplastic olefins (TPOs), polycarbonates, polyesters, polypropylene, polyurethanes, polyamides, or blends of these with, for instance, glass fibers, for strength and structural rigidity. There are many research conducted to compare the strength of plastics with steel.

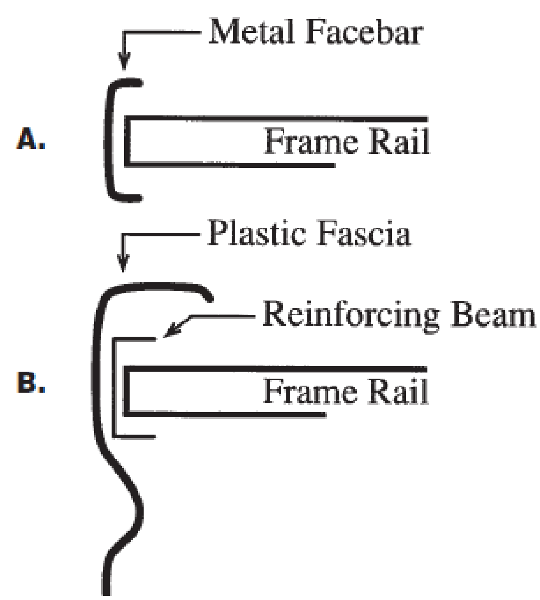
In the year 2014 three persons namely Praveen Kumar. A, Sameer Belagali and Bhaskar has published a journal on their studies of bumper materials in the name Comparative study of automotive bumper with different materials for passenger and pedestrian Safety. In this paper they have analyzed an automotive bumper to check its crashworthiness using two materials steel and composites. There is also a second phase for the research in which they have used honeycomb structures and foams in bumpers as energy absorbents and they have analyzed the strength of the bumper. [6] They have modeled a bumper using Pro-E and analyzed it using ANSYS. The properties of the steel used are as following.

Table 3: Mechanical properties of steel [6]

Compressive strength	1000-2000 MPa
Tensile Strength	1800 MPa
Modulus of elasticity	207 GPa
Poisson Ratio	0.3

The same bumper is analyzed using a composite material. In the present day competitive world the fuel economy plays an important role so in order to achieve this the researchers are moving towards light weight bumpers such as composite bumpers.It was found from the analysis results that the carbon fiber gives the higher strength to weight ratio in comparison with steel and dissipates energy.

1.6.1 Types of automobile bumper assembly



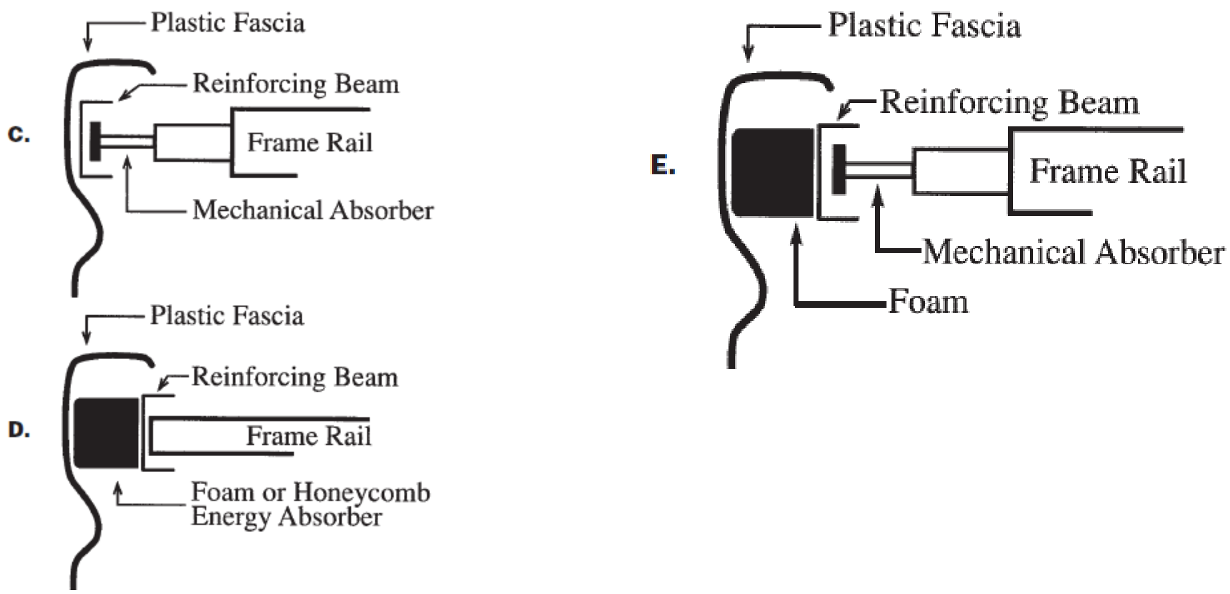


Figure 3: Types of automobile bumper system a) Metal bumper b) Plastic bumper with reinforcement beam c) Plastic bumper with a mechanical absorber d) Plastic bumper with foam or honeycomb energy absorber e) Plastic bumper with foam and mechanical absorber [7]

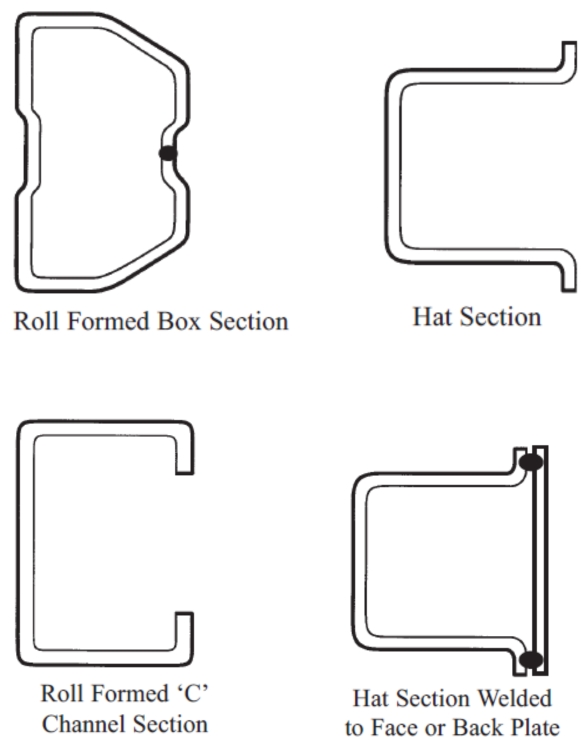
The above shown figures clearly explains the different types of bumpers used in the present day automobile sectors. These types of bumpers vary in automobiles according to the use of the vehicles. For example in Light Motor Vehicles like cars we concentrate on aesthetics of bumpers without compensating with the strength of the bumper and also the requirement in quantity is more and so ease of production is taken to consideration. Hence for these kind of constraints plastics are the best suited materials as they have very good weight to strength ratio when compared to steel and the way of production is easy when compared to other materials. [8]

When considering trucks which carries heavy loads using only of plastic bumpers is not preffered because when the truck with heavy load undergoes crash a plastic bumper cannot withstand the crash hence plastic fascia along with some absorbers like foam or mechanical absorbers are used as shown in the above figure.

1.6.2 Reinforcement Beams

The reinforcing beams are the key components of the bumper system as they employ them. The reinforcement beam absorbs the kinetic energy during the crash of the vehicle thus providing safety to the rest of the part of the vehicle and the passengers inside the vehicle. During the design of a reinforcing beam certain considerations are to be considered like the strength, manufacturability, weight, recyclability and cost .Reinforcing beam are of various shapes and types as follows. [8]

1. Steel Reinforcement Beams
2. Aluminium Reinforcement Beams
3. Plastic Reinforcement Beams



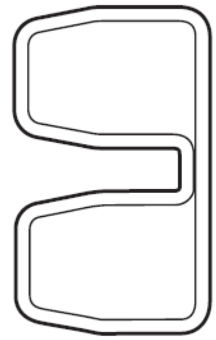


Figure 4:Types of reinforcement beams used in automobiles[8]

1.6.2.1 Steel Reinforcement Beams

Steel Reinforced Beams are usually roll formed or hot stamped using ultra high strength steel . Roll formed beams are the most commonly used beams and are becoming more popular as a result. The most common cross section for roll formed beam is the B Section which is shown in above figure. The most common for hot stamped beams are box and hat sections. Sometimes a stamped or roll formed face or back plate is welded to a roll formed or hot stamped C-section to create a boxed section. The steel reinforcing beams are subjected to corrosion protection.Some beams are made up of hot dip galvanized sheet. Sometime zinc coating is provided which acts as an excellent corrosion resistant.Other beams are protected from corrosion by providing a paint system such as E-coat.

Tensile strength of cold stamped and roll formed beams ranges from 900-1500MPa.Tensile strength of hot stamped beams,after heating and quenching ranges from 1200-1400MPa.The elastic Modulus of steel beams is 207GPa.Aluminium coatings and electrocoatings are also used as an corrosion resistant.After mounting the reinforcement beam to a vehicle frame it is normally covered by cosmetic or energy absorbing fascias.

1.6.2.2 Aluminium Reinforcement Beams

Aluminium Reinforced Beams are made by stretch or press forming extruded shapes made from a variety of aluminium series.The heat treated aluminium beams have a tensile strengths upto 550MPa and an elastic modulus of 69000MPa.

1.6.2.3 Plastic Reinforcement Beams

Two types of plastic beams are used for this purpose.One is glass reinforced plastic and the other one is unreinforced plastic. Some of the plastic reinforced plastics include polypropelene which is usually compression molded, unsaturated polyester which is also compression molded and polyurethane which is mostly injection molded. Some examples of unreinforced plastic beams include polycarbonate/polybutylene which are usually injection or blow molded and polypropylene which is blow molded. Plastic beams have a flexural modulus upto 15000MPa and tensile strength upto 275MPa. [8]

1.6.3 Steel

Steel where the first used and still existing type of bumpers for all kind of automobiles. It decorates and covers the front and the rear part of the vehicle. Steel bumpers are usually cold stamped from low carbon to high strength steels. It has a tensile strength of 500Mpa and Young's Modulus 207GPa. Usually the steel bumpers are painted or Chrome plated in order to avoid corrosion and to improve the appearance.

The main disadvantage of steel bumpers are its weight to strength ratio which is too low when compared to some plastic materials like Acrylonitrile Butadiene Styrene, Polypropylene and composite materials. One more disadvantage of using steel bumper is its aesthetic. A steel bumper has certain restrictions in manufacturing in terms of shape and size but plastics can be easily molded to the required form and shape which also improves the aesthetic of the bumper.

1.6.4 Acrylonitrile Butadiene Styrene

ABS is a combination of three components which can be added in various proportions to obtain different material properties. Usually ABS is manufactured with 50% of styrene and the remaining proportions include acrylonitrile and butadiene. The polymer is manufactured by several methods like emulsion, suspension and continuous mass polymerization. Out of these processes emulsion is the oldest method of manufacturing. In suspension process styrene acrylonitrile is blended with high rubber content medium butadiene. Continuous mass polymerization, is the most preferred method of manufacturing in spite of its higher capital cost and less process flexibility because of its less energy usage and absence of effluent water in its process. ABS is a tough and rigid thermoplastic material and it has a high impact strength with good resistance to stress, cracking and creep. It is also resistant to moisture and chemicals like inorganic salts, alkalies and acids. It has an excellent electrical properties, heat resistant and flame retardant. When compared with polystyrene it has a better thermal stability and Chemical properties .These properties of ABS makes it suitable suitable for injection molding, extrusion, blow and foam molding and thermoforming. It can be easily machined, bored, turned, milled, sawed, die cut, routed, filed, sanded, ground buffed and polished. These properties of ABS makes it suitable to use it in automobile applications where the material undergoes extreme stress and dimensional stability is required. The property of ABS with high resistant to scratch, wear and easy maintenance makes it to be used in electronic applications. [10]

1.6.5 Polypropylene

Polypropylene(PP) is a long chain polymer and as it is inferred from its name PP is made up of propylene monomers and is similar to Polyethylene but with methyl groups attached at every second carbon atom on the polymer backbone. Atactic, isotactic or syndiotactic polypropylene can be manufactured just by changing its catalyst and polymerization method which alters the molecular configuration. Atactic polypropylene is tacky, amorphous and usually has a low molecular weight. By reducing the crystallinity of the polypropylene it can be used as a "plasticizer". Some mechanical properties like low temperature performance ,processability,optical properties and elongation can be improved just by adding small amounts of atactic polymer. A high degree of crystallinity is provided by the most stero regular structure of isotactic polypropylene. This high crystallinity of isotactic polypropylene improves the chemical resistance, strength, creep resistance, rigidity, heat resistance and stress cracking resistance. Polypropylene has a higher temperature resistance and tensile strength when compared to polyethelene. Syndiotactic polypropylene is just recently becoming a commercially available product. When atactic and isotactic are arranged in blocks in the same polymer chain gives it a elastometric type of material property. Most polypropylene however is of the isotactic variety and is described below. Polypropylene has a lower density when compare to other thermoplastic materials which reduces the weight of the material. Polypropylene is an excellent resistant material towards chemicals like solvents, acids, bases even in very harsh environments. It has no known solvent at room temperature. Surface crazing and material swelling is caused when exposed to some chemicals like liquid hydrocarbons, strong oxidizing acids and chlorinated chemicals. It has a very low resistant to weathering unless ultraviolet light absorbers and stabilizers are used. Some of the excellent properties of polypropylene include moisture barriers, dielectric properties, good optical properties, tear resistance and fatigue resistance. Flexural modulus makes polypropylene an excellent material for molded-in hinges. The semiconductor industry usually uses polypropylene manufactured with high level of purity. The property of polypropylene to resist bacterial growth makes it suitable for disposable syringes and other medical equipment. At 121 °C polypropylene can be repeatedly autoclaved . Polypropelene is used in piping, bottles, outdoor carpet, automotive interiors, bumper facias, fan shrouds, fender liners, packaging film, caps and closures, pallets, crates, bottles, food containers, housewares, furniture, dish washers, washers and dryers, refrigerators, luggage, pump components and housings, prosthetic devices, die cutting pads, clean room walls, toys, battery cases, sporting goods, baby care products, DVD cases, microwave cookware, rope, chemical resistant tanks, laboratory consoles, sinks and ducts, floors and ceilings, trigger sprayers, totes, pails, buckets, trash cans, lawn furniture, garden tools, hospital disposables, blood and centrifuge tubes, test tubes, beakers, pipette tips, and contact lens. [11]

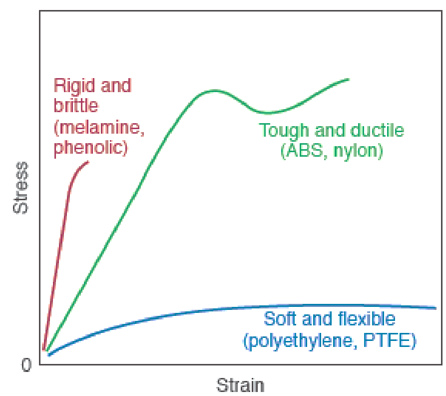


Figure 5: Stress strain graph for different plastics[10]

1.6.6 Polycarbonate

Polycarbonate was discovered by Dr. H.Schnell at Bayer AG. This thermoplastic material is light in weight and is made up of phosgene and bisphenol. This material was started to be used commercially on late 1950’s. Polycarbonate was initially used in electrical and electronic applications like distributor and fuse boxes, displays and plug connections and glazing for greenhouses and public buildings. Space helmets are also manufactured using polycarbonates. Application of polycarbonates increased only in 1980’s. Audio CD's, CD-ROM's and recently DVD's makes use of polycarbonates unique optical properties. At the same time, automobile parts like head lights and tail lights started using

Polycarbonates. Polycarbonate is transparent, extremely strong, rigid, has good thermal properties from -130 to +130 °C. Polycarbonates are affected by chemical reactions like bases , concentrated acids and hydrolytic attack at high temperatures. This is because of the carbonate linkage in the polymer chain. Polycarbonate has a poor UV resistant which can be overcome by adding some additives.. Polycarbonate is also a versatile blending material, with polyester (PET) and Acrylonitrile Butadiene Styrene (ABS). Applications in addition to the ones mentioned above include, light fittings, safety helmets, sporting goods, consumer electronics, household appliances, incubators, kidney dialysers, blood oxygenators, tube connectors, food storage containers, bottles, medical components, cell phones, computers, eyeglasses, circuit breakers, cable sockets, displays, relays, buckles, shavers LEDs, safety switches, high voltage plugs, fluorescent lighting diffusers, compass and binocular cases, ship's lights, ski boot and hair dryers. [11]

1.6.7 COMPOSITES

Smart materials often consists of mixtures of several different passive and active materials. Mixing the required material in the right way makes it possible to make new smart composites.In the recent times almost all parts of an automobile is being tried with composite materials in order to reduce the weight of the vehicle. Composite bumpers absorbs more collision energy when compared to steel.

1.6.7.1 Advantages of Composite Bumper

One of the most advantageous reasons for considering their use over steel is their reduced weight.

- Absorb more collision energy.
- Excellent corrosion resistance.
- High impact strength.
- Material properties of composite bumper allow rapid response to induced or release stress. [14]

1.6.8 Glass Fiber

The aim of fiber reinforced plastics is to combine the stiffness and strength of fibrous material. This material has corrosion resistance, low density and mould ability. The majority of reinforced plastics produced today are glass reinforced epoxy or polyester resins, both of which are thermosetting. Glass fibers have also been used with phenolics, silicones, polystyrene and polyvinyl chloride. Glass fibers are the obvious choice as reinforcing agents, principally because of the relative ease with which high strengths can be obtained fiber a few microns in diameters. It is possible to produce composites with a range of strength according to glass content and nature of the reinforcement. The epoxy resins have lower shrinkage than the other resins.

1.6.8.1 Properties

Some of the basic properties of glass fiber are,

- Specific Strength
- Low density
- Corrosion resistance
- Impact resistance
- Electrical properties

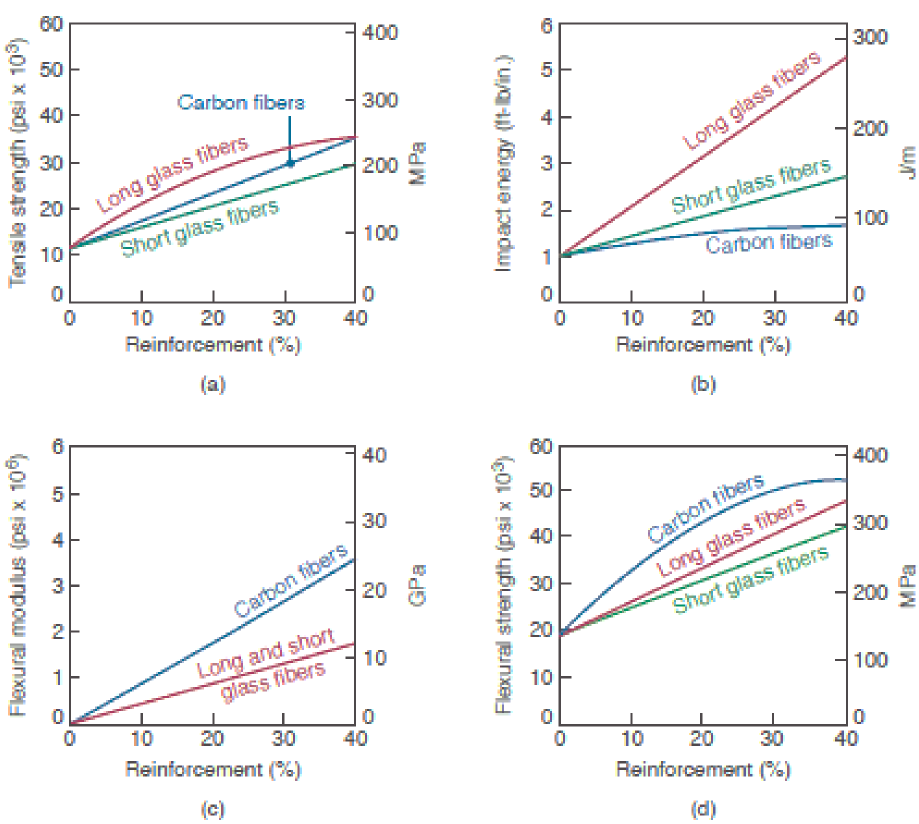


Figure 6:Effect of the percentage of reinforcing fibers and fiber length on the mechanical properties of reinforced nylon. Note the significant improvement with increasing percentage of fiber reinforcement. [14]

1.6.8.2 Different Types of Glass Fibers

Glass is the most common fiber used in polymer matrix composites. The most commonly used glass fibers are E-glass, S-glass, R-glass, C-glass and D-glass fibers. The E in the E-glass stands for electrical as it was designed for electrical applications. E-glass fiber is a high quality glass fiber used as a standard reinforcement for all the resin systems and as a well complying with mechanical property requirements. Thus E-glass fiber was found appropriate for our applications. In S-glass S stands for higher content of silica. It retains its strength at high temperature and has higher fatigue strength. It is used mainly in aerospace applications. In C-glass C stand for corrosion, it is designed to give improved surface finish. It is available usually in the form of a surface tissue for the reinforcement of corrosive barriers in chemical plant. In D-glass D stands for dielectric used for applications requiring low electric constants. [14]

1.6.8.3 Advantages of Glass Fibers

Glass fiber is most widely used as are reinforcement of all composites due to the following advantages:

- Molten glass easily drawn into high-strength fibers
- Readily available/easy to fabricate
- Relatively strong fibers produce very high strength in composite form
- Chemically insert in plastics.

These materials are limited to low temperature applications where strength is important without the need for high rigidity. Typical uses for this material are boat hulls, flooring materials and automobile bodies. The main type of glass used is E-glass. However, it is used for many other purposes now such as decorations and structural applications.

1.6.8.4 Types of Reinforcement of Glass Fibers

1. Matrix with particles
2. Matrix with short or long fibers or flakes

3. Continuous fibers
4. Laminate Composite Structure
5. Sandwich composite structures using a foam or honeycomb core

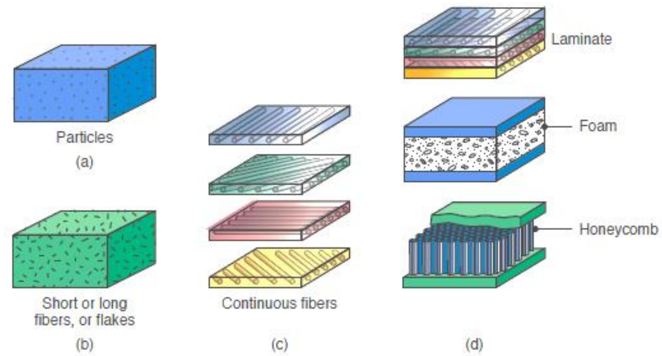


Figure 7: Schematic illustration of types of reinforcing plastics. (a) Matrix with particles; (b) matrix with short or long fibers or flakes; (c) continuous fibers; and (d) laminate or sandwich composite structures using a foam or honeycomb core . [14]

1.6.9 Injection Molding

Injection molding is a manufacturing process by which plastic materials are manufactured from both thermoplastic and thermosetting plastic materials. Plastic is heated to the melting point and injected into the mold at a high pressure in order to shape the plastic into the required mold profile. After the design of the molds by engineers it is manufactured by mold maker's using steel or aluminium according to the requirements. Injection molding is a widely used process for manufacturing a variety of components, from the smallest plastic part to entire body panels of cars.. A standard tool consists of a core plate with a core insert in it and a cavity plate with a cavity insert. The most commonly used thermoplastic materials used in injection molding process are polystyrene (low cost, lacking the strength and longevity of other materials), Acrylonitrile Butadiene Styrene (a tar-polymer or mixture of compounds used for everything from Lego parts to electronics housings), polyamide (chemically resistant, heat resistant, tough and flexible-used in manufacturing combs), polypropylene (tough and flexible – used for manufacturing containers), polyethylene, and polyvinyl chloride or PVC (more common in extrusions of pipes or as the insulation on wiring where flexibility is required by the inclusion of a high proportion of plasticizer).Injection molding is also used to manufacture parts from aluminium or brass (die casting).

The melting point of plastics are very low when compared to these metals ,this higher melting point of metals makes substantially shorter mold lifetimes despite the use of specialized steels.

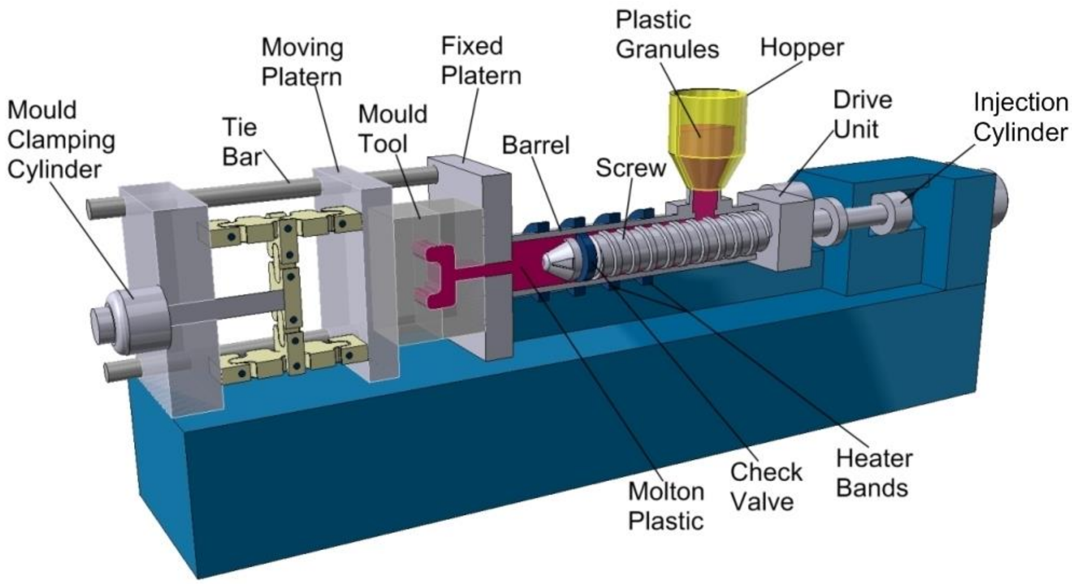


Figure 8.Injection Molding machine[19]

Injection molding is a process by which a wide variety of products are manufactured from small parts to very complex parts. The main requirements for an injection molding process include the injection molding machine, plastic materials and the mold. The plastic are provided in the form of granules which are melted at high temperatures in the injection molding machine and are injected into the mold with high pressure so that the plastic in molten state fills the mold and acquires the required shape.

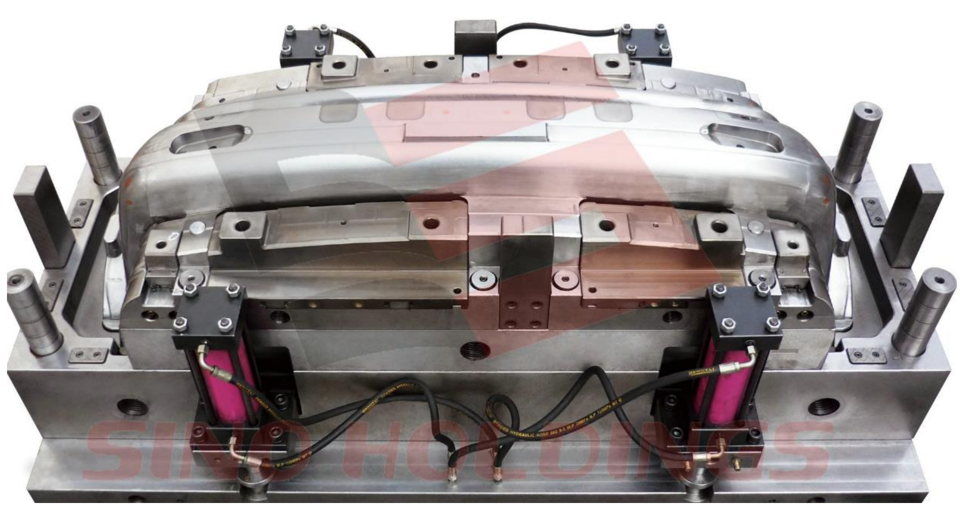


Figure 9:Bumper mold core plate[18]

By this process of injection molding only thin walled components can be produced like the plastic housings. Plastic housing is a thin-walled enclosure, and requires many ribs and bosses on the interior for its strength. These housings has a vast range of applications which household appliances, consumer electronics, power tools, and as automotive dashboards. Other common thin-walled products include different types of open containers, such as buckets. Several everyday products like tooth brushes are manufactured using this process. Many medical devices, including valves and syringes, are manufactured using injection molding as well.

2 METHODOLOGY

The Bumper is analyzed for different types of materials and also one analysis is made for geometrical modifications in bumper. The materials used in analysis are as follows,

1. Steel 1006
2. Aluminium 2024
3. Acrylonitrile Butadiene Styrene (ABS)
4. Polypropylene (PP)
5. Polycarbonate (PC)
6. 30 % Glass Filled ABS
7. 30% Glass Filled PP
8. 30% Glass Filled PC
9. Bumper with ABS and ribs with Steel

There are one ferrous and one nonferrous material which are commonly used in automobile industries. Three types of thermoplastic materials are used ABS,PP and PC. The main idea of choosing these materials is because of their properties which well suits for bumper like the impact strength, Surface finish, ability to paint and the most important is their properties which suits for injection molding process. The other three materials are composites of the same plastic materials. The last one is with a geometrical change in ABS bumper which is addition of few ribs of steel to withstand impact.

2.1 MODELLING

The bumper model is created using CATIA V5 as it is best suited for surface models. The bumper which is modeled is inferred from a SUV vehicle namely TATA Safari in India. As this bumper has few complicated surface to be analyzed it was simplified for the purpose of analysis. All the dimensions of the bumper where obtained from the SUV vehicle TATA Safari. The dimensions of the modeled bumper are shown in below table.

Table 4: Dimensions of bumper model

Length in mm	Width in mm	Height in mm	Volume in m^3	Thickness in mm
1800	700	600	4.73E-03	3

CATIA V5 consists of many workbenches for different types of modelling like the Part design workbench which is used for part or solid modelling, separate workbench is provided for sheet metal modelling, surface modelling, assembly etc. This makes this software unique from other modelling softwares. In order to create this model three workbenches where used Part design, wireframe and surface design and generative shape design.

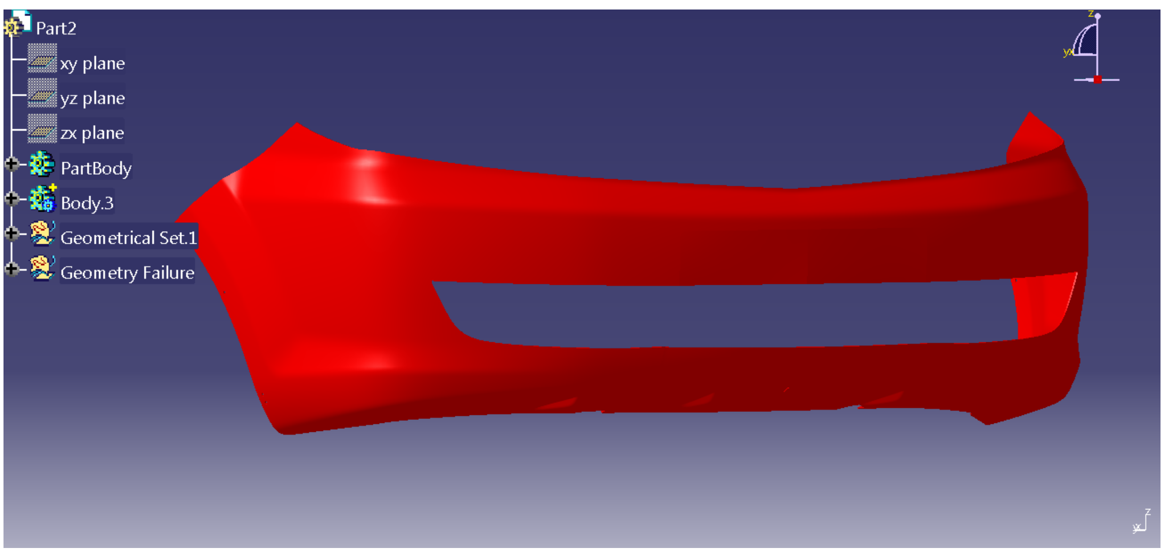


Figure 10: TATA Safari Bumper Model

The model shown in the figure is the Bumper model of SUV TATA Safari. I have followed the dimensions of a running SUV because a bumper has to qualify the UN regulations in size and shape for the purpose of safety. The bumper modeled for the purpose of analysis is shown in the below figure

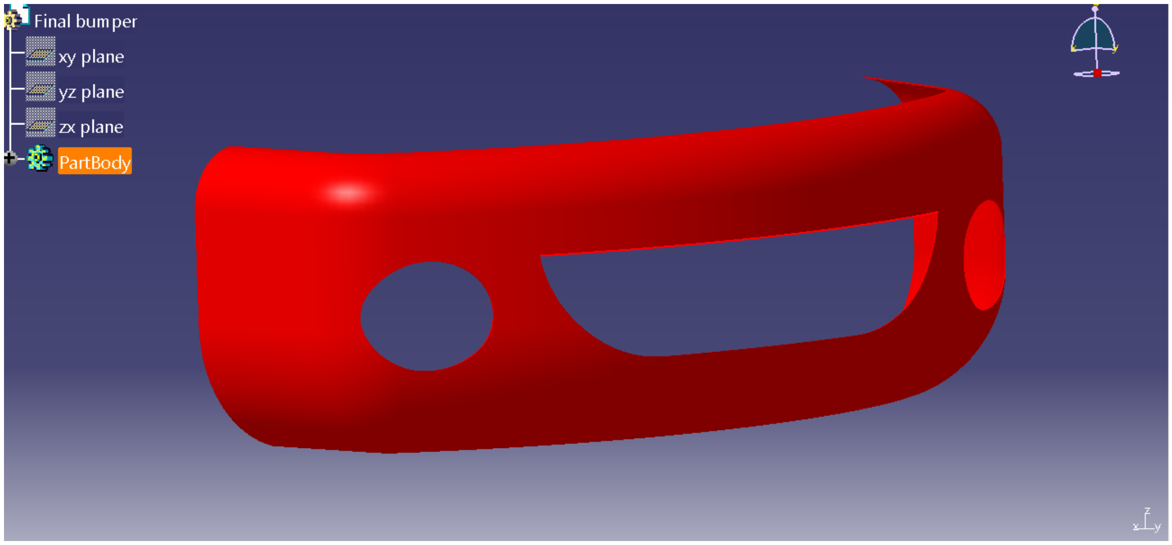


Figure 11: Bumper model for analysis

The cross section view of the model and the sketches are also shown in the below figure for clear understanding of the bumper model. The images on the left side show the cross section sketches and those on the right hand side shows the section cut view .Thus the side view and the top view of the model is shown.

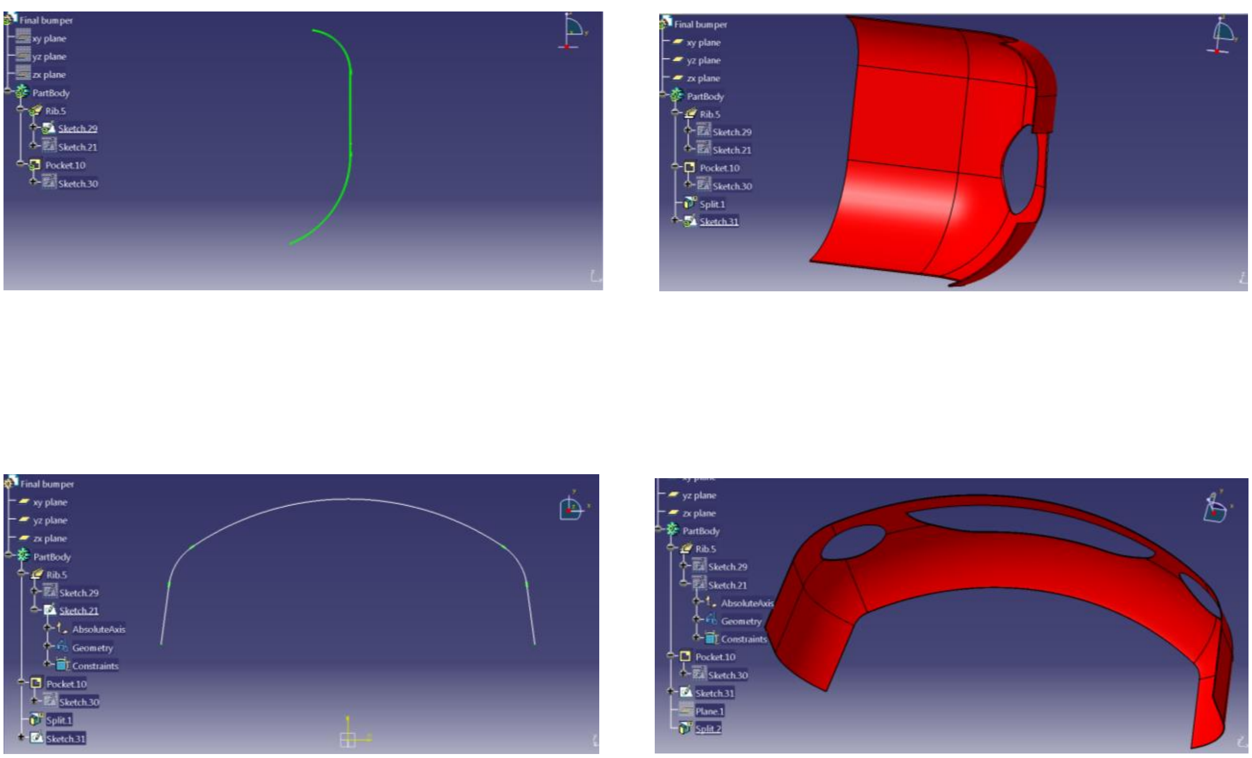


Figure 12 : Cross section view of the bumper modeled in CATIA V5

Usually when a bumper is fixed in a vehicle it is fixed over a reinforcement beam on the car body. During a crash the bumper absorbs the energy and transfers it to the reinforcement beam which further transfers to the car body. In the model a fixture block is used in the place of reinforcement beam. The block holds only the sides of the bumper as shown in the figure so that the bumper sides do not flap during the crash. Apart from material changes a bumper is analyzed by changing its geometry that is by adding few ribs made of steel in order to increase its impact strength. The ribs are of 5mm thick and 5mm height which is much smaller than the plastic ribs because these ribs are made of steel. The bumper with ribs is checked for only one material ABS.

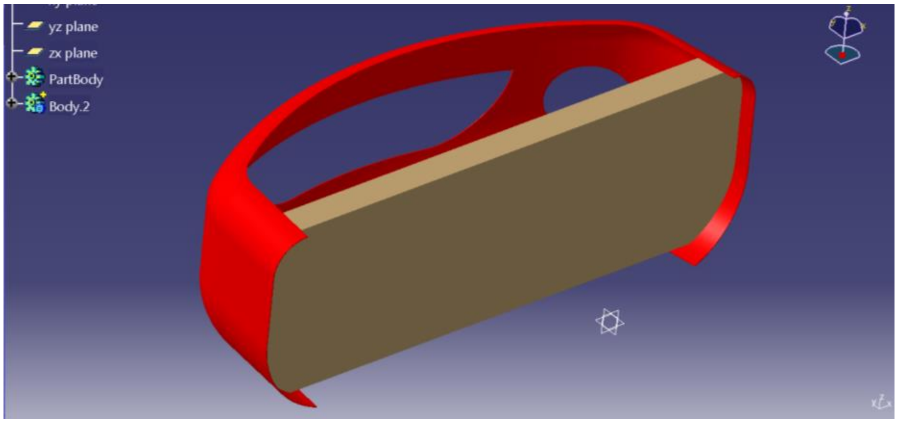


Figure 13:Bumper Model with fixture

2.2 ANALYSIS

The bumper that is modeled is analyzed using ANSYS 14.5. It is a multipurpose finite element software used in a broad wing to solve engineering problems. The different kinds of analysis that can be solved using Ansys software include transient and steady state heat flow, static and dynamic analysis, computational fluid dynamics and a lot more engineering problems are solved using this finite element software. In order to analyze a bumper we have used Explicit Dynamics since it's especially used for impact analysis and crash test.

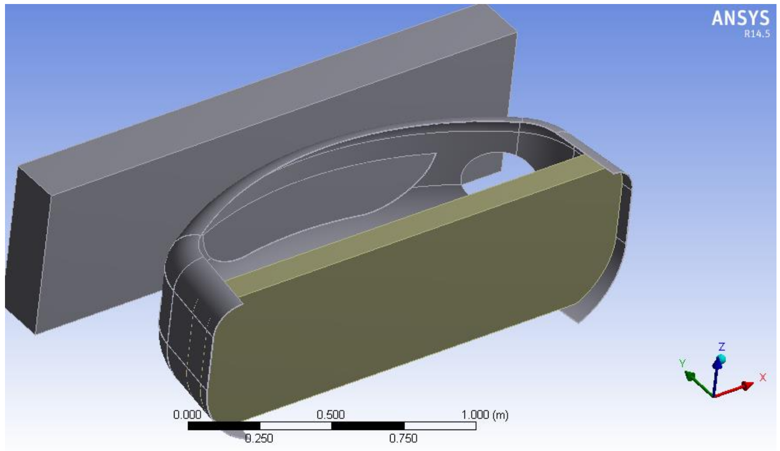


Figure 14: Bumper with fixture and the target concrete wall in ANSYS 14.5

In this analysis the bumper moves with a velocity of 7m/s along with the bonded mass and hits the concrete wall as shown in the figure. All the boundary conditions are maintained the same for different type of materials. The boundary conditions in this analysis includes the velocity with which the bumper travels, the distance of the bumper from the concrete wall, the type of connections used, the type and size of mesh elements and also the target material and size of the wall.

2.2.1 PROPERTIES OF WALL

The wall is kept as the target on which the bumper hits at a velocity and is crashed. The property of the wall and its dimensions are listed below and is maintained the same for all materials of bumper.

Table 5: Parameters of concrete wall

Material	Concrete(Ansys Material Library)
Density	2440 Kg/m³
Meshed	Yes
Type of Mesh	Quadrilateral
Size	2m X 0.2m X 0.6m
Stiffness Behavior	Rigid
Volume	0.24 m³
Mass	585.6 kg
Nodes	441
Elements	240

2.2.2 PROPERTIES OF FIXTURE

A fixture is provided at the back of the bumper in order to fix the ends of the bumper. It acts like the reinforcement beams in the cars on which the bumper is usually attached. This fixture is bonded to the bumper so that the bumper ends do not move outwards and inwards thus creating a flap movement during the crash. It is only used for a support and is not considered in the analysis part during the impact. The properties and dimensions of the fixture is provided on the below table.

Table 6: Fixture Parameters

Material	Structural Steel(Ansys Material Library)
Density	7850 Kg/m³
Meshed	Yes
Type of Mesh	Quadrilateral
Size	1.8m X 0.1m X 0.6m
Stiffness Behavior	Rigid
Volume	9.7224e-002 m³
Mass	800 kg
Nodes	262
Elements	109

2.2.3 BOUNDARY CONDITIONS

The boundary conditions are maintained to be the same for all type of materials used for bumper and also for the bumper with ribs. The different type of boundary conditions are explained in detail below.

2.2.3.1 BODY INTERACTIONS

A frictionless bonding is provided between the bumper and the target body which is the concrete wall. This frictionless bonding provides the software to understand the impact between the bumper and the wall.

The second type of body interaction is between the bumper and the fixture which is bonded type so that it also moves with the same velocity as bumper and keeps the edges fixed.

2.2.3.2 *MESH*

Two types of mesh are used for the analysis. Bumper is meshed using Triangular type whereas the concrete wall and the fixture attached to the bumper is meshed using a quadrilateral type. Triangular meshes are chosen for bumper as it well suits to mesh a surface with corners and edges. The wall and the fixture are given quadrilateral mesh as they are not included in the analysis .The properties of mesh are listed below in the table. The meshed surface is shown in the figure.

Table 7: Mesh Parameters

Physical Preference	Explicit
Relevance	-40
Advanced Size Function	Fixed
Relevance Center	Fine
Smoothing	High
Transition	Slow
Min Size	5.2096e-4 m
Max Face Size	0.10m
Max Size	0.104190 m
Min Edge Length	3.0212e-003m
Nodes	1982
Elements	3732
Body Element Size	6e-002m

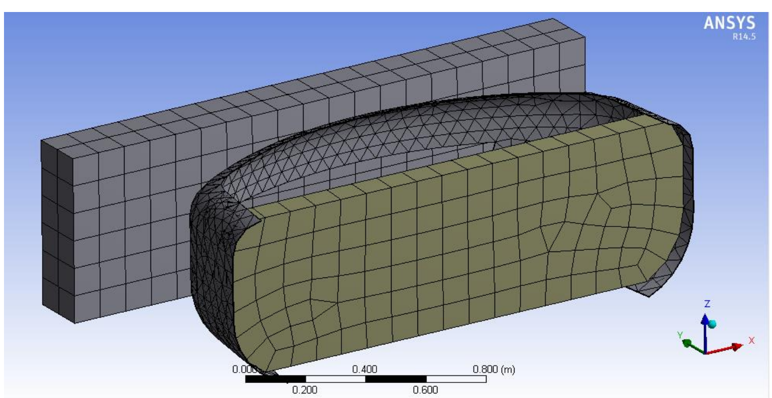


Figure 15:The meshed bumper model

2.2.3.3 INITIAL CONDITIONS

2.2.3.3.1 VELOCITY

The bumper along with the fixture moves with a velocity of 7m/s at hits the concrete wall. As per the UN Regulations a bumper has to qualify a velocity of 4Km/hr for straight impact. For a bumper it is not sensible to consider high velocity impact because no material can withstand at high velocity impacts and that is the reason for which UN regulations consider only the low velocity impact. In this paper the bumper is analyzed for impacts at different velocity from 4km/hr (1.11m/s) and it is found that ABS material shows a failure only at 7m/s and hence it is taken as the reference velocity.

2.2.3.3.2 ANALYSIS SETTING

It includes the parameters that are taken into consideration during the process of impact. These parameters are as shown on the table.

Table 8: Analysis parameters provided in the software

End Time	0.07 sec
Beam Solution Type	Bending
On Geometric Strain Limit	Yes
Geometric Strain Limit	Depends on Material (Elongation at Break %)
On Material Failure	Yes

2.2.3.3.3 FIXED SUPPORT

The concrete wall is made as a fixed support as the wall has to be rigid when the bumper hits the wall at a velocity of 7m/s. Hence wall is made fixed and the bumper along with the fixture is not fixed.

2.3 MATERIAL PROPERTIES

2.3.1 STEEL

Table 9: Mechanical properties of steel

Material	Steel 1006(Ansys Material Library)
Density	7896 Kg/m³
Shear Modulus	8.18e+10 Pa
Geometric Strain Limit	0.2
Young's Modulus	200 GPa
Ultimate Stress	360 MPa
Strength to weight ratio	46 KNm/kg

2.3.2 ALUMINIUM

Table 10: Mechanical properties of Aluminium

Material	AL 2024 (Ansys Material Library)
Density	2785 Kg/m³
Shear Modulus	2.8e+10 Pa
Geometric Strain Limit	0.2
Young's Modulus	73 GPa
Ultimate Stress	200 MPa
Strength to weight ratio	72 KNm/kg

2.3.3 ACRYLONITRILE BUTADIENE STYRENE (ABS)

Table 11: Mechanical properties of ABS[20]

Material	ABS
Density	1080 Kg/m³
Shear Modulus	1.0741e+09 Pa
Geometric Strain Limit	0.1
Young's Modulus	2.9 GPa
Ultimate Stress	110 MPa
Strength to weight ratio	80 KNm/kg

2.3.4 POLYPROPYLENE (PP)

Table 12: Mechanical properties of polypropylene[20]

Material	PP
Density	902 Kg/m^3
Shear Modulus	3.7594e+08 Pa
Geometric Strain Limit	1.5
Young’s Modulus	1 GPa
Ultimate Stress	100 MPa
Strength to weight ratio	81 KNm/kg

2.3.5 POLYCARBONATE (PC)

Table 13: Mechanical properties of polycarbonate[20]

Material	PC
Density	1200 Kg/m^3
Shear Modulus	7.2993e+08 Pa
Geometric Strain Limit	1
Young’s Modulus	2 GPa
Ultimate Stress	150 MPa
Strength to weight ratio	99 KNm/kg

2.3.6 30% GLASS FILLED ABS

Table 14: Mechanical properties of 30% Glass Reinforced ABS[20]

Material	30 % Glass Filled ABS
Density	1280 Kg/m^3
Shear Modulus	2.2222e+09 Pa
Geometric Strain Limit	0.02
Young’s Modulus	6 GPa
Ultimate Stress	110 MPa
Strength to weight ratio	80 KNm/kg

2.3.7 30% GLASS FILLED PP

Table 15: Mechanical properties of 30% Glass Reinforced PP[20]

Material	30 % Glass Filled PP
Density	1140 Kg/m^3
Shear Modulus	1.3889e+09 Pa
Geometric Strain Limit	0.03
Young’s Modulus	3.75 GPa
Ultimate Stress	100 MPa
Strength to weight ratio	81 KNm/kg

2.3.8 30% GLASS FILLED PC

Table 16: Mechanical properties of 30% Glass Reinforced PC[20]

Material	30 % Glass Filled PP
Density	1385 Kg/m^3
Shear Modulus	2.7037e+09 Pa
Geometric Strain Limit	0.035
Young’s Modulus	7.3 GPa
Ultimate Stress	130 MPa
Strength to weight ratio	91 KNm/kg

3 RESULTS OF BUMPER ANALYSIS

All the materials where analyzed in ANSYS 14.5 with the boundary conditions and material properties explained in the methodology part. The analysis result of each material is explained in detail below. The total deformation, stress values both with images and graph are explained under each material.

3.1 STEEL

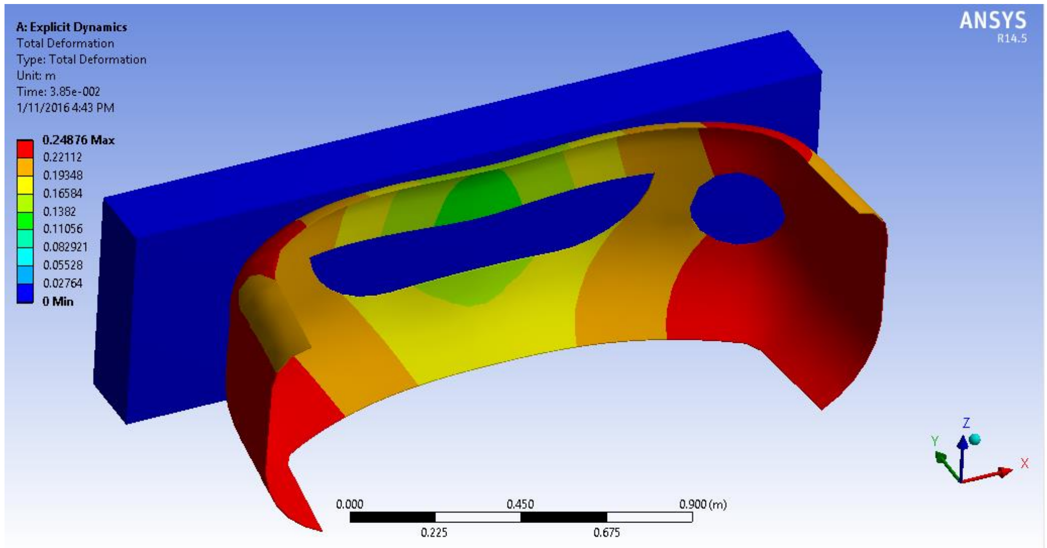


Figure 16: Total deformation of steel

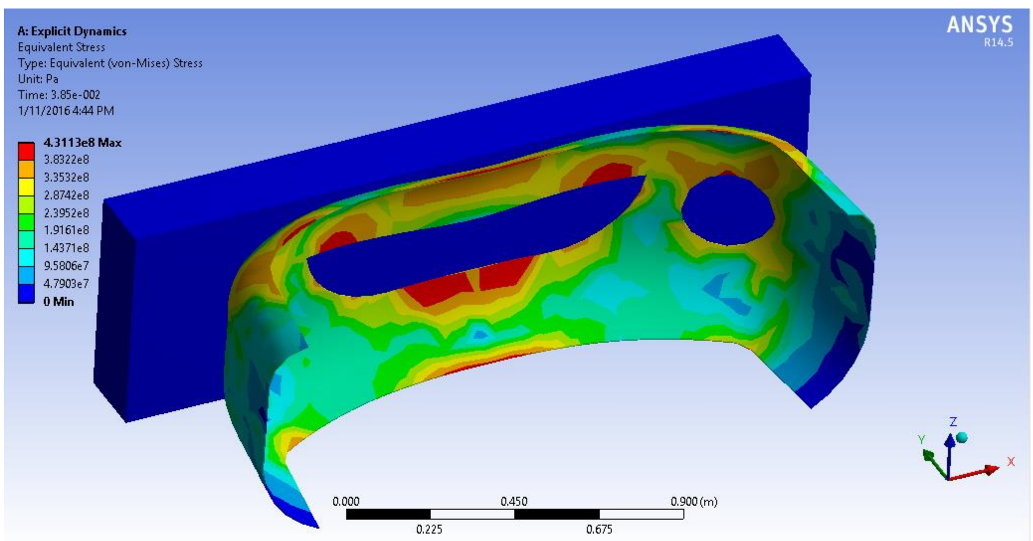
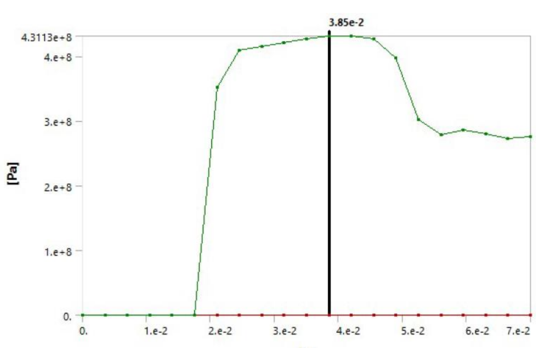
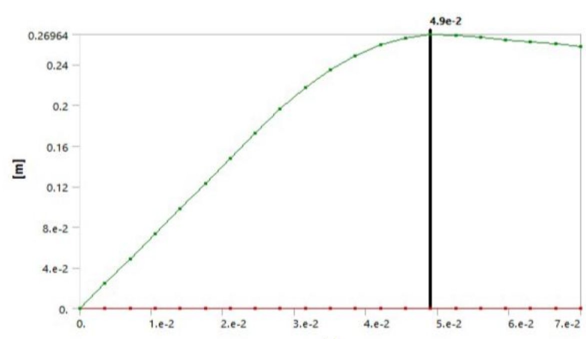


Figure 17: Equivalent von mises stress of steel





Graph 1:Stress Vs Time for steel

Graph 2:Deformation Vs Time for steel

3.2 ALUMINIUM

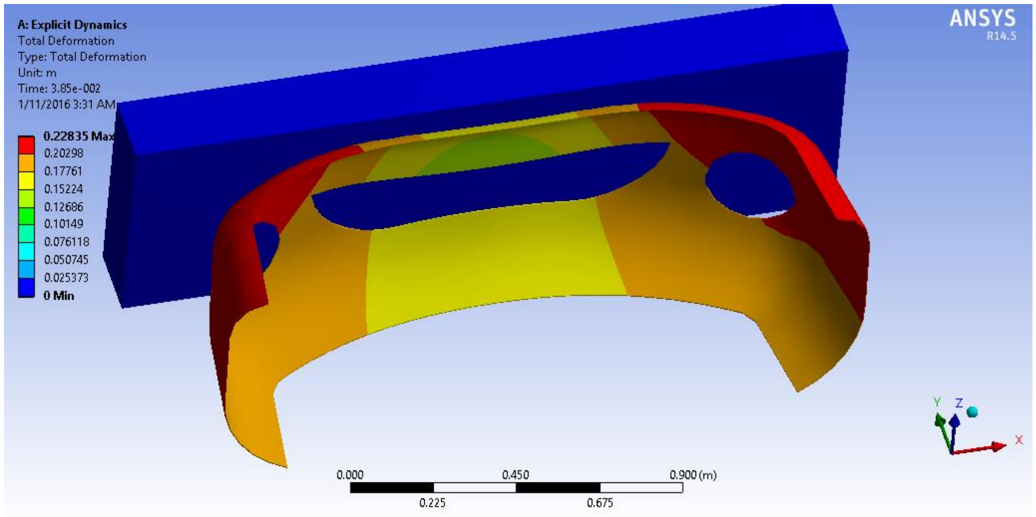


Figure 18: Total deformation of aluminium

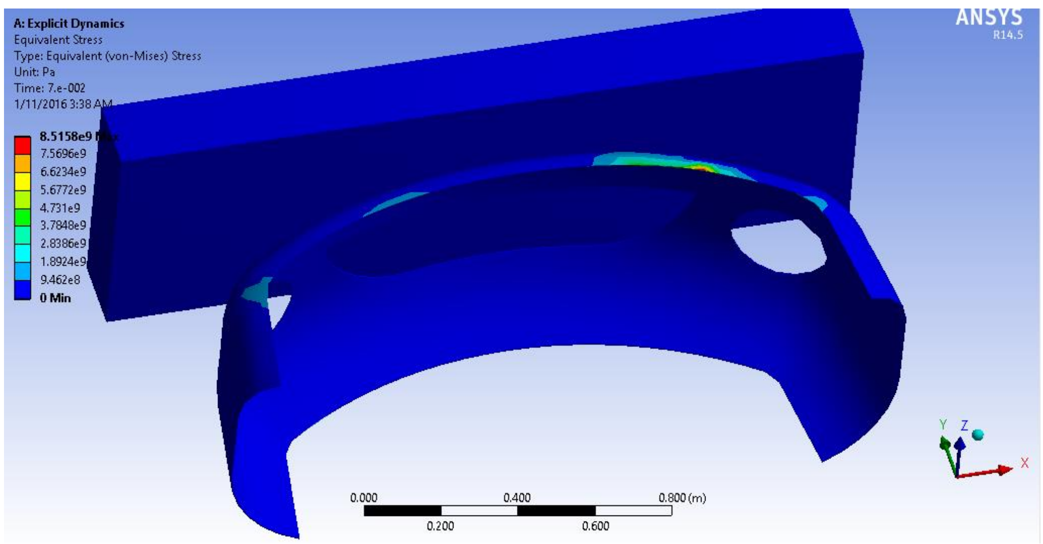
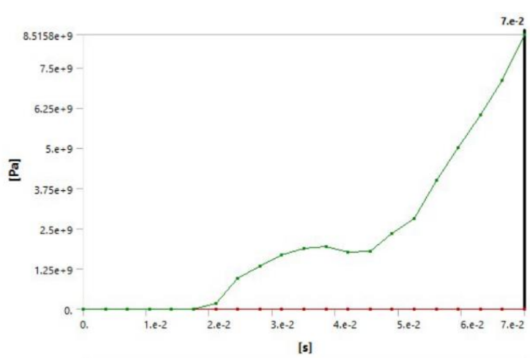
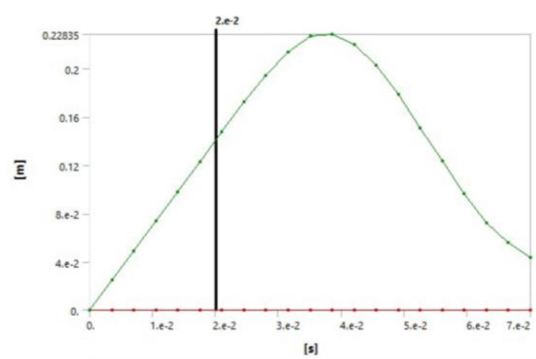


Figure 19: Equivalent von mises stress of aluminium



Graph 3:Stress vs time for aluminium



Graph 4: Deformation vs time for aluminium

3.3 ACRYLONITRILE BUTADIENE STYRENE

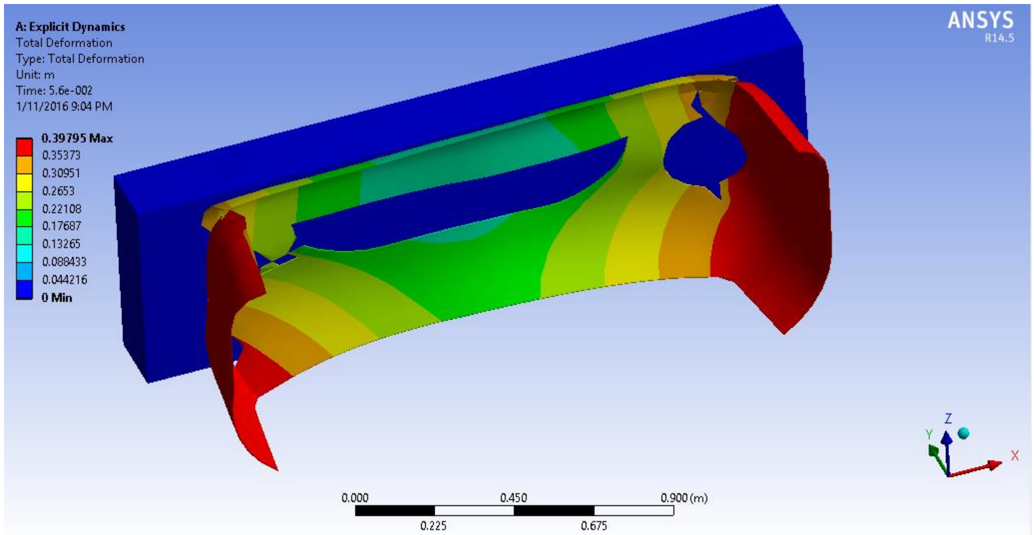


Figure 20: Total deformation of ABS

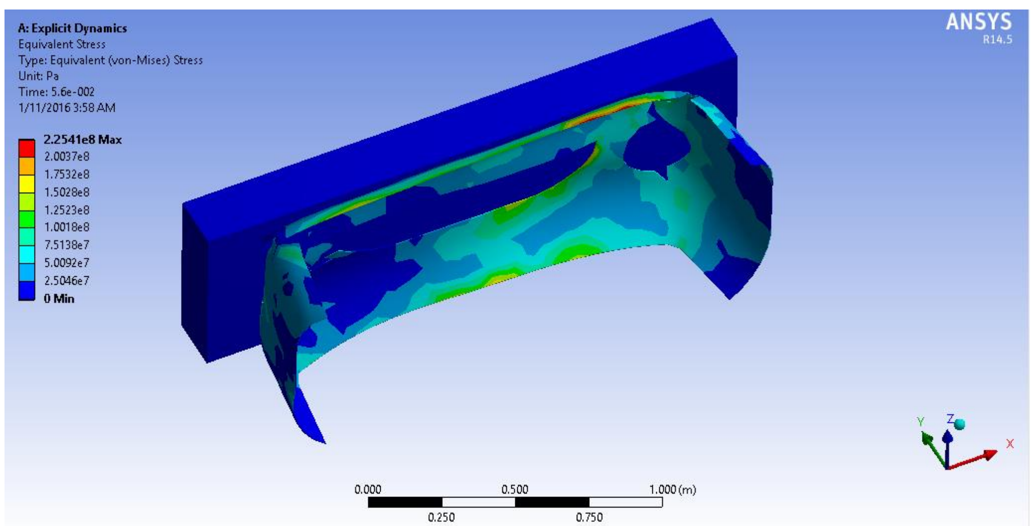
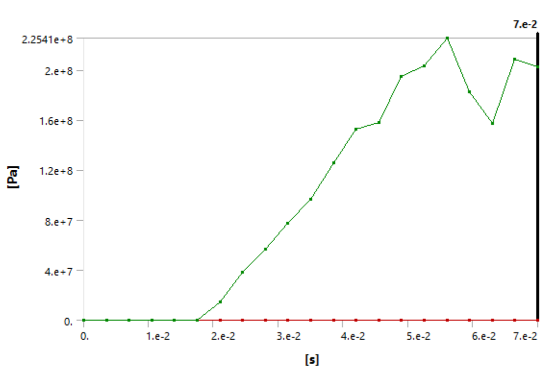
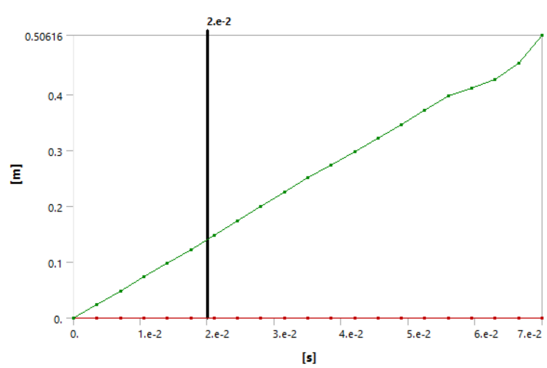


Figure 21: Equivalent von mises stress of ABS



Graph 5:Stress vs time for ABS



Graph 6: Deformation vs time for ABS

3.4 POLYPROPELENE

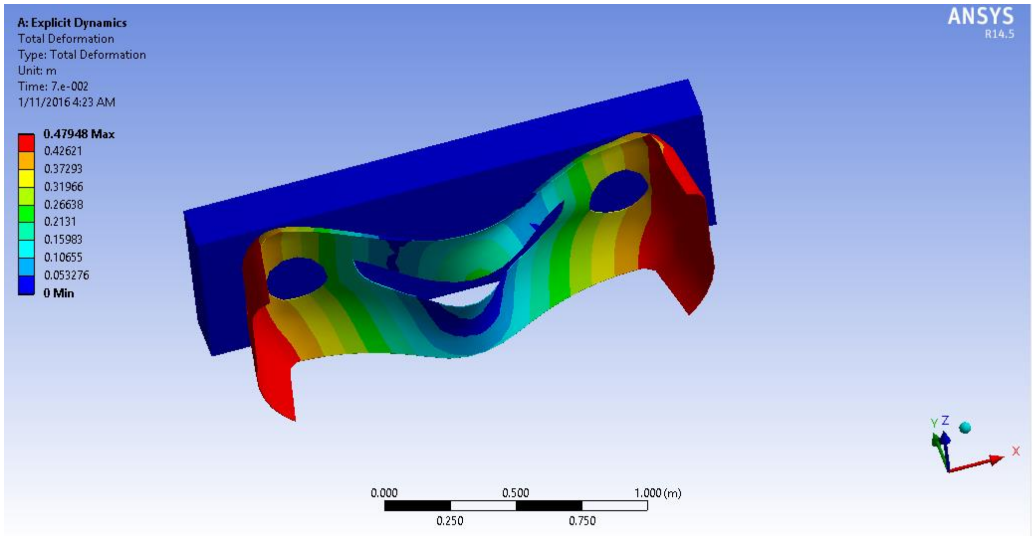


Figure 22: Total deformation of polypropelene

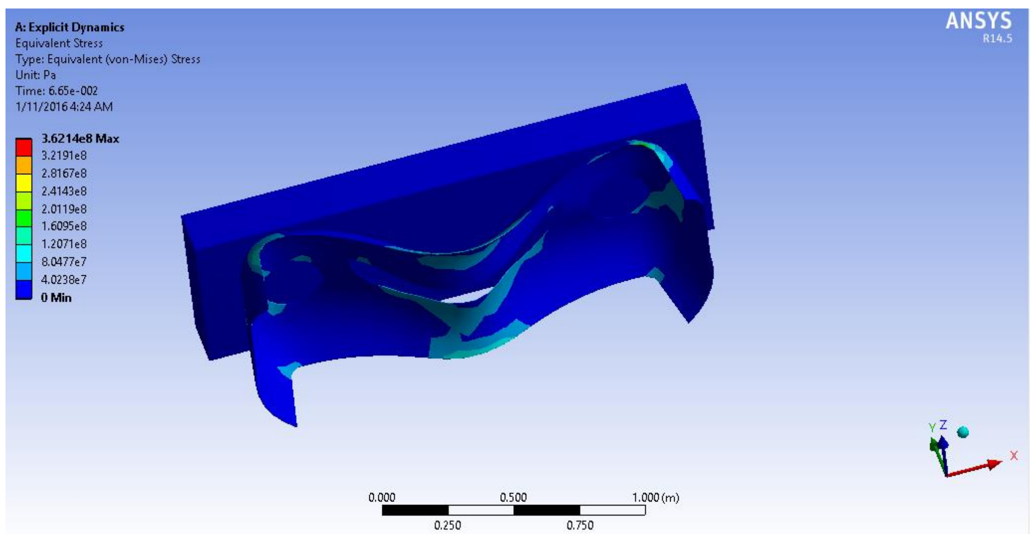
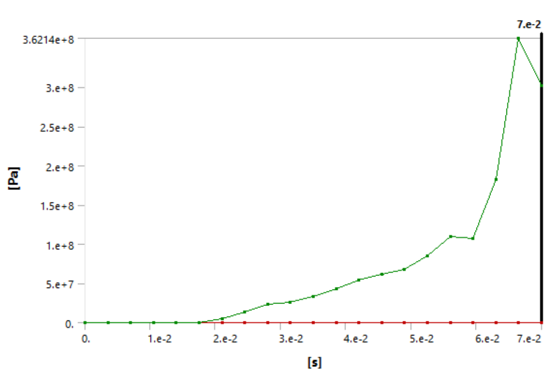
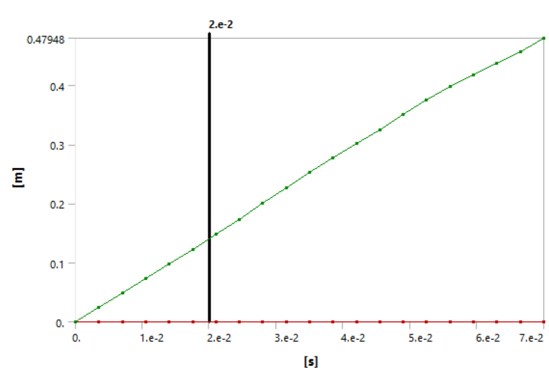


Figure 23: Equivalent von mises stress of polypropylene



Graph 7: Stress vs time for PP



Graph 8: Deformation vs time for PP

3.5 POLYCARBONATE

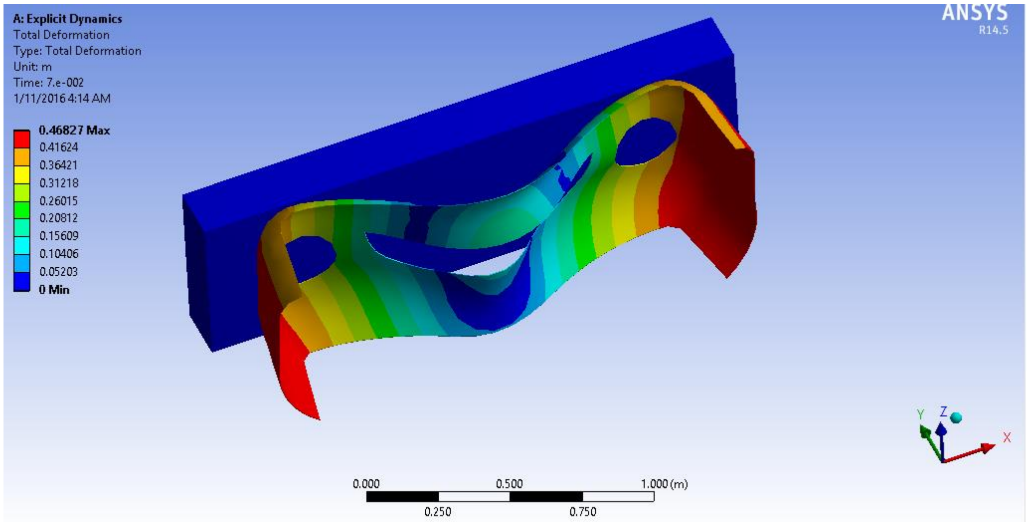


Figure 24: Total deformation of PC

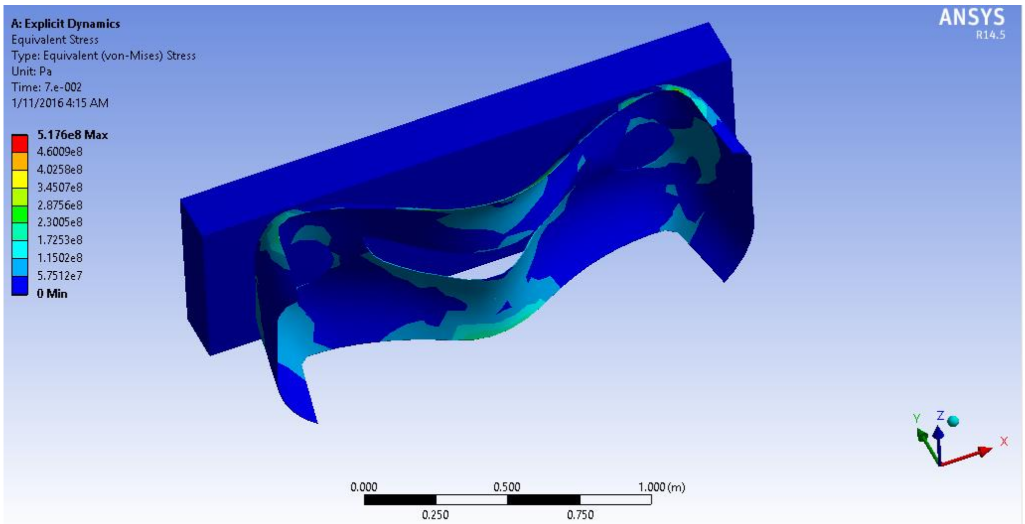
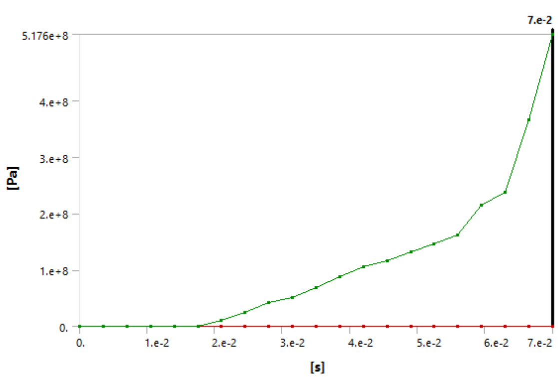
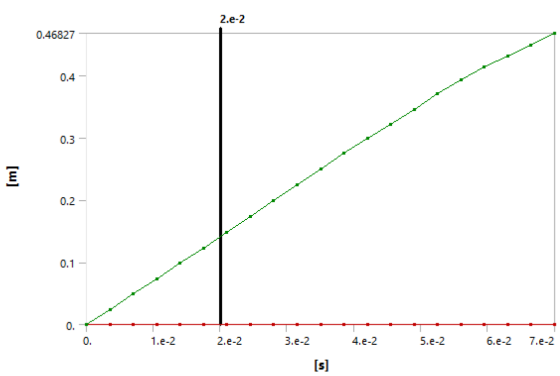


Figure 25: Equivalent von mises stress of PC



Graph 9: Stress vs time for PC



Graph 10: Deformation vs time for PC

3.6 30% GLASS FILLED ABS

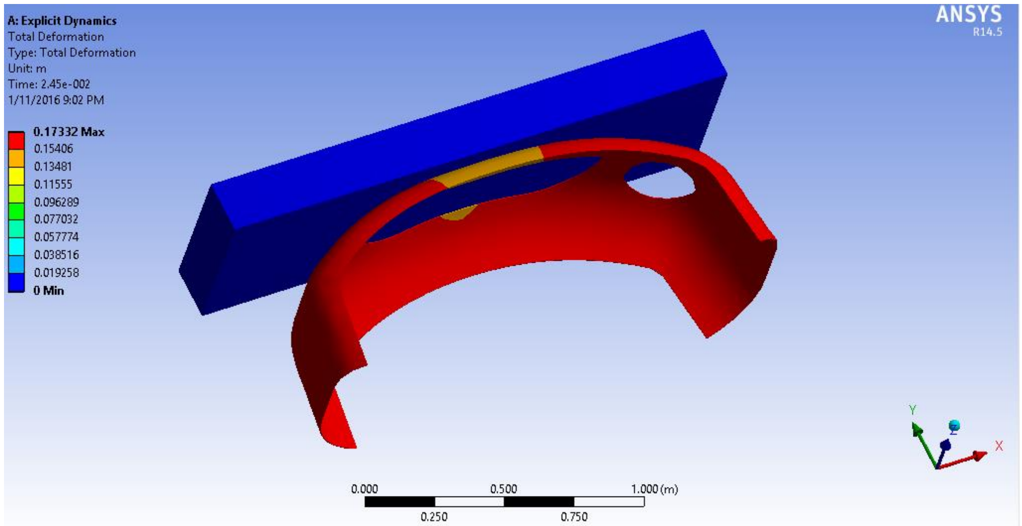


Figure 26: Total deformation of 30% GF ABS

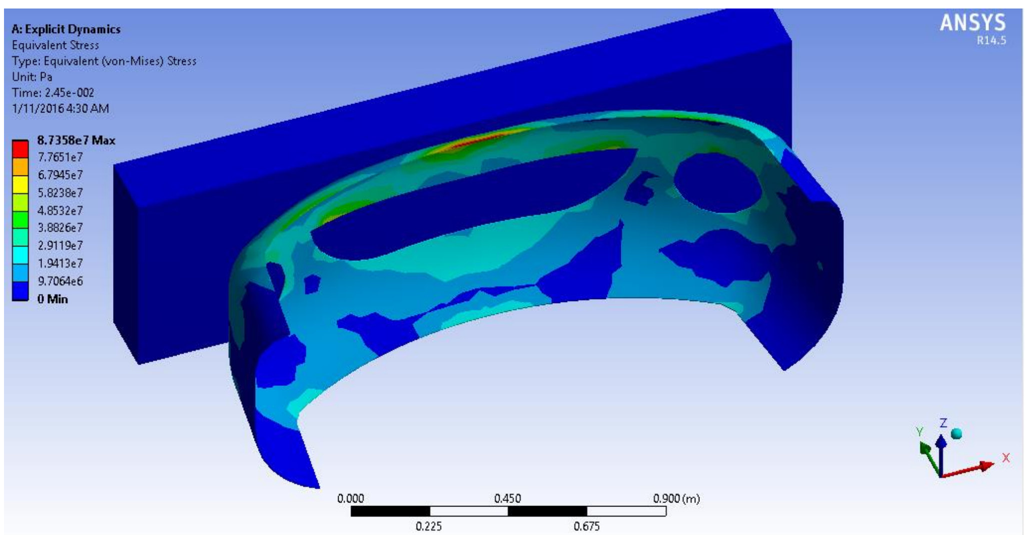
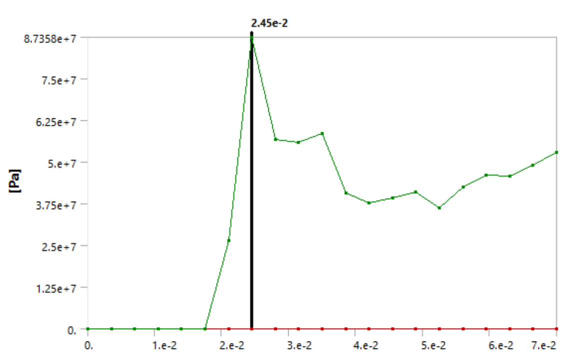
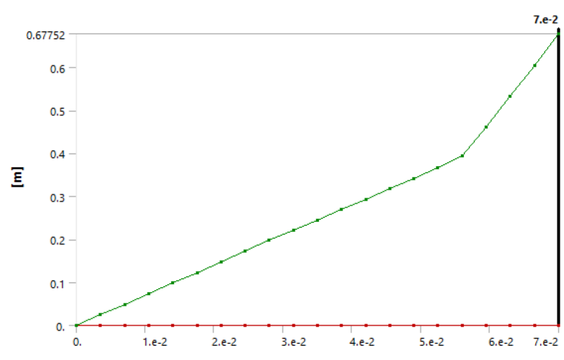


Figure 27: Equivalent von mises stress of 30% GF ABS



Graph 11: Stress vs time for GF ABS



Graph 12: Deformation vs time for GF ABS

3.7 30% GLASS FILLED PP

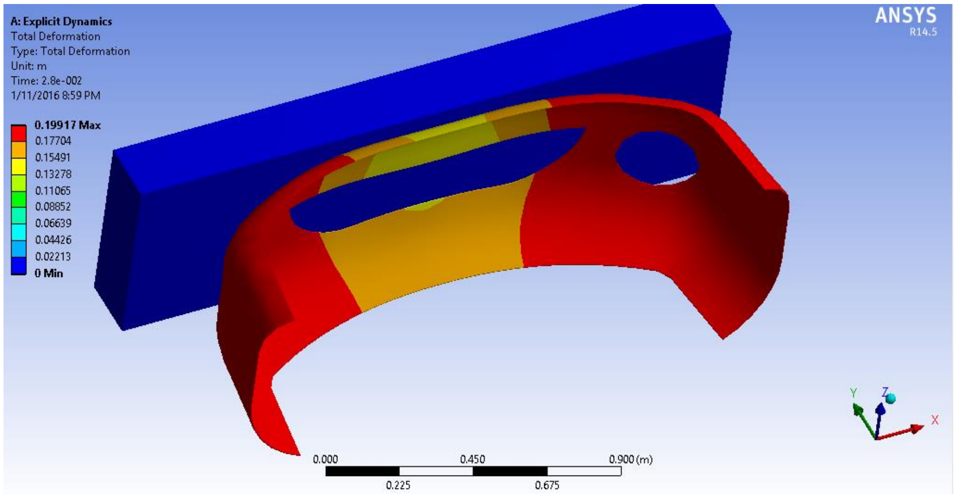


Figure 28: Total deformation of 30% GF PP

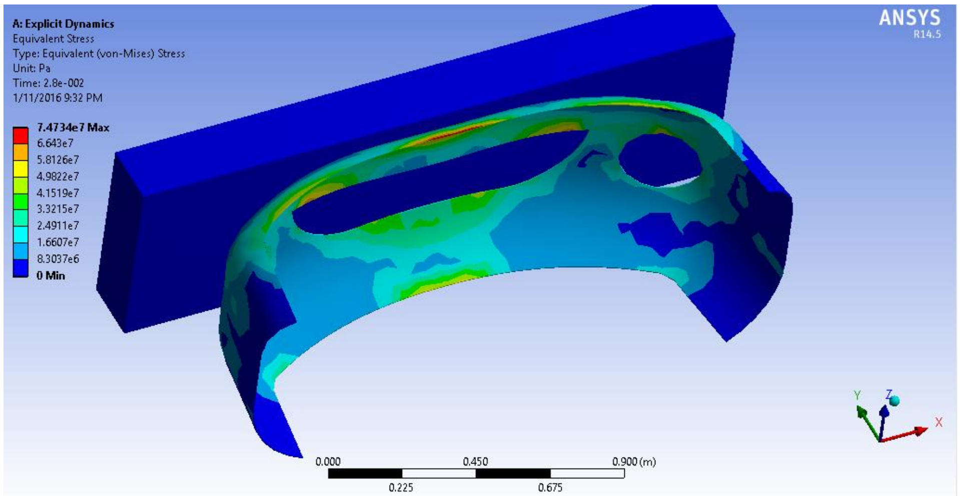
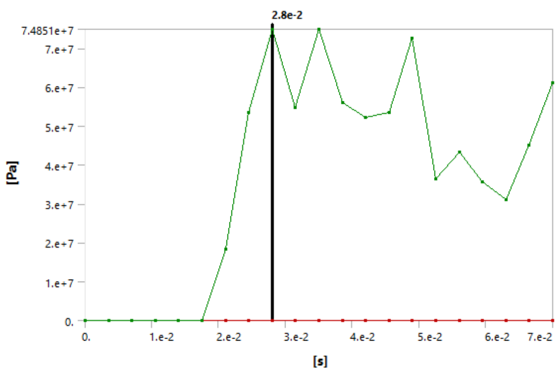
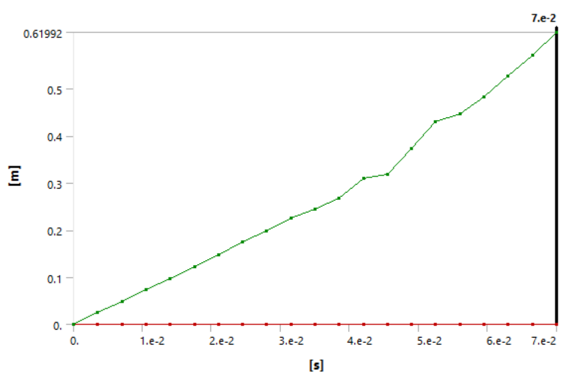


Figure 29: Equivalent von mises stress of 30% GF PP



Graph 13: Stress vs time for GF PP



Graph 14: Deformation vs time for GF PP

3.8 30% GLASS FILLED PC

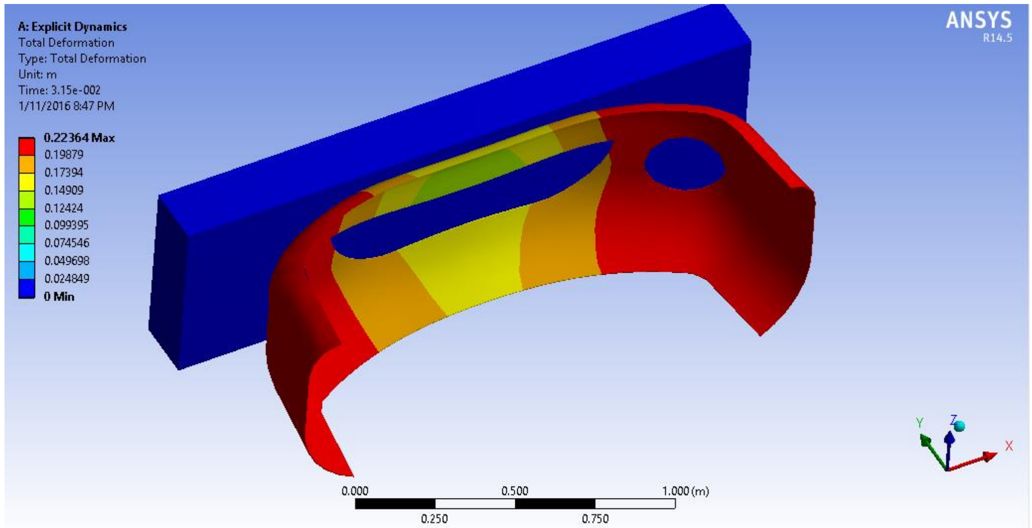


Figure 30: Total deformation of 30% GF PC

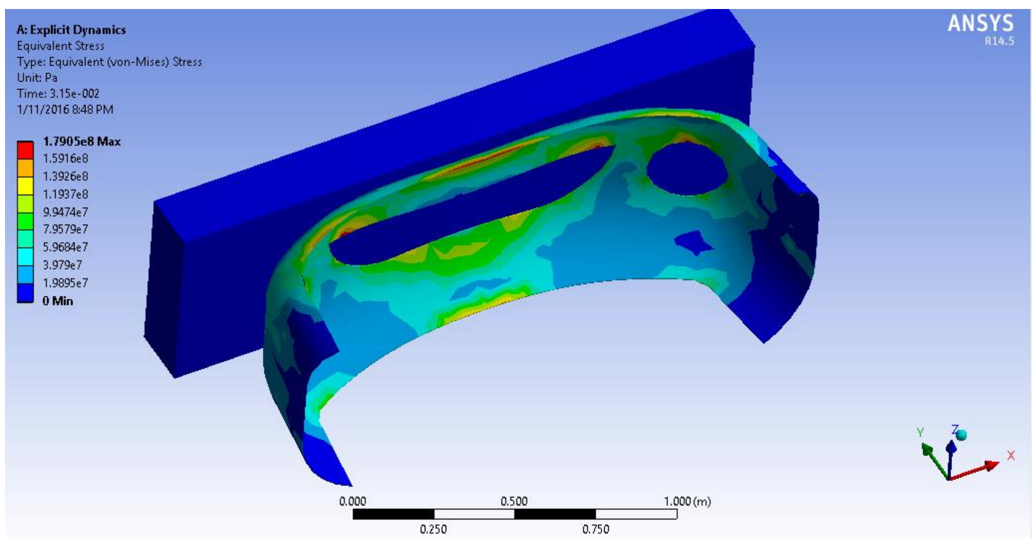
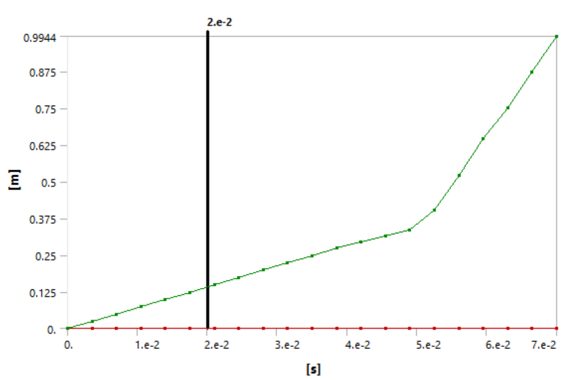
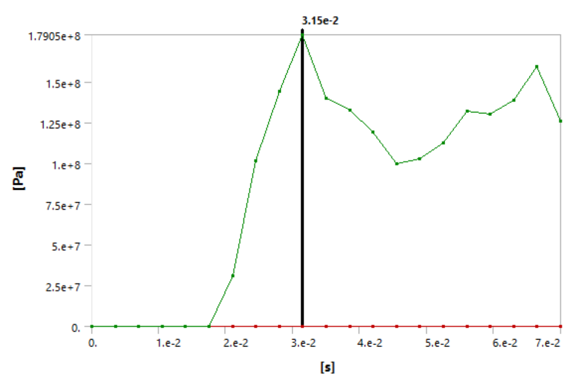


Figure 31: Equivalent von mises stress of 30% GF PC





Graph 15: Stress vs time for GF PC

Graph 16: Deformation vs time for GF PC

3.9 ABS WITH STEEL RIBS

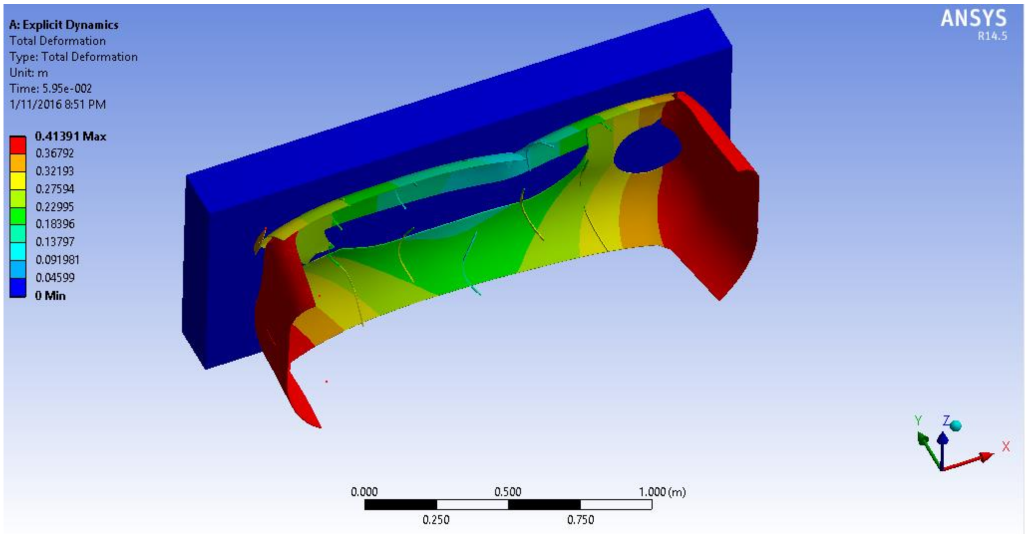


Figure 32: Total deformation of ABS with steel ribs

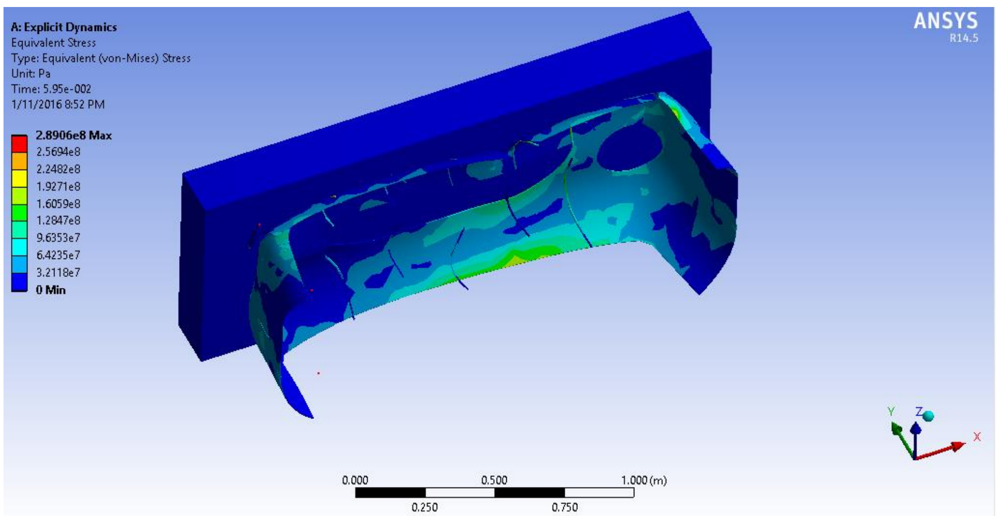
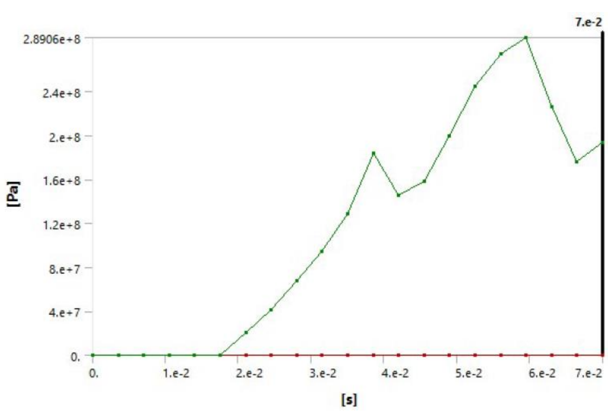
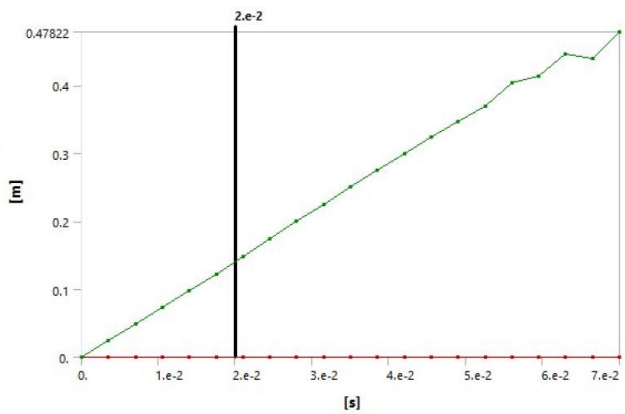


Figure 33: Equivalent von mises stress of ABS with steel ribs





Graph 17: Stress vs time for ABS with ribs

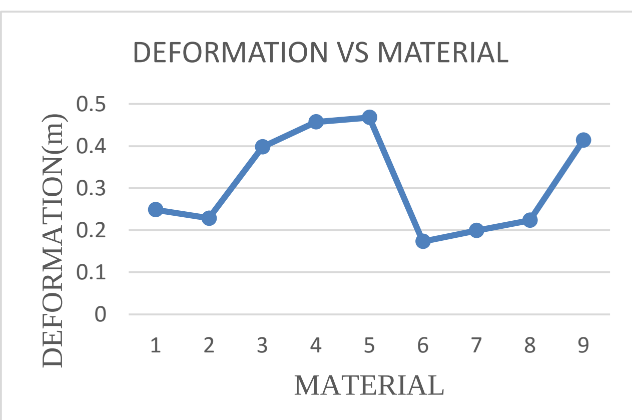
Graph 18: Deformation vs time for ABS with ribs

The above images and graphs show the deformation and stress plot of all the materials that where analyzed. These images represent the behavior of each material within a period of 0.07 seconds within which the bumper is on impact on the concrete wall. The graph clearly shows the downs and peaks of deformation and stress of the considered materials during the impact. The images shows the intensity of stress and deformation over the bumper surface during the impact using the colour codes which are explained clearly on the images.These images and graphs are the automatically generated results from Ansys software which is further interpreted to understand the material behavior.

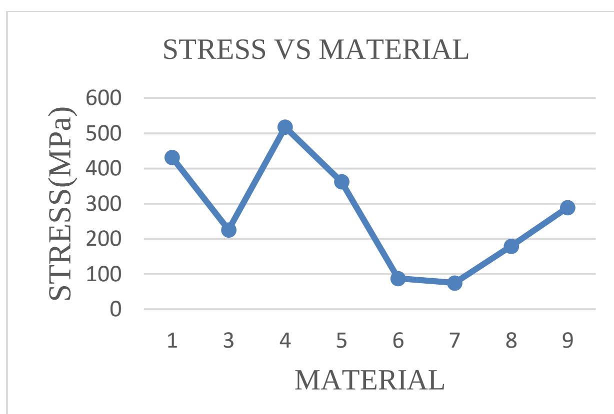
3.10 STRESS AND DEFORMATION GRAPH

Table 17: Stress and deformation values of the considered materials

SL.NO.	MATERIAL	DEFORMATION(m)	STRESS(MPa)
1	Steel	0.24876	431.13
2	Aluminium	0.22835	8515.8
3	ABS	0.39795	225.4
4	PP	0.45742	517.6
5	PC	0.46827	362.14
6	30% GF ABS	0.17332	87.358
7	30% GF PP	0.19917	74.734
8	30% GF PC	0.22364	179.05
9	ABS with ribs	0.4139	289.06



Graph 19: Deformation vs Material



Graph 20: Stress vs Material

The above table shows the maximum stress values and the deformation at that particular time of maximum stress for all the considered materials. These maximum stress values and deformation where obtained from the stress and deformation graphs.Two graphs are shown where stress and deformation are plotted against material individually.This makes our understanding easier how different materials behave during impact.The stress value of Aluminium is not considered in graph 20 as the stress value is much higher and reduces the scale for other materials making the graph uninterpretable.

3.11 FACTOR OF SAFETY

$$FOS = \frac{\text{ULTIMATE STRESS (MPa)}}{\text{ACTUAL STRESS (MPa)}}$$

Table 18: Calculated Factor of Safety for the considered materials

MATERIAL	ULTIMATE STRESS(MPa)	ACTUAL STRESS(MPa)	FOS
Steel	360	431.13	0.83501496
Aluminium	200	8515.8	0.02348576
ABS	110	225.4	0.4880213
PP	100	517.6	0.19319938
PC	150	362.14	0.41420445
30% GF ABS	110	87.358	1.25918634
30% GF PP	100	74.734	1.33807905
30% GF PC	130	179.05	0.72605417
ABS With Ribs	110	289.06	0.38054383

Factor of safety is calculated using the above mentioned formula. The table 18 shows the values of ultimate stress and maximum stress obtained through analysis for all the considered materials and the calculated factor of safety.The ultimate stress values of all the materials where obtained from the references.Both the stress values are represented in Mega Pascal.

4 RESULT DISCUSSION

Crash test of a bumper is simulated using Ansys and the obtained results where shown below the heading results. Three results were obtained with respect to the considered materials, the amount of deformation, stress distribution and Factor of Safety.

4.1 Deformation

The amount of deformation with respect to materials are shown in graph 19.It shows a very low value of 0.17m and 0.19m for 30% Glass filled ABS and PP respectively. Deformation value of steel and Glass Filled PC are very closer with values 0.22m and 0.24 respectively. Whereas the other plastic materials ABS,PP and PC are in a range between 0.4m to 0.46m which is twice as that of steel and other Reinforced plastics. These results clearly show Reinforced plastics are good at bearing the impact

4.2 Stress

The maximum stress values are compared with different materials in the graph 20.The stress value of aluminium is very high to the value of 8515 MPa and hence not represented in the graph. This high value ofstress in aluminium is due to less thickness of bumper. The stress values of Reinforced ABS & PP are found to be below 100MPa and the values of reinforced PC and ABS are closer to each other.

4.3 Factor of Safety

The factor of safety for the considered materials are clearly shown in table 18.Reinforced ABS and PP show a better value of FOS with values 1.2 and 1.3 respectively .Steel and reinforced PC are closer with values 0.8 and 0.7 respectively. Other plastic materials are in the range of 0.2 to 0.4.

The above results of deformation, stress and factor of safety show similarity with the type of materials. Hence the materials can be aligned under three groups. The first group includes 30% glass reinforced ABS and 30% Glass Reinforced PP. The second group includes steel and 30% glass filled PC. The third group includes ABS,PP and PC. The three groups are formed with respect to the ability to withstand the impact. According to the result obtained by simulation and analysis the first group of materials proves to be good to withstand impact than the second and third group of materials. But taking into consideration of material cost, ease of manufacturing and strength to weight ratio 30 % Glass Filled ABS and 30% Glass Filled PP are better materials for bumper to withstand impact. The second better option are the ABS and PP.

5 CONCLUSION

The aim of the thesis is to simulate crash test analysis on bumper using different materials and to analyze the material best suited for bumper. According to the aim the conclusion were obtained

1. The bumper is modeled as per the International regulations using CATIA V5.

2. The bumper is simulated for crash test analysis in Ansys 14.5 using Steel, Aluminium, ABS, PP, PC, 30% glass filled Reinforced ABS, 30% glass filled reinforced PP, 30% Glass filled reinforced PC and ABS Bumper with steel ribs.

3. The results of deformation and stress were obtained from the stress plots and deformation plots generated by the Ansys software.

4. The Factor of Safety was calculated theoretically using the formulas and the obtained results.

5. The results of stress, deformation and factor of safety of the considered materials were compared and analyzed.

6.The materials were aligned in an order of ability to withstand impact considering not only the obtained results but also the cost of material, ease of manufacturing and strength to weight ratio(for weight reduction).

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