IMPACT ANALYSIS OF AUTOMOTIVE BUMPER

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ABSTRACT

Automotive design with economy and safety has been a great challenge. Automotive frontal bumper beam plays an important role in absorbing impact force. Bumper absorbs 15% of total energy in New Car Assessment Programme (NCAP) crash test. In this paper parameters such as shape, material, design and analysis of bumper has been studied to improve its crash performance, material selection and designing having more importance. Modelling and Analysis of the part is being done in SOLIDWORKS. Virtual analysis been more advantageous than impact test as it provides a great platform to carry out simulation of the model in real conditions, which in turn saves a lot of capital and provide more accurate results.The most important step of material selection is done keeping in mind engineering design and its feasibility. Moreover, the material selected is checked for its environmental impact.

Keywords: *NCAP, Solidworks, Simulation, Virtual Analysis.*

1. INTRODUCTION

Car accidents are unpredicted, which happens every day. Nearly 1.3 million people die in road crashes each year, on an average 3287 deaths a day. An additional 20 to 30 million are injured or disabled. These statistics are alarming and raises a concern over safety of passengers and car system. One of the safety features are in build in the front of automobile that is bumper beam system. Bumper became standard equipment of automobile in 1925. The uses of bumper has evolved from a mechanism being placed on the front and rear of the car to protect the body and safety features of motor vehicle from getting damage due to low speed collisions. They protect the hood, trunk, grill, fuel, exhaust and cooling system. They also protect the equipments such as parking lights, headlamps, tail lamps, radiator system and major engine part. Therefore, the bumper should be designed in such a way that they absorb major part of energy through energy absorbing device and transfer rest of it to chassis of automobile.

The simulation of motor vehicle is done for low velocity impact test, on the other hand, it should absorb all the energy excluding the energy absorbed by body panel, bumper over, reinforcement, radiator support, Et-cetera,. According to United Nations Economic Commission for Europe(ECE) Regulation number 42.

Although, nowadays bumper is being designed more for aesthetics of motor vehicle rather than the actual functionality. The styling of bumper has become more important than structural design of the bumper. Nevertheless, the standards and regulations governing the design of the bumper should not be compromised in any circumstances. The study carried out by Federal Motor Vehicle Safety Standards and Regulations (FMVSS) highlights how the present day bumpers on motor vehicles are connected to the fenders rather than frame of the motor vehicle where it would be of more use and steady during low speed collision. The design of automobile parts and assemblies, components must be positioned with tight tolerances, so as to maintain automotive aerodynamics and functionality of components with respect to each other. Furthermore the support structures must not deform bumper components by applying unnecessary stresses. Therefore energy absorbing devices are installed in the bumper beam system. This device absorbs major part of energy during the impact and transfers rest to the surrounding.

Most automotive energy absorbers that are in the market today are designed to meet safety regulations with respect to individual geographic locations. North American markets will require that the design should satisfy FMVSS regulations that require the energy absorbers just to protect the car. The European and Asia Pacific markets have different set of requirements that focuses also on the safety of the pedestrian. However, the difficulties of designing a bumper system that is rigid enough to protect the vehicle and, at the same time compliant enough to protect a pedestrian raise questions as to whether these ideas are compatible.

2. LITERATURE REVIEW

- **Alen John, Nidhi (2014)**- They studied that Composites has the maximum stress value and it having the highest strength to weight ratio and producing low deformation as compared to Aluminium B390 alloy, Chromium coated and mild steel.

- **Alen John, Sanu Alex (2014)-** The objective of the study was to study desirable properties of polymer composite materials and compare with currently used materials.
- **Nitin S. Motgi, S.B.Naik, P.R.Kulkarni (2013)-** The objective was to study stress pattern of designed automotive bumper selecting suitable materials such as metals and composites. And comparing the results obtained. They found composite materials were more effective than metals.
- **A.R. Mortazavi Moghaddam, M.T. Ahmadian, Hosseinzadeh (2011)**- They studied the structure, shape and impact condition of Glass Mat Thermoplastic (GMT) bumper and the results are compared with conventional metals like steel and aluminium. GMT showed very good impact behaviour compared to with steel and aluminium, which all failed and showed manufacturing difficulties due to strengthening ribs or weight increase due to use more dense material.

3. METHODOLOGY

- Study the literature related to bumper design and its performance improvement by referring to books, journal papers and related manuals.
- Obtaining design data of existing bumper model.
- 3D modeling of bumper model in SolidWORKS.
- Selection of bumper material in accordance with design.
- Theoretical calculation of impact force on bumper system.
- Analysis of part being designed using SolidWORKS.
- Calculation of von-mesis stress and displacement and comparing the results obtained.

4. IMPACT MECHANICS

4.1 Low speed collisions at 30kmph

Weight of car =1400kg

Weight of four passengers = 100kg

Total weight of vehicle in motion = weight of car + weight of passengers

= 1400 +400

= 1800kg

During collision the energy (work) is generated in form of kinetic energy, which is given by

$$\textbf{Kinetic Energy} = \frac{1}{2} m v^2$$

Where m is the mass of the car, kg

v is the velocity of the car, m/s

Now, converting the velocity of car in m/s

$$v = 30 * \frac{5}{18} \text{ m/s}$$

$$v = 8.33 \text{ m/s}$$

On substituting the above value, we get the kinetic energy generated during the impact

$$\text{Kinetic Energy} = \frac{1}{2} * 1800 * 8.33^2$$

$$= 62450.01 \text{ Joules}$$

This kinetic Energy is the work done during collision, therefore Kinetic Energy = Work Done (W)

Work Done (W)=62450.01 Joules

To overcome the amount of kinetic energy generated, there should be a displacement of car components. Since, it is a frontal impact let us constrain the maximum displacement to 500 mm for passenger and other major component's safety.

As we know, the work done can also be calculated as,

$$W = F * d$$

Where W is energy, J

F is Force, N

d is maximum displacement of bumper, m

$$62450.01 = F * 0.500$$

$$F = \frac{62450.01}{0.500}$$

$$F = 124900.02 \text{ N}$$

$$F = 124.9 \text{ kN}$$

Therefore, during the frontal impact the car experiences the force of 124.90 kN at the speed of 30kmph.This Force is equal to 7 times the G-Force, which is fatal to human body.

4.2 Low speed collisions at 60kmph

Weight of car =1400kg

Weight of four passengers = 100kg

Total weight of vehicle in motion = weight of car + weight of passengers

= 1400 +400

= 1800kg

During collision the energy (work) is generated in form of kinetic energy, which is given by

$$\textbf{Kinetic Energy} = \frac{1}{2} m v^2$$

Where m is the mass of the car, kg

v is the velocity of the car, m/s

Now, converting the velocity of car in m/s

$$v = 60 * \frac{5}{18} \text{ m/s}$$

$$v = 16.67 \text{ m/s}$$

On substituting the above value, we get the kinetic energy generated during the impact

$$\text{Kinetic Energy} = \frac{1}{2} * 1800 * 16.67^2$$

$$= 250100.01 \text{ Joules}$$

This kinetic Energy is the work done during collision, therefore Kinetic Energy = Work Done (W)

$$\text{Work Done (W)} = 250100.01 \text{ Joules}$$

To overcome the amount of kinetic energy generated, there should be a displacement of car components. Since, it is a frontal impact let us constrain the maximum displacement to 500 mm for passenger and other major component's safety.

As we know, the work done can also be calculated as,

$$W = F * d$$

Where W is energy, J

F is Force, N

d is maximum displacement of bumper, m

$$250100.01 = F * 0.500$$

$$F = \frac{250100.01}{0.500}$$

$$F = 500200.02 \text{ N}$$

$$F = 500.2 \text{ kN}$$

Therefore, during the frontal impact the car experiences the force of 500.2kN at the speed of 60kmph.This Force is equal to 28 times the G-Force, which is fatal to human body.

5. 3D MODELLING OF BUMPER IN SOLID WORKS

SolidWorks is a solid modeling computer-aided design (CAD) and computer-aided engineering (CAE) computer program that runs on Microsoft Windows. SolidWorks is published by Dassault Systèmes. Building a model in SolidWorks usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SolidWorks means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.

5.1 3D Modeling of front bumper:

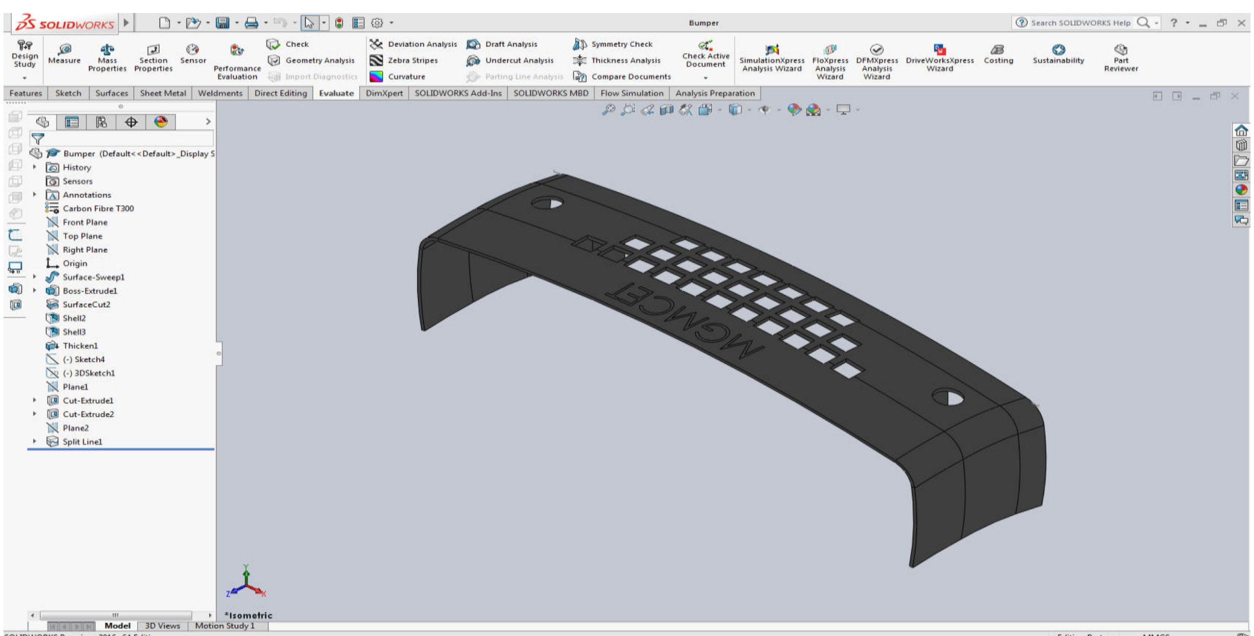


Figure 1: Modeling of front bumper.

5.2 3D Modeling of rear bumper:

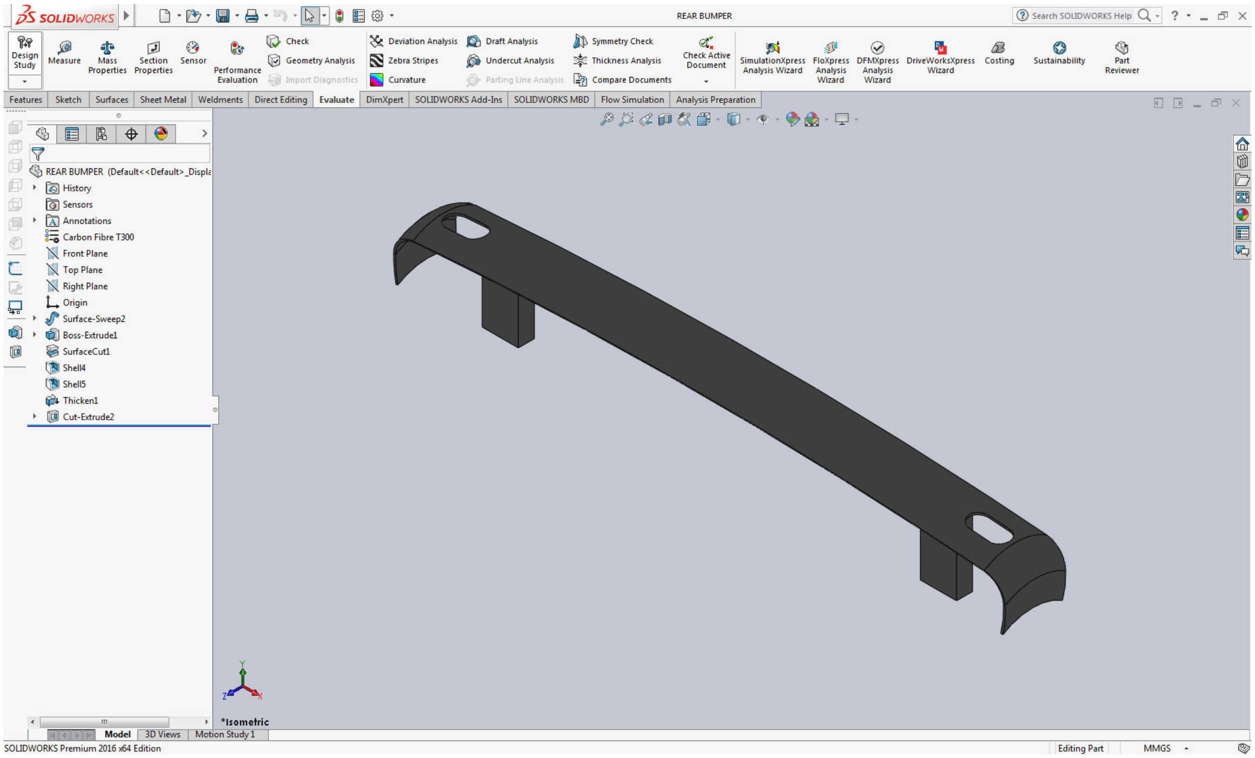


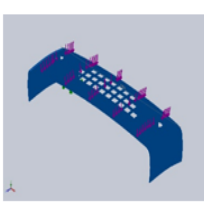
Figure 2: Modeling of rear bumper.

6. IMPACT ANALYSIS ON BUMPER MODEL USING SOLIDWORKS

The analysis on bumper model was done is SOLIDWORKS. The analysis was carried out with two materials plain carbon steel and carbon fiber T300. One being metal and other being composite polymer. The study was done at two impact forces one at 30 km/hr and other at 60 km/hr on front bumper and the rear bumper was studied at 30 km/hr.

6.1 Front bumper system: Plain carbon steel at 30km/hr and 60 km/hr:

6.1.1 Properties of plain carbon steel

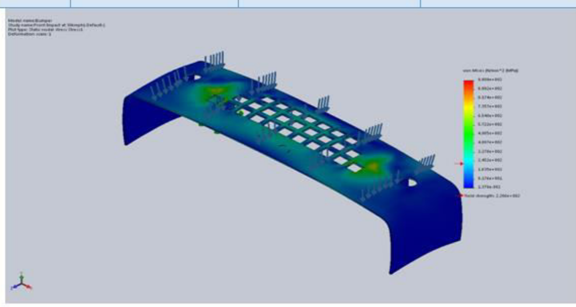
Document Name and Reference	Treated As	Volumetric Properties	Date Modified
Split Line1 	Solid Body	Mass:65.4111 kg Volume:0.00838603m^3 Density:7800 kg/m^3 Weight:641.028 N	Mar 14 14:14:20 2018

Name:	Plain Carbon Steel
Model type:	Linear Elastic Isotropic
Default failure criterion:	Max von Mises Stress
Yield strength:	2.20594e+008 N/m^2
Tensile strength:	3.99826e+008 N/m^2
Elastic modulus:	2.1e+011 N/m^2
Poisson's ratio:	0.28
Mass density:	7800 kg/m^3
Shear modulus:	7.9e+010 N/m^2
Thermal expansion coefficient:	1.3e-005 /Kelvin

Figure 3: properties of plain carbon steel of front bumper.

6.1.2 Stress and displacement at 30 km/hr:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.013704 N/mm^2 (MPa) Node: 9545	980.936 N/mm^2 (MPa) Node: 16261



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1523	21.3695 mm Node: 1005

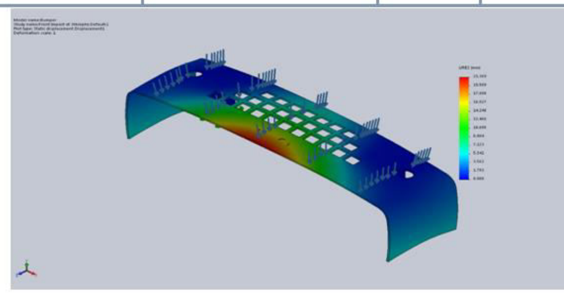
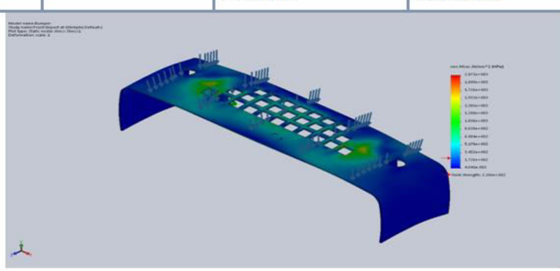


Figure 4: stress analysis of PCS at 30 km/hr.

Figure 5: Displacement analysis of PCS at 30km/hr.

6.1.3 Stress and displacement at 60 km/hr:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.0464118 N/mm^2 (MPa) Node: 9769	2071.23 N/mm^2 (MPa) Node: 16261



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1523	45.1666 mm Node: 1005

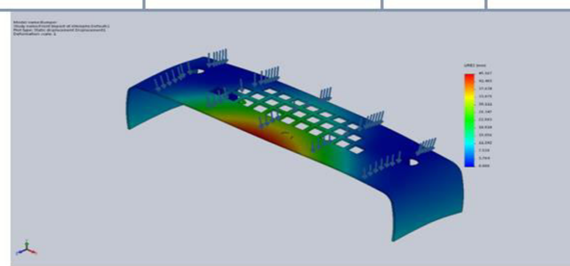
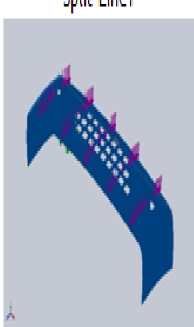


Figure 6: Stress analysis of PCS at 60km/hr.

Figure 7: Displacement of PCS at 60km/hr.

6.2 Front bumper system: Carbon fiber T300 at 30km/hr and 60 km/hr:

6.2.1 Properties of carbon fiber:

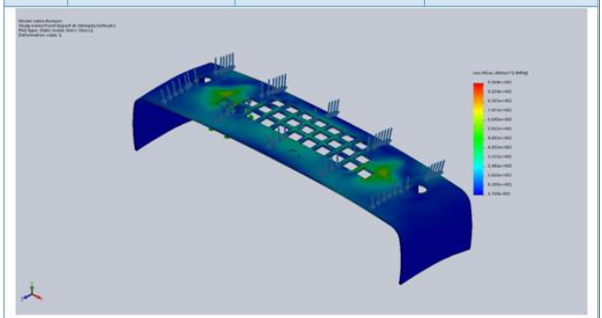
Document Name and Reference	Treated As	Volumetric Properties
Split Line1 	Solid Body	Mass:14.7594 kg Volume:0.00838603 m^3 Density:1760 kg/m^3 Weight:144.642 N

Properties	
Name:	Carbon Fibre T300
Model type:	Linear Elastic Isotropic
Default failure criterion:	Unknown
Tensile strength:	4.9e+009 N/m^2
Elastic modulus:	2.3e+011 N/m^2
Poisson's ratio:	0.22
Mass density:	1760 kg/m^3
Shear modulus:	1.39e+010 N/m^2

Figure 8: properties of Carbon Fiber

6.2.2 Stress and displacement at 30 km/hr:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.0176935 N/mm^2 (MPa) Node: 1793	996.397 N/mm^2 (MPa) Node: 16261



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1523	19.2078 mm Node: 1005

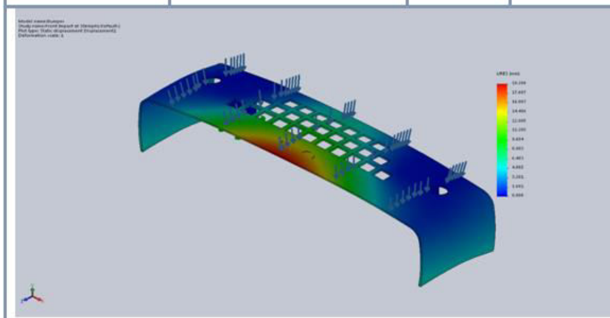
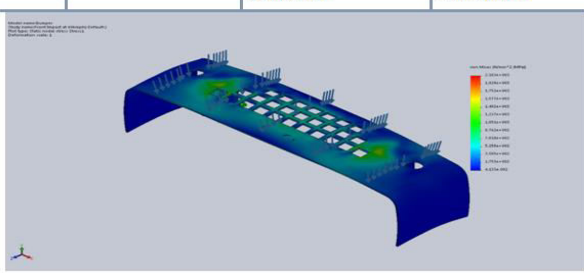


Figure 9: Stress analysis of Carbon Fiber at 30 km/hr.

Figure 10: Displacement of Carbon Fiber at 30 km/hr.

6.2.3 Stress and displacement at 60 km/hr:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.041327 N/mm^2 (MPa) Node: 9769	2102.92 N/mm^2 (MPa) Node: 16261



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1523	40.7826 mm Node: 1005

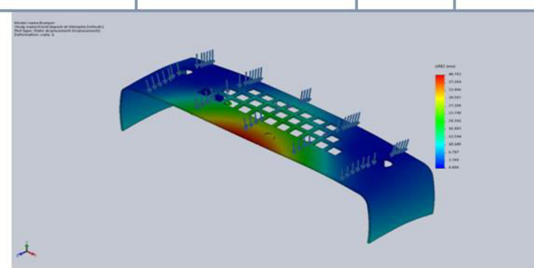


Figure 11: Stress analysis of Carbon Fiber at 60 km/hr.

Figure12: Displacement of Carbon Fiber at 60 km/hr.

6.3 Comparative study of front bumper at 30 km/hr:

Material	Stress(MPa)	Displacement(mm)
Plain Carbon Steel	980.936	21.369
Carbon fiber T300	996.397	19.207

6.4 Comparative study of front bumper at 60 km/hr:

Material	Stress (MPa)	Displacement (mm)
Plain Carbon Steel	2071.23	45.166
Carbon Fiber T300	2102.92	40.782

From the above results we can say that Displacement of Carbon Fiber T300 is minimum as compared to other materials.

6.5 Rear bumper system: Plain carbon steel at 30km/hr:

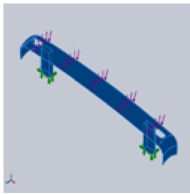
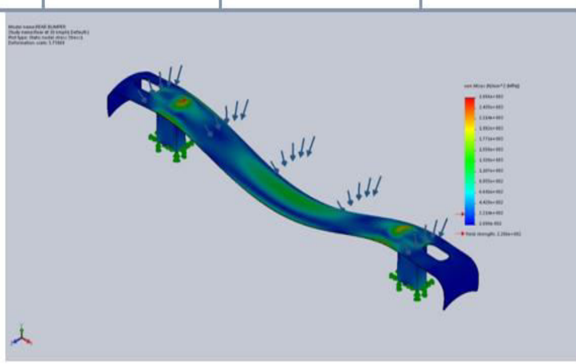
Document Name and Reference	Treated As	Volumetric Properties	Date Modified
	Solid Body	Mass:13.8182 kg Volume:0.00177156 m^3 Density:7800 kg/m^3 Weight:135.418 N	Mar 16 23:17:29 2018

Figure 13: Properties of plain carbon steel of rear bumper.

6.5.1 Stress and displacement at 30 km/hr:

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.0268009 N/mm^2 (MPa) Node: 15233	2656.38 N/mm^2 (MPa) Node: 23300



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 33	40.7074 mm Node: 1358

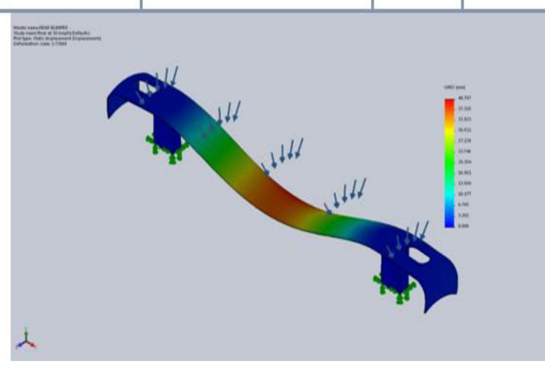


Figure 14: stress analysis of PCS at 30 km/hr.

Figure 15: Displacement analysis of PCS at 30km/hr.

6.6 Rear bumper system: Carbon fiber T300 at 30km/hr:

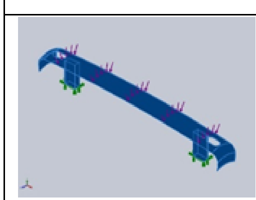
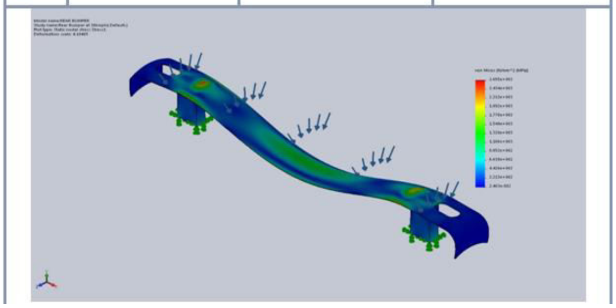
Document Name and Reference	Treated As	Volumetric Properties
	Solid Body	Mass:3.11795 kg Volume:0.00177156 m^3 Density:1760 kg/m^3 Weight:30.5559 N

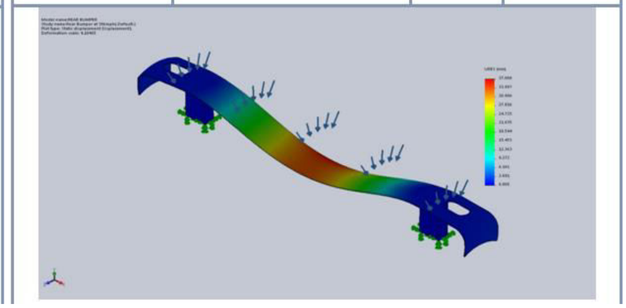
Figure 16: Properties of Carbon Fiber of rear bumper.

6.6.1 Stress and displacement at 30 km/hr:



Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.0246272 N/mm^2 (MPa) Node: 15230	2655.49 N/mm^2 (MPa) Node: 23300

Figure 17: Stress analysis of Carbon Fiber at 30 km/hr.



Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 33	37.0878 mm Node: 1358

Figure 18: Displacement of Carbon Fiber at 30 km/hr.

6.7 Comparative study of rear bumper at 30 km/hr:

Material	Stress (MPa)	Displacement (mm)
Plain Carbon Steel	2656.38	40.7074
Carbon Fiber T300	2655.49	37.0878

7. CONLUSION

From the above results it is clearly indicative that use of composite polymers is very advantageous than metals, due to following reasons:

- Decrease is weight of system, increases fuel efficiency of an automobile
- Displacement experienced by Carbon Fiber T300 is less compared to plain carbon steel, therefore use of carbon fiber makes system more compact and reliable.

Nowadays, the composite materials such as TPO, Polypropylene used in bumpers are attached to the fenders due to this the displacement is more and the stress handling capacity is less as compared to Carbon Fiber T300.Bumpers made up of Carbon Fiber T300 does not need any extra attachments they can be directly attached to the car chassis which can improve its capacity.

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