

Effect of Frontal Crash on Composite Bumper Beam & Chassis Strength of passenger vehicle using FEM Analysis

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ABSTRACT: In this paper the analysis is done on the automotive bumper and the crash box assembly to check the crashworthiness for the passenger safety and effect of the most favourable frontal bumper beam on the chassis. For this we have done static analysis on 3 types of material and sections by applying various forces on them. The model is created using CATIA software where static analysis is done by using Ansys 14.5. From the result obtained best fit has been analysed in dynamic form and its results were compared with the experimentation results to see if the dynamic and actual results are affecting similarly to chassis or not.

KEYWORDS: Chassis Analysis, Composite Bumper Beam, Frontal Crash, FEM.

I. INTRODUCTION

Transportation is identified as the major sector contributor to the accidents and the CO₂ emissions. The greatest challenges faced by the automotive industry has been to provide safer vehicles with high fuel efficiency at competitive cost. Weight reduction has been the main focus of automobile manufacturers in the present scenario. As it's not always possible to optimize weight of complete vehicle we tried doing it from the very first part of the BIW. The automobile energy absorbing component equipped at the front end of car is one of the most important automotive parts for crash energy absorption. BIW is considered as the complete basic body of the vehicle and that part is frontal bumper beam and crash can assembly. Study has been done on various sections, materials to show which one has similar or more effect on chassis of vehicle despite of low weight and cost.

1.1 Kinetic Energy during the impact

In passenger vehicle complete body act as a chassis so the structure of the body is designed in such a way that it should transmit the energy as shown in below figure surviving a crash is all about kinetic energy. When body is moving, it has a certain amount of kinetic energy. After the crash, when passenger comes to a complete stop, they will have zero kinetic energy. To minimize risk of injury, it is required to remove the kinetic energy as slowly and evenly as possible. For optimal frontal crash behavior, all kinetic energy should be dissipated by the front structure.

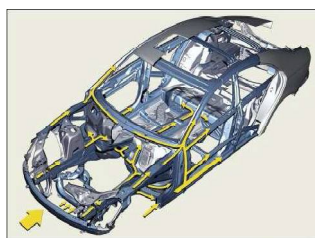


Fig 1. Energy absorbing flow of force within the body (a)

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II. OBJECTIVE OF WORK

- To compare the load carrying capacity, stresses, deflection and weight saving at same load applied to composite Automotive Bumper with that of EN45 steel Automotive Bumper.
- The focused on the implementation of composite material by replacing steel in frontal crash beam of a bumper to reduce weight, improving safety, and durability.
- To design and analyzed composite bumper for automobile, under static loading and comparing the result with the FEA results of steel bumper
- Find out the variation between composite material and steel material Automotive Bumper, after finite element analysis.
- To find out the weight ratio of steel aluminium and composite material Automotive Bumper Beam.

LITERATURE REVIEW

- a) Pradeep Kumar Uddandapu presented paper in which the analysis is done on the automotive bumper to check the crashworthiness for the passenger safety.
- b) A.R. MortazaviMoghaddamand M. T. Ahmadian AhmadianThe goal of this paper is to design a bumper with minimum weight by employing the Glass Material Thermoplastic (GMT) materials.
- c) Bhavesh A. Bohra, Prof. D. B.Pawar presented paper in which the analysis is done on the automotive bumper to check the crashworthiness for the passenger safety.
- d) Mr. Nitin S. Motgi, S. B. Naik, P.R.Kulkarni.focused upon finding an optimum cross sectional shape of a crash box to ensure high capability for energy absorption without crash bead.
- e) Javad Marzbanrad Mehdi Mehdikhan, AshkanSaeedi Pour presented a paper introducing the research course of vehicle crash safety performance..

ANALYTICAL CALCULATIONS

The moment for steel aluminium and composite bumper is assumed to be same.

For calculating moment of inertia for steel bumper For designing the composite bumper an already existing ambassador steel bumper is used as mould. Dimensions are assumed as same as that of steel bumper for fabrication.

Dimensions And Properties of Existing Steel Bumper

Effective length = 0.975m Total length = 2.055m

Thickness = 0.002m Effective breath = 0.078m

Total breath = 0.172m

Weight = 5.16kg

Material = mild steel (chromium coated)

Tensile strength = 460MPa (design data book)

Density = 7800 kg/m³

The moment for steel and composite bumper is assumed to be same.

Therefore the moment for steel is

Where, M = Bending moment (Nm)

I= Moment of inertia (m⁴)

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σ = Tensile strength (N/m²) $y = d/2$,

$I = bd^3/12$

There are three sections in the bumper I1, I2, I3 respectively.

$I1 = 0.058 \times 0.0023/12$

$= 3.86 \times 10^{-11} \text{ m}^4$

$I2 = 0.078 \times 0.0023/12$

$= 5.2 \times 10^{-11} \text{ m}^4$

$I3 = 0.058 \times 0.0023/12$

$= 3.86 \times 10^{-11} \text{ m}^4$

$I = I1 + I2 + I3$

$= 1.2932 \times 10^{-10} \text{ m}^4$ Tensile strength of the steel

$= 460 \times 10^6 \text{ N/m}^2$ (from PSG data book)

The moment equation, $M = 59.4872 \text{ Nm}$

Thickness of the Composite Bumper:

$d1 = 3.543 \times 10^{-3} \text{ m}$ $d2 = 3.055 \times 10^{-3} \text{ m}$ $d3 = 3.543 \times 10^{-3} \text{ m}$ Average thickness (d) = $d1 + d2 + d3 / 3 = 3.38 \text{ mm}$

Force Acting On the Bumper

$F1 = 134864.94 \text{ N}$ $F2 = 235200 \text{ N}$ $F3 = 34529.88 \text{ N}$

Model dimensions of the Bumper and crash box

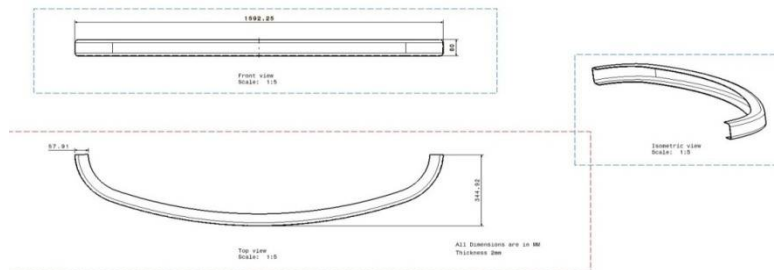


Fig 2. Drafted view with dimension of front bumper (a)

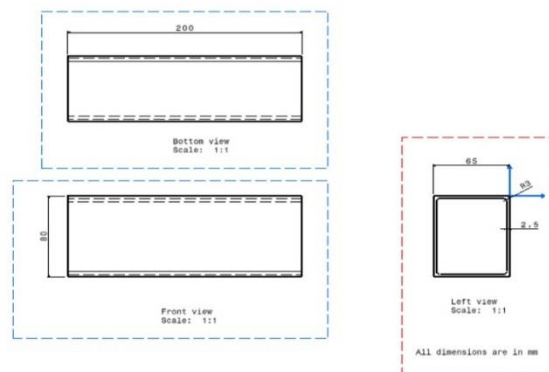


Fig 3. Dimensions of the crash box (a)

III. FEA ANALYSIS

For three sections and three material FEA static analysis is done in this by changing each parameter at a time. The sections used here for frontal bumper beam are C-section, Box section and Double box section. Material used are steel,

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Aluminium which are regularly in use but the third composite material is selected as keeping in mind the Requirements of the Automobile sector.

Composites used here are Fibre-E-glass is a high quality glass fiber, which is used as a standard reinforcement and has good mechanical property requirements.

Resins– Epoxy resin, Dobeckot 520F, which is solvent less is used.

Hardener – Hardener 758 which is a low viscosity polyamine is selected.

DESCRIPTION	STEEL	ALUMINIUM	COMPOSITE
Element type	Solid186	Solid 6111	Solid191
PressureLoad (N/mm2)	0.13	0.13	0.13
Young's modulus(N/mm2)	2x105	70x103	78x103
Poisson ratio	0.33	0.30	0.27

Description for Steel aluminium and Composite properties

As we obtained the results from Static the best product obtained is composite double box section. So the dynamic analysis is done on it obtaining the result as shown in below graph. 45KN of energy should be transmitted from the crash can after its deformation upto 25-30mm upto the chassis i.e all over the body then it's considered to be safer.

MATERIAL	SECTION TYPE	FORCE	VON MISSES STRESS (Mpa)		DEFORMATION
			Max.	Min.	
CASE I					
Steel	C section	Force 1	110.7	0.00543	3.413
Steel	C section	Force 2	194.2	0.009525	5.98
Steel	C section	Force 3	285.1	0.00139	8.287
Aluminum	C section	Force 1	109.7	0.00544	8.5
Aluminum	C section	Force 2	192.5	.00955	1.719
Aluminum	C section	Force 3	282.6	0.01402	2.523
Composite	C section	Force 1	109.4	0.00546	8.329
Composite	C section	Force 2	191.8	0.00958	1.5485
Composite	C section	Force 3	281.6	0.01406	2.273
CASE II					
Steel	Box section	Force 1	897.0	0.00128	2.725
Steel	Box section	Force 2	157.3	0.00225	4.779
Steel	Box section	Force 3	230.9	0.00331	7.016
Aluminum	Box section	Force 1	919.7	0.00130	7.828
Aluminum	Box section	Force 2	161.3	0.00229	1.373
Aluminum	Box section	Force 3	236.8	0.00336	2.015
Composite	Box section	Force 1	939.4	0.0133	7.050
Composite	Box section	Force 2	164.7	0.0234	1.236
Composite	Box section	Force 3	241.8	0.0344	1.815
CASE III					
Steel	D. Box section	Force 1	453.0	0.00160	1.908
Steel	D. Box section	Force 2	794.5	0.00281	3.346
Steel	D. Box section	Force 3	116.6	0.0369	4.912
Aluminum	D. Box section	Force 1	456.0	0.00151	5.461
Aluminum	D. Box section	Force 2	799.7	0.00264	7.577
Aluminum	D. Box section	Force 3	117.4	0.0288	1.406
Composite	D. Box section	Force 1	458.8	0.0144	4.905
Composite	D. Box section	Force 2	804.7	0.142	8.603
Composite	D. Box section	Force 3	118.1	0.162	1.263

Static result for all the three cases showing deformation and Von misses stresses

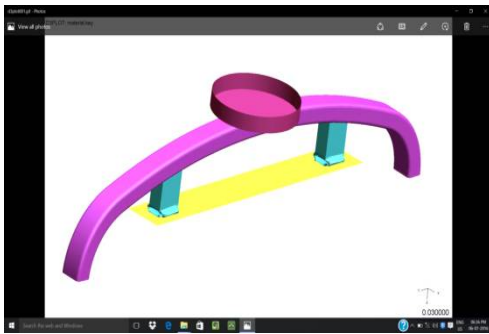


Fig 4. Result obtained after dynamic simulation (a)

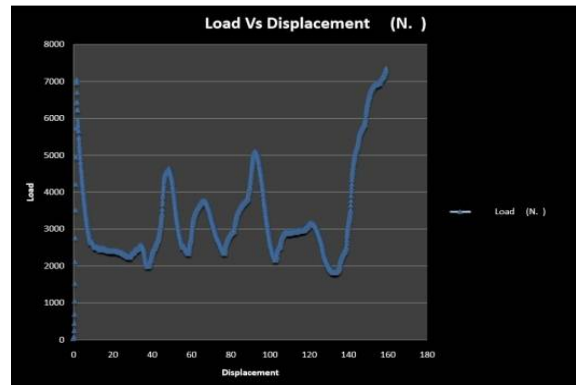


Fig 5. Force Vs Displacement graph of showing deformation Assembly in Analysis (b)

IV. FABRICATION AND EXPERIMENTATION

Fabrication- Hand lay-up technique is used in this for fabrication of composite fiber. The templates (mould die) were made from aluminium plate. The glass fibers were cut to the desired lengths, so that they can be deposited on the template layer by layer during fabrication. In the conventional hand lay-up technique, a releasing agent (gel/wax) was applied uniformly to the mould which had good surface finish. This is followed by the uniform application of epoxy resin over glass fiber. Another layer is layered and epoxy resin is applied and a roller was used to remove all the trapped air. This process continued till the required dimensions were obtained. After curing rectangular aluminium extrusion of crash box length are assembled with it.

Experimentation- In this we have experimented the assembly under universal testing machine to obtain the behaviour of the parts. As per above discussion we needed to find the effect of impact on deflection of the frontal bumper beam and crash can. We want to see that in our experimented model can we obtain the result similar to the analysis results. The standard method to carry out the bumper beam and crash can test is of Crash test. It is the only test which is carried after FEA. But as this test is so costly and beyond our reach we have gone for the comparatively cheap test of UTM. Even though the test is less costly but it will provide us the parameters we need to check in our process. Here with UTM test We are making sure if our parts are actually able to sustain the shown force and does it provide the require deflection without fail.



Fig 6. Experimental setup of UTM machine (a)

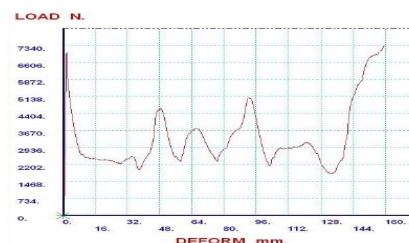


Fig 7. Experimentation Result showing (b) F-D grap

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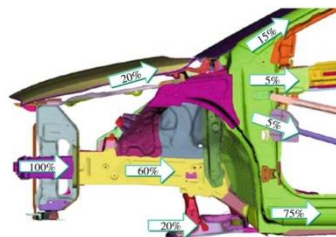


Fig 8. Impact on chassis (a)

V. CONCLUSION

1. Composite Double box and also box section is the better option to replace with the currently used frontal crash assembly as they provide better energy absorption and show similar effect on chassis as that of the other current used parts and materials. Composite material can sustain more load than the current parts.
2. Weight of the frontal bumper beam is reduced by nearly 50% from steel and 15% from aluminium fulfilling our other prospective i.e. light vehicle parts providing same better or same safety.
3. Factor of safety of composite material is also high i.e. 3.34
4. The material cost less than both steel and aluminium.

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