LS-DYNA-Based Car Frontal Fascia Simulation During Collision

Jalapudi Laxmi Prasanna[1](✉), Kandukuri Vasantha Kumar[1], Burragalla Dhanraj[2], and Uday Kumar Madduri[1]

[1] Department of Mechanical Engineering, JNTUH University College of Engineering, Jagtial 505501, India
dkpraween85@gmail.com
[2] Department of Mechanical Engineering, Vardhaman College of Engineering, Hyderabad 501218, India

Abstract. The bumper beam assembly of an automobile is crucial for absorbing impact energy and shielding occupants from front and rear collisions. Crash testing is a type of destructive testing that is typically used to verify that cars or related components meet safe design requirements for crashworthiness including crash compatibility. Utilizing computer software to simulate car wrecks has become a vital strategy for cutting expenses and development times for automobiles. This article examines the frontal fascia of cars in a simulated crash test. The simulation of a car collision test is reported in this paper. This work seeks to verify the findings of simulating a frontal impact collision of an automobile. In order to lessen the forces encountered during the crash, it is also intended to change some of the materials that make up the parts. To assess the vehicle's collision characteristics, computer models were utilized. This particular model was a version of the Chevrolet C1500 pickup truck. The simulation is conducted using LS-DYNA software. The automobile sector uses it extensively to analyze car design. It foretells a car's actions in an accident with accuracy. The simulation's results were then verified by contrasting them with the outcomes of an identical test conducted by the NCAC (National Crash Analysis Center).

Keywords: Solid works · crash · LS-DYNA · HYPERMESH

1 Introduction

Car accidents occur daily, with many drivers believing they can avoid them. However, it's crucial to consider the alarming statistics: tens of thousands die, and hundreds of thousands to millions are injured each year. The need to enhance automobile safety is evident from these statistics. Car bumpers, specifically the fascia covering them, play a crucial role in protecting vehicles during accidents. These front and rear bumpers are designed to absorb or minimize the impact's damage, safeguarding critical components like the hood, trunk, grill, and safety-related equipment such as lights.. In cases of bumper impact, like in parking accidents or low-speed legislative tests, the bumper fascia alone

© ICST Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2025
Published by Springer Nature Switzerland AG 2025. All Rights Reserved
X. Cheng (Ed): BROADNETS 2024, LNICST 602, pp. 167–177, 2025.
https://doi.org/10.1007/978-3-031-81171-5_17

may not be sufficient to withstand the forces. As a result, four key strategic parameters are typically examined during such tests to ensure safety and performance.

This study examines several critical factors related to car bumpers. Firstly, it explores the influence of material type on impact specifications and considers alternative materials to reduce part weight, assessing the impact of factors like modulus of elasticity, yield strength, and Poisson's ratio on bumper beam performance. Secondly, it investigates the impact of bumper beam thickness on specifications. Thirdly, it explores how minor changes and modifications can simplify manufacturing processes and reduce material volume without compromising impact strength. Bumpers, typically made of steel, aluminum, rubber, or plastic, serve as protective shields mounted on the front and rear of passenger cars.

In low-speed collisions, the bumper system serves to absorb the shock, minimizing or preventing damage to the car. Some bumpers incorporate energy absorbers or brackets, while others utilize foam cushioning material. The primary purpose of car bumpers is to safeguard the front and rear ends of passenger vehicles in such collisions, and they are not intended to be structural components that substantially enhance crashworthiness or occupant protection during front or rear impacts. Their role is not to act as a safety feature to prevent or reduce injury severity to occupants in passenger cars. Automotive bumper systems play a crucial role, not just in absorbing impact energy but also in terms of aesthetics. With a growing emphasis on lightweight design and safety in the automotive industry, the market trend is moving towards bumper systems equipped with thermoplastic materials and energy-absorbing elements. The key design focus for these systems is the efficient absorption of impact energy within the limited space between the rear face of the bumper and the vehicle's body parts. While experimental testing can be expensive and time-consuming, finite element analysis offers engineers a valuable tool for studying design concepts in the early stages when prototypes are not yet available.

1.1 Crash- Test

A collision test is a type of harmful testing that is often carried out to guarantee safe design requirements for crashworthiness and crash compatibility for cars or parts linked to them. Automobile makers conduct crash tests on their cars at various angles, on different sides, and with other objects, such as other vehicles, in order to evaluate the safety ratings of the automobiles under various situations as well as different sorts of collisions. The following is a list of the most typical accident test types.

- Front offset crash test,
- side impact test,
- front impact test,
- roll over test

1.2 Method of Analysis (LS-DYNA)

Crash testing is time-consuming, expensive, and necessitates the destruction of several test vehicles throughout the testing process. A recent and more common practice is computer-simulated testing for crashes. Here, a Finite Element (FE) model of the vehicle is created in place of a real vehicle, and it is utilized to do the various tests which were conducted using actual automobiles beforehand. While there are several software programs capable of handling car crash testing, LS-DYNA, developed by Livermore Software Technology Corporation, is one of the most often used. Automotive manufacturers and their suppliers may save time and money by using LS-DYNA to evaluate automobile designs without the need to build or test a prototype experimentally. Although the package's capabilities for calculating several intricate, practical issues are constantly expanding, its foundation and primary expertise are in highly nonlinear transient dynamic finite element analysis (FEA) with explicit time integration. Applications for LSDYNA are found in many different sectors.

2 Literature Review

Literature findings emphasize that bumper design factors, including shape, size, weight, and impact conditions, play a critical role. In low-speed front or rear collisions, the bumper's primary function is to absorb energy, preventing or minimizing damage to the vehicle. It is not intended to serve as a structural component contributing to occupant protection but rather to shield essential components like the hood, lights, and cooling system.

In the event of a crash, vehicle damage can be extensive. To mitigate deformation and damage, careful consideration of design and material selection is vital. This project explores the use of aluminum, steel, and plastics for the fascia to determine which material absorbs the most internal energy, especially in low-speed and high-speed impacts. Without incorporating materials like a metallic bar and foam, the fascia and crush box would undergo significant deformation, potentially exposing the passenger compartment to excess energy. Design adjustments based on simulation results, material selection, and strengthening the fascia are crucial to enhance vehicle safety.

According to the 2018 WHO Global Status Report on Road Safety, road accidents had a devastating impact in 2016, causing 1.35 million deaths worldwide. These accidents ranked as the eighth leading cause of death globally, with an average of 18.2 deaths per 100,000 people. Shockingly, road accidents were the leading cause of death for children and adolescents aged 5 to 29. The burden of road traffic casualties is widespread, with 93% of fatalities occurring in low- and middle-income countries, despite these countries accounting for only 41% of the world's automobiles. The victims of these accidents included 29% four-wheel drive drivers, 23% pedestrians, and 3% cyclists [1].

Organizations involved in testing or deploying Automated Driving Systems (ADS) should prioritize methods to swiftly return ADSs to a safe state following a crash. The response should be proportional to the crash severity and might involve actions like shutting off the fuel pump, disabling motive power, moving the vehicle to a secure location off the road, cutting off electrical power, and other measures that aid the ADSs in mitigating the impact. When communication channels with operations centers, collision notification centers, or vehicle communication technologies are available, sharing relevant data is encouraged to minimize harm resulting from the crash [2].

Vehicles equipped with software as well as hardware that performs the driving task have the potential to significantly reduce fatalities national serious injuries by lowering the number of collisions on American roads and highways. However, there may be obstacles with this new technology that prevent passengers in the remaining wrecks from being protected. It is planned to introduce new ADS vehicles which are not intended for passenger use. The only purpose of these freshly introduced ADS cars would be delivery. Today, the Federal Motor Vehicle Safety Standards (FMVSS) - such as FMVSS No. 208, “Occupant Crash Protection,” or FMVSS No. 214, “Side Impact Protection” - mandate that the majority of cars produced in the US must adhere to occupant protection regulations [3].

A 1997 Honda Accord was used in a crash-testing simulation research by Thacker et al. [4]. An actual car was first acquired, disassembled into its component pieces, each of which was recognized, tagged, having the material assessed. Information that might be effectively expanded upon from already-existing sources was gathered.

A 1997 Honda Accord DX Sedan was the subject of a similar study conducted by Cheng et al. [5], with the goal of reverse engineering the car and creating a FE model that would work well in computer simulations of full frontal, offset frontal, side, and oblique car-to-car impact testing.

A vehicle bumper is fastened to the front and back of an individual’s automobile. It is usually constructed of steel, aluminum, rubber, or plastic. The purpose of the bumper system is to lessen or avoid automobile damage in low-speed crashes by absorbing the impact’s shock. While some bumpers employ foam padding, others include hooks or energy absorbers. Their main responsibility in low-speed crashes is to protect passenger car front and rear ends. It’s crucial to remember that car bumpers aren’t intended to be structural components that considerably improve crashworthiness or occupant protection in frontal or rear crashes, nor are they meant to be safety features meant to prevent or lessen occupant injuries. Singh, Alok, et al. [6].

There are car accidents every day. Most drivers firmly believe that they can steer clear of these problematic circumstances. However, we also have to consider the fact that, according to Naheed Saba et al. [7], there are 10,000 fatalities and hundreds of thousands to millions of injuries annually.

The alarming statistics highlight the need to enhance automobile safety in accidents. Car bumpers, specifically the front and rear parts covering the car’s chassis, play a crucial role. These bumper fascias are designed to enable the vehicle to withstand impacts without compromising safety. Protecting vital parts including the hood, trunk, grill, gasoline, exhaust, cooling system, and safety-related equipment like parking lights, headlights, and taillights, they help avoid or lessen physical damage to the front and rear ends of passenger cars during crashes. Udhayasankar, R. et al.

A destructive evaluation technique called crash testing is utilized for assessing the safety and design requirements for crashworthiness including crash compatibility across a range of vehicle classes, such as small, medium, & heavy-duty cars and trucks, as well as the systems and parts that go with them.. These tests evaluate vehicle performance under different crash conditions and angles, often involving objects like rigid walls, three-strand cables, concrete barriers, and guardrail systems. Crash tests are typically conducted through numerical simulations or experimental trials, and various types of crash tests are commonly employed for this purpose [9, 10].

As previously mentioned, crash testing is a destructive testing method used to verify that cars and their associated parts adhere to safe design guidelines for crashworthiness including crash compatibility. Automakers conduct crash tests on their vehicles to evaluate how safe they are in a variety of scenarios and collision types, testing them from different perspectives, from different sides, and with other objects, such as other cars [11].

Laminated glass was subjected to ball drop studies by Hardy RN et al. [12] in order to study the material's temporal reaction to a strong spherical impact. A compressive shear strength experiment was utilized by Muralidhar et al. [13] and Rahul kumar et al. [14] to investigate the de-bonding phenomena that takes place at the glass polymer interface. In general, quasi-static as well as dynamic studies are two distinct categories into which tests for examining the mechanical response of such composite materials with regard to of various strain rates may be divided. MG Stout et al. (2015).

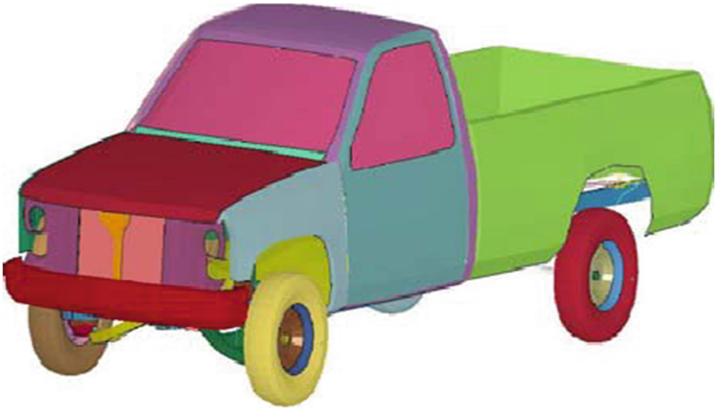
3 Methodology

The components in Test Model 1 are the same ones that were initially utilized to build the vehicle. In contrast, Test model 2's materials were changed in view of the growing usage of lighter alloy metals in the production of vehicles. The components used in the two test models Tejasagar A et al. [16] are.

- AA3005
- AA5182
- AA5454
- A319
- ASTMA514

Material		TestModel2
Aluminium	AA3005	Radiator
	AA5182	Door, Hood, Fonder, Wheelhousing
	AA5454	Tirerim
	A319	Engine
Steel	ASTMA514	Rail

A crucial step involves simulating and assessing a frontal impact crash test with a vehicle model traveling at 15.65 m/s (35 mph; 56.3 km/h) into an unyielding, rigid barrier, assuming no use of brakes. The data collected will then be cross-referenced with the National Crash Investigation Center's (NCAC) findings from a matching real test involving the same crash scenario. The NCAC is a reference because they conducted the test with an actual vehicle under identical conditions, creating a finite element model of the car using reverse engineering. They replicated the test with the model and confirmed their results by comparing them with the physical test data.



	NCAC Model	Test Model1	Test Model2
Weight(kg)	2015	1884	1654
Number of parts	257	61	61
Number of elements	62313	10729	10729

The frontal impact crash test employs a Chevrolet C1500 as the test FE model, with the car initially traveling at 35 mph (approximately 56 km/h) before colliding with the barrier. The simulation is set with an end time of 0.15 s due to the rapid deceleration rates associated with stiff barriers, which necessitates a specific termination time. Remarkably, most energy transmission in head-on or frontal car accidents with stiff obstacles happens in less than 0.2 s; in fact, prior experimental investigations have shown that it can happen in as little as 0.07 to 0.02 s.

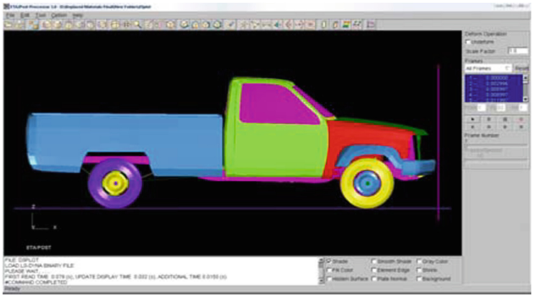
The simulation process is conducted in three distinct steps:

- pre-processing
- solver
- post-processing.

The post-processor reads the database file generated by the simulation engine and presents the results in a visual display.

The finalized model comprises around 65 parts, 61 different materials, 10,693 elements, and 11,060 nodes. It incorporates a variety of structural components and specific element types.

- Solidelements
- Belytschko-sayshellelement
- Hughes-Liubeamelement



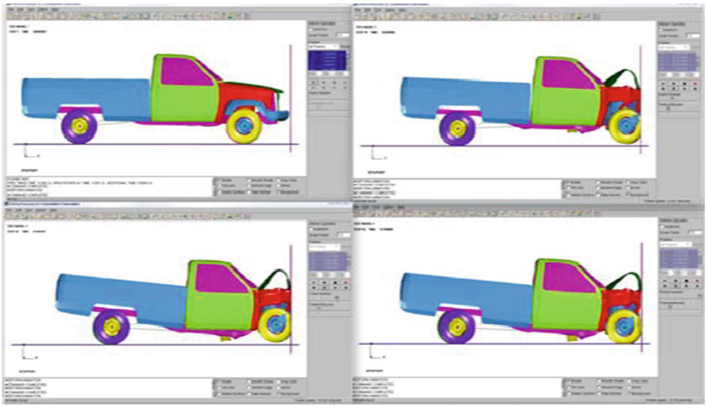
```
FILE: D3PLOT
LOAD LS-DYNA BINARY FILE
PLEASE WAIT.......
FIRST READ TIME 0.079 (s), UPDATE DISPLAY TIME 0.002 (s), ADDITIONAL TIME 0.0150 (s)
#COMMAND COMPLETED
Ready
```

Boundary Conditions

Boundary conditions are used to specify and produce loads and constraints for finite element models. All weights and boundary conditions present during the actual collision event must be represented in order to mimic a full vehicle auto accident. The simulated model should have a representative gravitational force applied, just as an automobile is in reality subjected to gravitational stresses. The simulation must take into consideration the friction forces that exist between the tires and the road surface since they have a significant influence on how the vehicle responds to an accident. In actual life, the air-filled tires will have an influence on how severe a collision is. The interaction of the tires during impact must be simulated via tire modeling. It is necessary to provide a velocity to the vehicle in a way that prevents unrealistic acceleration or makes the simulation run for a long period. Thankfully, Ls-Dyna offers ways to replicate each of these demands.

4 Results and Discussion

For the frontal impact, two simulations were run; the Test model 1 used the NCAC model's materials while the Test model 2 used newer components materials. The generated results were then verified against those of comparable simulations carried out by the NCAC. The photographs that follow show the car before and after it strikes the stiff wall at the prescribed 35 mph (56 kmph) speed. a series of pictures demonstrating the Test model 1's influence on the wall from t = 0 to t = 0.15 s at the intervals of t = 0, t = 0.05, t = 0.10, and t = 0.15 s.



Graphs of Energy Balance

To determine how Testing model 2 performs in comparison to Test model 1, the energy balance graphs of Test model 1 and Test mode 2 are first compared. For both simulations and the NCAC test, graphs displaying the Kinetic energy, Internal energy, and Total energy Vs. Time acquired after the simulation are shown (Figs. 1 and 2).

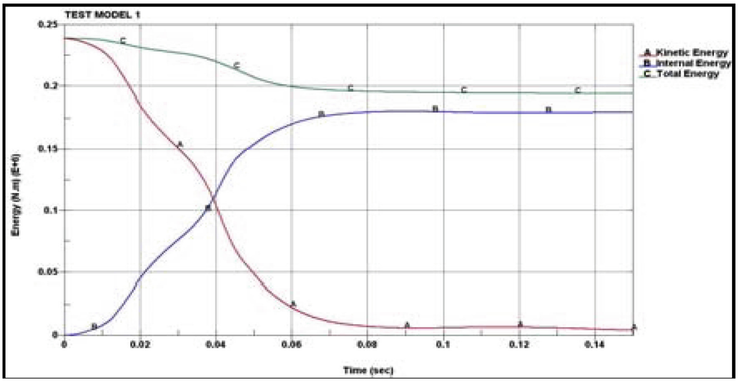


Fig. 1. Energy balance graph of test model 1

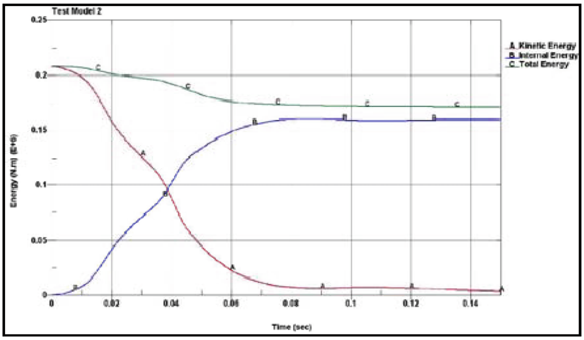


Fig. 2. Energy balance of Test model 2.

As can be seen, the bumper, radiator, engine, and rails absorb the majority of the impact's energy. Before the tires hit the wall, these parts absorb the majority of the crash's energy. The first and second test models have maximal kinetic energies of 239.126 kJ and 208.301 kJ, respectively. The lower values of the results are not surprising for Test Model 2, whose primary goal was to lighten the vehicle. Due to its lighter weight, the Test model 2 will be subject to weaker forces.

Deceleration vs Time

The graph indicates a little variance in the deceleration profiles between the Test model 1 and the Test model 2. It is found that the greatest retardation of the Test models 1 and 2 is 84.83 g as well as 98.94 g, respectively (Figs. 3 and 4).

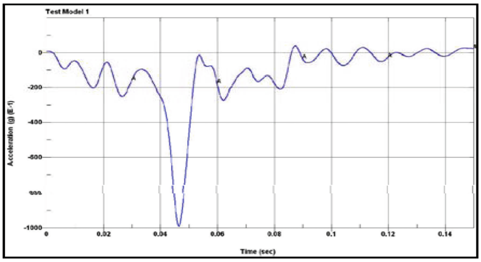


Fig. 3. Acceleration Vs Time graph of Test Model 1

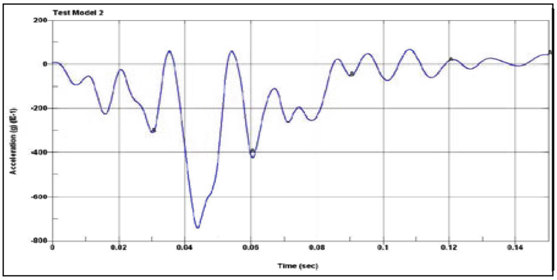


Fig. 4. Acceleration Vs Time graph of Test Model 2

Since body mass and deceleration are connected, it is known that Test model 2 has a smaller mass than Test model 1 (as shown in Table 3.1). Consequently, it is not surprising that Test model 2's slowdown was less than projected.

Velocity vs Time

The graph shows that both of the Test models' velocity profiles have extremely similar characteristics. A modest negative velocity is present here as well at the end of the impact event. The forces produced by the vehicle's collision with the wall are what lead to this (Figs. 5 and 6).

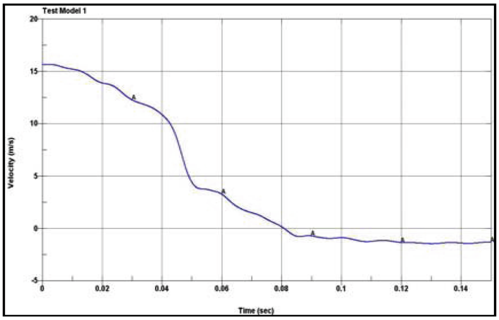


Fig. 5. Velocity Vs Time graph of Test model 1

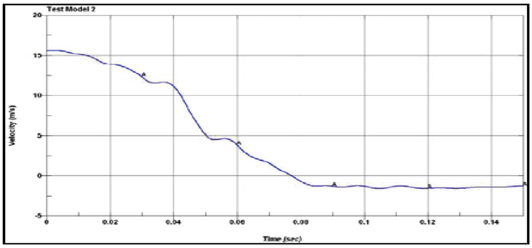


Fig. 6. Velocity Vs Time graph of Test model 2

5 Conclusion

The work's main goal was to mimic a frontal collision test and confirm the simulation findings using data from the crash test. The simulation was done with the LS-DYNA program. By contrasting the simulation findings with those of the NCAC model simulation, the simulation results were shown to be valid.As seen, most of the energy is absorbed by the rails, engine, and bumper before the wheel hits the wall. After around 0.04 s after the crash's beginning, these components absorb over 50% of the crash's energy.Both the cabin's deformation and the intrusion of components into the cabin have been found to be at a minimum. Therefore, it may be presumed that any part that enters the cabin after a collision would not cause any harm to the people within.A simpler test car model was used due to the restricted computer resources available, which eventually led to the inaccurate results. There are some inconsistencies in the results since there are fewer elements in the test models than in the NCAC model.A more exact model would be needed to get more accurate findings, but doing the simulations would have required considerably more computing power. It was necessary to find a compromise so that the simulation could be run without the outcome deviating too much.The graphical findings all demonstrated that, during the crash event, the test models' behavior was comparable to that of the NCAC model.The Test Model 2's somewhat different behavior may be traced to the fact that the components' materials were altered, which altered some of the simulation's results.

References

1. Saba, N., Tahir, P.M.: A review on potentiality of nano filler/natural fiber filled polymer hybrid composite. Univ. Putra Malaysia **6**, 2247–2273 (2014)
2. Rahman, M.A., Praveen Babu, D.: Simulation of car frontal fascia during crash using LS-DYNA. Int. J. Eng. Res. Technol. (IJERT) **8** (2019)
3. Ghamarian, A., Zarei, H.R., Abadi, M.T.: Experimental and numerical crashworthiness investigation of empty and foam-filled end-capped conical tubes. Thin-Wall. Struct. **49**, 1312–1319 (2011)
4. Thacker, J.G., et al.: Experiences during development of a dynamic crash response automobile model. J. Finite Elem. Anal. Des. **30**, 279–295 (1998)
5. Chenga, Z.Q., et al.: Experiences in reverse-engineering of a finite element automobile crash model. J. Finite Elem. Anal. Des. **37**, 843–860 (2001)

6. Singh, A., Singh, S.: Study of Mechanical Properties and Absorption Behaviour of Coconut shell Power-Epoxy Composite. PSIT College of Engineering, Kanpur (2013)
7. Saba, N., Tahir, P.M.: A Review on Potentiality of Nano Filler/Natural Fiber Filled Polymer Hybrid Composite. Universiti Putra Malaysia, Malasia (2014)
8. Udhayasankar, R., Karthikeyan, B.: A Review on Coconut Shell reinforced Composite. Annamalai University, Tamilnadu (2015)
9. Zarei, H.R., Kroeger, M.: Multi-objective crashworthiness optimization of circular aluminum tubes. ThinWall. Struct. **44**, 301–308 (2006)
10. Ambati, T., Srikanth, K.V.N.S., Veeraraju, P.: Simulation of vehicular frontal crash-test. Int. J. Appl. Res. Mech. Eng. (2012)
11. Deba, M.S., et al.: Design of an aluminium-based vehicle platform for front impact safety. J. Impact Eng. **30**, 1055–1079 (2004)
12. Grunert, J., et al.: Constitutive laws for complete componentsewindscreen and other materials. APROSYS report “AP-SP3–012” (2004)
13. Muralidhar, S., Jagota, A., Bennison, S.J., Saigal, S.: Mechanical behaviour in tension of cracked glass bridged by an elastomeric ligament. Acta Mater. Mater. **48**, 4577e88 (2000)
14. Rahul, K.P., Jagota, A., Bennison, S.J., Saigal, S.: Interfacial failures in a compressive shear strength test of glass/polymer laminates. Int. J. Solids Struct.Struct. **37**, 7281e305 (2000)
15. Stout, M.G., Koss, D.A., Liu, C., Idasetima, J.: Damage development in carbon/epoxy laminates under quasi-static and dynamic loading. Compos. Sci. Technol. **59**, 2339e50 (1999)
16. Tejasagar, A., Srikanth, K.V.N.S., Veeraraju, P.: Simulation of vehicular frontal crash-test. Int. J. Appl. Res. Mech. Eng, **2**(1), (2012)