

Comparative analysis of frontal car bumper during impact

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ABSTRACT

An automobile's bumper is the front-most or rear-most part, designed to allow the car to sustain an impact without damage to the vehicle's safety systems. They are not capable of reducing injury to vehicle occupants in high-speed impact. In this paper, review of the most important variables like material, structures, shapes and impact conditions are studied for analysis of the bumper beam in order to improve the crashworthiness during collision. More emphasis is given on selection of bumper material.

Keywords:-bumper, impact loading, Analysis, Frontal

1.INTRODUCTION

An automobile's bumper is the front-most or rear-most part, designed to allow the car to sustain an impact without damage to the vehicle's safety systems. They are not capable of reducing injury to vehicle occupants in high-speed impacts, but are increasingly being designed to mitigate injury to pedestrians struck. In this study, the most important variables like material, structures, shapes and impact conditions are studied for analysis of the bumper materials of two types in order to improve the crashworthiness during collision. The simulation of a bumper will be characterized by impact modeling using Pro/Engineer, impact analysis is done by using impact loading machine according to the speed that is (48 km /h-) given in order to analyze the results. This speed is according to regulations of Federal Motor Vehicle Safety Standards, FMVSS 208- Occupant Crash Protection whereby the purpose and scope of this standard specifies requirements to afford impact protection for passengers. In this project work, analysis is done for various speeds according to regulations and also by changing the speeds. Results will be plotted to select best material out of those proposed for testing. i.e PEI and ABS Plastic. A good design of car bumper must provide safety for passengers and should have low weight. Different countries have different performance standards for bumpers. Under the International safety regulations originally developed as European standards and now adopted by most countries outside North America, a car's safety systems must still function normally after a straight-on pendulum or moving-barrier impact of 4 km/h (2.5 mph) to the front and the rear, and to the front and rear corners of 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 (FMSS: Federal Motor Vehicle Safety Standards) and Canada (CMVSS: Canadian Motor Vehicle Safety Standards), it should meet 4KMPH pendulum and barrier impacts. Automotive development cycles are getting shorter by the day. With increasing competition in the marketplace, the manufacturers and suppliers main challenge is to come up with time-efficient design solutions. Researchers are trying to improve many of existing designs using novel approaches. Many times there is conflicting performance and cost requirements, this puts additional challenge with R&D units to come up with a number of alternative design solutions in less time and cost compared to existing designs. These best solutions are best achieved in a CAE environment using some of the modern CAD and FEM tools. Such tools are capable of effecting quick changes in the design within virtual environment. Bumpers are fixed on the front and on the back side of a car and serve as its protection. They reduce the effects of collision with other cars and objects due to their large deformation zones. The bumpers are designed and shaped in order to deform itself and absorb the force (kinetic energy) during a collision. The whole frontal bumper system consists the following parts (also seen in Figure. 1).

- the cover,
- the mechanical and deformation energy absorber,
- bumper reinforcement.

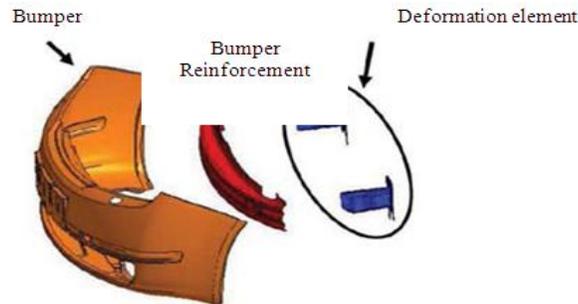


Figure 1 Frontal bumper system components

2. TYPES OF CAR BUMPERS

2.1 Plastic Bumper

Most modern cars use a reinforced thermoplastic bumper, as they are cheap to manufacture, easy to fit and absorb more energy during a crash. A majority of car bumpers are custom made for a specific model, so if you are looking to replace a cracked bumper with a similar one, you would have to buy from a specialist dealer. However, many companies now offer alternative designs in thermoplastic, with a range of fittings designed for different models.

2.2 Body Kit Bumper

Modified cars often now have a full body kit rather than just a front and rear bumper. These kits act as a skirt around the entire body of the car and improve performance by reducing the amount of air flowing underneath the car and so reducing drag. Due to each car's specifications, these have to be specially purchased and can be made from thermoplastic, like a standard bumper, or even out of carbon fiber.

2.3 Carbon Fiber Bumper

Carbon fiber body work is normally the thing of super-cars, but many car companies, and specialist modifiers, are starting to use it for replacement body part on everyday cars. This is because it is very light and is safe during a crash. It is, however, a lot more expensive than normal thermoplastic.

2.4 Steel Bumper

Originally plated steel was used for the entire body of a car, including the bumper. This material worked well, as it was very strong in a crash, but it was very heavy and dented performance. As car engine design has improved, steel bumpers have pretty much disappeared for anything except classic cars. Replacing one involves a lot of searching for scrap cars or having one specially made. Improving passenger car damageability and repairability has been an important RCAR topic since the Council was established in 1972. In order to prevent unnecessary damage to the structure of passenger cars in low speed crashes, a 15 km/h, 40 % overlap test was implemented in the 1980s and revised again in 2006 (the impact angle was changed from 0° to 10° and the rear impact moving barrier weight was increased from 1000 to 1400kg). This test is referred to as the RCAR Structural Test. Car manufacturers design their vehicles to perform well in this RCAR structural test but some have fitted vehicles with countermeasures that do not exhibit good crash behavior in real world crashes. In some cases, manufacturers have eliminated the bumper beam and replaced them with localized countermeasures, such as crush cans, to manage the test. Such sub-optimised designs are in most cases not robust and often lead to expensive damage in car-to-car crashes. Insurance claims data indicate that rear bumpers are often under-ridden by a striking vehicle due to bumper system instability or vertical dive of vehicles during braking. In these cases it is desirable to have bumper systems that have sufficient vertical overlap to maintain engagement. To this end, bumpers should ideally be mounted at slightly different heights front and rear but have sufficient height to maintain engagement over a wide range of circumstances. However, insurance data also show that rear bumpers are overridden when struck by high ride-height vehicles (SUVs, pickup trucks). Vehicle damageability would be improved in both these situations with taller front and rear bumper beams. Real world claims data also show a significant number of crashes in which damage is limited to the vehicle corners. Vehicle bumpers should prevent or limit much of the damage sustained in these minor crashes. However, many vehicles do not have bumper reinforcement beams that extend laterally much beyond the frame rails, leaving expensive vehicle components such as headlamps and fenders (wings) unprotected. An international RCAR working group has developed test procedures to assess how well a vehicle's bumper system protects the vehicle from damage in low speed impacts. Damage in these tests closely replicates the damage patterns observed in real world low speed crashes and addresses three components of bumper performance:

1. Geometry – vehicle bumpers need to be positioned at common heights from the ground and extend laterally to the corners in order to properly engage other vehicles in low speed crashes.
2. Stability – vehicle bumpers need to be tall and wide enough to remain engaged with the bumpers of other vehicles despite vehicle motion due to loading, braking, etc.

3. Energy-absorption – vehicle bumpers should absorb low speed crash energy without damage to other parts of the vehicle.

3. LITERATURE REVIEW

Today's plastic auto bumpers and fascia systems are aesthetically pleasing, while offering advantages to both designers and drivers. The majority of modern plastic car bumper system fascias 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. Hosseinzadeh RM and et.al[1] in their paper says that bumper beams are one of the main structures of passenger cars that protect them from front and rear collisions. In this paper, a commercial front bumper beam made of glass mat thermoplastic (GMT) is studied and characterized by impact modeling using LS-DYNA ANSYS 5.7 according to the E.C.E. UNITED NATIONS AGREEMENT [UNITED NATIONS AGREEMENT, Uniform Provisions concerning the Approval of Vehicles with regards to their Front and Rear Protective Devices (Bumpers, etc.), E.C.E., 1994]. Three main design factors for this structure: shape, material and impact condition are studied and the results are compared with conventional metals like steel and aluminum. Finally the aforementioned factors are characterized by proposing a high strength SMC bumper instead of the current GMT. In this paper, Marzbanrad JM et.al[2] discussed the most important parameters including material ,thickness, shape and impact condition are studiedfor design and analysis of an automotive front bumper beam to improve the crashworthiness design in low-velocity impact. The simulation of original bumper under condition impact is according to the low-speed standard of automotives stated in E.C.E. United Nations Agreement Regulationno.42,1994. In this research, a front bumper beam made of three materials: aluminum, glass mat thermoplastic (GMT) and high-strength sheet molding compound(SMC) is studied by impact modeling to determine the deflection, impact force, stress distribution and energy-absorption behavior. The mentioned characteristics are compared to each other to find best choice of material, shape and thickness .The results show that a modified SMC bumper beam can minimize the bumper beam deflection, impact force and stress distribution and also maximize the elastic strain energy. In addition ,the effect of passengers in the impact behavior is examined . Different countries have different performance standards for bumpers. Under the International safety regulations originally developed as European standards and now adopted by most countries outside North America, a cars. America (FMSS: Federal Motor Vehicle Safety Researchers are trying to improve many of existing designs using novel approaches. Many times there is conflicting performance and cost requirements, this puts additional challenge with R&D units to come up with a number of alternative design solutions in less time. some of the modern CAD and FEM tools are capable of effecting quick changes in the design within virtual environment.

4. FINDINGS OF THE LITERATURE REVIEW

The above mentioned literature can be summarized in the following way:-

- a. There are few studies reporting about the work done related to improvement in the design of front bumper of passenger car.
- b. The applicability of these studies for passenger cars (India) is not validated.
- c. Present studies have not identified the effect of shape, size and or material
- d. The safety of the passenger needs to be increased.

The literature does not address the impact analysis of the passenger cars considering the material and size for the Indian cars.

5. SCOPE OF THE WORK

The study will focus on existing design performance, advantage and limitations. Based on Observations design improvements will be made in terms of shape & material based on design Modification objectives. Modified front bumper design will be tested using FEM software for impact loads as per international standards. Side view of a bumper is shown in figure no. 2

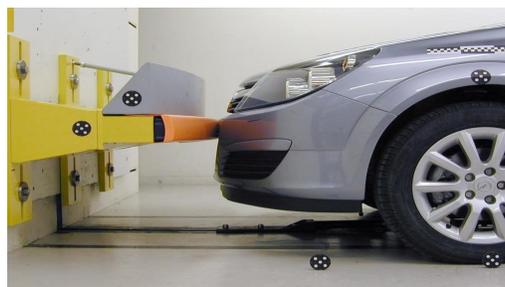


Figure no. 2 Side view of a bumper

6. COMPARISON OF BUMPER MATERIAL

Because of a unique balance of properties, modern ABS copolymers are being used on an ever increasing scale for the manufacture of many industrial and domestic products. The material is very tough and resilient, has high impact strength, good chemical resistance and is non toxic and taint free. Acrylonitrile - Butadiene - Styrene (ABS) identifies a family of engineering thermoplastics with a broad range of performance characteristics. The co polymeric system is allowed to yield the optimum balance of properties suited to the selected end use.

ACRYLONITRILE - imparts chemical resistance and rigidity.

BUTADIENE - endows the product with impact strength, toughness and abrasion resistance.

STYRENE - contributes to the luster, ease of processing and rigidity. Design Improvement in Front Bumper of a Passenger Car using Impact Analysis for two types of material defines the statement of the problem. The PEI properties are listed below to have basic idea of necessary properties required for impact analysis.

6.1 Material Properties of PEI

Name	: PEI
Model Type	: Linear Elastic Isotropic
Tensile Strength	: 2.41×10^8 N/m ²
Yield Strength	: 2.41×10^8 N/m ²
Elastic Modulus	: 3.38×10^{10} N/m ²
Poisson's Ratio	: 0.4
Mass Density	: 1480 kg/m ³
Shear Modulus	: 3.189×10^8 N/m ²

The formulation used by Eurapipe has been developed in conjunction with polymer manufacturers to optimize performance in respect to tensile strength, chemical resistance, ductility, resistance to weathering, heat stability, low toxicity, taint free and ease of processing from raw material to finished product. ABS is tough and strong over the recommended temperature range of -30°C to +60°C.

The outstanding properties of ABS are:

1. High impact strength and ductility, which combine to give exceptional toughness.
2. Good chemical resistance.
3. Abrasion resistance.
4. High strength solvent weld jointing which allows efficient system assembly and modification.

The ABS properties are listed below to have basic idea of necessary properties required for impact analysis.

6.2 Material Properties of ABS Plastic

Name	: ABS Plastic
Model Type	: Linear Elastic Isotropic
Tensile Strength	: 3×10^7 N/m ²
Elastic Modulus	: 3.38×10^7 N/m ²
Poisson's Ratio	: 0.394
Mass Density	: 1020 kg/m ³
Shear Modulus	: 3.189×10^8 N/m ²

When ABS products are exposed to the weather, they will suffer some minor degradation of the exposed surface. The degradation results in a reduction of surface gloss, and shift in surface colour to light grey. The degradation is confined to the exposed surface only. The effect of long-term exposure to sunlight over prolonged periods has minimal effect on the physical properties of ABS systems. Because of the relatively high flexural modulus of ABS, the stresses induced in a component whilst in service result in smaller strains, therefore minimising the possibility of environmental stress cracking of the exposed surface. ABS is a relatively ductile thermoplastic, which exhibits very high impact strength compared to other thermoplastics such as particularly at low temperatures. It is for this reason ABS is used in demanding applications requiring exceptionally high impact strength material such as construction site safety helmets. ABS is unique in retaining high levels of impact strength at sub zero temperatures and is significantly superior to most other thermoplastics used in pipe systems.

7. OBJECTIVES OF THE WORK

The aim of this work is to study front bumper of one of the existing passenger cars in Indian market and suggest design Improvement in front bumper of a passenger car in terms of material selection using Impact Analysis.

1. To analyze the mechanical properties on front part (fascia) of car bumper by comparative speed impact analysis.
2. To analyze on mechanical properties focus on stress analysis
3. To modeling the actual dimension of the car bumper into the SolidWork or PRO-e software and analyze by using impact loading .

4. To investigate Optimum and effective material bumper based on their geometry and other parameters that influence the compatibility of car bumper with Finite Element Analysis.

8. RESULTS

Results can be obtained by observing the graphs of stress and Displacement to decide the optimum material. It will be necessary to compare experimental Impact Analysis results like

- Stress
- Displacement
- Strain for Various speeds

All these parameters will be based on comparative experimental analysis of both ABS and PEI materials.

9. CONCLUSION

From the above discussion, it can be concluded that the bumper is an important member of an automobile from the safety point of view. Thus analysis of bumper will help to increase the safety considered to replace the existing materials like steels and general fiber. The project data can be used for best bumper designs of modern vehicles from material point of view. Impact loading parameters can be evaluated for varying speeds. The project work will be helpful to have optimum material choice for frontal car bumper design based on comparative results of both materials i.e PEI and ABS plastic. This work will be milestone in Automotive industry as per as vital issue of passenger safety is concerned.

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