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Design and analysis of Front Bumper for Light Passenger Vehicles

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Abstract: Car accidents are happening every day. If, we take into account the statistics, ten thousand dead and hundreds of thousands to million wounded each year. These numbers call for the necessity to improve the safety of automobiles during accidents. Automotive bumper system is one of the key systems in passenger cars which help to protect the vehicle during impacts.

Bumper is one of the main parts which are used as protection for passengers from front and rear collision. The aim of this study is to analyze and study the structure and material employed for car bumper in one of the car manufacturer. In this, 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. The model of the bumper is drawn in Ansys 14.0 considered thickness as 10 mm. Structural analyses has been performed for all the two cases and the results obtained are compared with the standard previous results.

Keywords: Bumper, FEM, Impact Test, Ansys 14.0.

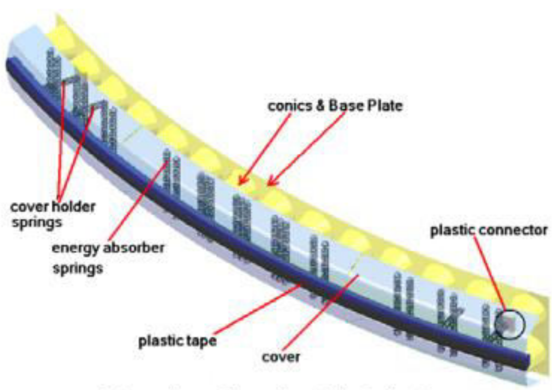
IIntroduction

Car accidents are happening every day. Most drivers are convinced that they can avoid such troublesome situations. The front and rear of the vehicle should be protected in such a manner that low speed collisions will only damage the vehicle slightly, or not at all. For this purpose front and rear bumpers were invented. The uses of bumpers has evolved from being a mechanism placed on the front and rear of the car to protect the body and safety features of a motor vehicle from damage due to a low speed collision to a decorative ornament designed more for the aesthetics of the motor vehicle rather than the actual functionality

An automobile's bumper is the front-most or rear-most part, ostensibly 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 by cars. Front and rear bumpers became standard equipment on all cars in 1925. What were then simple metal beams attached to the front and rear of a car have evolved into complex, engineered components that are integral to the protection of the vehicle in low-speed collisions. 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. The use of plastic in auto bumpers and fascias gives designers a tremendous amount of freedom when it comes to styling a prototype vehicle, or improving an existing model. Plastic can be styled for both aesthetic and functional reasons in many ways without greatly affecting the cost of production. Plastic bumpers contain reinforcements that allow them to be as impact-resistant as metals while being less expensive to replace than their metal equivalents. Plastic car bumpers generally expand at the same rate as metal bumpers under normal driving temperatures and do not usually require special fixtures to keep them in place. Some of the plastic products used in making auto bumpers and fascias can be recycled. This enables the manufacturer to reuse scrap material in a cost-effective manner. A new recycling program uses painted TPO scrap to produce new bumper fascias through an innovative and major recycling breakthrough process that removes paint from salvage yard plastic. Tests reveal post-industrial recycled TPO performs exactly like virgin material, converting hundreds of thousands of pounds of material destined for landfills into workable grade-A material, and reducing material costs for manufacturers. Why has bumper effectiveness been reduced in preventing damage in a minor collision? One reason could be that statutory bumper standards were made quite loose. As a result, many of today's bumpers allow cars to be damaged more easily.Automotive bumper system is one of the key systems in passenger cars. Bumper systems are designed to prevent or reduce physical damage to the front or rear ends of passenger motor vehicles in collision condition. They protect the hood, trunk, grill, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights, etc. 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 be meet 4KMPH pendulum and barrier impacts.

A car bumper is a front part of the car that covers the car’s chassis. The cover of the car bumper called fascia. An automobile's bumper is the front-most or rear-most part, ostensibly 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 by cars. Front and rear bumpers became standard equipment on all cars in 1925. What were then simple metal beams attached to the front and rear of a car have evolved into complex, engineered components that are integral to the protection of the vehicle in low-speed collisions. When a vehicle involves the low speed accident, the bumper system will absorbs the shock or force which will help in preventing the vehicle from serious damage. In certain type of bumper systems, the energy absorber or brackets are used while others used foam cushioning materials. The bumpers are designed with safety features since it is intended to reduce the magnitude of deceleration during the impact. Automotive development cycles are getting shorter by the day. With increasing competition in the marketplace, the OEM’s 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 and these are the parts of the bumper model.

A bumper is a car shield made of steel, aluminums, rubber, or plastic that is mounted on the front and rear of a passenger car. When a low speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. Some bumpers use energy absorbers or brackets and others are made with a foam cushioning material. The car bumper is designed to prevent or reduce physical damage to the front and rear ends of passenger motor vehicles in low-speed collisions. Automobile bumpers are not typically designed to be structural components that would significantly contribute to vehicle crashworthiness or occupant protection during front or rear collisions. It is not a safety feature intended to prevent or mitigate injury severity to occupants in the passenger cars. Bumpers are designed to protect the hood, trunk, grille, fuel, exhaust and cooling system as well as safety related equipment such as parking lights, headlamps and taillights in low speed collisions.



Schematic configuration of the desired bumper

Automotive bumper system plays an important role not only in absorbing impact energy but also in a styling stand point. A great deal of attention with in the automotive industry has been focused upon light weight and sufficient safety in recent years. Therefore, the bumper system equipped with thermoplastic and energy absorbing element is a new world trend in the market. The major point for the design of bumper system is summarized as a degree of absorption of impact energy in a limited clearance between back face of bumper and body parts of the vehicle. While experimental test is rather costly and time consuming, finite element analysis helps engineers to study design concept at an early design stage when prototypes are not available.

Polymer; Thermoplastic; Elastomer, TPE Characteristics:

- wide hardness range
- does not require vulcanization-quite higher saving on the processing costs
- remains flexible at low temperatures
- high temperature resistance
- electrical insulator with very low conductivity
- has grades with very low conductivity
- grades with very high abrasion resistance
- excellent tear resistance
- 100% recyclable
- PVC free
- resistance to solvents
- resistance to oil
- resistance to acids, bases, and detergents
- resistance to UV and ozone
- resistance to bacterial and fungus growth
- has low toxic potential, with many grades conforming with FDA regulations
- halogen free flame retardancy
- coloured grades available
- allows direct colouring during processing by utilizing coloured PP and PE master batches
- 2-shot moulding onto many other plastics
- Appropriate co-extrusion process.

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Energy absorbers:

Energy absorbers are designed to absorb a portion of the kinetic energy from a vehicle collision. Energy absorbers are very effective in a low speed impact, where the bumper springs back to its original position. Energy absorber types include foam, honeycomb and mechanical devices. All foam and honeycomb absorbers are made from one of three materials: polypropylene, polyurethane or low-density polyethylene. Mechanical absorbers are metallic and resemble shock absorbers. However, mechanical absorbers have several times the weight of foam or honeycomb absorber and receive very limited usage. In some bumper systems, the reinforcing beam itself is designed to absorb energy and separate energy absorbers are not required.

LITERATURE REVIEW

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 their 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 conditions are studied and the results are compared with conventional metals like steel and aluminium. Finally the aforementioned factors are characterized by proposing a high strength SMC bumper instead of the current GMT.

Marzbanrad JM et.al [2] discussed the most important parameters including material, thickness, shape and impact condition are studied for 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: aluminium, glass mat thermoplastic (GMT) and high-strength sheet moulding compound(SMC)is studied by impact modelling 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 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 be meet 4KMPH pendulum and barrier impacts. [3]

Mohapatra S [4] discusses that automotive development cycles are getting shorter by the day. With increasing competition in the marketplace, the OEM’s and suppliers main challenge is to come up with time-efficient design solutions. Researchers are tryingto 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.

A bumper is a car shield made of steel, aluminium, rubber, or plastic that is mounted on the front and rear of a passenger car. When a low speed collision occurs, the bumper system absorbs the shock to prevent or reduce damage to the car. Some bumpers use energy absorbers or brackets and others are made with a foam cushioning material. The car bumper is designed to prevent or reduce physical damage to the front and rear ends of passenger motor vehicles. Generally, a bumper is attached to either end of a vehicle to absorb impact in a collision, thereby protecting passenger. As shown in the figure below, a conventional bumper system comprises a bumper cover 1 defining an outer appearance of the bumper system, an energy absorber 2 formed of an elastic material such a polypropylene foam body or an urethane foam body to absorb energy, an impact beam for supporting the energy absorber 2, and a stay 4 for connecting the impact beam 3 to a vehicle body. [5]

Andersson R et.al[6] disclosed is a bumper system including a bumper cover, an energy absorber formed of a synthetic resin material through a foam moulding process, an impact beam for supporting the energy absorber, the impact beam being formed of a glass mat thermoplastic sand having a "C"-shaped section, and a stay for connecting the impact beam to a vehicle body. Tips are formed on front upper and lower portions of the impact beam, and a web portion is formed on the impact beam between the tips. Tip insertion grooves in which the tips are inserted are formed on an inner surface of the energy absorber, and a pressure receiving surface corresponding to the web portion is formed on the inner surface of the energy absorber.

Butler M et.al[7] focuses that to increase crash performance in automotive vehicles it is necessary to use new techniques and materials. Components linked to crash safety should transmit or absorb energy. The energy absorbing capability of a specific component is a combination of geometry and material properties. For these components the chosen material should have high yield strength and relatively high elongation to fracture. These demands have led to increasing interest in the use of high strength stainless steels.

Carley ME et.al[8] the objective of this study is to design efficient epoxy structural foam reinforcements to improve the energy absorption of front and rear automotive bumper beams. Three bumper structural performance criteria were studied.

Evans D and Morgan T[9] as vehicle manufacturers continue to become more aggressive with the styling of new vehicles, bumper system technologies will be required to find new solutions that fit into the reduced package spaces while continuing to meet the vehicle performance and cost requirements. The purpose of this paper is to introduce new and innovative Expanded Polypropylene (EPP) foam technologies and techniques.

Witteman WJ[10]automotive styling trends point to reduced bumper overhang, greater sweeps, and reduced overall package space for the bumper system. This paper will review the industry trends associated with bumper energy absorbers and explore the potential fit of this new prototype energy absorber design as an alternative to EPP foam. Also included is a review of the simulated performance of the prototype ETP energy absorber and a comparison of its actual test results for 8 km / h FMVSS Part 581 impact series to the performance of EPP foam packaged in the same environment.

OBJECTIVES:

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 perform the Impact Test on 2 variable designs.
2. Build the FE model as per the cad and perform impact test using a barrier.
3. And find out the energies, stress and displacements for a Assumed high-strength sheet molding compound (SMC).

Material properties

Discription	Structural steel	ABS plastic
Young's Modulus	2E11 N/m^2	3.38E7 N/m^2
Poissons ratio	.33	.35
Desnsity	7830 Kg/m^3	1040 kg/m^3
Ultimate tensile strength	460 Mpa	30 Mpa

Calculation of Impact force

NHTSA standard is followed for this test . The test is conducted at a velocity of 8Km/hr i.e 2.2 m/s.

Mass of vehicle = 1554 kg

F=m*(v-u)/t

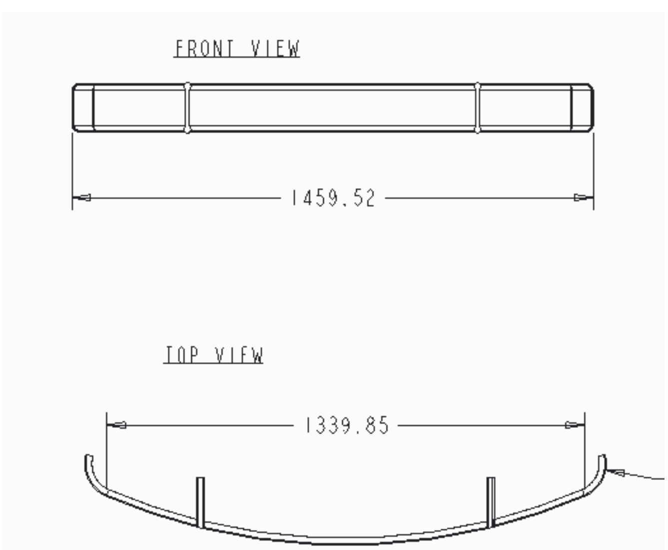
Here v=0

U=2.2 m/s

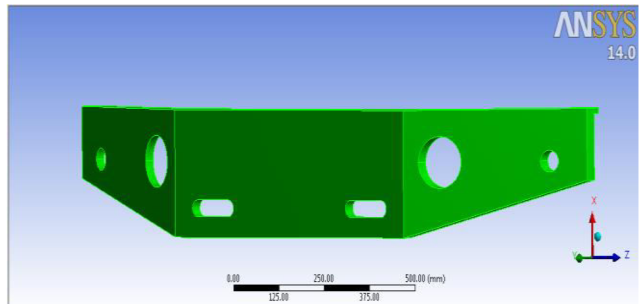
T= .1 secs

Hence F=1554*22.2 = 32529.88N

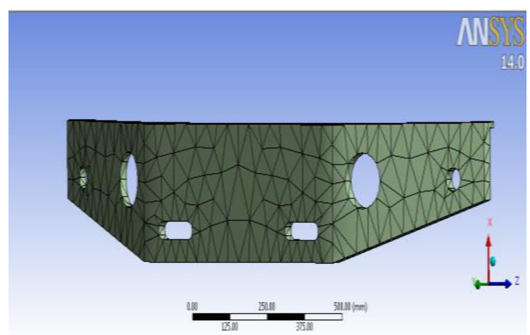
Dimensions of Bumper



CAD model of Bumper



RESULTS

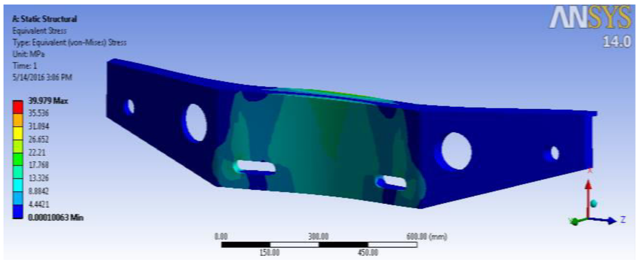


Material

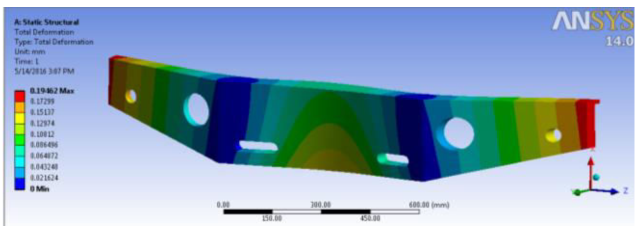
Discription	Structural steel	Polyethylene
Young's Modulus	2E11 N/m^2	1.1e9 N/m^2
Poissons ratio	.33	.42
Desnsity	7830 Kg/m^3	950 kg/m^3

Structural Steel results

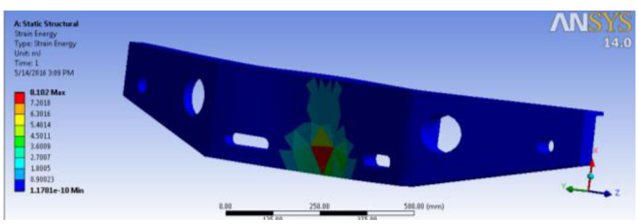
Von-Mises Stress

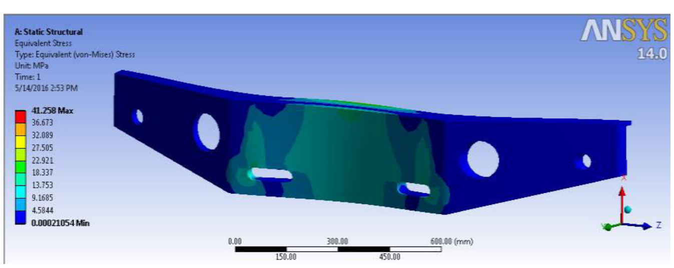


Total Deformation

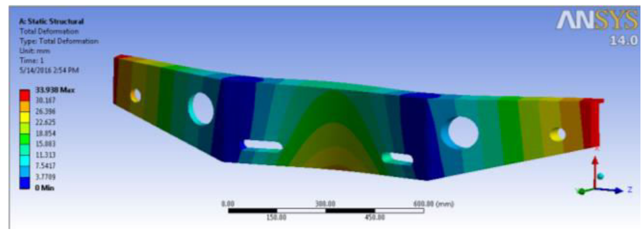


Strain Energy

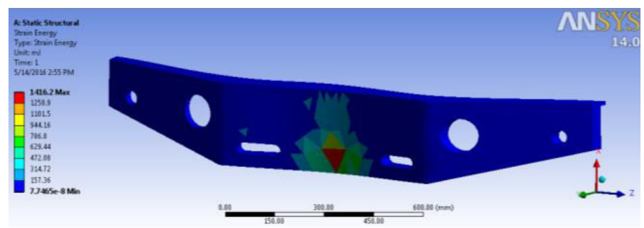




Total deformation



Strain energy



Results

Material	Von-Mises Stress	Deflection	Strain Energy
Structural Steel	39.97 Mpa	0.1946 mm	8.102 J
Polyethylene	41.258 Mpa	33.938 mm	1416.2 J

Comparing the both designs, second material design (optimized) is absorbing more loads because of bumper with removed material. And as per the assumed material for beam, stresses are near to yield. Polyethylene has good chemical resistance. Two types are used; low density polyethylene (LDPE) and high density polyethylene (HDPE) can be manufactured in a range of densities. Application: glass reinforced for car bodies, electrical insulation, packaging, where strength and aesthetics are important.

CONCLUSION

As we knew through several tests made to identify the suitable material useful for Bumper is Polyethylene. We were trying to get the better design and feasible thicknesses (considering manufacturing feasibility). This report shows us the Polyethylene bumper made of 10 mm thick. The objective is to get a better optimized design with comparative deflection and stress contours with very less plastic strain in the beam (assuming the rest of parts in the vehicle as lumped mass). Finite element method is used to perform these tests non-physically. Thus, Setup and boundary conditions were made more physically as illustrated in the earlier slides. A result from FE Data explains that the optimized design is very useful to continue the further research on assuming various materials to the required mass of the vehicle.

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