Analytical And Mathematical Model For Testing Of Automotive Bumper By Using Different Foam Materials

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Abstract- *A bumper plays an important role in automobile for preventing impact of energy being transferred to passengers. This can be achieved by filling foam material in hollow section of bumper. The foam used is polyethylene (XPE) and cross-linked polyethylene (XLPE). The analytically test conducted on front bumper of Maruti- Suzuki Omni vehicle. Density of XPE is less than density of XLPE. Hence different density cause energy absorption is also different. The test result represents best suitable foam for energy absorption with light weight and less cost. The research shows axial impact is 35-40% of total impact on vehicle. In response this, study have been undertaken to analytically investigate axial crushing response and energy absorption performance of empty and foam filled bumper.*

Keywords- bumper, XPE-XLPE, foam filled bumper, energy absorption, axial impact.

I. INTRODUCTION

Number of vehicles on road has been rapidly increasing every year due to the continuous development of both automobile and transportation industry. There has been increasing demand for vehicles as modern society is more relying on transportation systems. A vehicle is crashworthy when it sufficiently protects the occupants from severe injury in collision accidents including frontal and rear- end collision. Subsequently, vehicular accidents have now become major worldwide concern and continuous focus is on to address safety issues. This is especially in case for road vehicles such as cars, vans trucks and heavy vehicles. Bumper beams are one of the important structures in passenger cars. For which we need to have careful design and manufacturing in order to ensure good impact behavior. The new bumper design must be flexible enough to reduce the passenger and occupant injury and stay intact in low-speed impact besides being stiff enough to dissipate the kinetic energy in high speed impact convenience, and health and safety considerations. Foam expands in situate to Low-density foam is currently being used for noise, vibration, and harshness improvement in many automobiles. The improvement is typically achieved by injecting the foam into the hollow cavities of the body sections such as bumper. XPE and XLPE foams' are used to analytically examine impact resistance and crushing performances. The project has been aimed to examine automotive bumper with and without foam. The XPE foam filled in bumper will undergo the mechanical stresses. Therefore the test has been performed, including impact test with & without foam on bumper. The test measure, change in deformation and energy absorption after damage of front area of bumper.

II. LITERATURE REVIEW

Praveen Kumar et al. analyzed for the steel and composite material with the basic bumper design in the first phase and then front part is modeled with the honeycomb and foam type in second phase to compare the deformation and energy absorbed during the impact. Then it is proved that by the utilization of carbon fiber, honeycomb and foam we can reduce shortcomings of normal bumper[1].Sunil Kumar et al. evaluated comprehensive study have been undertaken to experimentally and numerically investigate axial crushing responses, energy absorption performance of empty and foam filled aluminum concentric tube with different density of foam and examined the crush and energy absorption response of empty and foam filled concentric tubes under axial loading [2]. Saeed abualyazeedalbatlan et al. performed experimental test applied on front bumper of fiat-sahin vehicle and showed the improvement about 260% in bumper impact resistance when using 1 layer of honeycomb cardboard cell and cardboard sheet [3].Brooks h. smith et al. contains 3 sets of results: experimental characterization of compressive and tensile properties of hollow sphere steel foams, simulations of the compressive stress-strain response with meso-scale model and calibrations of continuum foam plasticity. To analyze model needs to be sufficiently large to obtain reasonable

estimate of macroscopic material properties. Overly small sample size may result in incorrect estimate of strength and stiffness. [4]. Alirezanoorpoor et al. make Development, calibration and validation of a three dimensional model of the Leg form impactor for pedestrian crash with bumper are presented. Lower limb injury is becoming an increasingly important concern in vehicle safety for both occupants and pedestrians. Designed leg form impactor and concluded that crush performance of conform foam used to model leg form impactor is affected by both temperature and humidity. [5]. MatteoStrano et al. are investigate the performance of anti- intrusion bars, made by tubes filled with aluminum foams. The reason for using cellular material as filler deals with its capacity to absorb energy during plastic deformation while being light weight and then compare the overall performance of side impact absorber For evaluating the effect of shape and interaction between foam and tube for global performance of component [6].

K. lilleyet al. performed the bending testes show the effectiveness of rigid polyurethane foam in improving the strength of automotive body structures. by using foam , it is possible to reduce pillar section and to reduce thicknesses. Or eliminate reinforcements inside the pillars and they concluded that polyurethane foam can improve roof crush strength about 14% with a mass penalty 1.24 Kg per vehicle; although section is 20 mm narrower which space is utilized to add EA structure such as extended ribs, foam padding [7].

Svoboda jiri et al. performed the parametric analysis of bumper system under lower leg impact. The modification in bumper system, which required minimum package space to meet lower leg impact limits were design. It will show the effect of design changes, leading to improvement in the lower leg impact, on the total kinematics and loading on the pedestrian was investigated. Simulations of vehicle-dummy collision for all configurations of the bumper system considered during optimization of the leg form impact were carried out at velocity 40km/h. objectives for the front panel defined as: the lower leg form under limit together with reduction of package space were not in contrary to requirements on pedestrian kinematics to reduce its injury risk [8].

III. METHODOLOGY

First we selected bumper material. Best suitable material for bumper is steel. There are various reason for which steel is used for bumper. Steel material has high strength to weight ratio. Dead weight of steel structure is relatively small. This property makes steel attractive structure. Steel undergoes large plastic deformation before failure thus provides large reserve strength. It shows large visibility deflection before failure thus it has great energy absorbing capacity and will not occur sudden failure. Steel shows elastic behavior up to a relatively high and usually well defined stress level. Steel suitable for mass production Steel is noncorrosive in nature. By using above characteristics we are select bumper of Maruti-Suzuki Omni bumper. There are various foam used in automobile for various application but according to our application we selected foam material is Polyethylene [XPE]. Various desirable properties are high buoyancy, soft and strong, easy fabrication and high energy absorbing capacity, light in weight. Because of this properties we use polyethylene foam.

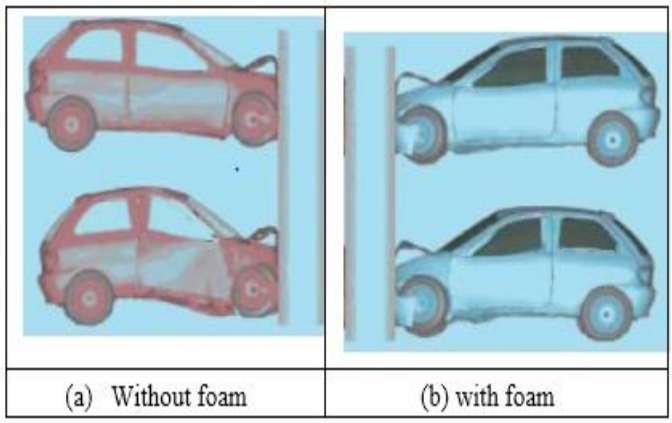


Fig. 1 crash test of bumper

By using above properties we are selected the Polyethylene [XPE] foam for impact test of bumper. The material of both energy absorbers was the high density foam, which was widely used in automobile interior and bumper systems and provides excellent energy absorption capabilities for a certain level. In test first of all we perform crash test of vehicle without using foam in bumper and make calculations for energy absorption and deformation. After this same test is perform by using foam filled bumper and calculate the energy absorption and deformation.

IV. SIMULATION PROCEDURE

The aim of this work is to conduct impact test on an automotive bumper without and withfoam and calculate change in deformation and energy absorption for that, first of all we take a bumper of maruti– Suzuki Omni with all its specification and dimensions. Then according to dimension make the parametric model in creo. The length of bumper is 1404 mm and height is 320 mm, and the length of upper surface is 650 mm. and it is 60 mm in diameter. So here we make two models one is hollow and another is solid for without and with foam bumper testing. After this for analysis purpose import the parametric

models hollow and solid both in Ansys. So after this, select the material according to following properties for steel and foam material.

Table 1.Properties of Materials

Parameters	Young's modulus (Gpa)	Poisson's ratio	Density (kg/m3)
steel	200 Gpa	0.3	7.8
XPE foam	1.10 Gpa	0.42	30

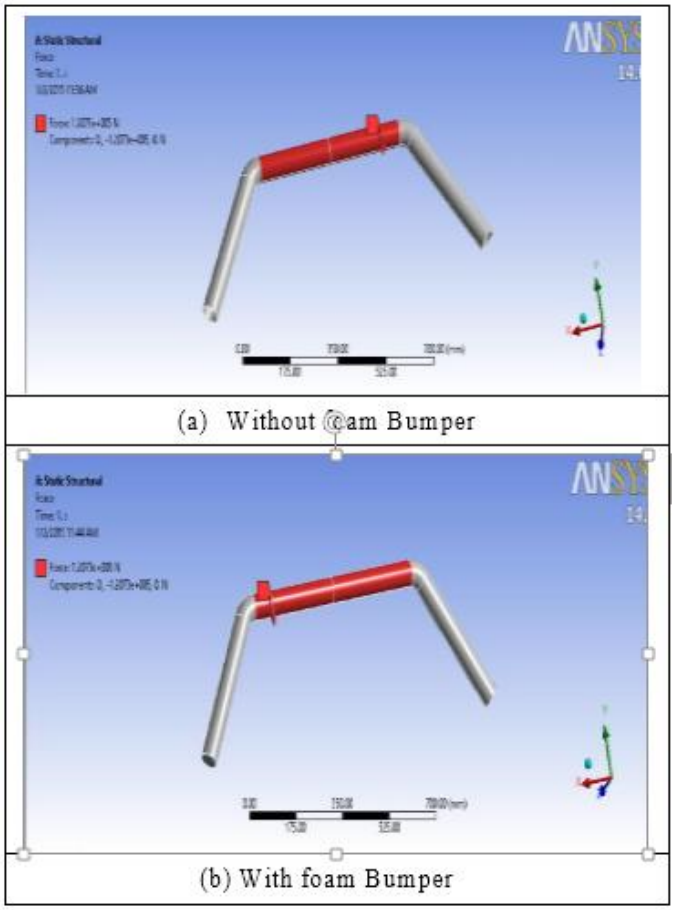


Fig.2 Loading and fixing of bumper

As per above properties given to material to without and with foam bumper, once give the material so after these meshing operation was done on both models. The goal of meshing is to provide robust, easy to use meshing tools that will be simplify the mesh generation process to high degree of user control. For both without and with foam bumper and we select beam as element type. So for without foam bumper 2716 nodes and 378 elements are there. And for with foam bumper 3979 nodes and 636 elements are there, which are combinations of both steel and XPE foam.

Apply boundary condition s to both objects such as constraints and load on bumper. Load applied is -120730 N. In both cases, for calculating above load we consider mass of vehicle with gravity. Then the results of with and without foam bumper is plotted, by considering the form of deformation and energy absorption.

V.RESULTS AND DISCUSSION

The section present analytical results obtained for without and with foam of automotive bumper. These results are in the form of deformation and energy absorption. Each analytical test indicated and substantial improvement when specimen (bumper) charged with polyethylene (XPE) filling material due to that it has higher impact resistance.

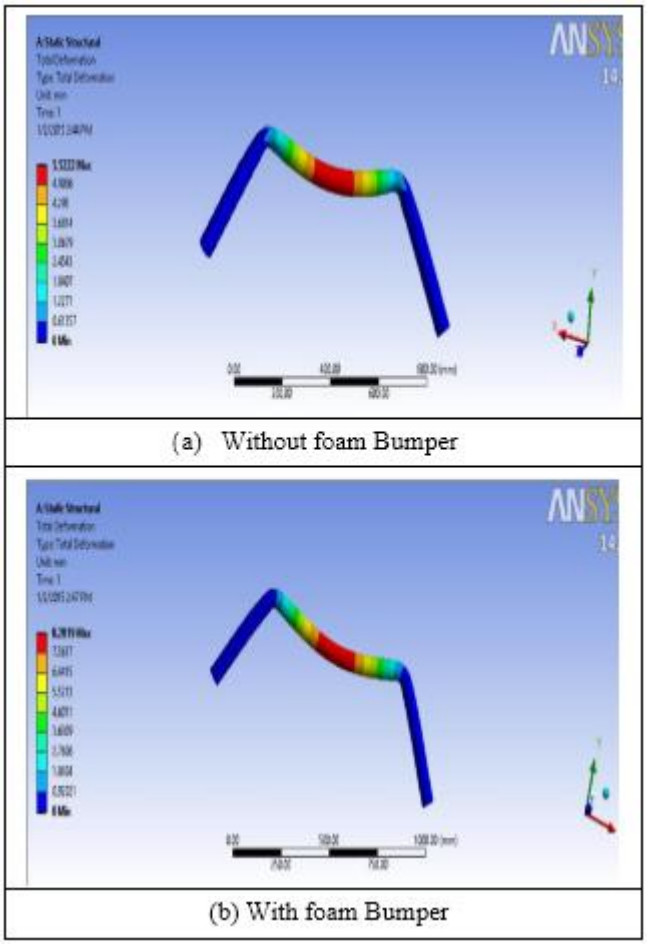
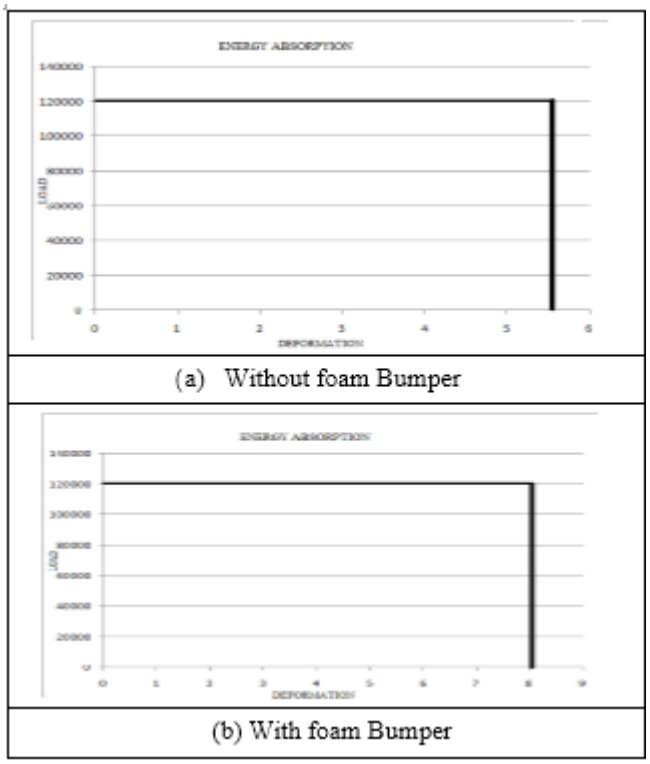


Fig.3 Deformation of bumper

For both cases result obtained in ANSYS are as follow, Deformation without foam = 5.52 mm,
Deformation with foam = 8.28 mm

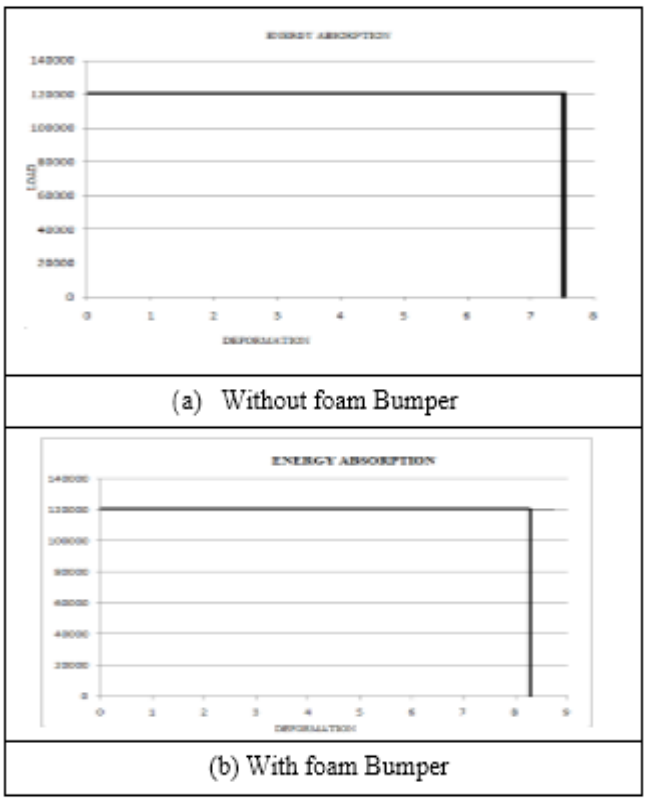


(a) Without foam Bumper

(b) With foam Bumper

Fig.4 Result and Energy absorption in ANSYS

For both cases result obtained in ANSYS are as follows,
Energy absorption without foam = 666.42 kN.mm,
Energy absorption with foam = 999.64 kN.mm



(a) Without foam Bumper

(b) With foam Bumper

Fig.5 Energy absorption by mathematical calculations

For with and withoutfoam bumper using mathematical calculations,For both cases, we calculate deformation by given formula

$$\delta = \frac{5WL^4}{384EI}$$

Deformation without foam = 7.50 mm
Deformation with foam = 8.44 mm.

For both cases, we calculate energy absorption as follows;

Energy absorption without foam = 905.47 KNmm.
Energy absorption with foam = 1018.96 KNmm.

Result summary of Simulation and mathematical solution for with and without foam bumper:

Table.2 Results of deformations and Energy absorption.

	Simulation Results		Mathematical Results	
Parameter	Deformation (mm)	Energy absorption (kN.mm)	Deformation (mm)	Energy absorption (kN.mm)
Without foam	5.52	666.42	7.50	905.47
With foam	8.28	999.64	8.44	1018.96

VI. CONCLUSION

The main objective of this study was to investigate on the energy absorption behavior of empty and foam filled bumper and facilitate their application in energy absorption system. It made easier to compare the amount of energy which will be absorbed in empty bumper when compare to foam filled bumper.

In order to achieve the aim, this study has comprehensively examined the crush and energy absorption response of empty and foam filled bumper under impact loading. The geometry of bumper, the wall thickness, length, diameter were made constant and XPE foam is used the loading parameter were kept constant through the study. As per analytical and mathematical results, it is concluded that the deformation of bumper with foam is more than deformation of bumper without foam. So the deformation is directly proportional to energy absorption means when deformation increases then absorption of energy increases. According to this analysis, the bumper with foam is best suitable for vehicle.

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