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Comparative Analysis of Frontal Car Bumper during Impact

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Abstract
Automotive industry is a very huge ground and research is still evolving. From this safety and comfortably of passenger, hence the researchers have to be focused on safety and comfortably. In tune with this improvement in the design of a bumper which is very important according to the safety issue. In this project we select the Maruti Suzuki Alto car bumper for analysis the simulation of a bumper is characterized by impact modeling using Pro/Engineer; impact analysis is done by varying speed according to regulations and also by changing the materials ABS plastic and PEI for same bumper design. Simulation using ANSYS under FEA, according to the speed is 20.83 m/sec (75 km/hrs.) and 33.33 m/sec (120 km/ hrs.). This research aims towards improvement in the design of front bumper of passenger car and gives the economical solution for the front bumper material and design by emphasizing the safety increasing aspects. Based on the performance analysis, we can conclude that the ABS plastic is superior bumper material among comparison and modified bumper design is best as compare to existing bumper design.
Keywords: Creo, ANSYS, Meshing, Bumper Design, Stress, Displacement, Strain.

I. Introduction

Bumpers play an important role in preventing the impact energy from being transferred to the automobile and passengers. Saving the impact energy in the bumper to be released in the environment reduces the damages of the automobile and passengers. Therefore researchers have sought to make bumpers lighter without sacrificing strength, ability to absorb impact, or passenger safety. On April 9, 1971, the agency issued its first passenger car bumper standard "Federal Motor Vehicle Safety Standard" (FMVSS) 215.This standard called for passenger cars, beginning with model year May 1973 [5].

The Finite Element Analysis (FEA) is a numerical method for solving problems of Engineering and mathematical physics. It is useful for problems with complicated geometries, loadings, and material properties where analytical solutions cannot be obtained. Design geometry is a lot more complex; and the accuracy requirement is a lot higher, so we need Finite Element Analysis tool [7].

- To understand the physical behaviors of a complex object (strength, heat transfer capability, fluid flow, etc.)
- To predict the performance and behavior of the design; to calculate the safety margin; and to identify the weakness of the design accurately; and
- To identify the optimal design with confidence.

The finite element method (FEM), sometimes referred to as finite element analysis (FEA), is a computational technique used to obtain approximate solutions of boundary value problems in engineering. Simply stated, a boundary value problem is a mathematical problem in which one or more dependent variables must satisfy a differential equation everywhere within a known domain of independent variables and satisfy specific conditions on the boundary of the domain. Boundary value problems are also sometimes called field problems. The field is the domain of interest and most often represents a physical structure.

1.1 Objectives

The main objective of this work is to determine energy absorption structure to absorb the impact energy during different speeds 75 km/h and 120 km/h. In order to achieve the main objective, the analysis of stress, strain, displacement for existing and our modified bumper then to study these two bumpers in comparative manner.

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.

- To analyze the mechanical properties on front part (fascia) of car bumper by comparative speed impact analysis.

- To analyze on mechanical properties focus on stress analysis
- To modeling the actual dimension of the car bumper into the software and analyze by using impact loading

II. Modelling of Car Bumper by Creo – Software

Creo/Engineer is new version of pro-e it is a software application within the CAID/CAD/CAM/CAE category, along with other similar products currently on the market. Creo/Engineer is a parametric, feature-based modeling architecture incorporated into a single database philosophy with advanced rule-based design capabilities [8]. The capabilities of the product can be split into the three main heading of Engineering Design, Analysis and Manufacturing. This data is then documented in a standard 2D production drawing and the 3D modeling of car bumper is done with help of Creo - software and dimensions are selected from one of car bumper. Design dimension of Maruti Suzuki Alto car bumper same for first design called as existing bumper design. As the impact is more for the front portion of bumper only outer dimensions of car bumper has been considered, Slots provided in middle of car bumper is used for reducing drag effect in car bumper.

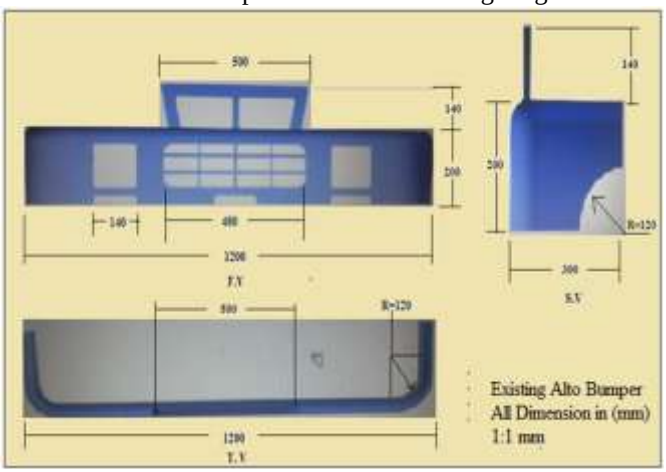


Fig. 1Existing Maruti Suzuki Alto bumper drawing sheet

III. Meshing of existing car bumper:

The new mid surface mesh tool enables direct extraction of a shell mesh from solid geometry and applies the thicknesses to the corresponding meshed output. Thin Solids mesh enables the automatic hexa and/or penta dominant mesh for thin plastic or sheet metal-type parts.

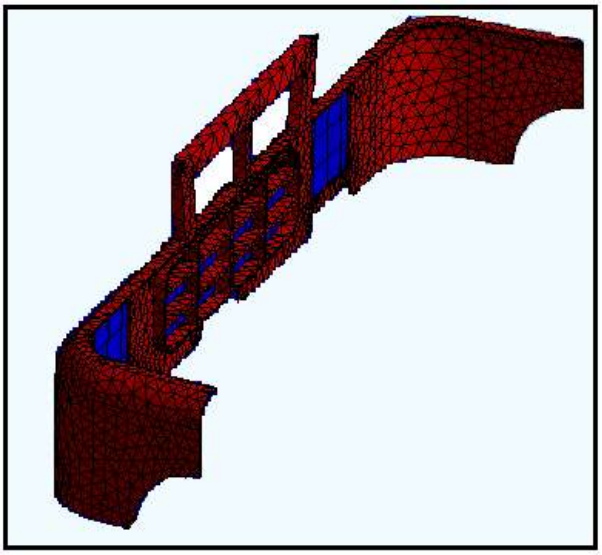
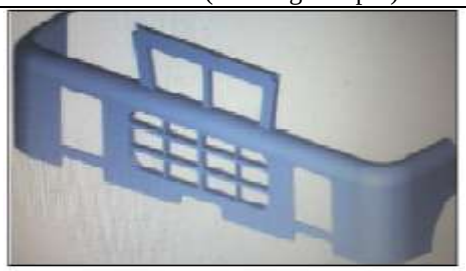


Fig. 2Meshing of existing car bumper design

3.1Analysis on modified car bumper

3.1.1ABS Plastic material (Existing bumper)

Table 1
ABS Plastic (Existing bumper)



Model name: - Maruti Suzuki Alto car front bumper
Current configuration: - Default

Solid Bodies	
Treated as	Volumetric properties
Solid body	Density (ρ): - 1020 kg/m^3 Weight (W): - 2.95 kg

a) Setup information

Table 2
Setup information (a)

Type	Velocity of impact
Velocity magnitude	20.83m/sec or 75 km/hr
Impact velocity reference	Face [1]
Gravity	9.81m/sec
Gravity reference	Face [2]
Parallel to reference plane	Plane 1
Friction coefficient	0
Target stiffness	Rigid target

b) Units

Table 3
Units (Existing bumper design)

Unit system	SI(MKS)
Length/ displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure / stress	N/mm^2

c) Material properties of ABS plastic

Table 4
Material properties of ABS plastic

Name	ABS plastic
Model type	Linear elastic isotropic
Default failure	Max vol stress
Tensile strength	3e+0.007 N/m^2
Elastic modulus	2e+0.009N/m^2
Poisson's ratio	0.39
Mass density	1020 kg/m^3
Shear modulus	3.189e+0.008

i) Displacement for speed 75 km/hr (ABS Plastic)

Name	Type	Minimum	Maximum
Displacement (d)	Resultant displacement	0 mm	10.484 mm

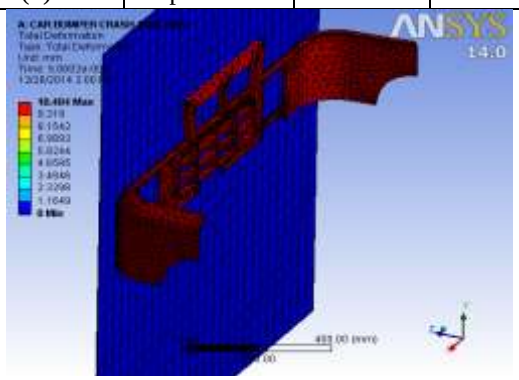


Fig. 3 Displacement for speed 75 km/hr (ABS Plastic)

ii) Stress for speed 75 km/hr (ABS Plastic)

Name	Type	Minimum	Maximum
Stress (σ)	Resultant stress	0 mm	53.109 N/mm^2

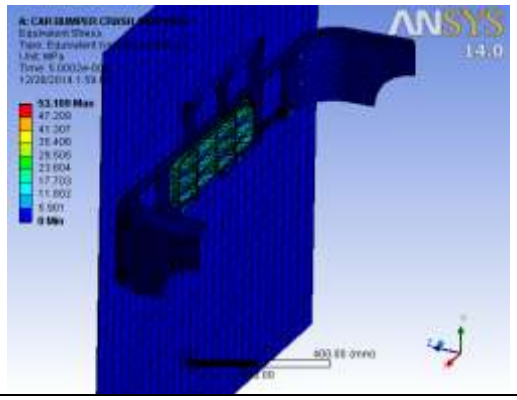


Fig. 4 Stress for speed 75 km/hr (ABS Plastic)

Impact analysis by taking speed 120 km/hr for existing bumper design and material is ABS plastic.

Table 5
Setup information (b)

Type	Velocity of impact
Velocity magnitude	33.333 m/sec or 120 km/hr
Impact velocity reference	Face [1]
Gravity	9.81m/sec
Gravity reference	Face [2]
Parallel to reference plane	Plane 1
Friction coefficient	0
Target stiffness	Rigid target

i) Displacement for speed 120 km/hr (ABS Plastic)

Name	Type	Minimum	Maximum
Displacement (d)	Resultant displacement	0 mm	17.717 mm

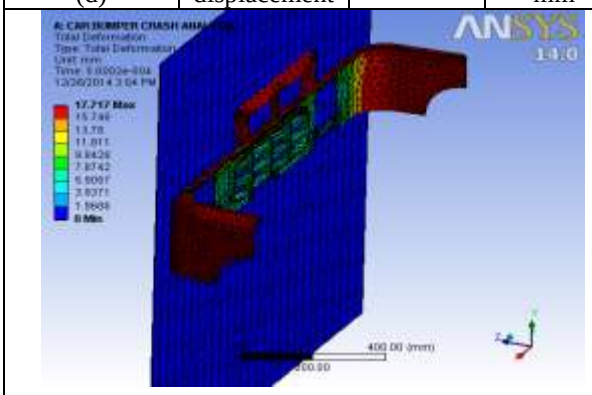


Fig. 5 Displacement for speed 120 km/hr (ABS Plastic)

ii) Stress for speed 120 km/hr (ABS Plastic)

Name	Type	Minimum	Maximum
Stress (σ)	Resultant stress	0 mm	60.027 N/mm^2

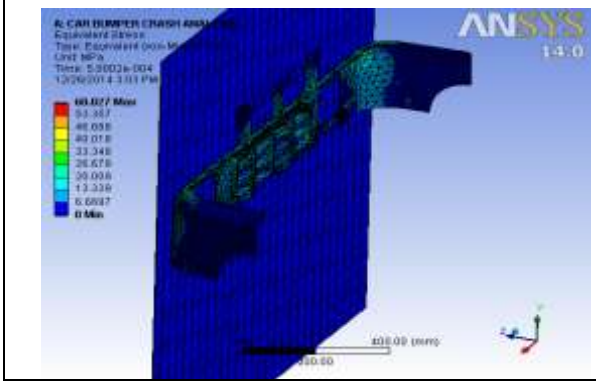


Fig. 6 Stress for speed 120 km/hr (ABS Plastic)

3.1.2 Poly Ether Imide material (Existing bumper)

a) Setup information

Table 6
Setup information (c)

Type	Velocity of impact
Velocity magnitude	20.83m/sec or 75 km/hr
Impact velocity reference	Face [1]
Gravity	9.81m/sec
Gravity reference	Face [2]
Parallel to reference plane	Plane 1
Friction coefficient	0
Target stiffness	Rigid target

b) Material properties of Poly Ether Imide (PEI)

Table 7
Material properties of Poly Ether Imide (PEI)

Name	Poly Ether Imide (PEI)
Model type	Linear elastic isotropic
Default failure	Max von stress
Tensile strength	2.3e+0.008 N/m^2
Elastic modulus	3.1e+0.010N/m^2
Poisson's ratio	0.3
Mass density	1480 kg/m^3
Shear modulus	3.189e+0.008

i) Displacement for speed 75 km/hr (PEI)

Name	Type	Minimum	Maximum
Displacement (d)	Resultant displacement	0 mm	10.467 mm

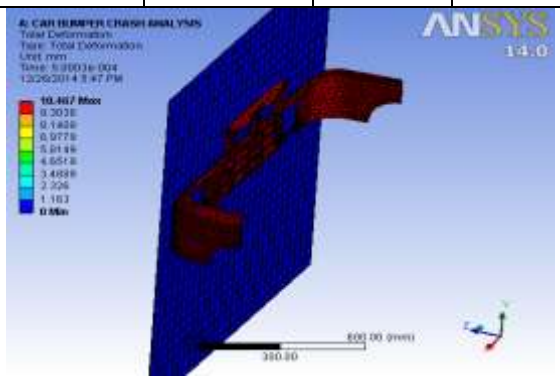


Fig. 7 Displacement for speed 75 km/hr (Poly Ether Imide)

ii) Stress for speed 75 km/hr (Poly Ether Imide)

Name	Type	Minimum	Maximum
Stress (σ)	Resultant stress	0 mm	112.97 N/mm^2

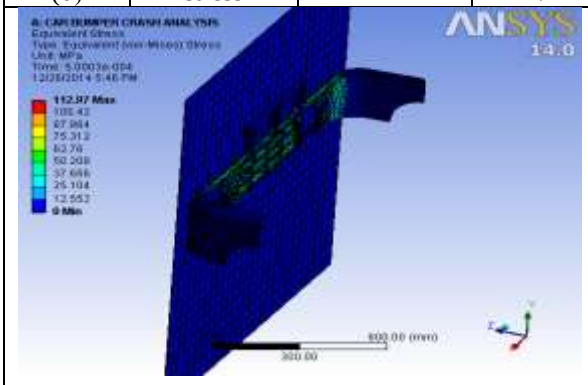


Fig. 8 Stress for speed 75 km/hr (Poly Ether Imide)

Impact analysis by taking speed 120 km/hr for existing bumper design and material is PEI.

Table 8
Setup information (d)

Type	Velocity of impact
Velocity magnitude	33.333 m/sec or 120 km/hr
Impact velocity reference	Face [1]
Gravity	9.81m/sec
Gravity reference	Face [2]
Parallel to reference plane	Plane 1
Friction coefficient	0
Target stiffness	Rigid target

i) Displacement for speed 120 km/hr (PEI)

Name	Type	Minimum	Maximum
Displacement (d)	Resultant displacement	0 mm	17.882 mm

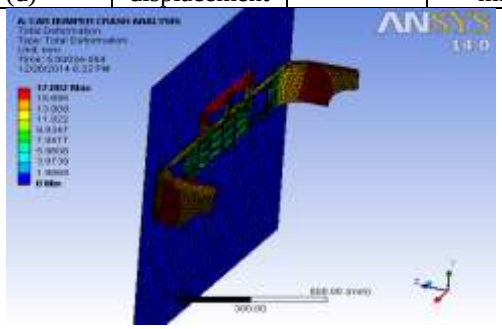


Fig. 9 Displacement for speed 120 km/hr (Poly Ether Imide)

ii) Stress for speed 120 km/hr (PEI)

Name	Type	Minimum	Maximum
Stress (σ)	Resultant stress	0 mm	434.04 N/mm^2

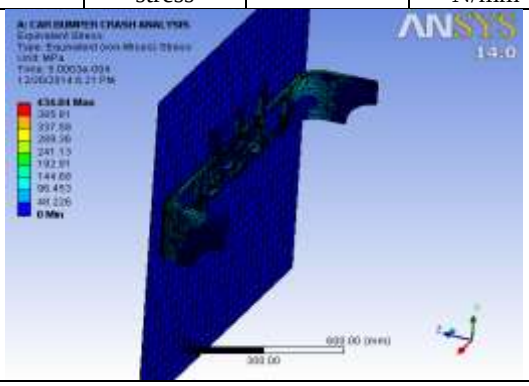


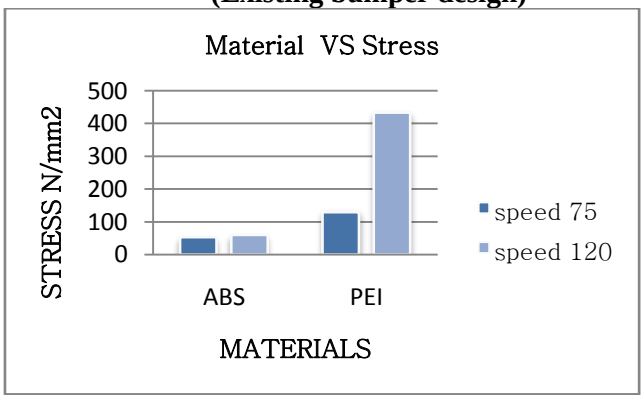
Fig. 10 Stress for speed 120 km/hr (Poly Ether Imide)

Existing Maruti Suzuki Alto car bumper impact results

Table 9
Existing alto Maruti Suzuki car bumper impact results

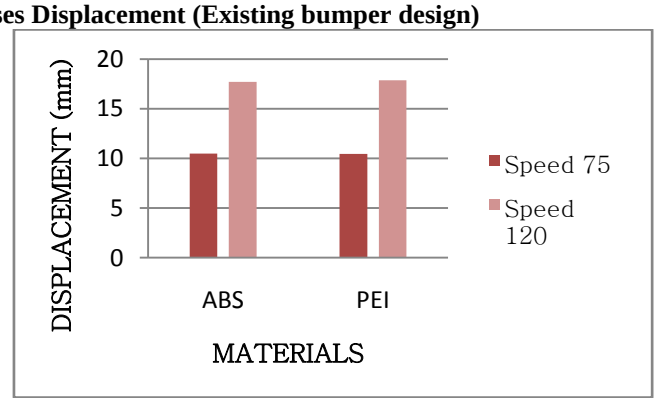
Material	Speed (Km/hr)	Stress (σ) (N/mm2)	Displacement (d) (mm)
ABS Plastic	75	53.109	10.484
	120	60.027	17.717
Poly Ether Imide(PEI)	75	112.97	10.467
	120	434.04	17.882

IV. Comparative graphical data of existing bumper design Graph for material verses stress (Existing bumper design)



Graph: 1 Material Verses Stress (Existing bumper design)

Graph for material verses Displacement (Existing bumper design)



Graph: 2 Material Verses Displacement (Existing bumper design)

Observing the graphs of stress and displacement, values of ABS plastic are less than PEI material, the ABS plastic has good impact resistance for this design when compared to PEI material. Our objective is to increase impact resistance of bumper by changing the design. By modifying the actual design of car bumper we can increase the performance of same passenger car bumper.

V. Modeling of modified bumper for Maruti Suzuki Alto

From the above result and discussion it's come to known that objective is to increase impact resistance of bumper by changing the design and material. By modifying the actual design of alto car bumper we can increase the performance of same bumper. So that we designed a new bumper by changing its central straight strip structure in to curve shape and at the top side some material quantity has to increase for increased the performance of bumper.

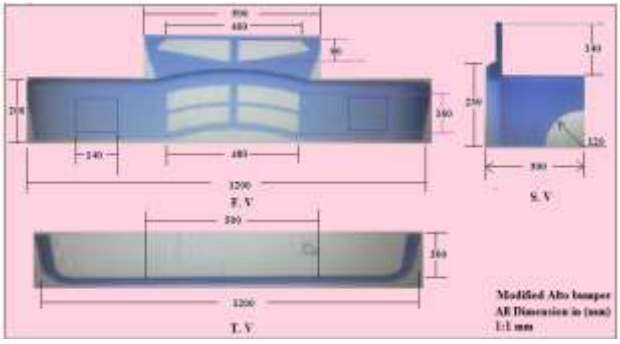


Fig. 11 Modified bumper drawing sheet

5.1 Analysis of modified bumper by ANSYS softwarewith FEA

Create a study defining its analysis type and options. Define parameters of modified bumper model. Parameters are model dimension, a material property, a force value, which impact on the design.

VI. Meshing of modified car bumper

The new mid surface mesh tool enables direct extraction of a shell mesh from solid geometry and applies the thicknesses to the corresponding meshed output. Thin Solids mesh enables the automatic hexa and/or penta dominant mesh for thin plastic or sheet metal-type parts.

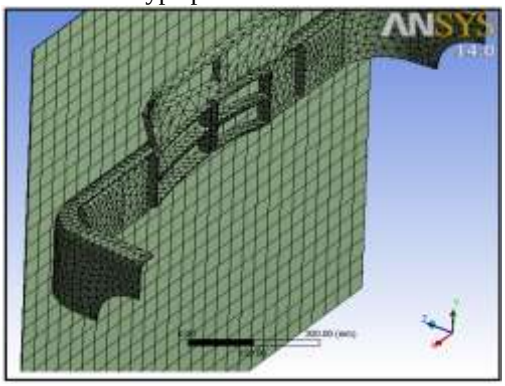


Fig. 12 Meshing of modified bumper design

6.1 Analysis on modified car bumper

From the results of existing bumper the ABS material is best so that for this modified design only ABS material is use and impact result will calculate by using ANSYS software with FEA.

6.1.1 ABS Plastic material (Modified bumper)

Table 10
ABS Plastic (Modified bumper)

Model name: - Modified bumper
Current configuration: - Default

Solid Bodies	
Treated as	**Volumetric properties**
Solid body	**Density (ρ): - 1020 kg/m^3** **Weight (W): - 2.95 kg**

a) Setup information

Table 11
Setup information (e)

Type	Velocity of impact
Velocity magnitude	20.83m/sec or 75 km/hr
Impact velocity reference	Face [1]
Gravity	9.81m/sec
Gravity reference	Face [2]
Parallel to reference plane	Plane 1
Friction coefficient	0
Target stiffness	Rigid target

b) Units

Table 12
Units (Modified bumper design)

Unit system	SI(MKS)
Length/ displacement	Mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure / stress	N/mm^2

c) Material properties of ABS plastic (Modified bumper)

Table 13
Material properties of ABS plastic (Modified bumper)

Name	ABS plastic
Model type	Linear elastic isotropic
Default failure	Max vol stress
Tensile strength	3e+0.007 N/m^2
Elastic modulus	2e+0.009N/m^2
Poisson's ratio	0.39
Mass density	1020 kg/m^3
Shear modulus	3.189e+0.008

i) Displacement for speed 75 km/hr (ABS Plastic)

Name	Type	Minimum	Maximum
Displacement (d)	Resultant displacement	0 mm	10.467 mm

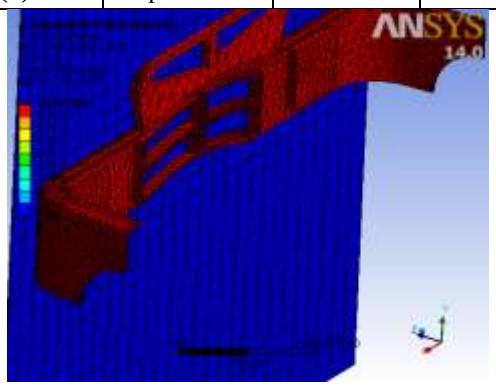


Fig. 13 Displacement for speed 75 km/hr (ABS Plastic)

ii) Stress for speed 75 km/hr (ABS Plastic)

Name	Type	Minimum	Maximum
Stress (σ)	Resultant stress	0 mm	34.92 N/mm^2

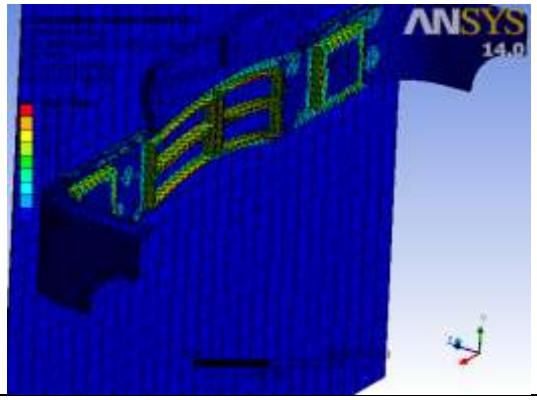


Fig. 14 Stress for speed 75 km/hr (ABS Plastic)

Impact analysis by taking speed 120 km/hr for modified bumper design and material is ABS plastic.

Table 14
Setup information (f)

Type	Velocity of impact
Velocity magnitude	33.333 m/sec or 120 km/hr
Impact velocity reference	Face [1]
Gravity	9.81m/sec
Gravity reference	Face [2]
Parallel to reference plane	Plane 1
Friction coefficient	0
Target stiffness	Rigid target

i) Displacement for speed 120 km/hr (ABS Plastic)

Name	Type	Minimum	Maximum
Displacement (d)	Resultant displacement	0 mm	17.307 mm

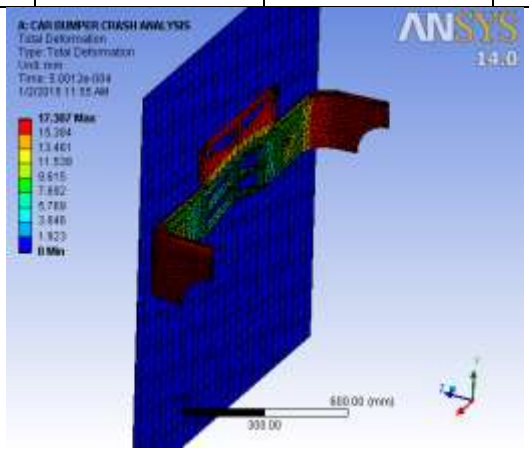


Fig. 15 Displacement for speed 120 km/hr (ABS Plastic)

i) Stress for speed 120 km/hr (ABS Plastic)

Name	Type	Minimum	Maximum
Stress (σ)	Resultant stress	0 mm	50.1 N/mm^2

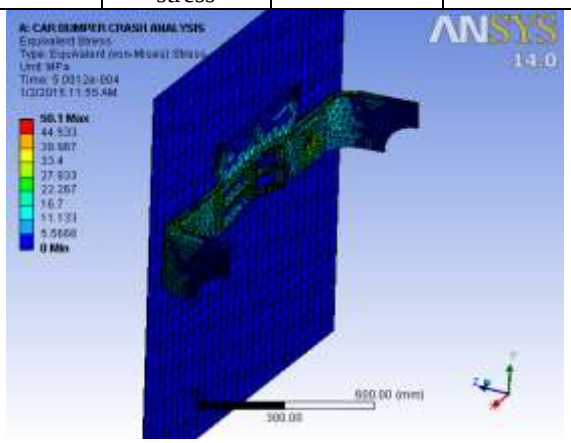


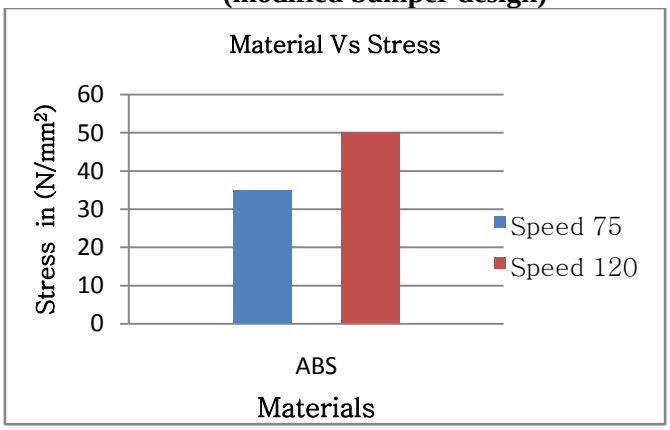
Fig. 16 Stress for speed 120 km/hr (ABS Plastic)

Modified Maruti Suzuki Alto car bumper impact results

Table 15
Modified bumper impact results

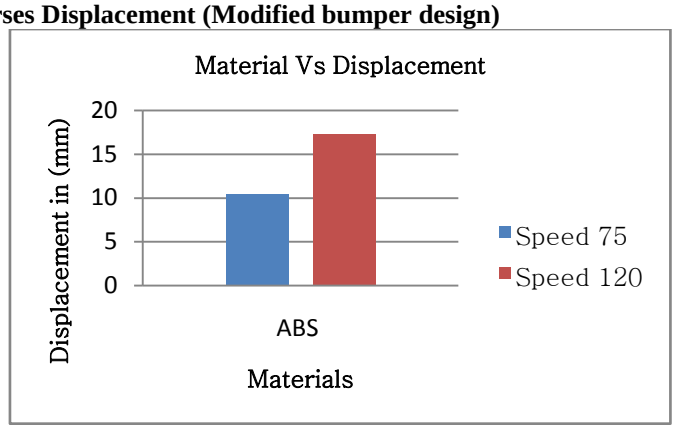
Material	Speed (Km/hr)	Stress (σ) (N/mm2)	Displacement (d) (mm)
ABS Plastic	75	34.92	10.467
	120	50.10	17.307

VII. Comparative graphical data of modified bumper design Graph for material verses stress (modified bumper design)



Graph: 3 Material Verses Stress (Modified bumper design)

Graph for material verses Displacement (Modified bumper design)



Graph: 4 Material Verses Displacement (Modified bumper design)

Observing the graphs of stress and displacement the ABS plastic has good impact resistance for this new bumper design. Projectobjective is completed impact resistance of bumper increases due to this new modified design and ABS material is good for this design.

VIII. Advantages

i) It increases impact resistance of car bumper.
ii) It absorbed the maximum shock as compared to existing bumper.
iii) It increases the life of car.

IX. Disadvantages

i) After damage, it needs replacement.

X. Applications

i) This modified bumper design can be used for same passenger car that is Maruti Suzuki Alto car.
ii) This modified bumper we can use for same alto type passenger cars.
iii)

XI. Results and Conclusion

Table 16
Comparison between existing and modified car bumper designs

Material	Speed (Km/hr)	Stress (N/mm^2) Existing	Stress (N/mm^2) Modified	Displacement (mm) Existing	Displacement (mm) Modified
ABS Plastic	75	53.109	34.92	10.484	10.467
	120	60.027	50.10	17.717	17.307
Poly Ether Imides (PEI)	75	112.97		10.467	
	120	434.04		17.882	

- Among the two used material the ABS plastic is best as compared to the poly ether imides (PEI) for both existing and modified Maruti Suzuki Alto car bumper design for speed 75 km/hr and 120 km/hr.
- From the comparison of both the bumper results it is observed that modified design has given the reduction in the stress and displacement value of the bumper during impact

- This modified bumper gives more impact resistance as compared to existing bumper design. The modified design shows the better result over the existing Maruti Suzuki Alto car bumper model.
- The modified design will defiantly provide reduction in injury and damage of automobile parts and passenger if this modified bumper applied in upcoming Maruti Suzuki Alto cars.

Future scope

- The FEA tool can be used to analysis for mechanical properties of automotive parts.
- To study the load distribution in automotive parts for respective field to optimize the better design.
- This new modified bumper design we can implement in upcoming Maruti Suzuki Alto cars instead of existing bumper.

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