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Design, Development and Impact Analysis of Car Bumper

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Abstract – *The bumper of an automobile is the front-most or rear-most element that is designed to withstand an impact without causing harm to the vehicle's safety systems. They are ineffective at reducing injury to car occupants in high-speed collisions. In this work, the most essential variables such as material, structures, forms, and impact conditions are explored for bumper beam analysis in order to increase crashworthiness during collision. More attention is placed on bumper material selection. The most crucial factors, including material, structures, forms, and impact conditions, are examined in this study in order to analyse the two different types of bumper materials and increase their crashworthiness in a collision. In order to analyse the findings, the simulation of a bumper will be defined by impact modelling using Pro/Engineer and impact analysis utilising an impact loading machine at the provided speed of (48 km/h). This speed is in accordance with FMVSS 208—Occupant Crash Protection—of the Federal Motor Vehicle Safety Standards, which sets forth standards for providing impact protection for passengers. In this project, analysis is carried out for various speeds in accordance with requirements as well as when speeds are changed.*

Keywords: *Frontal, impact loading, and bumper*

INTRODUCTION

The safety of vehicles on our roadways is greatly enhanced by the presence of car bumpers. They operate as the first line of defence during collisions and are especially made to disperse and absorb impact forces, minimising damage to the car and lowering the possibility of occupant injuries. Car bumpers are highly built parts that considerably improve overall safety; they are not just decorative embellishments to the car's exterior.

The purpose of car bumpers is to disperse and absorb the energy created during crashes. By doing this, they contribute to lessening the impact's severity as it is transmitted to the car's occupants. High energy-absorbing materials, including plastics, composites, or specialised metal alloys, are frequently used to make bumpers. The transmission of energy to the rest of the vehicle is significantly reduced by the use of these materials, which are chosen to withstand impact forces and deform under controlled conditions. Between the critical parts of the car and the outside world, bumpers act as a barrier for protection. By absorbing the impact and dispersing the pressures away from the primary structure, they are made to limit harm to the vehicle's frame, engine, and other vital systems. This increases general safety and lessens the financial strain on vehicle owners by helping to avoid expensive repairs and ensuring the vehicle stays operable after an accident.

Governmental agencies and organisations that set industry standards are responsible for enforcing strict safety laws that apply to car bumpers. These rules specify the minimal performance standards for bumpers, ensuring that they adhere to strict crashworthiness standards. To emphasise the significance of bumpers in vehicle safety, compliance with these requirements guarantees that vehicles are outfitted with efficient bumper systems. Additionally important in protecting people in collisions are car bumpers. Through the use of energy-absorbing materials, impact sensors, and carefully planned constructions, they are made to lessen the severity of pedestrian injuries. Modern bumper designs frequently have pedestrian-friendly elements like

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deformable structures or pop-up hoods that lessen the power of impact and the danger of serious injury in collisions involving pedestrians.

Design: The project's goal is to create unique and effective automotive bumper designs. This requires taking into account a number of things, including the choice of material, shape and size optimisation, and structural integrity. The goal of the research is to develop bumpers that can efficiently absorb impact forces and minimise damage during crashes by investigating new design paradigms.

Development: The project seeks to create working prototypes of the suggested bumper designs. It requires the use of cutting-edge engineering methods and equipment, including computer-aided design (CAD) software, finite element analysis (FEA), and manufacturing technologies for prototypes. The project tries to test the designs' viability and practicality during the development phase to make sure they can be successfully implemented in real-world circumstances.

Impact Analysis: Assessing and analysing the impact of the planned bumpers is a crucial component of the project. To do this, thorough testing and simulations must be run in order to evaluate how well they perform in various crash scenarios. In the impact analysis stage, variables such crash forces, energy absorption capacities, damage control, occupant protection, and pedestrian safety are taken into account. The project tries to gauge and quantify how well the proposed bumpers contribute to increased vehicle safety by looking at these factors.

By creating better designs and technology for car bumpers, the initiative hopes to increase vehicle safety standards. The project aims to increase the bar for safety in the automotive sector by concentrating on impact absorption, damage reduction, and occupant protection.

PROPOSED METHOD

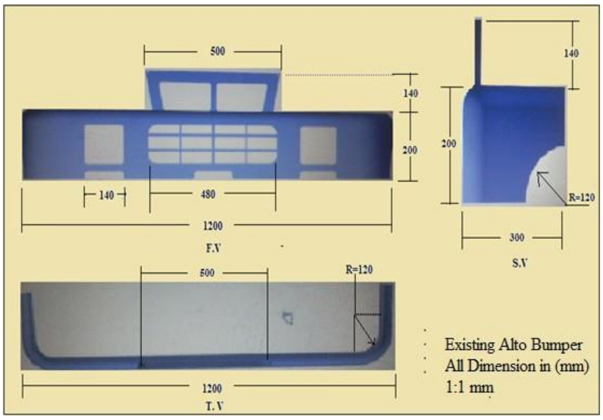
The major goal of this effort is to identify an energy absorption structure that can withstand impacts at varied speeds between 75 and 120 km/h. In order to accomplish the main goal, we must first analyse the stress, strain, and displacement for the original bumper and our modified bumper before comparing the two.

The purpose of this work is to examine a current passenger car's front bumper in the Indian market and make design & improvement suggestions for a passenger car's front bumper in terms of material selection utilising impact analysis.

- To perform a comparative speed impact examination on the mechanical characteristics of the automobile bumper's front portion (fascia).
- Stress analysis is a key component of mechanical property analysis.
- To represent the real bumper dimensions in the programme and perform impact loading analysis

A. Creo software modelling of the car bumper

In the same vein as other recently released tools in the CAD/CAD/CAM/CAE category, Creo/Engineer is the latest edition of Pro-e. With sophisticated rule-based design capabilities, Creo/Engineer is a parametric, feature-based modelling architecture that is integrated into a single database philosophy. Engineering Design, Analysis, and Manufacturing are the three basic categories under which the product's capabilities can be divided. This information is then recorded in a typical 2D production drawing, and with the aid of Creo modelling software, a car bumper's proportions are chosen. The dimensions of the Maruti Suzuki Alto's present bumper design are the same as the original



design. As the front area of the bumper just exterior is more vulnerable to impact.

Figure 1. CAD schematic of the Maruti Suzuki Alto bumper.

B. Meshing of an already-existing car bumper

With the help of the new mid surface mesh tool, a shell mesh may be directly extracted from solid geometry, and thicknesses are applied to the matching meshed output. For thin plastic or sheet metal items, Thin Solids mesh enables the automatic hexa and/or penta dominating mesh.

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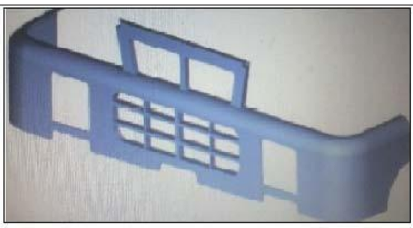
Name	ABS plastic
Model type	Linear elastic isotropic
Default failure	Max vol stress
Tensile strength	3e+0.007N/m^2
Elastic modulus	2e+0.009N/m^2
Poisson's ratio	0.39
Mass density	1020 kg/m^3
Shear modulus	3.189e+0.008



Model: Front bumper for a Maruti Suzuki Alto vehicle Arrangement: - Standard

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

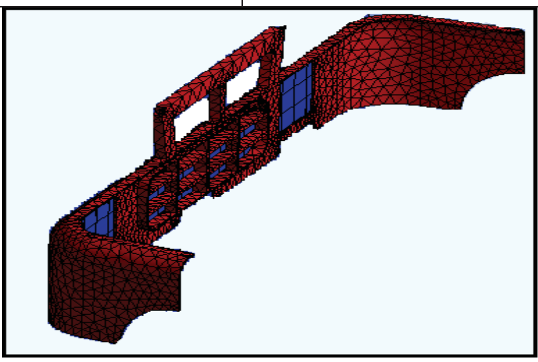


Figure 2: shows how the current car bumper design meshes.

METHODOLOGY

A. Analysis of an altered automobile bumper

The existing bumper is made of ABS plastic.

Table -1 Experiment Result: ABS Plastic (Existing bumper)

B. Set up details

Table 2: Set up details (a)

Type	Impact velocity
Velocity magnitude	20.83 m/sec or 75 km/hr
Impact velocity reference	Face [1]
Gravity	9.81 m/sec
Gravity reference	Face [2]
Parallel to reference plane	Plane1
Friction coefficient	0
Target stiffness	Rigid target

C. ABS plastic's material characteristics

Table 3: ABS plastic's material characteristics

i) ABS Plastic displacement at 75 km/hr

Name	Type	Min	Max
Displacement (d)	Resultant displacement	0 mm	10.484 mm

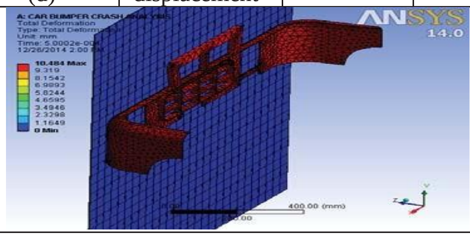


Fig. 3 ABS Plastic displacement at 75 km/hr

ii) ABS Plastic stress at 75 km/hr

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

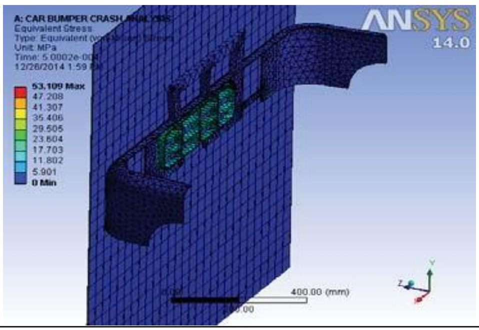


Fig. 4 ABS Plastic stress at 75 km/hr

D. Impact analysis using a speed of 120 km/hr for the current bumper design and ABS plastic material.

Table 4: Set up details (b)

Type	Velocity of impact
Velocity magnitude	33.333m/sec or 120 km/hr
Impact velocity reference	Face [1]
Gravity	9.81 m/sec
Gravity reference	Face [2]
Parallel to reference plane	Plane1
Friction coefficient	0
Target stiffness	Rigid target

a) Poly Ether Imide (PEI) material characteristics

Table 5: Poly Ether Imide (PEI) material characteristics

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

i) PEI displacement at 75 km/hr

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

Name	Type	Min	Max
Displacement (d)	Resultant displacement	0 mm	10.467 mm

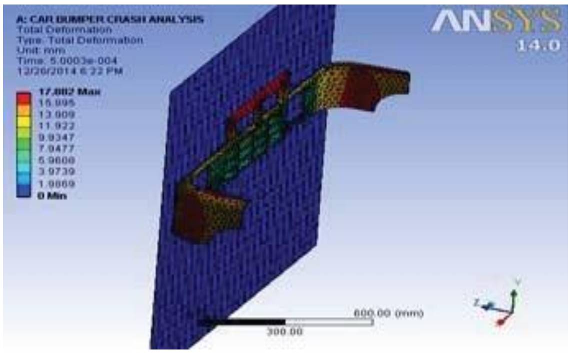


Fig. 5 Poly Ether Imide displacement at 75 km/hr

F. Impact study with a speed of 120 km/h for the current bumper design and material is PEI

Table 6: Set up details (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	Plane1
Friction coefficient	0
Target stiffness	Rigid target

i) PEI displacement at 120 km/hr

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

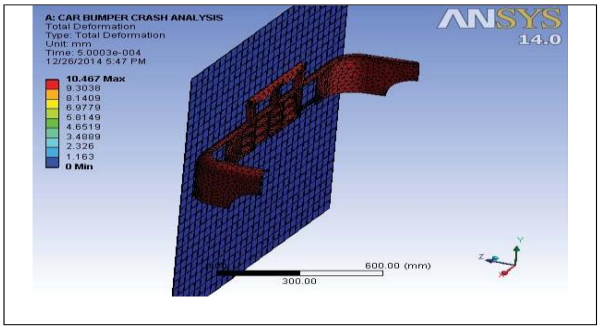


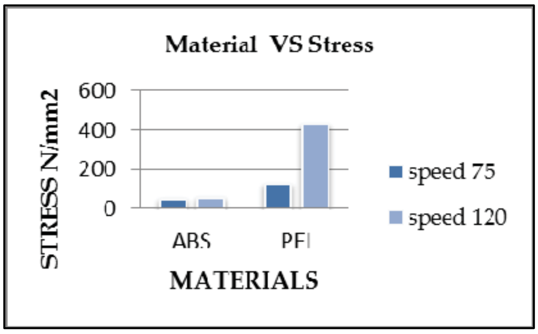
Fig. 6 PEI displacement at 120 km/hr

G. Impact of the current Maruti Suzuki Alto bumper

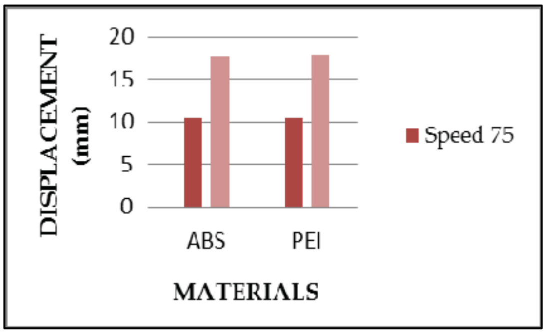
Table 7: Impact of the current Maruti Suzuki Alto bumper

H. Comparison graphs of bumper designs currently in use Material vs. Stress Graph (Original Bumper Design)

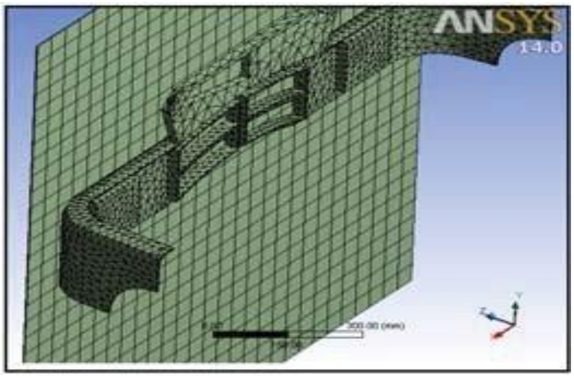
Graph 1: Material vs. Stress (Original Bumper Design)



Graph 2: Material vs. Displacement (Original Bumper Design)



According to the graphs of stress and displacement, ABS plastic has better values than PEI material, indicating that it has better impact resistance for this design. By modifying the design, we want to boost the bumper's impact resistance. We can improve the performance of the identical passenger car



bumper by altering the real design.

I. Modelling a redesigned bumper for a Maruti Suzuki Alto

discussion it has come to light that the goal is to improve bumper impact resistance by altering the design and substance. We can improve the performance of the identical bumper by changing its real design for the Alto automobile. Therefore, we created a new bumper by modifying its core straight strip structure into a curve shape. Additionally, some material quantity had to be raised at the top side of the bumper in order to boost its performance.

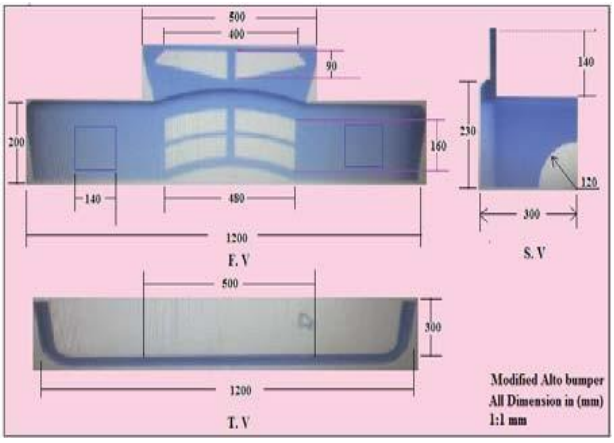


Figure 7: Redesigned bumper drawing sheet

I. Using ANSYS software and FEA, analyse the modified bumper

Make a study outlining the type of analysis and available alternatives. Set the modified bumper model's parameters. Model dimensions, material characteristics, and force values are examples of parameters that affect design.

J. Meshing of modified car bumper

With the help of the new mid surface mesh tool, a shell mesh may be directly extracted from solid geometry, and thicknesses are applied to the matching meshed output. For thin plastic or sheet metal items, Thin Solids mesh enables the automatic hexa and/or penta dominating mesh.

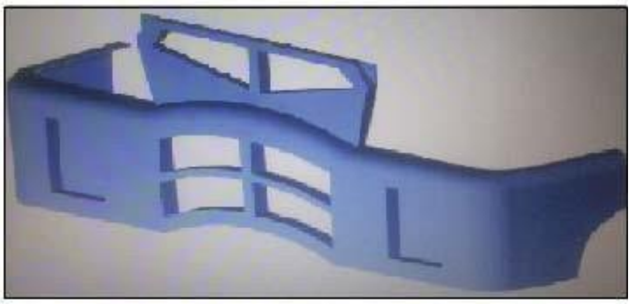
Fig. 8: Meshing of a redesigned bumper

K. Analysis of a modified car bumper

Since ABS material performs the best based on findings from current bumpers, ABS is the only material used in this redesigned design, and the impact result will be calculated using ANSYS software and FEA.

L. Modified bumper made of ABS plastic

Table 8 Modified bumper made of ABS plastic



Model: Modified bumper

Arrangement: - Standard

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

a) Set up details

Type	Velocity of impact
Velocity magnitude	33.333m/sec or 120km/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

Table 9 - ABS plastic's material characteristics for modified bumpers

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

ABS Plastic displacement at 75 km/hr

Name	Type	Min	Max
Displacement (d)	Resultant Displacem ent	0 mm	10.46 7 mm

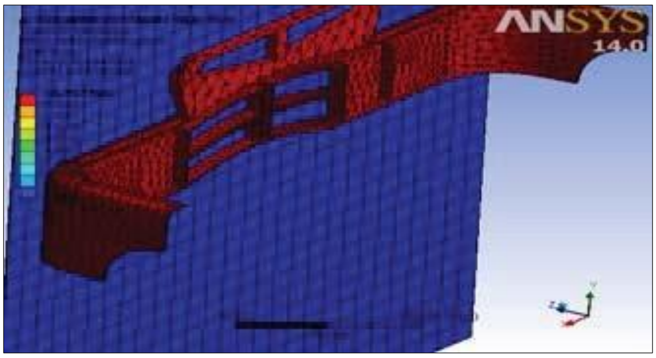


Fig. 9: ABS Plastic displacement at 75 km/hr

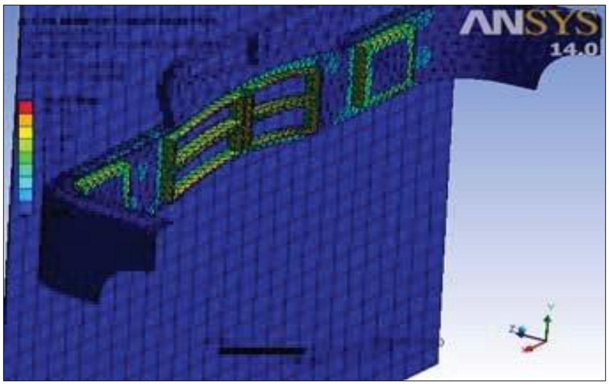


Fig. 10 ABS Plastic stress at 75 km/hr

i) ABS Plastic at 75 km/hr

For the improved bumper design and ABS plastic material, an impact analysis at 120 km/hr was performed.

Table 10 Set up details (f)

Name	Type	Min	Max
Stress(σ)	Resultant stress	0 mm	34.92 N/mm^2

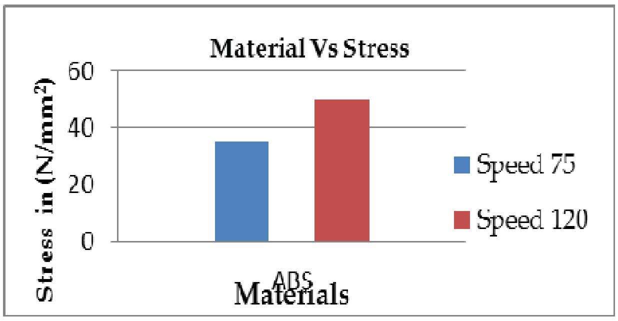
Impact outcomes of Modified Maruti Suzuki Alto car bumper

Table 11 impact outcome of Modified bumper

Material	Speed (Km/hr)	Stress(σ) (N/mm^2)	Displacement (d) (mm)
ABS Plastic	75	34.92	10.467
	120	50.10	17.307

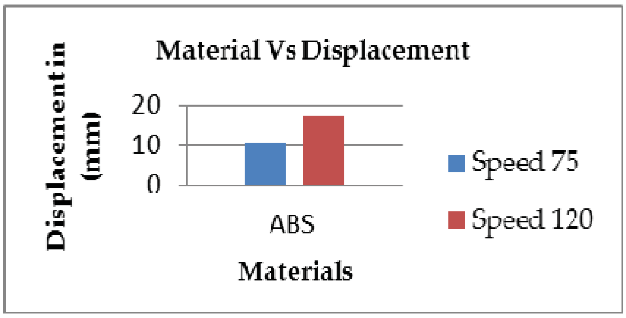
CONCLUSION

Graph showing Material vs Stress for a Modified Bumper Design



Graph 3: Material vs Stress for a Modified Bumper Design

Graph showing Material vs Displacement for a Modified Bumper Design



Graph 4: Material vs Displacement for a Modified Bumper Design

For this innovative bumper design, the graphs of stress and displacement show that the ABS plastic has good impact resistance. The new updated design improves the impact resistance of the bumper, and the ABS material is suitable for this design.

Table 12: Comparison between existing and modified car bumper designs

Material	ABS Plastic		Poly Ether Imides (PEI)	
Speed (Km/hr)	75	120	75	120
Stress (N/mm2) Existing	53.109	60.027	112.97	434.04
Stress (N/mm2) Modified	34.92	50.10		
Displacement (mm) Existing	10.484	17.717	10.467	17.882
Displacement (mm) Modified	10.467	17.307		

At both the original and modified Maruti Suzuki Alto automobile bumper design at speed 75 km/hr and 120 km/hr, the ABS plastic is the best material when compared to the poly ether imides (PEI).

- From comparing the findings of the two bumpers, it can be seen that the changed design has decreased the stress and displacement value of the bumper upon impact.
- In comparison to the previous bumper design, this redesigned bumper offers greater impact resistance. When compared to the existing Maruti Suzuki Alto automobile bumper model, the redesigned design performs better.
- If this improved bumper is used on incoming Maruti Suzuki Alto vehicles, there will undoubtedly be a decrease in injuries and damage to passengers and vehicle parts.

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