ANALYSIS OF A CRASH ON A VEHICLE SYSTEM BY ADJUSTING APPROPRIATE INPUT PARAMETERS TO MANAGE ENERGY ABSORPTION CAPACITY FOR ENHANCING PASSENGER SAFETY

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Highlight
To develop a front bumper system that will absorb more energy than the present bumper in the case of a frontal impact.

Abstract
The aim of the research is to develop a front bumper system that absorbs maximum impact energy as compared to the current bumper available in the market, Bumper design is based on increasing the area of the crumping zone to slow down the collision and observe the impacts taking place at the time of jerks and reduces the percentage of damage. To develop the system, the number of load cases tested numerically in passive safety simulation has increased significantly in recent years. The variety of applications may be divided into three main topics: structural crashworthiness of the whole car, passenger protection, and crashworthiness of components. Present theories and practices. To absorb impact, the front bumper of the car uses a spring-loaded system that is installed between the bumper and the support for the chassis structure. This system is made of metal and serves as the bumper's structural foundation. A honeycomb structure is being added to the bumper as a composite material together with a layer of galvanized iron as it is being created in this manner, which increases strength while weighing less. This arrangement design is suitable for psychoacoustics, varying velocity explicit analysis is performed with the approach of finite element analysis, experimental testing is carried out for the validation of the value and advanced manufacturing methods are implemented with statistical results, and one of the cheapest systems is developed as compared to the current bumper systems.

Keywords
Bumper system, crash analysis, composite material, CAD, experimental testing, FEA.

Introduction

In an automobile, both the front and rear elements consist of a bumper system to resist the impact taking place on the vehicle and a system that absorbs shock to reduce damage (as in a collision). In the bumper system, a grill is implemented for ventilation purposes for a projected lamp for visibility, headlamps, and the aesthetic look of the vehicle. The aim of this paper is to highlight a system that is more suitable for modern automobiles with better passenger safety aspects. To develop this system, we have to consider various kinds of materials used, such as Galvin sheets, ABS plastic sheets, Honeycomb aluminium panels, etc., which are combined and put into one combination to make a composite material. This composite material is very strong, with high strength and less weight. The design has an aerodynamic effect. Research mainly focuses on parameters such as materials, design, CAD, GD&T, CAM, CAE-Simulation, Programming, Hand Calculation, Advanced Manufacturing Process, Experimental Testing, Validation, and Comparison Depending on all these criteria and parameters, the development of energy observing systems is done. It observes the energy inside it and reduces the impact, which is beneficial for the passenger for safety purposes. In automotive assiduity, energy immersion capability is veritably important in adding safety for passengers as vehicles are used considerably. Structural crashworthiness is an essential requirement in the design of the automotive corridor. Crashworthiness alludes to the reaction of a vehicle when it is engaged with or goes through an effect. Crashworthiness performance is good when there is less damage to the vehicle and passengers after a crash. Crashworthiness for structural members needs to be dissected before being enforced in the factual field [1]. This system is very helpful for the

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development of an automobile. It has a unique component system that reduces the impact. Jerks and the percentage of damage to the passenger are very low, and they are also in a safe zone with a safety factor, and the manufacturing cost is very low in comparison to others. Figure 1 highlights the basic representation of the energy-absorbing bumper system.

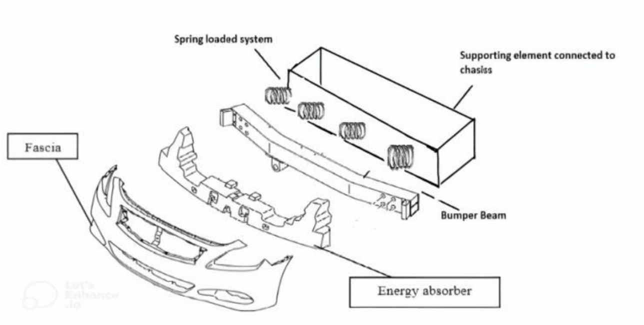

Figure 1. Automobile Front Bumper (Energy Absorption System). *Source: Own.*

Methods

Research studies

Objective is to study bumper system and design and development a bumper system which absorb maximum energy inside bumper system in the form of a crumping zone and more effective as comparing to the present bumper, According to the aforementioned literature research, an appropriate impact force distribution can enhance a bumper's performance in terms of a vehicle's and its occupants' safety. Additionally, there are methods for efficiently dispersing the energy that the bumper system absorbs in order to achieve safety with the least amount of damage. An investigation was conducted [2]. Found that balancing the weight of bumper system components by controlling their thickness may lead to lower stress levels, which indirectly protects the safety of the components. Since the energy from impacts is distributed equally among the components and we may fortify the components during assembly thanks to the properties of the material, the use of varied materials is justified. Also. For fenders that might devaluate further energy, design specifications must be determined. According to the experimental disquisition report and study trouble applicable to advancements in the frontal cushion design of a passenger auto, there are some significant factors that may be taken into consideration for enhancement and a gap in the literature.

- The bumper's ability to absorb energy must be increased considering the friction damper.
- A novel energy perception framework is required, which can notice the energy inside it and decrease the effect, like a spring-stacked framework or hydraulic cylinder.
- Experimental data for analysis of passenger safety.

Material Properties & Analysis

The bumper system consists of two major component system one is the spring-loaded system which is connected inside the bumper to the chassis other is the body parts of the bumper system as shown in the Figure 2 both analyses is carried out for the selection of the better material, Proper alloy composition is made which contains different percentages of material properties. Also, proper solidification time is given to extract material properties at the time of manufacturing so it can sustain maximum impact on the materials.

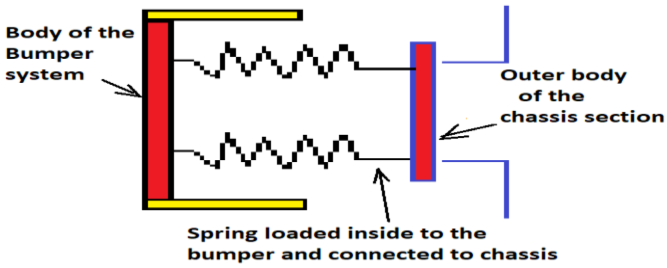

Figure 2. Different component systems used for the bumper. *Source: Own.*

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Diverse types of materials are used to build bumper systems and composite materials are also utilized, aver materials have different properties; with varied materials taken into consideration for the system's study, the goal is to analyse each of these materials in terms of low weight and high strength. The typical characteristics of the Guard are listed below, mainly consisting of the Chief Tomahawks of Dormancy and the Head Snapshots of Inactivity, etc. The mechanical characteristics of the guard plan framework for energy retention are displayed in Table 1 below.

Table 1. Material Properties for the bumper system. *Source: Own.*

Material	**Modulus of elasticity E (GPa)**	**Poisson's ratio μ**	**Yield strength Sy (MPa)**	**Density ρ (kg/m³)**
AISI 316 Stainless Steel Sheet (SS)	211	0.265	170	8027
Aluminium 1345 Alloy	59	0.33	28	2700
S2 Glass	86.9	0.23	310	2460
ABS Plastic	2.5	0.394	48	1050

In the Solid Works tool mass properties analysis is done for the bumper system as shown in Table 2

Table 2. Mechanical Properties for the Bumper Design Systems. *Source: Own.*

Mass	**Volume**	**Surface area**	**Centre of mass: (inches)**
6202.89 grams	6202890.90 m^3	3616.72 3 in^2	X = -51.35 Y = -1.14 Z = -17.39

A bumper design configuration and coordinate system are defined as shown in the Figure 3, the system diagram is obtained in CAD tool and analysed parameters.

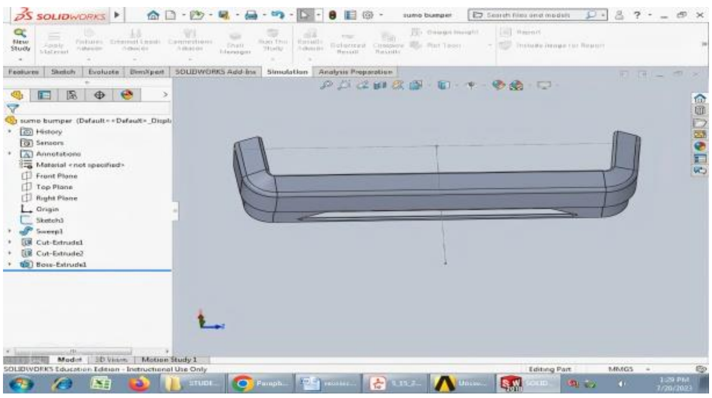

Figure 3. Bumper system configuration diagram. *Source: Own.*

Following material analysis is carried AISI 316 Stainless Steel Sheet (SS), Aluminium, Glass and ABS plastic, for checking suitable material as shown in Table 3

Table 3. Materials analysis for selecting suitable material and model outcomes for auto front guards. *Source: Own.*

Parameters	**ABS Plastic**	**S2 Glass**	**AISI 316 Stainless Steel Sheet (SS)**	**Aluminium 1345 Alloy**
Absolute Disfigurement	0.31992	0.26661	0.74322	1.23211
Stress	1.40e+09	1.17e+10	879083.88	877002.44
Strain	1.5741	0.15533	0.000002	0.000001

Consisting of material properties and bumper analysis we can predict S2 Glass fibre is a better material, Also implement steel sheet combined with polycarbonate which act as a honeycomb structure reinforcement as

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compared to the analysis point of view is stronger and light weight, Outright Deformation 0.2155, stress 1.05e+10 N/m². Different part is made of different material in the bumper which act as the composite material.

The chemical properties of chromium-vanadium steel springs as shown in Table 4 are considered for the development of spring-loaded bumper system, a spring is a very critical element in this system. The chemical composition is very important at the time of the manufacturer's spring. If some percentage mismatch takes place, the breakdown of the spring occurs after a few intervals of time. Table 4 refers to the chemical properties for developing the energy absorption material [3,4].

Table 4. Chemical compositions considered for developing energy absorb system. *Source: Own.*

Carbon	**Silicon**	**Vanadium concentrations**	**Magnesium**	**Chromium (Cr)**	**SAE Steel Grade**
0.4% to 0.5%	(0.3 to 0.5% Si)	0.1 to 0.2%.	0.5 to 0.8% Mm	0.9 to 1.1%	6000 Series

Deformation takes place when a load is applied to the spring in the energy absorbed, the spring will be returned to its original state by means of the oscillating motion when you quickly launch a weight from this position. With this technique, the spring builds strength through deflection when the load is applied [5,6]. When there is a crash, the energy is absorbed and transformed into a system's internal potential energy, the spring-loaded bumper system has 11493397.4 psi as material shear modulus.

Energy absorption impacts fundamental and the bumper system's-built structure.

The equation below shows the impact analysis fundamentals that are used to solve impact elastic and plastic & available in two different varieties. Energy and momentum conservation equations can be expressed as follows.

(1) $$\frac{1}{2}\mathfrak{m}_{A}\mathcal{V}_{\mathrm{A}}^{2} = \frac{1}{2}\mathfrak{m}_{A}\mathcal{V}_{\mathrm{A2}}^{2} + \frac{1}{2}\mathfrak{m}_{B}\mathcal{V}_{\mathrm{B2}}^{2}$$

(2) $$\mathfrak{m}_{A}\mathcal{V}_{\mathrm{A}} = (\mathfrak{m}_{A}+\mathfrak{m}_{\mathrm{B}})\,\mathcal{V}_{0}$$

Where $\mathfrak{m}_{A}$is the mass of the impactor$\mathfrak{m}_{B}$the mass of the vehicle, $\mathcal{V}_{\mathcal{A}}$ the haste of the impactor before impact, and $\mathcal{V}_{0}$ the final haste of the impactor and vehicle at the moment of highest deviation point.

The coefficient of restitution (e) can be used to calculate the velocities following a collision.

(3) $$\frac{\mathcal{V}_{\mathrm{B2}}-\mathcal{V}_{\mathrm{A2}}}{\mathcal{V}_{\mathrm{A}}-\mathcal{V}_{\mathrm{B}}}$$

The impactor's kinetic energy prior to the impact

(4) $$E\mathrm{plastic} = \frac{1}{2}\mathfrak{m}_{A}\mathcal{V}_{\mathrm{A}} + \frac{1}{2}\mathfrak{m}_{B}\mathcal{V}_{\mathrm{B}} - \frac{1}{2}\mathfrak{m}_{A2}\mathcal{V}_{\mathrm{A2}} - \frac{1}{2}\mathfrak{m}_{B2}\mathcal{V}_{\mathrm{B2}}$$

The chassis serves as a supporting element for the bumper system; it is made of lighter carbon steel or aluminium alloy. At the rear and front end of the chassis, a bumper system is implemented on a horizontal beam in this same beam with a perpendicular formation. We have added a series of spring-loaded systems to observe the energy. A spring-stacked system is planned in such a manner to utilize a twist spring to store energy from contorting movement. It additionally notices the strain inside and delivers the energy the other way. Spring-loaded systems observe maximum energy inside them, and very little energy is transferred to the passengers. At the time of impact, the forced distribution takes place in a circular motion to reduce the impact. Also, we can implement a hydraulic cylinder inside the chassis at the vertical front of the chassis body. This is one type of suitable method that can be implemented in vehicles and is a very cost-effective method where the vehicle falls under a safety zone. This method can be used to make a vehicle five-star under the Global NCAP rating and is a more suitable method. Also, we can implement a crash box that can be fitted between the chassis and the bumper element. This type of method is adopted nowadays in vehicles. As compared to our system, a hydraulic cylinder for the vertical component has been installed at the front of the chassis. The horizontal front beam of the chassis part has a spring-loaded mechanism added to it to cushion the blow. This system is fitted between the vehicle chassis and the inner element of the bumper. A series of springs are added in this system at the front frame of the chassis section. The formation of a collusion force takes place. Spring sustains the impact and bumper life is increased. This system is very suited for the off-roading area in its rigid condition, and for high to low ground clearance, it is very effective. Chrome strips were added for support and styling purposes and to enhance the look. This system is fitted between the front chassis section and the inner element of the front bumper. Further, the outer body of the bumper is made with a honeycomb structure in a natural hexagonal honeycomb formation. The structures are used to build the bumper system, which consists of a PVDF coating with rigidity and stability for the panel. They are fixed inside and outside of the bumper system with an inside honeycomb structure between them. They are also used for aerospace applications, known as ACP aluminium panel sheets. In this panel, we are using the pattern of an, I beam, which has the most strength with less weight, which enhances its efficacy to withstand extreme stress. They also act as heat and sound insulation, which reduces engine noise. The hexagonal structure of the sheets has a hollow space in the middle that inhibits airflow and prevents heat and sound from passing between the sheets. Once the honeycomb structure was completed according to the parameters, we added a Galvin sheet that acts as a composite material; galvanized metallic systems are widely used for exterior buildings in the current metropolitan society, including crash barriers, lamp poles, fences, buildings, facades, and roofs. A heat treatment process is used to increase its strength. An electroplating process has been applied to metal surfaces using warm dipping [7,8]. The first layer will be aluminium-coated, and the second layer will be I beam of honeycomb. The third layer will be aluminium, and the fourth layer will be a Galvin sheet. The combination is in such a way that it has high strength with less weight so that maximum strength will increase. In an automobile, both the front and rear elements consist of a bumper system to resist the impact taking place on the vehicle and a system to absorb shock to reduce damage (as in a collision). In the bumper system, a grill is implemented for ventilation purposes a projector lamp for visibility, and headlamps. The aesthetic look of the vehicle becomes good. It is the most advanced concept that can be implemented in an automobile front bumper system for passenger safety aspects. Low manufacturing costs with rapid advanced production [9]. Figure 4 highlights the bumper system different components and the built structure of it.

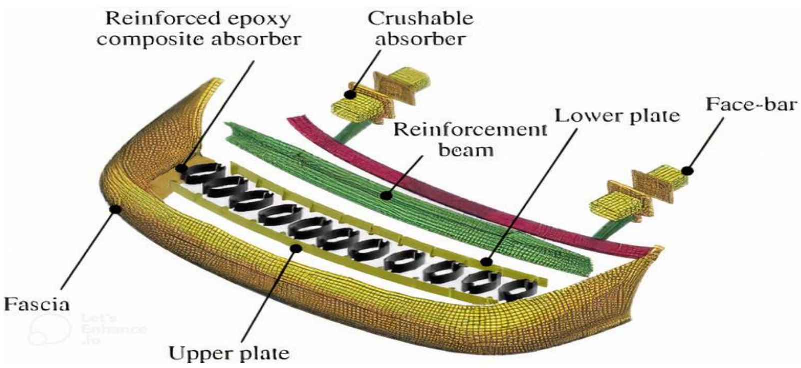


Figure 4. Bumper System with exploited View. *Source: Own.*

Results and discussion

Bumper system simulation

The most important thing to consider in the development of automobile front bumper systems is that we have defined the physical parameters such as thickness, length, height, different angles, angle of curvature, internal Di & external Do diameter, Ti-difference between two elements, Th-thickness of the supporting element, Ao-the difference between slot area and aesthetics look is created for the beauty of a bumper system. After designing, we implement the Pre-Processing, Processing, and Post-Processing Phases. We also implement Mat-Lab platform Programming supporting Simulation and Calculation.

Base model evaluation

We are provided a cushion assembly, as shown in Figure 5, whose component consistency is specified in the table.

The automobile's front bumper panel consists of various parts. The thickness for the base model ranges between 1.50 mm and 12 mm, and the chassis section is 10 mm. The analysis is divided into three parts: pre-processor, processor, and post-processor. Pre-Possessor – The process mainly consists of discretization into a number of small parts, each part consisting of a node and an element they are properly connected to one another, allowing force to transfer from one side to the other and acquire static or dynamic loading conditions [10]. Mostly, this process is followed to convert an infinite into a finite for a higher thickness component; we use a top-down approach where the mesh is created on the top face and extended to the bottom face. For the smallest thickness at midplane, the mesh is created by extruding on both faces. Since the third feature of a multitude of variables, consistency is negligible compared to the other two constraints, length, and range, we prefer 2D meshes or hulls. Furthermore, the conjunction provisions do not impose permanent limitations on the effective section. After recording, the model looks like Figure 6. The type of network, a fitted model, is also examined. Once the mesh is created, the model is assessed for quality and compliance to standards, allowing precise characterization of stress zones and mapping surrounding boundaries across material packages, similar to the modulus of plainness and venom rate [11,12].

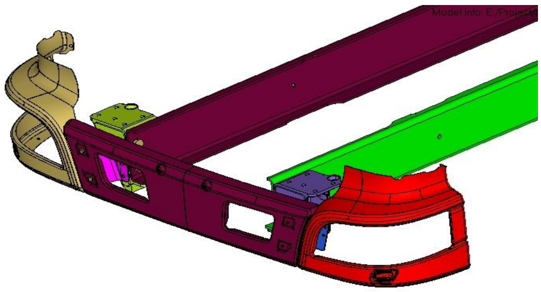


Figure 5. Assembly of the Bumper System of the Base Model Analysed. *Source: Own.*

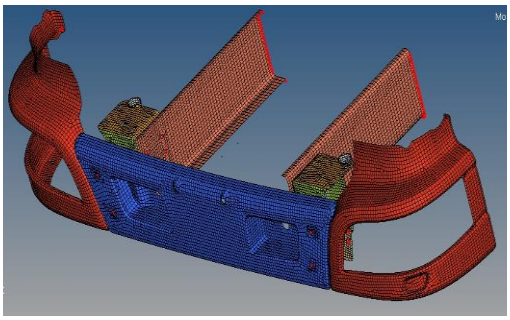


Figure 6. Bumper system assembly mesh model (front view). *Source: Own.*

The viscosity of the material, etc. we are handed a sword as an introductory material, whose parcels are described in Table 5 below.

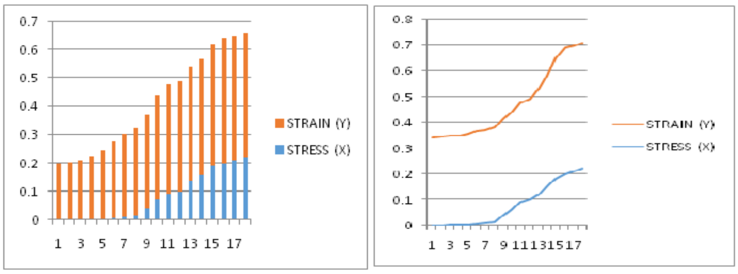
Table 5. Steel Material Characteristics. *Source: Own.*

Material	**The elasticity modulus**	**Density**	**Poisson ratio**
Steel	215 kN/ mm^2	7.9e^-6 kg/ mm^2	0.3

Soft steel is used to make the front panel and side panel of the car's front bumper, whereas the chassis portion and support bracket are composed of tough steel, and the impactor is stiff. In addition, this material is divided into two groups: mild steel and durable steel, which are allocated to components like these. Below are the values and angles of the stress vs. strain charts for the two materials. Figure7 highlights Stress-Strain for the soft & hard steel [13].

Soft & durable steel compression between Stress-Strain is highlight in Figure 8, the non-linear curve used to compare durable steel to soft steel; Boundary conditions refer to issues that arise during analysis. This has to do with fixing the model, operating the loads, providing the right connections, etc.

Following that, we are given the restricted circumstances, the vehicle's mass, which is approximately 1000 kg, and the impact speed, which is 1.5 m/sec. Shafts provide bolt couplings, which are thus properly constrained. The processing stage is where FEA equations are used to solve the stages and compile the findings of the study.



Stress-strain curve data for soft steel **Stress-Strain curve data for hard steel**

Figure 7. Data on the stress-strain axes for both soft and durable steel. *Source: Own.*

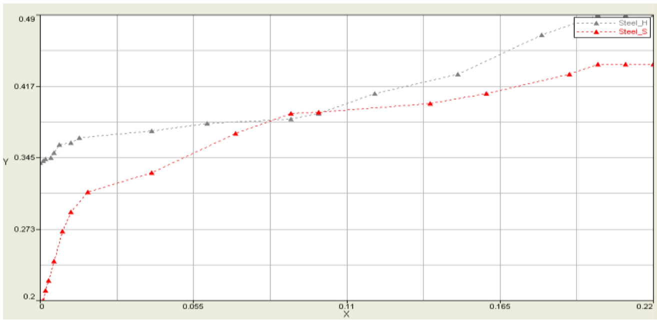


Figure 8. Comparison graph between hard and soft steel. *Source: Own.*

<u>Post-Processor (Base Model)</u>
The Results of the analysis are displayed in the hyperview module after completion and validated with the corresponding method. Figure 9 and Sub Figure 9 A-B-C-D-E; highlight the Base model analysis for different components.

For soft swords, the acceptable values for plastic deformation are 0.25 (25) and 0.33 (0.33), respectively. The support type (cushion type) is 0.33, which is higher than the allowed value. Because of this, the bumper side panel's design is dangerous, and the real amount of plastic deformation must be lowered to a reasonable level. The plastic strain value for the first swelling model is shown in Table 6.

For components made of soft steel, the allowed values for plastic strain are 0.25 (25%) and 0.33 (33%) for those made of durable steel. We conclude that the bumper bracket exceeds the actual allowable strain value, as indicated in Table 2. Making the appropriate tweaks to the assembly process will help to secure the design by bringing the plastic strain values down to a manageable level. To make sure that all components enter the safe zone, a modified analysis of the basic model is carried out based on the findings. Therefore, the accompanying Table 4 [14,15], provides the fundamental model with the change in element thickness.

Table 6. Displays the plastic strain values for each part of the original model in the complex model. *Source: Own.*

The name of the component	The model's original thickness	Model original Plastic strain
Body of the bumper's front panel	1.7 mm	0.26 (26%)
Panel on the bumper's side	1.7 mm	0.08 (8%)
Part of the bumper panel that supports the brackets	4.0 mm	0.35 (35%)
Component of the supporting bracket	11.0 mm	0.21 (21%)
Body section	10.0 mm	0.01(1%)

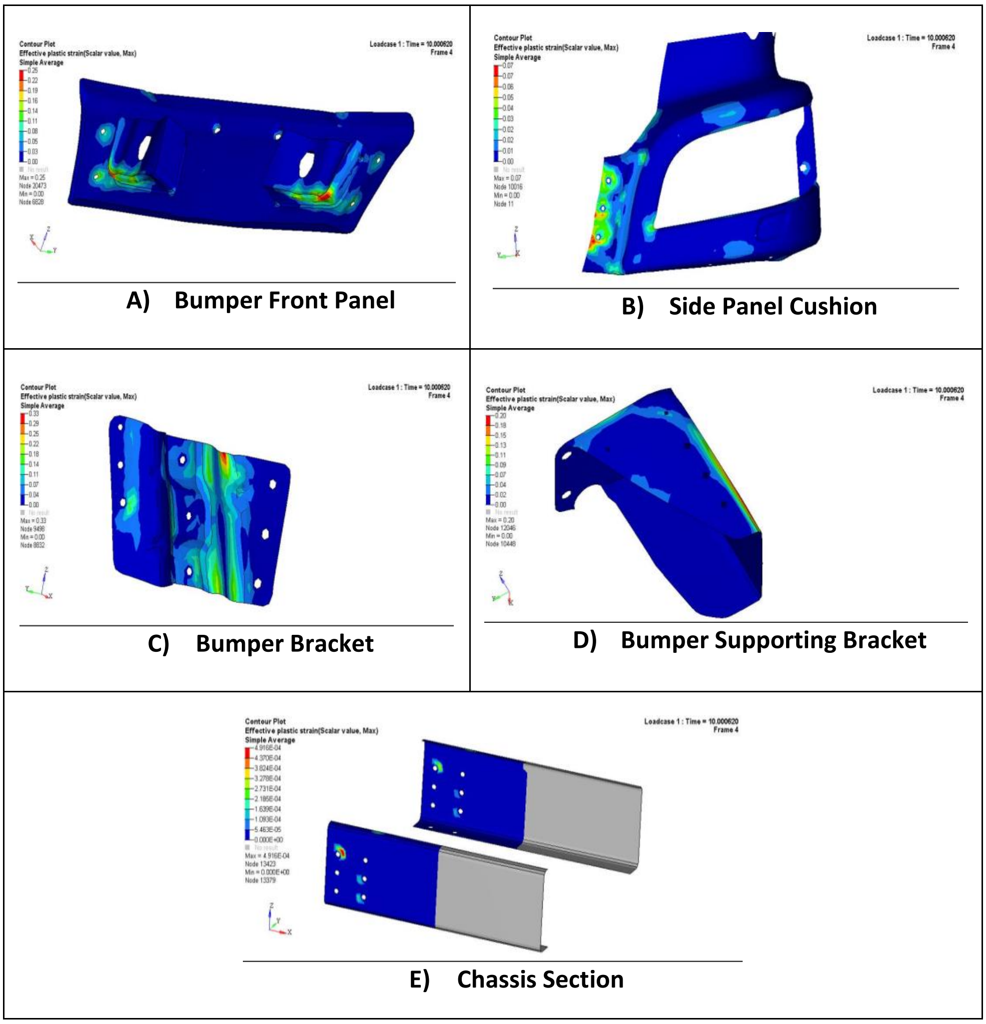


Figure 9. Contour diagram analysis of the actual values of plastic deformations of various parts of the front bumper and chassis sections. *Source: Own.*

Possible solutions are:

- Redesigning components: To get the best results we can redesign the component. This results in the redesign of components, increasing costs by adding more ribs or changing calculations.
- Material modifications: Component materials can be modified to ensure appropriate pressure distribution. We can use additional composite materials to avoid poor design.
- The thickness of each component can be varied to determine the correct plastic strain values for each component. The promotion process is expensive and time-consuming. To determine plastic strain values and create a safe strategy, we choose the third option from the list above.

<u>Changed Guard front board and skeleton area examination.</u>
As a result, the new front bumper panel of the car had a thickness ranging from 2 to 12 mm and the chassis section had a thickness of 10 mm. This led to the creation of the upgraded model with the modified component thickness for the new bumper assembly. With the same limit circumstances after the thickness adjustments, the effects of the modified model are as follows: Figure 10 and sub-Figure 10 A-B-C-D-E display the component analysis of the improved bumper system for various sections.

For the vehicle chassis and front bumper parts, the plastic deformation values are between 0.26 and 0.01, which is equal to or lower than the permissible limit. This makes the structure safe. If it is in a safe zone, we can take the changed value into account and run the project. Table 7 shows the modified plastic deformation of the model.

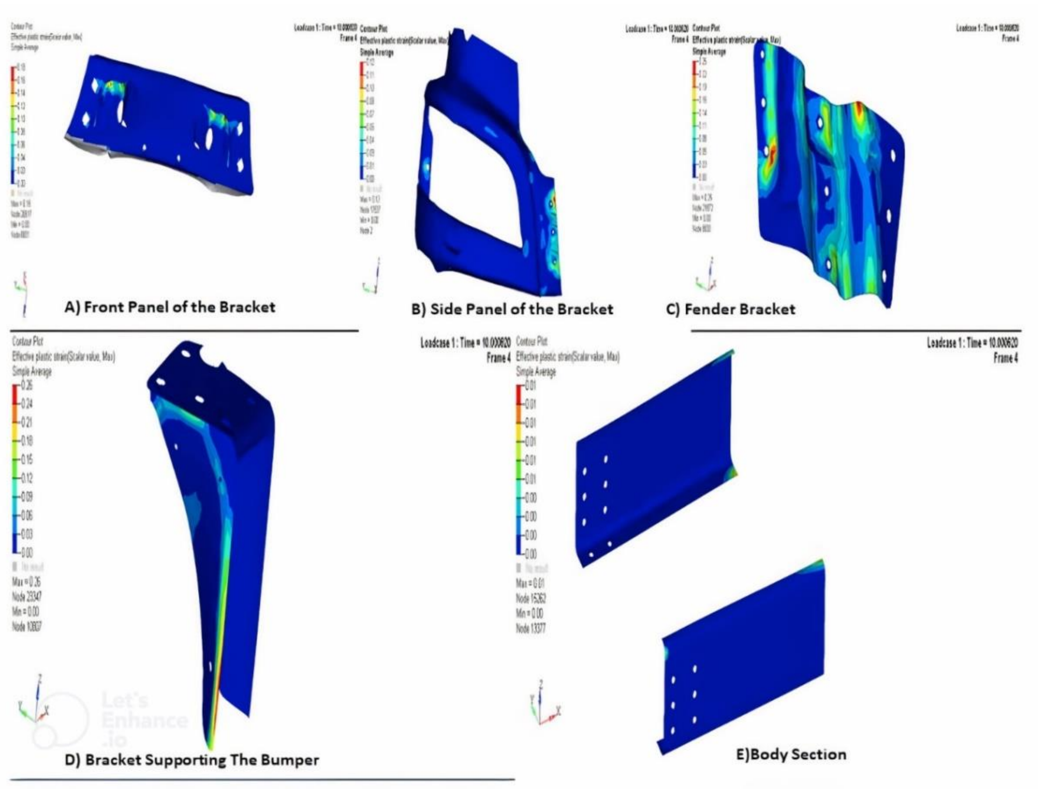


Figure 10. Contour plot study of actual plastic strain values for chassis section and front bumper panel modifications. *Source: Own.*

Table 7. Values for Plastic Strain in Changed Guard Get-together. *Source: Own.*

Name of the part	The thickness of the model has changed	Altered model
Panel in front	2.0 mm	0.18 (18%)
Lateral panel	1.6 mm	0.12 (12%)
Bracket	6.0 mm	0.25 (25%)
Supporting Bracket	11.0 mm	0.26 (26%)
Chassis	10.0 mm	0.0004 (0.04%)

For mild steel, the permissible plastic deformation values are 0.25 (25%) and for durable steel 0.33 (33%). Table 8 shows the compression between the original and modified models.

Table 8. Compare the results of the original and revised models. *Source: Own.*

Name of the part	Model's original thicknesses	The values of the initial model strain	Model thicknesses have been modified	Values for model strain have been changed.
Panel in front	1.7 mm	0.26 (26%)	2.00 mm	0.18 (18%)
Lateral panel	1.7 mm	0.08 (8%)	1.60 mm	0.12 (12%)
Bracket	4.00 mm	0.35 (35%)	6.00 mm	0.25 (25%)
Supporting Bracket	11.00 mm	0.21 (21%)	11.00 mm	0.26 (26%)
Chassis	10.00 mm	0.01 (1%)	10.00 mm	0.0004 (0.04%)

The allowable plastic strain grades are 0.25 (25%) and 0.33 (33%) for components manufactured of strong steel and sensitive steel, respectively. All the components in Table 4's updated model piece are therefore within a reasonable distance [2,16]. To approve it, we have also defined the real boundary; we have computed each component design calculation using the traditional way of analysis (by hand), Explicit analysis in LS-DYNA R11.2.0

has been carried out for varying velocity as shown in Table 9; S2-Glass fibre combined with aluminium sheet is used as composite reinforcement material in the analysis as per analysis deformation is increases with increases the velocity comes in the contact of collision also Bumper design has perform under asymmetric loading and it is suitable for asymmetric loading condition.

Table 9. Explicit analysis result carried in LS-DYNA. *Source: Own.*

Part	**Material**	**Speed Km/hr.**	**$v$final (m/s)**	**Body Mass(kg)**	**Collision Distances d(M)**	**KE (J)**	**F (N)**
Bumper System	Composite	52 to 57	14.7222	1200	0.100	129654	1296540
	Composite	58 to 62	16.3889	1200	0.110	159414	1449218
	Composite	63 to 68	17.7778	1200	0.150	375948	2506320

<u>Experimental Testing</u>
The experimental testing method was adopted according to the standards of AIS-006, the test procedure is designed to violently impact a raised piston, vertically connected at the top centre, against the bumper system and use the impact to calculate the degree of destruction and rupture of the material. The results show that the material fracture on the vehicle occurs under the influence of the crack propagation generator at the time of impact of the settlement mechanism and considering the material damage. The Experimental set-up as shown in Figure 11 below is designed to test the vehicle bumper during impact conditions, ram angle is used at impact to test the sidewalls and calculate the impact of the anti-slip bumper system. The structure of the building is very simple and in a classic style [17,18].

Furthermore, we have shown the parameters and mathematical formation with expression. Impact testing is carried out to determine how much energy is absorbed or how much energy is required to destroy the unit under test (UUT). Engineers can reduce the impact force of a car by increasing the stopping distance by using "crumple zones," where the distance travelled matches the change in kinetic energy, according to the work-energy principle, where the average impact force times the design., F = ma [N] to calculate the anticipated impact force. Using the final haste calculated from the discussion of energy Equation v = √ 2gh, [m/s)] we may cipher the performing impact acceleration.

The network performed during an impact is equal to the average impact force times the impact's travel distance.

(5) $$\text{Wnet} = {}^{1}/_{2}\, m_{final^2} - {}^{1}/_{2}\, m_{initial^2}$$

In a drop test operation a drop,

(6) $$\text{Wnet} = {}^{1}/_{2}\, m_{final^2}$$

Since the original haste ($\boldsymbol{v}$initial) is equal to zero. Assuming one could fluently estimate the impact distance, the average force, F, is calculated as follows.

(7) $$F = \frac{\text{Wnet}}{\text{d}}$$

where d = distance travelled [mm]

Results of the experiment: This was done to verify the impact performance of the various vehicle bumper system components using the Impact Pendulum Test Method. Values are displayed with a safety factor for modified bumper systems that meet the safe standards. We tried them with various strategies to approve them. The experimental results are highlighted in Table 10.

Figure 11. Experiment Setup with Specimen. *Source: Own.*

Table 10. Experimental testing Data. *Source: Own.*

Part / component name	Modified model thickness	Modified model Plastic strain values
Front panel	2.00 mm	0.21
Side panel	1.6 mm	0.14
Bracket	6.00 mm	0.20
Supporting Bracket	12.00 mm	0.18
Chassis	10 mm	0.02

A low-speed crash test was performed for experimental testing of the bumper system the parameters were set as 3km/h for the side and 5 km/h for the front panel testing, the vehicle hit with this speed to the rigid barrier and checked for the deformation, Table 11 below shows experimental testing results from a low speed.

Table 11. Velocity version experimental testing of the bumper system. *Source: Own.*

Mass of the vehicle	Impact parameters	Impact Velocity	Average Impact Force (kN)	Peak Impact Force (kN)	Kinetic Energy (kJ)
1000 Kg	Front Panel	8 km/h	24.691	49.383	2.4691
	Side panel	4 Km/h	6.173	12.346	617.2840

As per experimental testing result analysis, we can predict bumper design is under safe zone, design is succeeding in achieving crumple zone to absorb impact energy during a collision.

Comparison & Validation

The current market SUV standard model is compared with our base model of SUV. As per comparison, the standard method is followed. Further, we have validated the design as per ISO standards with a satisfying outcome. This framework is according to the direction of information and determinations of ARAI. The platform was designed and modified to support NCAP Global' s standing. The platform is designed to withstand crashes and is suitable for all materials and amalgamations. We have also validated all the parameters such as Design CAD GD&T, CAM & Analysis, Testing, Simulation, and Programming with real-time performance data. Taking all these factors into account, we can conclude that the development of a machine front cushion system that observes energy and sustains impact at the time of the crash and keeps the passenger within the safety zone with a low-cost, high-performance outcome with continuity. Table 12 shows the comparison of experimental, analytical, and experimental testing reports [19,20].

As a result, it was discovered that the trial tests agreed with the analytical values suggested. Consequently, the bumper assembly's design is secure.

Table 12. Correlation of exploratory and examination results for the base model and changed Calculation. *Source: Own.*

Name of the component	Strain values (existing geometry) by analysis	Strain values (novel base geometry) by experimentation	% difference
Front panel	0.18 (18%)	0.21	+3
Side panel	0.12 (12%)	0.14	+2
Bracket	0.25 (25%)	0.20	-5
Supporting bracket	0.26 (26%)	0.18	-8
Chassis	0.0004 (0.04%)	0.02	+1.9

Impact

The bumper system analysis results can be developed to absorb maximum impact energy and enhance passenger safety. The use of composite materials and advanced manufacturing processes further contribute to the strength and durability of the bumper system. As technology continues to advance, it is important to continuously improve and innovate bumper systems to ensure the safety of vehicle occupants, When comparing the modified bumper system with the current market standard models, the performance and safety of the modified system are found to be superior, experimental testing is conducted using impact pendulum testing to verify the impact performance of the bumper system components. The results of the testing show that the modified bumper system meets the safe standards and effectively absorbs energy during a collision. Low-speed crash tests are also performed, and the results demonstrate that the bumper design is within the safe zone and successfully achieves crumple zones to absorb impact energy, this system can be implemented in automobile for better safety with cost effective.

Conclusions

A unique system has been developed to reduce the cost with a higher outcome. Cost-effective method that is 30% less expensive than the regular method Furthermore, we can implement this system in automobiles. Different material analyses were done & and investigated the suitable material for automobile bumper systems that absorb max impact energy with less weight strength, Several sensitivity analyses were conducted on a design that is better than the regular design. It observes the maximum impact and endures under it. In terms of energy absorption, it resists 50%, and the percentage of damage to passengers is reduced. Also, the design is aesthetic and eye-catching. By comparing standard models with modified and new innovation-generated versions of the models, we can predict the above results. This system can be preferred for hatchback sedans and SUVs to achieve a better Global N-Cap rating.

Conflict of interest

There is no conflict of interest.

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References

[1] N.S. Muhammad, A. Hambali, J. Rosidah, W.S. Widodo, M.N. Ahmad, A review of energy absorption of automotive bumper beam, Int. J. Appl. Eng. Res. 12 (2017) 238–245.

[2] J. Marzbanrad, M. Alijanpour, M.S. Kiasat, Design and analysis of an automotive bumper beam in low-speed frontal crashes, Thin-Walled Struct. 47 (2009) 902–911. https://doi.org/10.1016/j.tws.2009.02.007.

[3] L. Mei, C.A. Thole, Data analysis for parallel car-crash simulation results and model optimization, Simul. Model. Pract. Theory. 16 (2008) 329–337. https://doi.org/10.1016/j.simpat.2007.11.018.

[4] A. Bhuyan, O. Ganilova, Crush can behaviour as an energy absorber in a frontal impact, in: J. Phys. Conf. Ser., 2012: p. 012009. https://doi.org/10.1088/1742-6596/382/1/012009.

[5] R.E. Elewa, S.A. Afolalu, O.S.I. Fayomi, Overview Production Process and Properties of Galvanized Roofing Sheets, in: J. Phys. Conf. Ser., 2019: p. 022069. https://doi.org/10.1088/1742-6596/1378/2/022069.

[6] N. Abedrabbo, R. Mayer, A. Thompson, C. Salisbury, M. Worswick, I. van Riemsdijk, Crash response of

advanced high-strength steel tubes: Experiment and model, Int. J. Impact Eng. 36 (2009) 1044–1057. https://doi.org/10.1016/j.ijimpeng.2009.02.006.

[7] X. Yang, Y. Xia, Q. Zhou, P.C. Wang, K. Wang, Modeling of high strength steel joints bonded with toughened adhesive for vehicle crash simulations, Int. J. Adhes. Adhes. 39 (2012) 21–32. https://doi.org/10.1016/j.ijadhadh.2012.06.007.

[8] R. Gümrük, S. Karadeniz, The influences of the residual forming data on the quasi-static axial crash response of a top-hat section, Int. J. Mech. Sci. 51 (2009) 350–362. https://doi.org/10.1016/j.ijmecsci.2009.03.010.

[9] C.L.F. Rocha, D.A.K. Fabricio, V.M. Costa, A. Reguly, Quality assurance of absorbed energy in Charpy impact test, in: J. Phys. Conf. Ser., 2016: p. 012009. https://doi.org/10.1088/1742-6596/733/1/012009.

[10] E. Wilhelm, L. Rodgers, R. Bornatico, Real-time electric vehicle mass identification, World Electr. Veh. J. 6 (2013) 141–146. https://doi.org/10.3390/wevj6010141.

[11] Y.Q. Sun, C. Cole, M. McClanachan, The calculation of wheel impact force due to the interaction between vehicle and a turnout, in: Proc. Inst. Mech. Eng. Part F J. Rail Rapid Transit, 2010: pp. 391–403. https://doi.org/10.1243/09544097JRRT350.

[12] T.L. Teng, F.A. Chang, Y.S. Liu, C.P. Peng, Analysis of dynamic response of vehicle occupant in frontal crash using multibody dynamics method, Math. Comput. Model. 48 (2008) 1724–1736. https://doi.org/10.1016/j.mcm.2007.10.020.

[13] M. Of, R. Transport, Automotive Vehicles - External Projections -Performance Requirements for M1 Vehicles, Automot. Res. Assoc. India. (2016) 1–18.

[14] ECE, Uniform Provisions Concerning the Approval of Vehicles With Regard To Their Front and Rear Protective Devices (Bumpers, Etc.), 1980.

[15] F. Xu, X. Tian, G. Li, Experimental Study on Crashworthiness of Functionally Graded Thickness Thin-Walled Tubular Structures, Exp. Mech. 55 (2015) 1339–1352. https://doi.org/10.1007/s11340-015-9994-3.

[16] PCB Piezotronics Incorporation, Impact and Drop Testing, New York. (2007) 1–14.

[17] D. Johnsen, L. Ostendorf, M. Bechberger, D. Strommenger, Review on Smart Charging of Electric Vehicles via Market-Based Incentives, Grid-Friendly and Grid-Compatible Measures, World Electr. Veh. J. 14 (2023) 25. https://doi.org/10.3390/wevj14010025.

[18] H. Chang, Z. Su, S. Lu, G. Zhang, Application of Deep Learning Network in Bumper Warpage Quality Improvement, Processes. 10 (2022) 1006. https://doi.org/10.3390/pr10051006.

[19] K. Kumar, Journal of Automobile Engineering and Applications Study of Two-distinct Automotive Bumper Beam Designs during Low speed impacts, J. Automob. Eng. Appl. 7 (2020) 16–28. www.stmjournals.com.

[20] A.T. Beyene, E.G. Koricho, G. Belingardi, B. Martorana, Design and manufacturing issues in the development of lightweight solution for a vehicle frontal bumper, in: Procedia Eng., 2014: pp. 77–84. https://doi.org/10.1016/j.proeng.2014.11.129.

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