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EXPERIMENTAL INVESTIGATION ON THE EFFECT OF A CRASH ON A CAR FRONT GUARD BY CHANGING SUITABLE INFO BOUNDARIES TO CONTROL THE ENERGY ASSIMILATION

Summary. The main motive of this research is to develop an energy absorber system for automobiles and perform an experimental disquisition by applying different parameters to check the effect of the crash on the machine's front cushion by perfecting energy-absorbing capacity for the passenger safety aspect. Considering automobile vehicle speed limits similar to (Low, Medium, and High), the speed limits in India vary by state and vehicle type. In Karnataka, there is no limit (60 km/hr for buses in Bangalore except on Airport Road where it is 80 km/hr and 100 km/hr for buses only on NH and 66 km/hr between Mangalore and Udupi). Transport vehicles have a limit of 66 km/hr. This data is set with cooperation between the state and the ministry of highway department for light motor vehicles and buses. My exploration: considering the norms as per international safety regulations, and the purpose of an automobile's safety systems, the experimental set-up was designed so that a straight pendulum would strike the bumper system, and the front, and rear impacts would hit at 4.5 to 5 km/h, and the loaded or unloaded car would hit at 3 km/h and 46 cm above the front and back corners.

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To achieve this goal and to develop the energy absorber system, we used appropriate parameters such as CAD, CAM, CAE, testing, Simulink, and hand computation, enforcing the criteria in a unique development perspective by adding crash capability with a spring-loaded system, minimising crash effects, increasing immersion capacity, and implementing it on the SUV front cushion system.

Keywords: disquisition, parameters, speed norms, impact vehicles testing, SUV bumper

1. INTRODUCTION

The cushion is an element that resists impact to a certain extent and is installed frontally and rearward in the machine, preserving all of the original position of impact by energy-absorbing capacity, keeping the vehicle and passengers safe from the road and a certain number of impacting conditions. While designing and developing a unique cushion to increase immersion capacity while considering suitable parameters such as CAD, CAM, CAE, testing, Simulink, hand computation, and confirmation using CAD, we've unequivocally designed a cushion in such a way that it supports manufacturing with an aesthetic look and moulding curve with the required strength. After making the CAD model, we went for preprocessing, where we analysed different parameters. For a quality outcome, advanced automation is used to manufacture its supposed critical notches and drills with the proper shape and size. Testing equipment has been developed for the analysis of the fracture point and impact analysis. The experiment aims to measure the extent to which the front bumper absorbs energy.A mathematical model has been developed to calculate the hand calculation and validate it with standard results. Research is focusing on the design and development of automotive front bumpers to sustain impact loads in such a way that they cannot transfer maximum effect to the passenger. It has the quality of being lightweight, which increases the performance of the vehicle with high strength to withstand any external impact collision. [1, 2]. The thin fold zone for impact energy drenching in current car models is a drawback.. In any case, the planner should be mindful so as to guarantee that, to save weight, traveller security is not offered and that, in that frame of mind of a front-facing or backside mishap when the vehicle is moving gradually, the pad will retain the power to help or diminish harm to the vehicle. Subsequently, the pad's capability is to cover additional components like the vehicle's cap, lights, and cooling framework as opposed to acting as a primary part that relentlessly adds to the inhabitant's wellbeing during front-facing crashes or forestalls them., Simple words, we have developed a bumper system that is better as compared to the current bumper systems on the market for automobiles. It consists of a unique energy formation system which absorbs impact and is cost-effective with a high weight-to-strength ratio. It can be utilized in the coming days for automobiles. Figure 1 depicts the bumper system's fundamental introduction. [3]

1. LITERATURE SURVEY

- Jovan Obradovic, "Lightweight design and crash: a composite frontal impact energy-absorbing structure analysis," On runners 423-430 of the 2011 Science Direct distribution, the methodology to continue to make specific feather-light effect attenuators is depicted. Basic CFRP rounded developments must be reproduced and erected when the material to be employed has been depicted exercising a numerical detailing and the express FE law LS-

DYNA. Likely, trial-and-error dynamic testing was performed using a drop-weight test gimmick.

- "Modeling of high-strength steel joints bonded with toughened adhesive for car crash simulations," by Xin Yang and colleagues According to Science Direct Paper No. 21-32 from 2012, the difficulty of simulating crashes using adhesive-bonded car structures grows as structural adhesive technology advances. In this study, it was suggested to use a simpler finite element model to simulate the toughened adhesive-bonded junction.
- Fast Plan of Crash Parcels for Safe Buses A Theoretical Methodology, D. Landheer's Ph.D. Exposition, Eindhoven College of Innovation, Research Centre for Car Designing, Eindhoven, The Netherlands, 1997 Reference indicator 183. While assessing the crashworthiness of auto developments, examination strategies are employed. No natural structure (model) is essential for fine accident recreations. It is possible to anticipate the accident conduct by exercising a PC model of the construction. The most encouraging are used because of the primary standard correlation made conceivable in the early phase. The enclave associated with security is especially crucial since it hasn't yet been put to useIt is evident that there is no standardized or established factor that has a significant impact on securityGuidelines that should be fulfilled for the frame to be employed in the vehicle design frame are assessed by exercising programming from the purported" Quality Capability Organisation" approach.
- "Design and evaluation of a machine cushion ray in low-speed anterior crashes," by Javad Marzbanrad in 2009, is a Science Direct paper. In order to enhance a vehicle's crashworthiness in low-hastle collisions, 902- 911 has utilized the most crucial parameters, including material, consistency, form, and impact on circumstance, to demonstrate and evaluate the frontal cushion ray. The reproduction of exceptional bumpers in specific conditions was previously in accordance with the low-speed congruity of automobiles, as noted in E.C.E. Joined Countries Arrangement, Regulation No. 42, 1994. Weight and influence were investigated after the compound and aluminum fabric cushion ray evaluation was completed. In the past, the energy in flexible mode was drenched with strength, which meant that strain would occur in most extreme deviation circumstances. In this stage, auto vehicles should be designed for the safety of the traveler while also being light in weightAdditionally, manufacturers are limiting the weight of passenger buses as a result of gasoline efficiency and emission regulations becoming increasingly important in recent years.
- „Crash Compatibility Between Engines and Light Trucks "von Alexander P. Genetos, Bryan C. Baker, Joseph M. Nolan, Brian O'Neill und Bryan C. Baker Science Direct Article 2014, 1016/j.aap.2007.04.008 confirmed that passenger vehicles are designed to absorb impact energy in a frontal collision by twisting or breaking energy consuming structures in front of the renter's passenger compartment. However, due to the frequent discrepancies between the height of these structures and the colliding vehicles, collisions between vehicles and smaller vehicles such as vans and SUVs can also result in the capacity of the energy-absorbing structures not being fully utilized. Car manufacturers deliberately introduced new regulations in 2003 to reduce confusion between cars and light commercial vehicles. By September 2009, all new light commercial vehicles will have either a basic front shape that generally conforms to the frame members, or a secondary shape that follows the original shape and is low enough to work with the car's basic structure, which would normally be near the frame members is the upper part of the front bumper on most vehicles. To assess the utility of voluntary participation, actual collisions of light vehicles already assembled to height standards were compared with the experiences of light vehicles not yet assembled to

the 2000–2003 light truck model standards in collisions with passenger vehicles from 2001 to 2001 compared in 2004. The estimated benefits of reducing the form of energy absorption at the front end included a 19-percentage point (p=0.05) reduction in crash risk for seat belt drivers at the front end in light pickup trucks and a 19-percentage point reduction (p=0.05) risk of accidents for motorists in the event of a head-on collision with light vehicles.

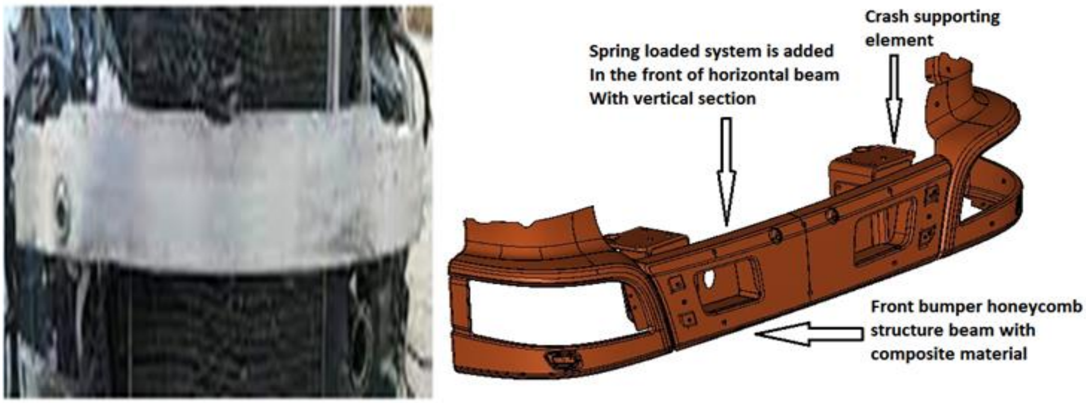

Fig. 1. Automobile front bumper

2.1 Outcome of literature survey

Based on the literature review, we conclude that special substances such as GMT proposed by A.R. Mortazavi Moghaddam and M.T. Ahmadian, aluminium proposed by Robert Vendrig, and others can be very useful for improving the overall performance of bumpers in terms of car and occupant security by using an ideal distribution of force. Witteman and Willibrordus J., among others, proposed strategies for the applicable distribution of electricity absorption via a bumper machine to achieve security with the least possible damage. We can learn from Javad Marzbanrad et al. (2009) that by balancing the weight of bumper device factors by controlling their thickness, we can end up reducing stress degrees, which does not directly ensure component security. It also concludes that the use of various substances can be beneficial because the power absorption through affect is evenly distributed amongst the elements, and we can also help the elements in assembly due to fabric properties. We can make adjustments in geometry by way of the addition of ribs or by including greater fabric to beef up the meeting and limit the excessive stress regions. According to Bryan C. Baker (2007), the applicable function of bumpers in SUV automobiles can reduce the harm caused by cars and increase the protection of occupants during an accident, thus lowering the dangers. Various simulating techniques are described for evaluating the overall performance of bumper gadgets, out of which simulation with the aid of an express solver can be chosen for an applicable bumper meeting or system. [4, 5]

2.2 Gaps in literature and work to done

- A few studies report on the work done to improve the design of a passenger car's front bumper.
- Design parameters have to be derived for bumpers that could attenuate more energy.
- The rubbing damper ought to be considered while improving the guard's capacity to assimilate energy.

- A unique energy observation system is needed, which can observe the energy inside it and reduce the impact, such as a spring-loaded system.
- Experimental data for the analysis of passenger safety

3. CAD MODEL

A CAD tool is applied, such as AutoCAD, Solid Works, and Catia as shown in Considering Initial parameters are as follows: length, height, width, thickness, and angle of curvature. Considering all these parameters, we have designed a bumper system in such a way that it matches the requirements for the vehicle after comparing it with the standard model. The CAD model was ready for analysis, as per the analysis result. Changes and modifications were made to the CAD model, considering that particular changes in the CAD model come under a safe zone with increasing strength. To build a CAD model, we have designed and optimised the parameters such as Part, Assembly, Surfacing, Drafting, and Geometric Dimension and Tolerance. Considering all the data, we can predict that the bumper system will be as per the rules and regulations of ARAI under safety criteria. Figure 2 shows the CAD model that was created using a CAD tool. It contains different parts such as bumper covers, absorbers, reinforcement bars, mounting systems, etc.

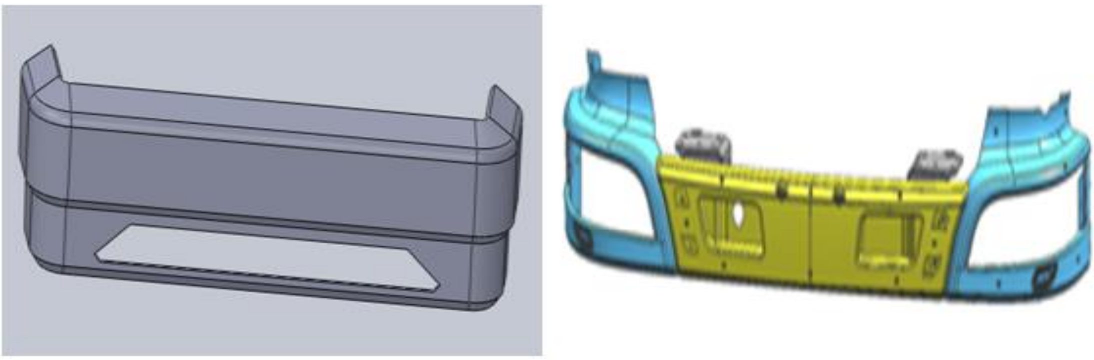

Fig. 2. CAD model of an automobile front bumper

Together, it is assembled to act as a one-element CAD bumper model; this assembly supports the chassis and body section to absorb maximum impact energy. Figure 3 depicts a summary of the number of components developed using the CAD tool for the bumper system. All the components are in different colour formations. The CAD model is designed with parameters defined, such as curve, notch, slot, and honed ribs to increase strength; angle of deviation with formation internal and external; thickness, length, and width, which are the most important parameters. To create these parameters, we must first solve the design concept, generate a mathematical formation using the design data (one mathematics parameter has been completed and is defined in the CAD tool to generate CAD), perform hand calculations and solve the equation, and make the necessary changes to the parameter value to place the component in the safe zone under the factor safety. [6, 7]

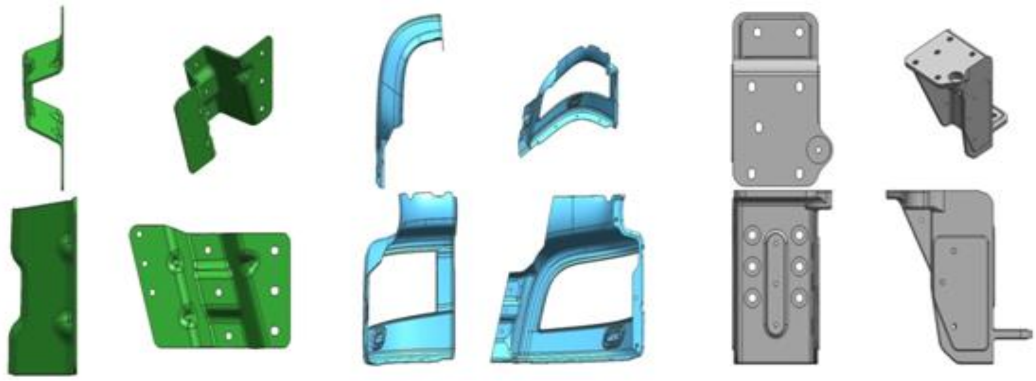

Fig. 3. The various components that support the bumper

4. CAM

An advanced manufacturing process is implemented for the production of automobile front bumpers. It supports all the curve angles with maximum strength retention. Robotics technology is also implemented for some parts, and layer-by-layer manufacturing of critical parts is done with the approach of rapid prototyping and Figure 4, 5 & 6 shows the Composite material combination and fabrication process of the material.

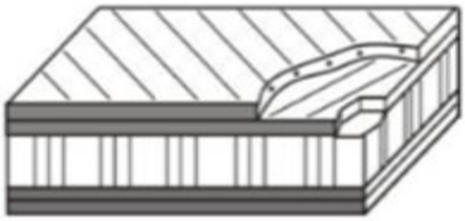

Fig. 4. Honeycomb composite material

Galvanized sheet with a honeycomb structure is used as a composite material to form a high-strength with less weight. It is a combination of two or more constituent materials with notably dissimilar chemical or physical properties that are integrated to form a cloth with properties that differ from the individual parts.

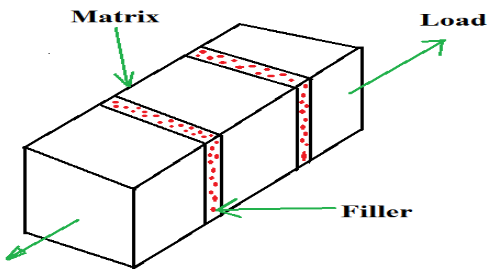

Fig. 5. Combination of a composite material

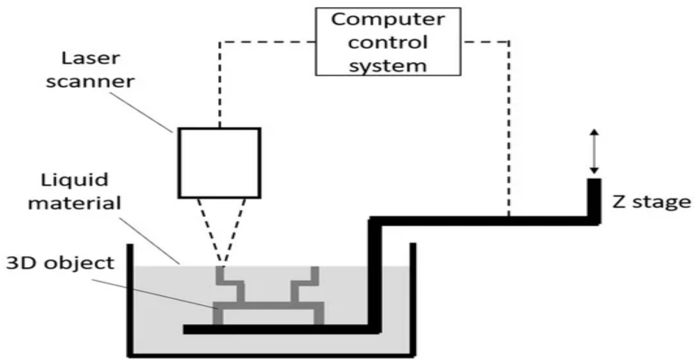

Fig. 6. Stereo lithography set-up

The strategies utilized incorporate particular laser sintering, melded testimony display, and covered object creation.

5. CAE STANDS FOR COMPUTER-AIDED ENGINEERING

An approach is applied to solve the complicated problem related to energy absorption. To increase the absorption capacity, with the use of FEA techniques, a mathematical model is created. For the computer modelling of issues in solid mechanics analysis, the Numeral Element Method (FEM) has come to be the de facto method. The system has been considerably used to gain approximate results for boundary value problems that describe colourful physical marvels and solvers such as Ls-Dynaand PAN Crash. To solve complicity further, both comparisons are done for an effective outcome. The following equation represents a mathematical model with solver analysis. [8]

5.1 Analysis

The three processes are followed for CAE, such as Preprocessing, Processing, and Post-Processing (Preprocessing) in preprocessing, mesh or discretization is applied in such a way that it divides the body into an equivalent number of infinite degrees of freedom. Figure 7 shows different mesh elements that can be applied to the geometry.

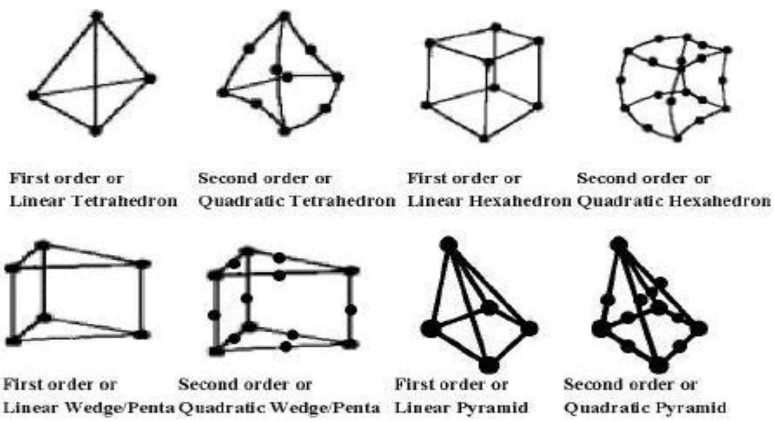

Fig. 7. Different meshing element

The system is converted into a fine and the degree of freedom depends upon the conditions to be satisfied. Colorful types of rudiments are used for meshing. Figure 8 highlights the mesh applied to the model.

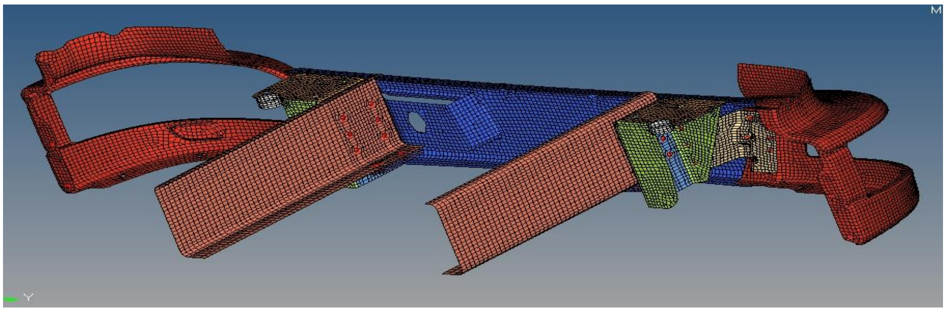

Fig. 8. Model of the pad framework get together that is snared (thwart view)

After meshing, the model is examined for quality and normalcy to ensure that stress zones are designated correctly for analysis. Following entrapment, their material parcels, which function similarly to the modulus of pliantness, assign them the fittings of various corridors, poisson rate, viscosity of material, etc. Then, as introductory material, we are given a steel, the components of which are listed in the table below. [9,10]

Tab. 1

Steel product package

Material	A measure of elasticity	Density	Poisson ratio
Alloy Steel	212 kN/mm^2	7.97e^-6 kg/mm^3	0.3

Components like the front panel are granted material credit for being made of either soft steel or hard steel, according to the further classification of this material and side panels of the automobile's front bumper are made of soft steel, the support bracket and chassis section are made of hard steel & the impactor is rigid. The vehicle's mass, which is approximately 887 kg, and the collision velocity, which is 11 m/sec, are the restricted circumstances in this case. Bolt connections are provided via beams, and the appropriate limitations are used. Figure 9 depicts the constrained model.

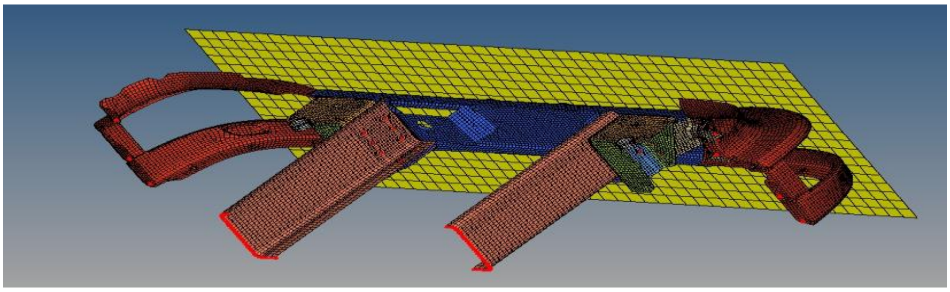

Fig. 9. Bumper assembly after preprocessing

5.2 Processing

Processing is the stage in which FEA equations are applied and assembled in order to solve the stages and obtain analysis results. Result stage: We use LS-Dyna for analysis purposes, which is an unambiguous solver that unambiguously refers to the numerical system used to represent and break the time derivations in the instigation and energy equations after the pre-processing model is further transferred for analysis results check (known as a post-processor). Unambiguous time integration is depicted graphically in the following figure, where the relegation of knot n2 at time position equals the known relegation values for bumps n1, and n2.

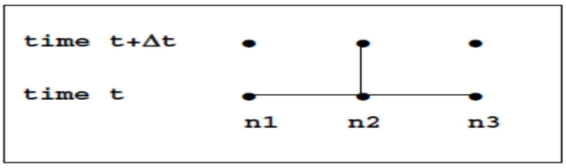

Fig. 10. Graphical description of time and relegation

For all the bumps in the mesh at location t in time, n3 is expressed as a system of unambiguous algebraic equations. Answers are given to each equation in turn for the unidentified knot point deportations. Unambiguous styles are computationally quick yet unstable under certain conditions. The time step must be less than a threshold number in order to prevent the growth of computational crimes and undesirable results. The step must be smaller than the time required for a signal flowing through the material at sound speed to bridge the space between the knot locations. [11, 12]. Figure 11 shows how the model shows up in the LS-Dyna solver.

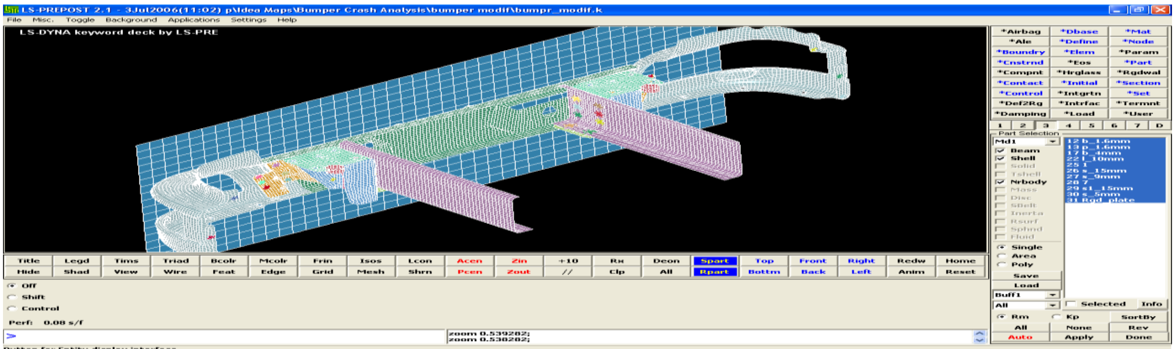

Fig. 11. Guard gathering in LS-Dyna Solver

5.3 Post-processing (analysis of base model)

In a Post- Processing process, we mainly check for the final results and validate it with the standard outcome results with ARAI Data or Standard design Data, results of the analysis are displayed in the Hyperview module after completion. Our study exhibits nonlinear behaviour or type. Next, the relevant parameter values for the actual strain in plastic are discussed. Our primary goal when doing analysis is to keep the levels of plastic strain in the variables within their permitted tolerance ranges. For soft steel and heavy steel, allowable plastic strain values are 25% and 33%, respectively. Figure 12 shows that the guard front board's greatest plastic strain esteem is 0.25, which is inside the allowed range and demonstrates that the plan is secure.

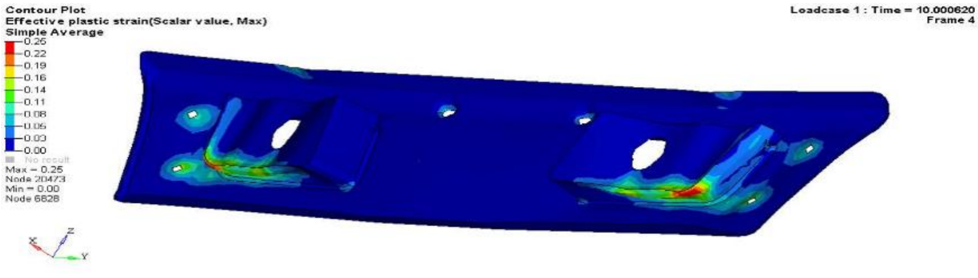

Fig. 12. Effective plastic strain values contour plot for the front panel

The guard sideboard's plan, as found in Figure 13, is secure since the most extreme plastic strain esteem is 0.07, which is inside as far as possible.

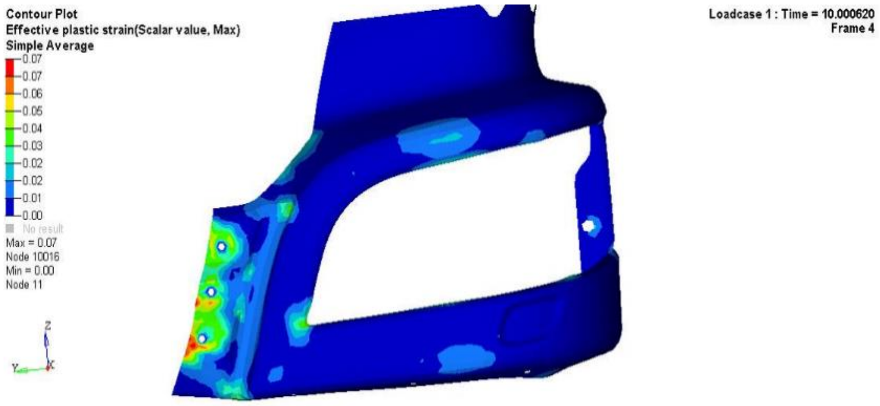

Fig. 13. Successful plastic strain values plotted on a shape for the guard sideboard

Figure 14 shows that the most extreme plastic strain as an incentive for the guard section is 0.33, which is more prominent than as far as possible and recommends that the plan is hazardous.

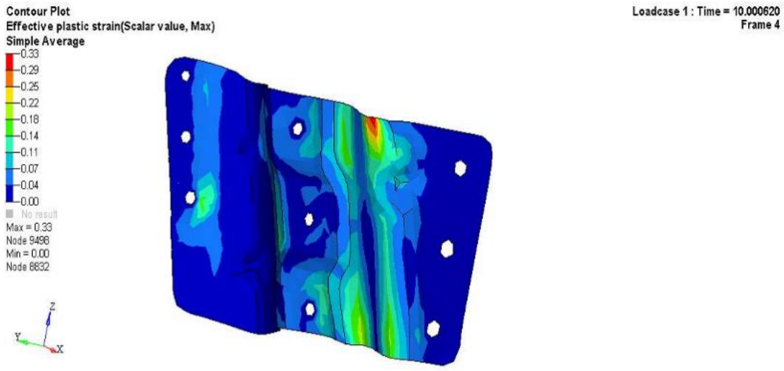

Fig. 14. Effective plastic strain values contour plot for bracket

The bumper supporting bracket's 0.20 maximum plastic strain value indicates a secure design, as shown in Figure 15.

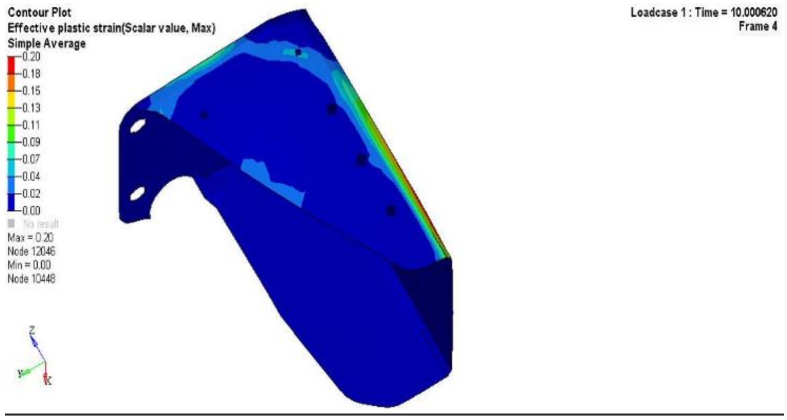

Fig. 15. Powerful plastic strain values for keeping up with shape plots of sections

Figure 16 shows the most extreme plastic strain for the guard undercarriage segment is 0.00049, which is inside OK limits.

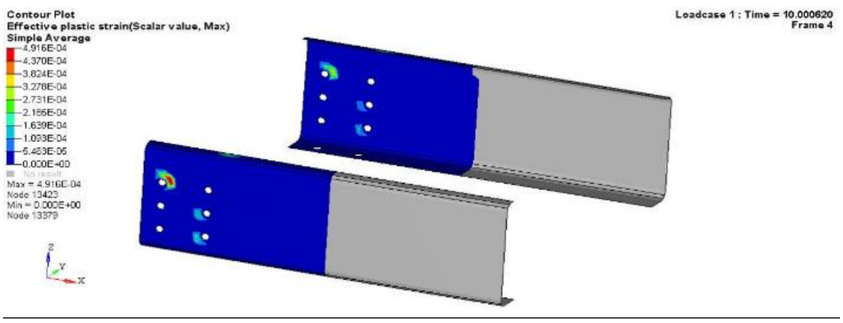

Fig. 16. For the case segment, a shape plot of powerful plastic strain values

The maximum plastic strain value ranges from 0.25 to 0.0004 for different parts of the bumper system and chassis section. For the front, the permitted limits for soft steel and heavy steel are 0.25 and 0.33, respectively, while the permitted values for strain in plastic, side panel, supporting bracket, and chassis section are less than or equal to the permissible value. Thus, the design is secure. [13,14] The bumper type is 0.33, which exceeds the permitted outside. Since the design of the cushion side panel is unsafe, it's necessary to lower the effective plastic strain value to a position that's within respectable bounds.

Tab. 2

For each original model part in the assembly, plastic strain values

Sr. no.	The name of the component	The model's original thickness	Model original Plastic strain
1	body of the bumper's front panel	1.61mm	0.255 (25%)
2	panel on the bumper's side	1.61mm	0.077 (7%)

3	**part of the bumper panel that supports the brackets**	**4.01mm**	**0.333 (33%)**
4	component of the supporting bracket	12.01mm	0.21 (20%)
5	body section	10.01mm	0.041 (04%)

For mild steel (SS) and HSC, the acceptable values for plastic strain are 0.25 (or 25%) and 0.33 (or 33%) respectively.

The cushion type exceeds the effective allowed strain value, as shown in Table 2. In order to ensure that the design is secure, some necessary adaptations to the assembly should be made to lower the plastic strain values to a respectable position. [15,16]. Potential remedies include a) component redesign: we can alter the design of a component to get the desired outcomes. This results in reworking the components, which raises the cost by adding ribs or modifying the geometry. b) Material modification: To ensure correct stress distribution, the components' materials might be changed. We can use additional composite materials to prevent a faulty design. c) Change in thickness-To obtain the effective plastic strain values for each component, we can alter the thickness of the component. It is both a time-and money-consuming approach to change. We choose the third option from the list above to obtain the plastic strain values and create a secure design. [17]

5.4 Front bumper modification and analysis of chassis sections

Consequently, the improved model with the change of component thickness for the redesigned bumper assembly followed as modified different parts of the automobile's front bumper panel ranged from 2mm to 12mm and chassis section 10mm. The adjusted model's findings following the thickness adjustments are as follows, with the boundary conditions remaining the same. Figure 17 shows that the front guard board's greatest plastic strain esteem is 0.18, which is not exactly the maximum allowed. The front part of the guard is safeguarded in view of this design. For the case segment, a shape plot of compelling plastic strain values

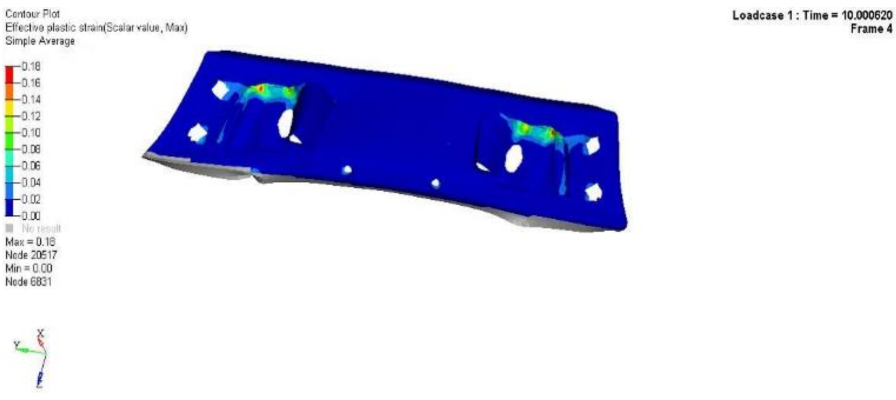

Fig. 17. Investigation of the shape plot for the upgraded guard front board's powerful plastic strain values

The greatest plastic strain as an incentive for a guard a sideboard with a protected rating of 0.12 is displayed in Figure 18.

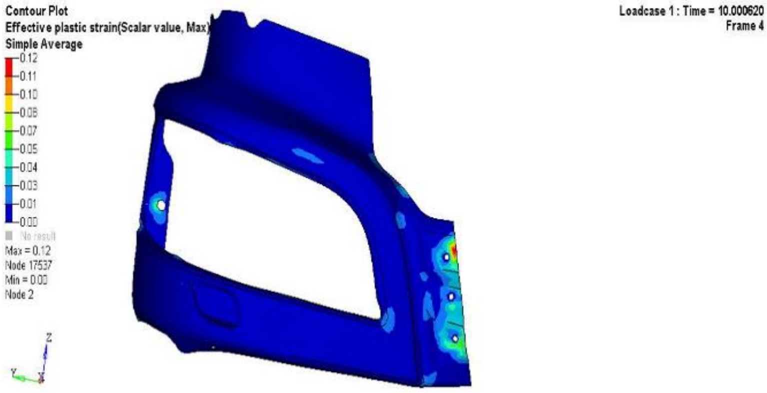

Fig. 18. Investigation of the superior guard sideboard's viable plastic strain values from the shape plot

For bumper brackets, 0.25 panel is the safe plastic strain value limit – Figure 19.

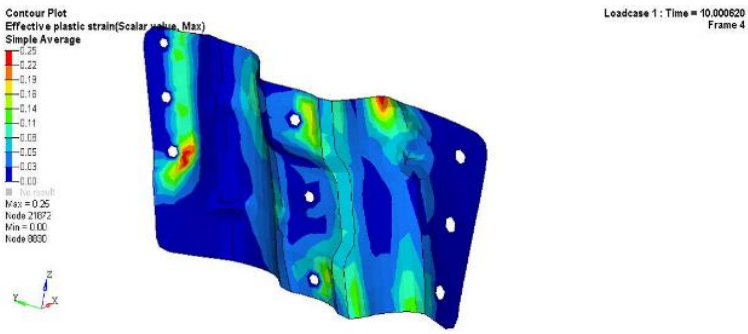

Fig. 19. Investigation of the better bumper guard's compelling plastic strain values from the shape plot

Since the greatest plastic strain worth of 0.26 is not exactly the allowed furthest reaches of 0.33, the plan for the guard supporting section is secure. As per Figure 20.

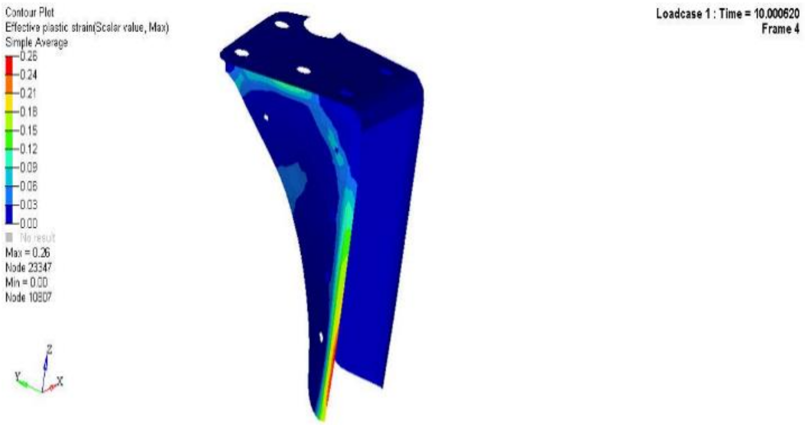

Fig. 20. Investigation of the shape plot for the superior supporting section guard's compelling plastic strain values

Since the most extreme plastic strain an incentive for the guard suspension component is 0.01, which is inside as far as possible, the plan is secure – Figure 21.

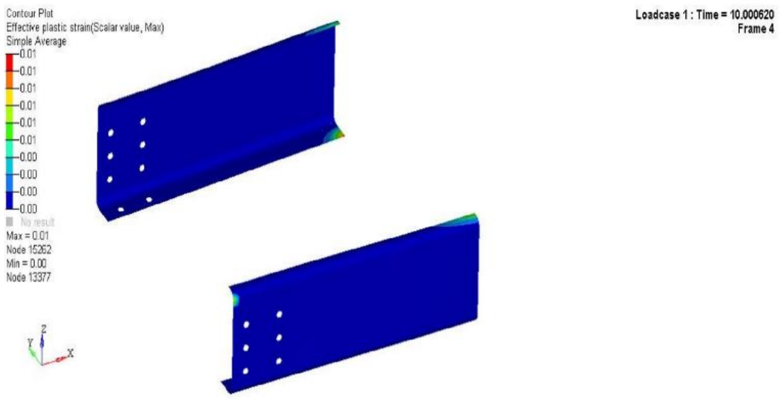

Fig. 21. Investigation of the shape plot for the changed skeleton segment's compelling plastic strain values

For the body segment and front guard portions of a car, the plastic strain values range from 0.26 to 0.011, which is equivalent to or not exactly as far as possible. As a result, the design is safe. We can consider the modified value and design for manufacturing if it is in a safe zone. For delicate steel, the OK qualities for plastic strain are 0.25 (25%) and for solid steel, 0.33 (33%) separately.

Tab. 3

Values for plastic strain in an updated guard gathering

Sr. no.	Name of the component /Parts	Model thickness has been altered.	Modified model "plastic strain measurements
1	Front portion	2.01 mm	0.181 (18%)
2	Lateral bumper panel	1.63 mm	0.121 (12%)
3	Bumper brace	6.01 mm	0.252 (25%)
4	Supporting section	12.05 mm	0.262 (26%)
5	Chassis section	10.05 mm	0.012 (1%)

Tab. 4

Compares the results of the original and modified models

Sr. no.	Name of the component /Parts	Original model thicknesses	The original model strain values	Model thicknesses were changed	Modified model strain values
1	Front panel	1.6 mm	0.25 (25%)	2.00 mm	0.18 (18%)
2	Side panel	1.6 mm	0.07 (7%)	1.61 mm	0.12 (12%)
3	Bracket	4.00 mm	0.33 (33%)	6.05 mm	0.25 (25%)

4	Supporting Section	12.05 mm	0.20 (20%)	12.05 mm	0.26 (26%)
5	Case	10.05 mm	0.0004 (0.04%)	10.05 mm	0.01 (1%)

Admissible qualities for plastic strain are 0.255 (25%) for delicate steel and 0.333 (33%) for hard steel parts. As a result, all of the parts in Table 4 for the modified model column are within the allowed range.

6. ENERGY ABSORPTION AND IMPACT TESTING ANALYSIS

Isometric views of the Impact Layout are shown in Figure 22.

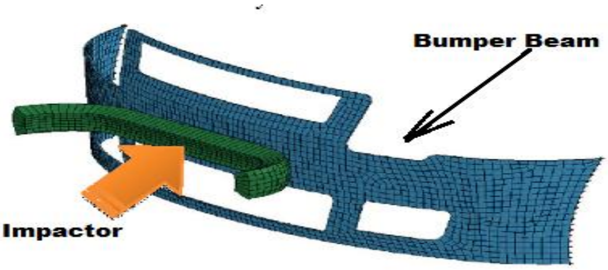

Fig. 22. Isometric views of the impact layout

Plastic and flexible effect come in two assortments. Energy and induction protection conditions can be communicated as follows:

$$\frac{1}{2}m_A V_A^2 = \frac{1}{2}m_A V_{A2}^2 + \frac{1}{2}m_B V_{B2}^2 \tag{1}$$

$$m_A V_A = (m_A + m_B)\, V_0 \tag{2}$$

m_B Is the mass [kg] of the impactor's speed before impact where m_A is the impactor's mass [kg] and V_0 [m/s] is the final speed of the impactor, and vehicle at the maximum divagation point, the rapidity after impact can be determined by the measure of reparation (e).

$$e = \frac{V_{B2} - V_{A2}}{V_A - V_B} \tag{3}$$

The impactor's motor energy preceding effect

$$E\text{plastic} = \frac{1}{2}m_A V_A + \frac{1}{2}m_B V_B - \frac{1}{2}m_{A2} V_{A2} - \frac{1}{2}m_{B2} V_{B2} \tag{4}$$

7. EXPERIMENTAL TESTING

An experimental apparatus is created to carry out experiment testing; a number of tests are carried out to validate the parameters; analysis and results are plotted with validation. As per the experimental testing result, we have modified the geometry and model. Better outcome results are obtained on the energy absorption system with passenger safety in the equipment after modification and testing. All testing is performed as per the guidelines given by ARAI. Also, Matlab Simulink is generated to check the performance outcome and analysis. Matlab programming is carried out to support Simulink. Furthermore, we have verified hand calculation and validation.

Some of the parameters to be considered for conducting a crash test

- The ground should be clean and a proper distance should be maintained.
- Energy stored at the time of the vehicle leaving the platform should be connected properly.
- The dummy should be fixed properly with the proper sensor
- The impact point should have a metal component that's solid enough to hold the sensor in place for recording. Proper distance and ground clearance should be maintained.
- The impactor (striker) test apparatus should be the right size and height when it is carried on the body of the vehicle during the impactor (striker) test.. The impact should be balanced and transfer the same amount of weight. The height reference is 500 millimeters, and the vehicles should be still.

The following are the testing methods that can be applied to check the impact, deflection, and percentage of energy absorbed in the elastic and plastic zone.

- As per the worldwide ncap-full-wrap front-facing crash test.
- The side crash assessment and the offset front-facing impact test.

A spurious test can be directed by setting fakers in the driver's and traveler's seats, striking the vehicle at a speed of around 60 km/h, and working out the extent of the vehicle's and travelers' harm.Following the calculation, there are a few emphasis pointsFinally, the vehicle is designed and modified with the proper parameters based on testing results. Figure 23 indicates full-wrap frontal collision test.

Therefore, the test findings are more reliable when compared to those of vehicles with almost identical body weights. Ultimately, when test vehicles load requirements are identical, those with superior safety assessments outperform those with inferior assessments in terms of well-being.

Fig. 23. Test image for a full-wrap frontal collision

The fakes head, chest, torso, and torso are examined for injuries, and the results are used to assign a rating from 1 to 5 to the degree of traveler protection. The front of the truck also features a shock-absorbing aluminum honeycomb that's designed to look like a standard traveler vehicle and boasts a similar degree of toughness. Realistic crashes of this nature typically occur at speeds that are slower than those utilized in this test. It is noteworthy to mention that the findings of this examination do not pertain to crashes that occur at a high frequency or encompass diverse types of impacts, such as those involving travelers who are not wearing safety belts or collisions involving large trucks. Figure 24 shows an image of a side collision test.

Fig. 24. Side collision test image

Also, these parameters are considered for experimental testing. Condition of the vehicle:

A. The vehicle must be halted.
B. The front wheels should be pointed straight ahead.
C. The suggested degree of tire filling from the producer should be utilized.
D. The transmission control should be in an unbiased position, and the brakes should be eliminated.
E. Vehicles having water-driven, hydro-pneumatic, or pneumatic suspension or a heap-evening out-system should be put through testing under the normal working conditions suggested by the maker.
F. All through the entire test, the pendulum's plane should stay opposite to its hub of upset.
G. Any point on the reference line for a parallelogram-suspended pendulum should follow a steady direction with a base range of 3.3 m.
H. The measuring instruments used to record the speed must be accurate to within one percent. Strain gauges are mounted and aligned on components for measuring the strain values.

Figure 25 highlights the impact test arrangement for testing of crash impact.

Fig. 25. Bumper impact test arrangement and image of the actual testing of a bumper

Table 5 shows the experimental results that were carried out with the impact pendulum test method for verification of crash performance for the different component automobile bumper systems. Values are plotted for modified bumper systems that meet the safety criteria with the factor of safety, and we tested them with different methods to validate them.

Tab. 5

Experimental results

Sr. no.	The component's name	Thickened model in modification	Values of the modified model's plastic strain
1	Front portion	2.03 mm	0.21
2	Lateral bumper panel	1.62 mm	0.14
3	Bumper brace	6.03 mm	0.20
4	Supporting section	12.01 mm	0.18
5	Chassis section	10.2 mm	0.02

Tab. 6

Actual crash test conducted on SUV Data

Sr. no.	Part	Material	Speed, km/h	v final, m/s	Body mass, kg	Collision distances Sd, m	KE, J	F, N
1	Bumper system	Composite material	50 to 55	14.7222	1200	0.100	129654	1296540
2		Composite material	55 to 60	16.3889	1200	0.110	159414	1449218
3		Composite material	60 to 65	17.7778	1200	0.150	375948	2506320

Table 6 shows the actual crash test data conducted on an Indian SUV, which implemented a unique bumper system that is fitted in the body section in such a way that a partial part is in the bumper and the remaining part is in the chassis section. A a completely new system mechanism is developed that absorbs maximum impact energy. Further, we have shown the parameters and mathematical formation with expressions to be used in impact testing and performed to determine the energy absorbed or the energy required to fracture a unit under test (UUT). Using the work-energy principle, where average impact force times the stopping distance, design engineers can lessen the impact force of an automobile by lengthening the stopping distance through the use of "crumple zones," where distance travelled equals the change in kinetic energy, we have shown that the energy required fracturing a unit under.

F = *m a* to calculate the anticipated impact force. Using the final speed calculated from the discussion of energy equation $v = \sqrt{2gh}$, we may cipher the performing impact acceleration.[18]

The average impact force times the impact's distance travelled equals the net work done during an impact.

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

In a drop test operation, Wnet = ${}^{1}/_{2}\, m_{final^2}$ since the original speed ($\mathcal{V}$initial [m/s]) is equal to zero.

Assuming one could fluently estimate the impact distance, the average force, F [N], is calculated as follows:

$$F = \frac{Wnet}{d} \tag{6}$$

where d [mm] = distance travelled

Tab. 7

Calculation of retained energy on the Charpy effect test and the Izod effect strength test

1	Point of fall: α	130°
2	Points toward the finish of the swing: β	45°
3	Length: R	3 m
4	The mass of the hammer: W	60 kg
5	Energy Loss: L	1 J
6	Gravitational acceleration: g	9.80665 ms^{-2}

A Charpy influence test and an Izod influence strength test on consumed energy. The point chart is displayed in the Figure 26 [19].

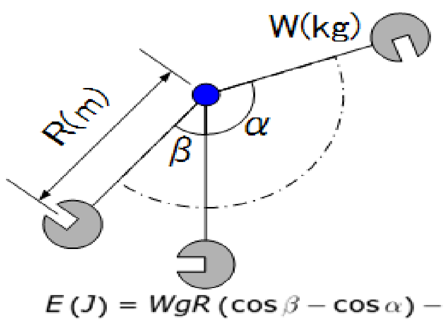

Fig. 26. Charpy impact testing machine

W (kg)=60, R (m)=3, α (°)=130, β (°)=45, L (J)=1.
Absorbed energy: E(J) =2381.829529086 J

When two things collide, an impact force is created. In the part below, we provide a step-by-step procedure to assist you in resolving the impact force. Look at them and follow them precisely to attain the desired result quickly.

Take any question:

- To solve the above problem, determine the mass velocity and time.
- Influence Power equation is.
- Influence force = $mv^2/ 2t$ (N s).
- Supplant the given qualities in the above equation.
- Register the essential number of related activities to get the effect of force esteem [20, 21].

Tab. 8

Actual conduction of the crash test referred data

A large concrete wall gets struck by a 2000-kilogram car that is moving at 60 km/h (16.7 m/s) [12]	Impact Force = $mv^2/2s$ Ns
Given Data: The front of the automobile impacts by 0.5 m	Impact Force = 1/2 (2000* $(1.67)^2$) / 0.5 Ns
Mass m = 2000 kg	=1/2 (2000* 2.7889)/ 0.5 kg
Velocity v = 16.7 m/s	= (1/2 *5577.8)/ 0.5 m/s
Speed S = 0.5 km/h	=5577.8 N

2. COMPARISON OF EXPERIMENTAL AND ANALYSIS RESULTS

Table 9 shows a correlation between the exploratory and examination reports alluded to in the test report of the supporting organization.

Tab. 9

Examination of trial and investigation results for changed math

Sr. No.	Component name	Strain values (modified geometry) by analysis	Strain values (modified geometry) by experimentation	% difference
1	Front panel	0.18 (18%)	0.21	+3
2	Side panel	0.12 (12%)	0.14	+2
3	Bracket	0.25 (25%)	0.20	-5
4	Supporting bracket	0.26 (26%)	0.18	-8
5	Chassis	0.01 (1%)	0.02	+1

As a result, it was discovered that the trial tests agreed with the analysis values. Therefore, the bumper assembly design is secure.

3. CONCLUSION

Full dynamic and impact simulations are run to determine how a vehicle's structural components will deform, stress, and absorb energy when it collides with a stationary or moving object. Based on the aforementioned analysis, we draw the conclusion that altering the thickness of bumper components can result in acceptable strain levels. The component assembly is safe because it effectively absorbs energy according to the results of the permitted plastic strain value. The component satisfies the plastic strain and energy thresholds when the base model is altered, where the minimum is 1% and the maximum is 26%, and additional experimental testing is carried out to validate it. This makes the component crash-worthy (safe). The proportion of discrepancy between the analysis and experimental outcomes is compared; therefore, an actual crash test results conclude vehicle structural is safe collision distances Sd 0.150 m which absorbs the KE 375948J, as per the results, we can predict the energy absorption capacity is increased with the development of bumpers with the tools CAD, CAM, and CAE. All the notations are under the factor of safety. We can develop a new and unique bumper system that resists crashes and impacts. Under the development process, we have implemented a crash can with a spring-loaded system that resists the maximum energy and does not transfer further to the passenger. This is the one new and unique system that can be used for the development of automobile vehicles with high passenger safety ratios that also resist the initial impact of the vehicle on the road. We can develop a new testing method that can be implemented for the testing of bumpers with a very low initial cost of equipment as compared to the standard testing method. This is a unique platform for tasting the bumper system. The CAM simulation is suitable for manufacturing even complicated parts with higher retention and strength, so we can conclude we have developed a unique part for automobile vehicles that resists maximum energy inside it and transfers a very small amount of impact further to the passenger.

Future scope: A unique system is developed to reduce the cost with a higher outcome. Further, we can implement this system in all automobiles, and we can add additional components to its hydraulic cylinder actuator and pneumatic cylinder as per the automobile specification system requirement. Also, in the future, we can adopt new methods such as AI and MI in this system to reduce impacts and observe maximum energy inside the cylinder to keep the passenger in a safe zone. Also, some modern materials can be considered, such as nanoparticles in composite materials.

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