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# MODELING AND ANALYSIS OF ALUMINUM BUMPERS FOR AUTOMOBILES

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## Abstract:

An automobile's bumper is a vital part that helps absorb impact energy and reduces damage to the vehicle's front end components, including the intercooler, radiator, and hoses connecting them. This increases safety and lowers unintentional damage costs. Because the government is prohibiting the use of additional bumpers on the front side of vehicles to ensure the proper functioning of the airbag systems, we have found ourselves in a situation where modeling and the use of the material for the bumper have been upgraded with improvements in the design and use of various composite quality materials to make the bumper of a passenger car. Since the front of the car absorbs the most of the impact force in most passenger car accidents, the bumper and other parts of the car are also damaged. Proper selection of material and design of the bumper play an important role in the safety of vehicle passengers and components and the need to release the radiator temperature for engine safety. The automobile industry places a high priority on safety, especially while designing and testing car bumpers. Using Solid Works 2022, this project replicates a crash test for automobile bumpers composed of Nylon 101 and Aluminum 1060 alloy. The bumpers are tested by slamming them into a wall at 50 meters per second. They weigh 1.8 kg (nylon) and have densities of 1150 kg/m³ (nylon) and 2700 kg/m³ (aluminum). The simulation collects findings in less than 30 μs and has a high-quality mesh with around 116,000 components. The purpose of this study is to compare these materials' performances in order to gain knowledge for future vehicle design.

*Keywords* **—Bumper, Simulation, Aluminum alloy, Deformation, Stress.**

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## INTRODUCTION

The bumper beam, one of the most crucial parts of passenger cars, needs to be manufactured and designed carefully in order to provide the best possible impact behaviour. The bumper beam is the main structure that deflects impact energy. This study looked at the variables that directly affected impact features because appropriate impact strength is the main necessity for such a structure. Based on impact modelling of off-the-shelf bumpers, the study made some basic alterations. A commercial front bumper beam was chosen for this work's modelling and impact engineering. Lightweighting bumper beam designs require consideration of crashworthiness and safety due to the implementation of auto safety laws. Car bumper weight can be reduced by using high-strength composite materials.A sincere effort was made to imitate the bumper as much as possible.

Under these conditions, the vehicle should be parked on a level surface, its brakes and gearbox removed, and it should be struck from both the front and the side, according to an impact test schematic illustration at low speed. Simplifications were made to allow finite element modelling because the agreement requires laboratory equipment to do the genuine low-velocity test.The disadvantage of adopting this idea is that, in certain situations, such as a parking accident or the approved low-speed impact pendulum test, the bumper fascia alone may not be strong enough to withstand collision from a rigid object.It was shown that the simplifying assumptions would raise the number of critical conditions rather than change the real circumstances.

This provides a strong basis for bumper beam design and analysis. Test modelling for metallic materials was initially conducted by looking at four key strategic factors.Priority one should be given to the material, i.e., how its kind can affect standards and what kinds of materials can be used in place of others to lower part weights. This section examined the effects of yield strength and module elasticity on bumper beam impact behaviour. Second, the thickness, or the manner in which the bumper beam's thickness may affect the impact requirements, Thirdly, the shape—or how even minute adjustments and modifications can simplify production procedures and minimise material volume without compromising impact strength—and the impact condition—or how test situations other than those mentioned above can affect the impact behaviour. Last but not least, the impact condition explains how test settings other than the ones previously mentioned may affect the impact behaviour. Steel and aluminium constructions with a specified thickness that passed the test provided ample evidence as to why they should not be used as bumper beam structures due to their increasing weight. They added about 500% and 100%, respectively, to the structure's weight over the initial design.

Datal, Jaichandra Tanajirao The front or back component of a car that protects the safety systems from harm in the event of an accident is called the bumper. In a high-speed collision, they will not protect the passengers from harm. This study examines the most crucial factors for bumper beam analysis, including material, structures, forms, and impact situations, with the goal of improving crashworthiness in the event of a collision. The material choice for the bumper is further emphasised.Laad Shaswat (2020) Conventional crash testing, in which the load runs lengthwise through the vehicle, are the exclusive focus of this study. We take a look at two distinct angles of modelling. The goal of the conventional method is to get the Ansys simulation results to agree with one another. It has been demonstrated that the necessary mass reduction is conditional on the loading circumstances, bumper and vehicle properties. High agreement for the time history of compression and force is also difficult to achieve when using the simple approach of mass reduction. On the other hand, the goal of the second modelling approach is to achieve a very accurate representation of the bumper system's force and compression history over time.As part of this research, the bumper was constructed using aluminium alloy 6061.In 2016, Bilal Abdullah Baig Every every day, car accidents occur. The numbers must be considered: 10,000 casualties and 200,000 to 2 million injured annually. There must be an improvement in vehicle safety during accidents if these figures are to be believed. One of the most important safety features of passenger vehicles is the bumper system, which prevents damage in the event of an accident. Front and rear bumpers of passenger cars are typically constructed of steel, aluminium, rubber, or plastic. Finding the lightest possible bumper design is the focus of this article. The software used to create the bumper model is SOLID WORKS. The LSDYNA programme was the subject of the crash test. The automobile industry makes extensive use of it for the purpose of analysing vehicle designs. A car's actions in a collision can be precisely predicted by it.New methods, including the use of energy absorbers and materials, are required to improve automotive vehicles' crash performance, as Andersonet al. has outlined. Accident prevention parts ought to be able to either dissipate or absorb force. A component's geometry and material qualities work together to determine its energy absorption capabilities.Based on their research, Evans and Morgan conclude that bumper system technologies will need to adapt to manufacturers' increasingly aggressive styling cues in order to satisfy performance and cost targets in increasingly constrained package spaces. Innovative expanded polypropylene (EPP) foam technology and procedures were proposed.Through software simulation, Bautista et al. optimised the bumper beam shape for the given material after studying various impact criteria. The impact of a metallic energy absorber in a bumper system was also investigated. Design criteria were maximum stress and deformation. In terms of bumper beam design, they have adhered to numerous international standards.The article by Hosseinzadeh RM and colleagues states that bumper beams are a significant component of passenger vehicles' crash protection systems. Using LS-DYNA ANSYS 5.7 for impact modelling, this paper examines and characterises a commercially available glass mat thermoplastic (GMT) front bumper beam in accordance with the E.C.E. UNITED NATIONS AGREEMENT [UNITED NATIONS AGREEMENT, Uniform Provisions concerning the Approval of Vehicles with regards to their Front and Rear Protective Devices (Bumpers, etc.), E.C.E., 1994]. We compare the outcomes with those of more traditional metals, such as steel and aluminium, and focus on the three primary design aspects of this structure: shape, material, and impact circumstances. As a conclusion, the issues described earlier are illustrated by suggesting a high-strength SMC bumper in place of the present GMT. It is evident from the aforementioned literature that various nations have their own standards, but very few of these have gained universal acceptance. The E.C.E. United Nations Agreement, 1994[4], was chosen for this investigation. The following are the design criteria that were chosen. The design's available gap space determines the maximum Von-Mises stress, which must be less than the yield strength, and the deformation must be less than the given limit. The deformation limit for this article is 40mm.In their study, Niranjan K.N. et al. (2017) looked into hybrid composites, which include a base material of aluminium alloy 6061 with reinforcements of sic (6% of the total) and graphite (3%, 6%, and 9% of the total). The results of tensile, compressive, and hardness tests were computed mechanically. By increasing the percentage of graphite used as reinforcement, they were able to lower the hardness while simultaneously increasing the tensile and compressive strengths through the action of sic particles. The mechanical characteristics of MMCs, as I deduced from the aforementioned study, The use of reinforcement particles in an aluminium lattice has a significant impact on the material's hardness, tensile strength, and compressive strength. Increasing the percentage of graphite in the reinforcement causes a decrease in hardness. In this study, we use a computer-aided design (CAD) model to conduct analyses on two materials—aluminum and Al 6061—using two methods: the quasistatic method and dynamic analysis. The study compares the equivalent stress produced by a vehicle bumper collision utilising carbon steel, cast iron, aluminium ceramic composite, and conventional structural components.In 2020, V. Sathish Kannan was a An automobile's bumper is a crucial component. When a collision occurs, the bumper acts as a barrier to protect the vehicle's occupants and the car itself from harm. The tragic reality is that deaths caused by accidents are all too common, and this is true not just in India but globally. Thus, prioritising passenger and vehicle body safety during vehicle design is essential. The strong impact strength of ABS makes it a popular material for use in car bumpers. Our goal in this study is to compare and contrast three distinct front bumpers of luxury vehicles that are at the forefront of their industries. The bumpers are modelled in CATIA V5R21 and analysed in ANSYS 19.2 using the relevant velocities. The research assumes a 5 mm thickness for all bumpers and a 10 mm thickness for the concrete wall that will be hit in order to create an impact collision. We find the optimal or optimistic design by comparing the outcomes of different factors such equivalent plastic strain, total deformation, directional deformation, and equivalent stress using explicit dynamic conditions with exact boundary conditions.

The following impacts on the vehicle's radiator and security features are possible with nylon 101 bumper plastics:

1. A higher potential for harmThe radiator could be more vulnerable to punctures or other damage if it is protected by plastic bumpers rather than metal ones in the event of a collision.

2. Airflow reductionOverheating may occur if air cannot reach the radiator due to specific plastic bumper designs.
3. The buildup of trash The plastic bumpers have the potential to trap rocks or leaves, which could subsequently move towards the radiator and cause damage or obstruction to it.
4-Stress and vibrationAs time passes, the radiator and its mounting points may develop fractures or failures due to the vibrations and stress transmitted by the plastic bumpers.
5. Repair access is limited.
Repairs to the radiator could be more difficult and time-consuming if plastic bumpers were used.
6. Optical Appeal Compared to metal bumpers, plastic ones may not be as aesthetically pleasing or protective, which could change the car's overall appearance. These issues can be circumvented through the meticulous installation and design of aluminum-based car bumpers, which are meant to be more protective and long-lasting than modern plastic bumpers.
7. Limited Ability to RecycleNylon 101's difficulty in recycling raises questions about its impact on trash and the environment.
8. The Effect of Low Temperature on BrittlenessCracking and breaking are more likely to occur when Nylon 101 is exposed to low temperatures because it becomes brittle.
9. Restrictions on DesignIn order to obtain the desired level of strength and stiffness using Nylon 101, certain design considerations like ribs or reinforcing may be necessary.

2. **Simulation of Front Bumper using Nylon 101 material**

Simulation of the front bumper cover body involves using computer-aided engineering (CAE) tools to analyze and predict its behavior under various loads and conditions.

**21 Model Information**

Specific details about a vehicle's bumpers are
1. Type: Cover for the Front or Back Bumper
2. Manufactured from: Steel, Aluminium, or Plastic (including Polypropylene, Polyurethane, or Thermoplastic Olefin).
Thirdly, form: aerodynamically shaped to match the profile of the vehicle
4. Size: 50-70 inches broad, 10-20 inches tall, and 2-5 inches deep is the standard, though it might vary by year, model, and manufacturer.
5. Points of attachment: fastened to the vehicle's framework or exterior via fasteners, clips, or glue
6. Characteristics (1) Zones for impact absorption
The use of strengthened ribs or beams
A licence plate holder-An assembly with integrated fog lights or headlights
Different designs for different trim levels, models, or areas of a vehicle are known as design variants.
8. Production Method: Casting, injection moulding, or stamping
9. Weighing around 5–15 pounds (2.3–6.8 kilogrammes), with exact measurements affected on material and size.
10. Built to resist small scratches, impacts, and environmental elements

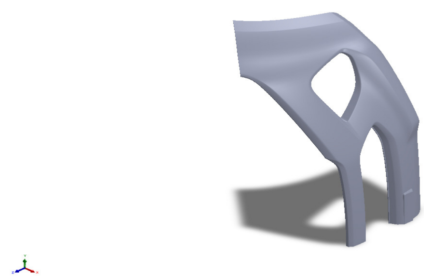


Fig. 1 Model of car bumper

**Table 1** Front Bumper Cover Body

| **Model name:** Front Bumper Cover Body<br>**Current Configuration:** Default | | | |
|---|---|---|---|
| **Solid Bodies** | | | |
| **Document Name and Reference** | **Treated As** | **Volumetric Properties** | **Document Path/Date Modified** |

| | | | |
|---|---|---|---|
| Front Bumper Cover Body.igs <1> | Solid Body | **Mass:1.85898 kg Volume:0.00161651 m^3 Density:1,150 kg/m^3 Weight:18.218 N** | **crash test proj\Front Bumper Cover Body.SLDPRT** Jul 4 23:54:19 2024 |

**Table 2 Study Properties**

***Table 3 Setup Information***

| | |
|---|---|
| **Type** | Velocity at impact |
| **Velocity Magnitude** | 50 m/sec |
| **Impact Velocity Reference** | Right Plane |
| **Gravity** | 9.81 m/s^2 |

| | |
|---|---|
| **Study name** | Drop Test 1 |
| **Analysis type** | Drop Test |
| **Mesh type** | Solid Mesh |
| **Large displacement** | On |
| **Result folder** | SOLIDWORKS document (D:\Riyaz\Work\Freelancing\crash test proj) |

| | |
|---|---|
| **Gravity Reference** | Front Plane |
| **Parallel to reference plane** | Plane1 |
| **Coefficient of friction** | 0 |
| **Target Stiffness** | Rigid target |
| **Critical Damping Ratio** | 0 |

***Table 4 Result Options***

| | |
|---|---|
| **Solution Time After Impact** | 30microsec |
| **Save Results** | 0 microsec |

| | |
|---|---|
| **Starting From** | |
| **No. of Plots** | 20 |
| **No. of Graph Steps Per Plot** | 20 |
| **Number of vertex** | 0 |

**Table 5 Units**

| | |
|---|---|
| **Unit system:** | SI (MKS) |
| **Length/Displacement** | mm |
| **Temperature** | Kelvin |
| **Angular velocity** | Rad/sec |
| **Pressure/Stress** | N/m^2 |

**Table6 Material Properties**

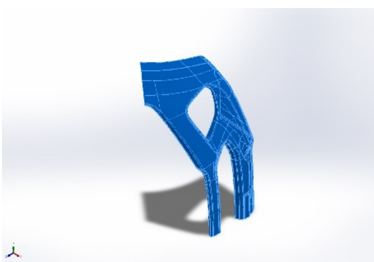
| Model Reference | Properties | Components |
|---|---|---|
|  | **Name:** Nylon 101<br>**Model type:** Linear Elastic Isotropic<br>**Default failure criterion:** Max von Mises Stress<br>**Yield strength:** 6e+07 N/m^2<br>**Tensile strength:** 7.92897e+07 N/m^2<br>**Elastic modulus:** 1e+09 N/m^2<br>**Poisson's ratio:** 0.3<br>**Mass density:** 1,150 kg/m^3<br>**Thermal expansion coefficient:** 1e-06 /Kelvin | SolidBody 1(Front Bump |
| Curve Data:N/A | | |

**Table 7 Mesh information**

| | |
|---|---|
| **Mesh type** | Solid Mesh |
| **Mesher Used:** | Blended curvature-based mesh |
| **Jacobian points for High quality mesh** | 16 Points |
| **Maximum element size** | 83.6186 mm |
| **Minimum element size** | 4.18093 mm |
| **Mesh Quality** | Very High |

***Table 8 Mesh information - Details***

| | |
|---|---|
| **Total Nodes** | 62846 |
| **Total Elements** | 72950 |
| **Maximum Aspect Ratio** | 1,659.3 |
| **% of elements with Aspect Ratio < 3** | 46.6 |
| **Percentage of elements with Aspect Ratio > 10** | 9.17 |
| **Percentage of distorted elements** | 0 |
| **Time to complete mesh(hh;mm;ss):** | 00:00:29 |
| **Computer name:** | DESKTOP |

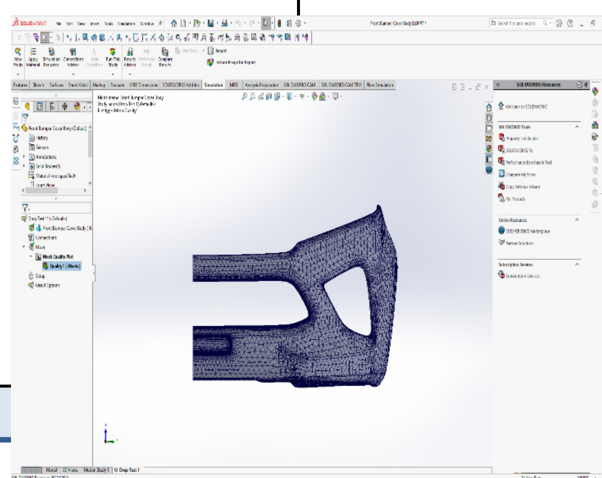


Fig2 Results Summary using solid works

Nylon 101 Bumper Results Summary
- Yield strength: 6 × 10^7 N/m^2
- Tensile strength: 7.92897 × 10^7 N/m^2
- Elastic modulus: 1 × 10^9 N/m^2
- Maximum von Mises stress: not provided
- Maximum resultant displacement: 1.735 mm
- Maximum equivalent strain: 7.472e-02

## 3. RESULTS AND DISCUSSION

### 3.1 Simulation of Front Bumper Cover Body aluminum

### 3.1 Model Information

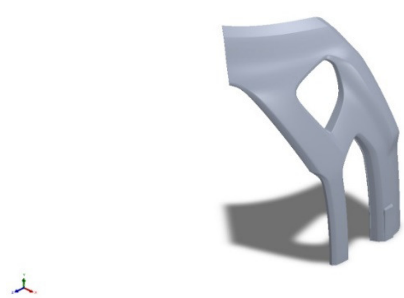


**Fig.3 Design of Aluminum bumper**

**Table 9** Model of Aluminum bumper using solid works

| **Model name:** Front Bumper Cover Body aluminium<br>**Current Configuration:** Default | | | |
|---|---|---|---|
| **Solid Bodies** | | | |
| **Document Name and Reference** | **Treated As** | **Volumetric Properties** | **Document Path/Date Modified** |
| Front Bumper Cover Body.igs <1> | Solid Body | **Mass:4.36456 kg**<br>**Volume:0.00161651 m^3**<br>**Density:2,699.99 kg/m^3**<br>**Weight:42.7727 N** | **D:\Riyaz\Work\Freelancing\ crash test proj\Front Bumper Cover Body aluminium.SLDPRT**<br>Jul 5 02:45:38 2024 |

The design and analysis of an aluminum bumper involves a combination of engineering and design principles to create a structurally sound and aesthetically pleasing component. Here's a general overview of the process:

### 3.2 Design

1. Please specify the needs for the design: Figure out what the bumper needs to look good and perform well, such as how durable it has to be and what vehicles it needs to fit.
2. Deciding on an aluminium alloy: Consider the alloy's strength, corrosion resistance, and formability before making a selection (e.g., 6061-T6, 6082-T6).
3. Construct a three-dimensional model with: Make a three-dimensional model of the bumper using CAD software, taking manufacturing limitations, aerodynamics, and structural integrity into account.
4. Make the design better: Maximise the design's impact resistance, airflow, and thermal management with the help of computational fluid dynamics (CFD) and finite element analysis (FEA).

### 3.3 Analysis

1. Analyse the bumper's structure using finite element analysis to see how it holds up under loads like impact, bending, and torsion.
2. Analyse the bumper's impact absorption and distribution capabilities by doing FEA or explicit dynamics simulations of various impact scenarios.
3. To make sure the bumper doesn't get too hot and damage other parts, thermal analysis involves running computational fluid dynamics (CFD) simulations to examine heat transport and dissipation.
4. Analyse the bumper's resilience to environmental variables, repeated loading and unloading, and other stresses using the use of finite element analysis (FEA) and fatigue simulations.

**3.4 Key design and analysis considerations**

1. Aluminium alloy choice, durability, and resistance to corrosion are material attributes.
2. Aerodynamics, vehicle compatibility, and packing are geometric restrictions.
3. The three pillars of structural integrity are resilience to impact, rigidity, and longevity.
4. Thermal management includes safeguarding adjacent components, regulating heat transport, and dissipation.
5. Factors affecting manufacturing include formability, weldability, and assembly.

By combining design and analysis, you can create an optimized aluminum bumper that meets functional, aesthetic, and safety requirements while ensuring manufacturability and durability.

**Table 10 Study Properties**

| | |
|---|---|
| **Study name** | Drop Test 1 |
| **Analysis type** | Drop Test |
| **Mesh type** | Solid Mesh |
| **Large displacement** | On |
| **Result folder** | SOLIDWORKS document (D:\Riyaz\Work\Freelancing\sugan sir crash test proj) |

***Table 11 Setup Information***

| | |
|---|---|
| **Type** | Velocity at impact |
| **Velocity Magnitude** | 50 m/sec |
| **Impact Velocity Reference** | Right Plane |
| **Gravity** | 9.81 m/s^2 |
| **Gravity Reference** | Front Plane |
| **Parallel to reference plane** | Plane1 |
| **Coefficient of friction** | 0 |
| **Target Stiffness** | Rigid target |
| **Critical Damping Ratio** | 0 |

| | |
|---|---|
| **Solution Time After Impact** | 30 microsec |
| **Save Results Starting From** | 0 microsec |
| **No. of Plots** | 20 |
| **No. of Graph Steps Per Plot** | 20 |
| **Number of vertex** | 0 |

***Table 12 Result Options***

**Table 13 Units**

| Unit system: | SI (MKS) |
|---|---|
| **Length/Displacement** | mm |
| **Temperature** | Kelvin |
| **Angular velocity** | Rad/sec |
| **Pressure/Stress** | N/m^2 |

**Table 14 Material Properties**

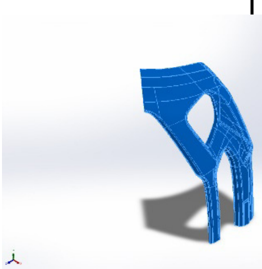
| Model Reference | Properties | Components |
|---|---|---|
|  | **Name:** 1060 Alloy<br>**Model type:** Linear Elastic Isotropic<br>**Default failure criterion:** Max von Mises Stress<br>**Yield strength:** 2.75742e+07 N/m^2<br>**Tensile strength:** 6.89356e+07 N/m^2<br>**Elastic modulus:** 6.9e+10 N/m^2<br>**Poisson's ratio:** 0.33<br>**Mass density:** 2,700 kg/m^3<br>**Shear modulus:** 2.7e+10 N/m^2<br>**Thermal expansion coefficient:** 2.4e-05 /Kelvin | SolidBody 1(Front Bumper Cover Body.igs<1>)(Front Bumper Cover Body) |
| Curve Data:N/A | | |

**Table 15 Mesh information**

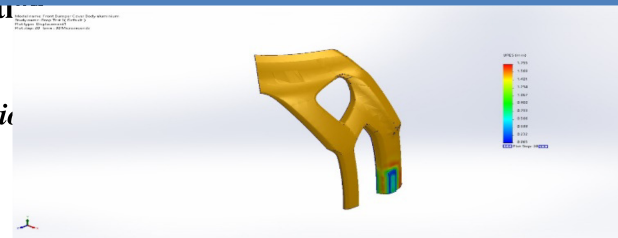
| Mesh type | Solid Mesh |
|---|---|
| Mesher Used: | Blended curvature-based mesh |
| Jacobian points for High quality mesh | 16 Points |
| Maximum element size | 83.6186 mm |
| Minimum element size | 16.7237 mm |
| Mesh Quality | Very High |

***Table 16 Mesh information***

| | |
|---|---|
| **Total Nodes** | 29147 |
| **Total Elements** | 33352 |
| **Maximum Aspect Ratio** | 6,459.2 |
| **% of elements with Aspect Ratio < 3** | 9.29 |
| **Percentage of elements with Aspect Ratio > 10** | 26.9 |
| **Percentage of distorted elements** | 0 |
| **Time to complete mesh(hh;mm;ss):** | 00:00:21 |
| **Computer name:** | DESKTOP |

| Name | Type | Min | Max |
|---|---|---|---|
| Displacement 1 | URES: Resultant Displacement | 0.065mm Node: 12318 | 1.735mm Node: 11639 |

| Name | Type | Min | Max |
|---|---|---|---|



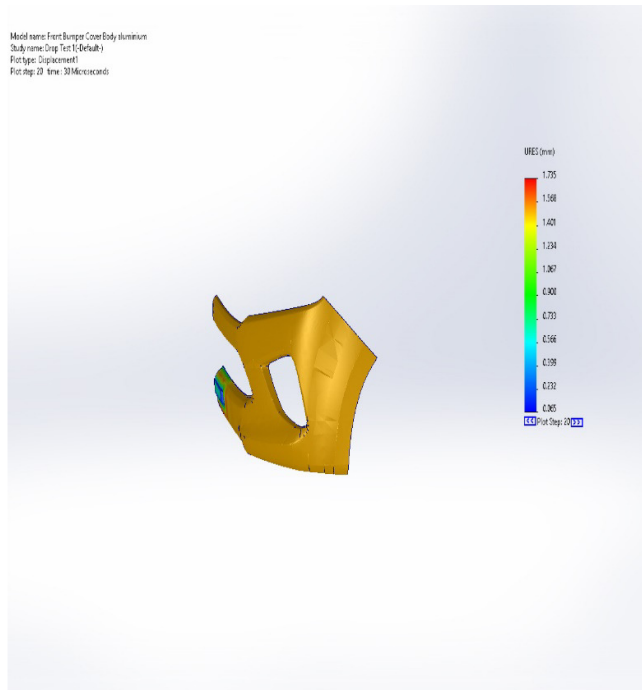



Fig.6 Front Bumper Cover Body aluminium-Drop Test 1-Strain-Strain1

**3.5 Summary**

The collision performance of Nylon 101 and Aluminium 1060 alloy automobile bumpers were compared and studied in this work using SolidWorks 2022. During a 30-second collision, mechanical properties such as von Mises stress, amount of displacement, and equivalent strain were the main points of attention. These are the most important characteristics of all the materials:

**3.6 Aluminium 1060 Alloy Bumper:**

- Yield strength: 2.75742 × 10^7 N/m^2
- Tensile strength: 6.89356 × 10^7 N/m^2

- Elastic modulus: 6.9 × 10^10 N/m^2
- Maximum von Mises stress: 1,314.488 MPa
- Maximum resultant displacement: 1.735 mm
- Maximum equivalent strain: 3.567e-02

**3.7 Nylon 101 Bumper**

- Yield strength: 6 × 10^7 N/m^2
- Tensile strength: 7.92897 × 10^7 N/m^2
- Elastic modulus: 1 × 10^9 N/m^2
- Maximum von Mises stress: not provided
- Maximum resultant displacement: 1.735 mm
- Maximum equivalent strain: 7.472e-02

1. Analysing

a. When comparing the two bumpers, the von Mises stress was higher in the aluminium 1060 alloy and lower in the nylon 101. This provides more evidence that the aluminium bumper can withstand more forceful collisions.

2. Evaluation of Results

a. The von Mises stress was larger in the aluminium 1060 alloy bumper, but the resultant displacement and equivalent strain were lower in the nylon 101 bumper. This bodes well for the aluminium bumper's crash performance because it is less prone to deformation and can soak up more impact energy.

3. Applicability of the Material

a. The aluminium bumper is more durable and less prone to deformation, while the nylon 101 bumper is a lightweight option that performs well thanks to its increased yield and tensile strengths. Considerations like weight and the desired energy absorption qualities are relevant to the application and will determine which of these materials is best.

4. What Does It Mean?

a. Based on the results, it seems like aluminium 1060 alloy is a strong material for bumpers for cars. Nevertheless, Nylon 101 presents an opportunity to reduce vehicle weight without sacrificing safety because to its reduced density and similar tensile qualities.

5. Restriction

a. Using high-quality meshes and accurate material models determines how accurate the simulation is. More elements including temperature impacts, material fatigue, and long-term durability should be considered in future studies for a more thorough evaluation.

6. Looking Ahead

a. It is suggested that more studies investigate hybrid materials that merge the advantages of nylon and aluminium. Validating the simulation results and refining material choices for maximum performance also requires real-world crash testing.

## CONCLUSION

This study used SolidWorks 2022 to compare and analyse the crash behaviour of Nylon 101 and aluminium 1060 alloy car bumpers. The primary emphasis was on mechanical properties like von Mises stress, equivalent strain, and consequent displacement after a 30-second collision. Here are the main features of each material:

**Nylon 101 Bumper :Existing Method**

- Yield strength: 6 × 10^7 N/m^2
- Tensile strength: 7.92897 × 10^7 N/m^2
- Elastic modulus: 1 × 10^9 N/m^2
- Maximum von Mises stress: not provided
- Maximum resultant displacement: 1.735 mm
- Maximum equivalent strain: 7.472e-02

The Nylon 101 bumper deformed substantially upon impact due to the large displacement and strain it experienced at high speeds. As a result of significant deformation under stress, the material may not be as useful in violent collisions, despite being robust and lightweight.

**Aluminum 1060 Alloy Bumper:**

- Yield strength: 2.75742 × 10^7 N/m^2
- Tensile strength: 6.89356 × 10^7 N/m^2
- Elastic modulus: 6.9 × 10^10 N/m^2
- Maximum von Mises stress: 1,314.488 MPa
- Maximum resultant displacement: 1.735 mm
- Maximum equivalent strain: 3.567e-02

The bumper made of aluminium 1060 alloy showed less strain and displacement after an impact, suggesting that it was more resistant to deformation and could absorb more energy. So, if you want to make passengers safer in high-impact situations, aluminium 1060 is the way to go.

A Comprehensive Analysis:

While aluminium 1060 alloy is great at absorbing impacts and controlling deformation, nylon 101 is great at conserving weight without sacrificing strength. However, in situations when weight reduction is of utmost importance, nylon 101 can be a suitable alternative to aluminium 1060, which is perfect for maximum safety and minimum deformation.

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