Finite Eleemnt Frontal Crash Analysis Of Nev Vehicle's Platform With Upper And Sub Frame Body

P.Sandeep Raj[1], V Sivarama Krishna[2]

[1]M.tech Student, Department Of Mechanical Engineering VignanaJyothi Institute Of Engineering &Technology, Hyderabad
[2]Assistant Professor Department Of Mechanical Engineering VignanaJyothi Institute Of Engineering &Technology, Hyderabad

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ABSTRACT
One way to improve a vehicle's performance is to reduce its weight. This is only one way to maximize performance. Given the recent advancements in the field of composites, it is clear that these materials may be the most effective substitutes for heavier materials, but we must take care to preserve their strength. Because composite materials are lighter, stronger, and more recyclable than other materials, research and development on them has profited immensely. In this thesis, ANSYS workbench is used to conduct a comparative computer-aided engineering study for the crash worthiness of an automobile body structure that was developed using CATIA V5 software. The primary benefit of CAE is that, without actually constructing the original component, the automobile body structure can be evaluated in a variety of environments to ensure optimal performance and durability. Three distinct materials, including AA7075 T651, stainless steel, and carbon fiber composite, are used to construct the car's body structure, and its crashworthiness is evaluated. Through the use of optimization techniques, the bulk of the automobile body is reduced while maintaining structural rigidity and durability. The ANSYS workbench software is used to do the CAE analysis and weight reductions. To determine the best materials that minimize weight while retaining stiffness and durability, the findings will be compared and discussed with the corresponding stress and total deformation value.

Keywords: NevVehicle'S, CATIA V5, ANSYS, Crash Worthiness

1. INTRODUCTION

A automobile is a four-wheeled transportation vehicle that transports people from one location to another and is frequently driven on roadways. Modern consumers have very high standards for cars in terms of weight and safety. This analysis aims to balance passenger safety with the vehicle's ability to cut weight without sacrificing strength. These days, automakers are paying greater attention to adopting lightweight components made of materials like aluminum, magnesium, plastic, composites, and other types of high-tech materials. Composite materials could provide the automobile industry with a number of advantages over steel in the future.Composite-built vehicles may be lighter, safer, and more fuel-efficient. A high-performance fiber (such carbon or glass) and a matrix material (epoxy polymer) combine to produce a composite, which has superior properties to both of its constituent parts. Most automakers employ lightweight materials like composites, aluminum, magnesium, or new types of high strength steels to reduce weight. These materials are not very strong or ductile in the case of a rupture, which happens frequently in auto accidents. The breakdown of material connecting is another consequence of a car's crash worthiness. The front end of an automobile experiences plastic deformation after taking on considerable stress in a collision.

NEV Platform

New Energy Vehicles (NEVs), encompassing electric and hybrid electric vehicles, represent a shift towards sustainable transportation. However, ensuring the structural safety of NEVs in the event of a crash is essential, as the material composition and design of NEV platforms differ significantly from traditional internal combustion engine vehicles. This paper investigates the behavior of NEV platforms under frontal crash conditions through finite element analysis (FEA). The key focus areas include the upper body and subframe, which play vital roles in energy absorption and passenger protection.The NEV platform consists of several critical components, including the upper frame (which encompasses the vehicle's roof, pillars, and structural bodywork) and the subframe (which supports the drivetrain, suspension, and other mechanical systems). NEVs typically employ lightweight materials, such as aluminum alloys and composites, to reduce weight while maintaining structural integrity.

Scope of the work

- The primary goal of a crash study is to determine how the vehicle will react in frontal crashes with three different materials, to choose the better materials
- The light weighing of a car's body and its crash worthiness are two significant factors to consider while designing a vehicle.
- Keeping the vehicle's weight down while maintaining its safety.
- To choose the material that reduces weight and withstands strength

2. LITERATURE REVIEW

Recent literature on crash analysis of NEVs focuses on their structural integrity, energy absorption capacity, and material selection, particularly due to the different weight distributions caused by the inclusion of heavy battery packs and the absence of traditional internal combustion engines. This review synthesizes the findings of various studies on NEV crash analysis, emphasizing frontal crash simulations, structural design, material innovations, and safety standards. Andrew Hickey et**[1]** In this study, the primary goal of an accidents investigation is to determine how the vehicles will react in front-end or side-impact collisions. Vehicle body light weighing and crash worthiness are 2 important factors to consider while designing a vehicle.. The main task is to transport the greatest amount of weight under all intended operating conditions.. This method offers an advantage enormous breadth throughout the whole car sector since it reduces the cost of true vehicle crash testing. H Ahmad **[2]**In this study, A composite is made up of a high-performance fibre (such as carbon or glass) and a matrix material (epoxy polymer) that, when combined, outperforms the individual components. Carbon-fiber composites are one-fifth the weight of steel while maintaining the same or better stiffness and strength. They also don't rust or corrode like steel or aluminium, and by reducing vehicle weight by up to 60%, they might enhance fuel economy significantly. J. Santhakumar**[3]**In this study FRP offers exceptionally high fundamental stiffness and strength ratings when compared to metal materials. By reducing the vehicle's bulk, the usage of FRP in current vehicle designs increases structural protection. When compared to other current materials, the use of FRP for BIW indicates the ability to reduce weight of up to 60% to 70%. .Steven Jones **[4]** This article is a study that how the behavioral pathways influence the severity of the crashes. Crashes that occurred at unsignalized four-way intersections and T-junctions in Alabama were used for model estimations. Three precrash actions, failed to yield right-of-way at the stop sign, failed to yield right-of-way at a turn, and running stop sign, were considered.Lin C. S, **[5]** In this study Ansys software's explicit dynamic module is used to analyse an automobile collision at some speed using some materials alternately. As a result, the automobile crashes due to a mechanical collision with a concrete wall on the front surface area of the car body. That is how equivalent stress, equivalent strain, and total deformation will be analysed. Narender et al **[6]** In this study, Aluminum alloys are used in modern automobiles' front and rear bumper beams, as well as other safety components including side door impact beams, frames, engine cradles, chassis, and suspension components, which are longitudinally extruded. Although the use of light weight materials reduces fuel consumption and hence CO2 emissions, another rigorous requirement from society is the passive safety provided when using light weight materials for automotive elements such as bumpers Naga SaiAbhishikt, **[7]** In this study, Dummies are subjected to calibration standards to guarantee that their bodies react similarly to humans in the event of an injury or accident, however this does not involve driver slump postures or keeping an upright posture behind the wheel. They run many crash tests, including Frontal Offset,Side-impact testing, Side-pole testing, Pedestrian Protection testing, Rear Impact testing, and Child Safety Testing.A Muhammad **[8]** In this study, This research uses explicit dynamics in ANSYS workbench to simulate and analyse the impact of an automobile frontal accident on various obstacles. The produced stress and deformation on collision into a steel material wall, both static and moving, are studied using an automobile body made of aluminium materials travelling at 35 m/s. L Praveen and N Sandeep Kumar **[9]** In this study, automobile manufacturers are putting greater emphasis on the use of light-weight parts in order to reduce weight. such as aluminium, magnesium, polymers, composites, and novel high-tech materials. Steels with high energy content The majority of Whether these ingredients are restricted power or ductility, rupture is always a serious possibility throughout the process. Byeong Sam **[10]** The study is about LS-DYNA finite element processor is a non-linear finite element processor that can solve any stated problem. In most frontal collisions, the vehicle's front end suffers severe deformations, whereas the middle and back sections suffer only minor deformations. Because these models are designed for frontal collisions, the vehicle's front frame is finely mesh, while the middle and rear frames are coarsely mesh.

3. METHODOLOGY

In this methodology is to analyze the suitability of three materials—Stainless Steel, AA 7075 T651 aluminum alloy, and Carbon Fiber Composite—for use in New Energy Vehicle (NEV) body structures. This analysis will focus on key factors such as material properties, crash worthiness, energy absorption, and overall impact on vehicle performance. The methodology includes material characterization, finite element analysis (FEA) simulations, and comparisons based on specific criteria.

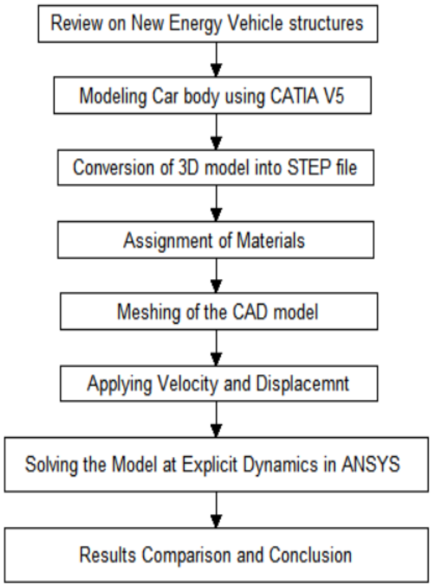

Figure 1. Analyzing process of car body structure

Using Car body structure Materials

The development of New Energy Vehicles (NEVs), such as electric and hybrid vehicles, requires innovative materials that balance weight reduction, strength, and crashworthiness. Traditional materials used in internal combustion engine vehicles are often not suitable for NEVs due to the unique challenges of battery weight, crash safety, and energy efficiency. This section reviews three key materials commonly used in the structural design of NEV body frames: Stainless Steel, AA 7075 T651 aluminum alloy, and Carbon Fiber Composites.

Table 1. Car body structure material properties

Properties	Stainless steel	AA 7075 T651	Carbon fibre composite
Density (kg/ m^3)	8000	2810	1400
YoungsModulus(GPa)	190	70	57
Poissons Ratio	0.265	0.32	0.005
Yield Strength (MPa)	250	510	530
UTS (MPa)	510	590	570

Car body structure modeling

The design of the car body structure is designed using CATIA V5 Software. The design has been modelled based on the reference dimension of a SUV type car vehicle. The below vehicle body design has a length of 4385mm, height of 1398mm and the width of 1890 mm.

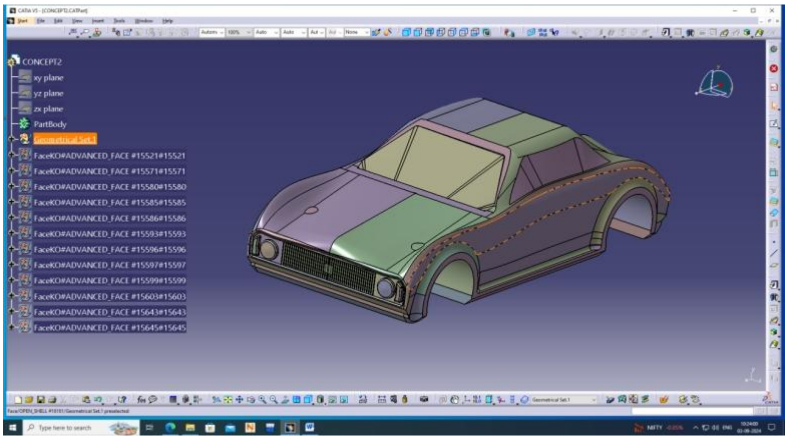

Figure 2. Modellings of the car body structure

Creating a wall for analysis

A wall is created in front of the body with a length of 3000 mm height of 2000 mm and with a thickness of 200mm, in which the impact of the body structure will be analysed.

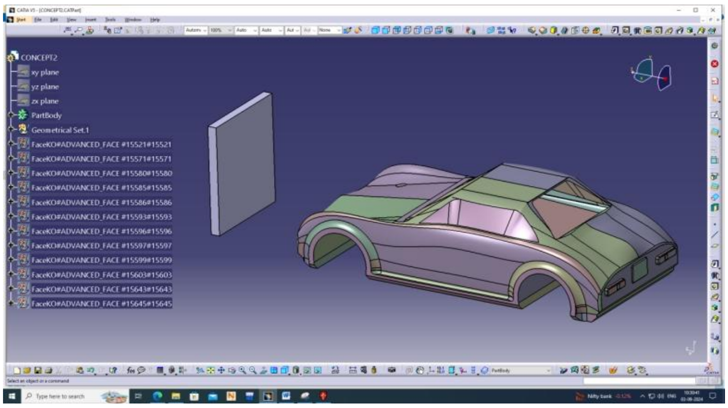

Figure 3. Modellings of wall

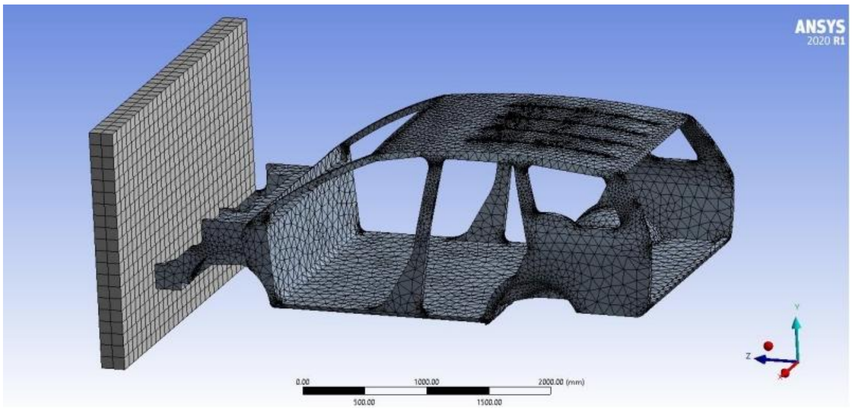

Figure 4. Meshed model

A bove figure shows a 3D model of a New Energy Vehicle (NEV), which is a vehicle powered by an electric motor or fuel cell. The cad model geometry describes the whole geometry of Solid Elements. Tetrahedrons are the element type for solid meshes that are three-dimensional the parabolic tetrahedral elements is 161798 and nodes 37741.

Boundary Conditions

These describe the current state of a few nodes in the finite detail mesh. This is a way of describing how a lot of the nodes in the version are limited. It is critical to describe adequate boundary conditions or limitations in order to compensate for impacts. Each node inside the structural device has six degrees of freedom: translational, three-square coordinate axes, and three rotating axes around each of the square axes. The velocity of 100kmph that is 27778 mm/s is given to the car body structure to crash into the wall for analysis The velocity 27778 mm/s is given in the positive z axis direction.

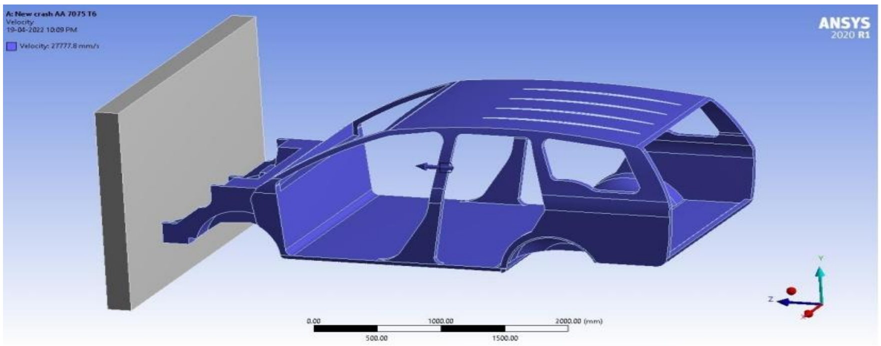

Figure 5. Velocity Assignment at 27778 mm/sec

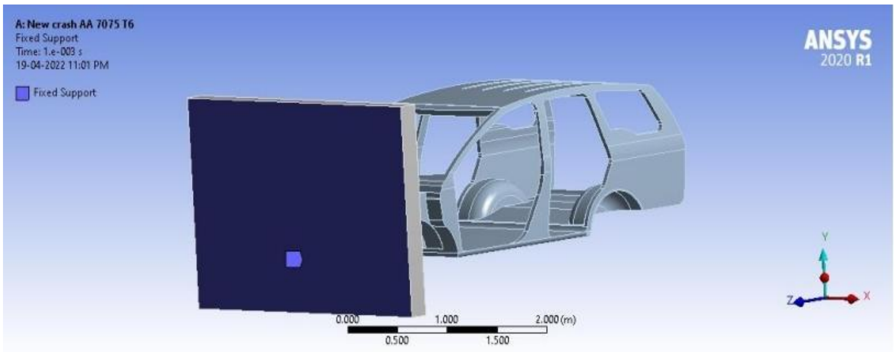

Figure 6. Fixed support

A bove figure shows the 3D finite element analysis (FEA) model of a car body colliding with a fixed wall. The model is likely being used to simulate a crash test to evaluate the structural integrity of the car and the potential for injuries to occupants.

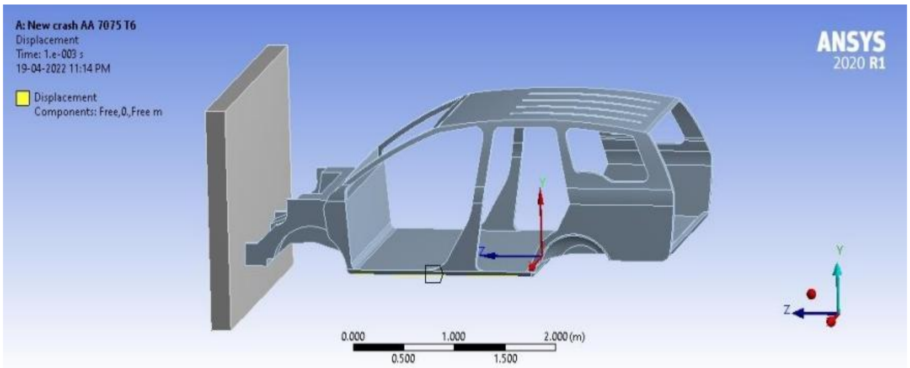

Figure 7. Displacement Assignment

A bove figure shows the displacement constraint produces an imposed transitional or rotational displacement in a given direction for a selected reference. Applying a displacement constraint is comparable to applying a load on a reference.

4. RESULTS AND DISCUSSION

The analysis done for the car body structure for three different material such as steel, aluminium AA7075 T651 and carbon fibre composite by crashing the car body structure into an wall with an velocity of 100kmph that is 27778 mm/s. The equivalent stress value and total deformation value for the three different materials is noted and each material value will be compared with the other two materials to find out the alternate material.

Explicit dynamic analysis of car body structure

Explicit dynamics is a numerical method used in finite element analysis (FEA) to simulate high-speed impact events, such as car crashes. It's particularly well-suited for analyzing transient events with large deformations and material nonlinearities

Analysis of car body structure using Structural steel

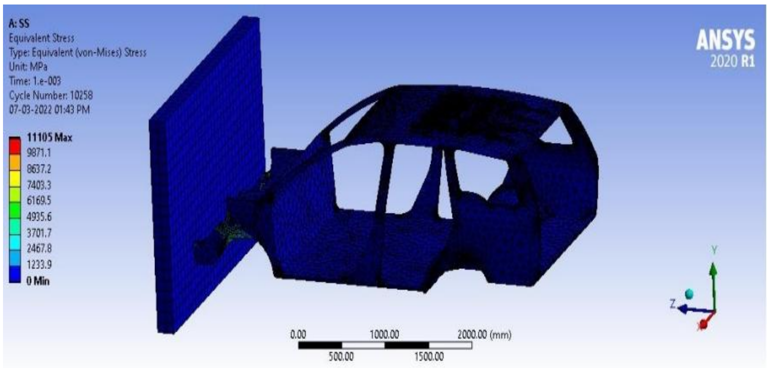

Figure 8. Equivalent stress

The maximum equivalent stress value when steel is implemented in the car body is 1105 Mpa whereas the total deformation value noted is 36.301mm and these values will be compared with the other two materials.

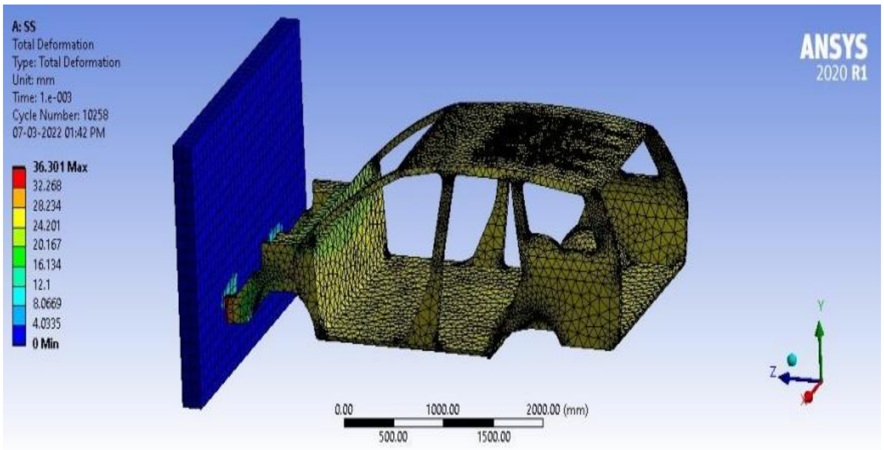

Figure 9. Total deformation

The maximum total deformation value for the steel component in the Fig: 9 is 36.301 mm. The color scale represents the total deformation, with blue indicating low deformation and red indicating high deformation. The maximum deformation value occurs at the point of impact between the car and the wall.

Analysis of car body structure using AA7075T651

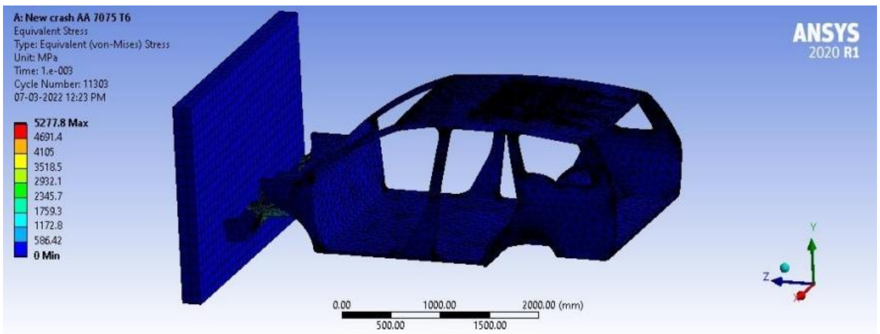

Figure 10. Equivalent stress

The car body structure is performed for analysis with Aluminium alloy 7 series that is 7075 T651 in which the equivalent stress value is 5277.8 Mpa which is less than steel and the deformation value is 47.305 mm which is higher than steel.

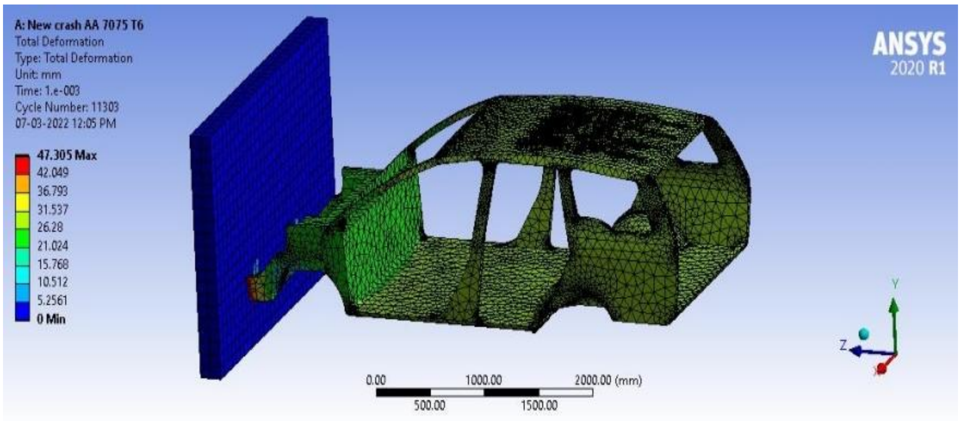

Figure 11. Total deformation

The maximum total deformation value for the AA 7075 T651 material in the figure is 42.049 mm. The color scale represents the total deformation, with blue indicating low deformation and red indicating high deformation. The maximum deformation value occurs at the point of impact between the car and the wall.

Analysis of car body structure using Carbon fibre Composite

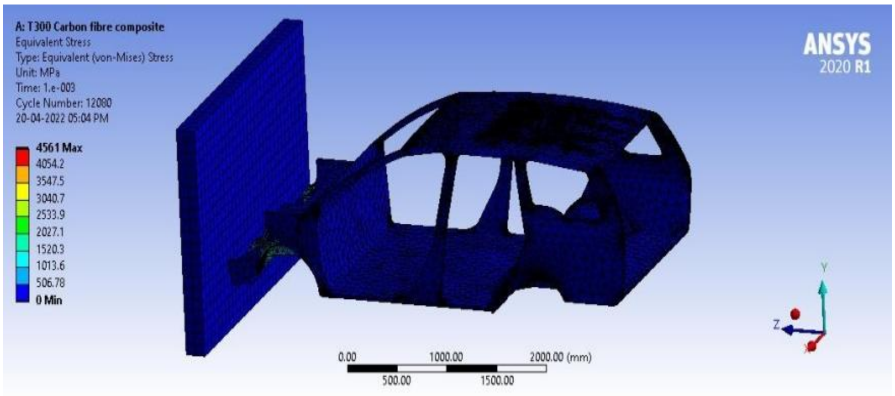

Figure 12. Equivalent stress

The material that is compared with aluminium and steel is the carbon fibre composite material which is imported to the car body with a constant velocity of 100kmph in which the stress value is 4561 Mpa and deformation value is 53811 mm.

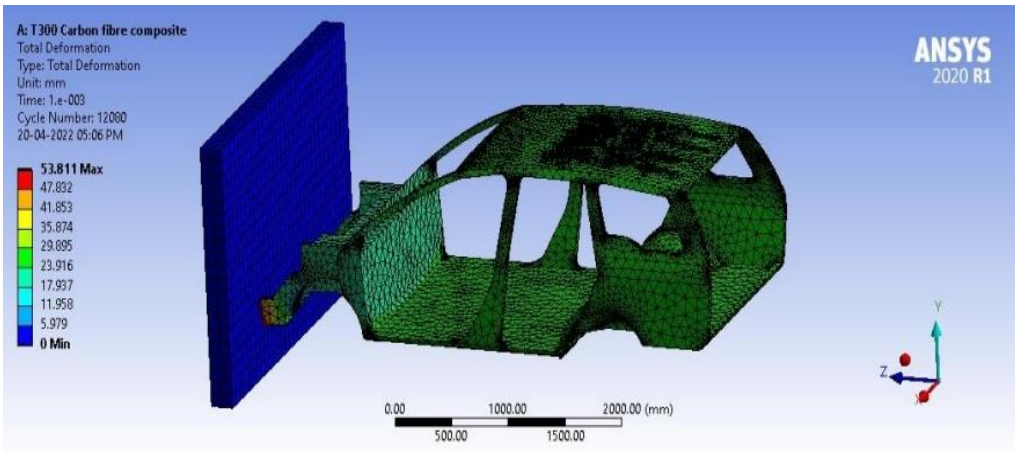

Figure 13. Total deformation

In this figure shows a finite element analysis (FEA) simulation of a car body colliding with a wall. The car body is made of carbon fiber composite material. The color scale represents the total deformation, with blue indicating low deformation and red indicating high deformation. The maximum total deformation value for the carbon fiber composite car body is 53.811 mm

Validation of car body structure using different materials

Validation is a crucial step in the development of car body structures, ensuring that the simulated behavior accurately reflects real-world performance. This is particularly important when using explicit dynamics analysis, a numerical method used to simulate high-speed impact events.By following these steps and considering the specific characteristics of each material, engineers can ensure that the explicit dynamics analysis of car body structures provides accurate and reliable results for different materials, including carbon fiber composite, structural steel, and AA 7075 T651.

Table 2. Comparison of car body structure using different materials

Materials	**Velocity(m/s)**	**Equivalent stress(mpa)**	**Total Deformation(mm)**
Steel	27.7778	11105	36.301
AA7075T651	27.7778	5277.8	47.305
Carbon fibrecomposite	27.7778	4561	53.811

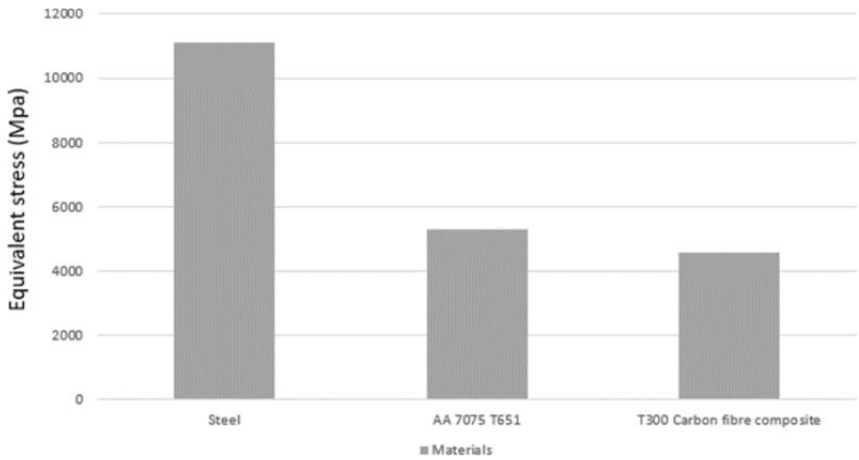

Figure 14. Validated the Equivalent stress with different materials

By comparing the results from analysis of three materials, the equivalent stress value of steel is higher when compared with aluminium and carbon fibre composite. The composite material Carbon fibre has the least stress value which conveys its higher strength and hence according to the analysis results on equivalent stress of three materials carbon fibre is the better alternate for other two materials.

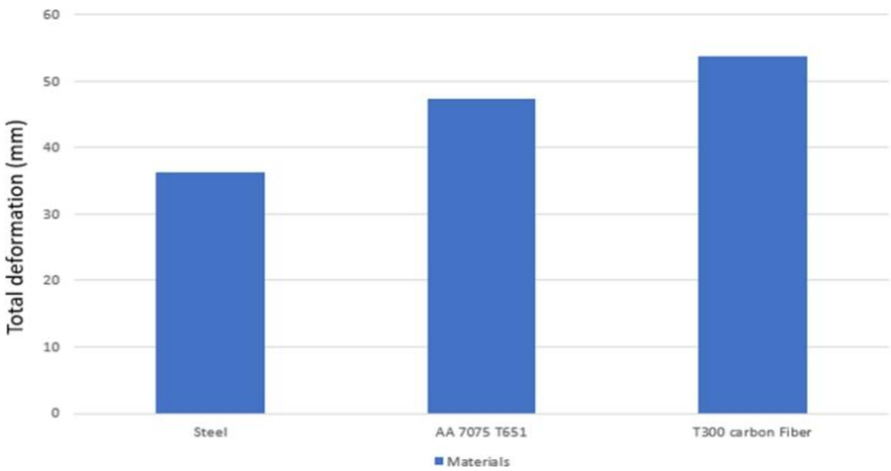

Figure 15. Validated the total deformation (mm) with different materials

Total deformation is a deformation option that allows you to see all of your model's deformation results in three coordinates (X, Y, and Z). You can select a coordinate (X, Y, or Z) in directional deformation to see the deformation result of your physical model in that direction.

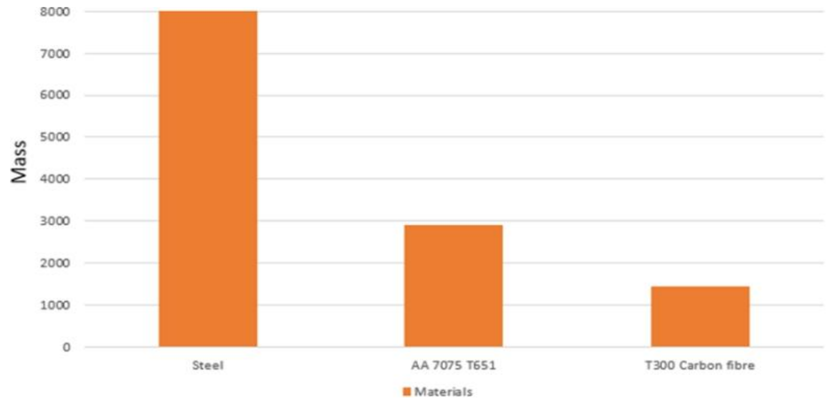

Figure 16. Validated the Mass of the structure with different materials

From the above analysis results of mass of the three materials for the car body structure is compared. From the comparison the carbon fibre composite material has the least weight when compared with the other three materials. Aluminium AA7075 T651 has slightly higher mass when compared with carbon fibre composite. Among the three materials steel has the highest mass. So from this comparison carbon fibre composite 81 % lesser and an better alternate material.

CONCLUSION

According to the results of equivalent stress value for the different materials, carbon fibre composite has the least stress value but it has a higher deformation value, and this material has the optimized weight when compared to other materials. Steel has high mass and stress value but the least deformation value, it couldn't be used due to its stress and higher mass. Aluminium alloy 7075 T651 has less weight and stress value when compared with steel. But the weight of carbon fire composite is less than AA7075 T651. From the results compared, AA 7075 T651 and carbon fibre composite could be used in the Car body structure. Due to its mass Steel couldn't be used. The weight of AA 7075 T651 is 63.76 % lesser than the traditional steel. The weight of carbon fibre composite is 81% lesser to the steel and 50.18% lesser than AA 7075 T651, hence weight is also optimized.

Future Scope

Finite element analysis proves to be a powerful tool in the design and validation of NEV platforms, helping engineers optimize structural performance while adhering to safety standards. Future research could explore more detailed interactions between various components during a crash and investigate how emerging materials like carbon fiber composites could further improve safety and weight efficiency.

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