International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

Crash Analysis of Car Body Structure Using Explicit Dynamics

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Abstract: ***The crashworthiness enhancement of vehicle structures is a very challenging task during the vehicle design process due to complicated nature of vehicle design structures that need to comply with different conflicting design task requirements. Although different safety agencies have issued and modified standardized crash tests to guarantee structural integrity and occupant survivability, there is continued rise of fatalities in vehicle crashes especially the passenger cars. This research envisages the application of various materials in manufacturing of car body along with the possible use of energy dissipator. Explicit dynamic analysis is performed using ANSYS software. The model used for analysis is Ford 2002 explorer.***

Keywords: Crashworthiness, ANSYS, LS DYNA, weight reduction

1. Introduction

In automotive design, the occupant and structural behavior in the event of a crash is of special interest. Non-linear finite element and rigid body analysis is applied to predict the responses of the structure or of the occupant. Decisions based on these computations can lead to significant design modifications. Usually, intuition leads the iterative process of finding the best design. It is often hard to determine necessary design modifications from the analysis results only. In some cases many variations are tried before a satisfactory designs found.The first motor vehicle fatality occurred in 1889 in New York City. Arguably this event led to the birth of automotive safety as a field of study. Over the past century, occupant safety has become an important design objective among all the performance criteria of ground transportation vehicles. Manufacturers realized early on the need to demonstrate occupant protection before the public accepted the automobile as a viable means of transportation. There are three distinct periods in the development history of automotive safety. The vehicle structure should be sufficiently stiff in bending and torsion for proper ride and handling. It should minimize high frequency fore-aft vibrations that give rise to harshness. In addition, the structure should yield a deceleration pulse that satisfies the following requirements for a range of occupant sizes, ages, and crash speeds for both genders:

2. Literature Review

Don O. Brush and Bo O. Almroth [1] demonstrate the classic buckling behavior of identical structural members subjected to axial crash loading in the book "Buckling of Bars, Plates, and Shells." In this book, the authors discuss common buckling problems and develop the equilibrium and stability equations for bars, plates, and shells. The authors also provide some particular examples that demonstrate how to determine the critical load using the stability equations. They include the direct numerical solution of the governing nonlinear equations.

Ishiyama, Nishimura, and Tsuchiya [2] report a numerical study of the impact response of plane frame structures with thin-walled beam members to predict the deformation and absorbed energy of automobiles under crash loading. The researchers investigate the collapse characteristics of thin-walled beam members under crashing loads, describe the inelastic deformations of the frame structure, and verify the important assumptions and conclusions via crash tests.

E. Haug and A. De Rouvray [3] illustrate the numerical simulation and prediction of the crash response of metallic components and structures. The algorithms of the numerical crashworthiness simulation and prediction are developed in their research. To validate the developed numerical algorithms, a full car crash simulation is performed using the numerical method. The reliability of the numerical method is verified by comparing the results of the simulations and the experiments.

A. G. Mamalis, D. E. Manolakos, G. A. Demosthenous, and M. B. Ioannidis [4] study the crashworthy behavior of thin-walled structural components subjected to various loading conditions, i.e. static and dynamic axial loading and bending. The authors describe the loading and deformation characteristics of the collapsed shells and discuss the influence of the shell geometry and the material properties on these characteristics. Also, the structural features related to vehicle collisions are introduced and useful conclusions for vehicle design and manufacture are provided.

H. S. Kim and T. Wierzbicki [5] investigate the rush response of thin-walled prismatic columns under combined bending-compression collapse loading. They construct the initial and subsequent failure loci representing the interaction between the axial forces and the bending moment. In their work, the researchers formulate a problem in which rectangular cross-section beams with different aspect ratios are subjected to a prescribed translational and rotational displacement rate. They then generate numerical results after solving the problem. From the numerical results, they continue developing the corresponding initial and subsequent failure loci, which describe the anticipated crush behavior of thin-walled columns under combined loading.

3. Problem Definition

When creating a car, it is very important to reduce its mass. This allows maintaining the basic characteristics of the car, using less powerful engines that consume less fuel and emit less harmful substances into the atmosphere. In addition,the inertia of the car decreases and for its acceleration or breaking it is necessary to spend less energy. Lowering the weight of the car also reduces the load on the suspension parts, which increases their lifespan. With increase in fuel cost and demand for more mileage from vehicle it has become more important for vehicle manufacturers to search for materials which are lighter in weight and absorb more crash energies as compared to conventional steel of carbon steel material. The new category of composites named MMC (Metal Matrix Composites) are getting popular due to low cost and improved mechanical properties. The current research is intended with the application of MMC material (Aluminum ceramic matrix composites) in manufacturing of car body.

4. Methodology

The analysis of car body is performed using Finite Element Method using ANSYS software. The CAD model of ford explorer is developed using Creo 2.0 software which is sketch based parametric 3d modelling software developed by PTC.

Figure 1: CAD model of Ford Explorer

The dimensions of Ford Explorer is 71”x190”x71” (W x L x H) [6]. The CAD model developed in Creo software is imported in ANSYS for meshing and applying with loads and boundary conditions. The model is meshed with tetrahedral elements and fine sizing.

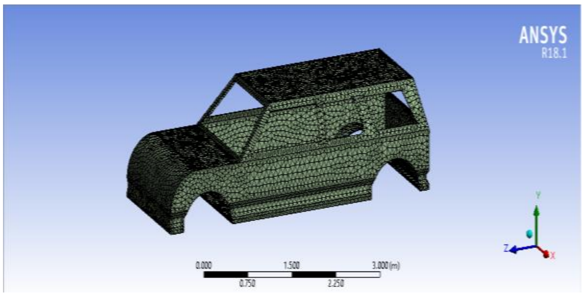

Figure 2: Meshed model of Ford Explorer

In current research crash investigation is performed using 2 different approaches which are discussed in detail in subsequent section. First approach is using quasi-static method and second approach is using dynamic analysis.

Explicit Analysis using Carbon Steel Material

Dynamic crash analysis is performed in CAD model of car using 2 materials namely carbon steel and Aluminium ceramic composite.

Table 1: Material Properties of Carbon Steel

Density (Kg/m^3)	7850
Elastic Modulus (GPa)	210
Poisson’s Ratio	.28
Tensile Strength (MPa)	1882
Yield Strength (MPa)	758

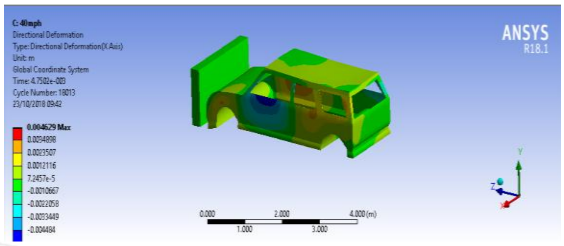

Figure 3: Direction deformation plot using carbon steel material at 64Km/hr

The deformation contour plots are derived for various time intervals/cycles using ANSYS LS DYNA. The crash analysis is performed using crash barrier as per ENCAP standard testing specifications at 64Km/hr speed. The analysis time is .005 secs, this time has been taken depending on processor speed and computational time. Energy curves, displacement curves are plotted.

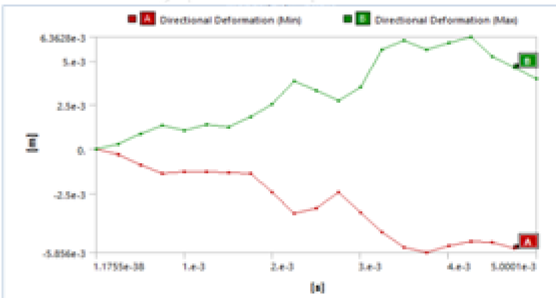

Figure 4: Max (green) and min (red) displacement curve at 64Km/hr

Directional deformation curve are plotted for maximum and minimum value for each time cycle. The curve plot shows that maximum deformation increases with increase in time cycle. The slight decrease in deformation in noticed after .035 secs and increases in further cycle.

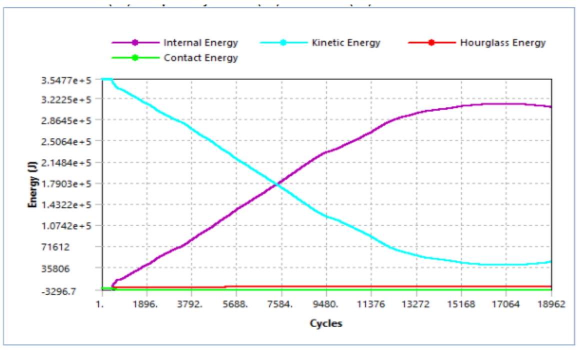

Figure 5: Energy curves at 64Km/hr using carbon steel material

The law of conservation of energy explains that energy inside a system cannot be created or destroyed, and it can be transferred from one form into another without changing the Total amount of energy. Considering mechanical systems, such as the vehicle systems, the absorbed work or internal energy of a system cannot exceed the work input. In theory, internal energy is equal to the work (E) done by external Forces on the system, which is equal to the product of the exerted force (F) and the distance (d) through which the force moves.

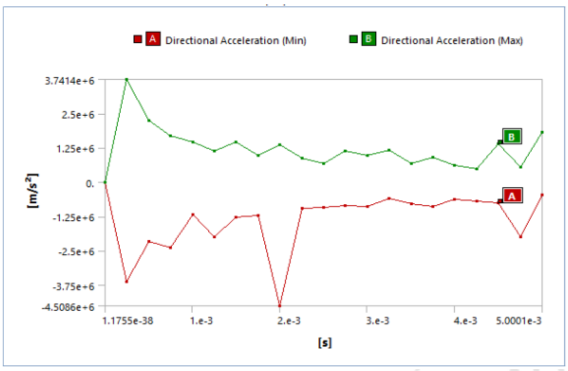

Figure 6: Max (green) and min(red) acceleration at 64 km/hr

The de-acceleration curve shows an increase in acceleration initially as the vehicle body makes first contact with barrier and reduces thereafter. This holds for both positive and negativeacceleration of entire body. The maximum deacceleration is 3.74e6 m/s^2 experienced by car body.

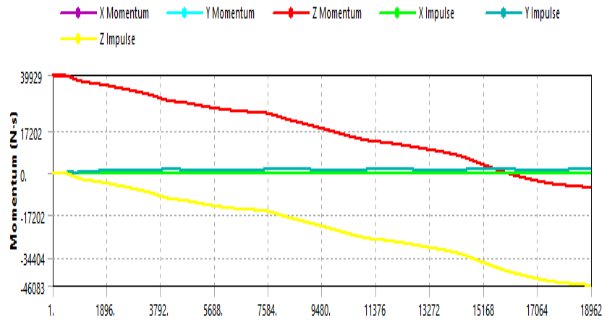

Figure 7: Max (green) and min(red) acceleration at 64 km/hr

The momentum curve for Z direction (red color) as shown in figure 7 shows higher magnitude of 39929 N-s which corresponds to initial contact with barrier which gradually decreases near to zero by end time. The impulse increases from zero during initial contact reduces to -46083 N-s by end of collision.

Explicit Analysis using AluminiumMatrix composite

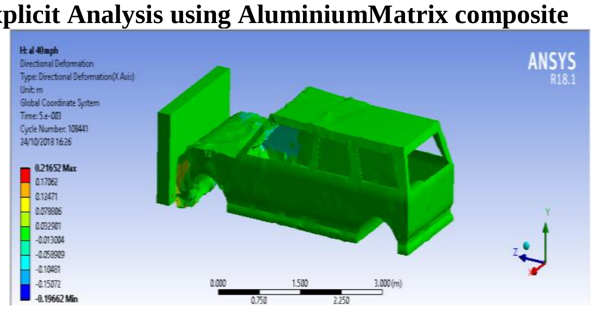

Figure 3: Direction deformation plot using aluminium matrix composite

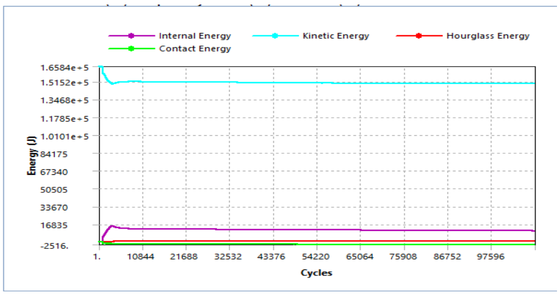

Figure 4: Energy plot using aluminium ceramic composite material

From energy plot shown in figure 4 above shows that aluminium car body has very low energy absorption characteristics. The kinetic energy at initial contact is 165840J and kinetic energy after impact is nearly 151520J throughout entire collision course. As the aluminium material absorbs very low energy, the remaining energy is causes very large deformation which is evident from figure 5.33 above which goes up to .2165m.

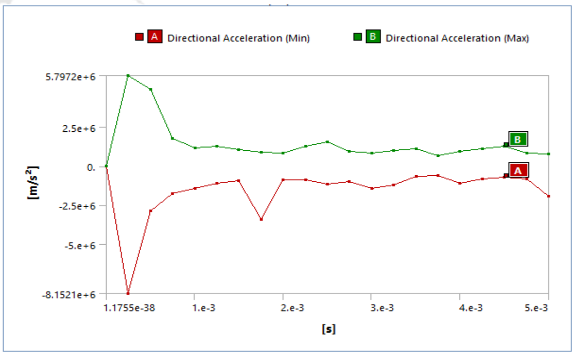

Figure 5: Deacceleration using aluminium ceramic composite material

The deacceleration value obtained for Aluminium material shows comparatively higher value than carbon steel. The deacceleration value is 5.797e6 m/sec^2. Higher deacceleration value possess higher risk of injury to passengers and damages the car.

Explicit Analysis using Honey Comb Structure

The current analysis is performed using honey comb structure between front bumper and car body, while car body material is made of carbon steel.

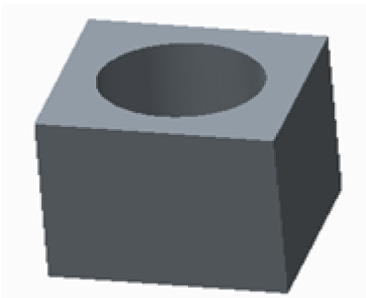

Figure 6: CAD model of honeycomb structure

The honeycomb structure is located between car body and front bumper as shown in figure 7 below. This honeycomb structures is useful for absorbing crash energy and prevent passenger cabin from distortion.

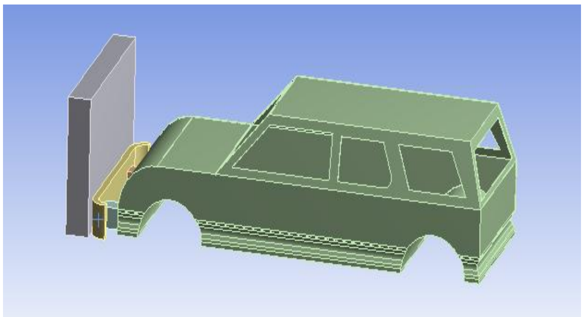

Figure 7: Blended body structure with honey comb energy absorbent

After conducting analysis using explicit dynamics the formation plot with respect to time/cycles is generated and shown in figure 8 below.

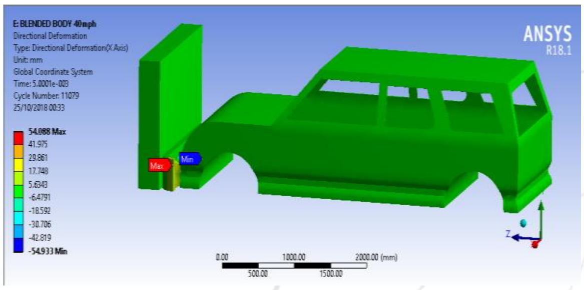

Figure 8: Deformation using honey comb energy absorbent material

The deformation graph shows maximum value of 54.08mm. It is noteworthy that the car structure doesn't experience any damage or deformation. The whole deformation can be seen in honeycomb structure only. Car body deformation is only due to initial motion and no distortion.

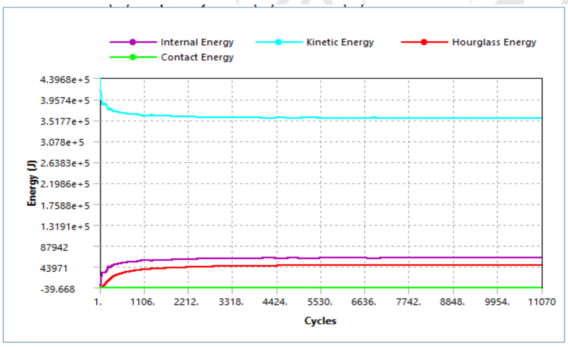

Figure 9: Energy plot using honeycomb structure

The energy summary curve for blended bodystructure using honeycomb is shown in figure 5.35 above. Honeycomb structure has considerably reduced kinetic energy of vehicle and shown excellent energy absorption characteristics shown by purple colour. Initial kinetic energy of vehicle was 439680J which is reduced to 351770J. Hourglass energy has also increased as compared to Aluminium ceramic materials and carbons steel material. The use of honeycomb structure has been successful in safeguarding the entire car body from damage which include crack initiation or propagation.

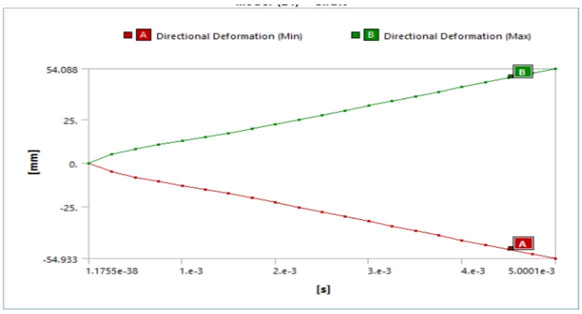

Figure 10: Deformation using honey comb structure

The deformation graph plotted in figure 5.36 above shows that increase in value with time /cycles. The maximum deformation after impact is 54.08mm which is experienced by honeycomb structure only.

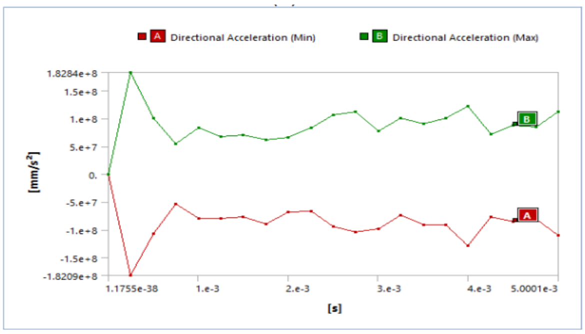

Figure 11: Deacceleration using honey comb structure

The maximum deacceleration value corresponds to honeycomb structure which experiences rapid deformation due to collision from crash barrier. The deacceleration value is zero at instant of first contact with barrier then shoots up andreduces thereafter the value shows ups and down with almost constant magnitude which goes up to last collision cycle.

5. Conclusion

Crash analysis shows that carbon steel material exhibits better material as compared to aluminum ceramic composite. But weight of carbon steel material is higher therefore building whole body with carbon steel would make it heavy and effect the mileage of vehicle. Application of honeycomb structure between front bumper and car body greatly reduces crash energy to a considerable extend. Thus, prevents car body from distortion or deformation. The optimized solution to achieve weight reduction without compromise in safety of vehicle is to use combination of carbon steel, honey comb structure and aluminum ceramic composite for different parts of vehicles.

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