

MODELING AND CRASH ANALYSIS OF CAR INTEGRAL FRAME USING FEM METHOD

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Abstract: The safety to driver and passengers is a major concern to every car manufacturer. For accomplishing this, new standards are being set for the safety of the occupant in different car scenarios like frontal head collision. The automotive chassis is the main load carrier and force taking component in all crash events. In the modern world, fuel consumption also constituted as a serious issue that has to be considered. Keeping all these constrains in consideration, a light and stiffer material should be used in chassis. In current work, integral frame chassis has been designed with honeycomb structure bumper using CATIA V5 software and was analysed using a finite element analysis (FEA) program ANSYS. The current research provides a standard finite element analysis procedure for designing off road vehicle integral frame. A multi body dynamic crash analysis is an option to understand the exact behaviour of the chassis for frontal collisions, to study the effect of speed (120 km/hr) of a vehicle, with different materials (Al 6061 body frame, Al 6061 body frame with Spring Steel honeycomb structure bumper, Al 6061 body frame with Titanium Grade 3 honeycomb structure bumper). This report includes the creation of the safe design and material mater for dynamic impact analysis under frontal head collision condition. Finally, concluded the suitable design and material based on results obtained by analysis.

Keywords: Car, Integral Chassis Frame, Honey Comb, Al6061, Titanium, Steel, Crash Analysis, CATIA V5, ANSYS.

1.

INTRODUCTION

1.1 ROLE OF CHASSIS IN AUTOMOTIVES:

Every vehicle body consists of two parts; chassis and bodywork or superstructure. The chassis is the framework of any vehicle. Its principal function is to safely carry the maximum load for all designed operating conditions. It must also absorb engine and driveline torque, endure shock loading and accommodate twisting on uneven road surfaces. The chassis receives the reaction forces of the wheels during acceleration and braking and also absorbs aerodynamic wind forces and road shocks through the suspension. So the chassis should be engineered and built to maximize payload capability and to provide versatility, durability as well as adequate performance. To achieve a satisfactory performance, the construction of a heavy vehicle chassis is the result of careful design and rigorous testing.

It should be noted that this 'ladder' type of frame construction is designed to offer good downward support for the body and payload and at the same time provide torsional flexibility, mainly in the region between the gearbox cross member and the cross member ahead of the rear suspension. This chassis flexing is necessary because a rigid frame is more likely to fail than a flexible one that can 'weave' when the vehicle is exposed to arduous conditions. A torsional flexible frame also has the advantage of decreasing the suspension



Figure 1 Crashing of Two Cars

1.2 FRAME CONSTRUCTION:

The frame construction usually consists of channel-shaped steel beams welded and fastened together. The frame (chassis) of vehicle will supports all the running gear mounted on it, it also including the engine, transmission, rear axle assembly (if rear wheel drive), and all the suspension components. The type of frame construction that is referred to as full frame, is so complete that most karts can usually be driven without the body. Terms and label of different kind of frame are as follows loading when the vehicle is on uneven surfaces.

1.2.1 INTEGRAL FRAME:

In this type of construction, there is no separate frame. It is also called unibody construction. Which means that all the assembly units are attached to the body and all the functions of the frame are carried out by the body itself. The body shell and underbody are welded into a single unit. The underbody is made of floor plates and box sections welded together. The first and biggest advantage is weight savings: Since every part of the car is key to structural integrity, there's no need for the added mass of a dedicated frame. Next, unibody designs make it much easier to protect passengers by directing energy from a crash away from the cabin.

1.2.2 PERIMETER FRAME:

This type of frame consists of welded or riveted frame members around the entire perimeter of the body as shown in Figure 2.2. The frame members will provide support underneath the sides as well as for the suspension and suspension components.

1.2.3 STUB-TYPE FRAME:

Stub-type frame shown in is a partial frame often used on unit-body vehicle, a type of vehicle construction, first used by the Budd Company of Troy, Michigan, that does not use a separate frame. The body is built strong enough to support the engine and the power train, as well as the suspension and steering system. The outside body panels are part of the structure to support the power train and suspension components. It is also called cradle.

2. PROBLEM DEFINITION

The most of the frontal crash accidents ends up with the death of the driver, as a results of this, the protection of driver and also the crew need to be ensured among the case of frontal crash accidents. The safety of driver is crucial, since driver is that the key person for keeping the control of the cars within the event of accidents so as there to safety of the passengers are getting to be ensured. Based on the technical analysis of real car head on impacts, in this paper a few modifications are introduced to ensure the passengers safety. If we take the frame of 2002 Ford Explorer heavy vehicle frame, it is manufactured with Structural Steel. When Steel structures exposed to air and water, such as bridges are susceptible to corrosion. In conditions of repeated stress and more temperatures it can suffer fatigue and cracks. These are the main problems of steel and these are compensated by inducing Al 6061 material. In addition to the normal vehicle frame, a frame made of honeycomb structure is provided at front portion of the vehicle to reduce the amount of force transferred to the passengers.

3. DESIGN CONSIDERATIONS AND PROCUDRE**3.1 MATERIAL PROPERTIES:**

Body materials should also possess sufficient strength and controlled deformations under load to absorb crash energy, yet maintain sufficient survivable space for adequate occupant protection should a crash occur. Further, the structure should be lightweight to reduce fuel consumption. The majority of mass-produced vehicle bodies over the last six decades were manufactured from stamped steel components. Manufacturers build only a few limited production and specialty vehicle bodies from composite materials or aluminum and for honeycomb structure.

MATERIAL PROPERTIES	AL6061 MATERIAL	SPRING STEEL	TITANIUM ALLOY GRADE 3
Density (Kg/mm ³)	2700	7850	4500
Modulus of Elasticity (GPa)	68.9	205	102
Poisson's Ratio	0.3	0.3	0.29
Yield Strength (MPa)	276	350	380
Ultimate Tensile Strength (MPa)	310	1100	1250

3.2 SPECIFICATIONS OF EXISTING HEAVY VEHICLE 2002 FORD EXPLORER:

The modeled car frame which is generated in CATIA, where the car was created as a life size model to accurately examine the effects of a car crash. The car model studied here is from Andrew Hickey & Shaoping Xiao International Journal of Modern Studies in Mechanical Engineering (IJMSME) Page | 2 2002 Ford Explorer. The dimensions of the car were researched online on the Ford website and translated into the design in CREO. The overall dimensions of a 2002 explorer are approximately 71"x190"x71" (W x L x H) depicts the model of the car that was generated. As mentioned before, only the frame of the explorer was generated in order to analyze how the frame structure deforms during the impact of a crash.

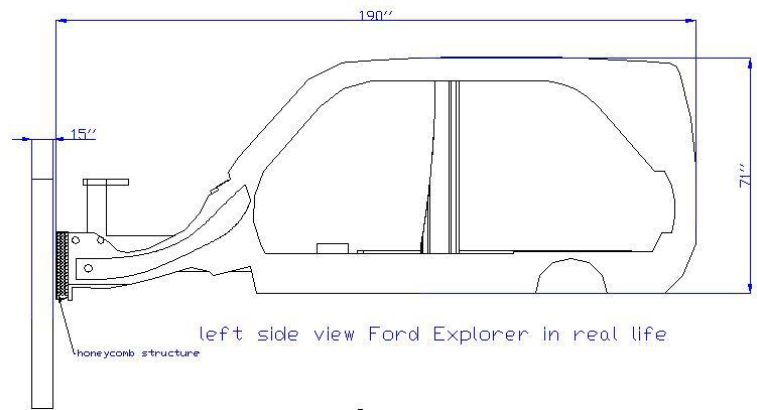


Figure 2 Dimensions of the Frame

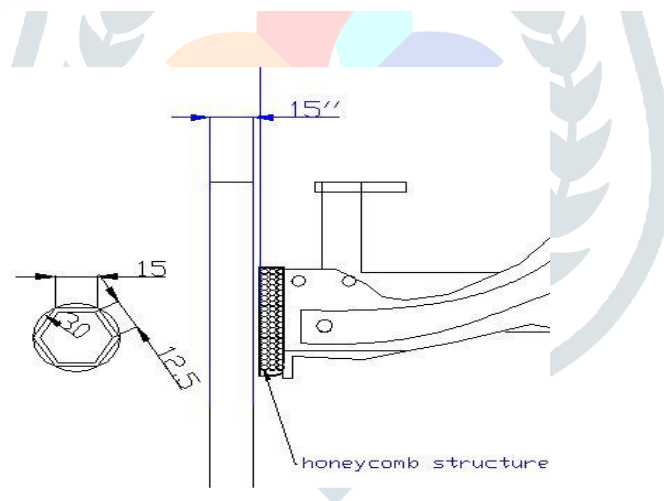
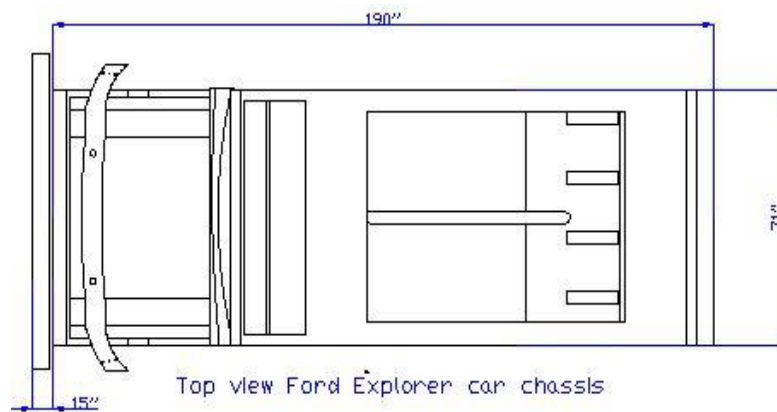


Figure 4 Honeycomb Structure Specifications

3.3 DESIGN PROCEDURE FOR CAR FRAME:

In CATIA V5, a 2D sketch (71"x190") of a car frame developed initially. This 2D sketch is developed into a solid body by using pad (71") option. A fillet of radius 200mm used to make the front portion and for the side part of body fillet of radius 150mm used. And the shell option is used for top and bottom side of the developed car body to remove unnecessary material. An offset command is used to complete the car body. By using the boss extrude option we are creating a wall in front of car body as shown in figure. Finally, a strip consists of honeycomb structure is attached to the front frame of the body.

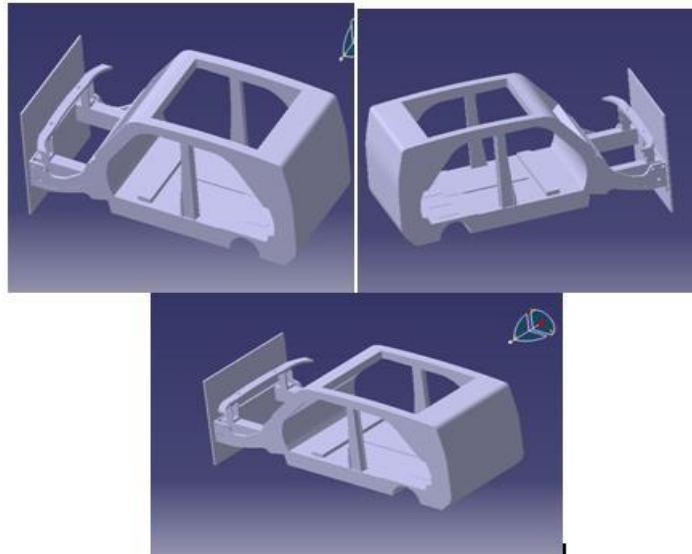


Figure 5 Modeled Car Frame

4. ANALYSIS

4.1 INTRODUCTION TO ANSYS:

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment. Also, it can work integrated with other used engineering software on desktop by adding CAD and FEA connection modules.

4.2 EXPLICIT DYNAMICS ANALYSIS:

ANSYS 14.5 delivers innovative, dramatic simulation technology advances in every major physics discipline, along with improvements in computing speed and enhancements to enabling technologies such as geometry handling, meshing and post-processing. Here the crash analysis is done in the explicit dynamic mode with the vehicle velocity of 120 km/hr. The geometry was exported as an IGS file from CATIA and then imported into ANSYS for mesh generation and FEM analysis. Upon importing the geometry, the material was set to aluminum alloy 6061, Al 6061+spring steel for honeycomb structure, Al 6061+titanium alloy for honeycomb structure of the car body. The mass of a Ford Explorer is 2458kg approx., based on the information in the Ford website. When the CATIA model of a vehicle was transferred into ANSYS, the mass was measured to be 2327.84kg, which is accurate to the real life model. A tetrahedral mesh was generated on the car as shown in Figure. At points of finer detail, there are more nodes and elements which are smaller because the geometry is more complex and thus better approximations must be made. The number of elements and nodes in the FEM model of the car are 88469 and 39045 respectively.

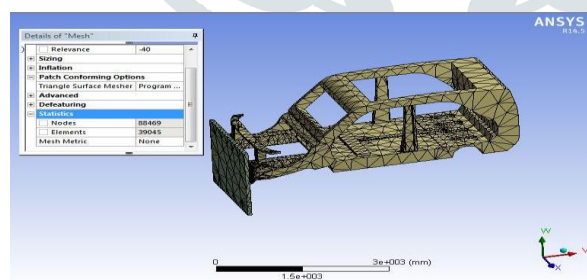


Figure 6 Meshed Model with Honeycomb Structure Bumper

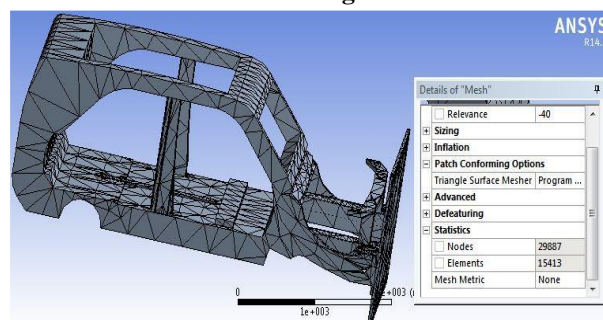


Figure 7 Meshed Model without Honeycomb Structure Bumper

4.4 BOUNDARY CONDITIONS:

The Wall in front of the vehicle frame is fixed and have zero degrees of freedom. The contact between wall and bumper is removed by deleting contact constraint. Finally, velocity of the vehicle is given in Z-Axis direction only to crash to the wall.

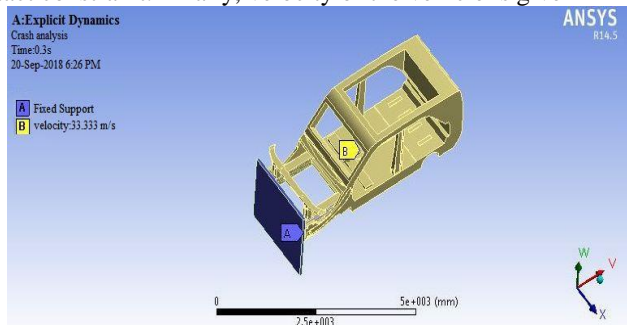


Figure 8 Boundary Conditions Velocity: 33.33m/S, Time: 0.3s

5. RESULTS AND DISCUSSION

The Vehicle frame made up of Al 6061 material without honeycomb structure bumper and with honeycomb structure bumpers (Spring Steel and Titanium Grade 3) was crashed to a fixed wall at 120 km/hr. The obtained results of the analysis are shown below.

5.1 AL 6061 FRAME WITHOUT HONEYCOMB STRUCTURE BUMPER:

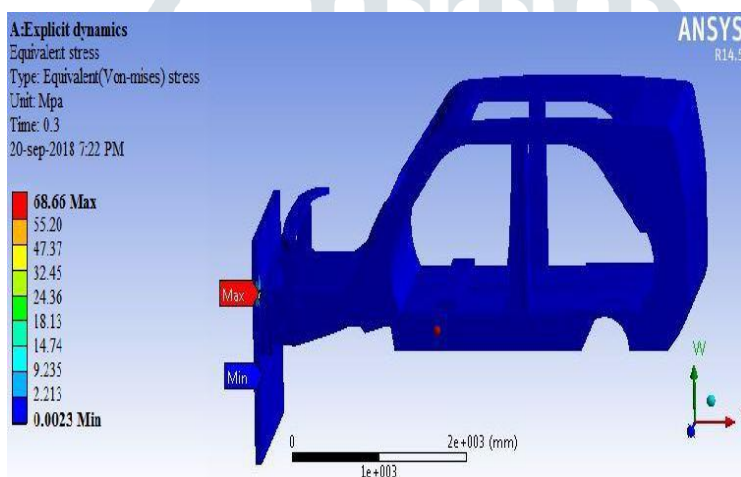


Figure 9 Von-Mises Stress of Al 6061 Frame without honeycomb Structure

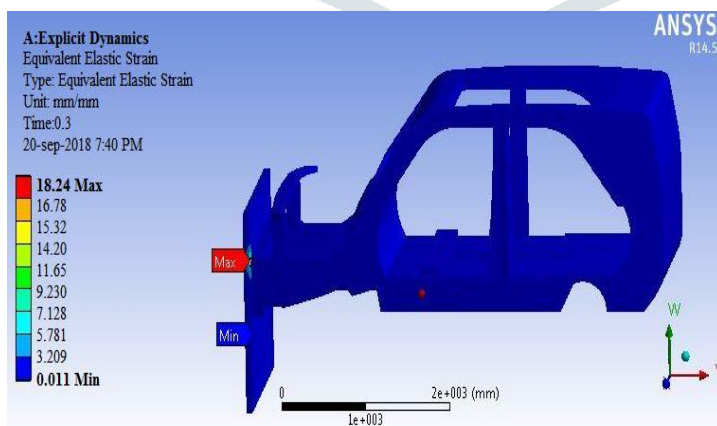


Figure 10 Strain of Al 6061 Frame without Honeycomb Structure Bumper

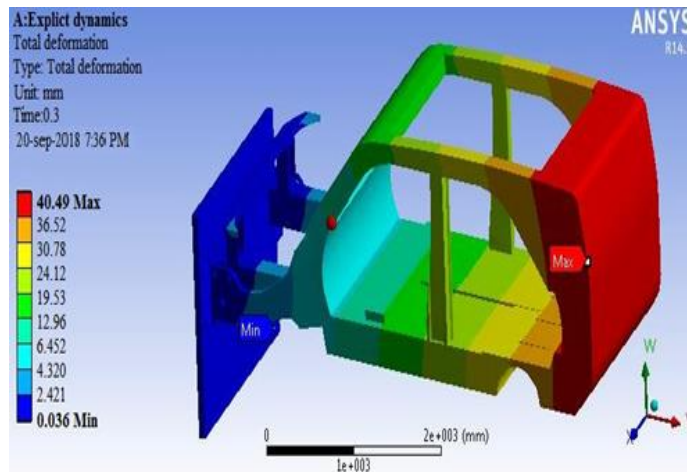


Figure 11 Total Deformation of Al 6061 Frame without honeycomb Structure Bumper

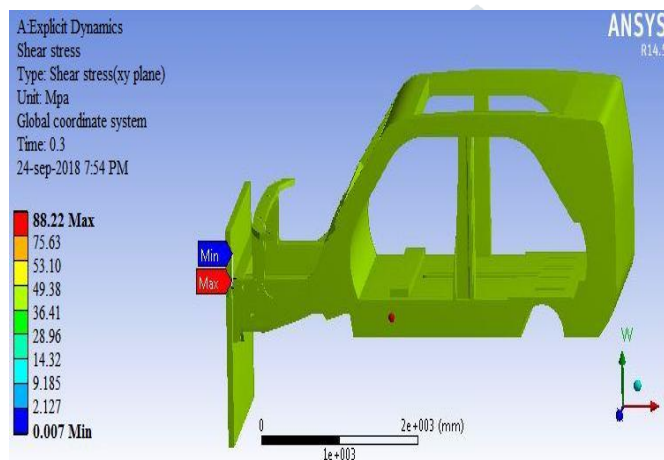


Figure 12 Shear Stress of Al 6061 Frame Without Honeycomb Structure Bumper

5.2 Al 6061 FRAME WITH SPRING STEEL HONEYCOMB STRUCTURE BUMPER:



Figure 13 Von-Mises Stress of Al 6061 Frame with Spring Steel Honeycomb Structure Bumper

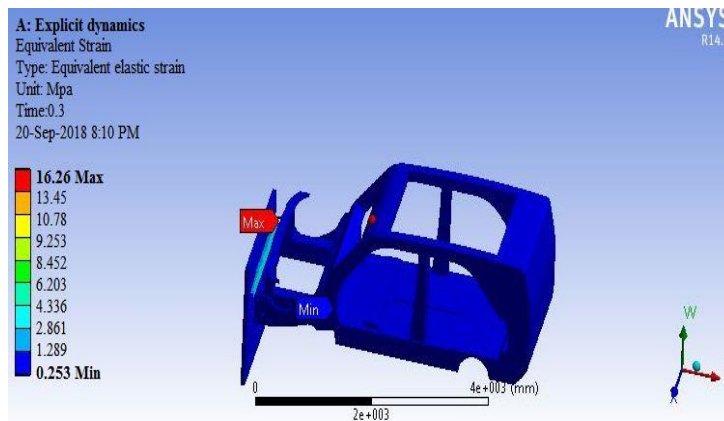


Figure 14 Strain of Al 6061 Frame with Spring Steel Honeycomb Structure Bumper

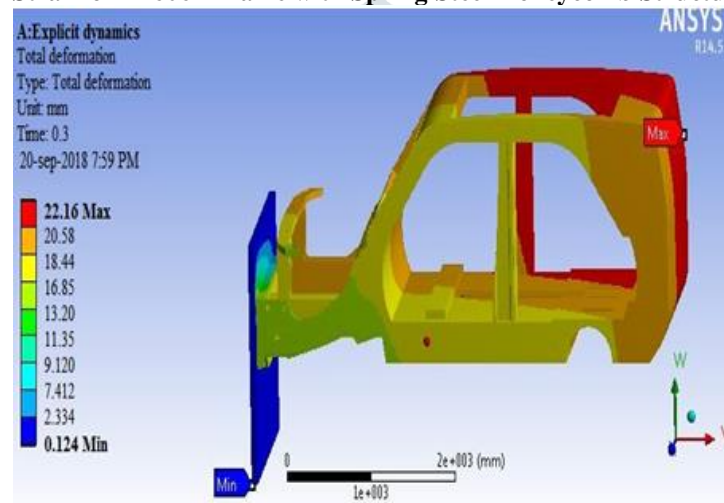


Figure 15 Total Deformation of Al 6061 Frame with Spring Steel Honeycomb Structure Bumper

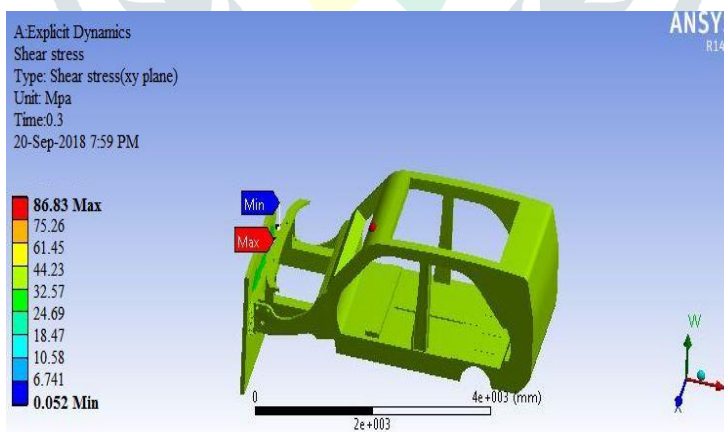


Figure 16 Shear Stress of Al 6061 Frame with Spring Steel Honeycomb Structure Bumper

5.3 AL 6061 FRAME WITH TITANIUM GRADE 3 HONEYCOMB STRUCTURE BUMPER:

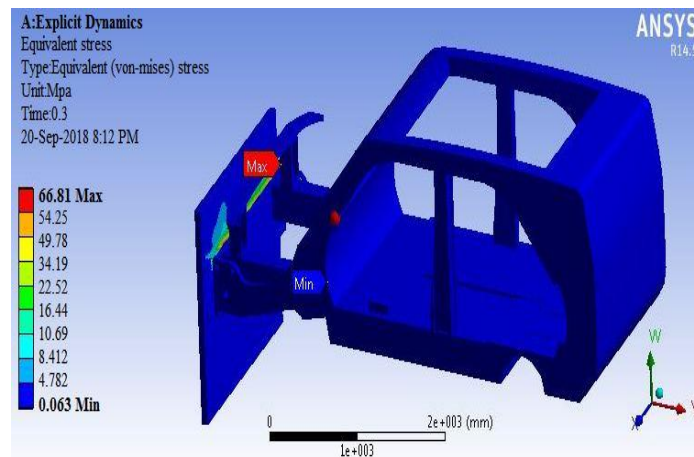


Figure17 Von-Mises Stress of Al 6061 Frame with Titanium G3 Honeycomb Structure Bumper

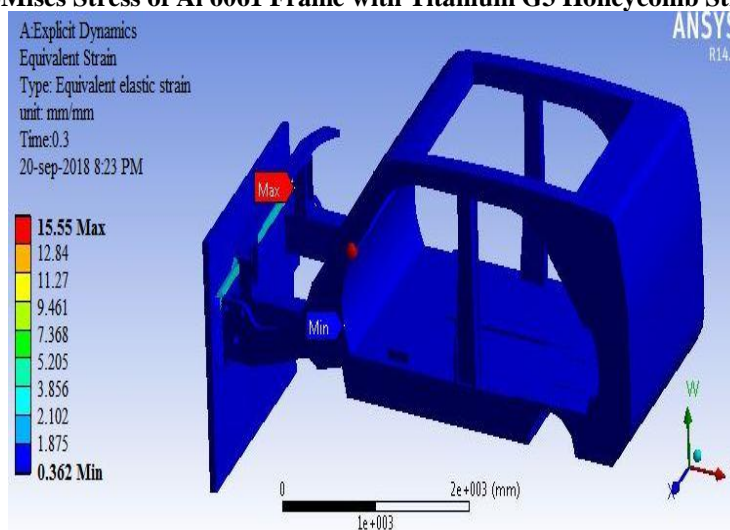


Figure 18 Strain of Al 6061 Frame with Titanium G3 Honeycomb Structure Bumper

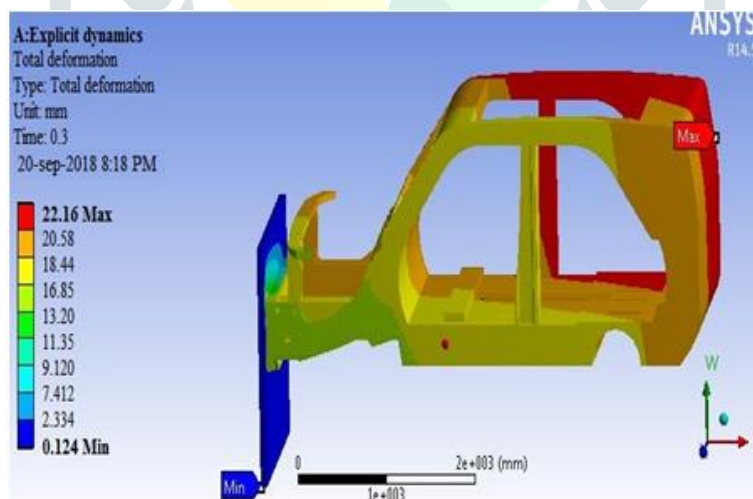


Figure 19 Total Deformation of Al 6061 Frame with Titanium G3 Honeycomb Structure Bumper

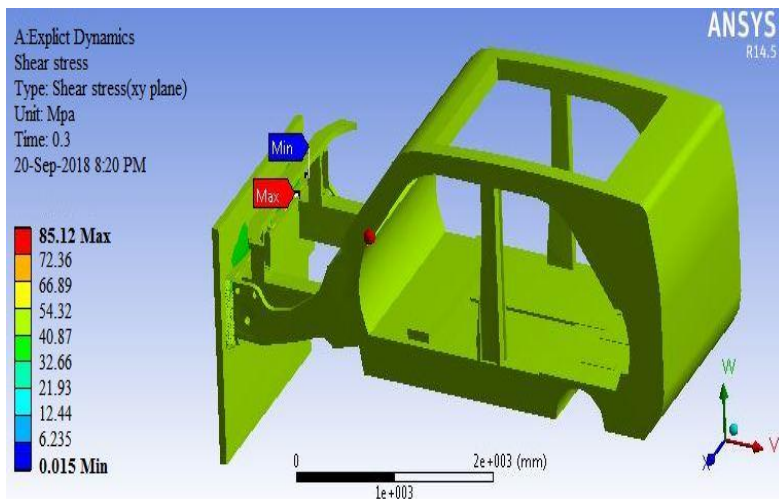
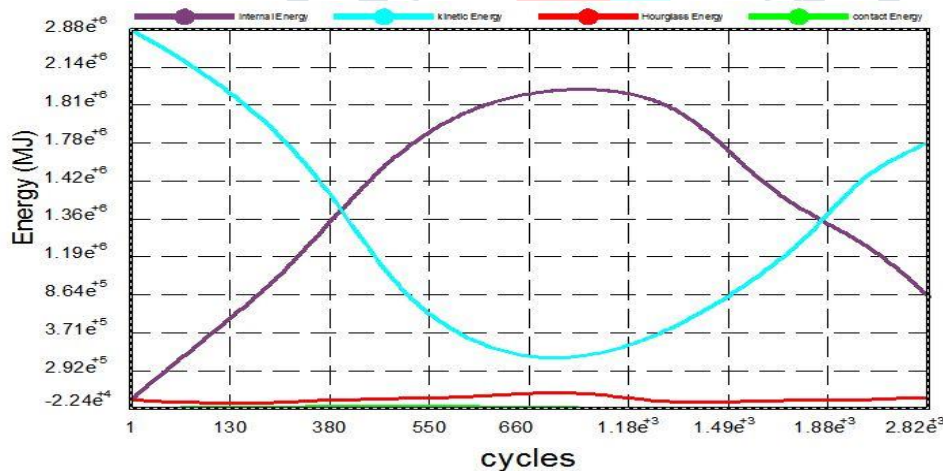


Figure 20 Shear Stress of Al 6061 Frame with Titanium G3 Honeycomb Structure Bumper

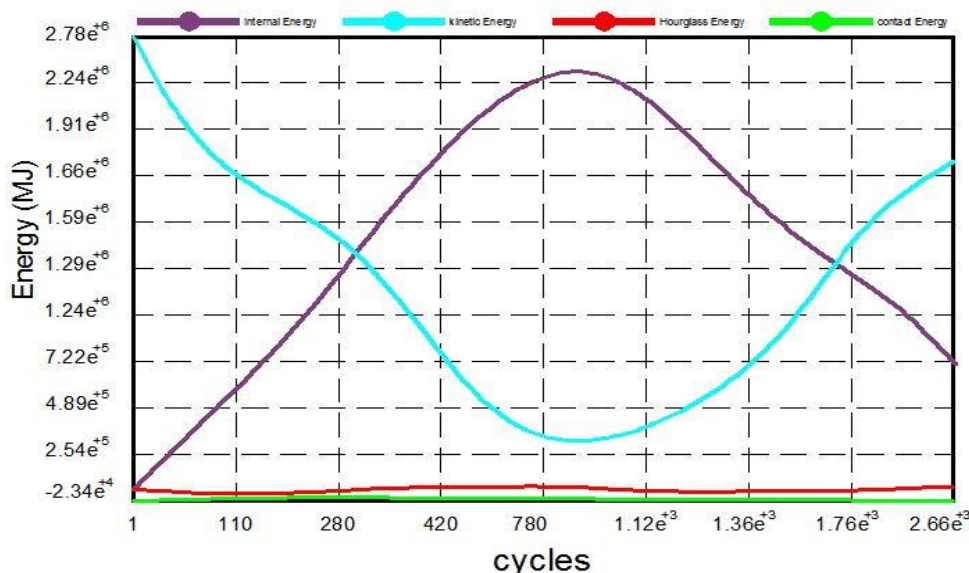
5.4 ENERGY SUMMARY CURVES:

Energy summary curves represents the total energy changes in the system which is car integral frame. Initially for Al 6061 frame without honeycomb structure, after applying boundary conditions and before car crashed into the fixed wall, its kinetic energy is maximum and no changes in its internal energy. Then after that we can observe the changes in its internal energy and kinetic energy while the frame is crashing to the wall. As the crash is proceeding the kinetic energy of the frame is reducing gradually and in opposite way the internal energy is increasing gradually as shown in energy summary curves below. The maximum point of internal energy and minimum point of kinetic energy in the curve represents the peak stage of crash. After that the we can observe the decrement of internal energy and increment of kinetic energy because of the bounce back of the frame after it impacted to the wall. Here internal energy represents the amount of force absorbed by the frame and bumper.

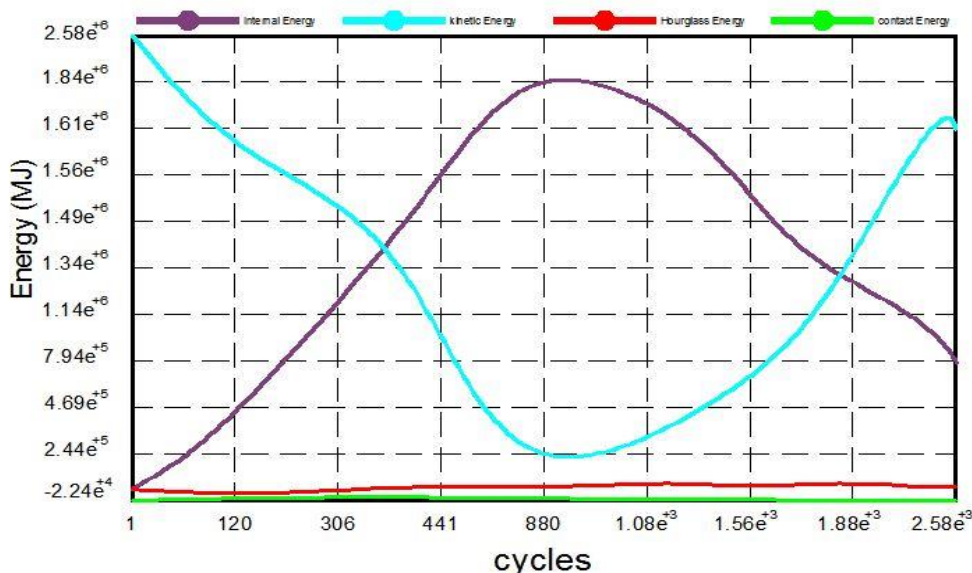
5.4.1 ENERGY SUMMARY CURVE FOR AI 6061 FRAME WITHOUT HONEYCOMB STRUCTURE BUMPER:



5.4.2 ENERGY SUMMARY CURVE FOR AI 6061 FRAME WITH SPRING STEEL HONEYCOMB STRUCTURE BUMPER:



5.4.3 ENERGY SUMMARY CURVE FOR Al 6061 FRAME WITH TITANIUM GRADE 3 HONEYCOMB STRUCTURE BUMPER:

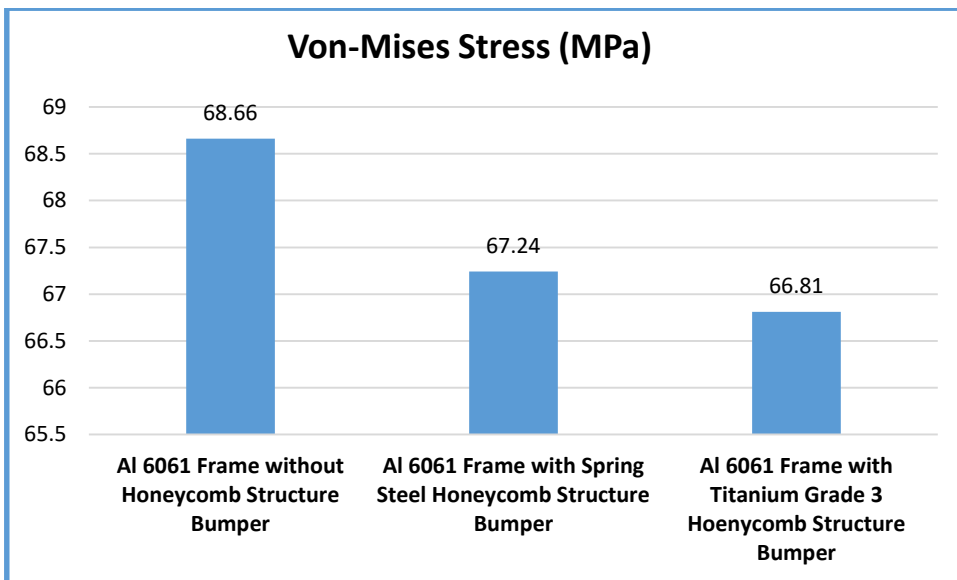


And similar manner the frames with honeycomb structure has the energy changes while they were crashed. It is clearly observed from the below energy summary curves, the frames with honeycomb structure bumper absorbed more impact energy.

6. GRAPHS

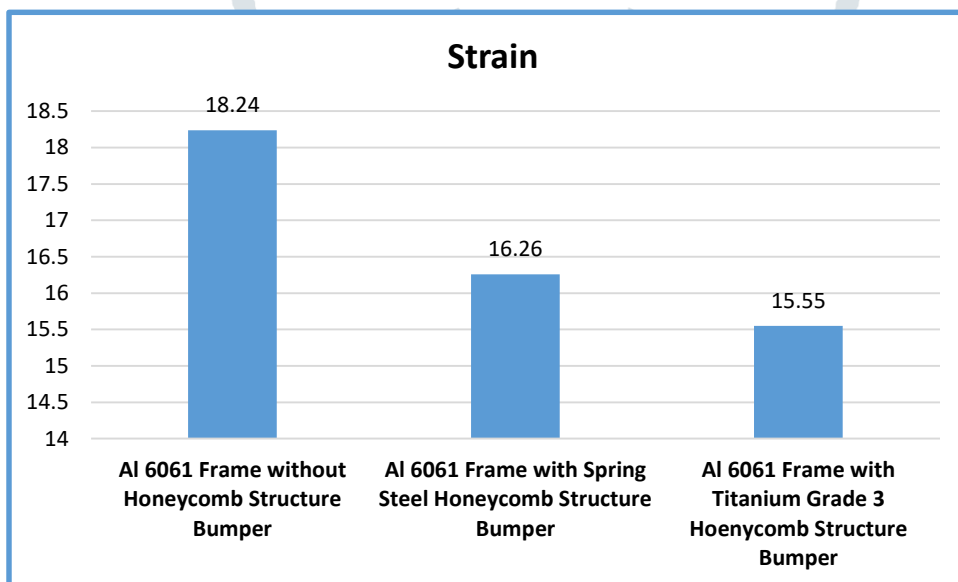
The variation of Von-Mises Stresses, Strains, Total Deformations and Shear Stresses among Al 6061 vehicle frame, Al 6061 frame with Spring Steel honeycomb structure bumper and Al 6061 frame with Titanium Grade 3 honeycomb structure bumper when they were impacted to a stationary rigid wall with 120km/hr. is illustrated below.

6.1 VON-MISES STRESS GRAPH



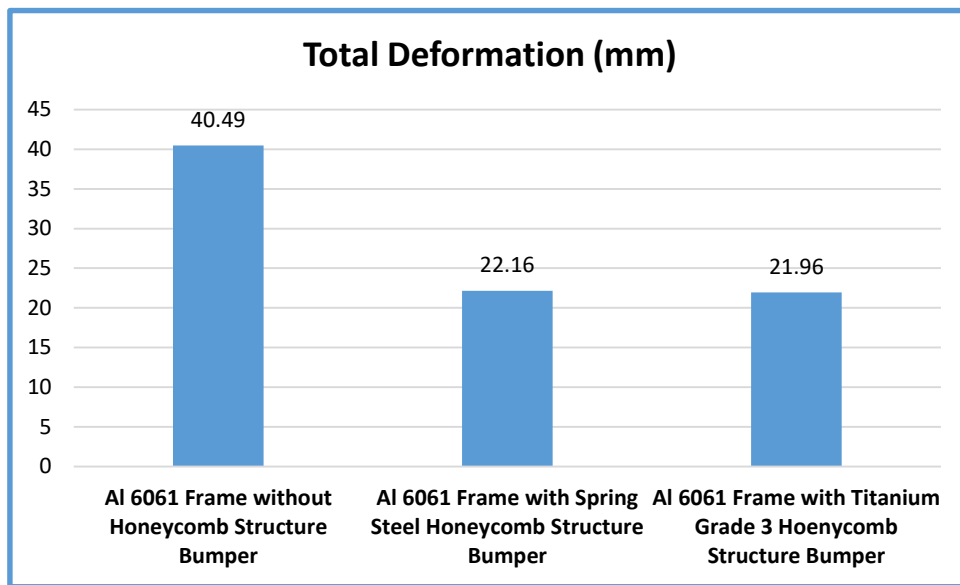
Graph 1 Von-Mises Stress Graph

6.2 STRAIN GRAPH:



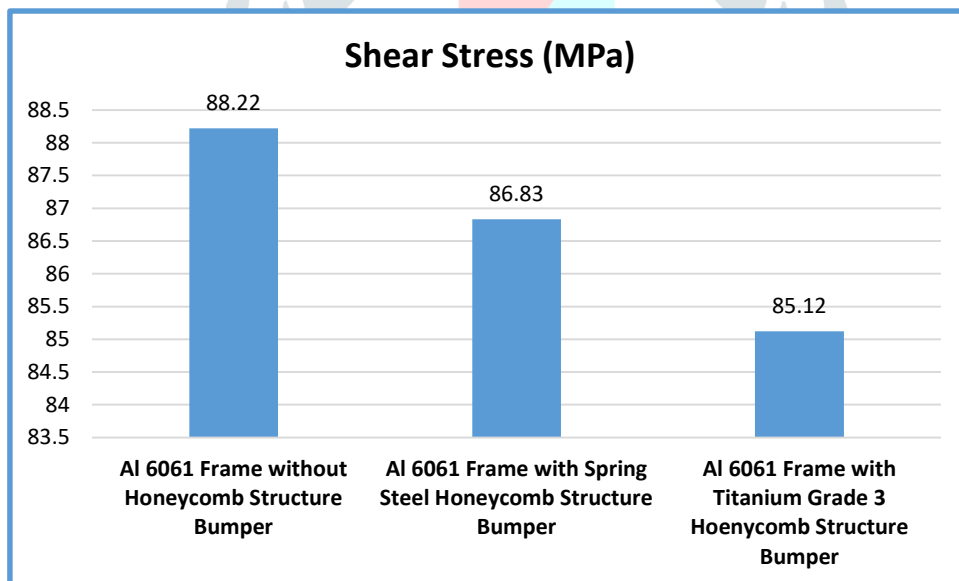
Graph 2 Strain Graph

6.3 TOTAL DEFORMATION GRAPH:



Graph 3 Total Deformation Graph

6.4 SHEAR STRESS GRAPH:



Graph 4 Shear Stress Graph

7. CONCLUSIONS

This Study was performed to determine the reliability of honeycomb structure with suitable material of vehicle body frame and bumper when it was crashed. The Al 6061 frame with Spring Steel and Titanium Grade 3 honeycomb structure bumpers and the AL6061 frame without honeycomb structure bumper were crash impact analysed at 120 km/hr speed of the car.

The following conclusions are drawn, based on the results obtained by analysis:

- The installation of honeycomb structure to the vehicle frame shows better results, cause of better impact absorption than the normal frame without honeycomb structure.

• From Energy Summary Curve, the vehicle frame with Spring Steel honeycomb structure bumper shows good energy absorption than the other frames but it has higher stress values when compared with Al 6061 frame with Titanium Grade 3 honeycomb structure bumper.

• Based on Overall Explicit Dynamic Analysis, the comparison of crashworthiness among Al 6061 vehicle frame, Al 6061 frame with Spring Steel honeycomb structure bumper and Al 6061 frame with Titanium Grade 3 honeycomb structure bumper indicates Titanium Grade 3 honeycomb structure bumper have good impact energy absorption, less deformation and lesser stresses induced.

Finally, it is concluded that Al 6061 vehicle frame with Titanium Grade 3 honeycomb structure bumper is recommended from this study.

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