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CRASHWORTHINESS OF THE VEHICLE BODY ON MATERIAL OPTIMIZATION USING AUTODYN SOLVER

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Abstract— **This research paper describes about the relevance of the crash analysis required for the safety of the automobile during the time of the crash. During the crash of the automobile, some parts in the front of an automobile body will have plastic deformation and absorb a lot of energy. Hence it is necessary to check the car structure for its crash ability so that safety is achieved together with fuel economy. Crash Simulation is a virtual restoration of a crash test of a destructive car by using simulation software in order to examine the level of safety of the car and its occupants. This paper was an effort to analyze the crashworthiness of the vehicle for different feasible materials, which are not only light weight but also have high energy absorption capacity while undergoing plastic deformation. A simple finite model of a car is developed in ANSYS and it is solved for full frontal impact in ANSYS explicit code. Computational simulations and various results are plotted and analyzed. There are various test configurations. We have limited our analysis to full frontal impact with a rigid wall at a speed of 120mph (33.33 m/s). It was noted that composite materials could be used more effectively for light-weightiness other than metallic materials without affecting the necessary impact energy absorbing capacity of the car body. Since composite materials and metallic materials absorb approximately the same energy during a car crash we conclude that composite materials can be used for light-weightiness in automobiles.**

Keywords— **Computer Simulation, Crashworthiness, Explicit Dynamics Code, AUTO DYN SOLVER, Impact Energy, Sensitivity**

I. INTRODUCTION:

For designing a car body two important aspects are considered in the present generation aspect-car body light weighting and the crash worthiness. The purpose of this consideration involves many assumptions but the primary factor is that vehicle when designed should be able to provide the adequate protection to the driver and passengers in a catastrophe. So to protect the occupants of a car, many new perceptible safety features such as airbags, anti-lock braking system and traction control are being used and new innovations are also taking place on these grounds but a less tangible feature that is considered on the terms of safety conditions and cannot be easily be seen by drivers and passengers is the crash response behaviour. During an automobile crash, some parts in the front of an automobile body will have plastic deformation and absorb a lot of energy. Structural members of the vehicle are designed to increase this energy absorption capacity and thus to enhance the safety and reliability of the vehicle. As the dynamic behaviour and static behaviour of the mechanical or the structural member is different, the crashworthiness has to be assessed by impact analysis. Hence it is necessary to check the car structure for its crash ability for safety measures along with fuel economy. There are two ways by which the safety features can be achieved:
1. Performing an actual crash test.
2. Simulating the crash in some FE code like ANSYS-LS OR AUTO DYN SOLVER

With the development of technology and innovations in field of automobile, people are demanding for more safety features in the automobiles that provide relatively passive safety and fuel economy, thus increasing the importance of the improvement of automobile structure crashworthiness and light weighting degree. A major step on considering the required improvements for the automobile structure is the development of vehicles that would consume less fossil fuel, thus compromising the safety of occupant resulting from the reduced weight of the automobile. Crashworthiness is an engineering term used to define the ability of a vehicle's structure to protect its occupants during an impact. The structure must fulfill the following requirements to be crashworthy-

- The structure must absorb as much impact energy as possible by plastically deforming in a controllable manner to minimize the remaining impact energy which can then be handled by the restraint system[1].
- The structure must preserve at least the minimum survival space to keep injury and fatality levels as low as possible[1].

Crashworthiness improvement can be approached in two ways: (1) Geometry optimization for crashworthiness and (2) Material optimization for crashworthiness[1]. This paper focuses on material optimization for crashworthiness. As we can see that in the present world of automobile industries, the automobile manufacturers are increasingly using lightweight materials to reduce weight; these include plastics, composites, aluminium, magnesium and new types of high strength steels. Thus a higher level deceleration will be experienced by the light weight car during a crash test when compared to its heavier opponent, as deceleration is considered as the ratio of crush load and mass. So, only those lightweight materials which possess high stiffness values can be considered as a replacement in case of heavy weight materials. Many of these materials have properties of limited strength or ductility. Further considerations also include taking rupture as serious occurrence of possibility during the impact of the crash. Furthermore, combining of these material compounds also presents a source of potential failure and when considered both potential failure and material combination will have serious consequences on vehicle crashworthiness and should be predicted to the possible extent. In this paper, (1) Steel V-250 (2) Aluminium Alloy (3) Magnesium Alloy, (4) Polycarbonate are considered for crashworthiness.

II. GEOMETRIC MODELING AND MESHING:

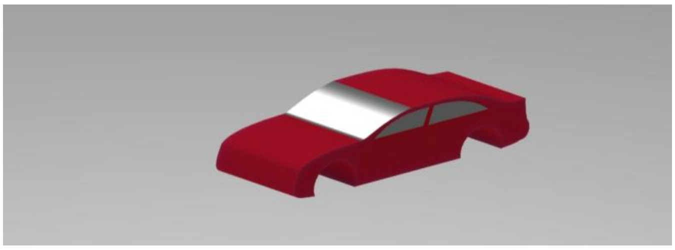

Figure-1:- Showing the solid structure design of modeled car**.**

The structural body panel required to measure the crashworthiness is designed using the modeling software solid works 2015. A set of equally spaced cross sections are also generated along the entire length of the structural body panel. The model is shown in the Figure 1.The designed body panel as shown in figure acts as a protective layer for the occupants of the vehicle. The frontal body panel structure behaves as the crumpling zone which absorbs the energy of impact during a crash. So, the body panel is the prime concern for the safety of the occupants. The designed model is imported to explicit dynamic analysis solver (ANSYS AUTO DYN SOLVER) for simulation. The wall against which the shell is subjected to a crash is modeled in Ansys workbench 14.0 Design Modeler. The Figure 2 shows the wall model with the body panel. The information of system is

Physics - Structural
Analysis – ANSYS Explicit dynamics
Solver – AUTODYN.

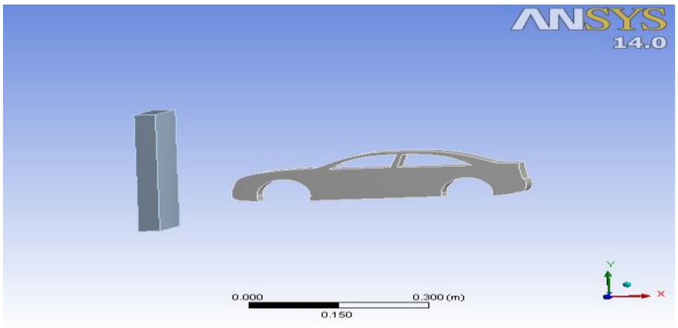

Figure-2:- Showing the structural body panel along with the wall.

A. MESHING SETTINGS:

The meshing of whole model is done by using ANSYS fine mesh feature in ANSYS workbench mesh 14.0.

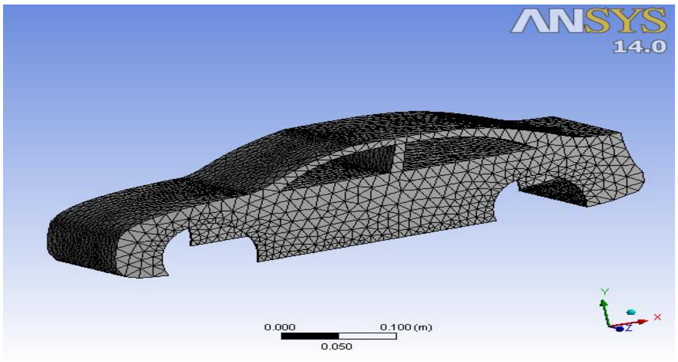

Figure-3:- Showing the meshing on the structural body panel.

Advance size function- Coarse.
Relevance centre – fine.
Minimum edge length – 3.e-003m
Translation ratio – 0.272
Maximum layer – 5
Nodes- 6309
Elements – 18150

B. ANALYSIS SETTINGS:

The type preference is kept as high velocity because the objective is to simulate a high velocity crash. Since, most of the explicit dynamics problems require more than 105 cycles, thus, the number of computational cycles for this crash analysis is set as maximum no. of cycles 1e+07. Due to computational capability and computational time limitations, all the crash simulations are done for an impact time of 1 ms. Maximum energy error for the solver is restricted to 0.1.

C. BOUNDARY CONDITIONS:

The stiffness behaviour of the wall is set as RIGID. The stiffness behaviour of the model is set as FLEXIBLE. The simulation is done to analyze a high velocity crash test. So, the body panel is given an initial velocity of 33.33 m/s in negative X-direction as per the required.

D. MATERIAL PROPERTIES:

Important material properties of steel V-250, Aluminium alloy, Magnesium alloy, Polycarbonate.

Table-1:- Material properties of the four materials used for analysis

Material properties	**STEEL V-250**	**Aluminium alloy**	**Magnesium alloy**	**Poly Carbonate**
Density (kg m^3)	2770 kg m^3	1800	8129	1200
Young‘s modulus(pa)	7.1e+10	4.5e+10	190gpa	-
Poisson’s ratio	0.33	0.35	-	-
Bulk modulus(pa)	6.9608e+10	5e+10	-	-
Shear modulus(pa)	2.6692e+10	1.6667E+10	7.18E+10	1e+09
Specific heat (jkg^-1c^-1)	875	1024	408	-

III. ASSUMPTIONS:

The following assumptions are made in the simulation of a crash –

- The Structural body panel is approximated to be the whole vehicle.
- The wall is assumed to be a rigid support.
- No friction is considered at the base of structural body panel.
- Effect of braking and deceleration is neglected just before the impact of the crash.
- The structural body panel is subjected to an initial velocity and constant acceleration.
- Air drag is neglected on the structural body panel’s surface.

IV. RESULTS AND DISCUSSIONS:

As per considered assumptions and required dimensional consideration, the material optimization for crashworthiness of the frontal body of a car when crashed against the wall has been carried out through analysis by appropriate FE software and ANSYS software

Material properties: The crash simulation was first performed with typical structural steel properties. Second an aluminium alloy was selected to re-place the steel structure. Next, magnesium alloy was chosen to replace the aluminium alloy structure. Finally, polycarbonate material was selected to replace magnesium alloy composite.

During an impact of the car body with the wall indulging in a crash, the crash structure dissipates the energy of the impact while ensuring that the occupants are not subjected to excessive acceleration and the survival zone remains intact within the car that is the crash structure does not ingress too far into the vehicle. The capacity of this dissipated energy is different for the different materials and as we have considered the four different materials for crash worthiness, each shows different capability properties out of which polycarbonate finds to be the best, but in this paper we have not considered the energy dissipation property instead we have considered different mechanical properties during the impact of the crash on which the crashworthiness of the structure body could be considered. The results of the energy dissipation property were taken from other reference papers. So when car body gets crashed against the wall then mechanical properties such as the equivalent stress, equivalent strain and total deformation can also be considered from which the crashworthiness could be considered. The results of the impact of the crash on the basis of the mechanical properties for the four different materials are shown below.

RESULTS OF STEEL V-250:

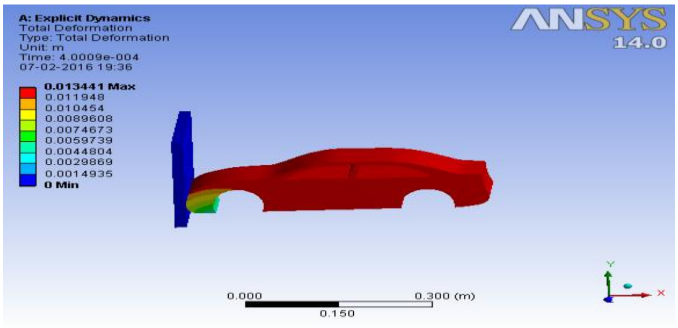

Figure-3.1:- Showing the results of Steel V-250 in case of Total Deformation.

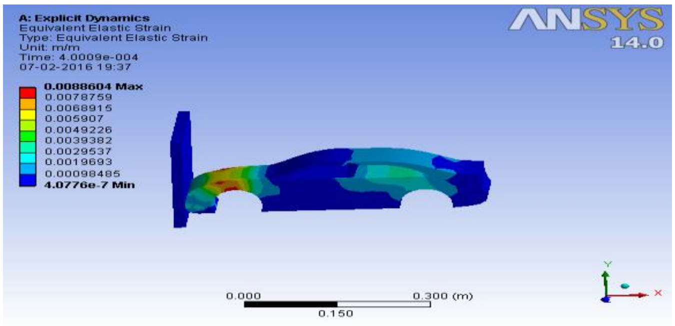

Figure-3.2:-Showing the results of Steel V-250 in case of Elastic Strain.

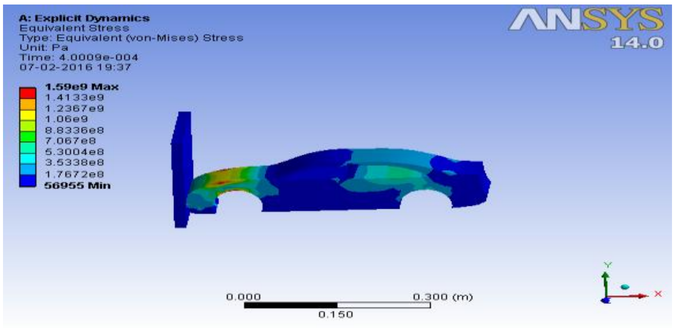

Figure-3.3:- Showing the results of Steel V-250 in case of Equivalent Stress.

RESULTS OF ALUMINIUM ALLOY:

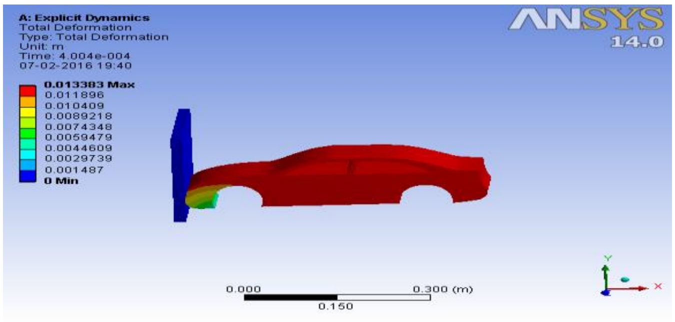

Figure-4.1:- Showing the results of Aluminium alloy in case of Total Deformation.

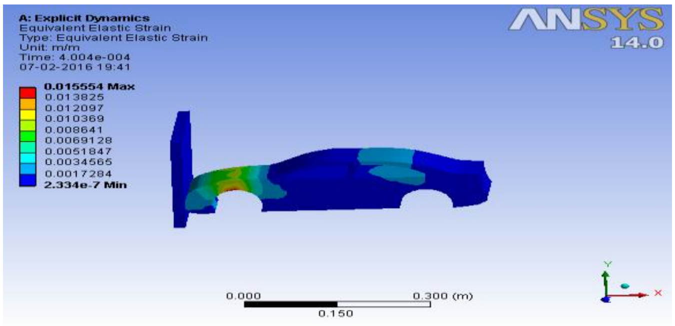

Figure-4.2:-Showing the results of Aluminium alloy in case of Elastic Strain.

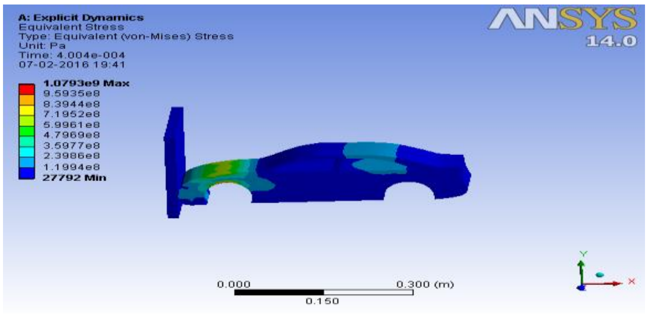

Figure-4.3:-Showing the results of Aluminium alloy in case of Equivalent Stress.

RESULTS OF MAGNESIUM ALLOY MATERIAL:

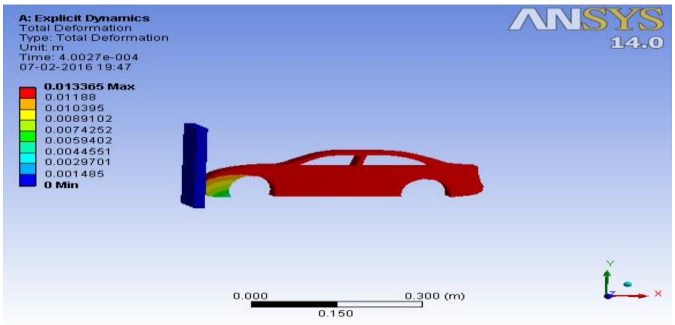

Figure-5.1:- Showing the results of Magnesium alloy in case of Total Deformation

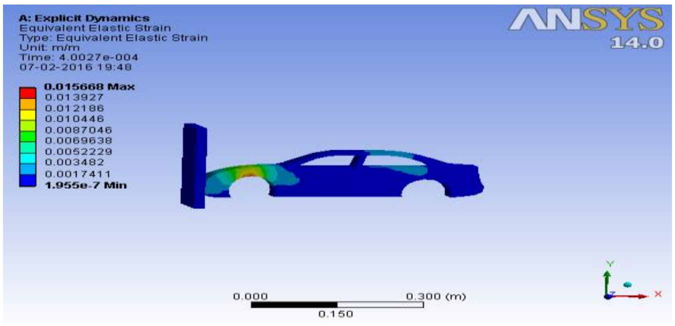

Figure-5.2:- Showing the results of Magnesium alloy in case of Elastic Strain.

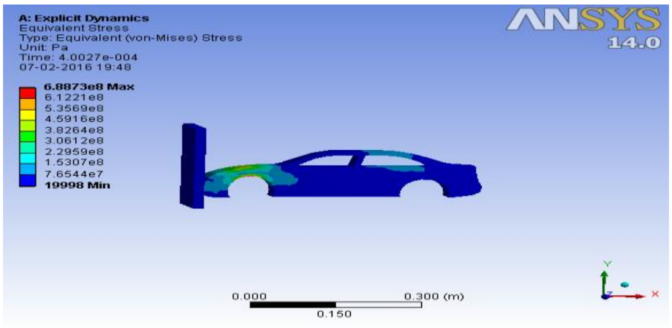

Figure-5.3:- Showing the results of Magnesium alloy in case of Equivalent Stress.

RESULTS OF POLYCARBONATE MATERIAL:

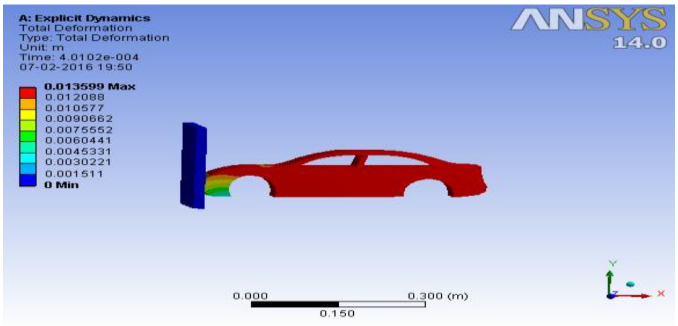

Figure-6.1:- Showing the results of Polycarbonate in case of Total Deformation.

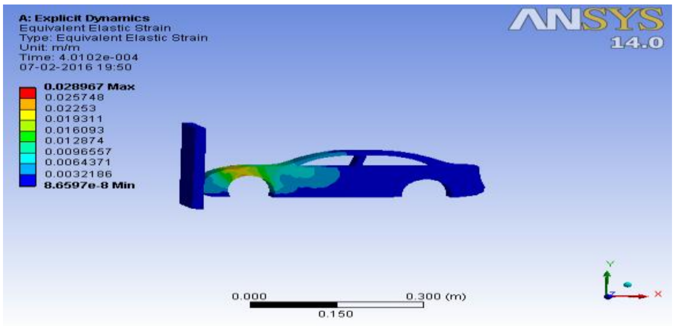

Figure-6.2:- Showing the results of Polycarbonate in case of Elastic Strain.

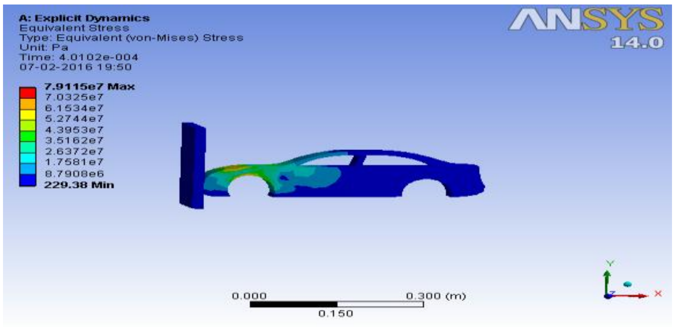

Figure-6.3:- Showing the results of Polycarbonate in case of Equivalent Stress.

Table-2:-Showing summary of results of different materials

Material	**Equivalent Elastic strain**		**Equivalent Stress**		**Total Deformation**	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**
Steel V-	4.0776	0.0088	5695	1.59	0	0.013

250	e^{-7}	604	5	e^{9}		441
Aluminium Alloy	2.334e^{-7}	0.015554	27792	1.0793e^{9}	0	0.013383
Magnesium Alloy	1.955e^{-7}	0.015668	19998	6.8873e^{8}	0	0.013365
Polycarbonate	8.657e^{-8}	0.028967	229.38	7.9115e^{7}	0	0.013599

In the above table we can see the summary of the results of mechanical properties occurred in the impact of the crash of car body which is made up of four considered materials based on which crashworthiness of body is considered. From the results we can see that the in case of Steel V-250, the elastic strain is found to be the least among the other materials while equivalent stress is highest and total deformation is of similar value with little difference when compared with others. Similarly is in the case of aluminium alloy and magnesium alloy where the elastic strain is higher than the steel while the equivalent stress is compared to be less than the steel and the total deformation is found to be little higher than the steel. Out of the aluminium alloy and magnesium alloy, in total deformation the value of the aluminium alloy is the highest. Now coming to the case of polycarbonate, we can see that elastic strain value is the highest or the max value when compared with the other three and the equivalent stress value is the least out of the three materials making it the light in weight. Also the total deformation the material can withstand is found to be the highest out of the other three materials thus making it a suitable material among the three.

V. CONCLUDING REMARKS:

Although the structure modelled was a fairly simple one, the AN-SYS crash simulations show that Steel V-250, Aluminium alloy, Magnesium alloy, Polycarbonate absorb almost similar amount of energy when these materials are used as for making bumper of a car. A good measure of crashworthiness basically is the specific energy absorbed by the structure. But the measure of crashworthiness can also be calculated by involving different mechanical properties occurring during the impact of the crash that has been shown in this paper and are hence concluded that Steel V-250 has the highest value of equivalent stress among the three while the polycarbonate has the least value. In case of equivalent stress polycarbonate is found to be the highest value in case of elastic strain while the structural steel has the least value. In case total deformation we can see that all the material have same range of value with little difference out of which polycarbonate is the highest. Thus based on the results of the value of materials on basis of mechanical properties during the impact of the crash, the polycarbonate is best suitable material for crashworthiness, since it can withstand high range of deformation and is light in weight than the other materials and also in case of energy absorption the polycarbonate is found to be the best which has been considered by referring other papers.

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