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ROOF CRUSH SIMULATION OF PASSENGER CAR FOR IMPROVING OCCUPANT SAFETY IN CABIN

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Abstract - *Rollover accidents of a car are the most occurring accidents we see in our daily lives. The passenger experience major injuries like neck, head and spine injuries. So to reduce the injuries of a passenger from major fatalities is to provide safety in the car. The safety is provided by seat belts as well as airbags during accidents. The passenger must have sufficient space for survival in the car during accidents. The roof of the car must have high strength to resist the crush force to avail the passenger space for survival. Therefore in my project, I have carried out roof crush test using FMVSS standards in LS dyna software. I have used Hypermesh software to mesh the model and to apply boundary conditions to it. And the rigid plate is used to crush the car roof as specified by FMVSS standards. The rigid plate is oriented on the car roof as specified by IIHS (Insurance institute of highway safety). And an alternate material is used to the car roof structure to the baseline model to check the crashworthiness of new material. The outcome of test results have shown that the new material has more strength to weight ratio (SWR) compared to baseline model. Hence we can say that the roof with new material is more crashworthy.*

1. INTRODUCTION

The rapid development in technology demands engineering design to be more competitive and creative enough to meet the challenging customer needs in automobile field. Nowadays, careful attention in meeting precision, modularity and eco friendly products in designing are gaining importance. The demand for new vehicles is increasing at an exponential rate with the increase in buying power of customers.

Transportation is identified as the major sector contributor to the accidents and the CO_2 emissions. The greatest challenges faced by the automotive industry are been to provide safer vehicles with high fuel efficiency at competitive cost. Automotive design with economy, safety and aesthetics has been a great challenge to design engineers. But along with these advantages of light weight, more fuel efficiency and corrosion resistance, safety is very important criteria for vehicle manufacturers, as vehicle rollover crashes are frequent accidents worldwide. Vehicle rollover crashes are causing many fatalities like severe neck, head and spine injuries around the world. Therefore, passenger safety is an important concern in the automotive industry, and this is gradually growing every year. Guaranteeing the physical safety of passengers is not only a marketing consideration, but has also become an obligation stipulated by international standards that are now in place in several countries, as well as a requirement by governmental organizations. According to a survey of the literature regarding rollover accidents, passengers can be ejected, partially ejected, or become the victims of roof intrusion, all of which may be fatal. For this reason, the "Federal Motors Vehicle Safety Standards enacted Regulation No. 216" is the standard for the vehicle Strength of Superstructure to protect the occupants during rollover accidents through the provision of space for survival. Thus, vehicle design must strictly satisfy regulatory standards, while the structural design must carry the required load with the minimum component weight without failure. Therefore, rollovers are simulated using the "finite element analysis" (FEA) program and researchers have found good agreement between the tests and the simulation analysis.

1.1 Automotive Vehicle Safety Standards

Earlier, in February 2009, the IIHS (Insurance Institute of Highway Safety) announced a new rating system based around roof crush testing. The rating is must to ensure the safety of the passengers during rollover accident of car. Although their procedure is similar to that of FMVSS 216 (Federal Motor Vehicle Safety Standards), which is the American safety standards used for roof crushing test. The requirement of this test set up is to earn the highest rating of 4.0 times the vehicle's weight. The rating is 4, specified by both IIHS and FMVSS to increase the safety of the passengers. This paper overview the IIHS test procedure and present data from both the FMVSS 216 and IIHS test protocols. Readers of this paper will gain a much broader understanding of roof crush testing and the impact it will have on future vehicle designs.

1.2 Roof Crush Resistance Test

A rectangular block measuring 30 inches wide and 72 inches long is used to apply the load on car roof with 1.5 times the unloaded vehicle weight with different angle inclination to rectangular block as indicated in below figure. And the moving distance of roof structure must be less than 127mm or 5 inches as per FMVSS standards.

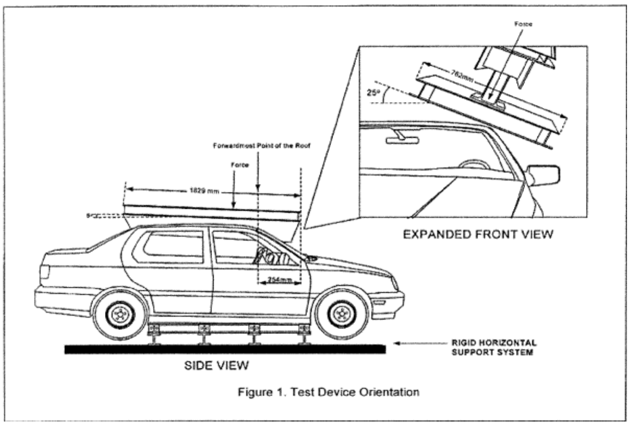
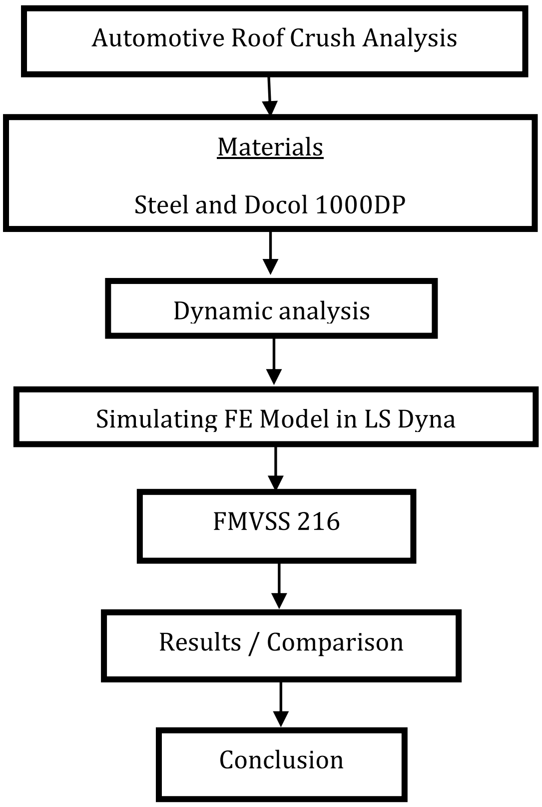


Figure 1: Orientation of the flat rigid rectangular block

1.3 Problem Statement

To suggest alternative material to the traditional sheet metal (CRCA rolled sheets) by utilizing CAD/CAM/CAE practices for addressing the Design and analysis phase and considering the Vehicle Manufacturers to provide effective solution by offering a competitive advantages while complying with the relevant standards in Automotive Engineering.

1.4 Methodology



1.5 Objective

The main objective of this project is to protect passengers during car rollover accidents. The reduction of mass of the car roof helps in reducing the overall mass to improve the efficiency of the car.

The work flow of this project work is as follows,

1. Identifying alternative material to the traditional sheet metal (CRCA rolled sheets) to reduce weight.
2. Suggest alternatives over Material and/or Process for mass manufacturing
3. Utilizing CAD/CAM/CAE practices for addressing the Design and Analysis phase
4. The roof to be compliant with the relevant standards in Automotive Engineering

2. GEOMETRIC MODELING

To carry out CAE analysis of any component, the solid model of the same is essential. It is also called body in white. Here the detailed description of CAD model discussed. Automotive design with economy, safety and aesthetics has been a great challenge to design engineers. The safety of the passengers during vehicle roll over can be ensured by using good strength roof. At the same time these automotive parts should not be massive in terms of weight contributing to the increase in total the weight of the vehicle. The CAD model is shown in figure below.

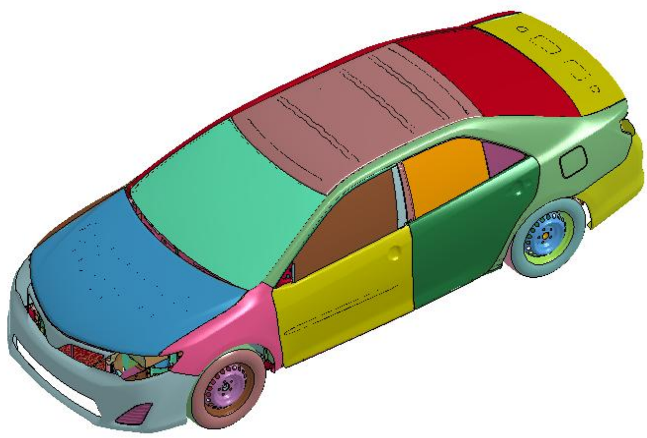


Figure 2: CAD Model

3. MESHED MODEL

The assembled SOLID WORK model is exported to Hypermesh in .igs format. Meshing of CAD model is carried out. Different car components are meshed using shell element quad4 with an average element size of 10mm. Triangular elements tria3 are also allowed in the finite element mesh in order to allow good mesh quality.

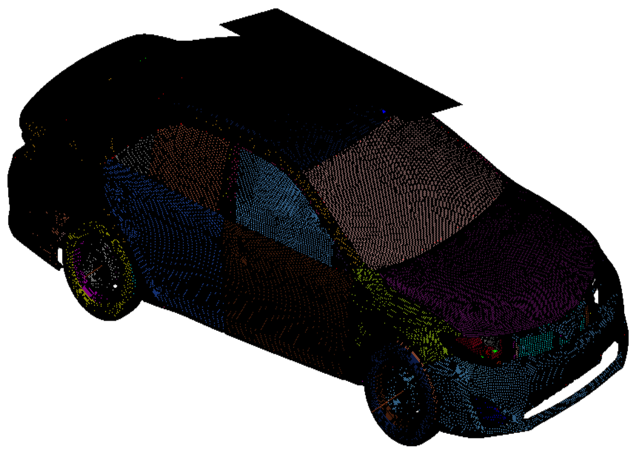


Figure 3: Meshed Model

4. SELECTION OF MATERIALS AND PROPERTIES

The different materials used to analyses this car model are Low carbon steel and Docol 1000DP. The different properties which are used in this analysis are mentioned in table below

Table 1: Material Properties

Material description	Young's modulus (E) GPa	Yield strength (S) MPa	Poisson's ratio	Density Ton/mm^3
steel	210	360	0.3	$7.850*10^{-9}$
Docol 1000DP	210	700	0.3	$7.150*10^{-9}$

5. BOUNDARY CONDITIONS

In this project boundary conditions are applied to the model. The car roof is applied with a force of 4 times the vehicle weight. And the plate shall not move faster than 0.5 inch/sec. The duration of the test shall not exceed 120 seconds. All 4 tires of the car are constrained and displacement is given to rigid plate on the roof of the car as shown in below figure 4.4. The orientation of the plate should be such that the initial contact is about 10 inches with the car roof in the longitudinal axis. The lower surface of the plate should always maintain tangential contact with the roof surface of the car.

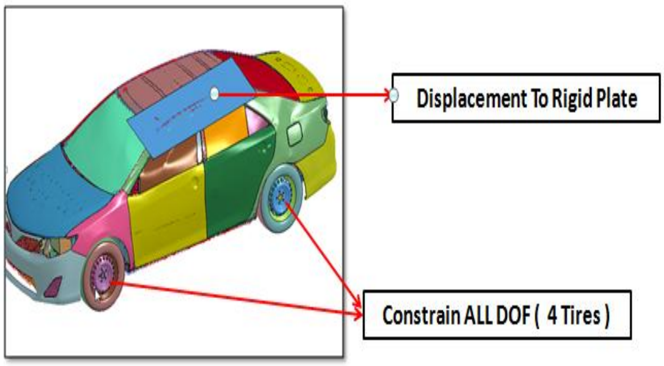


Figure 4: boundary conditions on model

6. SIMULATION AND RESULTS

The product is tested with defined boundary conditions. The results are compared between baseline and modified model.

6.1 Strains in Baseline Model Roof Made From Steel

The below Figure shows the strain percentage analysis carried out for Baseline model roof crush. The strain percentage obtained is 233%.

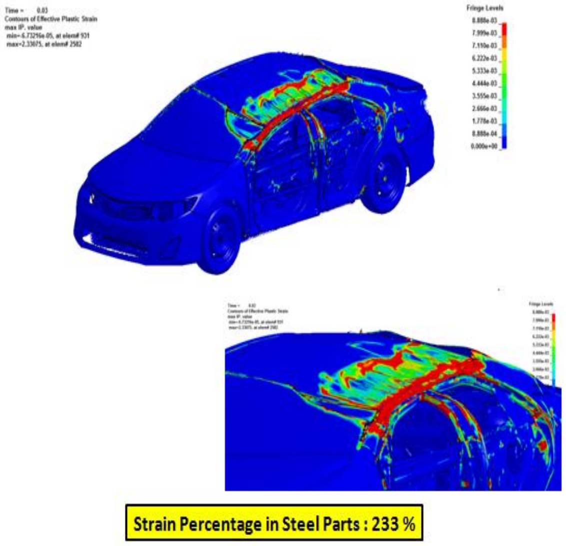


Figure 5: Strain Percentage in Steel Parts

6.2 Strains in Modified Model Roof Made From Docol 1000dp

The below Figure shows the strain percentage analysis carried out for Modified model roof crush. The strain percentage obtained is 169%.

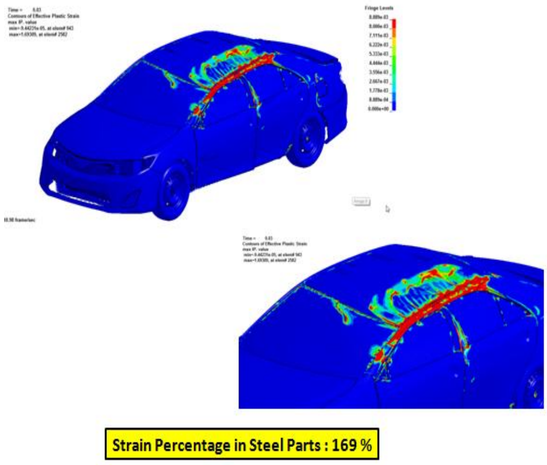


Figure 6: Strain Percentage In Docol 1000DP

6.3 Comparison of Roof Strength

The below figure compares the total force and B pillar force of baseline and modified models. The total and B pillar force are 108 KN and 16 KN in baseline model, which is comparatively less than modified model with total and B pillar force of 115 KN and 18.4 KN.

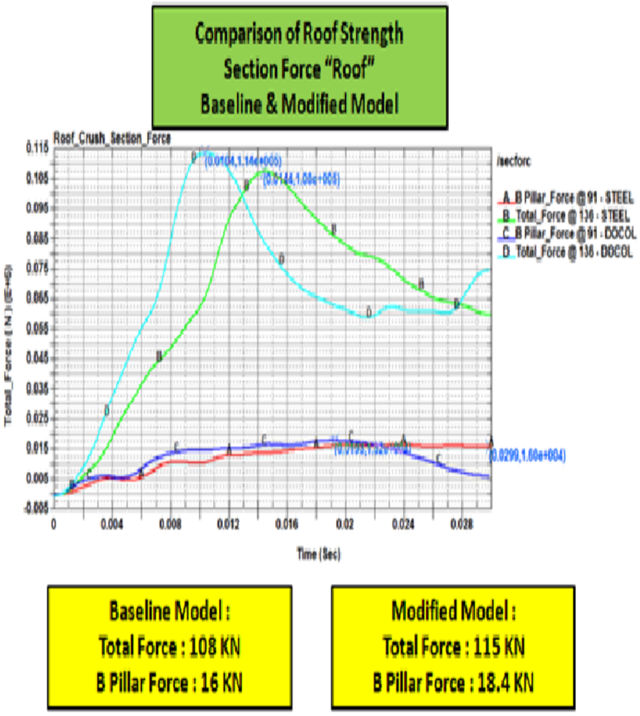
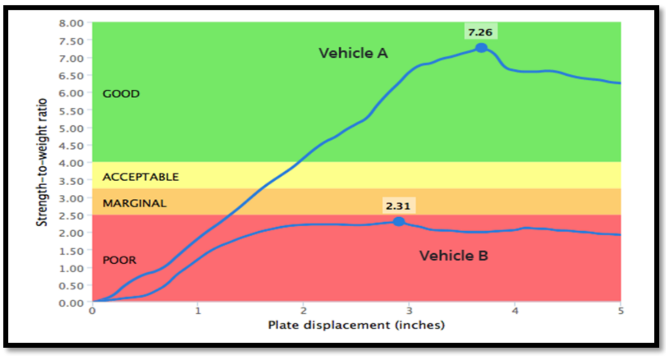


Figure 7: Comparison of Roof Strength

7. VALIDATION

A good rating requires a strength-to-weight ratio of at least 4. In other words, the roof must withstand a force of at least 4 times the vehicle's weight before the plate crushes the roof by 5 inches. For an acceptable rating, the minimum required strength-to-weight ratio is 3.25. For a marginal rating, it is 2.5. Anything lower than that is poor. The figure below shows sample results for two vehicles — one rated well and one rated poor. Peak force for Vehicle A is 7.26. Since that number is higher than 4, the vehicle is rated good. Peak force for Vehicle B is 2.31. Since that number is lower than 2.5, the vehicle is rated poor.



In the test of the 2010 Buick Lacrosse, the peak force is 19,571 pounds (84.5 KN) for a strength-to-weight ratio of 4.90 and a good rating. Therefore comparing this result with the modified and baseline models, the SWR of both models are obtained.

The below table shows the comparison of strength to weight ratio of standard, baseline and modified models. From table, it is confirmed that baseline and modified model both have good strength to weight ratio rating. And modified model has more SWR compared to baseline model.

Table 2: Comparison of SWR of Models

	Standard model	Baseline model	Modified model
Strength to weight ratio	4.90	6.26	6.70

3. CONCLUSIONS

The vehicle roof with new material is complaint with the relevant standards by comparison analysis with CAE which is beneficial for weight reduction and hence to improve vehicle efficiency and satisfy requirements of vehicle manufacturers.

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