Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **4(5),** 1-7, May **(2015)** *Res. J. Engineering Sci.*

Design optimization of vehicle body structure against roof crush as per FMVSS 216 using Finite Element Analysis (FEA)

Varun Pathak, Akshay Kutumbale, Deepika Potghan and Priyanka Potghan
Indore Institute of Science and Technology, Indore, INDIA

Available online at: www.isca.in, www.isca.me
Received 16th March 2015, revised 27th April 2015, accepted 15th May 2015

Abstract

Every year, more than 250,000 rollover accidents happen in the United States, Killing more than 10,000 individuals, as indicated by the National Highway Traffic Safety Administration. Indeed, rollover accidents represent roughly one-third of all auto related fatalities. Off and on again, wounds emerging from a rollover mishap are because of the carelessness or lack of regard of a driver. However on different events, these mishaps or the wounds they cause are the direct aftereffect of the inadequate plan or assembling of an auto, truck or SUV. To direct this, NHTSA has a code under motor vehicle security; to issue FMVSS and regulations to which creators of motor vehicle and rigging things should survey and confirm the model before adverting to the market. The US government presented a regulation for static top quality in 1973. In 1973 first FMVSS 216 was tried by presenting the front corner of the top to withstand a semi static energy equivalent to no less than 1.5 times the weight of the vehicle, up to 127mm of redirection. This is known as a quality to-weight proportion (SWR) of 1.5. Purpose of this paper is to watch resultant removal when the energy connected on the top of an auto by the testing plate. Measurement of testing plate has been taken by the security regulations of FMVSS 216 by National Highway Traffic Safety Administration. If, the resultant displacement is more than 127mm then vehicle will go under the class of hazardous model. To diminish this resultant relocation we have utilized composites as a part of request to expand the quality of top and it's likewise conducive for decrease the thickness of sheet metal of top segment. The technique is being finished with the aid of Finite Element Analysis (FEA) and Computer Aided Engineering (CAE) routines to upgrade a roof material. All things considered, data is being broke down by contrasting resultant uprooting in LS dyna device.

Keywords: Roll over, motor vehicle safety, finite element analysis, computer aided engineering.

Introduction

The necessities for roll over security of a car are characterized in FMVSS 216. The inspiration driving the standard is to decrease damage and wounds coming to fruition due to the breakdown of the top into the traveler's compartment in a rollover mischance. A schematic figure of the top pound wellbeing test is shown in figure-1[1]. A force is executed quasi statically to the top of the side rail at the standard angle of the vehicle top structure through an inconceivable power plate with suitable measurement as per NHTSA (National Highway Traffic Safety Administration)[2]. Exact and productive limited component demonstrating of the top pound safety test can encourage the outline of more secure automobiles and additionally lessen advancement and testing expenses. Safety standard FMVSS 216 was made to build insurance from Rollover of a car in accidents. FMVSS No. 216 looks to diminish passing and genuine wounds coming about because of the top being smashed and pushed into the tenant compartment when the top strikes the ground amid rollover crashes[3,4]. The test device must orient like following longitudinal axis: 5^0 and below the horizontal. Lateral axis: 25^0 below the horizontal.

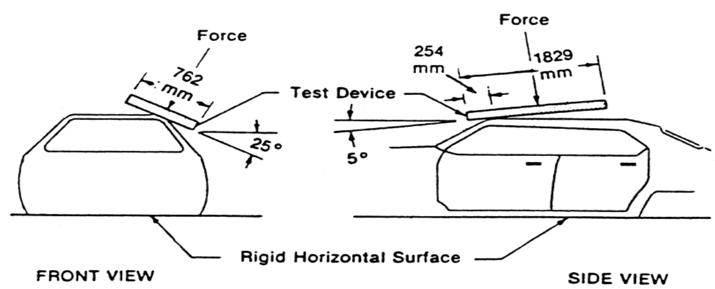

Figure-1
Test device location and application to the roof

Figure-1.1
Roof crash resistance test setup

Methodology

The Force Plate: A rigid plate was modeled with the dimension (1829*762) according to NHTSA and targeted over the roof also is put longitudinally at an edge of 5 degree to the level towards the front of the vehicle pivot is at a detachable point of 25 degrees beneath the flat. According to IIHS (insurance institute of highway safety) plate should bear the load of unloaded vehicle up to 4 times. This type of plate will be come under the good plate rating. Force will be applied according to Gross vehicle weight rating (GVWR) and the platen displacement should not exceed over 127mm for the safety purpose. The force plate placing is being shown in figure-2. Quasi-static process was being employed over the car roof and the force was 1.5 times of unloaded vehicle weight. Further, static response of force plate has been recorded[5].

Finite Element Modal of a car: The full vehicle model is modeled **a**nd meshed in HYPERMESH, and the components necessary for simulating the roof crush test are extracted. Only body in white of a car has been used excluding interior and exterior trims because it has a negligible effect on the overall roof crush resistance response. Furthermore, it has been observed that roof and pillar A, B andC have an immense significance over the roll over testing of a car. Although, front and rear mirrors have negligible effect over this testing still we are including these for the practical results. The whole process is based on the material testing and its optimization in order to ameliorate safety of a car in an optimum price range. The model geometry is shown in figure 2.

Setting up the connection between car (body in white) and force plate and rigid material update: In our methodology, we have used linear steel as a rigid material with card image MAT 20 In LS DYNA and properties with suitable stress- strain value has been executed for the force plate. Laminated glass has been used for the front and rear mirror and side window as well. Furthermore, displacement and force plots have been given to find out desired results of our simulation. Much iteration have been performed by varying the thickness of sheet metal and pillars and then resultant displacement has been measured over LS- DYNA PREPOST until it does not come less than 127mm which is desirable for the safety point of view[6]. Simulation and resultant displacement has been shown in figure 3 and 4 respectively.

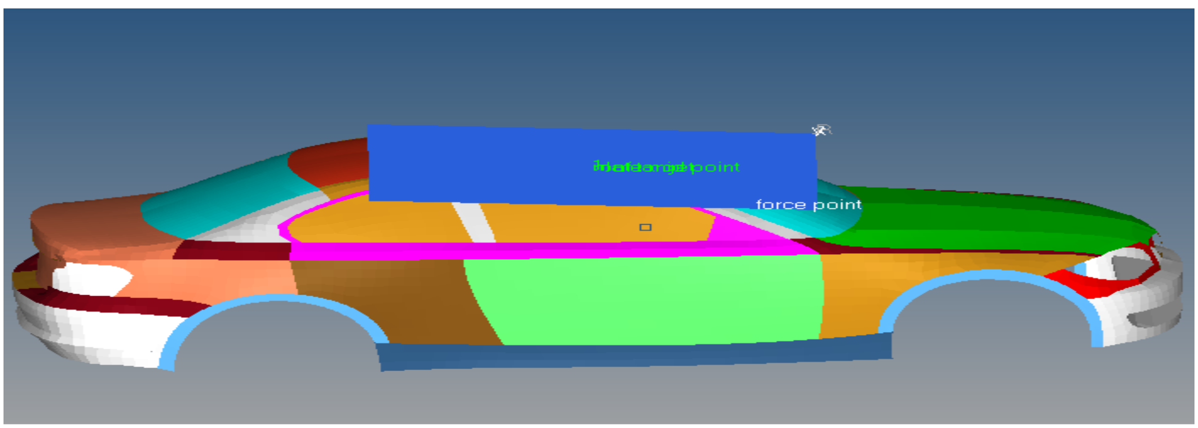

Figure-2
Simulation Setup of force plate and car

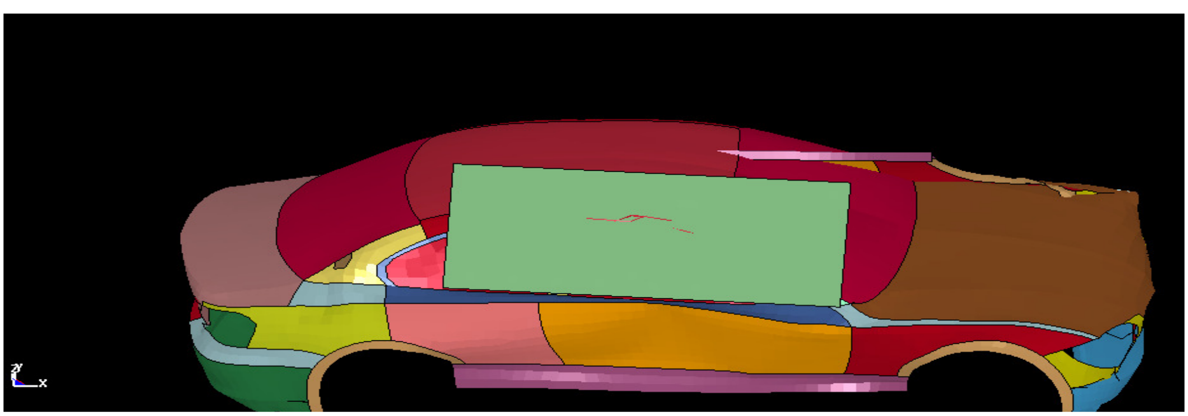

Figure-3
Roll over simulation of car

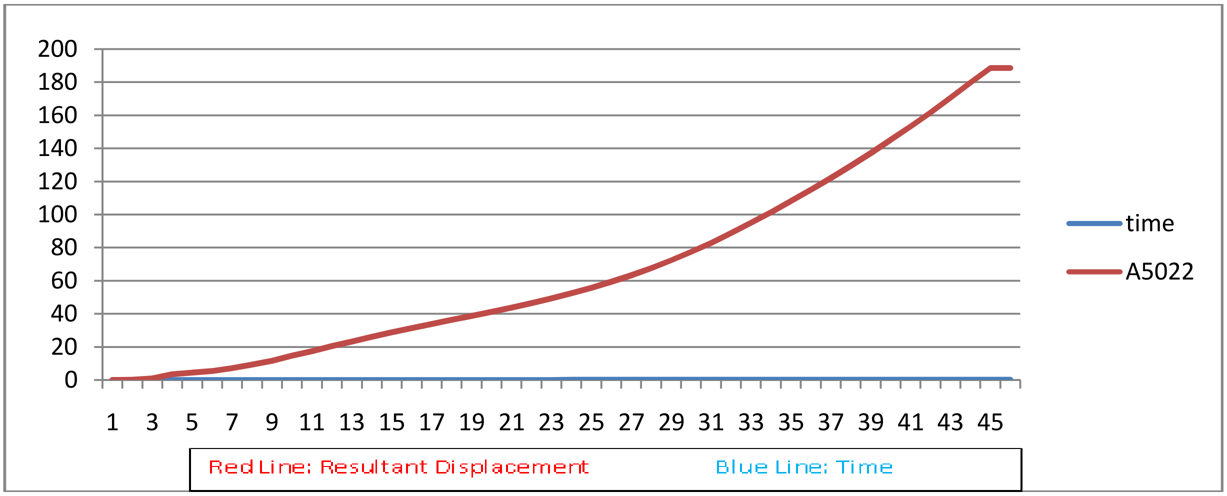

Figure-4
Resultant Displacement curve

After analysing the result we have observed the loop holes which cause major rollover accidents. Fatigue cracks are major cause of fatal in any vehicle body. Fatigue crack simulation can be observed by the mesh generation over the vehicle body[7]. Then, we have concluded car roof, side rails and pillars of a car are the major components which can give strength to a car and enhance the safety[8]. So, our first approach was to use best possible material which can enhance the strength of a car body. Further, we performed some iteration by taking 4 different grades steel and used dynamic transient analysis method to obtain the results[9].

Analysis using Steel AISI 4000: After that we have changed the material of individual components and we have used AISI 4000 steel to strengthening the car roof and pillars. We have updated the material and its respective properties in the components and performed some iteration. By varying the thickness of components finally we have achieved the displacement of plate which is below 127mm of the plate and final thicknesses of components are being shown in table-1. Resultant displacement of force plate is shown in figure-4.

Table-1
Thickness of individual components

COMPONENT	THICKNESS
ROOF	2.8
ROCKER ARM	3
SIDE RAIL	2.9
DOOR PILLARS	3.2
LAMINATED GLASS	1.5

Further, we have randomly performed some iteration over different grades of steel such as, ASTM A36, Molly- Chrome steel with the same thickness and following are the results are shown in figure-5.

Finally, after performing innumerable iterations over these steel grades we have observed better strength can be provided to vehicle by using steel grade AISI 4000.

Bead Design and Modelling: Now, we have continued our research in order to ameliorate the strength of roof of a car. To increase the strength of a car we have modelled the solid bead over the car roof and assigned the proper material and respective property to the bead component. Design of car component is in such a way that it can also be beneficial for the car aerodynamics point of view and also enhance the strength of car roof. Air can easily pass through the car bead which is good for vehicle aerodynamics. We have design the bead in such a way that it can mitigate the effect of stresses and can enhance the strength of roof which is a major cause of roll over fatal. Design of roof bead is shown in figure-6.

After creating the bead component we have again done simulation over the same car and performed the iteration by taking the material AISI 4000 and same optimized thickness of component and following Resultant Displacement vs. Time graph has been plotted in figure-7.

Advanced Octa Grid Design and Modelling: Advanced grid structure is an evolution of early aluminium isogrid stiffening concepts. These structures have broadly being used in aeronautical and civil engineering applications because of its high impact strength and fatigue resistance. The other real characteristic of this network is high quality energy assimilation. Energy engrossing materials are generally being utilized as a part of car commercial ventures in light of the fact that; inhabitant's security majorly relies on the retention of accident vitality of vehicle structure[10].

This octa grid is made up of two major components stiffeners and skin. In which, stiffener is ribs and skin is car roof. Further, this octa grid is installed over car roof and simulation is performed. Octa grid over car is shown in figure 8 and simulation result has been shown in figure-9.

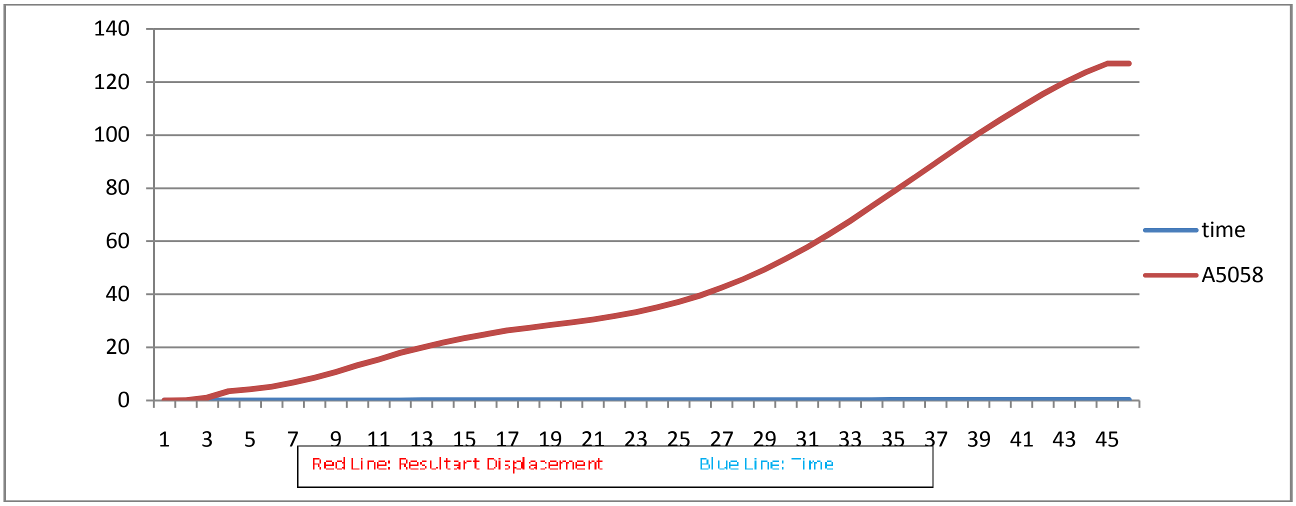

Figure-4
Resultant displacement Vs. Time Graph of steel grade AISI 4000

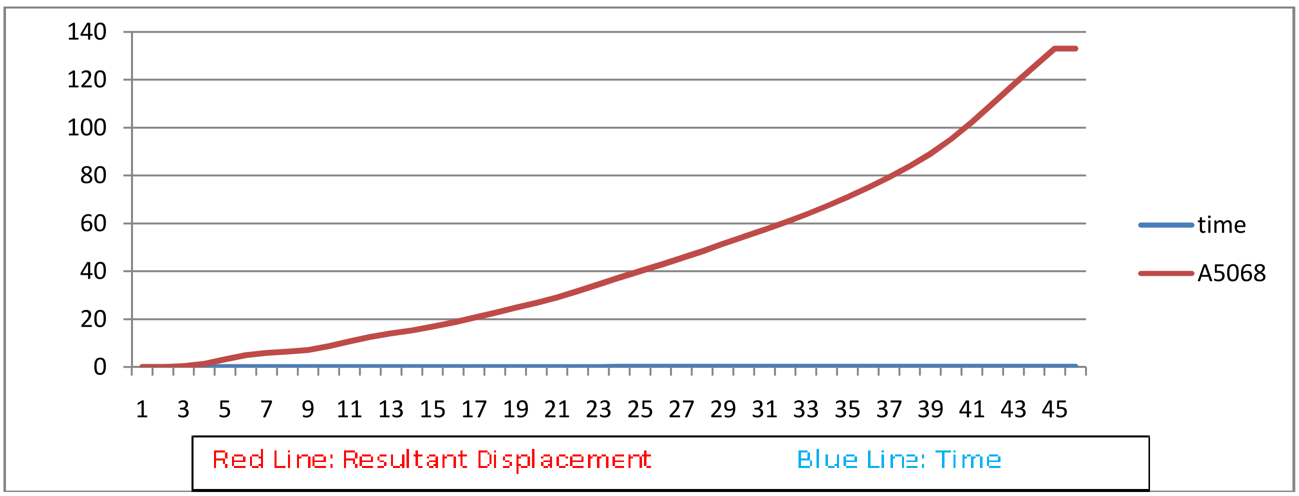

Figure-5
Resultant displacement Vs. Time Graph of Steel ASTM A36 grade

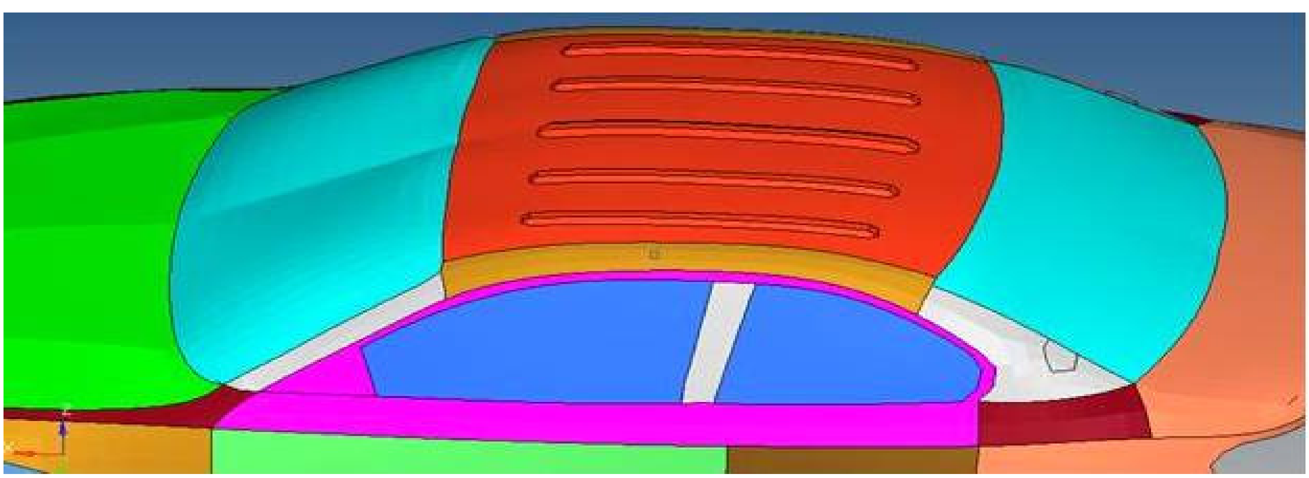

Figure-6
Design of bead component over car roof

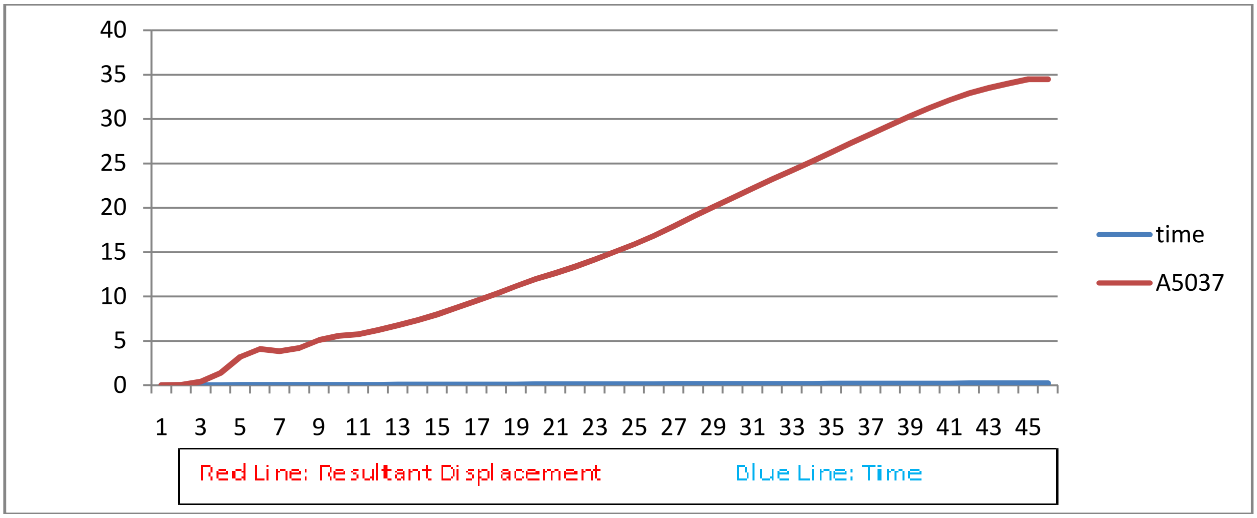

Figure- 7
Resultant vs. Time Graph of roof bead

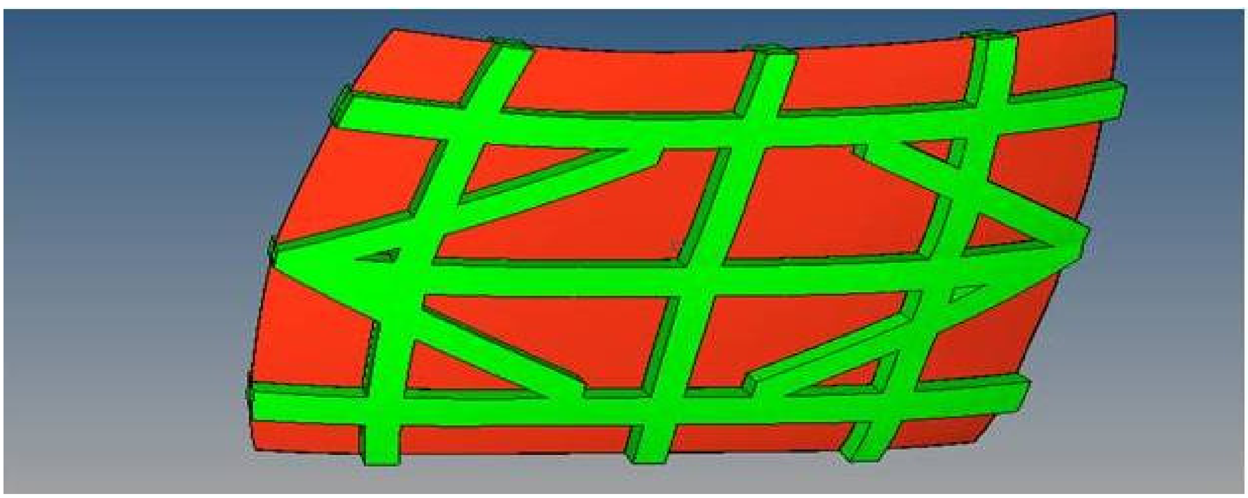

Figure-8
Formation of advanced Octa grid over the roof

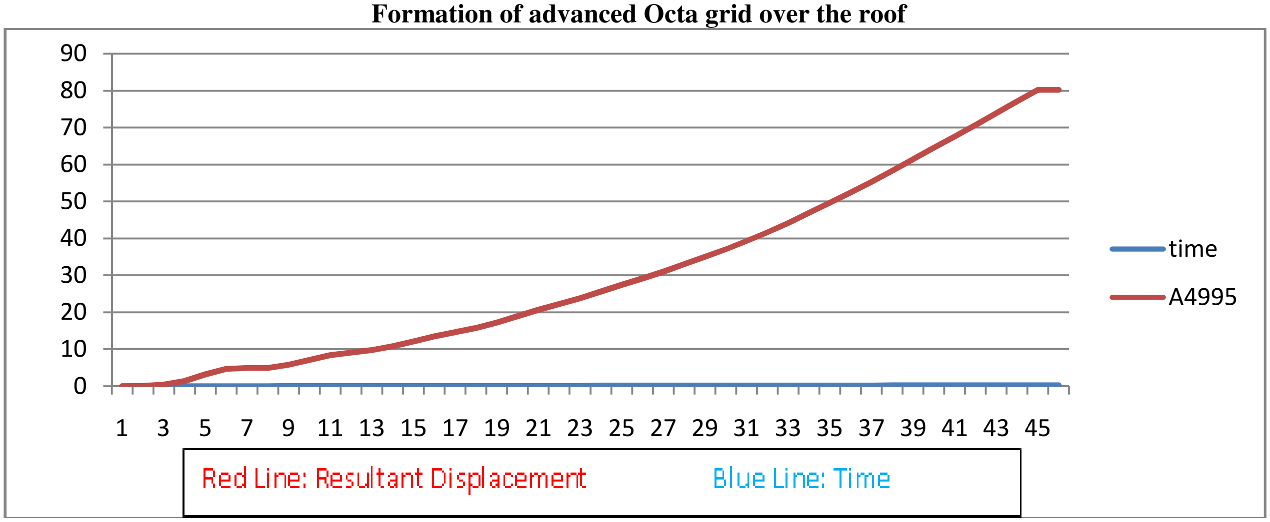

Figure-9
Resultant displacement vs. Time Graph of Advanced Octa Gr

Results and Discussion

First we have performed the iterations over the different steel grades and following results have been found is shown in table-2.

Table-2
Resultant displacement of force plate on different steel grades

Material	Resultant Displacement (in mm)
AISI 4000	122.8
ASTM A 36	133.2
Molly chrome steel	143.8
Kevlar composite	217.6

Second, we have done some modifications over roof component of a car and created solid bead and then, designed advanced octa grid and performed simulation over it. Following the results shown in table-3.

We have performed several iterations on different steel grades and then finalized the final steel grade AISI 4000 which best suited material for the car body. Further, to enhance the car safety in rollover crashes we have observed that key components are car pillars, roof, side rails and rocker arm and we have to provide strength to these components to design our vehicle durable. However, roof is the major part which plays vital role during rollover crashes and by strengthening the roof part we can enhance the safety of whole vehicle. So, we have designed bead over roof and analysed the result and further created advanced octa grid over the roof with proper analysis. Later, we compared the result by measuring the displacement of force plate which should be less than 127mm. The combines result has been shown in figure 10. In which, above 180 mm displacement had been shown by curve 1 which is of linear steel and 133.8mm displacement shown by curve 2 which is of steel grade ASTM A36. Hence, these materials are not suitable for the safety point of view because displacement of plate is 127mm. Furthermore, steel grade AISI 4000 has shown the optimized result in curve 3 which is 124.3mm. Curve 4 and 5 are of advanced octa grid and bead formation respectively and showing 80.mm and 34.8mm displacement.

Table.3
Resultant displacement of force plate with following modifications

Modification type	Resultant displacement (in mm)
Solid Bead	34.8
Advanced Octa Grid	80.1

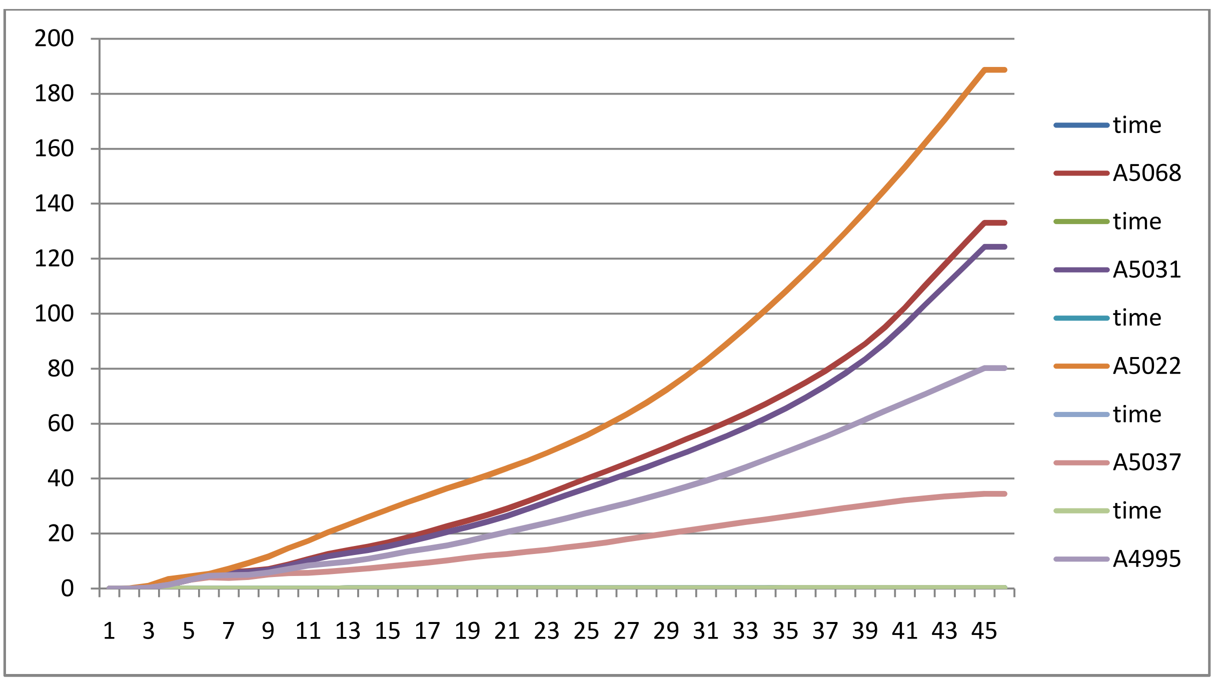

Figure-10
Combined Simulation result of different steel grades, bead formation and octa grid

Conclusion

Roof plays the major role during the rollover crashes and it has been found that strengthening the roof component of the car we can make car durable and safe. To increase the thickness of the component is not the only option because; it will increase the cost of the vehicle. So, with the help of software i.e. Hypermesh we have played with the roof geometry and performed some iteration by employing bead and advanced octa grid over the roof. Furthermore, Results were positive in both the cases and this can be executed by industries to avoid rollover crashes.

References

1. Louden E. Allison and Weston Doug, NHTSA research on improved restraints in rollovers, National Highway Traffic Safety Administration USA, 11-0213 **(2007)**

2. Mao M., Chirwa E.C., Chen T. and Latchford J., Static and dynamic roof crush simulation using LS-DYNA3D, *International Journal of crashworthiness*, **(2010)**

3. Code of federal regulations TP-216-05, Roof Crush Resistance, National Highway Traffic Safety Administration U.S. Department of Transportation, **(2006)**

4. Lange Robert, Iyer Madhu, Pearce Harry, Jacuzzi Eric and Croteau Jeffery, Rollover injury science and roll over crash typology, *24th International Technical Conference at United States*, 11-0116**, (2009)**

5. Bojanowski Cezary, Gepner Bronislaw, Kwasniewski Leslaw, Rawl Christopher and Wekezer Jerry, Roof Crush Resistance and Rollover Strength of a Para transit Bus, *8 Th European LS- DYNA® Users Conference*, (**2011)**

6. Ung Sung, Chul Young, Soon Ki and Bok Kwang, Study of optimal body structural design for coupe type vehicle in rollover events, 13-0173, **(2010)**

7. Purkar T. Sanjay and Pathak Sunil, Aspect of Finite Element Analysis methods for prediction of fatiguecrack growth rate, *Research journal of recent sciences*, **1(2),** 85-91**, (2012)**

8. Mao Mingzhi, Chirwa C.E. and Chen T., Vehicle roof crush modelling and validation, *5th European LS- Dyna user's conference***, (2005)**

9. Purkar T. Sanjay and Pathak Sunil, Analysis of crack Initiation in fretting fatigue specimen, *ISCA Journal of Engineering Sciences,* **1(1),** 26-34**, (2012)**

10. Shenoy S. Sudhir, Energy absorption of a car roof reinforced with a grid stiffened composite panel in the event of a rollover, Department of mechanical engineering and the faculty of graduate school of Wichita state university, **(2006)**