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Optimization of car roof structure as per FMVSS-216 by using FEA Method

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ABSTRACT

bjectives of this paper are to optimize the weight car roof structure as per requirement of FMVSS- y using FE method and study the advantages of light weighted cars on fuel economy. Talking about tance of roof structure, particularly the rollover crashes are have more rate fatality of occupants as ared to frontal, side or rear crash. Because in normal passenger vehicle the roof is likely to collapse ard the occupants and cause severe head injuries, traumatic brain injures (TBI), spine injuries. This in cause of human death. To avoid such rollover fatality various car assessment programs have sion to test rollover strength such as FMVSS-216.This paper is focus on FMVSS216 regulation which for improving car rollover safety.Today most of automotive companies are using FE simulation to ze various tests which are more costly and in many cases unrepeatable .This paper also include the study finite element model of car which is developed by National crash analysis center. As per ement of FMVSS-216 car model is tested for a quasi-static analysis. To getting most realistic results, E tools like LS-Dyna & Hypermesh software are used. This gives good reliable & consistent test s with respect to physical testing.

***Keywords* -- FMVSS-216, Rollover crash, FE model simulation, LS- Dyna.**

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I. INTRODUCTION

The most common reason for rollovers is due to the sudden change of cornering forces, this make destabilize the vehicle. When takes turn at corner, the three forces act on it: tire forces (centripetal force), inertial effects (centrifugal force), and gravity. The cornering forces from the tire push the vehicle towards the center of the curve. This force acts at ground level, below the center of mass. The force of inertia acts horizontally through the vehicle's center of mass away from the center of the turn. These two forces make the vehicle roll towards the outside of the curve. The force of the vehicle's weight acts downward through the center of mass in the opposite direction. When the tire and inertial forces are enough to overcome the force of gravity, the vehicle starts to turn over.Talking about importance of roof structure, particularly the rollover crashes are have more rate fatality of occupants; as compared to frontal, side or rear crash. Because in normal passer vehicle the roof is likely to collapse in toward the occupants and cause severe head injuries, traumatic brain injures (TBI), spine injuries. This is main cause of human death. The main objectives of this paper are to study the roof structure & its surrounding parts for design optimization using finite element methods. For maximize occupant safety during crash event of rollover. The roof is required to fulfill the FMVSS 216 regulation, which provides strict requirements in terms of design and human safety.

II. LITERATURE REVIEW

Mandell et al(2010)[1] observed that in the United States, a significant number of spine injuries, traumatic brain injuries (TBI), and deaths were due to the rollover crashes.

Brumbelow et al (2009) [2] observed that the vehicle rollover is a major cause of fatality in passenger vehicle crashes. Rollovers are more complicated than planar crashes, and potential injury mechanisms still are being studied and debated. A central factor in these debates is the importance of having a strong vehicle roof.

Christensen et al (2012) [3] investigates the effects of variations in modelling of roof crush loading scenarios upon topology and mass of a body in white (BIW) for a hybrid electric vehicle (HEV). These variations incorporated the proposed changes to the Federal Motor Vehicle Safety Standards (FMVSS) 216 standard.

Ping Zhu et al (2012) [4] used support vector regression method for optimization of roof structure. By using this method they are improved the roof crush resistance force & also lightweight design of vehicle front end structure.

Vishwajeet Belsare et al (2012) [7] observed that the road transport is the most commonly used way of transportation in India and in many countries. The passenger bus plays an important role in public transport. The capacity of carrying more passengers compared to other road transport medium is unfavourable in the event of major bus accident. The rollover crash accident of passenger bus, although occurs less frequently than any other type of accident, the fatality rate and severe injuries are highest in rollover crash. Hence the structure of the bus needs to be strong enough to ensure the minimum damage and at the same time it should absorb maximum impact energy.

III. FEDERAL MOTOR VEHICLE SAFETY STANDARDS (FMVSS)-216

The purpose of Federal Motor Vehicle Safety Standard (FMVSS) 216 is to reduce deaths and serious injuries when vehicle roofs crush into occupant compartments during rollover crashes. National Highway Traffic Safety Administration (NHTSA) agency was conducted a research program to examine potential methods for improving the roof crush resistance requirements. This testing was included full vehicle dynamic rollover testing, inverted vehicle drop testing, and comparing inverted drop testing to a modified FMVSS No. 216 test. After considering the results of the testing and other available information, the agency concluded that the quasi-static procedure provides a suitable representation of the real-world dynamic loading conditions, and the most appropriate results [5].The FMVSS-216 is applicable for bellow vehicles.

- For passenger cars and multipurpose passenger vehicles, trucks and buses with a Gross Vehicle Weight Rating (GVWR) of 2722 kg (6000 pounds) or less, and this vehicle roof structure must withstand the force is equal to 1.5 to 3 times the vehicle's unloaded weight.
- Vehicles with a GVWR greater than 2722 kg (6000 pounds), but not greater than 4536 kg (10000 pounds).The force requirement is 1.5 times the vehicle's unloaded weight.
- It is applicable for both side of roof (i.e. left& right side)

A) Test device

The test device is a rigid unyielding block whose lower surface is a flat rectangle measuring 1829MM X 762 MM.

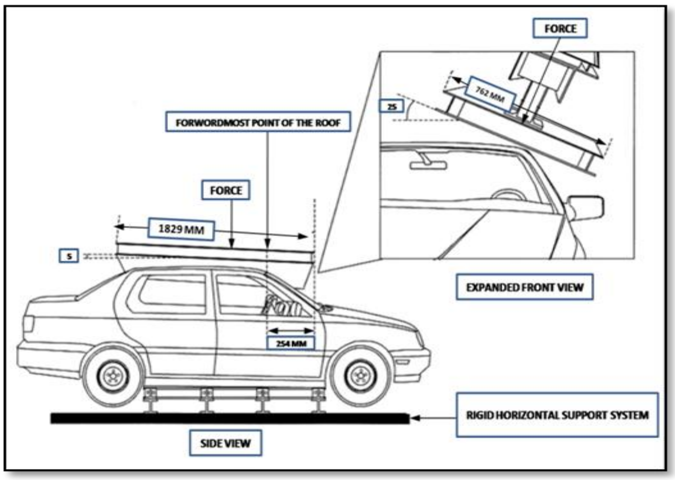

Fig.1 Test device orientation

B) Real test procedure

1. The frame of chassis is fixed permantaly with rigid horizontal plate as shown in fig.1.
2. The orientation of loading device of size 1829MM by 762MM is made such that,

(a) Its longitudinal axis is at a forward angle (in side view) of 5 degrees (± 0.5 degrees) below the horizontal, and is parallel to the vertical plane through the vehicle's longitudinal centerline;

(b) Its transverse axis is at an outboard angle, in the front view projection, of 25 degrees below the horizontal (± 0.5 degrees).

(c) The longitudinal centerline on its lower surface is within 10 mm of the initial point of contact, or on the center of the initial contact area, with the roof.

(d) The midpoint of the forward edge of the lower surface of the test device is within 10 mm of the transverse vertical plane 254 mm forward of the forward most point on the exterior surface of the roof, including windshield trim that lies in the longitudinal vertical plane passing through the vehicle's longitudinal centerline.

3. Apply force on test device which moves in a downward direction perpendicular to the lower surface of the test device at a rate of not more than 13 mm per second until reaching the force level specified in (c) and (d). Guide the test device so that throughout the test it moves, without rotation, in a straight line with its lower surface oriented as specified in setup 2. Complete the test within 120 seconds.
4. Repeat the test on the other side of the vehicle [5].

IV. CASE STUDY

Vehicle safety design is one of the major attributes in car product development. The vehicle structure must be design to absorbed crash energy through structure deformation as much s possible and attenuate the impact force to tolerable level when impact occurs [6].

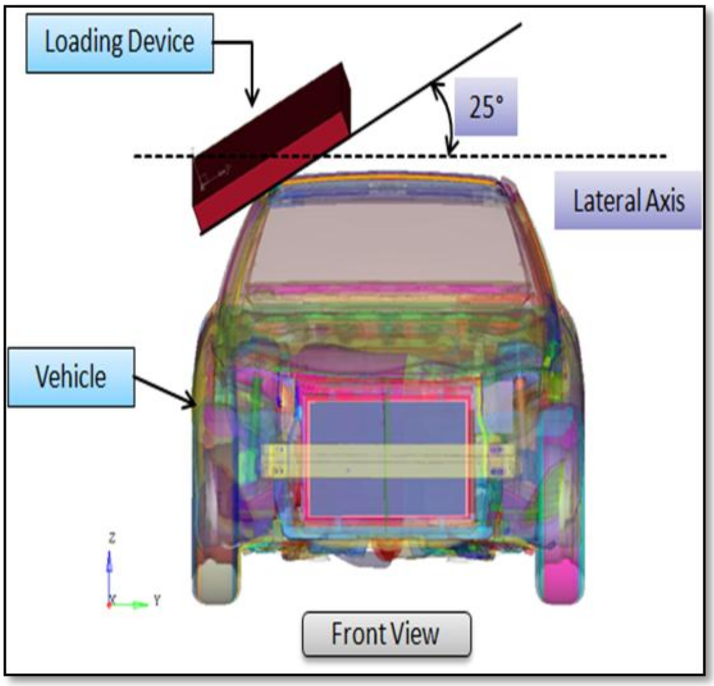

Fig.2 Finite element model for roof crush

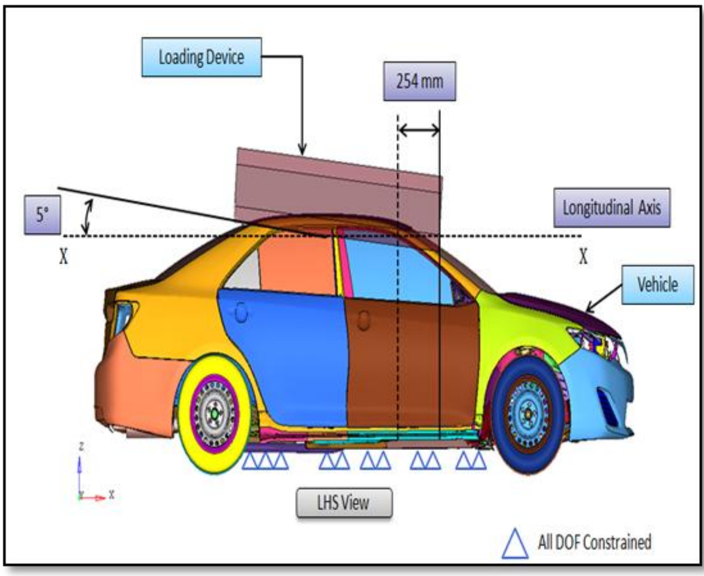

Fig.3 Front view of finite element model for roof crush

In this study, one case related to vehicle crashworthiness response of roof is done. For this purpose finite element of car is selected, The test procedure is based on Federal Motor Vehicle Safety Standards-216(FMVSS216). During crash simulation in LS dyna, the finite element car model is rigidly hold at bottom side frame as shown in fig.2 and loading device of rectangular plate with 1829mm by 762mm is added on deriver side top of the body as specified by FMVSS216 with roll angle (25^0) and pitch angle (5^0) .The loading device is kept 254mm from forward most point roof structure. With considering maximum intrusion of roof 150mm displacement is assign to loading device in 0.100millisecond. To find out roof strength, the force vs deformation relationship is plotted as shown in fig.6.

A) FEA results:

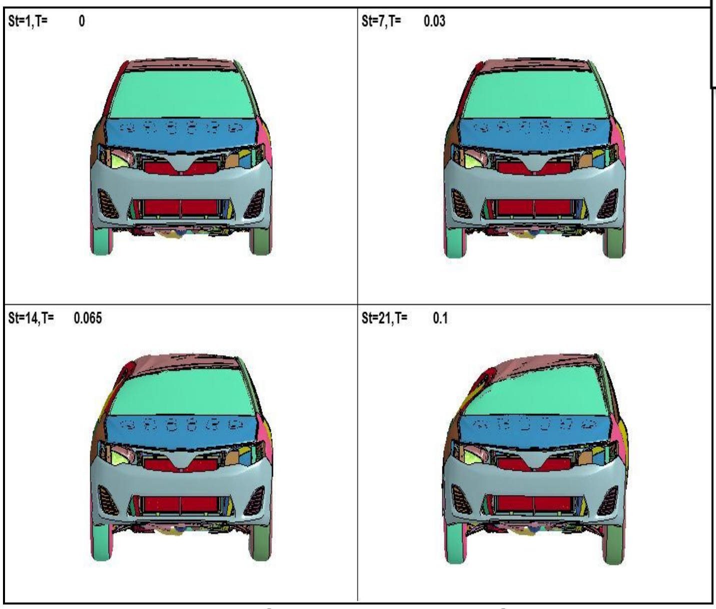

Fig.4 Simulation stages at time intervals

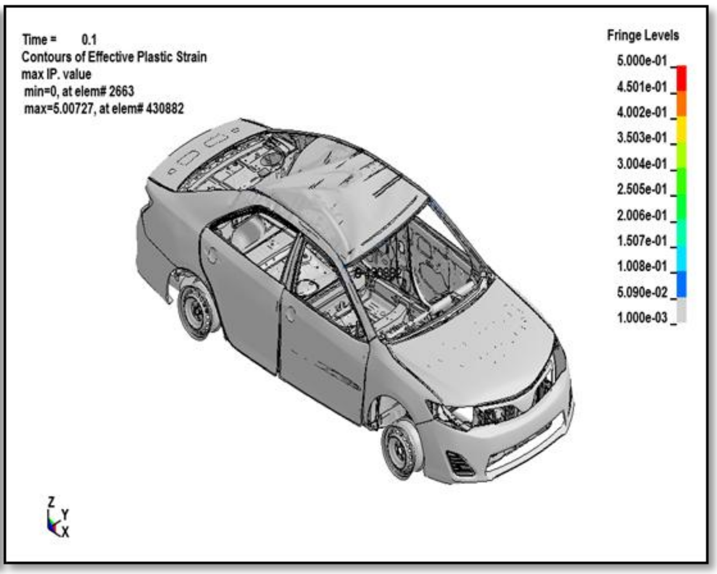

Fig5 Effective plastic strain

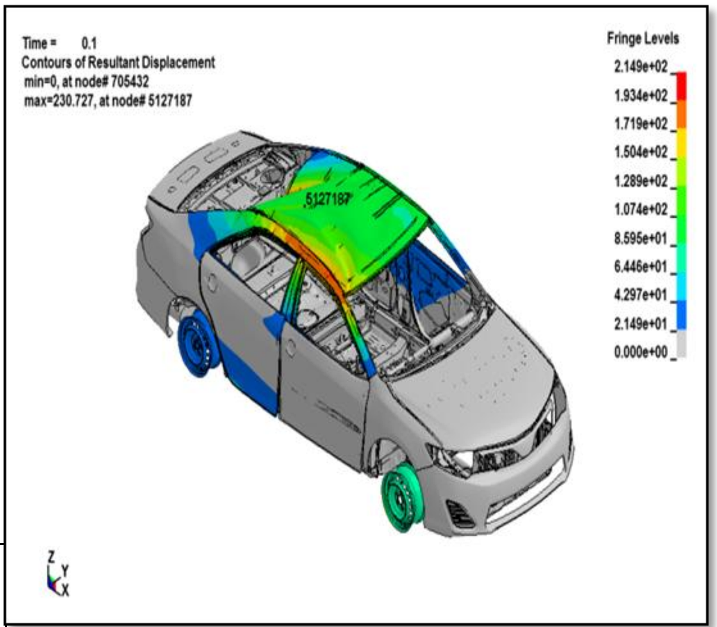

Fig.6 Resultant displacement of roof

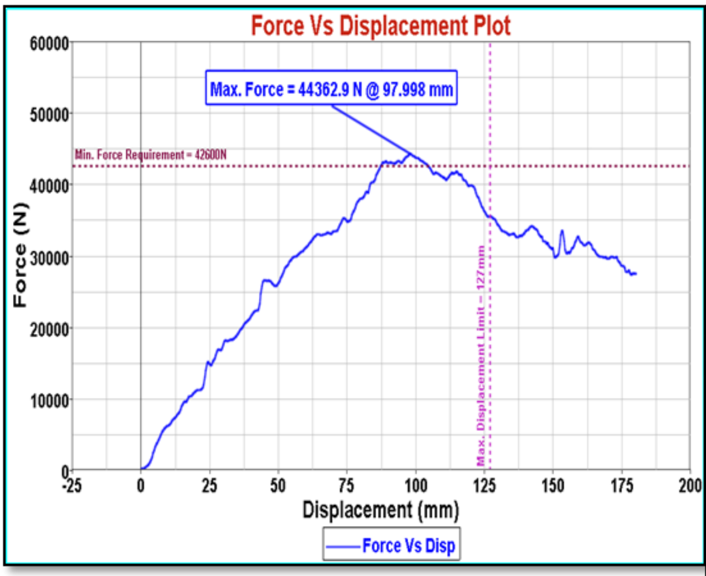

Fig.6 Force vs displacement results of finite element model

Above graph shows force vs displacement results of FE model which gives maximum load carry capacity is 44362.9 N@97.998 MM displacement.

V.TENSILE TEST PROCEDURE

To represent actual behavior of roof crash, BIW component (quarter panel) of actual vehicle is used. From this component exact size of specimen required for tensile test as per IS 1608 is taken by machining operation. To get exact material properties of specimen chemical is carried out which helps to indentify the material. For test purpose 300mm X 50mm X 0.66mm thick BIW sheet is selected.

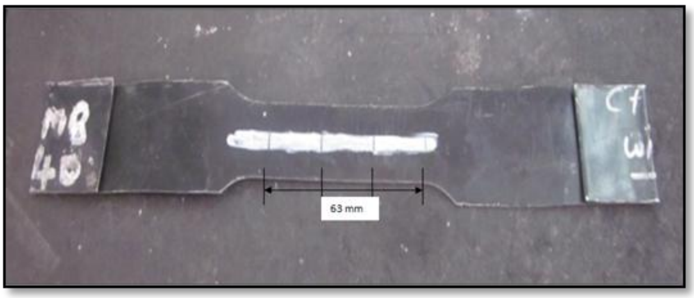

Fig.7 Test specimen cut from BIW sheet.

To get most realistically results of rollover crash simulation, a nonlinear finite element solver like Ls-Dyna solver is used. The exact specimen size is prepared as per standard IS 1608 tensile test. The engineering stress- strain curves and mechanical properties like ultimate tensile strength, breaking strength, elongation at UTS were obtained from the tensile test.

V. EXPERIMENTAL VALIDATION

Before the start of the analysis of complete car model material model validation is required. It was decided to compare the force versus displacement graph of experimental and finite element specimen to validate the material model. A sample specimen was prepared as per standard IS 1608 tensile test and loaded on Universal Testing Machine as shown in figure 8. The specimen was loaded with 2.95 KN tensile load at end portion. The mid-span deflection was recorded as a function of tensile load applied at the end side. The maximum displacement of 12.44 mm was recorded.

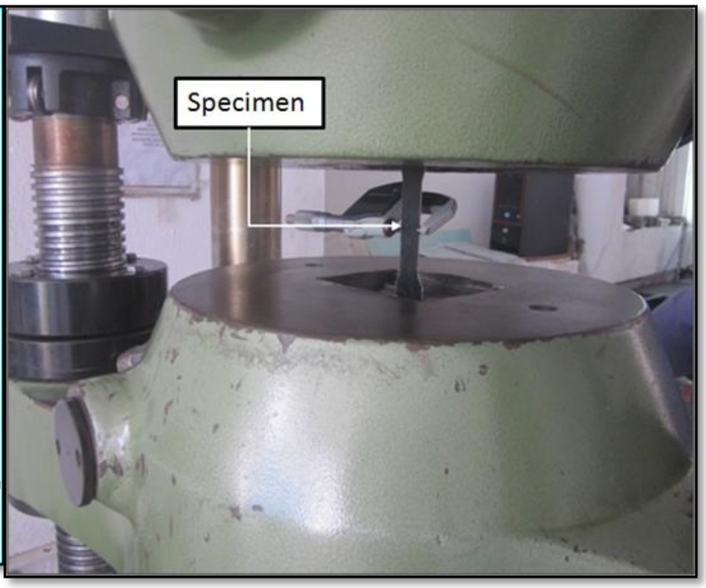

Fig.8 Tensile test experimental setup

To simulate the tensile test the finite element model was prepared as shown in figure 9 with the exact dimensions as that of the physical test specimen. The material properties obtained from the tension tests were applied to the finite element model. The true stress- strain curve obtained tensile tests were used as input to the elastic-plastic material card in LS-dyna. The displacement of specimen after the simulation is shown in the figure 10. The position of the specimen before and after the deformation is also presented.

Specimen Data		
Parameters	Value	Unit
Thickness	0.66	mm
Width	20.08	mm
Area	13.25	mm^2
Gauge Length	21.00	mm
Final Gauge Length	33.44	mm

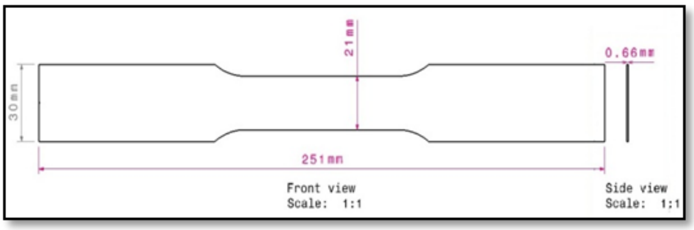

Fig.9. Specimen dimensions

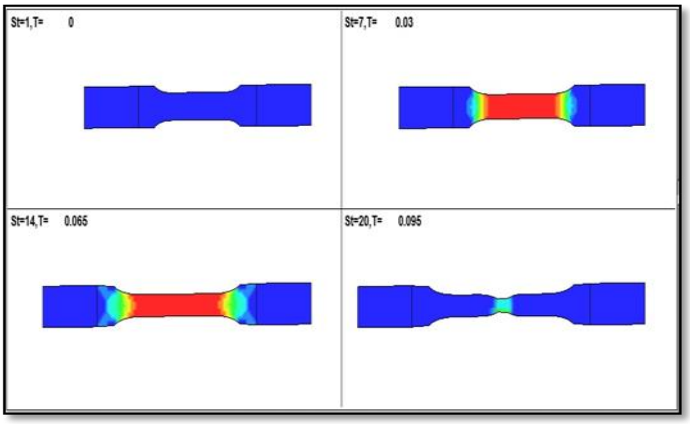

Fig.10. Displacement plot during tensile test simulation stages

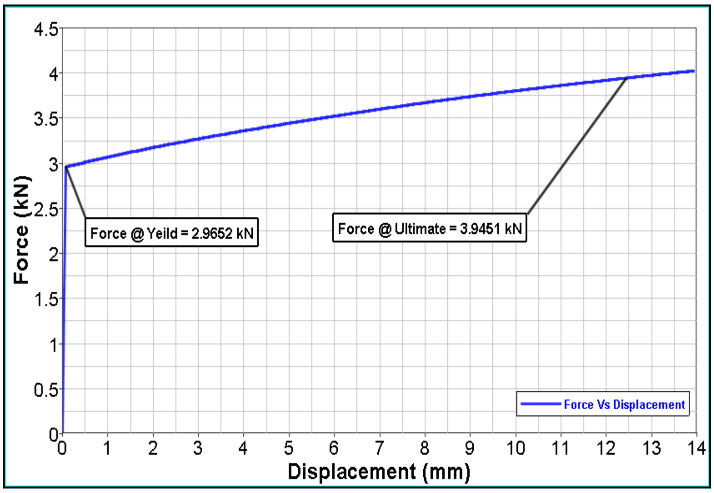

Fig.12 Force versus displacement during bend test

Parameters	Physical Test Value	FEA Value	Difference
Yeild Load (kN)	2.95	2.9652	0.0152
Ultimate Load (kN)	3.75	3.9451	0.1951
Yeild Stress (Mpa)	222.64	223.789	1.149
Ultimate Stress (Mpa)	283.02	297.743	14.723
Elongation (%)	59.24	59.219	-0.021

Figure12 shows the comparison of the force versus displacement plot of the experimental and FEA tensile test. The FEA curve shows the same behaviour as the experimental curve. The experimental test shows the 12.44 mm displacement at mid-span when the force is 2.95 kN while the FEA result shows the same displacement at a force of 3.94kN. The displacement is very close with the experimental values and hence it is concluded that the material model is validated

V. CONCLUSION OF RESULT

- As graph shows force vs displacement results of FE model which gives maximum load carry capacity by roof structure is 44362.9 N@97.998 MM displacement
- But; as per FMVSS-216 test requirement roof structure of this model should be sustain maximum 42600N@127MM displacement which is 3 times of unloaded weight (14210N).
- Hence, the current finite element model fulfill the requirement of FMVSS216 and also it optimize the weight of roof structure by 115kg to 91kg which gives 12% weight reduction of roof structure members.

VI. FUTURE SCOP

- The overall purpose of this study is to minimize the BIW mass and enhance strength of roof subjected to multiple crash scenarios.
- To reduce the weight of roof, new upcoming light weighted composite material like carbon fibers and various plastic like Glass Fiber Reinforced plastics (GFRP) can be use as alternative roof material.

VII.ACKNOWLEDGMENT

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