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OPTIMIZATION OF B-PILLAR AND BODY SIDE OUTER (BSO) TO IMPROVE OCCUPANT SAFETY DURING ROLL OVER / ROOF CRASH

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ABSTRACT

Roof Crash of the Vehicle during Rollover Accidents or during any other form of crash is one of the deadliest causes of death as the occupant have no survival space and the chance of escaping is completely difficult. In recent times, the concentration of Automotive Industry in improving the Passive safety of the Vehicles like Seatbelts, side curtain Airbagsetc. which help in preventing the Injuries during the Rollover are highly developed .However, these alone cannot prevent the Injuries during the Rollover. Because during the Rollover the roof tends to get deformed and bends inside towards the occupant when it comes in contact and gets hit by the ground resulting in reducing the survival space for the occupant to escape . So, a stronger roof is highly needed.

In this work, Roof Crash Resistance test and Validation is carried out on the Vehicle F.E model as per the FMVSS 216 (FEDERAL MOTOR VEHICLE SAFETY STANDARDS) laid by U.S Federal for Occupant safety.

These simulations are carried out on FE model by using ANSA as Pre-processor, LS- DYNA as Solver and Hyper view as Post-processor and Design optimizations are carried out on B-pillar and BSO by varying thickness, and adding FOAM (since it absorb impact energy).Later , Reaction force VS Displacement , SWR (Strength to Weight Ratio) is calculated for different iterations and results are compared to the Base line model result finding out the best iteration which have stronger roof(higher Reaction force or highest SWR)

KEYWORDS: Roof Crash Resistance, Roll over, Crash Analysis, Reaction Force, Strength to weight ratio, SWR, FMVSS Standard, Crash worthiness, CAE, ANSA, LSDYNA, Optimization.

INTRODUCTION

Roll over crash or Vehicle roll over during Road accidents are considered as the worse and deadliest accidents in recent times. it is one of the primitive reasons for many deaths. The number people losing lives, getting injured or getting disable are increasing in the past 2 decades. Roll over crash is considered as the worst because in roll over unlike other crashes the occupant will have no room to escape or get ejected during the impact. The survival space is very limited and since the occupant is inside an upside-down car one side is completely restricted by the Ground.

So, the best way of reducing the Roll over during the crash event is to restrict the car from getting rolled. This can only be possible by designing the vehicles with ESC (Electronic Stability control). This technology can significantly reduce the cars from getting rolled. Vehicles having ESC will obviously cost more. So, in developing nations like INDIA it is very difficult to incorporate in the vehicles because of economic challenges. The only way which we can do is to increase the strength of the Roof. Stronger roof can not only prevent the impact to reach the occupant but also, economical compared to the installation of the new ESC in cars. In countries like INDIA where the usage of seat belts are not followed strictly the stronger roof is very much important because this will at least reduce the impact and make the occupant to be inside the car than getting ejected from the glass.

In this work, in order to increase the strength during rollover the B-Pillar and the BSO (Body Side Outer) has been optimized by changing its thickness. Also,a new component are added which is made up of the shock absorbing FOAM. This Foam is inserted between BSO and the support parts and also between B-Pillar and the conditions, Modeling and dimensions, Model setup, load application is as per the FMVSS 216 standard or not. Finally result outcomes like SWR (strength to Weight Ratio) and Reaction force VS Displacement are Evaluated and compared and the best possible iteration with higher SWR, higher Reaction force is suggested. Because, higher the SWR or Reaction force Higher is the Strength of the Roof and surrounding Parts and greater the occupant safety.

1.1 AUTOMOTIVE VEHICLE SAFETY STANDARDS

In order to reduce the deaths, injuries and ensure the Occupant/Pedestrian safety U.S, EUROPE, CHINA and recently INDIA has created some bodies like NHTSA, IIHS, FMVSS, EC and AIS standards which provide the regulations specifying the Design, Durability and performance standards which helps in manufacturing much safer vehicles. As the vehicles should clear the tests before entering in market.

All the Roof crash standards are same. Here in the work I have followed the U.S regulation called FMVSS (Federal Motor Vehicle Safety Standard) and FMVSS 216 deals with the "ROOF CRASH RESISTANCE".

1.2 FEDERAL MOTOR VEHICLE SAFETY STANDARDS (FMVSS - 216)

After carrying out much iteration IIHS, NHTSA and FMVSS has finally suggested a Quasi-static procedure and a set of considerations that need to be followed. This standard is applicable for the following vehicles:

- For Multipurpose Vehicles and Domestic cars, buses, trucks whose GVWR (Gross Vehicle Weight Rating) of 2722kg or less, and this vehicle roof should withstand the force equals to 1.5 to 3 times the vehicle unloaded weight or should offer min of 22,400 N Reaction force whichever is less.
- For Vehicles whose GVWR (Gross Vehicle Weight Rating) is greater than 2722kg, but not greater than 4536kg. The roof should withstand the force equal to 1.5 times the vehicle unloaded weight.
- In other terms the main target is that the Roof should be able to offer a minimum of 22400N reaction force before it gets displaced for 127mm by the Impactor or test device.

In this paper it is evaluated whether the roof structure can be able to offer 22400 N reaction force before the impactor displaces the roof by 127mm.

Real Test Setup procedure:

a) Impactor: Impactor or Roof Test device which is a Rigid Block having flat rectangular shaped surface with dimension 1829 X 762 MM

b) Vehicle setup Arrangement:

- The Chassis frame is fixed permanently with the Flat plate which can be considered as a sled which is fixed as shown in Figure1.2.1
- The impactor or the test device is made to orient in a way that 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 and Its transverse axis is at an outward angle, in the front view projection, of 25 degrees below the horizontal (± 0.5 degrees). this roof arrangement can be seen in Figure1.2.2
- After orienting the Test device should be positioned in such a way that the center of the forward edge of the lower surface should be placed at a distance of 254mm to the outer most point of the roof.
- The longitudinal axis or the center of the lower surface of the test device should be 10mm from the first point of contact with the roof by translating the device in the direction perpendicular to the lower surface.
- Apply Force on the test device at the rate not less than 13mm/s in a direction perpendicular to the flat bottom surface of the device until the loading device travels 127mm and constrain it move in only that direction restricting it in all other DOF's and continue it for 120seconds. Set up can be seen in Figure1.1.1-1.1.3.

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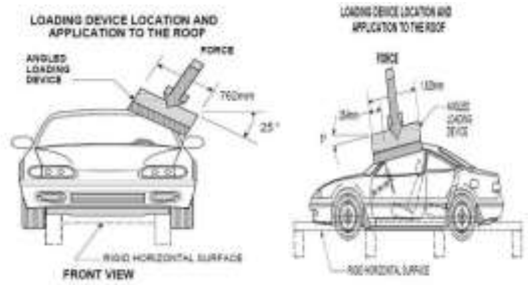

Figure1.1.1& Figure 1.1.2 Front *view and side view of the test setup and application of the Force onto Roof.*

Figure1.1.3 *Real test setup*.

1.3 PROBLEM DEFINITION

To suggest an Iteration model which has a higher an SWR (strength to weight ratio) by comparing different design optimization models like changing the Thickness, Addition of new Energy absorbing Foam component between B-pillar and the support structures or between BSO (Body Side outer) and its support structures.

1.4 OBJECTIVE

The main objective of this work is to protect the occupant during rollover crashes by suggesting a design model which can give an outcome of High SWR or High RC force.

Higher SWR can only be possible when the roof offers higher reaction force or if its weight gets decreased (SWR = Max Reaction force / weight of the vehicle.)

2 METHODOLOGY

The entire work can be explained with the help of the flow chart. These steps are followed systematically to find the best possible design iteration that meets the requirement and could able to provide the best SWR (STRENGTH TO WEIGHT RATIO)

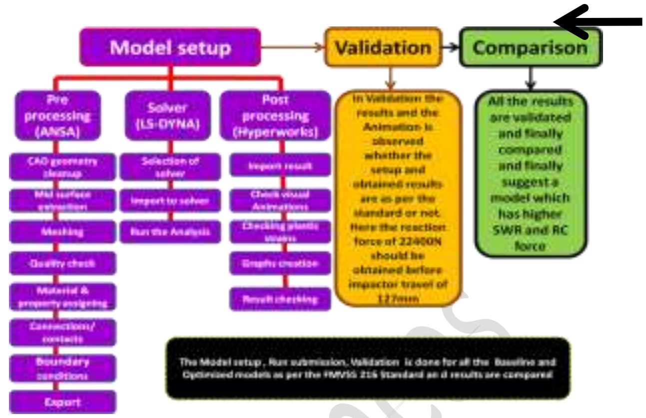

Figure2.1 *flow chart respresentation of paper*

The Entire work has been carried out by following this work flow process,

1. The CAD model of the Necessary Assemblies like BIW,Doos and the Roof is taken ,then the mid surface is extracted and modelled(discritize into finite elements) as per the Quality criteria as shown in Figure2.1.1 and Figure2.1.2

2.Now the Components are assigned with materials properties and thickness. Later, the inter assembly and intra assembly connections are given along with Boundary conditions as shown in Figure 2.1.3& 2.1.5

3.Now, the Impactor device is modelled 1829X762 mm and is positioned close to the Roof within 10mm away from the first point of contact of Impactor centre as per the standard with proper 25 degrees and 5 degrees Orientation as shown in Figure2.1.4 and 2.1.6

4. The force in applied on the Impactor like Quasi statically in the form of Disp vs Time 127mm within 150ms and submit for the simulation.

5. The obtained results are validated by seeing wether min 22400 N Reaction force is obtained or not and finally the Rc force Vs Displaement is plotted and SWR is calculated.

6. Above 1-5 steps are done for all the other optimization iterations, Compared and state the Best Model.

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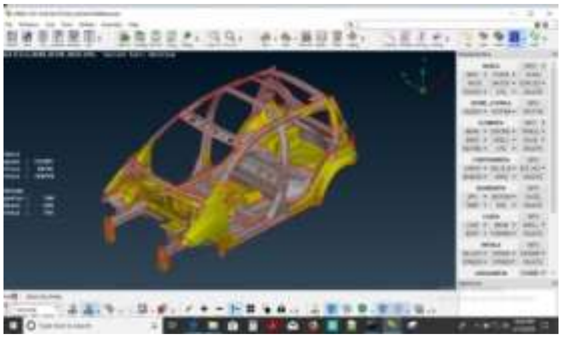

Figure 2.1.1 *CAD model*

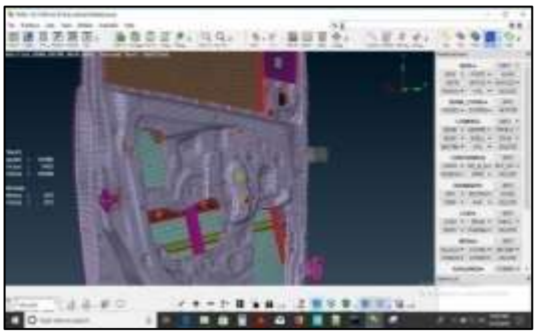

Figure2.1.2 *Midsurface Meshing*

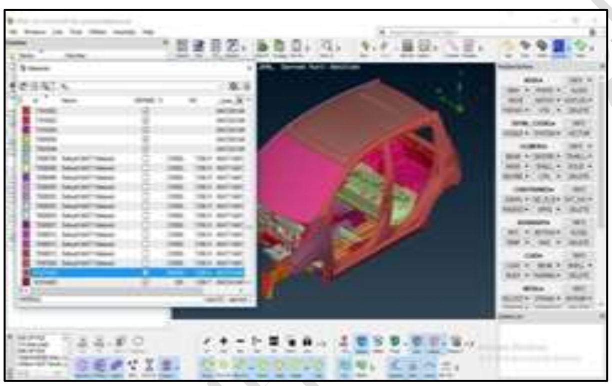

Figure 2.1.3 *Property assigning & constraining*

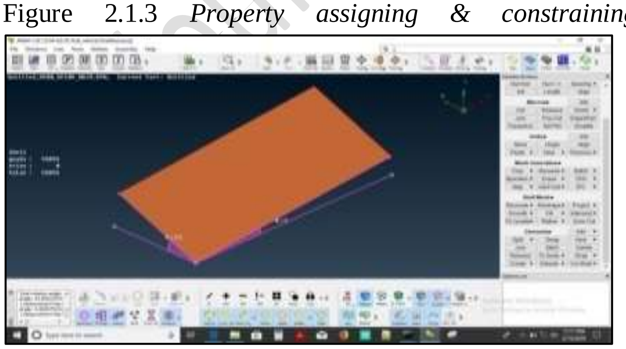

Figure2.1.4 *Impactor design and Orientation*

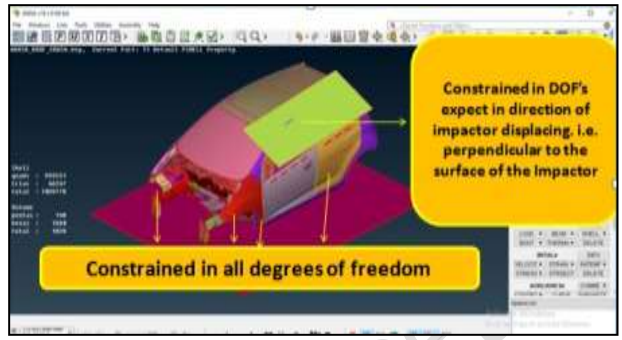

Figure 2.1.5 *Boundary Conditions Application*

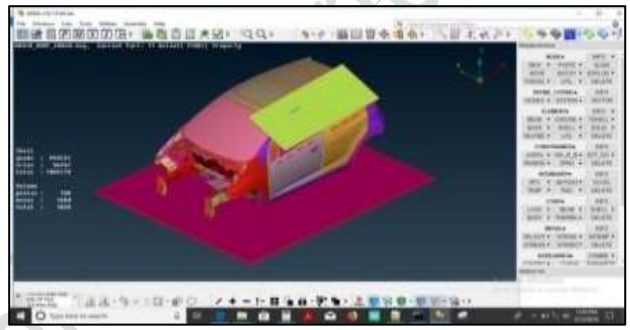

Figure 2.1.6 *Impactor positioning*

3.ITERATIONS

After the Baseline model is simulated the following iterations are done on it :

1. Energy absorbing soft Foam is modelled and placed between **BSO** and its support structures.
2. Energy absorbing soft Foam is modelled and placed between **B-pillar** and its support structures.
3. Optimized the soft Foam which is placed between BSO and its support structures.
4. Increased the thickness of the B-pillar and BSO by 0.2mm.
5. Placed the FOAM and also increased the thickness of the B-pillar.

The above five iterations along with its material can be seen in the below Figure 3.1.1-3.1.3

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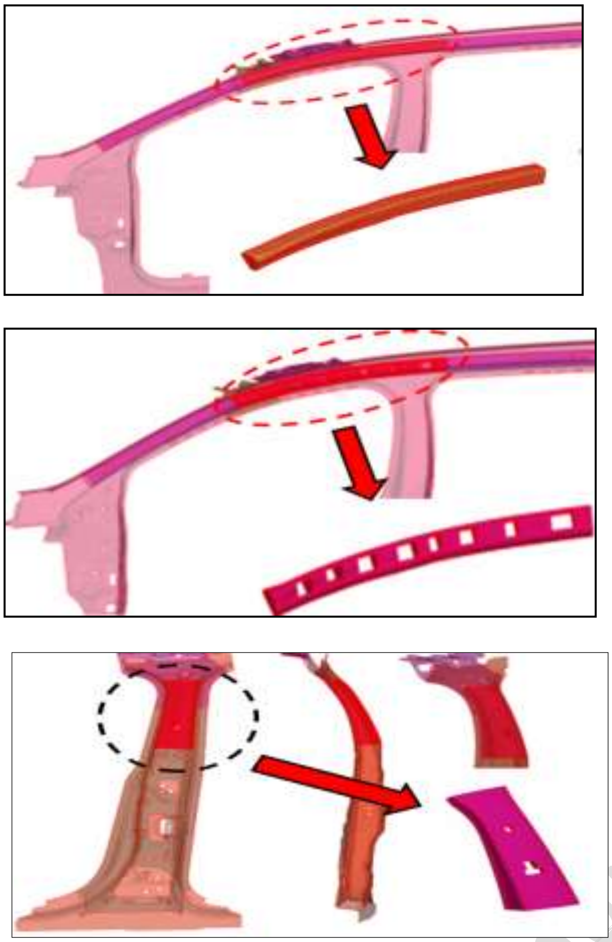


Figure 3.1.1 *iteraton 1,2,3 FOAM and Optimized FOAM between BSO and support parts and B-pillar and supporting parts*

Iteration 5 will have both iteration 1 and B-pillar thickness change by 0.2mm

Figure 3.1.2 *material of low density FOAM*

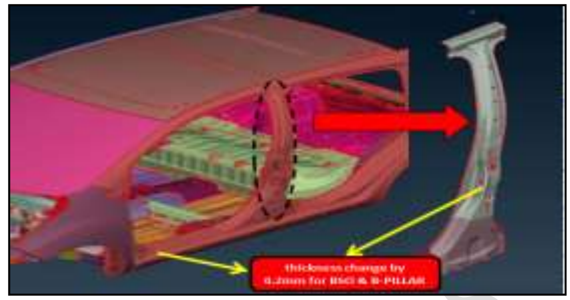
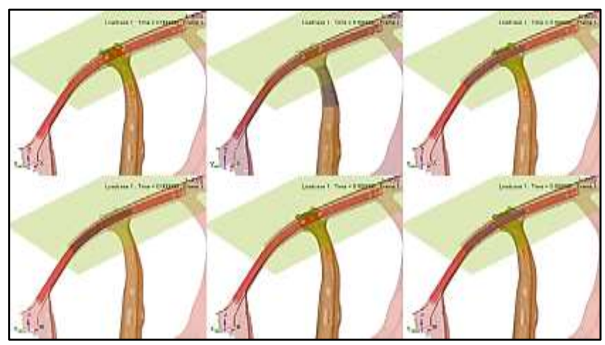


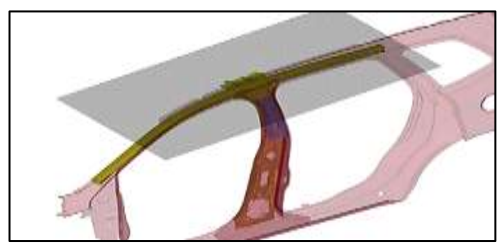
Figure 3.1.3 *Thickness change by 0.2mm in both BODY SIDE OUTER & B-PILLAR*

4 RESULTS

Both Baseline and Iterative models, results are calculated and are compared.

4.1 ANIMATION IMAGES AND EPS (EFFECTIVE PASTIC STRAIN) OBSERVATION.





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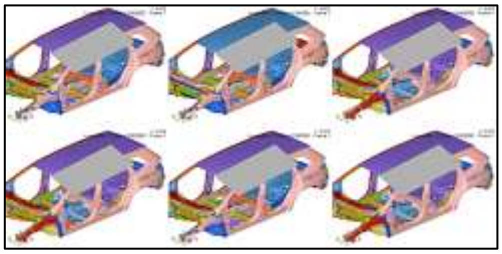

Figure 4.1.1 *Animation images of Comparison and Evaluation of All the Iterations.*

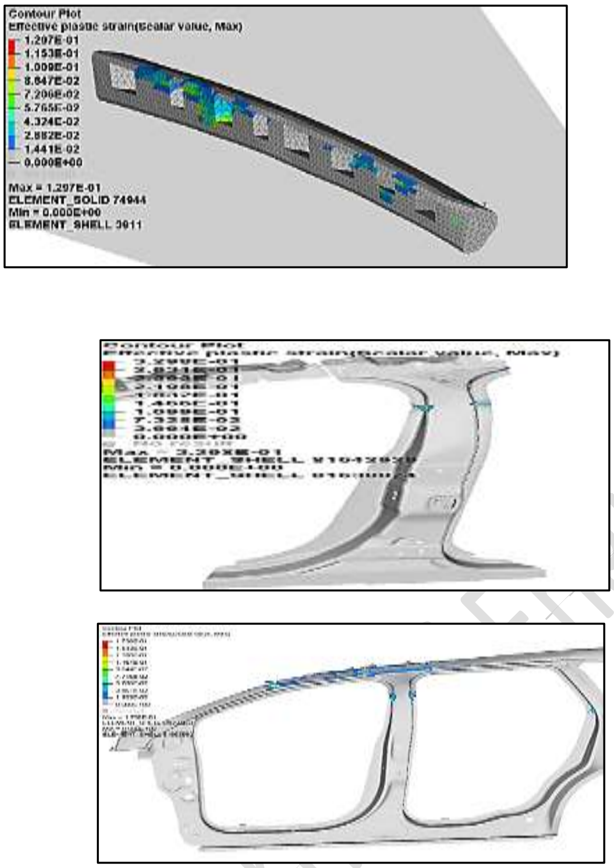

Figure 4.1.1 *Effective Plastic Strain Images of FOAM,B-PILLAR and BSO for Baseline Model*

The same way the EPS for different iterations are checked but are not tabulated or Evalauted because as per the FMVSS standard it mainly Evaluates Depending upon the Reaction force, Displacement and SWR. In the above images we can see that the foam is able to exihibit some plastic strain which means it is able to support the steel structure and absorbing the load.

4.2 MEASUREABLE QUANTITIES :

4.2.1 SWR (STRENGTH TO WEIGHT RATIO) :

To calculate strength to Weight Ratio the following formula is used :

$$SWR = \frac{\text{Max Reaction Force by Roof}}{\text{Weight of the Vehicle}}$$

The Weight is calculated from the Mass of the Vehicle multiplied by "g" i.e. W= m* g.

4.2.2 REACTION FORCE VS DISPLACEMENT

To calculate Reaction Force Vs Displacement we need to carry 3 steps. they are :

1. First Displacement Vs Time graph is plotted.
2. Now Reaction force Vs Time Graph is plotted.(The Reaction Forc offered by roof).
3. Finally Reaction Force Vs Displacement is plotted by cross plotting the first two curves

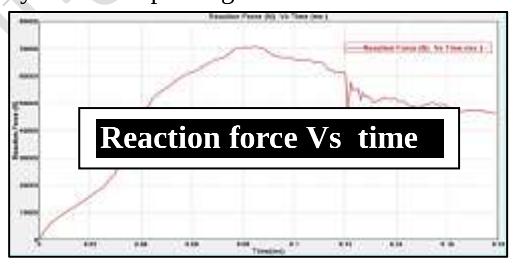

Figure 4.2.1 *Reaction Force Vs Time*

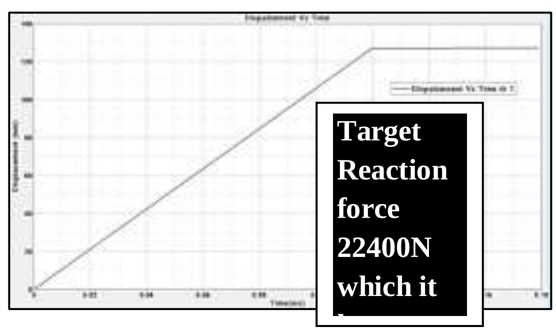

Figure 4.2.2 *Displacement Vs Time*

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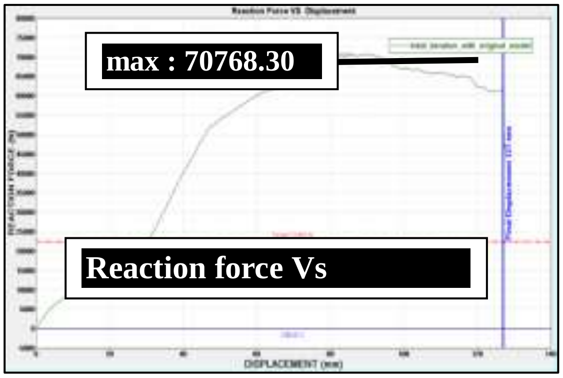

. Figure 4.2.3 *Reaction Force Vs Displacement for BASELINE model*

4.3 COMPARISON OF RESULTS BETWEEN BASELINE AND DIFFERENT ITERATIONS

The above graphs are ploted for a BASELINE model result. The same steps are followed for all the iterations and compared which can be seen in the below Curve.

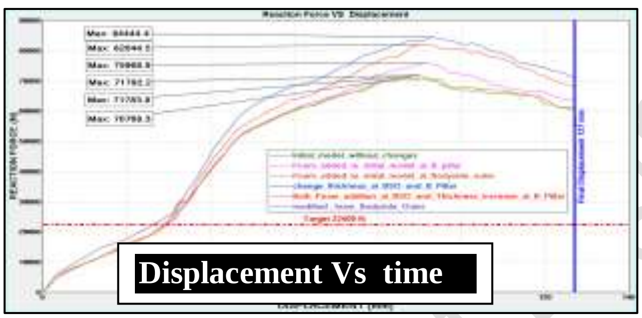

Figure 4.3.1 *REACTION FORCE(N) VS DISPLACEMENT (mm) for all iterations and Baseline Models*

Iteration models Name	Description of the Iteration	Max Reaction Force (N)	Mass of the car	Weight of the Car	Strength to weight Ratio (SWR)	Ranking order for the best
Baseline	Initial Downloaded Model	70768.3	1880	18800	3.7	5
Iteration 1	Foam in between Body side Outer and its support structures.	71783.8	1880+ 6.8kg foam= 1886.8	18868	3.8	4
Iteration 2	Foam in between B-PILLAR and its support structures.	75968.9	1880+ 5.3kg foam= 1885.3	18853	4.0	3
Iteration 3	Foam Beween BSO and Support and support structure is modified.	71792.2	1880+ 5.8kg foam= 1885.8	18858	3.8	4
Iteration 4	Thickness at BSO and Bpillar is incresed by 0.2mm	84444.4	1880+ 16kg =1896	18960	4.4	1
Iteration 5	Both Thickness change	82044.5	1880+ 6.8+6 = 1892.8	18928	4.3	2

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	at B-pillar and Foam Addition.					

Table 4.3.1 *Comparison of Reaction Force and SWR for all the Iterations.*

5 VALIDATION

The Above results obtained for Baseline and Iterations are Validated as per FMVSS 216 which is explained earlier by two conditions. If a simulation could satisfy those two conditions then the Vehicle Design model is set to be OK.

1. The minimum amount of RECTION FORCE offered by the Roof on to the Impactor should be 22400 N before the dispacement of the Impactor by 127mm
2. SWR (Strength to weight Ratio)of the Vehicle is a measure of its Rating. IIHS proposed that a Vehicle with **SWR > 4 is GOOD, SWR <4 and >3.25 is Acceptable and <3.25 and >2.5 is Marginal** and ratings are done.

From the Figure 4.3.1 it is very clear that Condition 1 satisfied by all the models that the Roof offered 22400N Reaction force before the Impactor Displacement by 127mm. Also, from the Table4.3.1 SWR is more than 3.5 so all the iterations are Acceptable and condition 2 is satisfied.

6 CONCLUSION

From the results obtained it is very clear that the optimization techniques or methods that are used to increase the roof strength come out positive. Especially, iteration 4 which means increasing the thickness at B-PILLAR and BSO is able to bring a difference of nearly 1300N more reaction force which is very big and is keeping the vehicle in much safer position with SWR>4. Also, from the results if we compare the addition of Foam part at B-PILLAR top (iteration 2) to the Baseline the reaction force by the roof is increased by 600N.

So, I conclude that if the thickness increase have any problem like Manufacturing cost, Die Restriction ETC.it is always better to add a LOW DENSITY FOAM at the Key positions so that it absorb the maximum load and help the steel structure to deform less and offer more reaction force.

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