Assessment and Evaluation of Thermoplastic Guardrail through Impact of Passenger Cars

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Abstract - *The vehicles are subjected to various types of collision: front impact, rear impact, side impact, rear angular impact, rollover etc. Accidents can happen in the city, at low speeds, or on the highways at higher speeds. In order to get better the vehicle performance and decrease the motor vehicle injuries and deaths, government organizations issue regulations and safety standards.. Median barriers are particularly effective in decreasing the chances of small, small passenger vehicles crashing into large heavy vehicles. The important task of roadside protection guardrail is to be capable of holding and redirecting errant vehicles in order to guard vehicle occupants from dangerous roadside features. Various kinds of guardrails have different protection mechanism. It is frequent in various countries they use deformable posts and beams to take up some of the vehicle's kinetic energy.*

Full-scale crash testing and computer simulation are most general approaches to simulate the impact performances of guardrail systems before their placements on highways. Since it is not possible to test all possible crash scenarios using physical testing, Computer simulations such as that using finite element (FE) analysis, provide another way to study barrier impact performances and find new designs. A crash simulation is a virtual recreation of a destructive crash test of a highway guard rail system using a computer simulation in order to inspect the level of safety of the car and its occupants.

The results of parametric study and the design of experiment conducted on a Baseline model (Steel material) were used to develop new modified model (Thermo plastic material with block out) guard rail design that was implemented in full scale finite element model of a Ford Taurus sedan car impacting a guard rail post. The new design consists of replacing the incompressible block out by a crushable one. The result of simulation show that the car was redirected safely with more reduced speed, less strain, less displacement of guard rail post than those for the baseline model.

***Key Words*: Solid Works V14, Hypermesh V14, Ls-Dyna, En-1317 standard.**

1. INTRODUCTION

The vehicles are subjected to various types of collision: front impact, rear impact, side impact, rear angular impact, rollover etc. Accidents can happen in the city at low speeds, or on the highways at higher speeds. In order to get better the vehicle performance and decrease the motor vehicle injuries and deaths, government organizations issue regulations and safety standards. The reduction of injuries can be achieved either by enhancing the traffic regulation or by implementing highly active safety features or by improving passive safety performance of the vehicle. The traffic guardrails are act like protection system in stopping vehicles from cross over the centre divider guard rail so as to keep away from accidents. The centre divider guard rails are particularly efficient in decreasing the probability of little vehicles impacting to big vehicles. The important task of roadside protection guardrail is to be strong to stop and change the direction of wrong direction moving vehicles to stop accidents and save the occupant from unsafe road side's directions. The variety of guardrails has different protection mechanism. It is frequent in various countries they use collapsible guard rail poles and beams to decrease the speed of vehicle to avoid accident. Crash experiment and computer simulation are most common tactics to simulate the impact efficiency of guardrail methods earlier than their position on roadside. Considering it's not viable to experiment all feasible crash eventualities utilizing physical experimenting, computer simulations corresponding to that using finite element evaluation, furnish one more strategy to gain knowledge of barrier influence performances and find various designs. A crash simulation is a virtual undertaking of a harmful crash test of a highway barrier rail approach and utilizing a computer simulation so as to check up on the extent of protection of the vehicle to its riders. These methods are used to computer Aided Engineering evaluation for rider's protection in computer Aided Design method of modeling barriers. Huge literature is to be had concerning the simulation of crashworthiness of guard rail in vehicular crash some of the journal papers and conferences are continuing. Out of these a couple of important works are simplified and in short awarded right here.

1.1 OBJECTIVE AND METHODOLOGY

The main objective of project is to improve crash worthiness of guardrail in passenger car impact and also increase the strength of guardrail beam and decrease the overall weight of guardrail, by using various materials and different cross section of guardrail beam. Strengthened guardrail on road, it implies decrease in fatalities and decrease in human injury expanses.

For initial study evaluate the energy absorbing capacity of steel and thermoplastic post (3 Point Bending) by analytically and comparing with Simulation results. The above comparison is to check the energy absorbing capacity of the thermoplastic materials then comparison with conventional materials. Therefore after the initial study the CAD model is developed in SOLIDWORKS, Then developing of the Mesh model in Altair Hypermesh-13 tool and checking the quality criteria of mesh model such as aspect ratio, jacobian, skewness, warpage etc.

After the Experimenting of actual crash analysis with specified vehicle speed and angles as per the standards, Deformation of guardrail beam of steel material and thermoplastic materiel compared by studying LS-DYNA results. Validating these results against CEN norm EN 1317 regulation and Based on the actual case study on deformation results and according to the standards, the conclusion for improvement will be suggested.

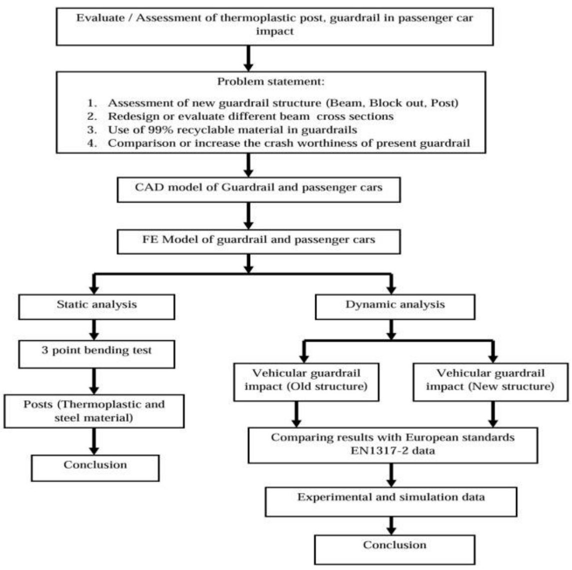

Fig -1: Methodology.

2. GEOMETRIC MODEL AND MESHING

A geometric model of the Guard rail and car was created using Solid Works V14 and Pro-E. Fig-2 and Fig-3 shows the geometric Car model. Fig-4 and fig-5 shows Assembly of baseline and modified model. The model is saved in .iges format.

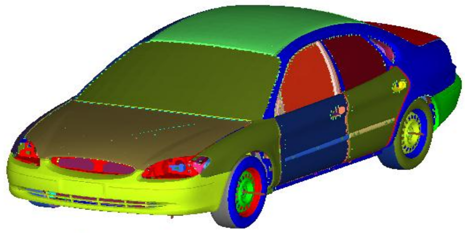

Fig -2: Car model.

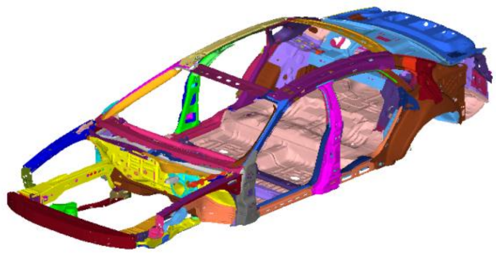

Fig -3: Car chassis model.

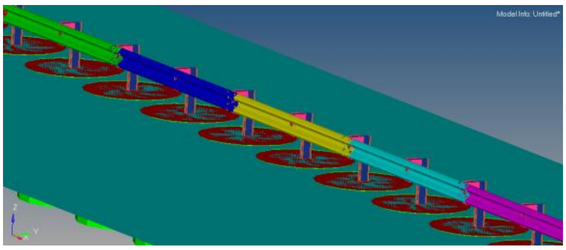

Fig -4: Guard rail model.

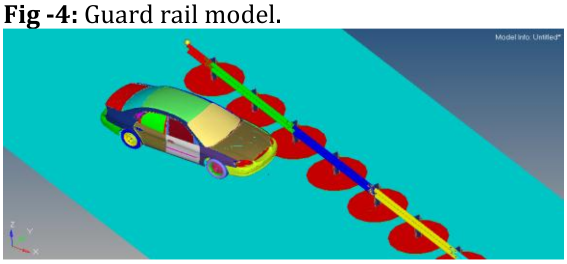

Fig -5: Assembly of Baseline model.

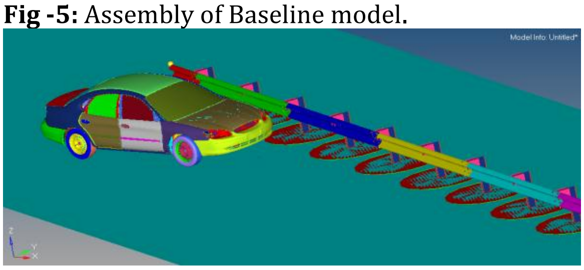

Fig -6: Assembly of Modified model.

2.1 Meshing

The geometric model in .iges format is taken in Hypermesh and the meshing was carried out. Shell mesh was done on the 2D components using 2D elements while tetra and hexa mesh was done on 3D components using 3D elements. The meshing was done as per the quality check. After meshing was completed the number of elements and nodes that were found are 1027216 and 968471. The Fig-6 and Fig-7 shows the meshed model of Baseline and modified model.

Total No. of Nodes	968471
Total No. of Elements	1027216
Tria3 Elements	62882
Quad4 Elements	877196
Tetra4 Elements	58704
Hexa8 Elements	137085

Table -1: Types and number of elements

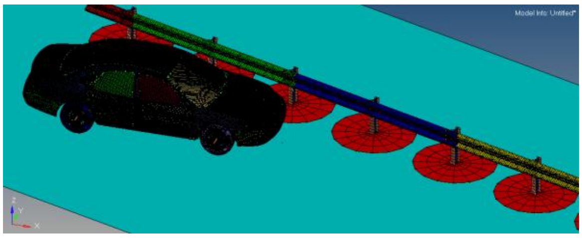

Fig -6: Baseline meshed model.

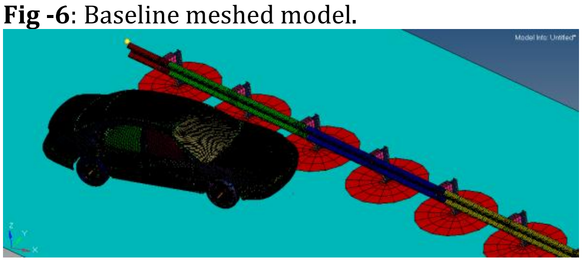

Fig -7: Modified meshed model.

2.2 Materials and Properties

The deck is prepared in Hypermesh where in the meshing is done using Hypermesh and the materials and properties are assigned then boundary and loading condition is applied and finally the simulation is carried out in Ls-Dyna. The materials and properties such as density, young's modulus and poisson's ratio have been applied to the parts as shown in the Table-2. After the material and properties are assigned the boundary and loading condition are to be applied. An initial velocity of 100 Km/hr with inclined angle 20^0 is given to the full assembly.

Parts	Material	Young's Modulus (E) (Mpa)	Yield Strength (S) (Mpa)	Poisson's Ratio	Density Ton/mm³
BIW, Door Panels, Other Sheet Metal Parts	Low Carbon Steel	200000	271	0.3	7.890e'9
Intrusion Beam	Low Carbon Steel	200000	800	0.3	7.89e'9
Engine Parts and Other Casting Parts	Cast Iron	200000	240	0.3	7.89e'9
Seats	Flexible Polymer Foam (LD)	3	0.3	.25	6.11e'11
Dash Board and Other Plastic Parts	Acrylonitrile Butadiene Stryrene	1000	20	0.3	4.0e'10
Bumper	Plastic(ABS)	1000	20	0.3	1.2e-9
Guardrail (Baseline model)	Steel	200000	298	0.3	7.89e-9
Guardrail (Modified model)	Thermoplastic	1750	35	0.2	8.49e-10

Table -2: Materials and Properties

The simulation is done only for this loading condition and hence stress and deformation are only for the loaded condition. Stresses generated due to stress concentration effects are neglected. High stresses near sharp corners and bolt holes are neglected due to the above assumption.

3. CRASH ANALYSIS

Crash test is a form of destructive testing performed in order to check safe design standards in crashworthiness and crash compatibility. Instead of physical models, a finite element model is generated and is used for the analysis. Crashworthiness simulation is less expensive and gives more information than experimental techniques.

When a crash analysis is been done is may so happen that a component may penetrate into the other which gives us wrong results so to avoid this contacts are used. Contacts are evoked using *CONTACT. The contacts that have been used are automatic single surface, automatic surface to surface, and automatic nodes to surface. After the contacts the control cards such as keyword, readme, output energy, hourglass energy, time step etc., have been used so as to avoid the unwanted time that it might take to execute the simulation.

3.1 Simulation Results

Simulation is a process by which the product validation can be done on the software. Simulations show how a system will behave in real life when it is subjected to a particular boundary and loading condition. Simulations are used when a mathematical model is complex. Baseline model was setup for two product crash simulation as shown in the Fig-8 consists of Car as impactor of 900 kg at angle 20^0 with velocity 100km/h and guardrail which is fixed in all DOF at soil region. Fig-9 and Fig-10 shows the modification in modified model and Modified model.

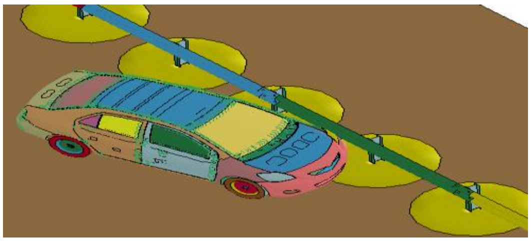

Fig -8: Baseline model.

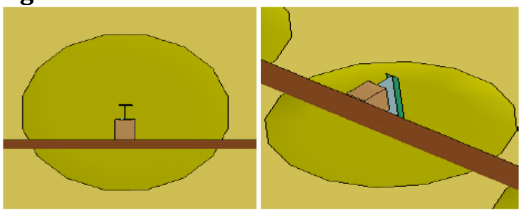

Fig -9: Modification in model.

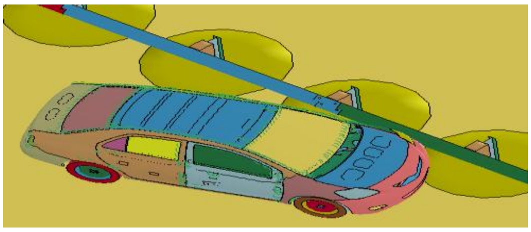

Fig -10: Modified model.

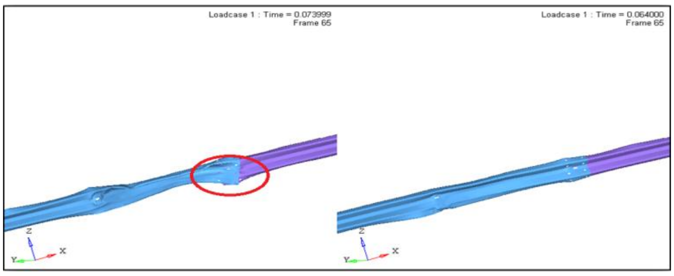

Fig -11: Impact plot for Baseline and Modified model

In above impact plot we can see the baseline model disengagement of W-beam which violets the acceptance criteria of crash simulation. The modified model passes the acceptance criteria without disengagement of guard rail.

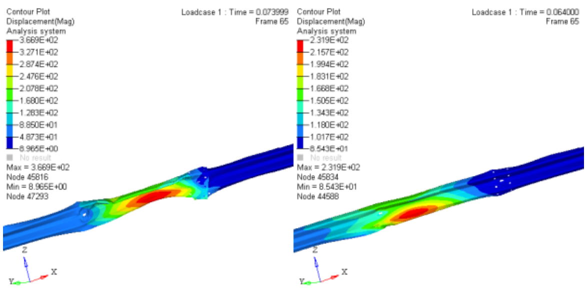

Fig -12: Displacement plot for baseline and modified W-beam model.

In above Fig-12 shows the displacement of Baseline model is 366.9 mm and modified model is 231.9 mm. Here modified model displaced lesser compare to baseline model because modified model most reliable one.

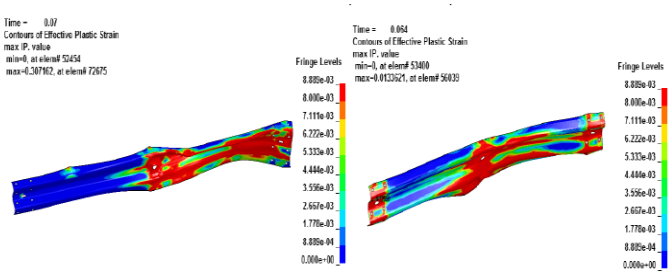

Fig -13: Strain plot for baseline and modified W-beam model.

Above Fig-13 shows the Baseline model 30.71% strained and modified model 1.33% strained. Here modified model strained lesser compare to baseline model.

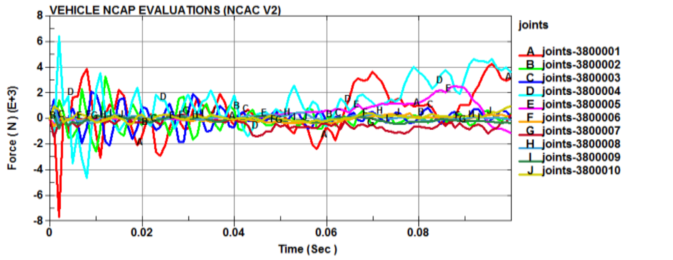

Fig -14: Section force plot for Baseline W-beam model.

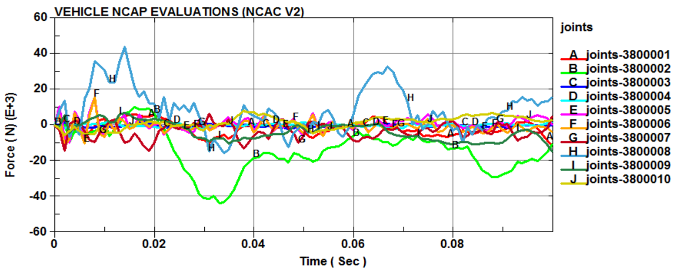

Fig -15: Section force plot for Modified W-beam model.

The graphs explain the force induced in various joints of baseline model and modified model. The maximum force reaches up to 8 KN in baseline model and 42KN in modified model. The modified model force absorption capacity will be increased by 80.9%.

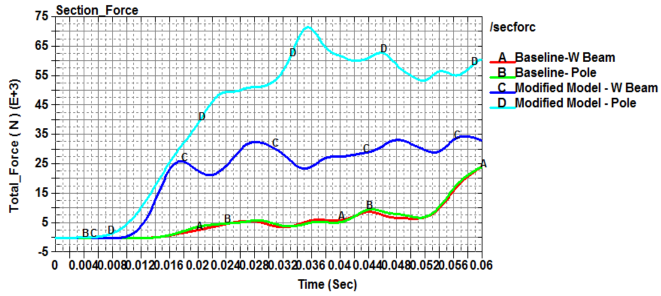

Fig -16: Force plot for Baseline and Modified model.

The above graph shows the force induced on W-beam and pole of baseline and modified model.

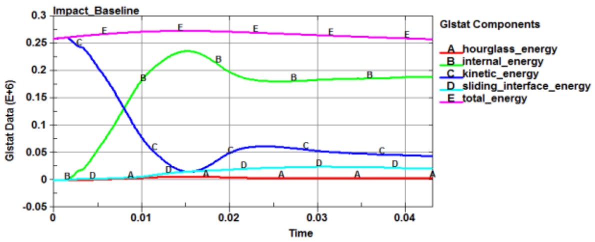

Fig -17: Energy plot for baseline model

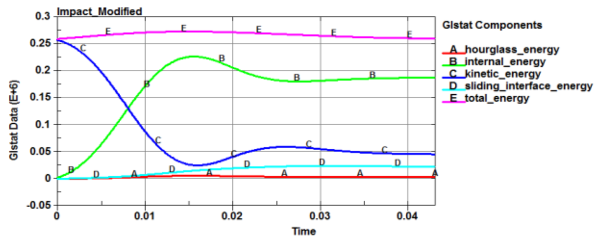

Fig -18: Energy plot for baseline model

The above Fig-17 and 18 are Energy plots for baseline and modified model. The following plots shows the actual behavior of energy when impact occurs between car and guard rail.

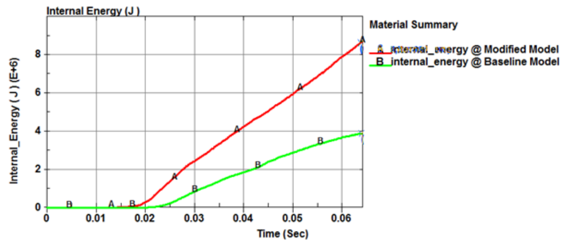

Fig -19: Global internal energy.

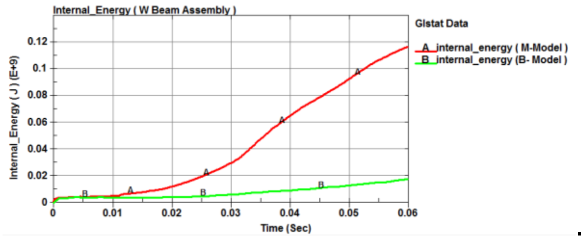

Fig -20: W-beam assembly internal energy.

The above graphs explain the internal energy of full assembly and W-beam assembly internal energy of Baseline and modified model.

Parameters	Simulation result of Baseline Model	Simulation result of Modified Model	Increase/Decrease in percentage
Complete assembly Internal Energy (KJ)	3900 KJ	8700 KJ	55.17 %(Increase)
W-Beam internal energy	18000 KJ	117000 KJ	84.6% (Increase)
Displacement (mm)	366.9	231.9	36.79% (Decrease)
Strain (%)	30.71%	1.33%	29.38% (Decrease)
Section force in W-beam	22 KN	32 KN	31.25% (Increase)
Section force in pole	24 KN	71 KN	66.19% (Increase)
Force induced in W-beam Bolts	8 KN	42 KN	80.95%(Increase)
Risk factor	Major risk	Low risk	

Table -2: Summary of Results

3.2 Validation

The validation of this project is done evaluating results according to standard acceptance criteria of EN 1317 regulations.

- **Safety barrier behavior**
  - The Guard rail should have capacity to redirect the car after impact and it should not break while impacting.

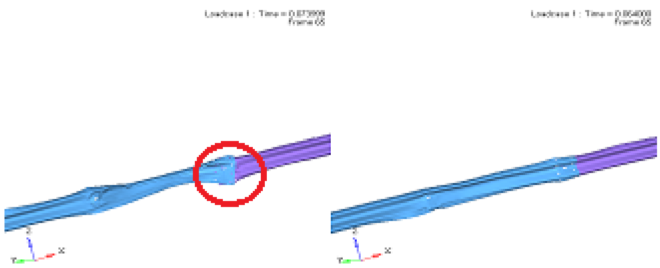

Fig -21: Impact plot for baseline and modified model.

In above Fig-21 baseline model disengaged from connection and it violets the acceptance criteria of standards. Modified model remain stable after impact which passed the acceptance criteria.

- **Test vehicle behavior**
  - No essential part of guard rail should turn out from structure otherwise it will increase the injuries.
  - The car should remain on wheel at time of experiment and after crash, although sensible rolling, pitching and yawing are tolerable.

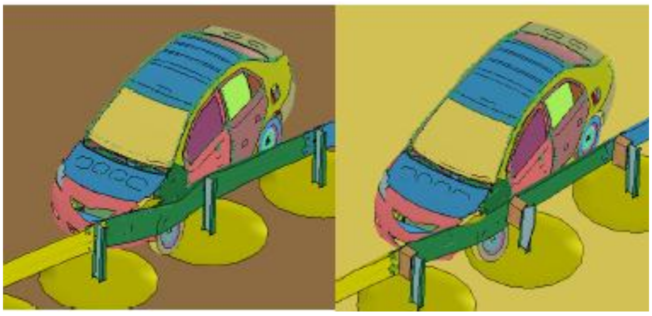

Fig -22: Baseline and Modified model.

In above Fig -22 we can see the car is stable after crash and there is no rolling and yawing in car structure.

- **Impact severity**
  - Evaluation and measurement of acceleration G values of car as per standards. It should be bellow 8.2 G's < 20G's

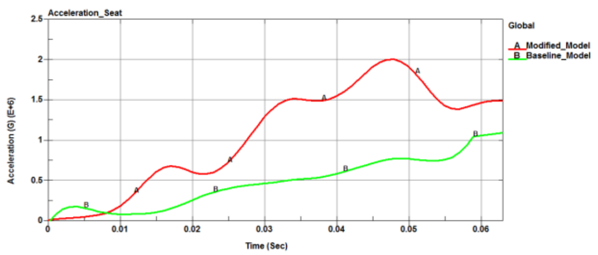

Fig -23: Acceleration G values.

The above Fig-23 shows the acceleration of baseline and modified model crash scenario. These simulation G values are below acceptance values thus the simulation is correct.

- **Deformation of safety barrier**
  - Evaluation and documenting the deflection of guard rail W-beam as per standards for permanent set 527 mm and for dynamic 925 mm.

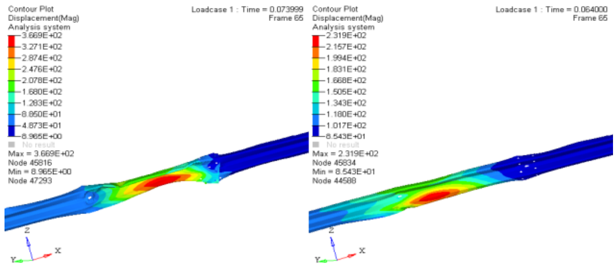

Fig -24: Deflection of W- beam.

In above Fig-24 shows deflection of baseline and modified model 366.9 mm and 231.9 mm respectively. According to acceptance values these values are safer side.

3.3 Conclusion

On this project work, crash evaluation of Guard rail simulation is done using LS-DYNA software. Simulation is implemented in two instances which are with steel material and thermo plastic material pole with block out. Right here Altair Hypermesh v13 tool is used for meshing the whole model and passed the quality check, Skewness, warpage, Jacobian etc. The FE model is successfully analyzed utilizing LS-DYNA software and tools; connections of the model are created as per current industry practices in an effort to co-relate it with realistic simulation. After finishing the analysis contour plots, global section force of entire model, energy absorbed of each the simulations are compared.

By showing the Thermo plastic material in pole and block out of the barrier body we can see various alterations in the activities of the particular parts in the vehicle. The movements that happened after both the propagations are force impelled in the particular parts and essentialness ingestion, displacement and effective plastic strain. The movements are according to the accompanying:

1. W-Beam assembly energy absorbed is 18000 KJ in the baseline model which is less compared to 117000 KJ in the modified model. To enhance the Crashworthiness, the rail should absorb as much energy possible and only transfer small amount of energy. The energy absorbed in the baseline model decreased by 55.17% compared to modified model and thus reduces the risk factor.

2. The strain of W-Beam barrier is 30.71% of Baseline model wherein the strain absorption rate is 1.33% for Modified model. The altered model

strain is diminished by 29.38% means the harms are less contrast with standard model.

3. The Baseline model W-Beam barrier displacement is 366.9 mm wherein the Modified model is having 231.9 mm. The threat segment diminished by 36.79% in displacement of guardian rail.

4. The section force affected in Base line and Modified model beam is 22 KN and 32 KN wherein the section force is 24 KN and 71 KN for Baseline and Modified d model post. The Baseline model W-beam and pole are decreased by 31.25% and 66.19% in section force contrast with modified model.

5. The forces induced in W-beam Bolt joints of baseline model is 8 KN and for modified model is 42KN. The Baseline model W-beam bolts joint force induced is decreased by 80.95% compare to Modified model.

By these conclusions we can say that the modified Model with Thermo plastic material and block out structure is safe and improves the Crashworthiness of the Guard rail. The improvement in the Crashworthiness of the Guard rail means less fatal human injuries; hence by introducing the Thermo plastic material and block out structure, energy absorbed by the parts of the vehicle is more compared to Steel material. More the energy absorbed by the Thermo plastic pole and Block out structure less the energy transferred to the W-beam of Guard rail. Thus we can conclude that Thermo plastic material more reliable for road side Guard rails.

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