OPTIMIZATION OF BUMPER ENERGY ABSORBER TO REDUCE HUMAN LEG INJURY

Bharatesh P Almane[1], Prof. S. A. Pachapuri[2]

[1]Department of Mechanical Engineering (M.Tech in Design Engineering)
KLE Dr. M S Sheshgiri College of Engineering and Technology Udyambag, Belagavi, Karnataka, India 590008
[2]Department of mechanical engineering (professor)
KLE Dr. M S Sheshgiri College of Engineering and Technology Udyambag, Belagavi, Karnataka, India 590008

Abstract - *Human deaths related to pedestrian accidents contribute to a more number of all traffic accidental human deaths. Therefore, walker security has turned out to be progressively essential in the automotive industry. There are 141,526 people were executed and 477,731 harmed in street car accidents in India in a single year. The lower extremities were the most frequently injured in all cases of injury. Around 80% of person on foot mischances were at speeds less than 35 mph. The outcomes from this investigation demonstrate that the head and lower comprised included 84% of the aggregate injuries. In the lower limb injuries 42% were because of tibia cracks, 18% to knee injuries, and just 2% to femur breaks.*

The principle point of this work is to create engineering countermeasures to diminish the possibility of person on foot bring down leg injuries by using a superior bumper design. The energy absorbing limit of the bumper framework could be the key. It will likewise be the objective in this work. A global technical regulation (GTR no. 9) has been created by the international community to reduce these walker injuries through enhanced vehicle guard frameworks. The Flexible Pedestrian Leg form Impactor (Flex-PLI) has been produced to fill in as a more biofidelic test gadget for use in this GTR test methodology.

***Key Words*: Leg form, Bumper system, Ligaments, Tibia, GTR9 regulation, Hyper-mesh software, LS Dyna software,**

1 INTRODUCTION

Human deaths related to pedestrian accidents contribute to a more number of all traffic accidental human deaths. Therefore, walker security has turned out to be progressively essential in the automotive industry. There are 141,526 people were executed and 477,731 harmed in street car accidents in India in a single year. The lower extremities were the most frequently injured in all cases of injury. Around 80% of person on foot mischances were at speeds less than 35 mph. The outcomes from this investigation demonstrate that the head and lower comprised included 84% of the aggregate injuries. In the lower limb injuries 42% were because of tibia cracks, 18% to knee injuries, and just 2% to femur breaks.

The principle point of this work is to create engineering countermeasures to diminish the possibility of person on foot bring down leg injuries by using a superior bumper design. The energy absorbing limit of the bumper framework could be the key. It will likewise be the objective in this work. A global technical regulation (GTR no. 9) has been created by the international community to reduce these walker injuries through enhanced vehicle guard frameworks. The Flexible Pedestrian Leg form Impactor (Flex-PLI) has been produced to fill in as a more biofidelic test gadget for use in this GTR test methodology.

1.1 Problem Statement

The lower limit is the most powerless body part in non-deadly pedestrian accident. The most frequently injured body part is the lower leg. The significant reason for bring down leg damage to the underlying contact amongst vehicle and pedestrian is quite often between the vehicle bumper and pedestrian down leg

Consequently, the fundamental point of this work is to create engineering countermeasures to diminish the likelihood of pedestrian down leg injuries by following parameters. The impact analysis is carried out in the LS-Dyna.

1.2 Objectives

The main objective/work carried out of this project work is as follows,

- Developing a CAD model in solid works.
- Developing the mesh model using the Altair Hypermesh-14 tool.
- Checking the quality criteria of mesh model such as aspect ratio, jacobian, skewness, warpage etc.
- Analysis is carried out using the LS-Dyna tool and proper cards are specified.
- The regulation GTR 9 contains the “to lessen pedestrian injuries through enhanced vehicle bumper design”.
- To achieve tibia bending moment and ligaments elongation value below its slandered injury reference values.
- To enable the generation of different design, the design variable are chosen as the thickness of bumper foam, shape of bumper foam and thickness of fascia to achieve the regulations / standards.

2 GTR-9 Regulation Standards

Objective of global crash standards is to enhance worldwide safety, diminish ecological contamination and utilization of energy and change burglary execution of vehicles and related parts and gear through Establishing global technical regulation (GTRs) in a Global Registry in view of UNECE Regulations or on national controls recorded in a Compendium of hopefuls GTR fitting them at the most elevated amount underneath In preface of Global Technical Regulation on Pedestrian Safety (GTR No. 9), published in January 2009

The fundamental techniques as laid out in Amendment 1 of the Proposal for a Global Technical Regulation (GTR) for the Protection of Pedestrians [GRSP, 2010]. A 'leg-form' impactor is moved toward a stationary vehicle at a speed of 40 km/h parallel to the vehicle's longitudinal hub. The lower leg form to guard test will be led if the lower guard reference line at the effect over the ground. The GTR test system expresses that the base of impactor ought to be 75mm over the ground reference plane at the season of first contact with the guard.

Table 1: Regulation parameters

Test method	Parameter	GTR No. 9	Euro NCAP	
			max. score	zero score
EEVC lower legform impactor to bumper	Velocity	40 km/h		
	Impact angle	0°		
	Acceleration	170 g (250 g)		
	Bending	19°		
	Shearing	6 mm		
Flex PLI to bumper	Velocity	40 km/h	40 km/h	
	Impact angle	0°	0°	
	Tibia Bending	340 Nm (2	282 Nm	340 Nm
	MCL Elongation	22 mm (2	19 mm	22 mm
	ACL/PCL Elong.	13 mm (2	10 mm	10 mm

3 Geometric and Finite Element Modeling

To do CAE simulation of any part, the strong model of the same is fundamental. It is additionally called body in white. In this part the detailed description of CAD models utilized as a part of this undertaking are examined. The CAD modeling software package like CATIA V5 is used to model the components of this project.

3.1 Bumper system and Leg Impactor

Car bumper system made up of plastic parts mainly it consist of (Fascia, Foam, Reinforcement, etc.) which thickness varies from 0.2mm to 4-5mm ,the CAD model of bumper system. Total weight of the model is 13.5kg. In that femur weight is 7.4kg and tibia weight is 6.1kg. The length of the femur and tibia is also 434mm and 494mm respectively shown in figure 7.3.

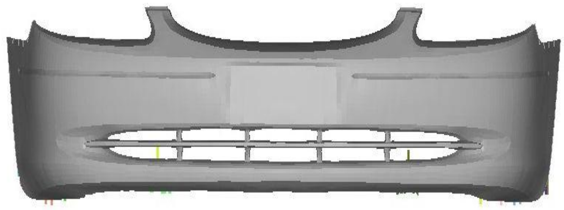

Figure 1: CAD model of bumper assembly

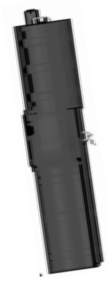

Figure 2: CAD model of leg form impactor

The meshing is done over the CAD model of bumper system and leg form (dummy) with element size of 5mm with considering good practices of meshing criteria. The following figure 3 shows the assembly view of bumper system with impactor.

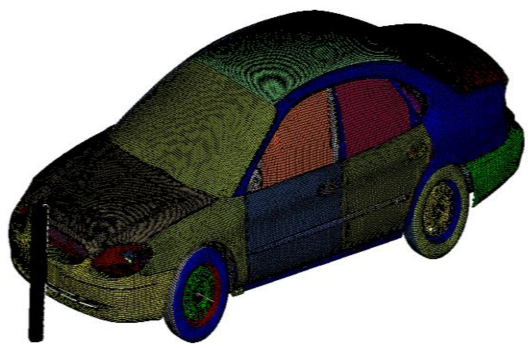

Figure 3: Assembly of bumper system with leg impactor

3.2 Material and Properties

Table 2: Material and Properties of Car Front Bumper

Materials	Parts	Poisons Ratio	Density mg/mm^3	Young's Modulus (E) MPa
AA6014	All Sheet Metal Parts	0.1894	2.7E-6	70.
AlMgSi	BIW	0.31	2.7E-6	70.
ABS_PP	Cooler Assembly Covers	0.02011	1.13E-6	2.1
PP_EPDM	Upper Reinforcement	0.01372	1.E-6	1.47
PP_EPDM_1	Lower Reinforcement	0.006578	1.05E-6	1.6
PA6	Front Grill	0.006498	1.23E-6	3.252
PCABS	Fascia	0.018	1.284E-6	4.5
EPP	Foam		3.E-8	0.01
Spot	Connection	0.3	7.85E-6	42.
ABS	Lower Air Duct	0.02837	1.07E-6	2.36

Table 3: Material and Properties of Leg Impactor

Material id	Material name	Material type	Material description	RHO	E	Nu
8600009	ELASTIC - BONE CORES	MATL1	*MAT_ELASTIC	2.2e-6	55.0	0.3
8600026	ELASTIC - CABLE BENDING	MATL1	*MAT_ELASTIC	3.925e-6	0.1	0.3
8600032	ELASTIC - CABLE TENSION	MATL1	*MAT_ELASTIC	3.925e-6	45.0	0.3
8600033	VELCRO STRAP	MATL1	*MAT_ELASTIC	1e-6	0.005	0.3
8600006	NULL - CABLE OUTER SHELLS	MATL9	*MAT_NULL	1e-9	5.0	0.3
8600022	NULL - CONTACT SHELLS	MATL9	*MAT_NULL	1e-9	5.0	0.3
8699001	NULL MATERIAL FOR KNEE CONTACT BEAMS	MATL9	*MAT_NULL	1e-9	45.0	0.3
8600001	RIGID - ALUMINUM (LINKS, KNEE COVERS, LAUNCH ATTACH)	MATL20	*MAT_RIGID	2.81e-6	71.7	0.33
8600002	RIGID - KNEE TIBIA BLOCK	MATL20	*MAT_RIGID	2.87e-6	71.7	0.33
8600003	RIGID - KNEE FEMUR BLOCK	MATL20	*MAT_RIGID	2.891e-6	71.7	0.33
8600004	RIGID - KNEE BRONZE RINGS	MATL20	*MAT_RIGID	7.85e-6	71.7	0.33
8600007	RIGID - VISUAL BARS	MATL20	*MAT_RIGID	1e-7	5.0	0.3
8600008	RIGID - KNEE MENISCUS ASSEMBLY 2	MATL20	*MAT_RIGID	1.15e-6	0.6	0.25
8600010	RIGID - INNER SEGMENTS (KNEE SIDE)	MATL20	*MAT_RIGID	2.6e-6	71.7	0.33
8600011	RIGID - FEMUR BOTTOM AND TIBIA TOP SENSORS	MATL20	*MAT_RIGID	1.8e-6	71.7	0.33
8600012	RIGID - FEMUR END PART	MATL20	*MAT_RIGID	2.42e-6	71.7	0.33
8600013	RIGID - FEMUR BONE CLAMPS	MATL20	*MAT_RIGID	3.05e-6	71.7	0.33
8600014	RIGID - INNER SEGMENTS	MATL20	*MAT_RIGID	1.097e-6	0.6	0.25
8600015	RIGID - SPACER BONE CONTACT THICK	MATL20	*MAT_RIGID	2.64e-6	45.0	0.35
8600016	RIGID - SPACER BONE CONTACT THIN	MATL20	*MAT_RIGID	1.58e-6	45.0	0.35
8600017	RIGID - FEMUR CABLE ASSEMBLY ENDS	MATL20	*MAT_RIGID	3.4e-6	205.0	0.35
8600019	RIGID - FEMUR END PART 2	MATL20	*MAT_RIGID	7.78e-6	71.7	0.33
8600020	RIGID - TIBIA END PART	MATL20	*MAT_RIGID	2.75e-6	71.7	0.33
8600021	RIGID - TIBIA CABLE ASSEMBLY ENDS	MATL20	*MAT_RIGID	2.8e-6	205.0	0.35
8699002	ADDITIONAL RADIUS FEMUR BLOCK	MATL20	*MAT_RIGID	1e-9	200.0	0.33
8600023	ELASTIC PLASTIC - NYLON KNEE IMPACT SEGMENTS AND MENISCUS	MATL24	*MAT_PIECEWISE_LINEAR_PLASTICITY	1.15e-6	3.7	0.41
8600029	ELASTIC PLASTIC - NYLON OPTIONAL SEGMENTS	MATL24	*MAT_PIECEWISE_LINEAR_PLASTICITY	1.045e-6	3.7	0.41

3.3 Boundary Condition

The boundary condition is the use of a load as well as constraints. In Hyper work, boundary conditions are put away inside a collector called load collector. The capacity of the boundary conditions is to make and characterize requirements and loads on FE models. In this task boundary conditions are connected to the all tires. Speed is connected to the impactor at 40 km/hr. What's more, stress close to the sharp corner and bolt gaps are dismissed because of stress concentration effect. Figure 4 shows boundary conditions for the GTR control models.

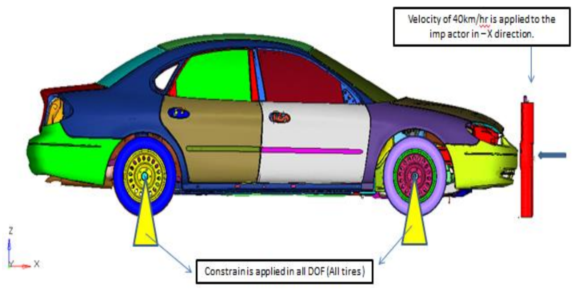

Figure 4: Boundary conditions

3.4 Contacts

Accurate Contacts forms an integral a part of several large deformation issues. Correct modeling of contact interfaces between bodies is crucial to the forecast capacity of the finite part simulations. There are different types of contacts are there however in this project the single surface contact is utilizing. This contact is generally utilized as a part of contact option in Dyna, particularly for crashworthiness application. With this sort the slave surface is commonly described as a rundown of part ID's. Regardless surface is characterized. Contact is considered between each one of the parts in the slave list, including self-contact of each part. On the off chance that the model is precisely characterized these contact sorts are extremely accurate and reliable.

4. Simulation and Validation

Simulation is the processes of product validation where the product is tested with defined boundary conditions and assumed parameters. The demonstration of reproducing something initially requires that a model be produced this model represents to the key attributes or behaviors/functions of the chose physical or conceptual framework or process. The represents to the framework itself, though the simulation represents to the activity of the framework after some time. Below figure 5, 6 & 7 shows the cut section of simulation during initial stage, intermediate & final stage where we can see the behavior of flex PLI impacting on the bumper.

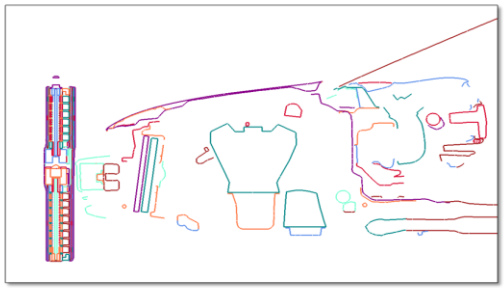

Figure 5: Cut section of leg impact simulation @ Y 000 mm (Initial Stage)

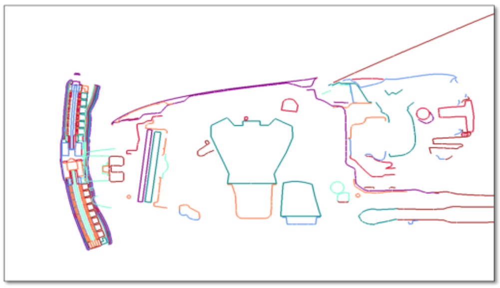

Figure 6: Cut section of leg impact simulation @ Y 000 mm (Intermediate Stage)

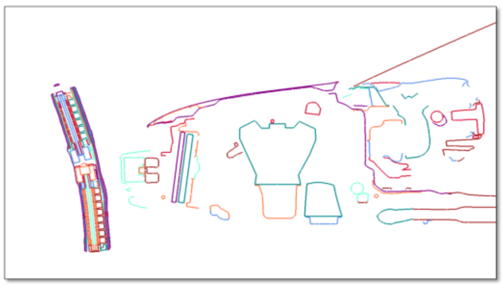

Figure 7: Cut section of leg impact simulation @ Y 000 mm (Final Stage)

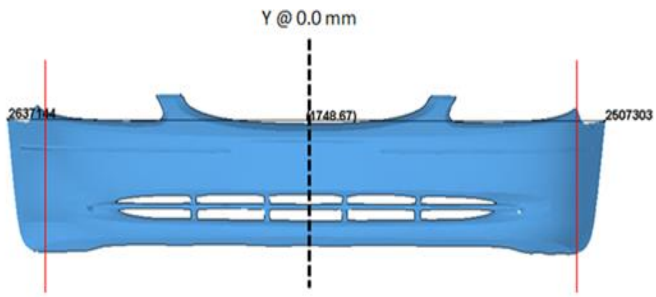

Figure 8: Impact points on the bumper from Y@ 000 mm

The impactor is made to impact on the overall length of the bumper to evaluate the values of MCL, ACL & Tibia Moments as shown in the figure 8.

4.1 Baseline Model Results

Baseline model is the initial stage of the design which is not mature to pass all the regulations as per the standards, were the simulation will help us to know the potential of baseline design and make some modifications to pass the standard's as per the regulations.

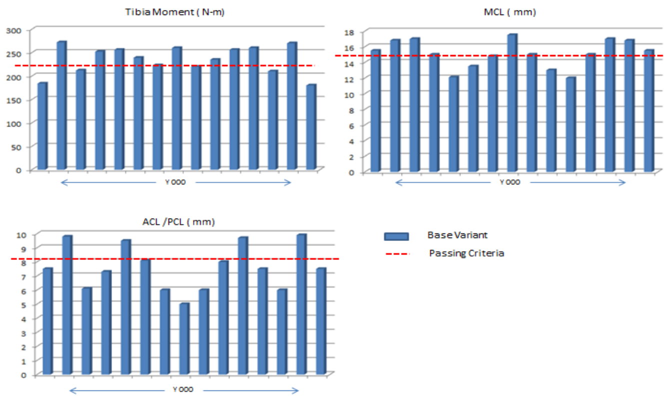

Figure 9: Tibia, MCL & ACL values for base line model

4.2 Modified Model Results

Modified model shows the some material removed or slightly design changes at the critical locations observed in baseline model. Base variant and modified variant designs shown in below figure.

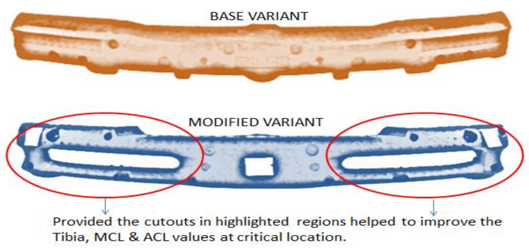

Figure 10: Baseline vs. Modified bumper foam model

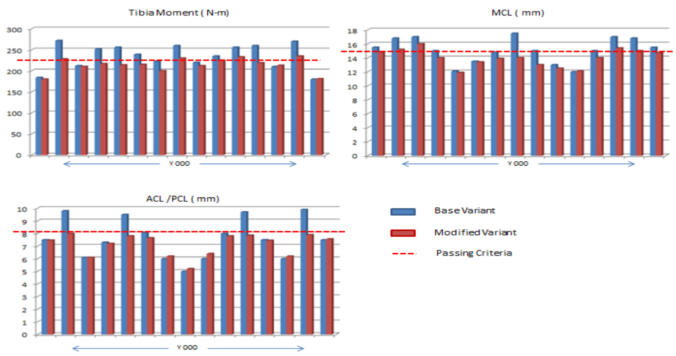

Figure 11: Tibia, MCL & ACL values for modified model.

4.3 Comparison Results & Discussion

In this area we will talk about and analyze the results of baseline and modified model such of Tibia, MCL and ACL/PCL moments.

Table No 4: Comparison between Baseline and Modified Model Tibia, MCL & ACL moments.

	Tibia Moments (Nm) <282Nm GTR <220 Nm ENCAP		MCL Moments (mm) <19mm GTR <15mm ENCAP		ACL Moments (mm) <10mm GTR <8mm ENCAP	
Impact Point	Base	Modified	Base	Modified	Base	Modified
Y -700	184	180	15.5	14.8	7.5	7.46
Y -600	272	228	16.8	15.2	9.8	8
Y -500	212	210	17	16	6.1	6.1
Y -400	252	217	15	14	7.3	7.2
Y -300	256	214	12.1	11.9	9.5	7.8
Y -200	239	215	13.5	13.4	8.1	7.65
Y -100	223	200	14.8	13.9	6	6.2
Y 0	260	230	17.5	14	8.1	7.65
Y 100	220	212	15	13	6	6.4
Y 200	235	225	13	12.5	8	7.8
Y 300	256	233	12	12.1	9.7	7.85
Y 400	260	219	15	14	7.5	7.45
Y 500	210	213	17	15.4	6	6.2
Y 600	270	235	16.8	15	9.9	7.9
Y 700	180	181	15.5	14.7	7.5	7.56

Below figure 12 shows internal energy in bumper foam for baseline and modified model. Figure 12 shows the internal energy of modified foam model is slightly larger than baseline model so baseline foam model is stiffer than the modified model.

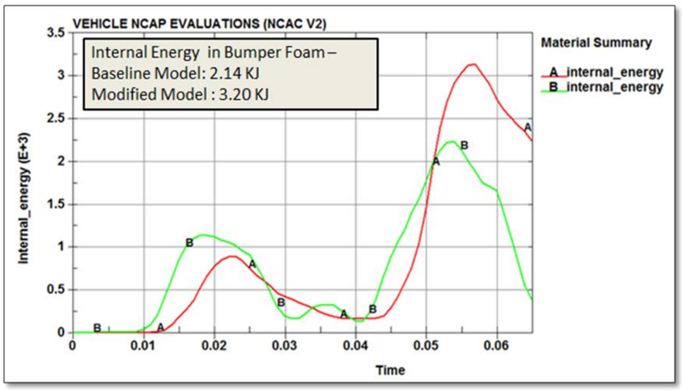

Figure 12: Internal energy in bumper foam for Baseline & Modified Model.

5 CONCLUSIONS

This project mainly concentrate impact analysis scenario which is carried out on to the car bumper system to reduce the tibia, MCL and ACL/PCL moment values according to GTR-9 regulation standard. The following are some of the points which are concluded from below table where comparison of tibia, MCL and ACL/PCL values of baseline and modified model at different points with the standard value.

1. Practice & standardized CAE process increases productivity, simulations can be used to improve the car bumper system design to pass the automotive regulation test.
2. Critical parameters/locations observed in baseline model of bumper foam for tibia, MCL and ACL/PCL moment values shown in figure 7.5 and listed in table no 7.1.
3. The values at critical parameters/locations observed are crossing the internal achievement values and also crosses the regulation standard values in ACL/PCL moment @+/-250mm as shown in figure 7.5 fracture in leg will be observed for physical testing.
4. In the modified model material is removed slightly or slightly design changes at the observed critical locations @+/-250mm and @+/-650mm with respect to standard values as shown in figure 7.7.
5. Next iteration of simulation gates a satisfied moment values w. r. t standard values as shown in figure 7.8.
6. Comparison of baseline and modified bumper foam model gates more satisfied tibia, MCL and ACL/PCL moment values in modified model w. r. t standard regulation values shown in figure 7.10 and listed in table 7.2.
7. Internal energy absorbsion at modified model is slightly larger (3.20KJ) than the internal energy absorbsion at baseline model (2.14KJ) shown in figure 7.14. Baseline model is stiffer than the modified model.
8. Modified design of bumper foam is satisfying the criteria for pedestrian impact such as

   Tibia Moment - Lesser than 282 Nm.

   MCL Moment - Lesser than 19 mm.

   ACL/PCL Moment - Lesser than 10 mm.
9. GTR 9 standard values for the pedestrian safety which need to be passed by all vehicles to launch the vehicle in the market and get 5 star rating.

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