# Bumper product design approach to meet pedestrian safety requirement

Mr. Nitinkumar, Mr. Yamgar B.S.
Wissen Baum Engineering Solutions LLP
Am steinacker 15a
*38446 Wolfsburg*
*kn@wissenbaumllp.com*

*"This paper addresses injuries in lower body region and proposes bumper design approach to reduce lower body injuries"*

KEYWORDS –

AIS 100, ECE R127, GTR 9, EURO NCAP

ABSTRACT

Each year, more than 270 000 pedestrians lose their lives on the world's roads. Globally, pedestrians constitute 22% of all road traffic fatalities, and in some countries this proportion is as high as two thirds of all road traffic deaths. Millions of pedestrians are non-fatally injured some of whom are left with permanent disabilities. These incidents cause much suffering and grief as well as economic hardship.
This paper addresses injuries in lower body region and proposes bumper design approach to reduce lower body injuries.
This paper is divided into three segments namely,

a) Pedestrian safety regulations
b) Bumper design approach
c) Testing

## INTRODUCTION

Transportation industry has been one of the important industries along the globe since last 120 years. The automotive vehicle OEMs has challenges such as fuel economy, Safety, durability, personalization, emission etc. The automotive safety is one of critical requirement in automotive industry. In last 120 years many global regulations to assure the Safety requirements and standards are created by many government and non-governmental agencies.
In pedestrian safety two main body regions namely head and lower limbs contributes respectively 31.4, 32.6% injuries. Hence the pedestrian safety regulations such as AIS 100, ECE R127, GTR 9, EURO NCAP etc. targets protection of head region and lower body region. In this paper the emphasis is given to lower limbs region only.

## 1.1.0 Pedestrian Safety Regulations

The overview of major safety regulation governing lower limbs impact are given in table 1.1. The key highlights are given below,
The minimum 3 impacts should be carried out.
The distance between 2 points should be minimum 132 mm and 66mm from corner of bumper with velocity of 40 kmph. (refer fig 1.1.1)
The impact zone / location is determined by the procedure specified in regulation.

| Description | AIS100/ GTR-9/R127 | | Euro-NCAP | KNCAP |
|---|---|---|---|---|
| Impactor | AIS100-LF/Flex Pli<br>ECE R127/GTR9-Flex Pli | | Flex PLI | Flex PLI |
| Impact Velocity (km/h) | 40 | | 40 | 40 |
| I/point Selection | Worst points | | GRID method | GRID method |
| Injury | Deceleration(g) | <170 | TIBIA (Nm) 282 -340 | |
| | Bending (deg) | <19 | MCL (mm) 19 -22 | |
| | Shear(mm) | <6 | ACL/PCL (mm) 10 | |

*Table 1.1.1*

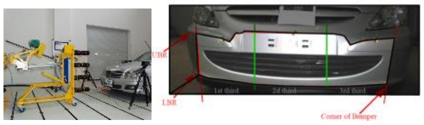
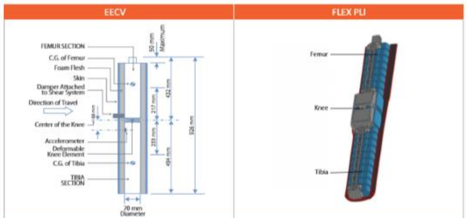


*Fig 1.1.1: Leg form test marking at ARAI Lab*

## 1.1.1 Lower leg form model

The lower leg form model is mainly classified in two types EECV and Flex PLI. The comparison of these leg forms are given in table 1.1.2.



| EECV | | FLEX PLI | | |
|---|---|---|---|---|
| **Physical Properties** | | | | |
| Mass (kg) | 13.4 | Mass (kg) | 13.4 | |
| Length (mm) | 926 | Length (mm) | 975 | |
| Diameter (mm) | 132 | Diameter (mm) | 132 - 140 | |
| The EEVC legform, which is the device that has been used for many years in the European New Car Assessment Program (Euro NCAP). Currently EECV Legform is used for AIS 100 and GTR 8. While the EEVC legform has been a repeatable and durable device for evaluating vehicles, it has some notable limitations, among them are; insufficient biofidelity due to completely rigid femur and tibia elements leading to its inability to simulate the combined loading at the knee present in actual pedestrian collisions. | | The Flex-PLI features biomechanically based femur, tibia and knee design, with biofidelic bending characteristics. The components of the leg consist of a segmented femur with a suspension bracket at the top, a knee consisting of two aluminum blocks connected together with wires and springs, a segmented tibia and a flesh system of rubber sheet and Neoprene. As with most modern test devices, the Flex-PLI legform is onboard DAS ready to ensure free flight control and prevent wire damage and/or signal loss. | | |
| **Injury Evaluation** | | | | |
| **Injury evaluation (GTR9)** | | **Injury evaluation (Euro NCAP)** | **4 Points** | **0 Points** |
| Acceleration (g) | 170 | Tibia Bending (Nm) | 282 | 340 |
| Bending (deg) | 19 | MCL Elongation (mm) | 19 | 22 |
| Shear (mm) | 6 | ACL/PCL Elongation (mm) | 10 | 10 |
| **Regulations** | GTR 9, AIS 100 | **Regulations** | ECE R 127, Euro NCAP, US NCAP (2018) | |

*Table 1.1.2*

## 1.2 Design Strategy

The lower body injuries are mainly function of deceleration, relative displacement and relative rotations of lower body parts. In order to reduce the lower body injuries in the bumper assembly design phase various aspects of design such as benchmarking study, Industrial design, bumper A surface design, Initial packaging, marking the impact zones, identification of hard points, material selections, countermeasure selections, product validation FEA are carried out. The details of few of the design activities are explained below,

## 1.2.1 Bumper Initial Design feasibility

The initial bumper design feasibility with packaging study are done to identify the initial hard points such as bumper beam, crash boxes, long member, Toe hook, headlight mountings, bonnet latch. This can be done by creating master sections at these hard points and X distance study can be done. The minimum packaging distance should be maintained to avoid sudden contact with lower body parts.

## 1.2.2 Bumper geometry

In order to prevent higher relative rotations and movements bumper geometries equipped with lower nose profile. These profiles collapse during impact and avoid excessive relative movement

Fig 1.2.1 shows lower nose mechanism geometry comparison with without nose mechanism geometry.

The nose bumper geometry profile is so designed to avoid higher relative motions, thus avoid the lower body injuries.

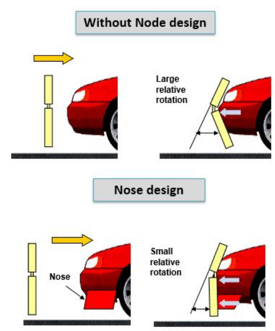



*Fig 1.2.1: Nose design*

The nose design features can be seen in most of the vehicles after 2016. The classical example with nose design construction in 2017 Honda CITY INDIA model


*Fig: 1.2.2: Honda CITY 2017 INDIA model*

## 1.2.3 Vehicle front bumper Design

In order to minimize the inertia forces various strategies are employed. One of the effective strategy is to create multi zone stiffness marking. In multi zone stiffness marking the bumper stiffness are defined in up down direction. Please refer below fig showing 3 zone marking

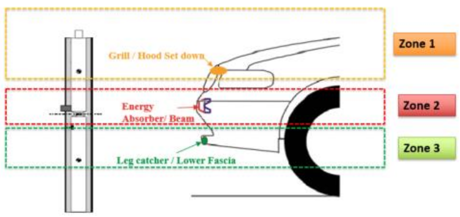



*Fig 1.2.3: Stiffness zone marking 3 zone marking*

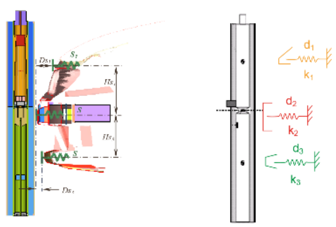


*Fig 1.2.4: Stiffness zone marking*

The X stiffness (K), the Z distance between zones (H) and X distance (D) between the bumper face and the vehicle BIW plays important role in controlling the lower body injuries. The following design aspects should be optimized in order to reduce the lower body injuries,

1. The difference between the Di (i= 1, 2, 3…. n) plays important role in bending defections. The optimum values should be selected to avoid higher defections.
2. The target stiffness corridor (Normalized) as shown in figure 1.2.5 should be used for initial design phase to package the bumper and counter measures. The details of the counter measures are explained in next section.
3. The connection of Bumper with the BIW

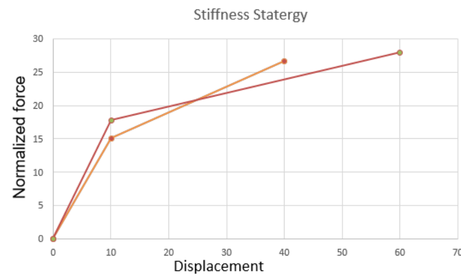



*Fig 1.2.5 Two Zone Spring Stiffness*

## 1.2.4 Countermeasure Strategy

In order to lower the lower body injuries, various energy absorbing (EA) countermeasures are available. These countermeasures absorb energy in controlled manner and minimizes the lower body injuries. The figure 1.2.5 shows the various counter measures available. These are namely EPP (Expandable Polypropylene) based, PP (Polypropylene) based and steel based. The PP based countermeasure can be moulded in complex shapes and has less weight and cost, which gives PP based counter measure advantage. The EPP counter measure are difficult to form complex shape but has advantage of light weight, cost and excellent elastic plastic characteristics makes EPP (Expandable Polypropylene) based as most preferred countermeasure.

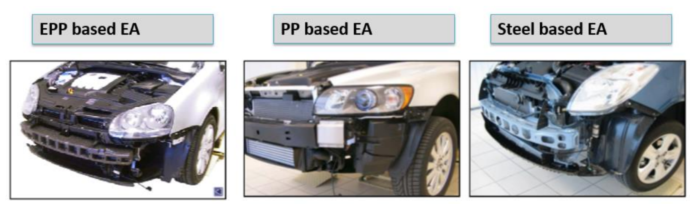



*Fig. 1.2.5 Energy absorbing safety measures*

The EPP (Expandable Polypropylene) foam energy absorbing countermeasure stiffness characteristics can be changed by using EPP foam of various densities. Normally higher is density of EPP foam tends to give stiffer response. Two different stiffness EPP foam can be used at two positions to minimize the lower body injuries. The figure 1.2.6 shows the two-stiffness countermeasure strategy, where in lower area stiffness 1 and in upper area 2 stiffness 2 is used.


*Fig 1.2.6 Two Countermeasure strategy*

### 1.2.5 Product validation FEA

Once the Initial design and detailed design is done. The advance engineering team perform the product validation loop using Finite Element analysis. An explicit analysis using CAE tools such as Radioss, LS Dyna, Pamcrash, Abacus etc. are done. The results such as force vs displacement functions, deformations, energy of parts, load transfer paths, interaction of leg form with bumper assembly and injuries can be plotted.

## 1.3 Testing

The test lab at ARAI Chaken is equipped with Universal testing machine to perform the test specified in table 1.1.1. The EECV Leg form certification tests are carried out to ensure the calibration of leg form. The test consist of static bending and static shear are done to ensure the force vs knee deflection corridor and force vs shear displacement corridor refer figure 1.3.2. The static testing equipment is shown in figure 1.3.1.

*Figure 1.3.1 Static Leg form Certification*

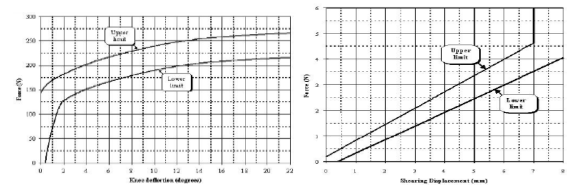


*Figure 1.3.2 The Force vs displacement corridor and Force vs shear displacement corridor*

For Flex PLI the bending tests are carried out. These tests are Femur and Tibia center bending deflection corridor tests, Knee assembly BM-MCL elongation corridor, ACL and PCL force elongation corridors. The figure 1.3.3 show the corridor for Tibia assembly and Femur Assembly

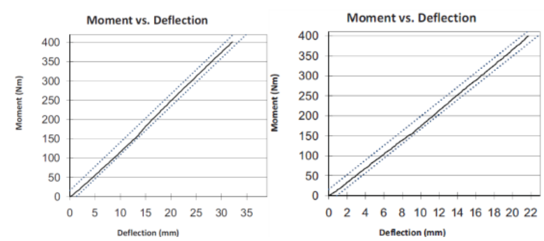



*Figure 1.3.3 Tibia Assembly Femur Assembly corridor*

Additional to above tests Dynamic Pendulum Impact and Dynamic linear impact are done to calibrate Tibia acceleration and elongation. The dynamic test description is shown in figure 1.3.4

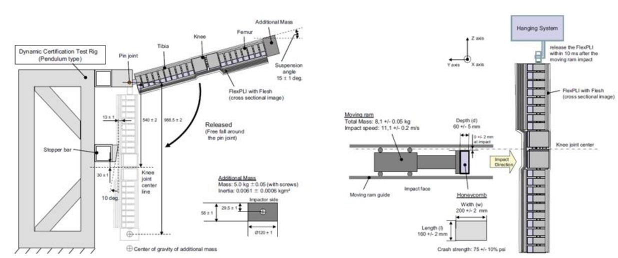


*Figure 1.3.4 Dynamic pendulum test and Dynamic linear impact test*

In Dynamic pendulum test the peak moment at four-gauge location is evaluated, Peak MCL, ACL and PCL elongations are taken and compared with corridor values

## 1.4 Reference

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