Case Study on Design Optimisation & Regulation Review of Vehicle Front End Structural Crashworthiness

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Abstract - *In day to day life, we always see there are many fatal injuries or that happen due to four wheeler road accidents, which can be fatal more than death caused by any disease. During crashing of the vehicle, it involves complex interaction between body structure and interior system. So whenever structure is subjected to high intensive loading, the result always be the deformation of the structure. So the total design of the vehicle should be such a way that it should absorb the energy created during impact and occupant area should be able to retain its rigidity. In this paper ,will take front bumper system from existing car model and will optimize the design by analyzing the impact area in frontal crash analysis so that particular region will be optimized also will Add energy absorbers to the horizontal members by analyzing the position into the system for experimental analysis & will conduct front impact test on existing model in analysis software then analyzed parts will be modified by design considerations so after number of iterations identified parts will be optimized, Different parameter graph will be plotted to differentiate the design changes before and after optimization.*

Key Words*: *Front crash test, Crashworthiness, Design Optimization, CAE, Regulations

1. INTRODUCTION

The statistics in the following data shows the percentage of the each type of crashes in a vehicle accident.

These all crash test have been performed by simulation in analysis software. In modern engineering analysis it is rare to find a project that does not There are different crashes happen on the road which causes occupants of vehicle either injured or killed. different types of crashes occur such as frontal, side,rear, rollover and other. For every crash there are different crash severities causes risk of injured to the occupants. But on the basis of survey in India most accidents happen by frontal impact which causes severe head and pelvis injuries to the occupants.

require some type of simulation for analyzing the behavior of the model under certain specified conditions. The advantages of simulation are numerous and important. A new design concept may be modeled to determine its real world behavior under various load environments, and may therefore be refined prior to the creation of drawings, when few rupees have been committed and changes are inexpensive.

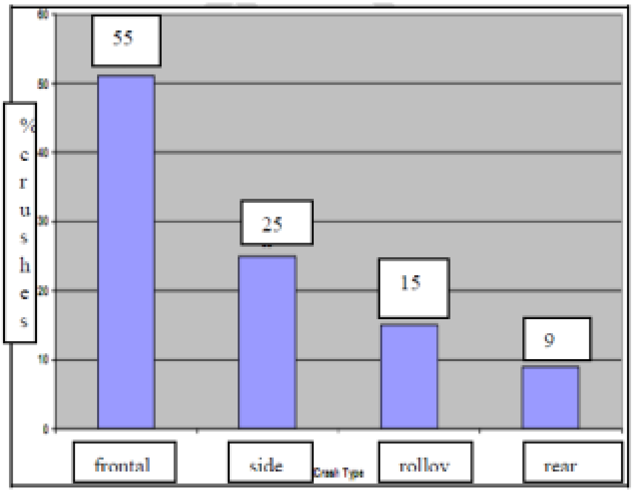

Fig.1: Vehicle crashes by Crash Type

Once a detailed CAD model has been developed, simulations can analyze the design in detail, saving time and money by reducing the number of prototypes required. An Existing product which is experiencing a field problem, or is simply being improved, can be analyzed to speed an engineering change and reduce its cost. Among all the accidents that take place, frontal impact has got a major share of 48%. Again in these conditions the injury caused to drivers or the front passenger is extremely high. According to the study during frontal impact of bus more than 80% of drivers die than any other members of the vehicle. In frontal impact scenario more significance should be given on structural integrity, and hence this project work is carried out in this direction. Crashworthiness is the ability of a structure to protect its occupants during an impact. This is commonly tested when investigating the safety of aircraft and vehicles. Currently, vehicle crashworthiness is evaluated in four distinct modes: frontal, side, rear and rollover crashes. But we will have through study when

Vehicle meet with Front Crash along with its analysis with Optimization of different parts by using Analysis software

2. CRASH TEST REGULATIONS

In general, car manufacturers have three different reasons to perform crash tests:

- Meeting US and European regulations in order to get the official approval and homologation for road service in the various countries.
- Meeting the requirements of various consumer tests such as EuroNCAP, US-NCAP, JNCAP etc.
- Research and development tests that give the design engineers valuable inputs to create safer cars.

2.1 US Regulations

The National Highway Traffic Safety Administration (NHTSA) has a legislative mandate for Motor Vehicle Standard, to issue Federal Motor Vehicle Safety Standards (FMVSS) and Regulations to which manufacturers of motor vehicles and items of motor vehicle equipment must conform and certify compliance.[5]

FMVSS 201 - Occupant Protection in Interior impact
FMVSS 202 – Head Restraint for Passenger Vehicle
FMVSS 203 - Impact Protection for the Driver from the Steering Control System
FMVSS 204 - Steering Control Rearward Displacement
FMVSS 208 - Occupant Crash Protection
FMVSS 209 - Seat Belt Assemblies
FMVSS 210 - Seat Belt Assembly Anchorages
FMVSS 212 - Windshield Mounting

2.2 European Regulations

The United Nations Economic Commission for Europe (UN ECE) Regulation on the protection of occupants in the event of a frontal impact, ECE Regulation No. 21. This Regulation applies to M1 category vehicles, i.e. passenger cars and multipurpose passenger vehicles, with a GVW not exceeding 2,500 kg; it requires them to be subjected to a frontal impact into an offset deformable barrier at a speed of 50 km/h.

ECE R-21 - Protection of the Occupant body parts in the event of Frontal Collision
ECE - 26 - Pedestrian Safety during front end collision
ECE R-12 - Protection of the Driver against the steering Mechanism in the event of Impact
ECE R-14 - Vehicle with Regards to Safety belt anchorages
ECE R-33 - Behavior of the Structure of the Impacted Vehicle in Head on Collision

ECE -26 Norm

This Regulation applies to external projections of category M1 vehicles. Purpose is to reduce the risk or seriousness of bodily injury to a person hit by the Vehicle or brushing against it in the event of a collision. This is valid both when the vehicle is stationary and in motion. The Pedestrian Protection score is determined from vehicle front-end structures such as the bonnet, windshield, bonnet leading edge and the bumper. In these tests, the potential risk at injuries to pedestrian head, pelvis, upper and lower leg are assessed.

Three Categories of pedestrian impact:-

Head impact:

Child and adult head form impactor measure the head accelerations caused by impact with the Bonnet top surface. Speed for measurement is 40Km/Hr.

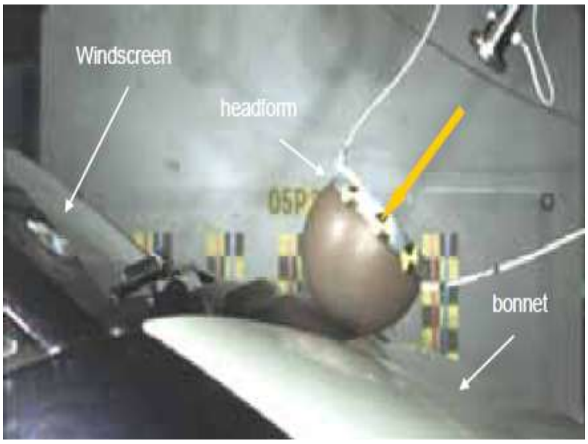

Fig. 2: Headform on Bonnet

Head impact Criterion:

- It is clear that the impact can endanger the whole body which includes legs, torso, thorax and the head.
- Modern cars are densely packed under the Bonnet. Stiff parts such as spring tower and top of the engine are very close to the bonnet.
- Due to this close packaging, there is no enough space for bonnet deformation due to head impact.
- As a result, the pedestrian suffers a severe or fatal head injury. ECE has thereby validated and updated the regulations that deal with pedestrian head impact.
- Head Impact Criteria plays a major role in this area as it calculates the impact value with respect to testing parameters and the vehicle designs.
- The value of the results directly specifies the passing of regulation in these criteria. [6]

$$HIC = (t_2 - t_1)\left[\frac{\int_{t_1}^{t_2} A_R \, dt}{(t_2 - t_1)}\right]^{2.5}$$

with: $(t_2 - t_1) \leq 15ms$

- HIC values < 1000 => risk for life threatening head injuries will be ≤ 15%
  < 2000 => the risk for potential head trauma and life risk.
- HIC is a complex calculation, as the driving factors have to be calculated in fraction of second. Values needs to be accurate and consistent and to be constantly validated. It is a function of force and duration.

a. Upper Leg Impact:

The shape of the hood or bonnet leading edge can play a critical role in the outcome of a vehicle impact with a pedestrian and contribute to injuries to the pelvis and femur. It represents the adult upper leg and pelvis for Measuring the bending moments and forces caused by the contact of the Bumper leading edge.

b. Lower Leg Impact:

A leg form impactor representing adult lower limb to indicate lateral knee-joint shear displacement and bending angle. Also for analyzing tibia acceleration, caused by the contact of the Bumper.

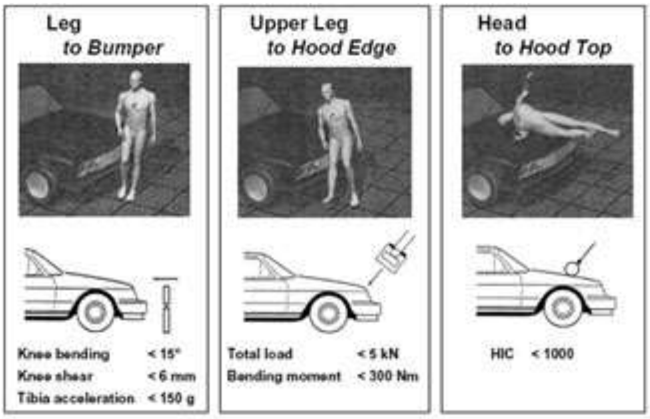

Fig. 3: Different Criterion for pedestrian

3. OVERVIEW OF PARTS IN FRONTAL AREA

a) Bumper
b) Front Grill
c) Fog Lamp
d) Toeing hook cover (Trappe)
e) Sensor cover
f) Sprinkler Cap
g) Lateral Support
h) Absorber
i) Deflector
j) Chrome Parts
k) Fog lamp interface
l) Head lamp absorber

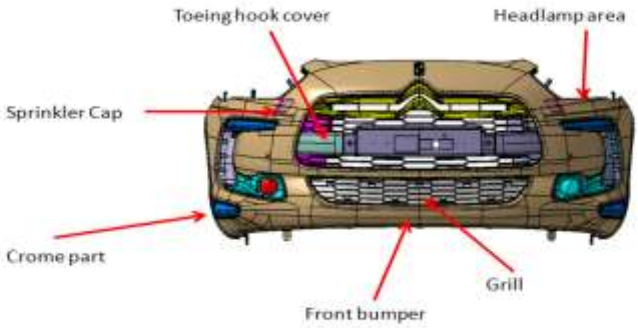

Figure 4: Typical Front bumper system, front view

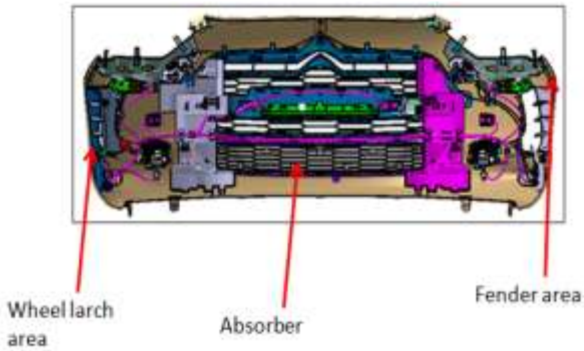

Figure 5: Typical Front bumper system, Rear view

4. PARAMETERS TO OPTIMIZE THE PART(S)

4.1 Addition of Rib or Honeycomb Structure

B-surface of the part contains all mounting features with other part at the time of assembly. This area can be optimized further by adding rib structure shown below for additional stiffness and rigidity.

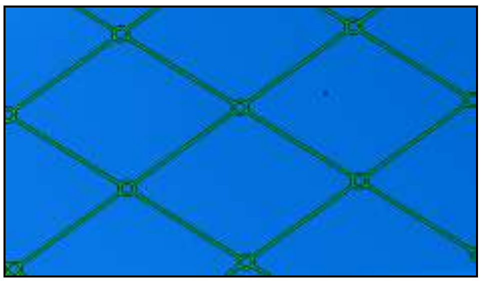

Figure 6: Cross rib with Cylinders

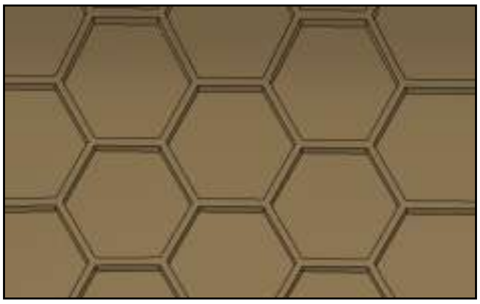

Figure 7: Honeycomb Structure

4.2 By Using Crushable Absorber

Energy absorber or Crush cones are the structural part in front end module of bumper system. During accident of the car, crush cones absorb the kinetic energy as much as possible. So impact energy will be dissipated into structural crash and will transfer energy as minimum as possible to the occupant area. It plays very vital role into the system.

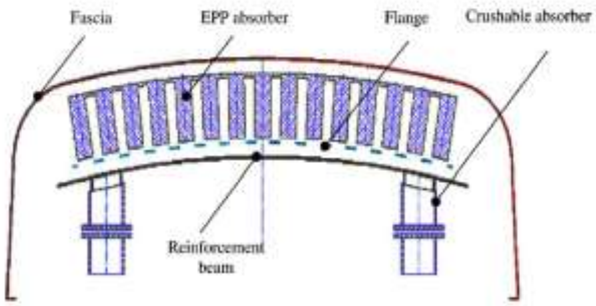

Figure 8: Cross section of Front Area in bumper system

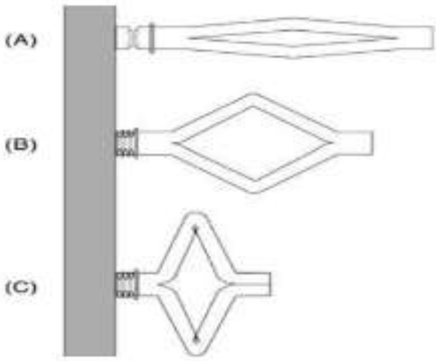

Figure 9: Deformation process in the fundamental model

4.3 By Using Hybrid Design

Hybrid design is nothing but the combination of the Metal and plastic, by using this combination, the properties like stiffness toughness, rigidity, durability etc can be increased in particular part. Ultimately end result will be optimized.

4.4"B" Surface Design Improvement

Design features should be optimized in proper way to get good result in terms of Part feasibility, stiffness, strength, rigidity etc. Below is the example that how part feature should be designed

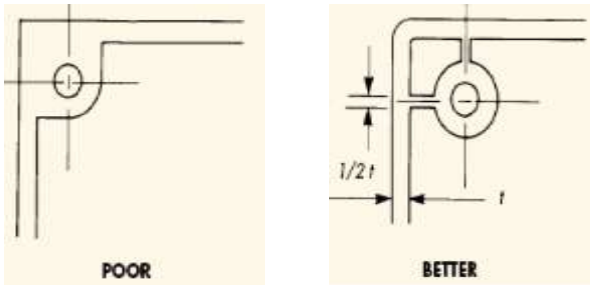

Figure 10: Design without Fillet & Chamfer

4.5 Part to Part Assembly Technique (Weld Technology).

There are different technologies used to assemble one part to another, most effective technique which can be used to get optimum strength and rigidity is welding of one part to another through weld boss or weld ribs shown below.

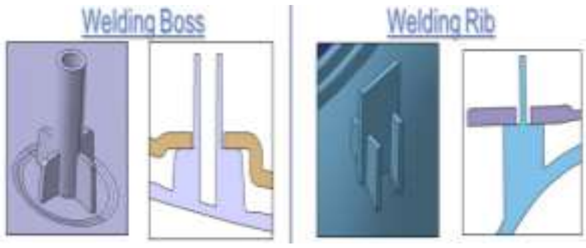

Figure 11: Welding Process

4.6 Crush Cone Feature

At the time of impact, the head will first deform the bonnet. So the bonnet will deflect and therefore press on the arresters which will be able to collapse. Therefore, the head will not go further downwards.

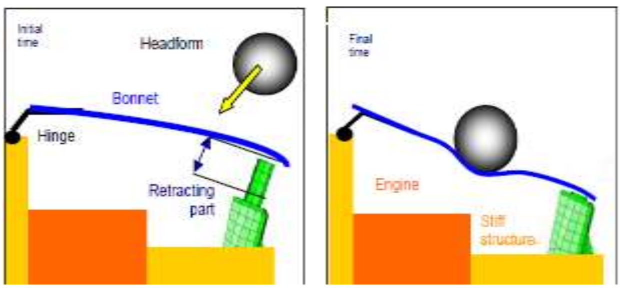

Figure 12: Crush Cone Feature Concept

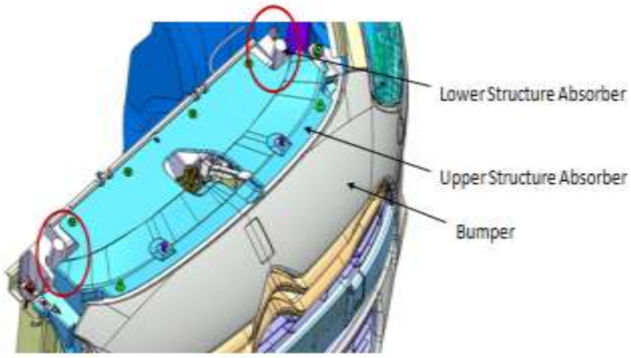

Figure 13: Crush Cone Feature

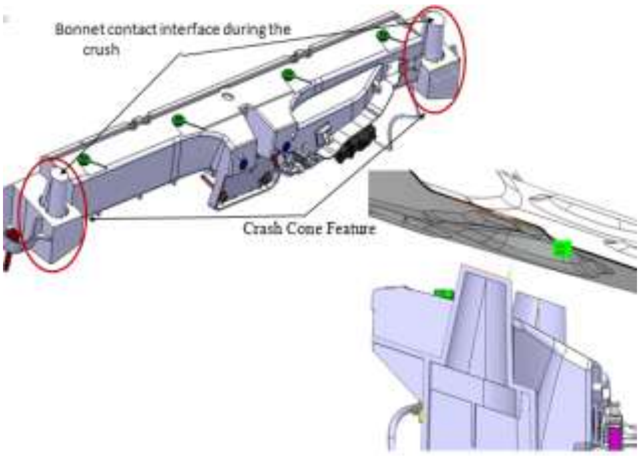

Figure 14: Crush Cone Feature in part

5. CONCLUSIONS

It has been understood that the load distribution on the structures are not uniform, which opens the door for the improvement in buckling characteristics of the structures.

By having crush Cones, the peak load can be reduced. This has been achieved by implementing such designs to some of the structural members, which can reduce around 4-6% peak load.

The design improvement that has been achieved is just for few structural elements, if this approach is followed for many other key structural members then the design could be far superior.

Also some of the parts designed and tested or the parts which are functioning in running condition of car can have loopholes so by finding the loopholes and having optimization in particular parts, we can achieve considerable performance of total vehicle during front impact so it will be having good achievement for the designer.

6. REFERENCES

1. Tejasagar Ambati, K.V.N.S. Srikanth & P. Veeraraju., "Simulation of Vehicular Frontal Crash-Test" Dept. Mechanical Engineering, Godavari Institute of Engg &Tech., Rajahmundry, India , International Journal of Applied Research in Mechanical Engineering (IJARME) ISSN: 2231 –5950, Volume-2, Issue-1, 2012

2. Loic Grall,Richard Zeitouni & Celine Adalian., "Frontal Imact Improvements – Enhanced modeling of the impact barrier" PSA Peugeot Citren,France ,Paper Number: 11-0435

3. Izabella Ferenczi,Dr.Stefan Kerscher & Dr.Frank Moller, "Energy Dissipation and Structural integrity in Frontal Impact" BMW Group,Munich,Germany, Paper Number: 13-0321

4. Satoshi Takizawa, Tomiji Sugimoto, Hideki SuzukiA, " Study of Compatibility test procedure in frontal impact" Honda R&D Co., Ltd. Tochigi R&D Center,Japan,2012

5. Nhtsa.gov. "FMVSS Standards" www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/.. ./FMVSS_208_II.pdf

6. crash-network.com., "ECE regulations" http://www.crashtwork.com/Regulations/ECE_Regulations/ece_regulations.html