Development Of Passenger Vehicle Door Trim For Occupant Safety By Using CAE

Rajesh P. Diwate, Prashant Deshmukh

Abstract: Vehicle interiors are primary source of injuries when occupants interact with them in the event of an accident. The extent of injuries is depending on energy dissipating characteristics of interiors and severity of accidents. For side impact tests vehicle interiors energy dissipating characteristics are assessed by FMVSS214 and ECE R95. Side impact test assesses occupant protection by door panel as vehicle interior during side intrusion test on door. In this paper, a certain type of car's side impact performance is discussed. The purpose is to express the relationship of the side impact response during door trim intrusion and safety. First, A Finite Element Model (FEM) of door trim is established which is based on a logical method to solve the problem during the modeling process. Then, the analysis the evaluates the indexes of side impact safety, traces the designing, got the side impact feature and point test data of this type of car, and verified the practicability of simulation result in the door developing process. Finally, expresses the connection between the side impact response for door intrusion and safety of door, aiming at discussing the occupant safety during side impact. The FE model is produced using Hypermesh 11 softwares and LS-Dyna solver is used for the simulations. The simulation results shows side impact protection system is capable of absorbing and dissipating required energy for protection of Pelvis.

Index Terms: Side impact simulation, Finite Element Analysis, Door intrusion test, Occupant safety, Safety criteria, Impact zone, Energy balance.

1 Introduction

In various traffic accidents, side impacts are frequent and often result in extremely harmful crashes. Global accident statistics show that side impacts account for approximately 30% of all impacts and 35% of total fatalities. Side impacts also require more attention because of considerably less crash zone for absorbing energy in the side of the cars compared to the front and rear structures and consequently the occupants sit almost within the crash zone, which often results in severe injuries. The region around the door of the vehicle is subject to large deflections into the driving personnel's space during side impact, it is therefore necessary to produce a standard 'worst case scenario' design criteria that a design can be produced for and attempt to reduce the risk of injury to the occupants. On the road cars, however, much research has focused on the development of countermeasures including the vehicle side structure energy absorption and human response in side impact events. In period of development stage of the car, it is very important problems to the vehicle industry that the side impact crashworthiness is forecasted. Now days the normal practice is CAE modelling and analyzing the methods. Based on the analysis process of the subsystem design for side impact performance in the CAE developing process of a certain type car, the paper expounds on the problem solving principle and method for the car side impact FEM simulation.

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The design and modelling of FEA subsystem considers the factors that influence side impact response like vehicle crush space i. e. amount of occupant space intrusion, Impact speed, Occupant position, Vehicle safety features dependent on model year, side door construction strength, use of deformable padding, availability of side impact air bags, height and consistency of impacting bumper, Use of safety restraints. The modelling quality depends upon the modelling methods of main parts, which, in turn, depends upon its structural features and response features in the impact process. Generally speaking, the modelling of door trim of side impact consists of three parts. The first is the body in white. The second is the assembly of plastic door. The third is connections between trim and BIW. The assembly of the door may be carried out as per the general guidelines prepared from experience of door development. The assemblage of the complete door model is realized through adding related connections or constraints at the connecting points. Finally, make of boundary conditions and all kinds of contact problems in the model.

2 Door intrusion safety regulations and impact zones

2.1 Side Impact Regulations

Occupant protection during impact with vehicle interiors e.g. Door trim, Dash board, Pillar trims, Steering wheel etc. has been an important safety parameter in any event of a vehicle crash. Regulations FMVSS214 in US and ECER95 in Europe defines the safety requirements for approval of high end class vehicles with regard to their interior fittings. A part of the regulation explains the energy dissipation requirements for the occupant pelvis, abdomen and thorax impacting against Door trim assembly. Tests are to be carried out with Side crash against a fixed pole. Since impact tests being destructive in nature, if a purely test based development approach is used for these requirements, it is very costly and time consuming as large number of prototypes are required to meet the necessary targets. Instead, analyzing the vehicles using CAE based tools for these requirements will significantly reduce development time as well as cost. This approach upfront helps in estimating the kinematics and impact response of pelvis, Abdomen and Thorax on the Door trim components and in case of failure, enables to undertake necessary design modifications to meet the performance requirements even before the physical parts are being made. Each OEM has some intrusion test specification decided on the basis of FMVSS214 and ECER95 legislation.

2.2 Pelvis, abdomen and thorax Impact Zone

Pelvis, abdomen and thorax impact zone on the DP components are identified and marked with the help of experience and biomechanical data of Human body. Pelvis hit to lower carrier region of door panel. Abdomen hit to armrest region of door panel and Thorax hit decorative trim region which top portion of the DP. Side impact zones on the door panel are shown in below image.

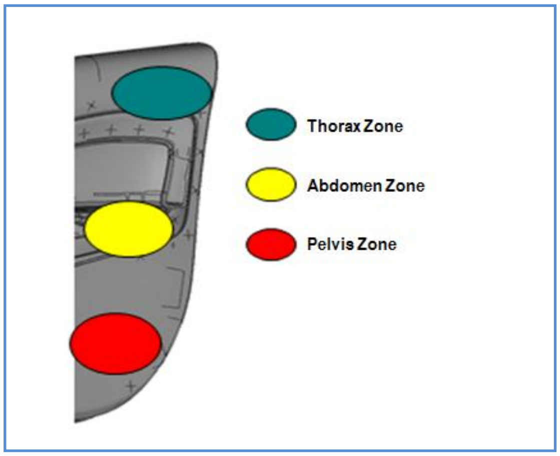

Fig. 1: *Impact Zone on Door Trim*

Identifying the side impact zone and assessment of critical impact locations upfront using CAE based tools on a preliminary design model before the physical prototype is made assists reducing development cycle time of DP and the vehicle considerably. Fig.1 shows different impact zones selected based on experience and biomechanical data.

3 ESTABLISHMENT OF SIDE IMPACT MODEL

3.1 FE Model Details

The FE model is build in Hypermesh software for effective and accurate modelling; it adopts the method of establishing respective LS-DYNA key documents for the sub-systems. This model include Body in white (BIW) and Door trim. Ribbing pattern along with its features and geometric details on the door trim assembly are carefully captured during meshing. Fulfilling the element size criterion offers accurate stiffness representation in the area as they significantly contribute in energy absorption during pelvis and abdomen impacts on the door trim surface. Carrier, map pocket, speaker grill, arm rest, grab handle, and corresponding mounting clips in each case are modeled to represent part stiffness adequately. The door model includes 52908 nodes, 49598 elements, 47 welding joints. Its weight complete door is 14.61kg. Typical parts in FE model of the door trim assembly include Carrier along with mounting clips, map pocket, top roll, trims for decorative purpose, trimmed BIW, foam padding for reduction of intensity of impact, the door armrest, speaker grill, grab handle for opening and closing purpose and some decorative component for aesthetic purpose.

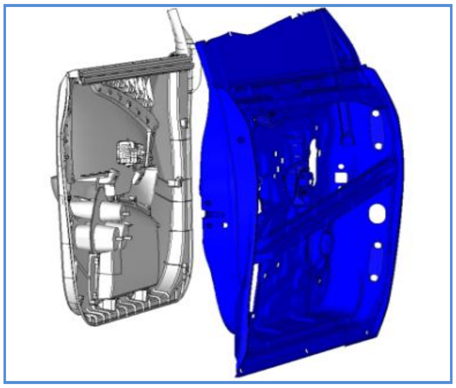

Fig. 2: *Door trim and BIW*

3.2 FE Connection and Boundary Condition Details

To capture all the geometric details, element size up to 5mm is considered for plastic parts. The connections of parts are realized through spot welding. The choice of joints in the model are mainly based on the method of welding of the parts and takes the procedure requirement of spot welding into consideration. The practical connection between door parts and BIW is screwing and is realized through node constraints in the modeling process. For other connections locators which are significant in the impact simulation are represented by rigid connection. For BIW, the rigid behavior is defined through modelling properties. Fig. 3 shows the Fixing locations of door trim on BIW.

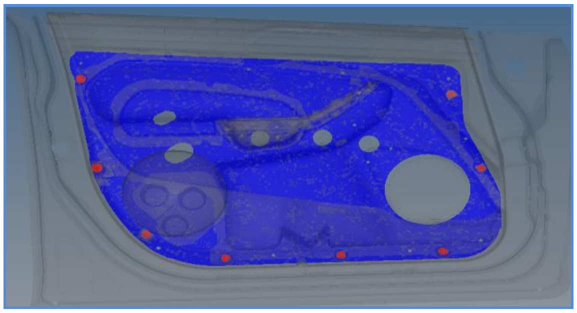

Fig. 3: *Fixing location of Door trim on BIW*

Following figure shows the screwing and locator behavior modelling for trim parts

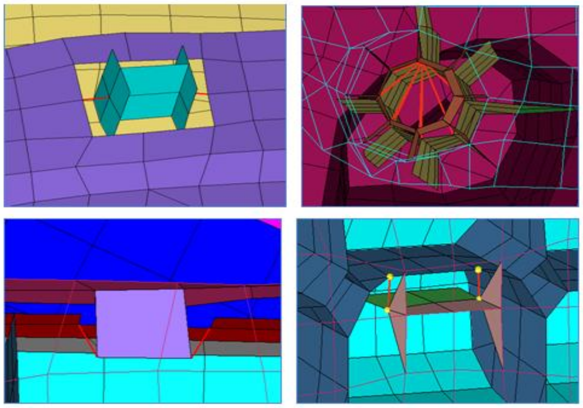

Fig. 4: *Screwing and Locator modelling*

4 Verification and Evaluation of Door Intrusion Simulation

The simulation result is usually evaluated through the means of qualitative and quantitative methods. Qualitative method is to compare the deformation of impact area in the simulation, the impact features of main parts and quantitative method is to compare simulation results and test results. The intrusion test has been done according to OEM specification of subsystem testing which was based on FMVSS 214 regulation test procedure for automobile Side Impact. The impact position is the surface overlapped by impactor during the test which is positioned according to probable impact location of pelvis with the door trim.

4.1 Description of test procedure and injury corridor

In physical test on the designed prototype, the 20kg impactor is impacted in pelvis zone so as to transfer 640J energy during impact. The impact point are predefined for test, they are decided from the data collected from various accidental cases and previous test experience over the years. Impactor shape is designed to represent the pelvis. Safety corridor is the range of 'force vs. displacement' limit within which occupant will remain safe and there will not be any fetal injuries. The design corridor used for the current work is of below type.

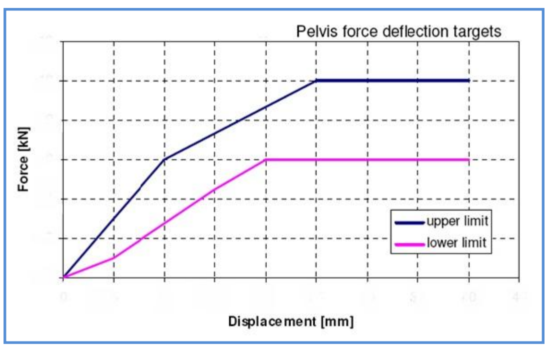

Fig. 5: *Safety corridor*

4.2 Energy balance for simulation

The accuracy of the FEA model is checked by the examining the energy pattern exhibited by the simulation results. Following checkpoints are considered for energy balance

1. The total applied energy should be constant throughout the simulation. Total energy is sum of kinetic energy and potential energy of complete system.
2. The kinetic energy should be decreasing and internal energy should be increasing; and ideally the some of kinetic energy and internal energy should be equal to total energy
3. The Hourglass energy should be less than 5% of total energy.

Hourglass energy is the energy lost due to improper FEA modeling during simplifying the geometry. Below energy pattern is observed during simulation.

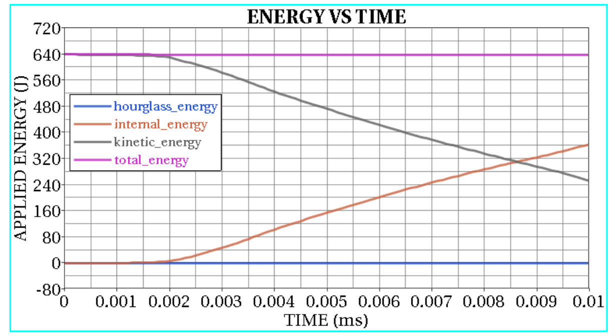

Fig. 6: *Energy balance in simulation.*

4.3 Comparison of simulation results with the test results

In side impact, the injury to people is mainly caused by the intrusion of the door. The direct contact between a person and the door trim will decide injury severity. For safety of pelvis, it is important that door trim should absorb maximum portion of the impact energy so that the 'force vs. displacement' plot would remain in safety corridor. After designing the safety padding which would respect the safety corridor, the physical test is done to validate the performance of product. After simulation and test, the intrusion and 'force vs. displacement' is compared against the safety corridor. The comparison is shown below.

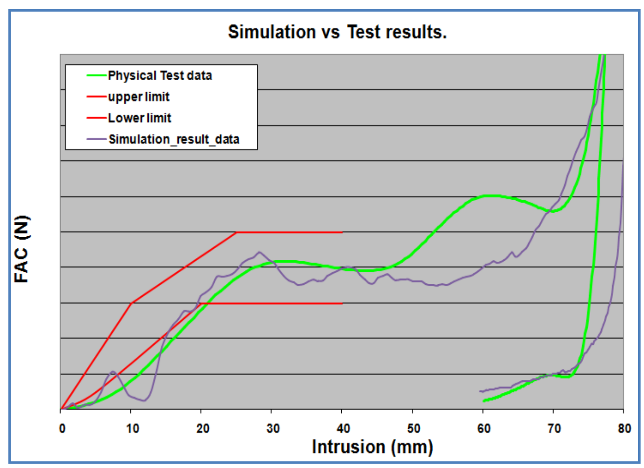

Fig. 7: *Simulation vs Test result*

The test data measured from the test is fine tuned to have a smooth curve. The test data received in any kind of prototype testing of crash activity will always have contingency and needs to fine tune is order to interpret the result and to have conclusive comparison with either other tests or simulation results. From above graph, it is very clear that the simulation results are closely matching with the test results hence it can be said as very good correlation. Though the test results are not obeying the safety corridor for earlier portion of the graph, the design is well accepted by car manufacture because of two main reasons; the deviation with lower limit is small and with the earlier work experiences the safety margin between theoretical test limit and complete car side impact test limit, the occupant will still remain safe with the above existing deviation.

5 Conclusion

Taking a door trim of certain car in a auto enterprise, this paper studies the problems of occupant safety in side impact simulation mode, and analyzes the practicability of simulation results and related evaluation based on real data of this car.

(1) In order to achieve satisfactory simulation result of car side impact, it is of great importance to simplify the FEM reasonably according to the side impact features.

(2) The experiment of door intrusion test on complete door trim shows that the simulation result of this paper is of good value in side impact structure and safety evaluation.

(3) With the proposed CAE methodology and modelling techniques, one can work on a preliminary concept design model in early phase of product development.

Using this approach CAE based design modifications can be evaluated quickly to reduce the overall development time and cost of door panel assembly for side improvements to achieve target impact response. Using this subsystem level approach CAE based design modifications can be evaluated quickly to reduce the overall development time and cost of door panel assembly for side impact requirements avoiding surprise failures in tests.

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