# Design and Performance Evaluation of Collapsible Door Armrest under Crash Test

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*Abstract—* ***Vehicle interiors are primary source of injuries when occupants interact with them in the event of an accident. The extent of injuries depending on energy dissipating characteristics of interiors and severity of accidents. Vehicle interiors energy dissipating characteristics are assessed by FMVSS214 [6] and ECE R95 [7] side impact tests. Side impact test assesses occupant protection by door panel as vehicle interior during side intrusion test on door armrest in side collision accident scenarios.***

***The present paper describes CAE based sub system level approach for door armrest development for side intrusion requirements as specified by OEM on the basis of FMVSS214 and ECER95 regulation; which is most critical region in door panel. In the conventional approach, door armrest design is certified for abdomen and thorax requirements based on physical testing where door panel samples from production tools are used. At this stage if any failure occurs, the changes in the door panel design becomes very expensive and time consuming as tooling is already made. To avoid this scenario during product development phase CAE based door armrest design is proposed in this paper. The proposed CAE based approach helps to assess and correct the proposed door armrest design in early phase of product development, to avoid likely failures during the physical testing. This paper describes the details of door panel assembly FE model content, various material models and simulation procedures for CAE based door armrest development for side impact intrusion test requirements for particular OEM. It is observed that a well discretised FE model and appropriate material models for plastics reasonably predicts physical test behaviour of the door panel assembly in side Intrusion tests.***

***Keywords— CAE, Side Impact, Pelvis, Abdomen, Thorax***

## I. INTRODUCTION

### *A. 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 [6] in US and ECER95 [7] in Europe define 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.

- 254 mm pole centered on dummy head gravity centre
- Impact speed : 29kph
- 1 Euro SID-2 seated at the driver place

Since pelvis, abdomen, thorax 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.

### *B. OEM specification for Intrusion test:*

Each OEM has some intrusion test specification decided on the basis of FMVSS214 and ECER95 legislation. For this study we are moving with 2KN reaction force level for first 20mm intrusion limit and 3KN reaction force level for next 10mm intrusion limit from door panel in abdomen region where door armrest falls.

This paper describes details about door intrusion test and good correlation of CAE results with Physical one. CAE helps to design door panel in early stage of design phase and avoid surprise failure in Physical test.

## II. FE MODEL DESCRIPTION

### *A. FE Model Details:*

The current study has been done on a subsystem for which the physical test data is available to validate the proposed methodology. 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

 

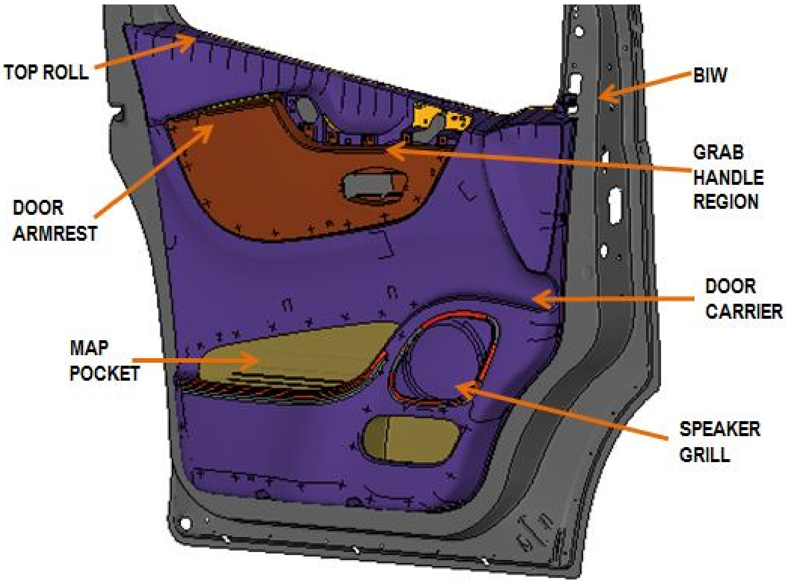


Fig.1 Typical parts in the FE model

speaker grill, grab handle for opening and closing purpose and some decorative component for aesthetic purpose. BIW on which the door trim assembly is mounted taken from a full vehicle FE model used for frontal simulations. Hypermesh used for meshing and modelling of all door trim parts using mid surface algorithm. Typical door panel contains six to eight parts; it may go above eight for high version door trim. The FEA assembly of door panel is shown in fig.1

*B. FE Connection and Boundary Condition Details:*

Ribbing pattern along with its features and geometric details on the door trim assembly is carefully captured during meshing, fulfilling the element size criterion, which offers accurate stiffness representation in that 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, side airbag container, explosive unit, airbag door and corresponding mounting clips in each case are modeled to represent part stiffness adequately. To capture all the geometric details, element size up to 3mm is considered for plastic parts. If certain parts for environment assembly mountings like dash board, BIW etc. are not available during the early phase of development, dog houses of door trim assembly should be constrained appropriately. Connections between parts were modeled appropriately for snap fits, locators, screws, clips and vibration welds as in the actual vehicle. Locators, screws and clips representing interfaces between BIW-carrier, BIW-map pocket, carrier-map pocket, armrest and other surrounding parts etc, were modeled using rigid patches. Joints between certain plastic parts were modeled for vibration welding using ribs. Top surfaces of the door panel are connected with the help of 1D element to the bottom part.Fig.2 shows different connection strategies used in FEA modelling.

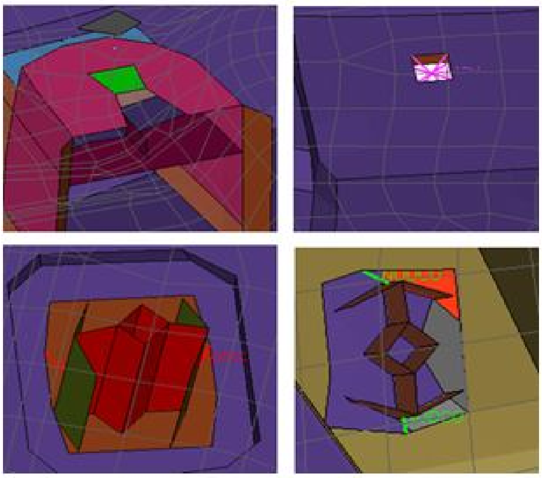

Fig.2 Dog House, Locator and Welding Connection

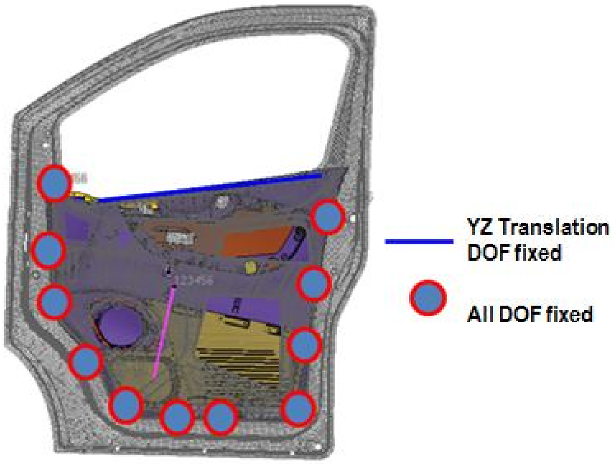


Fig.3 Boundary condition details

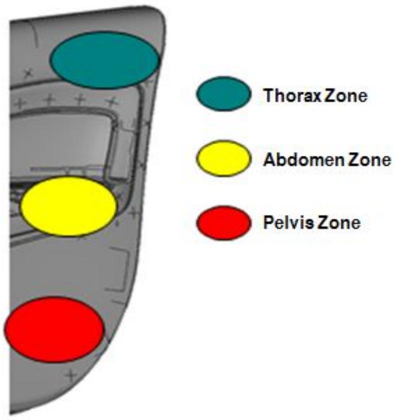


Fig.4 Head Impact Zone on Door Trim

Connections- joints, snap fits and vibration welds using rigids and beams. Fig.3 shows the boundary conditions used during the simulation as per the physical test condition.

*C. 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 DP. Abdomen hit to armrest region of DP and Thorax hit decorative trim region which top portion of the DP.Side impact zone as shown above. 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.4 shows different impact zones selected based on experience and biomechanical data.

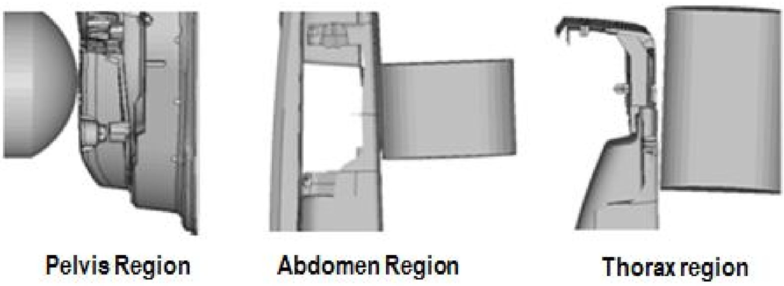


Fig. 5 Different Impact Positions

*D. Impactor Positioning:*

Different Impactors are modelled according to test requirement as per different legislation and re-aligned to DP normal as shown below. Necessary inputs are taken from OEM as per biomedical study of human being and experience; such as positioning co-ordinates, impacted energy and initial velocity.fig.5 shows impact positions.

## III. RESULT COMPARISON BY DIFFERENT METHOD

*A. FEA results:*

Impactor positioned as shown in fig.6. This impactor is moving with negative Y direction and hitting the door at abdomen region. FEA results are post processed by using Hyperview taking master node of rigid body of Impactor.

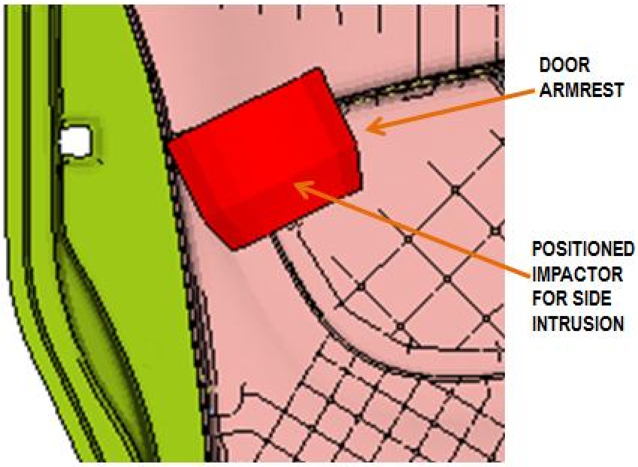


Fig.6 Position of Impactor in Abdomen test simulation

Fig. 7 shows amount of effort from door trim during impact vs. amount of intrusion of impactor. Results are useful for initial design phase of project. Horizontal red line in above graph shows requirement corridors which depend upon different OEM energy specification and different legislations. This will give us the preliminary design status of component assembly such as energy absorption capacity, stiffness of component. The above mentioned parameters are more important for occupant safe design during early phase of CAD development.

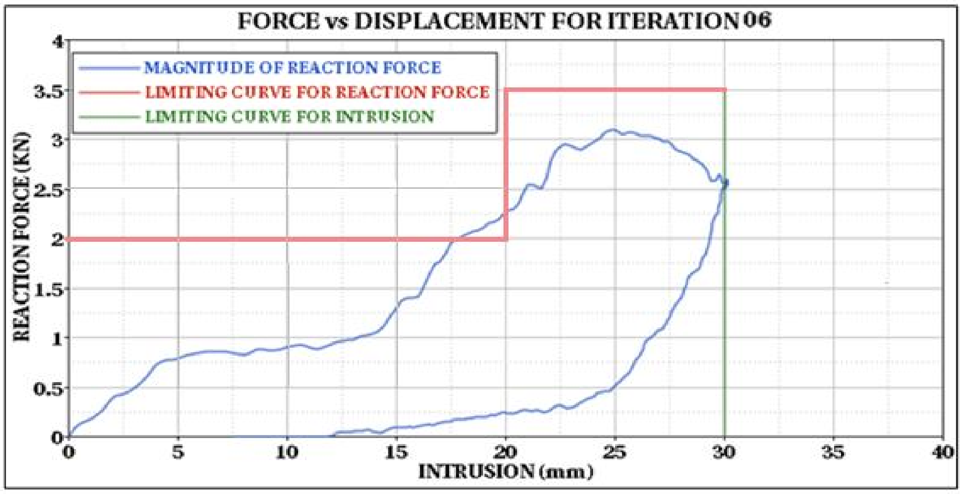


Fig.7 Results for FEA

*B. Experimental results:*

The door module supplier is required to prove the right load-intrusion characteristic by CAE simulations and by testing. Testing is defined on the door module as follows. A rigid abdomen shaped impactor hits the door module with a defined initial velocity and the door reaction force along with intrusion level is recorded. Thus obtained Force versus Intrusion must fit in the defined corridor. The test is usually done on a drop tower test set-up as shown in fig.8 and corresponding testing results for different impact location are shown by fig.9.

 

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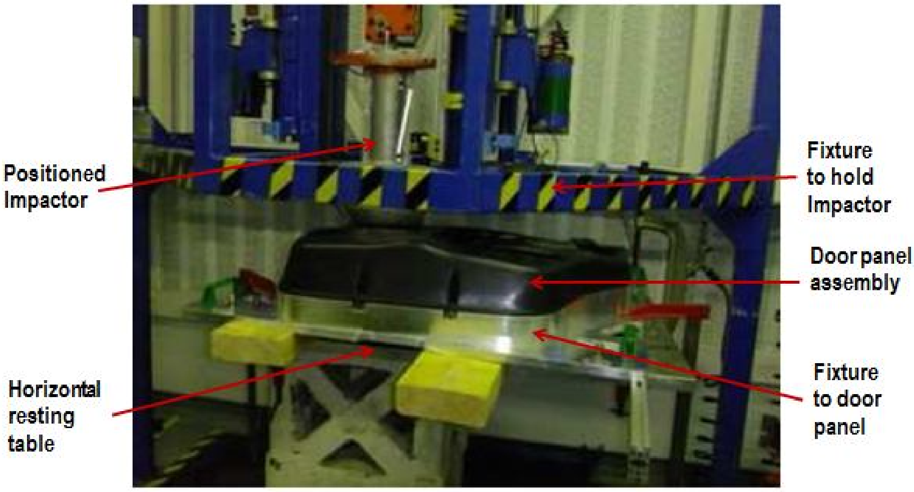


Fig.8 Physical testing setup

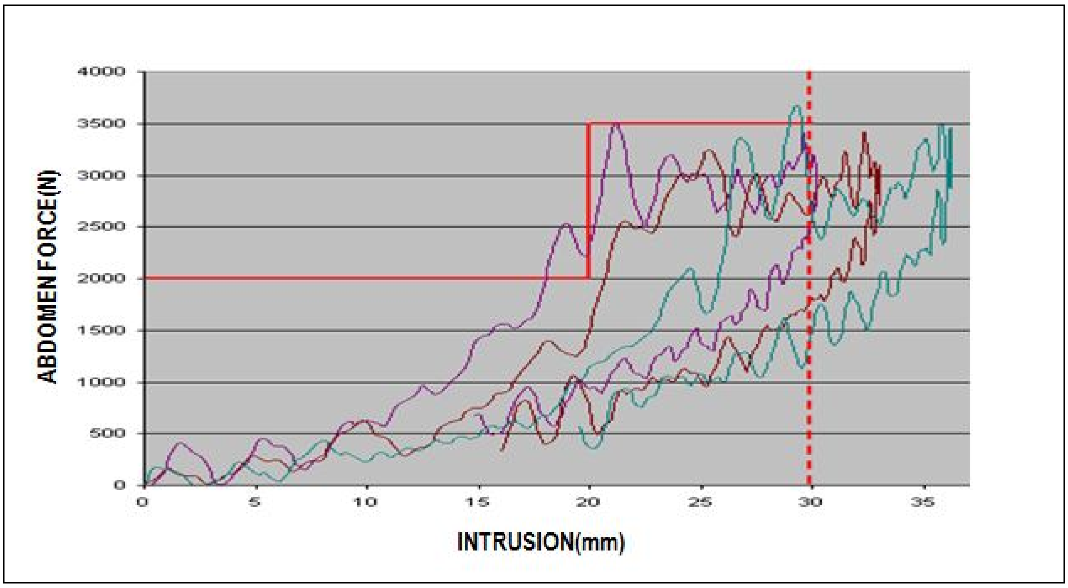


Fig.9 Results for testing

## IV. COMPARISON AND VALIDATION OF RESULTS

During the study comparison of Force vs. Intrusion curves from simulation and physical test data at different impact locations suggest reasonably good correlation for proposed CAE methodology. Fig 5 shows some of the impact locations and Table 1 below shows corresponding force vs. intrusion histories observed in test and CAE. For impact different points reasonably good correlation is observed between simulation and test results. This indicates that proposed CAE methodology reasonably predicts the resistance to deformation and deformation behavior of Door panel assembly at specified impact locations. Thus, outputs of the proposed CAE based approach are useful in developing a safe structure before the actual test, reducing large amounts of evaluation time and prototype cost of the vehicle. This procedure can be used to validate the entire side impact zone on the door panel assembly by selecting specific and critical impact points. This methodology also gives how effectively we can use the subsystem level approach to develop interior fittings and avoid any sudden or unexpected results from interior fittings during full vehicle crash test.

TABLE I
REACTION FORCE VS. INTRUSION RESULTS FOR PHYSICAL TEST AND CAE

| **Load Case Description** | **Test Intrusion (mm)** | **Test Max Force Level (N)** | **CAE Intrusion (mm)** | **CAE Max Force Level (N)** |
|---|---|---|---|---|
| Intrusion Test | 34.5 | 3600 | 30 | 3100 |

 

## V. CONCLUSIONS

In the present study the door panel was evaluated for its performance as per OEM specification developed based on FMVSS214 [6] and ECER95 [7] for side impact requirements using CAE tools and results were compared with the test results. Some important conclusions of this study were listed below as

- It was observed that abdomen positioned as per test on a well discretized FE model with appropriate material model predicts the impact response of door panel assembly reasonably well.
- With the proposed CAE methodology and modelling techniques, one can work on a preliminary concept design model in early phase of product development.
- The Percentage error observed in Maximum Force Level is less than 17% which shows CAE methodology is in line with physical behaviour.
- The Percentage error observed in Intrusion level is less than 16% which shows good correlation of CAE with realistic behaviour of door panel in actual test.

Thus the simulation results can give valuable inputs on identifying critical locations on door panel assembly which needs design improvements to achieve target impact response. 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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