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Parametric Study of Crash Padding Used In Automotive Door Panel Using CAE

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ABSTRACT

Many investigations of real world accidents, crash test results & simulation studies have established that in side crashes of passenger cars, thoracic & pelvic injuries of occupants are in large part caused by occupants impact against the interior side of the vehicle, primarily the door and other intruding side structures. In order to minimize the injury potential the designer must limit the interior impact velocity, improve energy dissipation & maintain the compartment integrity. One of the countermeasures that greatly improve the energy dissipation is the addition of the energy absorbing padding material in the door area. The Foam or plastic crash padding's are generally added in the door panel area. The Effectiveness of the energy absorbing capacity of door padding is highly dependent on the shape, Size & other dimensions of the padding. The paper will focus mainly on effectiveness of the door padding with different shapes & sizes. The objective of this paper is to find the most suitable shapes & dimensional parameters for the selected scenario. The FEM based CAE analysis tools (Hyperworks& LS Dyna) are used for this study.

Keywords— Computer Aided Engineering, Car interior, Crash padding, Crashworthiness, Side impact

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I. INTRODUCTION

The safety characteristics of motor-vehicles have long been a prominent focus of both safety research and vehicle design. India has a high number of deaths due to road accidents, and Indian automotive safety standards have been criticised as being insufficient and ineffective. Since 2006, India has been having more road deaths per year than any other nation, with 230,000 dying annually. India has the world's sixth-largest car market, but is still the only country among the global top ten car markets without proper new car safety regulation or testing programs. Crash tests of Nissan's Datsun Go and Maruti-Suzuki's Swift demonstrate a high risk of life-threatening injuries with both cars receiving zero-star safety rating for their adult occupant protection. These risks would be significantly reduced if the cars had to comply with the UN test regulation for frontal and side impact.

The Bharat New Vehicle Safety Assessment Program is a proposed New Car Assessment Program for India. Cars sold in the country will be assigned by star ratings based on their safety performance. It will be implemented in phases, according to the plans being drawn up by the National Automotive Testing and R&D Infrastructure Project. It is the 10th NCAP in the world and is being set up by the Institute of Road Traffic Education and the Federal Government of India. The program is expected to begin mid-2014. Within two years of implementation, new cars sold in India will need to comply with voluntary star ratings based on crash safety performance tests. Critical safety features such as airbags, ABS, and seat belt reminders will become standard in cars sold in India resulting from rankings and mandatory crash testing. Offset front crash, side, and rear impact tests will be required by 2017. Cars will gradually have to meet more stringent norms such as pedestrian protection, whiplash injury and child restraint systems standards and requirements.

Considering vehicle safety, we may break down the crash event into the pre-crash and the post-crash stage. At the pre-crash stage, crash occurrence is determined by the product of crash exposure and crash propensity. In general, crash exposure represents the amount of opportunities for crashes to which a vehicle is exposed. Crash propensity is the conditional probability of the vehicle being involved in a crash given a unit of exposure. While crash exposure is generally approximated by distance travelled, crash propensity is supposed to be associated more with human factors, that is, driver behaviour or performance. At the post-crash stage, what concerns us most is crash severity, which is dependent on the crashworthiness (CW) of the struck vehicle, that is, the self protective capacity of the struck vehicle and the crash aggressivity (CA) of the striking vehicle, that is, the hazardousness that the subject vehicle imposes on the counterpart vehicle(s) involved in the same crash, with other external factors being controlled [1].

Crashworthiness deals primarily with the "second collision", in which the driver and passengers collide against the interior of the vehicle. In order to minimize the injury potential the designer must limit the interior impact velocity & maintain the compartment integrity. An effective crashworthy vehicle design will distribute these injurious forces over as great a period of time and distance as possible, directing them to parts of the body that are more capable of withstanding them.

New Car Assessment Programs (NCAP) in Australia, Europe, Japan and the USA are giving increasing attention to the protection of vehicle occupants in side impact crashes [3]. The main difficulty in designing for side impact collisions is the limited crumple zone between the impacting vehicle and the impacted occupant. The main objective for introducing the side impact structural system is to maximize energy absorption and minimize injury to the occupant [2]. Strengthening the passenger compartment improve occupant protection, especially adding pusher foam or plastic crash padding is significantly lowering the injury values in SINCAP [4]. Many investigations of real world accidents studies have established that in side crashes of passenger cars, injuries of occupants are in large part caused by occupants impact against the interior side of the vehicle, primarily the door and other intruding side structures. To avoid the occupant injury it is important to absorb the whole kinetic energy both of the vehicle and of the occupants [6]. One of the countermeasures that greatly improve the energy dissipation in the car interior is the addition of the energy absorbing padding material in the door area. NHTSA, among the others has conducted tests with & without padding in the doors and found that the addition of padding reduces thoracic injury potential by about 30 percent in many production cars tested using the FMVSS 214 dynamic test procedure[7]. Proper control of padding stiffness is very important especially for abdomen & Pelvis protection [5].

The Effectiveness of the energy absorbing capacity of door padding is highly dependent on the Material stiffness, shape, Size & other dimensions of the padding. Hence it is planned to study the effectiveness of the door padding with different shapes & sizes so that the designer can start with selecting feasible padding to obtain the lowest possible injury measure for pelvis region in a side crash of the vehicle.

A.Side Impact Crashworthiness Test

In spite of the tremendous progress achieved in crashworthiness simulations of vehicle structures from components to full-scale vehicles, using the latest techniques in computational mechanics and super computers, final crashworthiness assessment still relies on laboratory tests. This is especially true in vehicle certification [10]

There are three categories of tests: component tests, sled tests, and full-scale barrier impacts. The complexity of the test and associated variables increases from component to full-scale tests. This may cause a decline in test repeatability – a reality that may not be realized from the mathematical models. The component test determines the dynamic and/or quasi-static response to loading of an isolated component. These component tests are crucial in identifying the crush mode and energy absorption capacity. Understanding their performance is also essential to the development of prototype substructures and mathematical models [10]. Fig. 1 shows the door trim component test set up in which spherical impactor drop over the door trim mounted on the fixture.

In a sled test as shown in fig 2, engineers use a vehicle buck representing the passenger compartment with all or some of its interior components such as the seat, instrument panel, steering system, seat belts, and air bags. Mechanical surrogates of humans (anthropomorphic test devices - “dummies”) or cadaver subjects are seated in the buck to simulate a driver and/or passenger and subjected to dynamic loads, similar to a vehicle deceleration-time pulse, to evaluate the occupant response in a frontal impact or side impact. The primary objective of a sled test is evaluation of the restraints. This is accomplished by high-speed photography of the dummy kinematics. In addition, various sensors located in the dummy and on the restraints monitor the forces and moments to help determine the impact severity and the effectiveness of the restraint system in reducing loads transferred to the occupant [10]

The typical full-scale barrier test involves collision of a guided vehicle, propelled into a barrier at a predetermined initial velocity and angle. Typically, a barrier test uses a complete vehicle. To evaluate individual substructures, a sled test can be equally effective, especially in evaluation of the restraint systems [10].

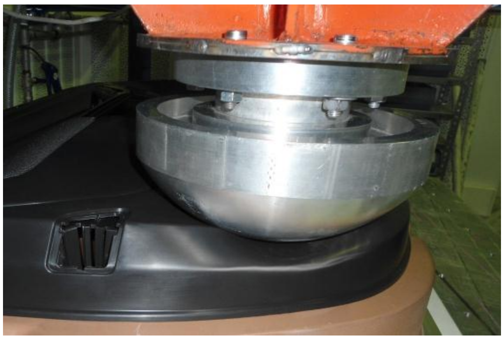

Fig. 1 Component Test Setup

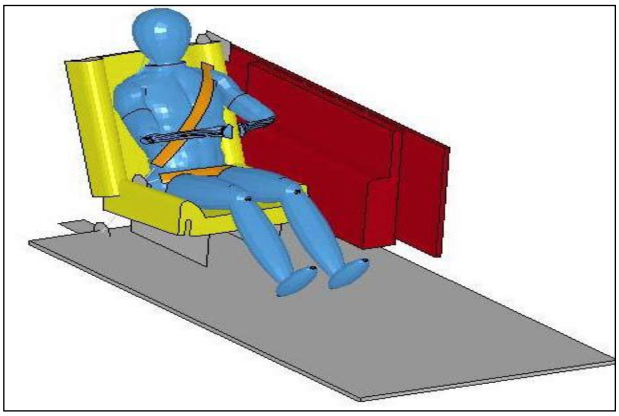

Fig. 2 Sled Test setup for door trim

II. CAE SIMULATION METHODOLOGY

In actual full vehicle crash testes, the BIW parts absorb the impact energy & interior plastic parts absorber the energy in collision with the occupant. To study & improve the crashworthiness of the door trim panel the subsystem side crash test or drop test is done on the door trim assembly. This test is based on the second collision between occupant & dummy. This test is similar to the sled test, in which engineers use a vehicle buck representing the passenger compartment with its interior components. Instead of Mechanical surrogates of humans (anthropomorphic test devices - “dummies”) or cadaver subjects like in sled test here steel impactor’s as shown in Fig. 3 are used to simulate a driver or passenger and subjected to dynamic loads, similar to a vehicle velocity-time pulse, to evaluate the occupant response in a side impact [8].

Fig. 3 below shows a block diagram of the CAE simulation/testing setup. We are interested only into the effectiveness of the crash padding. So we assumed that is no deformation of sheet metal BIW parts & the energy is absorbed completely by crash padding. We will represent the BIW by rigid plate & the crash padding base rested on the same with contact. Rigid impactor with the specific mass representing the occupant will be impacted with initial velocity to achieve the desired energy. The displacement verses contact force of impactor and deformation pattern of crash padding will be studied for each design iteration.

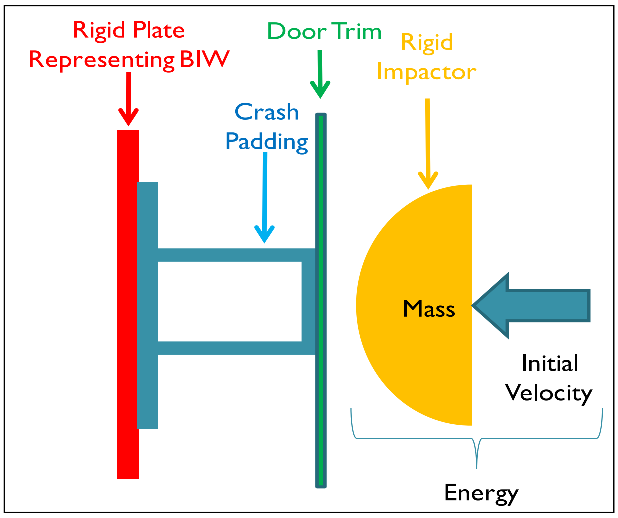

Fig. 3 Block diagram of component CAE Test setup

III. MATERIAL SELECTION & CHARACTERIZATION

The maximum force sustained by human pelvis is around 6KN hence we can’t go with the metals as the stiffness is very high. Plastic is the suitable material for the crash padding considering the stiffness and manufacturing feasibility. The main requirement of the padding is that the plastic strain should be sufficiently higher. Polyethylene (PE) & Polypropylene (PP) are two plastic materials which have comparatively higher plasticity. Polypropylene (PP) is used for this study.

The tests performed so far indicate that the finite element method (FEM) is a precious tool when they analyze the crash worthiness of any structure and predict the crush behaviours of structure under axial loadings. While, with the increasing demands on the reliability of crash simulation, it plays a key role to model damage behaviours of plastic components with different stress states in their various parts. In this case accurate results of simulation strongly depend on the precise material parameters under various stress states. In other words, characterization of material is very important for numerical simulation. The material used in this paper is developed by “Faurecia interior systems” with an extensive experimental research. Faurecia has also combined the material properties with numerical models to validate the material model with component simulation.

IV. CAE MODELLING

CAE model is build using Hypermesh V-11 for LS-DYNA V-971 software. 2D shell meshing is used to model the all parts. . As shown in fig 4 the impactor (wireframe plate) and padding resting plate (brown color) representing BIW is made rigid. The impactor and cone resting plate representing BIW is made rigid. All degrees of freedom of cone resting plate are constrained. Impactor is free in impact direction and all other degrees of freedom are constrained. The velocity used in pendulum/impactor test is generally 5–9 m/s. Impactor velocity of 5m/s & 25 Kg mass of impactor (representing pelvis) is selected for this study. Hence the input energy for this study will be 320J [9].

Generally 80-120 mm packaging space is available for door trims. So we will consider 100mm padding height for this study. Three cross-sections as shown in fig 5, circular (diameter 60mm), square (47mmx47mm) and rectangular (32mmx62mm) are selected to model padding keeping the perimeter of all cross section is same.. Analysis is done using LS-Dyna explicit solver. Displacement, acceleration & contact forces output is requested for post processing of results. Graph of total energy, internal energy and kinetic energy is plotted against time to confirm the model accuracy.

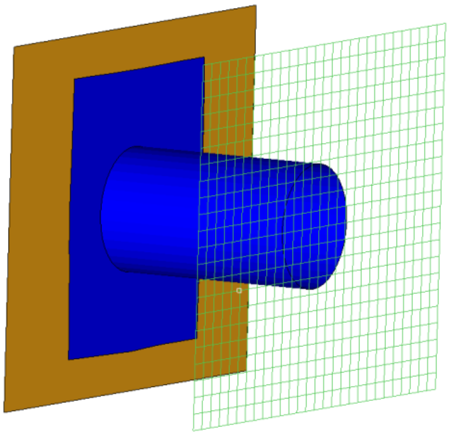

Fig. 4 CAE test setup

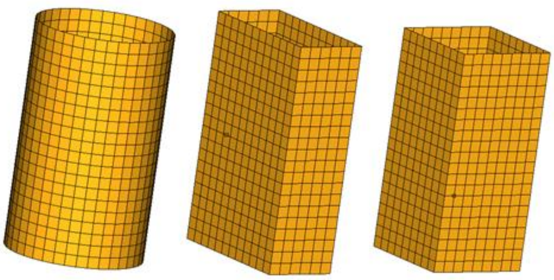

Fig. 5 Different shape cone mesh with same cross section perimeter

V. EVALUATION BASED ON F-D CHARACTERISTICS OF PADDING

The comparative study of force displacement characteristics of the crash padding with different shapes is studied first. Fig 6 below shows the typical target curves for pelvis positions. Pelvis positions generally have upper and lower force limit also. Force displacement characteristics for Circular, Square and rectangular shapes are studied keeping the cross section area and thickness same for each design. The thickness effect on the crash padding is also studied.

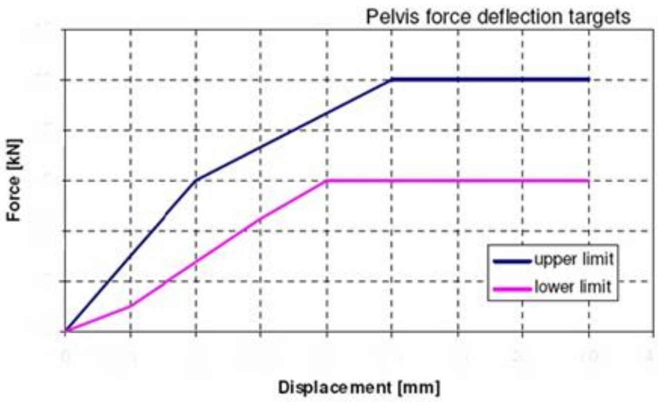

Fig. 6 Pelvis force deflection targets

VI. CORRELATION OF CAE MODEL WITH PHYSICAL TEST

Fig. 7 shows the load–displacement curves obtained by simulation and physical test results during crash loading. From comparison it is clear that the parameters of material acquired by characterization are correct and the simulation has remarkable value as well. Moreover, element size has important influence on simulation accuracy. Standard reasonable element size is about 5 mm, which gives smooth analysis and good prediction of crash process for both deformation and damage behaviour prediction. This study mainly focuses on the comparative study of different padding with changes only in the shape & size. Hence there is no need for a physical validation of everymodel.

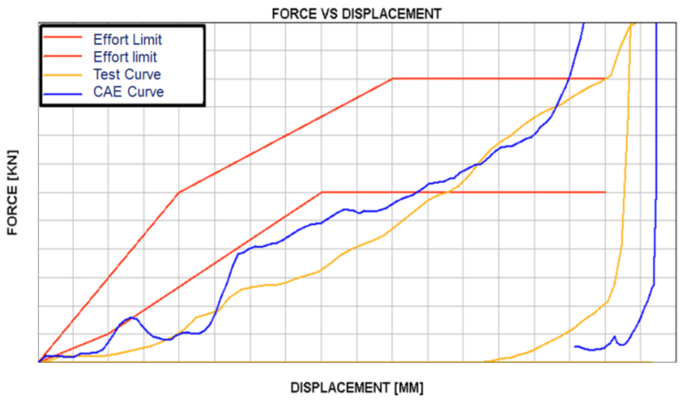

Fig. 7 Correlation of FEA model with physical test results

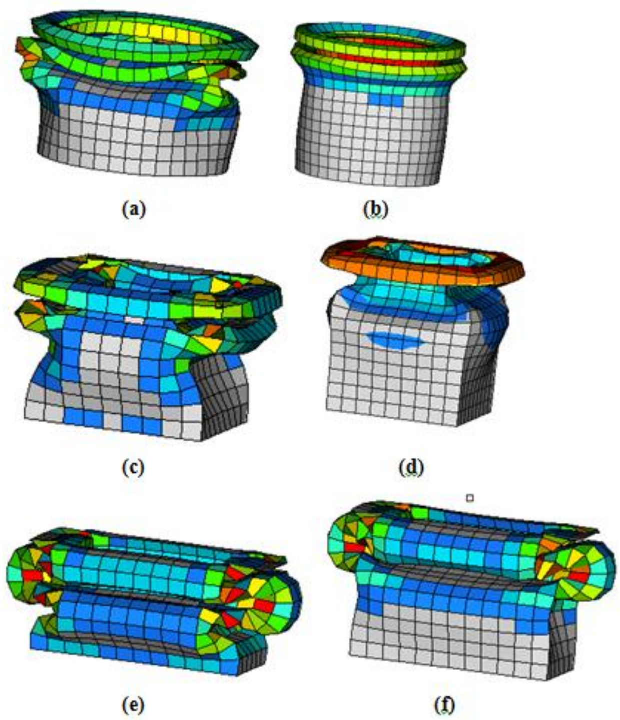

Fig. 8 Deformation patterns with displacement contour

Fig. 8 shows the deformation pattern of different padding with two thicknesses, 2mm & 2.5mm respectively. For 2 mm thickness all the shapes shows good collapsibility but the rectangular padding shows almost ideal behaviour shown in Fig.8 (e). For 2.5mm thickness padding, circular and square cross-sections are not collapsing completely for given energy input but rectangular still shows better collapsibility.

From the Force verses displacement graphs which have shown below in Fig. 9 & Fig 10 results shows that the circular cross section gives the highest effort in both 2mm and 2.5mm thickness models. 1st peak of effort is same in both rectangular & square cross-section but once the structure is collapsed rectangular section shows the lowest effort reaction. Effort values are different with different thickness of the padding but the behaviour remains same. Fig. 11 is a superimposed results of both 2mm and 2.5mm thickness padding.

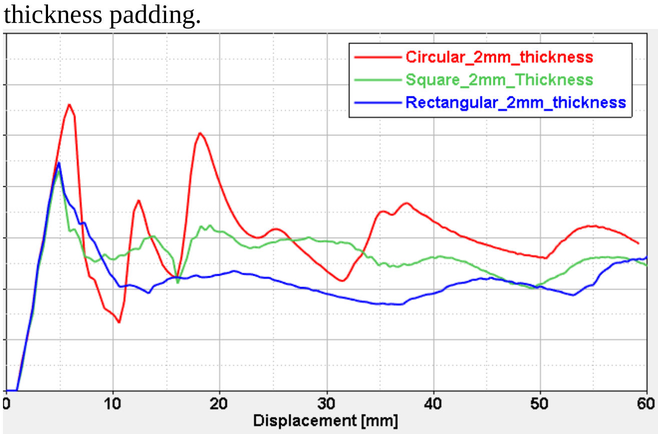

Fig. 9 Force Vs Displacement for 2 mm thickness

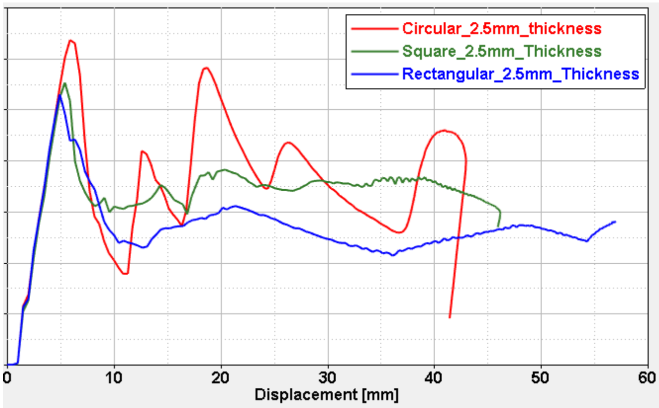

Fig. 10 Force Vs Displacement for 2.5 mm thickness

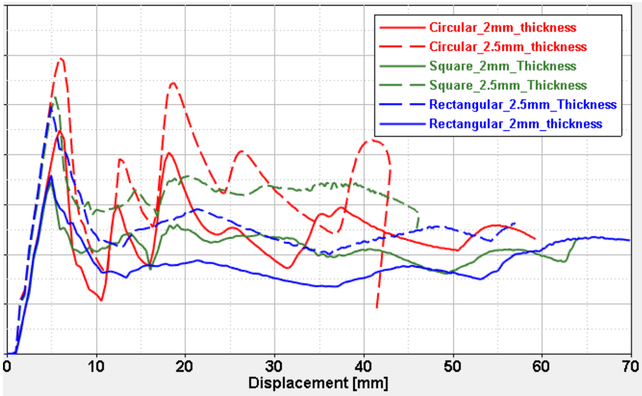

Fig. 11 Force Vs Displacement for all paddings

VII. CONCLUSIONS

This paper has evaluated the performance of different cross-sectional padding used in door trim panels for pelvic energy absorption in side impact.

Specific conclusions are as follows:

- Effort reaction of padding in impact event is dependent on shape or cross-section of the padding.
- For same cross section area, impact energy and length, rectangular cross-sections shows lowest effort reaction compared to circular or square cross section.
- Rectangular cross section shows almost ideal collapsing behaviour.
- Thickness variation has changed the effort magnitude of padding but behaviour of force versus displacement characteristics remains almost same.

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