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An Analysis of Side Impact Crash using Curtain Airbag

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Abstract

To reduce severity of side impact collisions has been an emerging area of research due to past years. The motor vehicle manufacturing and regulation in both NASS and Euro NCAP, many other countries have developed a dynamic side impact test and criteria to reduce the severity of vehicle-to-vehicle side impact collisions. The database was queried with the constraint that all vehicles must adhere to the Federal Motor Vehicle Safety Standards FMVSS 214, side impact car crash most often occurs at intersections when drivers run red lights or stop signs and have a higher chance of causing body damage when the struck car is broadsided by a larger car with a higher bumper. This paper presents preliminary side impact test and evaluation procedures for occupant safety using the curtain airbags. The purpose of this paper is to summarize recommendations for performing side impact crash test, describe the result of side impact according to the regulation and comparing it with the analytical results using LSPP and LS-Dyna.

Keywords— Side Impact; LS-Dyna; Curtain Airbag.

I. INTRODUCTION

Based on the most worst-case accidents, side impact accounts for 25 % of fatalities for passenger car and light truck crashes in the USA [l]. For passenger cars, side impact accounts for approximately 30 % of the fatalities in passenger car crashes. On other hand, side impact accounts for roughly 15 % of light truck fatalities. Since the use of dynamic Federal safety standards in side protection, began in recent years occupant protection in side impact crashes has received increasing interest. This interest comes from both the consumers and the automotive industry. [2]

In comparison with frontal collisions, the space between the occupants and the element in side crashes is extremely small. In addition, with, the side impact crash occurs much more rapidly. Consequently, occupant protection in side crashes presents a challenge to engineers designing a vehicle for safety.

Side airbags (Curtain Airbag & Torso Airbag) protect you from a side impact. Of course, it isn't that simple. Modern cars generally offer two types of side airbags. The first type is torso airbags, which are usually found in the side of the seats. As their name suggests, they protect your torso from a collision. Most cars only have these in the front seats, though some luxury models offer them in the back, as well. [2]

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The other common side airbag is the curtain airbag. This airbag is more important than the torso airbag, since it deploys from the car's ceiling to protect your head. Usually, curtain airbags cover front and rear seats, though they also can protect third-row passengers in some larger vehicles. The process is like the front airbags but as there is no deformation zone (crumple zone) for the impact, it is necessary to fire the gas generators and inflate the airbags much faster. In the event of a side impact at a speed of around 50 km/h, the generators must fire after approximating 7ms and the airbag must be fully inflated after 22ms. The side airbags are installed in the door trim panel or the seat backrest. When it comes to head airbags, a distinction is made between inflatable tubular structures and inflatable curtains. The inflatable tubular structure was the first design for the head airbag. It resembled a sausage which unfolds from the roof lining above the front doors. The inflatable curtain extends across the entire side of the vehicle at the top. It is installed in the roof frame, above the vehicle doors. [3]

The airbag provides an energy absorbing surface between the occupant and a steering wheel, instrument panel. As well as the body pillar, headliner and windshield. An airbag wants to do so is slow the passengers speed to zero with little or no damage. The constraints that it must work within a huge. The airbag has the space between the passengers and the steering wheel or dashboard and a fraction of seconds to work with. Even that tiny amount of space and time is valuable, however if the system can slow the passenger evenly rather than forcing an abrupt halt to his or her motion.

II. OBJECTIVE

- To determine the risk of injury from side impact crashes.
- To safeguard the occupant from those impact conditions which lead to side impact injury.
- To optimize padding for side impact protection.

III. RELATED WORK

Lau et al. pointed out that the maximum velocity of the intruding door (of the stuck car) is important because the door strikes the occupant directly. They compared the door’s motion to a powerful “punch” to the dummy. In their paper, they pictured1 the velocity of the intruding door as rising as high (in magnitude) as the velocity of the striking barrier. Strother et al. presented data from another crash that suggested the velocity of the intruding door rose to a lower level, roughly the terminal velocity of the struck calculations. [1]

Saeed Barbat et al. validated finite element models of an "average" SUV and an "average" passenger vehicle were used to explore the effects of geometry, stiffness and mass in front-to-side impact simulations. A design of experiments methodology involving Latin Hypercube sampling was employed to select the appropriate number of simulations and the design levels of each of the design variables that should be incorporated in each simulation. Five design variables: the SUV rail height, rail thickness, mass, bumper width and bumper metal thickness were chosen.[3]

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Hampton C. Gabler et al. evaluated the risk of injury from far side impact crashes in the United States. The analysis was based upon an examination of over 4500 far side struck occupants of passenger cars, light trucks and vans, which were extracted from the NASS/CDS 1993-2002 crash investigations database. The findings of the study were used to establish priorities for injury countermeasure development. [4]

IV. PROPOSED SYSTEM

In this section, the outline of proposed test procedure and optimal padding for occupant safety is included. Finite element modeling: Reliable finite element models of the vehicles are required to enable reasonable predictions of structural performance. In this study, a baseline front-to-side vehicle-to-vehicle FE model was constructed and correlated to a physical vehicle-to-vehicle front-to-side crash test. As in the physical test, the simulated passenger vehicle was stationary, and the simulated Toyota Camry was given an initial velocity of 56 Kmph as shown in Figure 1[4].

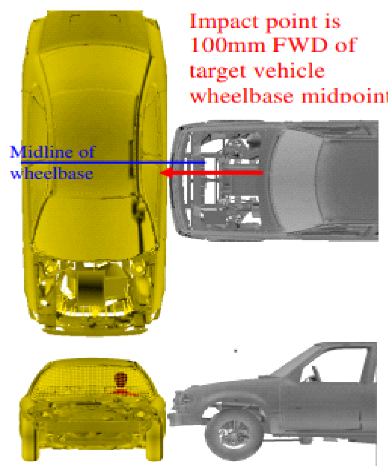

Figure 1: Side Impact Configuration

Front-to-side Toyota-to-passenger car simulations involve many complex and non-linear interactions. The nonlinear, explicit FE crash code, RADIOSS, was used for all the simulations. The simulated structural deformation and side intrusion of the struck vehicle in a front-to-side Toyota-to-passenger car impact was well correlated with test observations as shown in Figure 2. As there is no crumple zone in side impact the curtain airbags are integrated in the modeling of doors that deploy in the form of curtain.

Figure 2: Deformation in model with curtain airbags

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Parameters Affecting Performance: It is well known from literature that an intrusion profile which shows a negative vertical tilt is the best one to comply with regulation requirement, while padding behavior must be controlled properly. The effect of the first one is to reduce side intrusion speed relative to the thorax, Both by limiting the deformation at thorax level and by favoring the intrusion at pelvis level to push the dummy away from the side. The effect of the second one is to limit acceleration of the ribs and load on abdomen. Using MADYMO software and DOE technique, it is possible to show what are the most important parameters for the performance. A MADYMO model was generated and correlated to a crash test. Three factors were considered with a varied range as detailed below: upper door velocity: between the baseline intruding velocity profile and a profile which includes a reduction of 5 m/s in the first peak. [4]

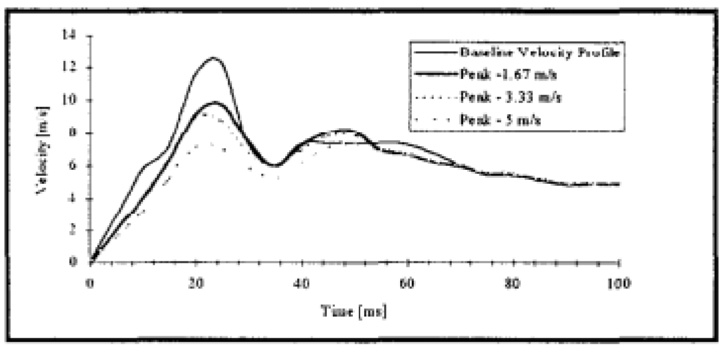

Figure 3: Velocity vs. Time

Figure 3- upper door velocity between the baseline intruding velocity profile and a profile which includes a reduction of 5 m/s on the first peak

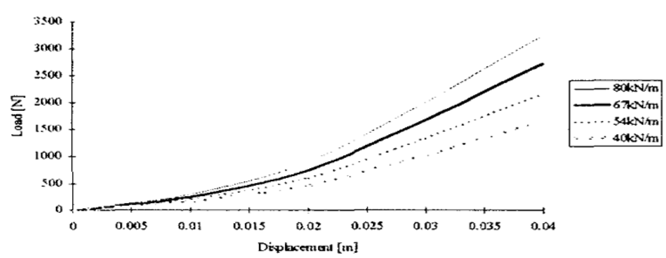

Figure 4: Load vs. Displacement

Figure 4- upper door stiffness between 50 KN/m and 40 KN/m, the upper door velocity profiles should be minimized to further reduce the response results. Other ribs have got similar behavior, even if the described effect are not same for all of them because of kinematics effects for example for a trim with higher stiffness the kinematics show more rotation of the dummies arm across the body and away front the door than lower stiffness trim. Let's analyze deeper the effect of lower door distance to occupy. If we consider the speed of the door relative to ribs, one at the impact time and the other between contact times against pelvis and thorns.

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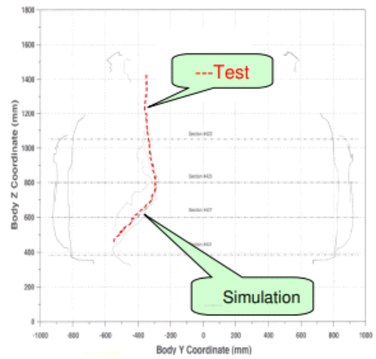

Figure 5: Intrusion Comparison

Padding Characters:

In the following the development method to characterize B pillar will be described. Both experimental and mathematical analysis can be performed. l B pillar can be isolated, constrained and loaded. Intrusions at roof level. R point level and 3% nun higher are taken through potentiometers in respect of R point intrusion can be evaluated just the first 50 nm of intrusion are enough to establish local plastic hinges [5].

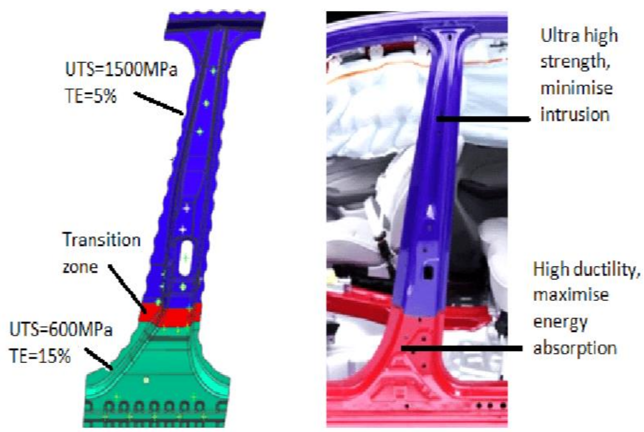

Figure 6: Constraining and loading of B- pilar

As we are looking for possible instabilities of B pillar when loaded in the described way a linear analysis can be performed. A simplified method using arch beams theory and few geometrical information has been developed in order to find the most critical sections. B pillar is considered as a two hinges arch and the problem is considered for plane, because of this it is possible to use equations from static; even if these are hard hypothesis. If the pillar is designed for this case it will deform in the desired shape in the static test. Nevertheless, some corrective factors must be introduced to consider the constraints which aren't perfect hinges. Then bending moment (M) distribution along the pillar can be found and dividing it by the inertia module (W) the tension distribution can be calculated. Comparison between tension distribution calculated and FEA mode location shows good agreement.

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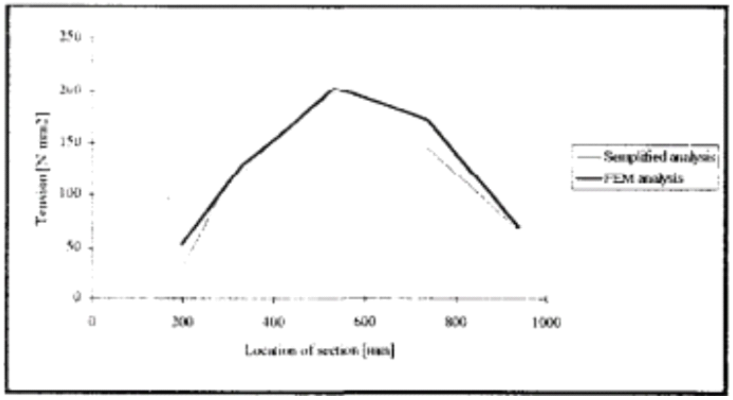

Figure 7: Tension vs. location of section

Instability of B pillar pointed out by simplified analysis are in the sections where M/W is maximum. Then the following design criteria can be expressed:

1. Critical section where instability occurs must be located wider under R point level.
2. Alternative stress (M/W) in the critical stress section must be higher than yield stress, in other sections (i.c. upper then R point level) it must be lower.

This method is useful in very early stage car & stages of design when the only style concept of a new project is available and main dimensions must be determined. The same can be applied to the doors of vehicle in order to have a good intrusion profile of B pillar being the most important for protection of backward occupants.

The DOE study demonstrated that bio-mechanical parameters at thorax level aren't very much affected by padding stiffness. In indications of padding stiffness for thorax protection arc present and were used to define a specification for side trim panels.

Let's define thorax mean, the very area hit by the ribs at Euro-SID. It is installed in car as defined by regulation and the seat is moved through all its possible positions. In 121 and 131 for a range of 60 to 100 KN/m stiffness are investigated in such an area. To evaluate stiffness of a real panel the following method was developed in FIAT. A rib-form with the shape of an Euro-SID (i.e. 120 mm x 40 mm) was built and mounted on a trolley suitable to 11: Te MTS machine for Body Block test [6].

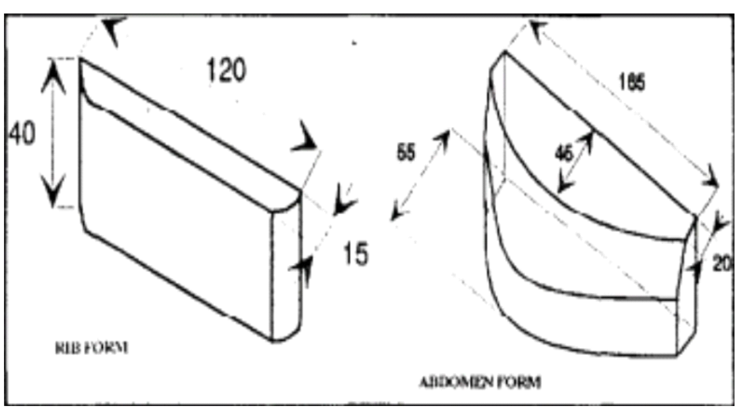

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Figure 8: Dimension used for foam

Results of side impact crashes with standard and prototype door panel:

Panel	HPC	Rib deflection [mm]		Rib VC [m/s]		Force [kN]	
		Min.	Max.	Min.	Max.	Abd.	Pelv.
Stand.	300	29	33	0.7	0.9	1.7	3.1
Proto.	340	38	43	1.04	1.16	0.98	3.8

It can be seen a general worsening of thorax performance. This is coherent with the parametric analysis in fact panel stiffness did not improve the performance and a slight difference in impact speed worsened it. Abdomen force was very much reduced by the use of a very soft armrest a maximum failure load of 1.4 kN must be guaranteed in order to have abdominal force lower than 1 KN in the crash test. Pelvis and thorax performance changed within experimental variability. [7]

V. SUMMARY

An analytical study supported by experimental evidence and by laboratory tests demonstrated that the main parameters which influence bio-mechanical performance in side-impacts are upper door velocity against the thorax, lower distance from occupant (pelvis Level) and failure load of armrest. Upper door stiffness doesn't appear as an important parameter.

Upper door velocity is influenced by the structural behavior of B pillar (in four door cars). A design specification for B pillar has been developed applying simple static analysis in order to guarantee stability of B pillar during impact.

Lower distance to occupant at pelvis level must be reduced by at last 50 mm, with respect to standard geometry. To achieve good performance at thorax level, this is an important item for design preliminary work. Use of foams and other absorbing materials should be validated

An experimental methodology for characterization of trim stiffness has been proposed. At an abdomen level, failure load of armrest can be measured. It comes out that door armrest must be designed to guarantee a maximum failure load of 1.4 kN to obtain a maximum abdomen load of less than 1 kN in side-impact crash. At thorax level proposed test is very sensitive to change in stiffness of the panel, but it shows poor correlation with side impact test result.

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