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Design and analysis of door stiffener using finite element analysis against FMVSS 214 pole impact test

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Abstract: *Passenger vehicle occupants involved in side impact crashes historically tend to fatal damages compared to the frontal or rear impact crashes due to the very limited survival space. Doors are the prominent part of the vehicle in protecting the passengers in side impact crashes. There are side beams inserted into the door which can absorb energy and reduce the intrusion of the impacting object. The strength, location and appropriate design of these beams are very important to save passenger's life in case of pole impact. Superior beam design can eliminate the dependency on other expensive passive safety equipment's like seat belts and side airbags. In past 15 years a lot of research work has been done to reduce the crash related injuries. The side door beams support the door structure in such a way that door cannot collapse easily. It absorbs most of the impact energies coming from the other vehicle or due to pole intrusion. Experimentally it is very expensive and difficult to perform multiple iterations. Finite Element Analysis technique is used in this research work to achieve optimize able design and locations of the side door beams against pole impact scenario.*

Key Words: side impact, pole impact, FEA, crash and safety

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I. Introduction

The road traffic calamities are one of the prominent causes of mortality in current society. Car safety became the most important issue immediately in the development of the automobile. Injuries due to road accidents are a problem that can be controlled considerably if adequate attention is given to accident and injury prevention strategies. Passive safety devices and features including airbags, energy-absorbing steering columns, side door beams, etc. can minimize the fatalities with great extent. It has been observed that the side-impact crashes are the second leading cause of fatality and injury in the road traffic accidents after frontal crashes. Unlike a frontal impact, side-impact crashes are particularly dangerous because of low space between an occupant and the side of the vehicle. Unlike front side of the vehicle, there are no energy absorption components such as bumpers, crush attenuators etc. Hence, the passenger has very slight protection when a vehicle is hit on its side.

To minimize this risk in a side crash, the advanced cars have airbags, side-door beams, cells, padding or other protection within the door structure. As the crash mechanism is very complex, generally, the way of analyzing the crash can be divided into two categories: experiments and numerical simulations. The energy absorption by different components of side structure was analysed by Yonezawa et al. (1996), Veeraswamy et al. (2016) and Saraf et al. (2017) [1], [2], [3]. The research by Yonezawa et al. (1996) has also described the effect of side structure reinforcement on energy consumption in each process. Human cadavers were also used in the past to assess biomechanical responses of human bodies. Zhu et al. (1993) investigated the pelvic biomechanical response and padding benefits in side impact based on 17 cadaveric tests [4]. FRP based on different conceptual design of doors were investigated by Adam et al. (1998) [5]. Miller et al. (2002) developed a compact sled system for linear impact, pole impact and side impact testing [6]. Vaidyaraman et al. (1998) developed a detailed and state-of-the-art modelling methodology to numerically simulate the folding and unfolding of a head/thorax side airbag system [7]. The occupant response with side airbags in side collisions is also evaluated. T. Tsuchida and Y. Shibuya (2003) performed crashworthiness evaluations by CAE using orthotropic damage & fracture model [8]. H. Lanzerath and R. Schilling (2003) presented the validation approach for aluminium foam and for polymeric structural foam in vehicle development [9]. Ito et al. (1997) studied the relationship of the door inner material crush characteristics and the rib deflection of EuroSID-1 using MADYMO simulation [10]. The crash characteristics are optimized using the sensitivity analysis method. Gandhi and Hu (1996) developed uncoupled lumped parameter models for the automobile structure and the test dummy based on the study of distribution of crash energy [11].

Side-door beams were developed to reduce the velocity and depth of door intrusion into the passenger compartment in side impact crashes. Assessing the effectiveness of side-door beams is significant for reducing occupant fatalities and serious injuries. In the evaluation methodologies for automobile side impact development, real car crash tests can achieve results closely resembling a real accident. However, this method is complex and expensive. CAE methodologies can increase product development process efficiency. Therefore, numerical crash simulations were used widely for automotive engineers. In this study, full-scale side-impact test finite element models were presented. The test numerical models are based on the FMVSS-214. Research for side impact collisions by using models have been done by Teng et al. (2006) adhering to the FMVSS-214 standards [12]. The crash simulations utilized the LS-DYNA finite element code. The capability of impact energy absorption of side-door beams is discussed herein. Analysis on the performance of beams in side crashes includes displacement and intrusion measurement of door and injury analysis of dummy. The study results indicate that the side-door beams have considerable potential for reducing occupant injuries. These results and procedures can be applied as a reference for the optimization design of the side-door beams. Furthermore, the full-scale side-impact test numerical models obtained could help evaluate vehicle crash safety and guide the future development of safety technologies.

II. Methods

In this study full vehicle FE model was used to simulate the FMVSS-214 pole impact test and propose finest optimized vehicle design and support beam of door against the same test. The deformation of side door of the model developed was made at one value of angle out of the various values proposed in laboratory test procedure for federal motor vehicle safety standard 214D (1995) [13]. In order to simulate FMVSS-214 side pole impact in FEA our understanding about this test must be clear. The setup of FMVSS-208 is shown in figure 1.

The test vehicle is propelled sideways so that its line of forward motion forms an angle of 75 degrees for the right (or left) side impact with the vehicle's longitudinal centre line. The angle is measured counter clockwise from the vehicle. The impact reference line is aligned with the centre line of the rigid pole surface, as viewed in the direction of vehicle motion, so that, when the vehicle-to-pole contact occurs, the centre line contacts the vehicle area bounded by two vertical planes parallel to and forward with reference line. The pole is 254 mm (10 inches) ± 3 mm in diameter and set off from any mounting surface such as a barrier or other structure, so that a test vehicle would not contact such a mount or support at any time within 100 milliseconds of initiation of vehicle-to-pole impact. The vehicles were tested at an impact speed of 20 mph (32.1kmph) for the oblique pole tests. Figure 1 shows the test setup of pole impact scenario.

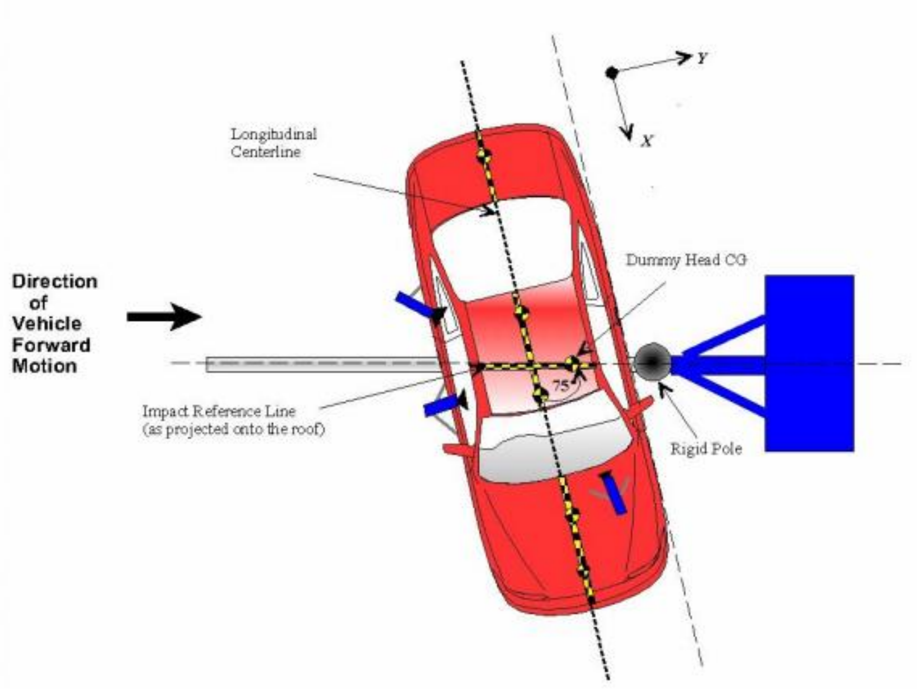


Figure 1: Oblique Pole Impact Test Scenario

Figure 2 below shows the FE model of the vehicle. Detailed non-linear material properties were used for sheet metal and glass. Rigid connections were used to provide weld connections between different parts.

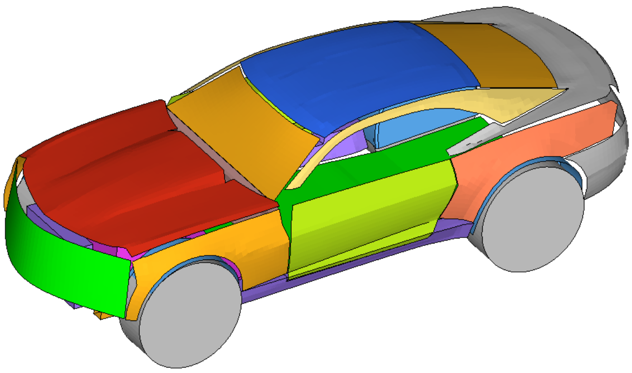


Figure 2: Detailed Finite Element Model of Vehicle

Figure 3 shows FE model setup of FMVSS214 pole impact test. The pole was modelled as rigid wall option available in ls-dyna. *Initial Velocity card was used to assign velocity to the vehicle.

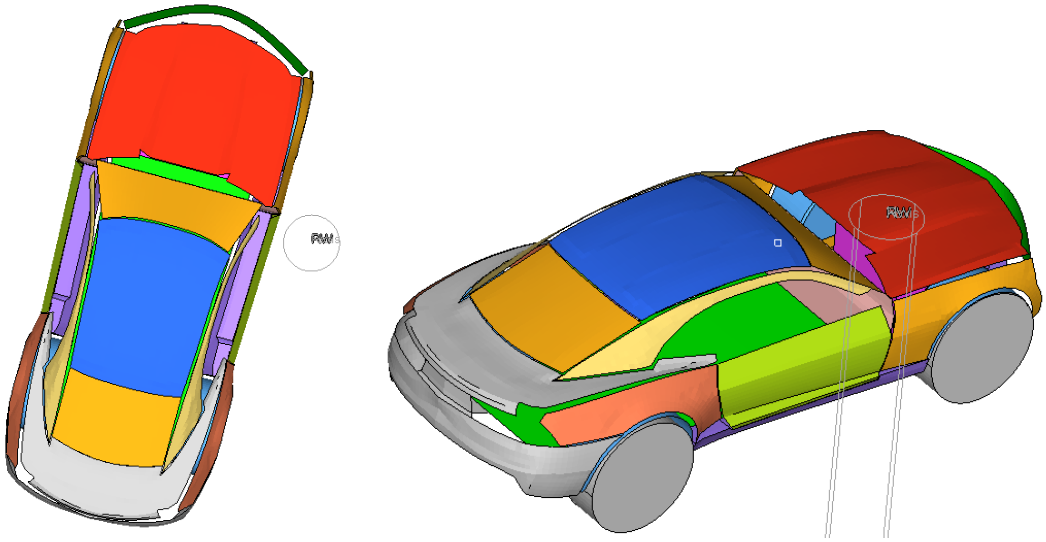


Figure 3: Pole impact scenario setup of FE Model

Two cases were simulated based on the door stiffener. The baseline case without door reinforcement and modified design with door stiffener is as shown in figure 4.

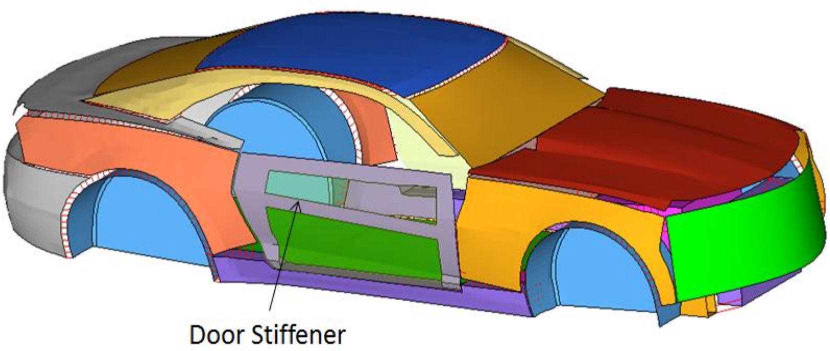
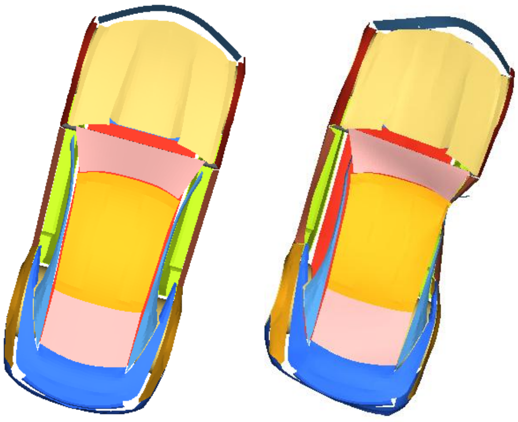


Figure 4: Modified design with door stiffener

III. Results

Figure 5a and 5b show the deformation stages of baseline case. The maximum door intrusion was found at the site of pole impact.



(a) (b)

Figure 5: (a) Un-deformed shape and (b) deformed shape of baseline case

Figure 6 shows the deformation contour of baseline case. The maximum door intrusion was found at the site of pole impact. The maximum door intrusion was found as 133 mm.

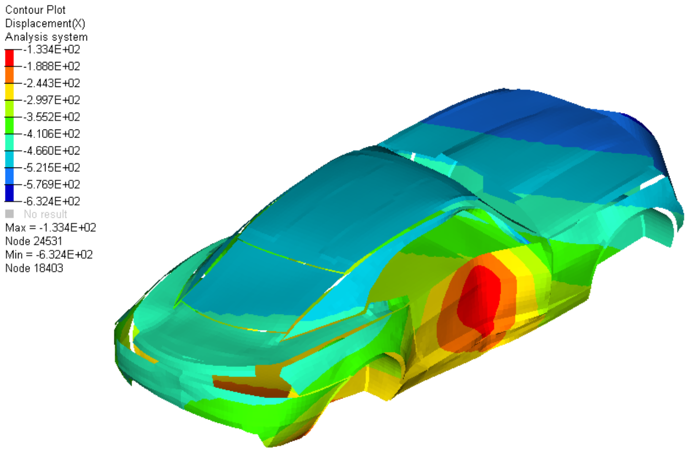


Figure 6: Deformation contour of baseline case

Figure 7 shows the door deformation time histories of baseline case. The maximum door intrusion was found at the site of pole impact. The maximum door intrusion was found as 133 mm.

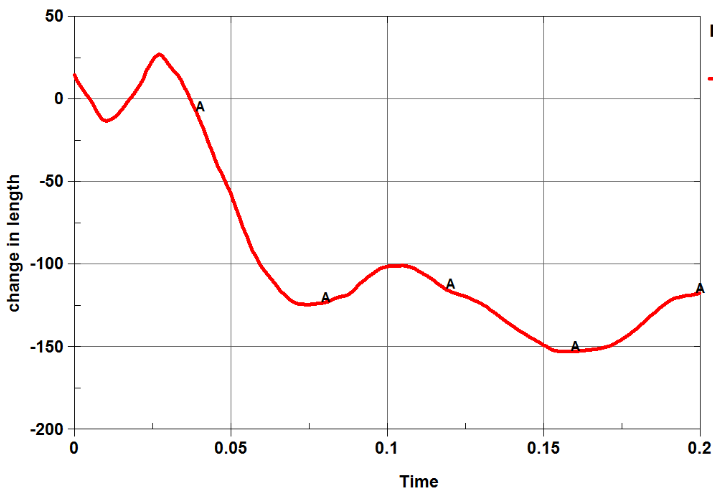
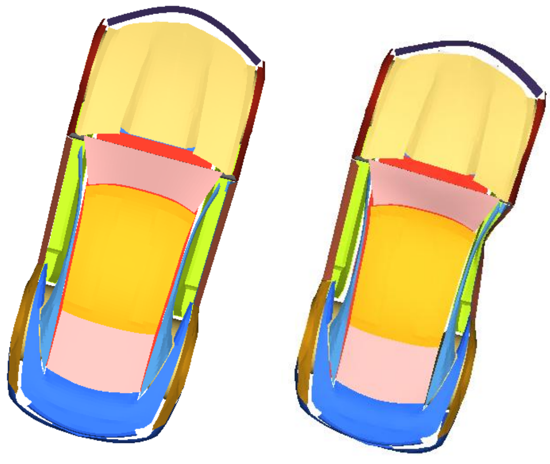


Figure 7: Door intrusion in baseline case

Figure 8a and 8b show the deformation stages of modified case. The maximum door intrusion was found at the site of pole impact.



(a) (b)

Figure 8: (a) Un-deformed shape and (b) deformed shape of modified design case

Figure 9 shows the deformation contour of baseline case. The maximum door intrusion was found at the site of pole impact. The maximum door intrusion was found as 118 mm.

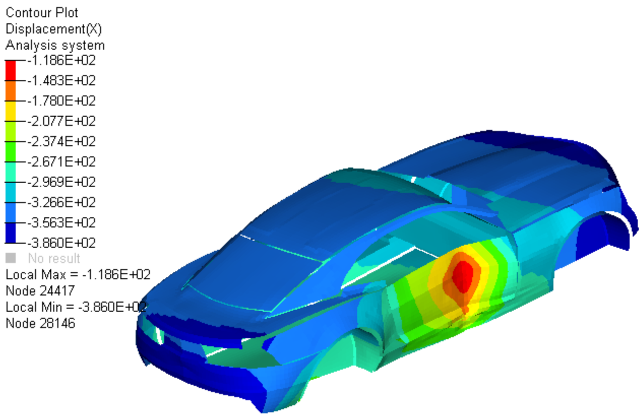


Figure 9: Deformation contour of modified design case

Figure 10 shows the door deformation time histories of baseline case. The maximum door intrusion was found at the site of pole impact. The maximum door intrusion was found as 118 mm.

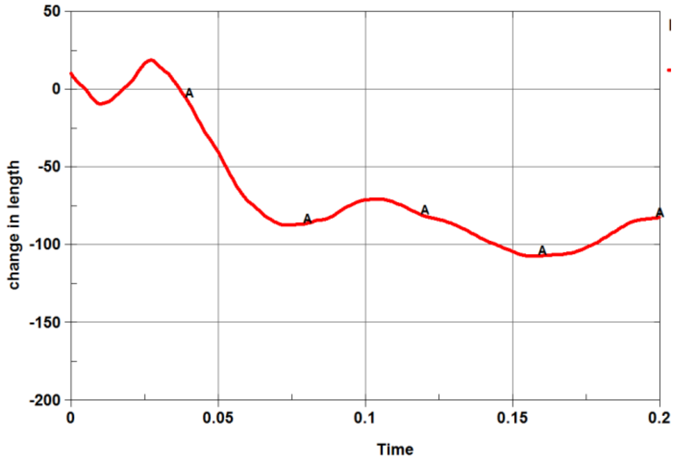


Figure 10: Door intrusion in modified design case

IV. Conclusions

Detailed FEA modelling of vehicle and side pole impact scenario as per FMVSS214 was simulated successfully. The effect of door beam was analysed successfully and found to be very effective in case of side impact. Within the door stiffener it was possible to minimize the door intrusion by around 15mm.

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