REVISTA INTERDISCIPLINAR DE PESQUISA EM ENGENHARIA

CILAMCE 2016
XXXVII IBERIAN LATIN AMERICAN CONGRESS ON COMPUTATIONAL METHODS IN ENGINEERING
BRASÍLIA - DF - BRAZIL

STUDY OF THE INFLUENCE OF DOOR INTRUSION VELOCITY IN LATERAL COLLISIONS: BIOMECHANICAL RESULTS

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Abstract. *The influence of door intrusion velocity in occupant injury according to Latin NCAP side impact 2016 protocol were studied isolating door panel design or clearance between occupant versus door panel with the main objective of understand purely structural features in a mobile deformable barrier side impact. A sled impact model was created with the validated MADYMO fiftieth percentile occupant model (EuroSid 2) and a finite element flat panel. Impact velocity was incremented from 3.5 to 9.5m/s in intervals of 1m/s. Occupant injury was measured for each case analyzing ribs, abdomen and pelvis behavior to identify a critical intrusion velocity according to project characteristic and its objectives.*

Keywords: *Biomechanics, Side impact, Occupant injury, Multi-body model, Door intrusion*

1 INTRODUCTION

The Latin American scenario is requesting safer vehicles due to progressive application of more demanding safety regulations. Driven by Global NCAP, it was created in 2010 the new car assessment program for Latin America (Latin NCAP) with the objective of encourage the Governments to implement the regulations required by the United Nations for vehicle crash tests and encourage manufacturers to improve their vehicle safety levels. The program classifies the vehicle according to its safety level from 0 to 5 stars. Before that, regarding to safety assessment, vehicles only needed to comply with frontal impacts to be sold in some Latin American market, but over the subsequent years was possible to verify a significant evolution in safety levels of the models commercialized.

The 2013-2015 Latin NCAP protocol started to request side impact good performance to classify a vehicle as 5 stars. In 2015 Ecuador adopted the side impact regulation as a compliance requirement to sell vehicles inside the country. In 2016, Latin NCAP published the new protocol (from 2016 to 2018) steadying the side impact performance assessment as standard test to classify the vehicle from 0 to 5 stars. Argentine Government announced that in 2018, the side collision will be necessary to sell vehicles there too. It is expected that Brazilian Government starts to require it from 2019. In other words, the major markets inside Latin America are adopting the side impact test as a compliance requirement and the Latin American assessment program is already testing them using side impact protocol to inform customers about safety level of cars. Due to those scenario changes, manufacturers are being challenged to improve and study new solutions that could provide higher safety levels without losing competitive features.

The side collision regulation is based in a European regulation (ECE95) and it is assessed impacting a mobile deformable barrier against the tested vehicle, with the driver occupant inside, at 50km/h centered in the R-point (95^{th} occupant position). The compliance test objective is to approve vehicles regarding the occupant protection in the event of a side collision. The difference between both test setups are shown in the Fig.1. The biomechanical assessment is different each other, while Latin NCAP has a maximum classification of 16 points in the performance assessment according to Fig.2, the minimum performance are the ECE95 requirements for compliance. The Government regulation approve or not the vehicle to be commercialized in the market, without any classification.

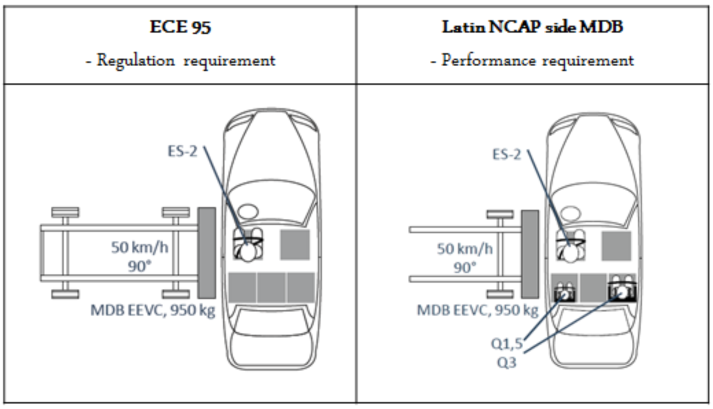

Figure 1 – Test setup difference between ECE95 and Latin NCAP assessment.

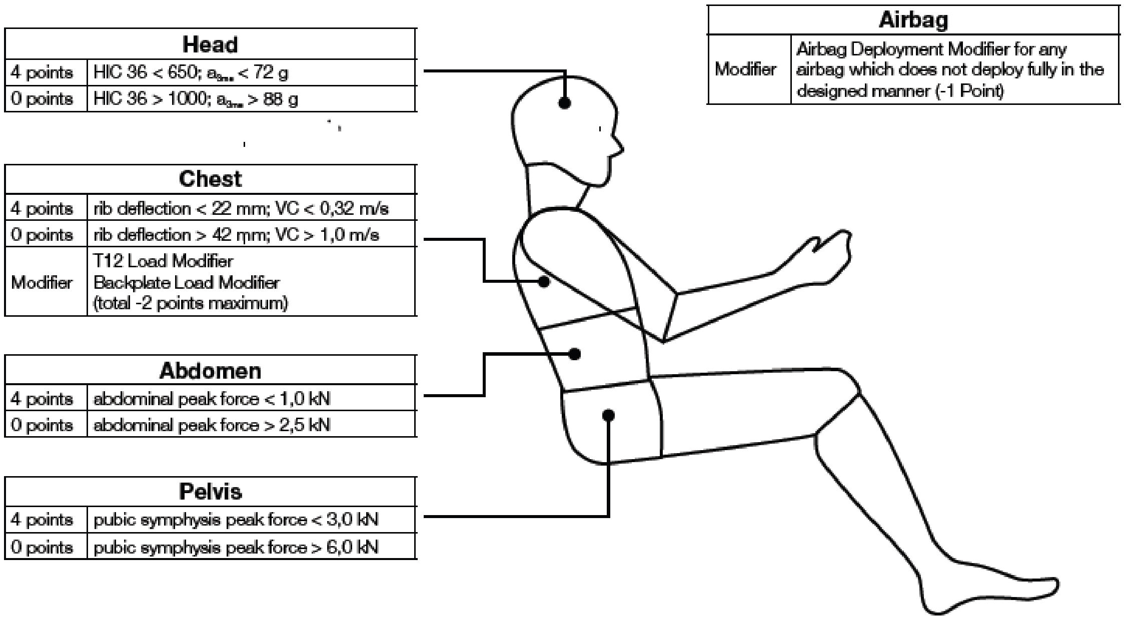

Figure 2 – Latin NCAP side impact occupant injury criteria.

2 METHODS

The method definition was made after a evaluation of 6 vehicles from different brands and segments in the side impact and theirs results. Using a range of vehicle mass (from 900 to 1300kg), brands and segment (from A to C). It was observed that due to the standard test setup, vehicles followed a standard behavior regarding to the pelvis results. The acceleration ramp for all the evaluated cases remained for 25ms. It means that dummy pelvic area remains in contact with door panel during a standard period as demonstrated in Fig.3.

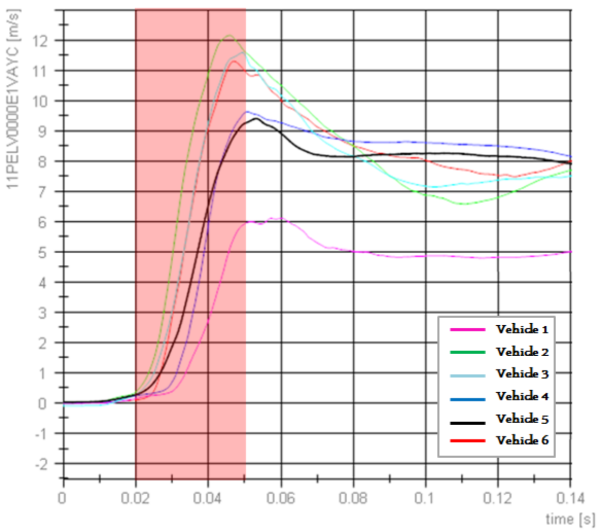

Figure 3 – Side impact benchmarking results for pelvic acceleration.

The benchmarnking analysis demonstrated that the range of door intrusion velocity has a substantial variation when comparing different masses and vehicle structural behavior. Among all the results found it were selected some of them, with the intention of having the worst, the best and intermediate biomechanical performances.

The EuroSid 2 model was used in multibody dynamics calculation using the software MADYMO, a worldwide standard software for analysing and optimizing occupant safety design. The model is consisted of head, neck, thoraz, abdomen, upper and lower extremities, and it was selected because of its application in the tests. The velocities were studied in a range from 3.5 to 9.5m/s analyzed in intervals of 1m/s. The impactor material was selected from a low cost vehicle and its dimensions covered all occupant body with exception of the head. In a lateral collision head impacts in the vehicle structure or window glass, but normally it has a good performance if rigid contact is not present. Because of that, head results were desconsidered in this analysis. Seatback was fixed in its travel course for horizontal and vertical adjustments, the angle was kept the same during all evaluations. To avoid influence of seat cushion and seat structure, the atrict was removed to allow the assessment of vehicle structure influence purely. Figure 4 shows MADYMO simulation configuration applied.

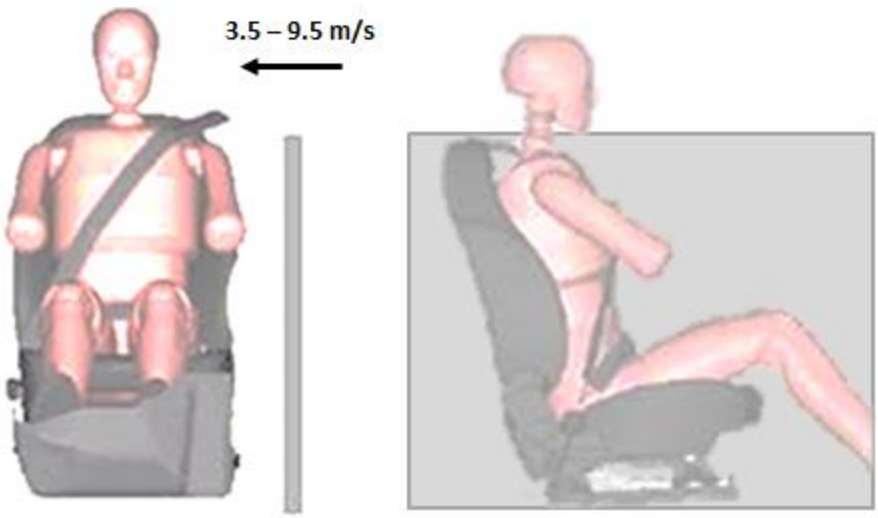

Figure 4 – MADYMO simulation setup.

The method was developed focusing in a vehicle lateral structure study. It means that all the internal trims and non-standard safety restraints that could influence in the biomechanical were removed in the analysis. Contact between pelvis and door panel was adjusted to remain during 25ms after first impact and stop to push, reproducing lateral collisions verified in standard regulations, where it is allowed to contact one time only, without double impacts. In controlled tests the mobile barrier has a brake device to avoid double contact, independent of the difference between vehicle and mobile barrier weights.

3 RESULTS

MADYMO simulation indicated the biomechanical results according Latin NCAP 2016 lateral impact protocol for all door intrusion velocity. Figures 5-9 present the biomechanical plots for the evaluate body areas. The graphs shows the expected trend of higher intrusion velocities directly connected with worse biomechanical results, and presented results that can be considered as good results considering the method applied (removal of internal trims, seat cushion friction and non-standard safety restraints). Abdomen area did not present the expected results, demonstrating a substantial variation, affecting this body area assessment. It was possible to obtain results that did not reach any score (9.5m/s case) until results that almost reached the maximum score (3.5m/s case).

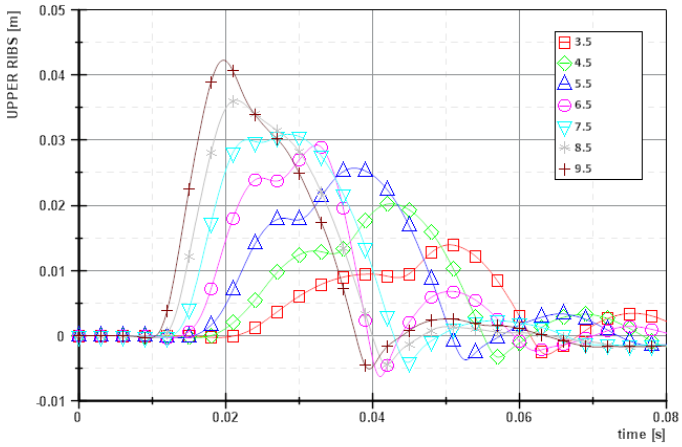

Figure 5 – Upper rib biomechanical results from different tested vehicles.

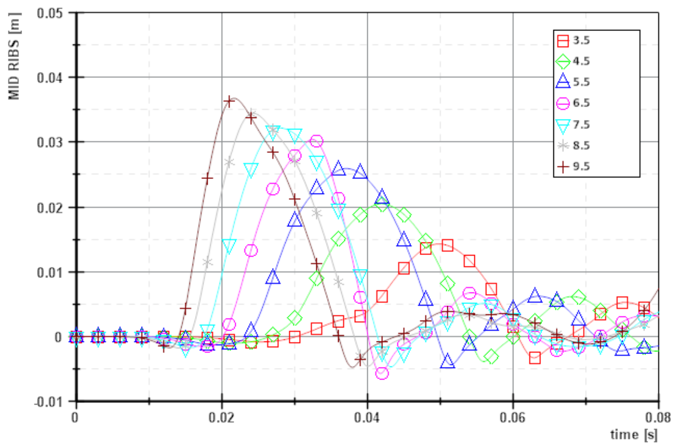

Figure 6 – Middle ribs biomechanical results from different tested vehicles..

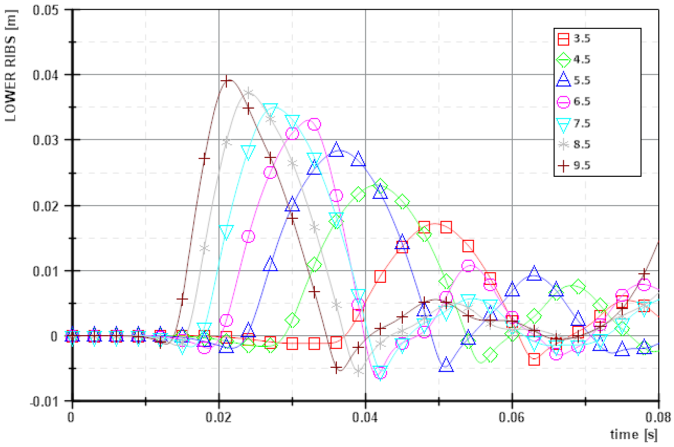

Figure 7 – Lower ribs biomechanical results from different tested vehicles.

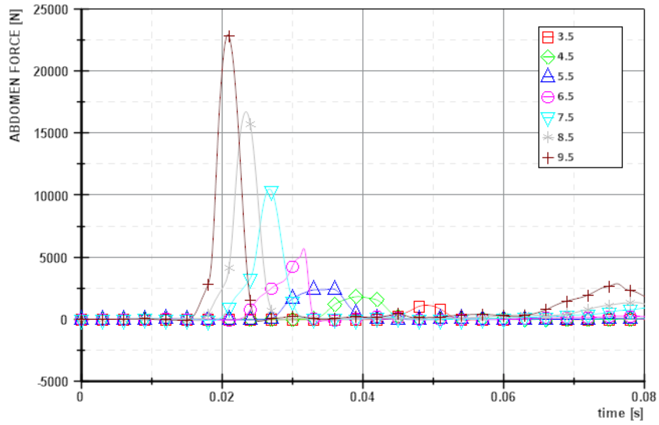

Figure 8 – Abdomen biomechanical results from different tested vehicles.

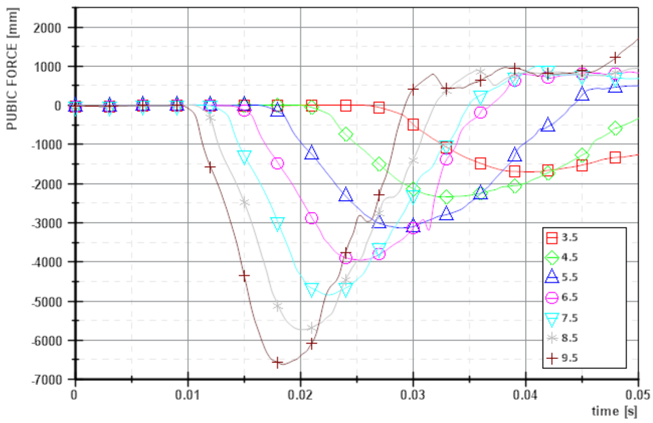

Figure 9 – Pelvis biomechanical results from different tested vehicles.

The detailed assessment for each case is demonstrated in the Table 1, where is possible to understand how a poor structure can affect the final assessment of the vehicle. Occupant injuries showed that is possible to leave from a safe condition until a deadly condition.

It was demonstrated that increasing 1m/s in the door intrusion velocity could affect negatively, crushing a vehicle market strategy. For this reason vehicle side structure shall be carefully designed to perform with maximum efficiency within project and costs limitation.

	3.5 m/s		4.5m/s		5.5m/s		6.5m/s		7.5m/s		8.5m/s		9.5m/s	
CHEST	VALUE	RATING	VALUE	RATING	VALUE	RATING	VALUE	RATING	VALUE	RATING	VALUE	RATING	VALUE	RATING
Top Rib Assessment														
Compression - mm	13.9	4.00	20.2	4.00	25.7	3.26	29.3	2.55	30.9	2.22	36.1	1.18	42.3	
Viscous criterion - m/s	0.10	4.00	0.19	4.00	0.26	4.00	0.40	3.52	0.63	2.16	0.92	0.48	1.29	
Middle Rib Assessment														
Compression - mm	14.3	4.00	20.5	4.00	25.9	3.21	30.4	2.31	32.2	1.96	34.5	1.51	36.8	
Viscous criterion - m/s	0.10	4.00	0.18	4.00	0.30	4.00	0.42	3.40	0.58	2.47	0.82	1.08	1.08	
Lower Rib Assessment														
Compression -mm	17.2	4.00	23.1	3.78	28.4	2.72	33.0	1.79	35.0	1.40	37.2	0.96	39.2	
Viscous criterion - m/s	0.13	4.00	0.23	4.00	0.35	3.83	0.48	3.06	0.69	1.85	0.94	0.35	1.21	
T12 Modifier (-2)														
T12 Fy-kN	1.21	0.00	2.14	-2.00	2.84	-2.00	7.18	-2.00	11.92	-2.00	18.77	-2.00	25.60	-2.00
T12 Mx-Nm	60.43	0.00	98.66	0.00	136.96	0.00	633.41	-2.00	1179.30	-2.00	1935.80	-2.00	2672.50	-2.00
Backplate Load Modifier (-2)														
Backplate Fy-Nm	0.23	0.00	0.33	0.00	0.45	0.00	0.71	0.00	0.00	-0.13	1.83	-0.55	2.43	-0.95
CHEST ASSESSMENT		4.00		1.78		0.72		0.00		0.00		0.00		0.00
ABDOMEN														
Front	0.10		0.23		0.30		0.40		0.53		0.70		1.20	
Mid	0.67		1.01		1.31		3.25		6.00		9.37		12.54	
Rear	0.38		0.59		0.87		2.09		3.98		6.67		9.23	
Peak lateral force - kN	1.13	3.66	1.83	1.80	2.45	0.14	5.71	10.49	10.49	0.00	16.72	0.00	22.93	0.00
ABDOMEN ASSESSMENT		3.66		1.80		0.14		0.00		0.00		0.00		0.00
PELVIS														
Pubic symphysis force - kN	1.70	4.00	2.34	4.00	3.13	3.83	3.95	2.73	4.84	1.54	5.73	0.36	6.62	0.00
PELVIS ASSESSMENT		4.00		4.00		3.83		2.73		1.54		0.36		0.00

Table 1 – Compiled biomechanical results according to Latin NCAP 2016 protocol.

It is clear that the door intrusion velocity shall be kept within a limit to avoid occupant risks and injuries. Even if the manufacturer do not select the best structural performance, it indicates a better condition for occupant impact against door panel with the overall system mounted. Other solutions that could improve performance even with a regular structural performance are safer internal trims, better safety restraints or in last case side airbags.

This study will feed an oncoming one that will study the influence of door panel design and features with the objective of find the best solution avoiding losing, after Latin American market adoption of side collision requirements competitive, characteristics according to vehicle strategy.

4 ACKNOWLEDGMENT

The authors kindly thank the immeasurable support of Pontifícia Universidade Católica de Minas Gerais – PUCMINAS, the Fundação de Amparo a Pesquisa de Minas Gerais – FAPEMIG and FCA Group.

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