PEDESTRIAN PROTECTION HEAD IMPACTS IN GLASS CORRELATION FEM-TEST IN THE NEW SEAT LEON.

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KEYWORDS –

FEM TEST Correlation, Pedestrian Protection, Finite model, HIC, Euro NCAP, glass model.

ABSTRACT –

Many factors should be considered in order to understand properly how a mechanical input to the head can result in a determined type of head injury: the severity, the nature of the mechanical input, the impact location, the direction of this input, the age of the patient, his gender, anthropometrics and previous state, and also the treatment and recovery of the patient.

Head injuries are either the most or second most commonly reported injuries to pedestrians struck by vehicles. Furthermore, among serious or life-threatening head and brain injuries far outnumber injuries to all other body regions. Around 40% of the adult head injuries are due to windshield impact.

Windshield modeling is currently a challenge in head pedestrian protection, the way the windshield breaks introduces a significant change in the Head Injury Criteria, and this is due to the non-lineal fracture that the glass is presenting during the headform collision. In this paper a new model for windshield pedestrian impact is presented for optimizing experimental-simulation correlation.

In this research a total of 90 experimental windshield test were performed, the head impacts were simulated using the software ANSA+PAMCRASH+META. The model was optimized through parametric adjustment methods.

With this present model the average HIC deviation between testing and simulation has been reduced in average below 10%

TECHNICAL PAPER -

1. INTRODUCTION

The glass breaking behavior presents a difficult characterization for pedestrian protection due to the high nonlinearity of the material, on these head to glass impacts, we have implemented a worst case strategy to control the results. In fact, the principal idea was not only to achieve a good correlation, we also had the intention of controlling the final results defining a safety boundary in all the HICs prognosis.

In some occasions the way the glass fails introduces a significant variability in the final results, in the Figure number 1 it can be observed how the glass breaks in different ways impacting the same point. The glass that has consumed more energy after the impact generates bigger mark in front of the glass that has failed in a big non-linear way. This mechanical behavior can also be deduced from the acceleration curves analysis. Figure 2

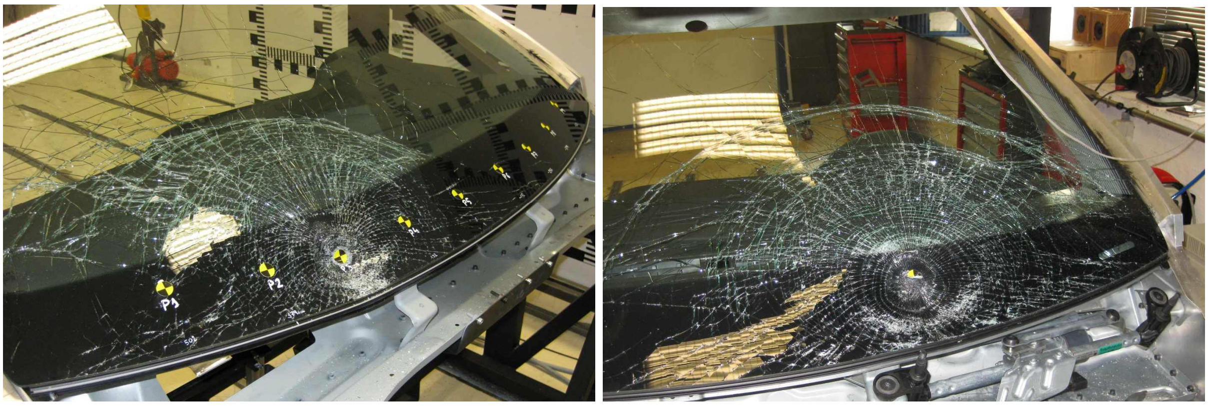


Figure 1 - Different final behavior of the glass after the impact.
HIC 804 vs 941. Reduced Pedestrian buck.

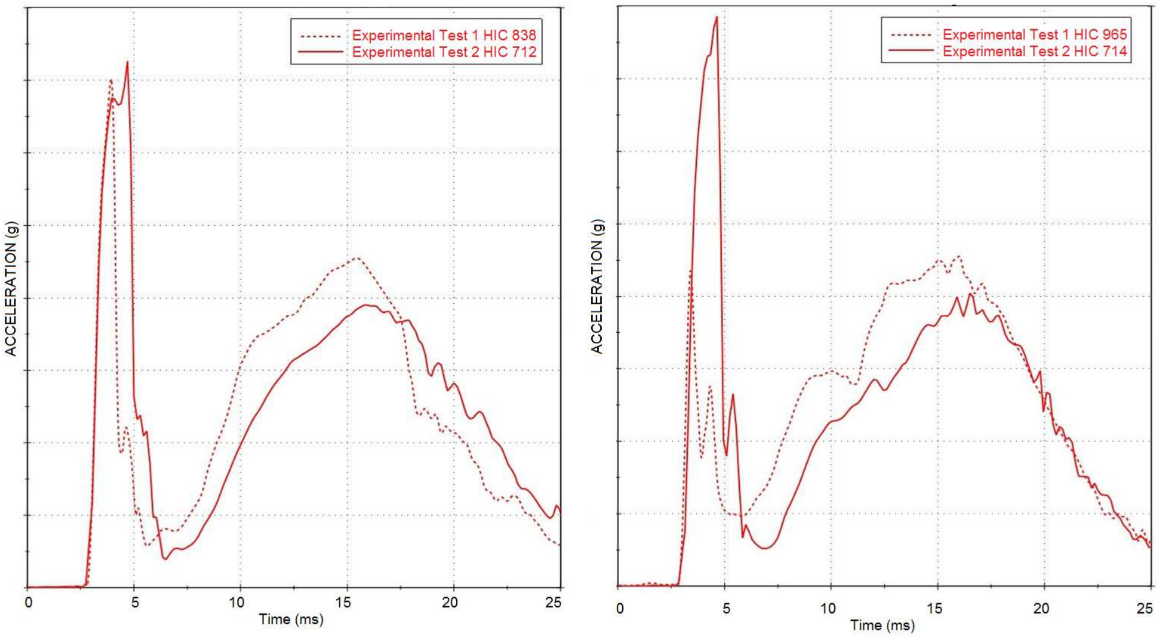


Figure 2 – Experimental Test, acceleration in the impactor (same point, same car)

This comparative between two different impacts evidences the different acceleration result due to the glass. It is also relevant to analyze in detail the two different initial peaks observed in the acceleration curve. On this case the HIC values difference represented near to (15-35) %.

In the Figure 3 the difficulty to predict the HIC is illustrated. The nonlinear behavior of the glass is responsible of many different acceleration initial peaks.

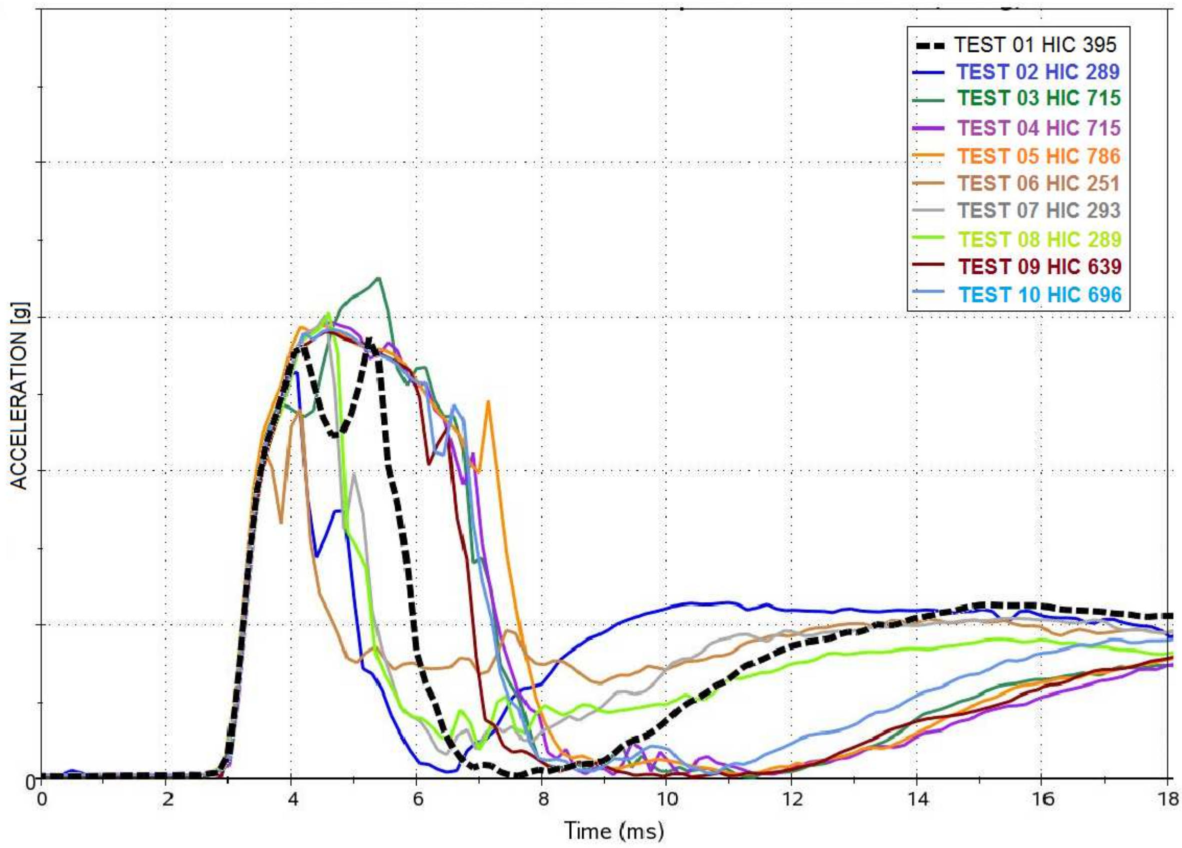


Figure 3 - Acceleration in the impactor. Identical impact points.
Experimental Test Full Seat Car

2. WINDSHIELD FEM DEFINITION: METHODOLOGY

The initial tests were performed with a reduced pedestrian buck or simplified vehicle. The Figure 4 show a CATIA screenshot of a description used to build the pedestrian buck for testing.

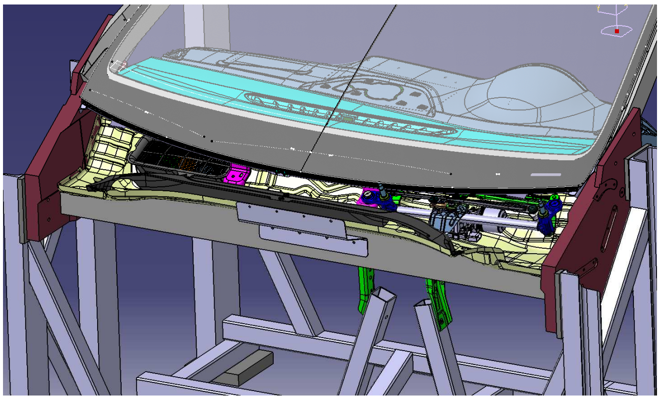


Figure 4 - Reduced Pedestrian buck CATIA TEST model

In the Figure 5 the configuration used in the pedestrian buck can be observed. The elements that had more influence in the head acceleration were included, for instance the wipers and the structural parts where the windshield are glued. The main objective was to allow the fast replacement of pieces to optimize the timing and the resources.

Figure 5 – Reduced pedestrian buck Experimental TEST model

The Figure 6, shows the FEM model used to compare with the experimental TEST

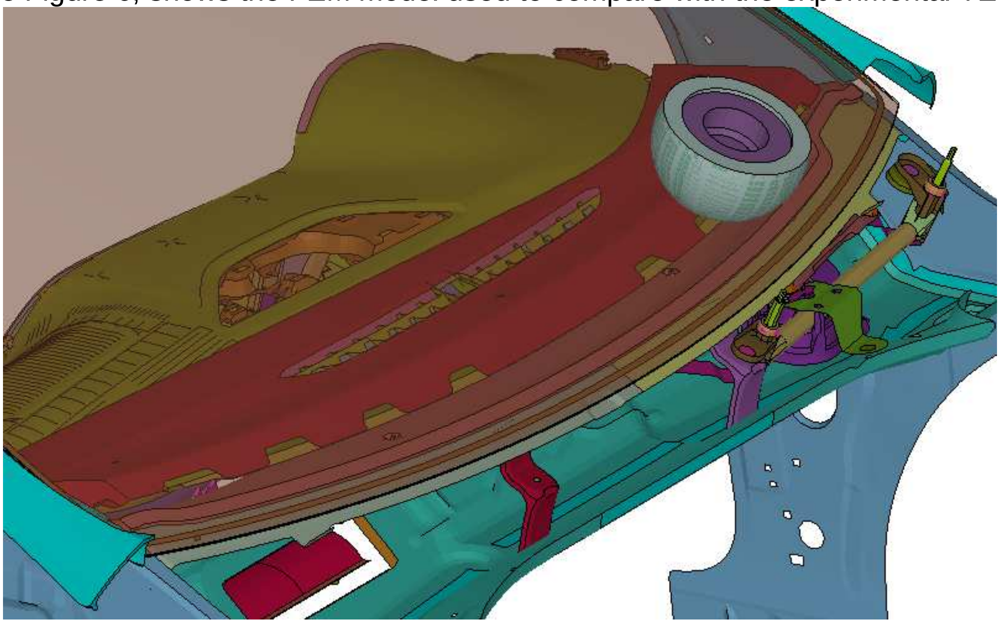


Figure 6 – Reduced pedestrian buck FEM model to correlate the TEST results

A – Windshield FEM definition

The material selected for the windshield FEM definition was the ESI PAMCRASH MATER 126 Implemented with the software pre-processor ANSA BETA-CAE. (Figure 7)

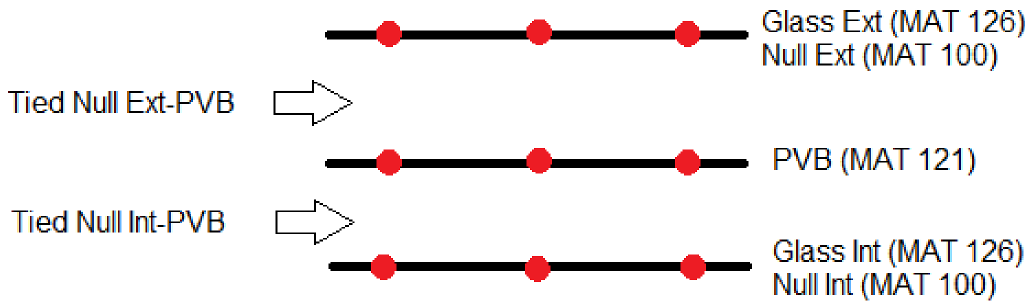
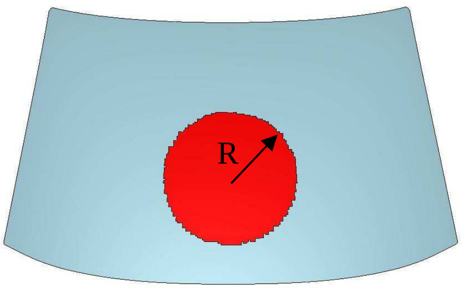


Figure 7 – Glass definition.

The parameters used in the model have been extracted from a comparison off different tests configurations. The most relevant variables taken in account in the definition of the glass-model were the definition of the glass damage and the glue between the glass and the car body.

B - Windshield damage definition

To define the parameters used in the Pamcrash damage glass definition, near of 90 real test were performed and also different simulations taken in account. In the graphic 1 the parameter Radius and Energy was changed and the results have been compared with experimental test results. (Figure 8)



$$R = Radius\ of\ the\ area\ for\ the\ sum$$

$$\sum membranes\ Energy$$

$$E = \frac{Membrane - Energy}{Wall\ thickness}\ (Limit)$$

Figure 8 – R, E definition for the glass model damage.

Further information about the parameters R (Radius) and E (Energy) can be obtained from Pamcrash solver reference manual NLAVE card.

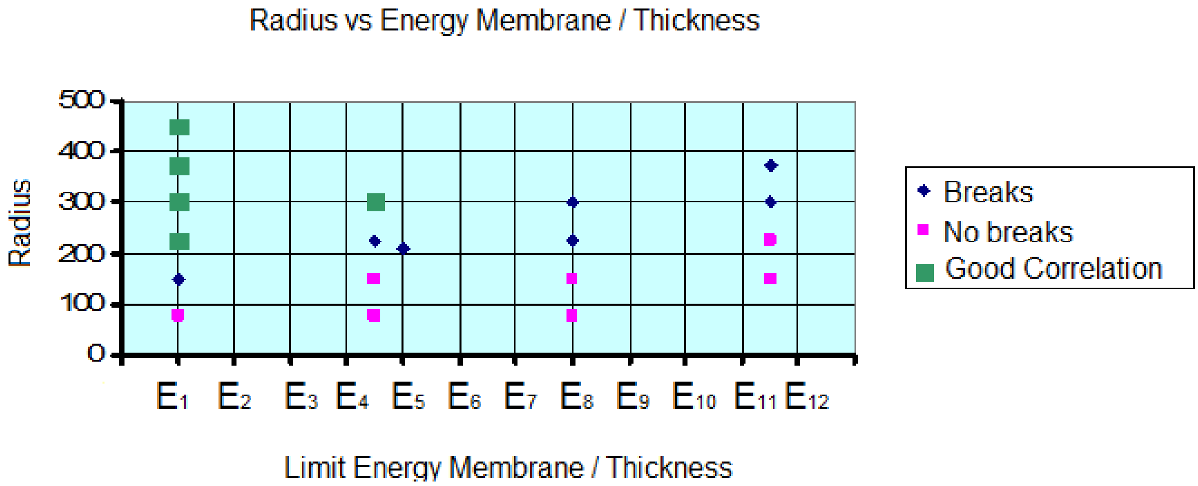


Figure 9 - Radius vs Energy

The Figure 10 reproduces the FEM acceleration results, measured at the pedestrian head with a different Radius, and Energy model configuration, comparing the experimental test vs different FEM configurations.

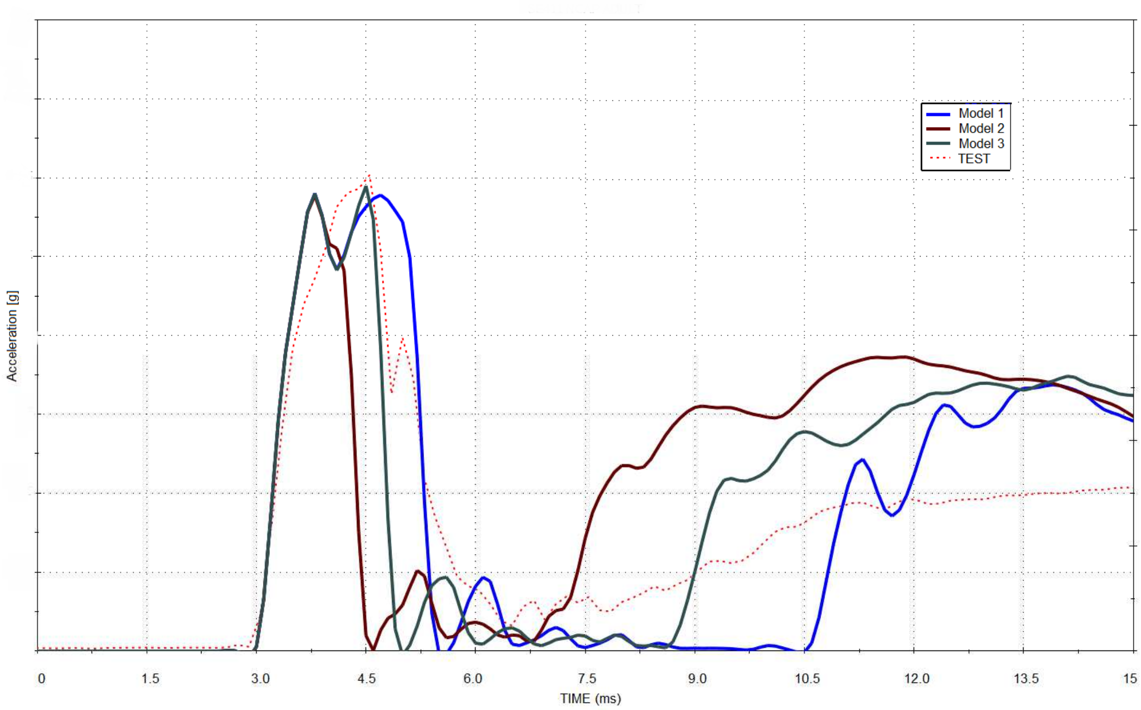


Figure 10 - Final acceleration FEM and Test vs Energy Radius combination

A dependency between the parameters R and E and the test impact point in the windshield has been found. For this issue a topological radius and Energy definition has been taken in account.

The Figure 11 shows different combinations off values R, E and the final result off the windshield, also the placement off the impactor was taken in account.

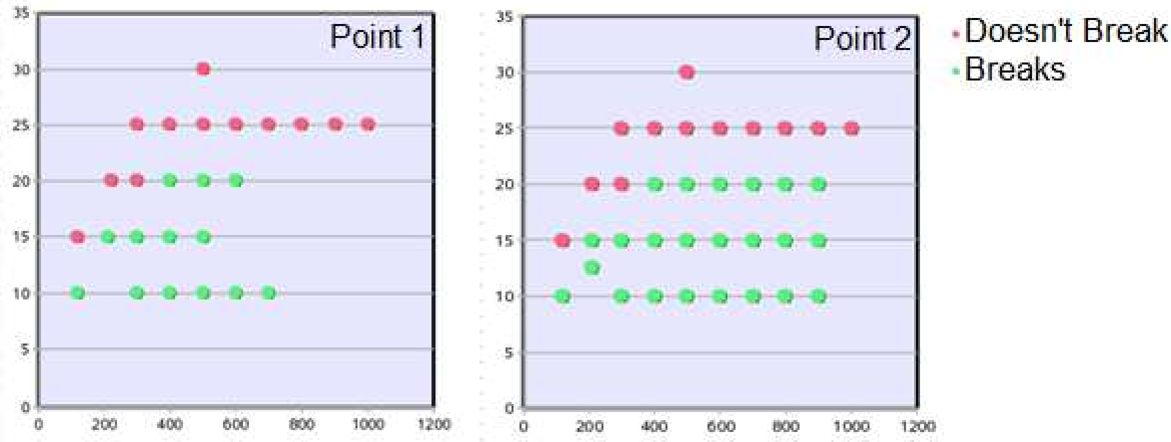


Figure 11 – Final results depending R, E used and in different impact points

Apart from the R and E, two additional values were used to adjust the final glass car the Critical failure stress and also the Young Modulus in the Pam Crash type 126 definition.

C - Glass structure definition

To model this glue the main the selection was: Hexa solid or Pamcrash Tied definition. A not accurate definition could lead to a divergent acceleration results, also the glue had different responses depending the impact topography. On this case, the analysis with real tests has been mandatory to obtain suitable cards for the FEM model. The Figure 12 shows a comparison between 2 different models of glue and a real reduced test.

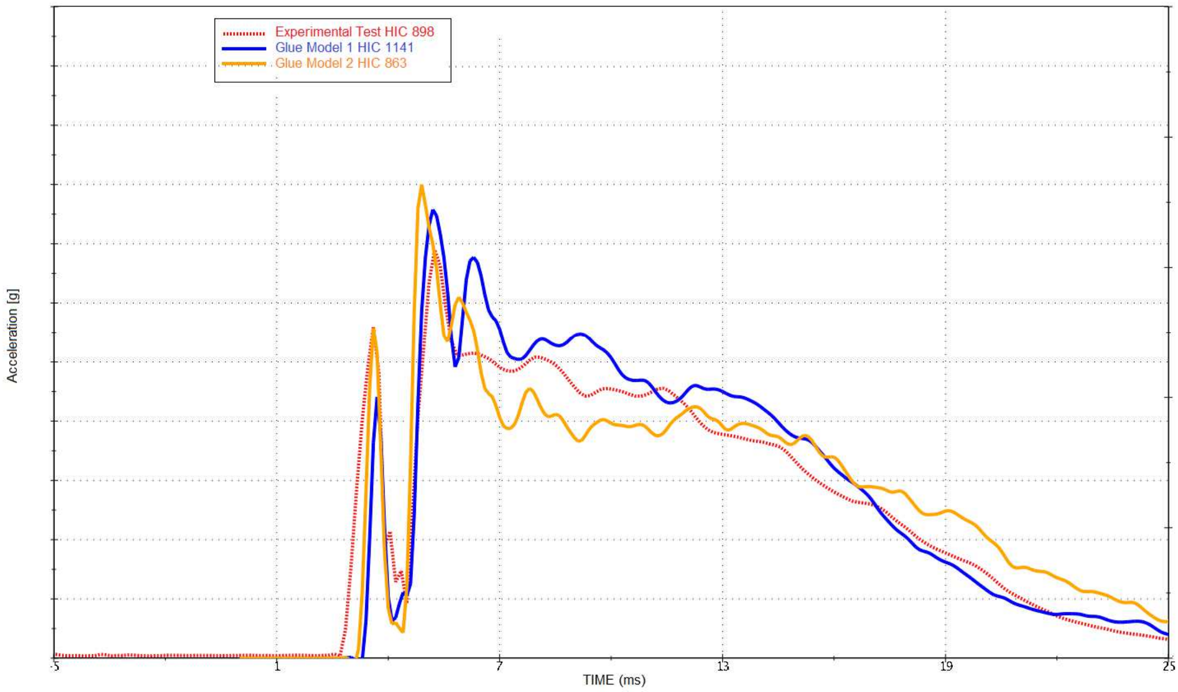


Figure 12 - Acceleration in the impactor.
Experimental test vs 2 different FEM GLUE models. Reduced pedestrian buck.

The next Figures 13-14 show two different glue solutions and the HIC results are presented.

Position	Model 1	Test	%
P725L	863	898	4.06%
P735L	942	1050	11.46%
P700L	811	756	-6.78%
P740L	1096	1137	3.74%

Figure 13 - acceleration in the impactor. Fem Test. Model 1. (FEM Glue 1)
Reduced pedestrian buck

Position	Model 2	Test	%
P725L	1141	898	-21.30%
P735L	1092	1050	-3.85%
P700L	992	756	-23.79%
P740L	1138	1137	-0.09%

Figure 14 - acceleration in the impactor. Fem Test Model 2. (FEM Glue 2)
Reduced pedestrian buck

3. TEST - CORRELATIONS

A - Different and less predictable behavior of the glass

To avoid future problems in the final HIC prognosis the FEM parameters were defined in a safe way mode. The main idea was to establish a definition that permits to work in the relevant parts of the car. Figure 15 reproduces a Test impact and two different FEM configurations

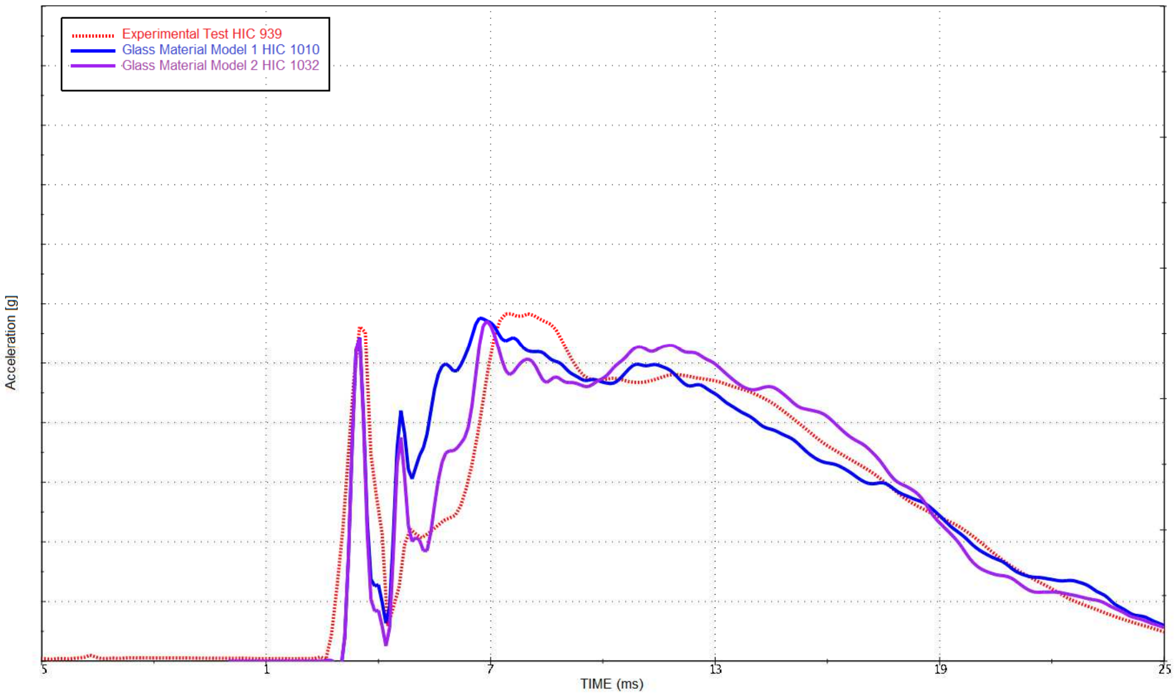


Figure 15- Acceleration in the impactor. Test vs two FEM models
The variable on this case modified was the Critical Failure Stress of the Glass. Seat Car León.

B - Impact point adjusting

In the correlation process we observed some impact points that after adjusting the velocity and point of impact, the experimental acceleration was too deviated. On those cases a small grid of impact points to adjust the point of impact and therefore achieve better curves was used, Figure 16 and Figure 17.

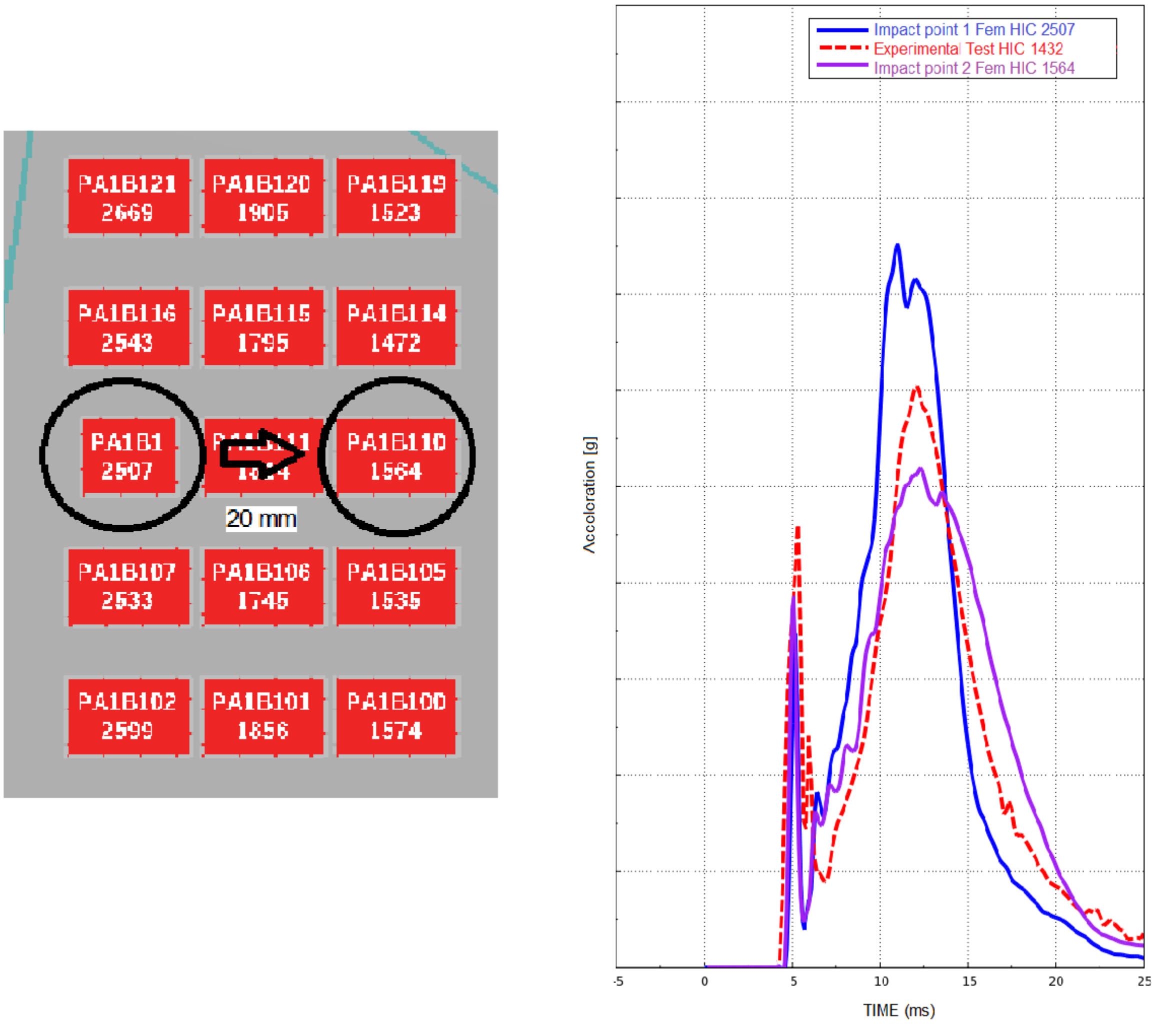


Figure 16- Impacts Grid and Acceleration in the impactor Impact point 20 mm displaced.

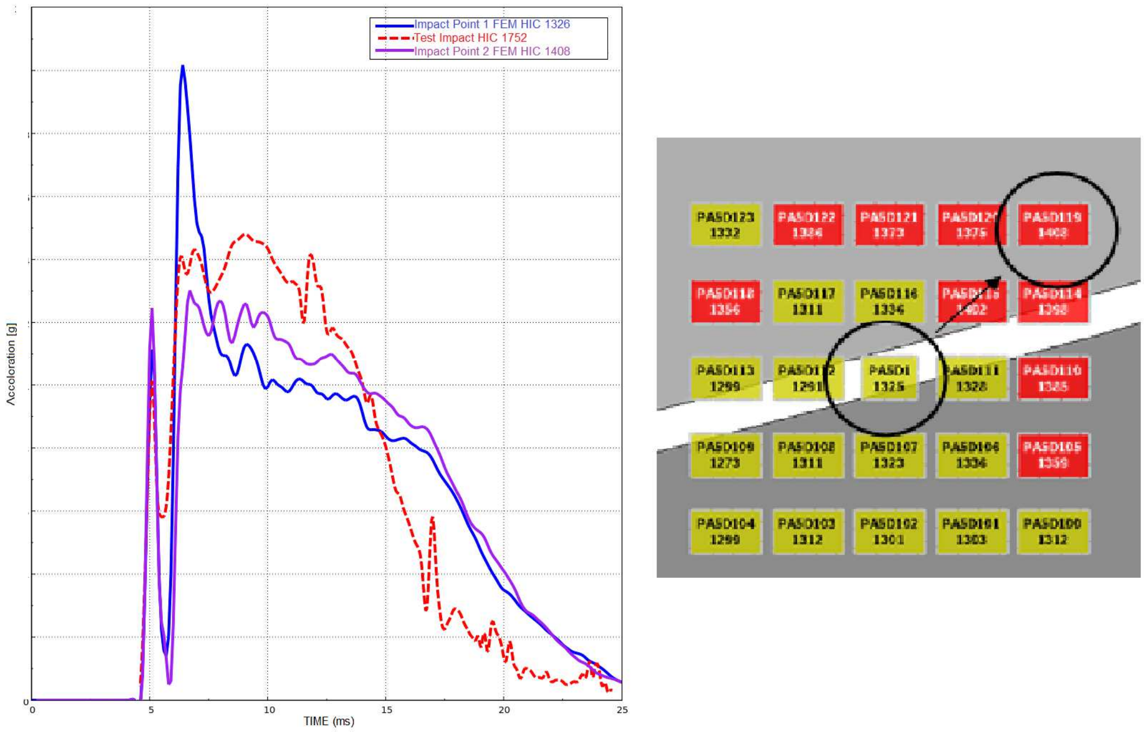


Figure 17 Acceleration in the impactor and Grid used to improve the correlation

On this case the improvement implemented was to displace the impact point. The second peak disappears and the acceleration curve obtained was more similar to the experimental result obtained. On the other hand the stiffness level of the model was not enough to represent the experimental results.

C – Correlations results

As a summary of the performed research, a total of 16 impact points were tested. The following Figures summarizes the obtained biomechanical values. A deviation minor that 10 % was obtained comparing for the pedestrian buck, the experimental results and the simulations.

In the Figures 18 and 19 there are the HIC experimental results obtained vs HIC finite model results. On this case the Hardware used was a Pedestrian Buck. Figure 18.

Point	HIC FEM	HIC Test	%	
P700L	925	841	9.99	
P725L	863	899	-4	
P735L	942	1051	-10.4	
P700L	811	756	7.3	
P740L	1096	1138	-3.7	
P700L1	933	842	10.8	
P700L2	1010	941	7.3	
P700R2	988	804	22.9	
P720L	902	898	0.4	
P735L	956	1050	-8.9	
P800L	714	680	5	
P740R	1043	894	16.7	
P700L	751	690	8.8	
P720L	886	866	2.2	
P730R	818	742	10.2	
P800L	806	791	1.9	
			8.1	**Σ(abs(%))/n**
			5.7	**σ Sigma**

Figure 18 HIC FEM vs Pedestrian buck Seat Leon Test results

The next step was to verify the tendencies with a full SEAT LEON CAR. In Figure 23 it can be checked the final results.

Point	HIC FEM	HIC Test	%	
P700L	1232	1167	5.6	
P740L	1101	957	15	
P730R	1294	1393	-7.1	
P740R	1233	1191	3.5	
PA5D	1326	1752	-24.32	
PA3C	1217	1132	7.51	
PA2C	1202	1326	-9.35	
PA5A	965	978	-1.33	
PA4A	1068	976	9.43	
PA2B	1028	972	5.76	
			8.9	**Σ(abs(%))/n**
			6.5	**σ Sigma**

Figure 19 HIC FEM vs Full Seat Leon Test results

Similar deviation minor from 10% was been obtained in the full car test.

4. CONCLUSIONS

Important efforts were done by SEAT to create an improved FEM model of the windshield that allows the optimization for pedestrian protection purposes the windshield area

The new Pam Crash material glass 126 has demonstrated to achieve good correlations between the FEM acceleration and the experimental curves obtained. Not only the glass simulation has relevance for pedestrian head impact, also the definition of the glue with the car body has showed his big effect in this study.

Starting from the Seat Exeo, continuing with the Seat Ibiza and at finally the Seat León has provided good head protection in case of pedestrian-vehicle collision. As a result of this effort the new SEAT León has obtained 25 points in pedestrian protection according to the Euro NCAP protocol 2012.

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