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Small Overlap corner instrumentation

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Abstract:
The introduction of the IIHS Small Overlap test configuration implies a more severe and critical load case at the structural parts of the vehicle that need more improvement. In 2012 IIHS began to evaluate the vehicles crashworthiness with the small overlap tests due to a recent crashworthiness study with new vehicles in the EU and USA that found a higher severity in frontal crashes. The result showed that occupant injuries and vehicle structure deformation were severe when the vehicle was loaded outboard (Small Overlap).

In order to have a better knowledge of the cinematics of this new test, several crash test and crash-worthiness analysis were carried out. IDIADA identified a lack of knowledge about how vehicles react to SOI impact. Due to that a barrier was instrumented with a tri-axial load cells at the center of the barrier and at the corner. With this new data, new studies of test severity and intrusion had been made and the forces involved and the vehicle's structural elements had been analyzed in order to improve the design strategies.

Vehicle manufacturers improved quite a lot the vehicle's structure in order to protect the occupant in frontal crash but real crashworthiness determine that more countermeasures and improvements should be made. Providing more tools to manufacturers for design vehicles will help reducing deaths and sever injuries in vehicle occupants.

Keywords: Small Overlap, testing, data analysis, Load cell wall

1 Introduction

Advanced Driver Assistance Systems such as crash avoidance and line control, adaptive cruise control, frontal collision warning, lane change system, have helped in the mitigation of frontal crashes but added different variables involved in frontal crash. Additionally, the quality of crashworthiness data in the EU and the USA has increased due to the awareness of the value of this data in helping to have better knowledge in accidentology in terms of occupant injuries and intrusion patterns. Focusing on more severe frontal crashes, a large percentage of fatalities were found in newer vehicles in which engagement of frontal structures was limited. State of art in small overlap frontal and oblique crashes are a new research priority for NHTSA [3][4] as was previously introduced by IIHS.

IDIADA initiated a development program with the aim of creating a new design of fully instrumented barrier to identify forces involved in small overlap crashes. After several crash tests and crashworthiness analyses, IDIADA identified the importance of the forces applied in each structural element involved in a small overlap crash. A need for knowledge about how vehicles react to SOI (small overlap impact) was identified and in order to help manufacturers with vehicle development a small overlap barrier able to record forces was developed. Better structural designs will lead to lower intrusions and decreased fatalities on the road.

2 Small Overlap Impact test

IIHS (Insurance Institutes of Highway Safety) introduced small overlap as a consumer test in the US after crashworthiness research with new cars with good results in full frontal and offset (40%) crash test. Results showed a new scenario of fatal accidents without engagement of structural elements designed for frontal crash. A test was carried out to reproduce real small overlap crashes. Vehicle was propelled at 64.4 km/h toward a rigid barrier; this was designed to replicate what happens in field cases when the front corner of a vehicle collides with another vehicle or an object such as a tree or utility pole. The test vehicle is aligned with the rigid barrier such that the right edge of the barrier face is offset to the left of the vehicle centerline by 25 ± 1 percent of the vehicle width. In most cases this causes the barrier to strike directly in outboard zone of its longitudinal structural members.

IIHS is an independent, non-profit, research and communications organization that is influential in the American market, which follows IIHS vehicle results and updates over social networks and on TV. For example, in 2014 the IIHS website was in the top 10 referring websites in the USA. Due to this fact OEM'S take seriously all the requirements and specifications that IIHS demands in their crash test protocols. Recent studies reveal an influence on sales depending on small overlap results [4]. Vehicles with good performance in IIHS's small overlap frontal crash test had positive consumer opinion and sales results compared with other vehicles with marginal or poor. Improving vehicle design to increase crashworthiness not only improves vehicle safety but also increases sales.

2.1 Implications of SOI test to vehicle design

Structural elements designed for energy absorption do not interact directly with the intrusive force in small overlap crashes. This fact cause higher damage in the footwell zone, A-Pillar and rocker panel. Frequently vehicles suffer oblique kinematics, and interaction along the struck side of the vehicle increasing the chances of injuries from outboard components such as the door and A-pillar.

A detailed review of injuries shows that KTH (Knee-Thigh-Hip) and pelvis injuries frequently occur in the absence of femur fractures AIS 3+ (70%) [8] especially in small overlap due to higher intrusions. The behavior of footwell and Lower A-pillar is very important in preventing higher intrusions in lower body area. The upper body region has the second area with more percentage in AIS 3+ (42%) in small overlap crashes, specifically in the chest area [8]. These injuries have been caused by the contact with the belt, door and steering wheel. To improve the assessment of the dummy, modifications in restraint systems should be made to prevent and control lateral motion of dummy during the crash kinematics.

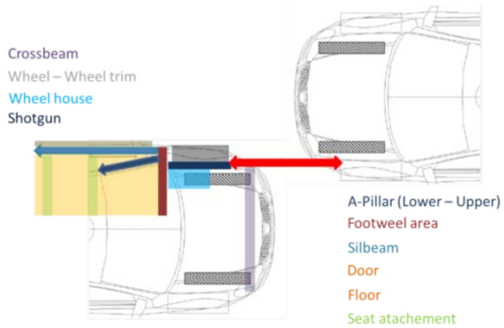

Figure 1. Structural elements involved in small overlap crash.

Vehicle manufacturers are responding quickly to the structural challenges associated with the newer field accidenthology. Different combinations of structural improvements for small overlap were found to be effective in reducing occupant compartment intrusion.

Countermeasures included vehicle structure modifications to promote stronger occupant compartments and new elements to absorb crash forces and reduce intrusions in occupant compartment. However, the high pulse caused by a very stiff structure demands more reaction of the restraint system to dissipate the increase of energy in occupants due increase of pulse.

3 Testing barrier necessity

IDIADA used an IIHS model barrier to design a new acquisition system following the protocol criterion for small overlap test. This barrier was redesigned with load cell (X,Y and Z) only in frontal part. Several crashes were performed by IDIADA with this barrier, but after analysis and research of crash energies and forces, more information of the barrier should be recorded. More research and innovation adds another step forward to achieving improved barrier in order to determine the role of each structural element in barrier corner.

After an internal study of the small overlap testing results, it was seen that a large amount of information was lost during the final part of the test. This lack of information was due to rotation and translation at the barrier's corner and that part of the barrier has no acquisition system. Energy observed for vehicle structure due the rotation and translation added another important component in structural elements used to absorb energy only in X axis. For this reason Y and Z component played another relevant scenario in this type of crash necessary to evaluate and implement countermeasures.

Figure 2 approximately represents the sum of forces registered in each delimited area by contact with barrier. Placing a vehicle without frontal bumper provided a general view of elements involved in each barrier load cell. These results showed forces involved for each structural elements facing barrier during the crash. As can be appreciated, applied forces give a general view of loads for each set of elements or body block. However, relevant energy applied on corner by heavy components such as rocker panel or A-pillar during rotation and translation were not recorded or identified.

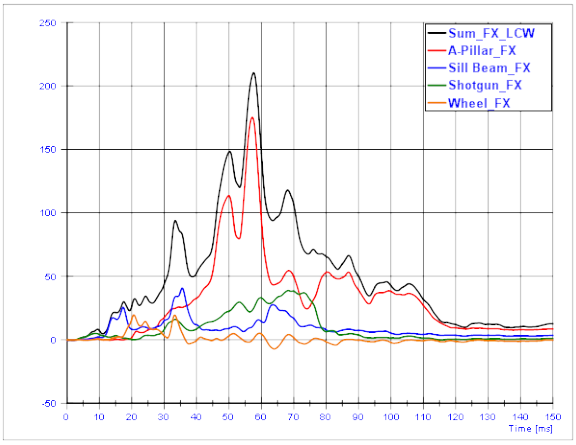

Figure 2. Sum of the barrier' forces obtained

Additionally, in order to quantify approximately the force of the vehicle recorded during the crash and compare it with the total force (Ft=m*a2) assuming all limitations by friction, differences of mass and mechanical losses, a simple calculation was done. Equivalent "force" was represented by acceleration of non-structural side (B-pillar) plus weight of vehicle. The red line of figure 3 represents the appropriate force (in a perfect scenario) of the vehicle and the green line represents the overall forces of the small overlap barrier registered. The yellow zone represents the period of test time when the data obtained by the barrier is lower than the supposed force applied by the vehicle.

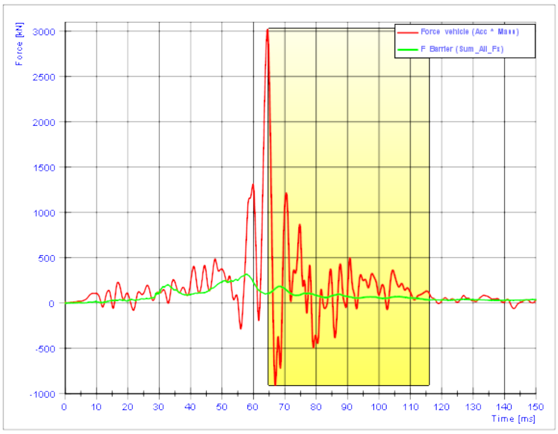

Figure 3. Comparison between the barrier and theoretical vehicle force

Part of the theoretical force was not recorded by the actual acquisition system. In order to know the amount of energy that was dissipated by the vehicle's absorption mechanisms and the real energy registered by the barrier during the test, several calculations were made. From the forces registered by the barrier, the vehicle has been considered as a rigid body and the energy has been obtained by following the work equation:

Some calculus had been made in order to obtain the theoretical displacement of the vehicle and the displacement obtained by the barrier at the test. After that, the forces shown in figure 3 have been integrated and represented versus the time, obtaining the results shown in figure 4.

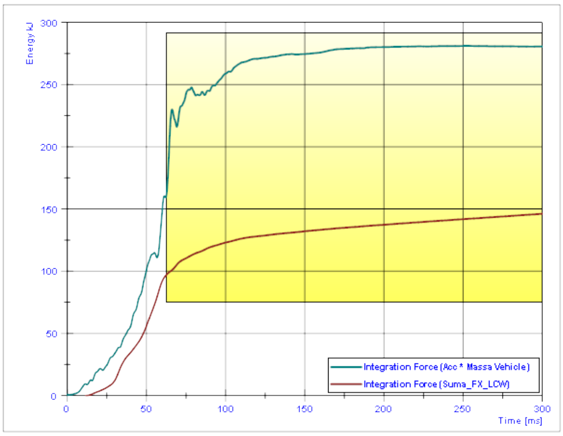

Figure 4. Comparative of Barrier's energy vs equivalent vehicle energy

As can be seen in figure 4, the difference between the theoretical energy of the vehicle (green) and the energy registered by the barrier (red) coincides with the results of figure 3. A gap of energy between the lines that should not be this big (both lines should be similar) can be seen. This gap is due to the amount of data that cannot be obtained due to the lack of load cells at the corner of the barrier.

The instrumentation of the corner will give data of the maximum forces produced during the test at the corner and will obtain more information about which forces make the vehicle rotate, deform and the role of each structural element. Also, the full instrumentation of the barrier will offer new data about the wheel's kinematics during the test. This will add new test data not available before that will help to have a better knowledge of one of the most important structural parts of the vehicle under this test conditions. Knowing this data will be extremely important to improving the structural mechanism to absorb energy during the crash and know how elements involved in wheel disconnection or wheel intrusion behave.

4 Testing improvement

The barrier has been redesigned at Applus+ IDIADA adding load cells to the previous barrier which only had load cells at the front. A new acquisition system has been implemented at the corner of the barrier ensuring non-deformation. Triaxle load cells have been set along the centre of the barrier and at the corner, obtaining information during all vehicle contact with barrier at all testing time in X, Y, Z directions. The triaxle cells will offer more information such as the vehicle's kinematics during the test and at the rotation and translation at the corner.

Figure 5. Small overlap barrier acquisition system

Also, the structure was redesigned to guarantee no deformation or rupture due to the new load cells and was reinforced at the frontal and corner area to protect the acquisition system. The load cells in corner fulfil IIHS protocol and provide a continuous reading during crash. In order to protect the load cells placed at the center and at the corner, special tools were designed and developed to create a uniform surface for the entire barrier.

Also, these tools offer the possibility to replace each load cell one by one without taking all of them out. The center barrier tool has a square form and can be seen in figure 6.

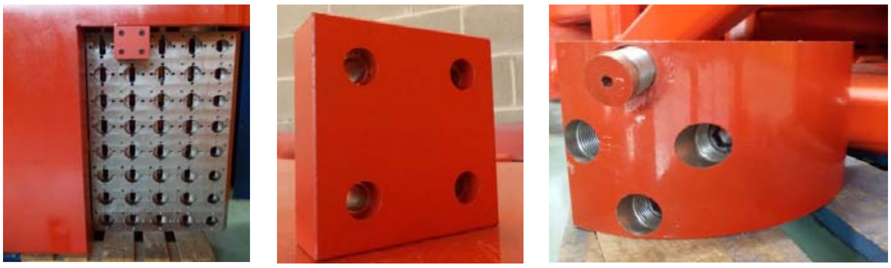

Figure 6. Square tool for the centre of the barrier and corner of the barrier

The tool for the corner had to be round, and the screws that fixed the tool to the barrier were specially designed in order to guarantee a perfect and uniform surface at the corner.

5 Results

A test validation was carried out with a similar structural vehicle in order to be able to compare the data obtained between the old barrier and the new one. Vehicles had similar weight, but due to confidentially, no testing information can be attached. A force diagram was elaborated by the acquisition system of the barrier. As can be seen in figure 7, the first impact of the car is almost not noticed by the old barrier while the new barrier has valuable data.

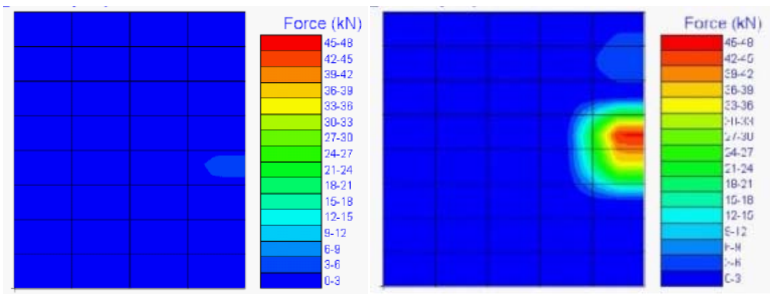

Figure 7. Old barrier (left) vs new barrier (right) at 7ms

Because the vehicle tested with the old barrier was slightly different (both SUV with similar weights) from the one tested with the new barrier, it can be seen that the timing of the tests was different. For example at 29ms in the old test the vehicle's wheel impacted the barrier while with the new barrier it did not. However the importance of the validation test is to compare in time the differences in forces and distribution

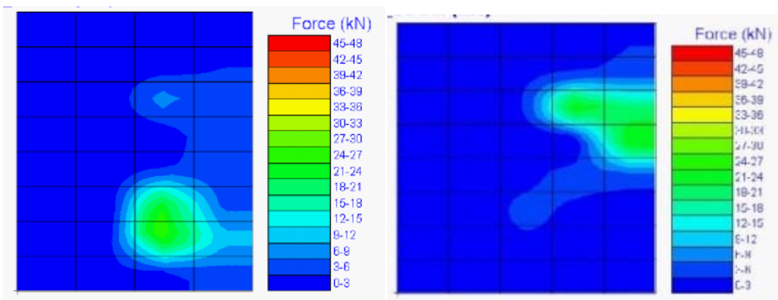

Figure 8. Old barrier (left) vs new barrier (right) at 29 ms

At 36ms both vehicles' wheels impacted the barrier. However, the information obtained by the new barrier is more accurate and has a wider range.

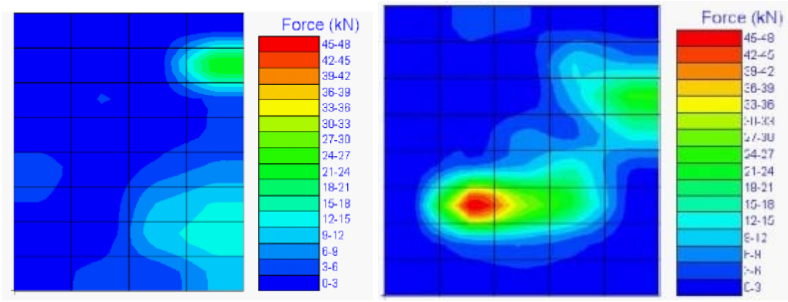

Figure 9. Old barrier (left) vs new barrier (right) at 36 ms

While wheel block and rocker panel impacted the barrier at 60ms, higher forces can be seen in the new barrier than the older one. The new results show that the only high forces present in the lower part of the diagram are the ones created by the wheel.

Also, high forces are present at the upper part of the barrier's corner due the interaction of shotgun and junction with upper A-pillar. These forces are relevant to controlling the vehicle trajectory and slide it off the barrier according to the manufacturer's strategy

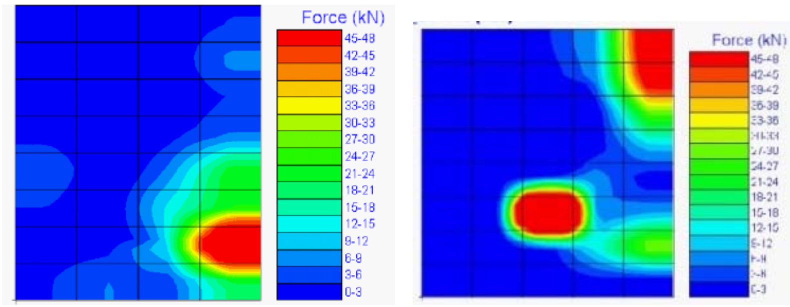

Figure 10. Old barrier (left) vs new barrier (right) at 60 ms

At 69ms the forces applied by vehicle on barrier affirm increase of red forces at starting oblique movement. Influence on upper A-pillar will help to identify intrusive forces that lead to deformations in engine compartment. These intrusions affect cross car beam and steering column changing restraint system behavior leading to reduced airbag interaction with occupants.

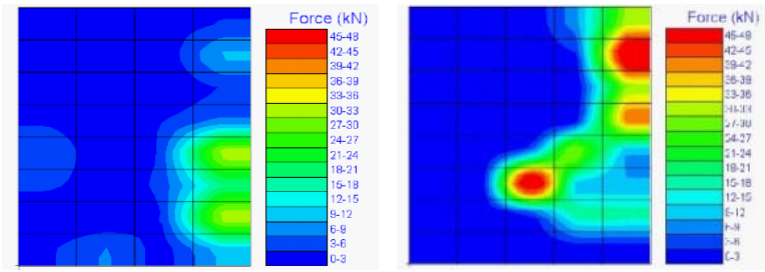

Figure 11. Old barrier (left) vs new barrier (right) at 69 ms

The new acquisition system provides more information from the beginning of the test until the end of the vehicle's separation. In the validation test of the new barrier, no vehicle front structure or response measures were measured.

6 Conclusions

The comparison between the new acquisition system barriers data provides more information to improve the testing equipment for critical translations and oblique movements in vehicles for small overlap test. More information during a crash test contributes to a better understanding of the structural element's behavior under compression and rotation forces. Due to this, new countermeasures in multiple vehicle structures to promote stronger occupant compartments were introduced to absorb the crash forces. Implementation of new structural crush areas will reduce harmful intrusions in occupant compartment.

Different combinations of structural improvements for small overlap were found to be effective in reducing occupant compartment intrusions and improving dummy kinematics in the IIHS small overlap test. Better testing tools give information to manufacturers to improve the state of art under this testing scenario.

The obtainment of better correlations in forces during crash provides essential information to face the challenges involved in new testing procedures and CAE analysis. These improvements cannot be done without a fully instrumented barrier, which is able to record and analyze all the available data during the test and correlate the effectiveness of each structural improvement. The development of new testing tools has importance, most of all to improve and develop vehicles and offer a better level of safety to road users.

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