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Comparative Study between the WorldSID and the EuroSID II in Static Impact Tests

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Abstract: In the past decade, most side impact protocols have been based on the results obtained from the EuroSID II. However, with the arrival of the new Euro NCAP 2015 protocol, the Passive Safety society will have to face a new challenge: to develop vehicles according to the results obtained using WorldSID. For this reason, an in-depth analysis of the WorldSID together with a comparison between both dummies has been done. Furthermore, a series of impact tests were defined, making a special effort to obtain test results from dummies in very similar configurations.This study will make it possible to reach conclusions in order to detect the differences obtained from the two dummies. By comparing the impact that side impact crashes can have on the two studied dummies, it will be possible to discern if there are any necessary changes to be done on future vehicle developments.

Keywords: WorldSID, EuroSID II, Comparison

1 Introduction

Global accident statistics show that approximately 30% of all impacts and 35% of total road fatalities are due to side impact crashes [1].

It is for this reason that it is so important to develop advanced safety systems to reduce vehicle occupant injuries and fatalities caused by side impacts. Because of this, all vehicle safety regulations include strict requirements that must be accomplished by means of side impact crash testing. These regulations and protocols intend to enhance the safety of new vehicles by obliging manufacturers to develop restraint systems based on the vehicle's behaviour to side impact. In this way, the vehicle occupants have a major protection in case of lateral accident.

However, although the main protocols to be tested have always been very restrictive in order to ensure vehicle integrity and passenger safety; they used to use a wide range of side impact dummies, with low biofidelity rank values, in their assessments [2,3]. Until the arrival of the WorldSID, all of the side impact dummies that were being used throughout the world obtained ISO Biofidelity Classification rates from Unacceptable to Fair, reaching a maximum Biofidelity ranking of 5.7 (out of ten).

The noticeable improvement found with the WorldSID in comparison to its predecessing side dummies has eladed to the incorporation of this new generation dummy to the new Euro NCAP Protocol that will be in force from year 2015, onwards.

Although most Euro NCAP test procedures suffered major changes in their main settings, the greatest challenge that OEMs will have to overcome when testing their vehicles according to the new Euro NCAP protocol is the use of the WorldSID (WS) instead of the EuroSID II (ES-2) in the Adult Occupant Protection (AOP) side impact assessment.

As it will be demonstrated further on in this paper, WS shows a clearly higher sensitivity to external stimulus than ES-2. This leads to a high probability of the vehicle being downgraded when assessed using WorldSID instead of its predecessor.

2 Methodology

2.1 Objectives

So as to understand the methodology and main testing decisions that were made, it is important to comprehend which were the most important aspects to be considered in this project. These were:

1. The high repeatability of the tests
2. Controlled boundary conditions
3. Similar level of impact as that of a Full Scale Crash test

For this preliminary testing, the interaction between the dummy and the vehicle was not studied, as the aim of the project was to carry out a direct comparison between both dummies under the same external stimulus. The main idea was to fulfill an in-depth analysis of both dummies and to correlate them before they were studied separately under crash impact conditions.

The tests to be carried out in this first phase of the project had to be as standardized as possible. These tests would become a useful analysis of the effect of performing Oblique Side Pole Impact tests instead of fully perpendicular impacts.

2.2 Test setup explanation

After considering the test objectives shown above, it was decided that the best option was to carry out tests with a similar setup as the calibration testing that is used to certify dummies for crash testing. These tests consist in using a 23.4 kg Standard Pendulum Rig to impact the dummies to be studied in a desired Impact Point. The impact points that were chosen were the shoulder bolt and the mid thoracic rib bolt. These areas were chosen due to their importance when studying side impact crashes and their common use as main impact areas against Side Airbags and/or door panels..

On the other hand, due to the fact that the WorldSID may not sit free without a backrest it was decided to carry out all of the tests with the dummy seated on the Standard WorldSID Calibration Bench. By doing all of the tests with the dummies seated in the same bench, the sitting position was kept fairly constant throughout the entire test matrix.

It was decided to carry out all of the tests with a target impact speed of 3 m/s. This decision was taken due to its similarity with the normal calibration and crash impact test speeds. Simulation carried out by the vehicle manufacturer showed that this speed corresponded to the actual intrusion speed that could be of interest in their vehicle development.

Furthermore, as the main objective of these tests is to assess the impact of Oblique Impacts on both the EuroSID II and the WorldSID, for this reason the tests were done using 5 different impact angles.

The test setup for the tests that have been carried out may be observed in the test matrix (Table 1) shown below:

3 Analysis – Summary of Results

In this section, some of the results that were obtained from the previously described component tests may be found.

Note that, the author would like to highlight the fact that most of the sensor results that are shown in the following graphs have been pre-processed before being graphically represented. In order to do this, the signals have been filtered (according to the same filtering criteria that are used for Euro NCAP Protocol tests) and, if necessary, an offset has been applied to ensure that all signals started at 0. The only signals that have not been pre-processed have been those that correspond to the rib rotation in the WorldSID.

Table 1. Dummy Static Test Matrix – First Phase

Test Settings	Impact Point	Impact	Tests
WorldSID Calibration Bench, 23.4 kg Standard (Male Dummy) Calibration Pendulum Rig, Target Speed: 3 m/s, Arm Positioning according to Euro NCAP Crash Test Protocol	Shoulder Bolt	0º (*)	2 x EuroSID II
			2 x WorldSID
		10º	2 x EuroSID II
			2 x WorldSID
		20º	2 x EuroSID II
			2 x WorldSID
		30º	2 x EuroSID II
			2 x WorldSID
		45º	2 x EuroSID II
			2 x WorldSID
	Middle Thoracic Rib Bolt	0º	2 x EuroSID II
			2 x WorldSID
		10º	2 x EuroSID II
			2 x WorldSID
		20º	2 x EuroSID II
			2 x WorldSID
		30º	2 x EuroSID II
			2 x WorldSID
		45º	2 x EuroSID II
			2 x WorldSID
Extra Tests (for repeatability analysis			
Same Tests Settings as (*)			1 x WorldSID
			1 x WorldSID

3.1 Shoulder Impact Tests

To start with, the data corresponding to the Shoulder Impact Tests has been studied. In this case, only the upper thoracic rib displacement and acceleration have been analyzed. It has been chosen to study these channels because in all of the shoulder impact tests, the upper thoracic rib is the most critical one during side impacts (specially pole tests). Also, it is important to bear in mind that the upper thoracic rib is the closest rib to the impact point and that is present in both dummies. Of course, in the case of the WorldSID, studying the Shoulder rib displacement and acceleration is of vital importance too but as it is not present in the EuroSID II it has not been studied in this paper. Furthermore, the shoulder force has also been analyzed to see the different behaviors of the shoulder assembly from both dummies.

In Figure 1, it is possible to see that the Upper Thoracic Rib Displacement curves show a clear trend where, as it was expected, the values of the registered displacement in the purely lateral direction increase as the impact angle decreases. This effect is one of the main reasons why it is considered that the EuroSID II has shortages. As the ES-2 is only capable of measuring purely lateral displacements, and not resultant rib deflections, the EuroSID II will always read remarkably lower chest deflections when tested under oblique conditions. This fact may derive in an underestimation of the injury that an occupant may suffer during a vehicle collision in an oblique impact direction.

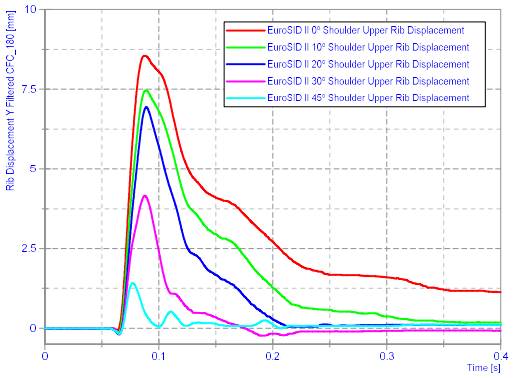

Figure 1. EuroSID II Upper Thoracic Rib Displacement in Y. Comparison by Impact Angle.

The previously mentioned effect of oblique testing can also be seen in Figure 2, shown below. It can be seen that, in the WorldSID Shoulder Impact results, again, the rib intrusion values show a trend by which the rib intrusion values decrease when the impact angle increases.

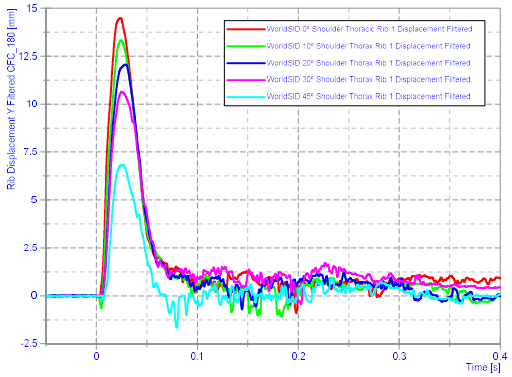

Figure 2. WorldSID Upper Thoracic Rib Displacement in Y. Comparison by Impact Angle.

Nevertheless, in the case of the WorldSID the differences found between each of the studied curves (one for each impact angle) are remarkably smaller than the ones that were perceived in Figure 1.

Moreover, the fact that the rib rotation varies depending on the impact angle will also have a non-equal effect on the calculation of the Rib Resultant Displacement, making the evaluation of the oblique tests much more trustworthy than in the case of EuroSID II. This phenomenon may be observed in Figure 3, found in the next page.

On the other hand, when analyzing the previous graph, an unexpected result was obtained. In the case of the 0º Shoulder Impact very high positive rotation is obtained. A certain positive rotation was expected, as the WorldSID has a clear tendency towards forward movement but, this rotation was expected to be minor than 2º-2.5º (negligible). In this case, a maximum positive rotation of 6.46º was observed. This absolute value is close to the one that was obtained in the 30º test (-6.96º) with the opposite sign.

The results that have been previously highlighted were surprising and lead to two different considerations. On one hand, one of the options that was considered was the presence of a human error during testing. This option would justify the obtained results and would be the easiest solution. For this reason, the 0º Shoulder Impact test configuration was repeated once again, obtaining almost identical results to those that were gained in the first two repetitions.

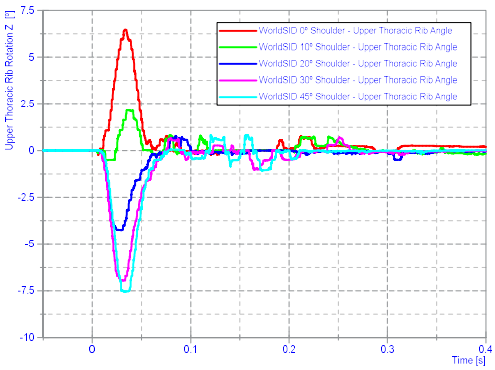

Figure 3. WorldSID Upper Thoracic Rib Angle in Z. Comparison by Impact Angle

Subsequently, the human error option was discarded. Therefore, it was deduced that this dummy has a clearer tendency towards positive rotation than other side impact dummies and, although the trend that may be seen when increasing the impact angle can seem logical, the starting point is not as neutral as it would be expected. In other words, when the WorldSID is tested under non-oblique conditions, the resulting rotation is highly positive, and not neutral.

Furthermore, the positive rotation of the upper rib has also been justified with the movement that the rib must do when it is pressed by the dummy's arm during the impact. This phenomenon will be studied in the Thorax Impact Test Result Analysis.

In addition, it has been observed that, in general, in shoulder impact tests the chest intrusion values that have been obtained when testing with the WorldSID are clearly higher than those that derive from testing the ES-2 in the same configuration.

By analyzing the dummy signal graphs and the videos that were recorded during the testing it has been deduced that, the differences found between the WS and ES-2 rib displacement values occur due to the fact that the WorldSID has a greater sensitivity and because the dummy's arm presses on the ribs during the impact. This effect can be seen in the general results for the upper rib displacement where the WorldSID upper rib values are always approximately 6 mm higher than for the EuroSID II.

It has also been observed that, in all Shoulder Impact tests, the peak values for the Shoulder Force in Y are very close in all cases (approximately -1 kN). However, there is a noticeable difference in the trends found with one dummy and with the other. In Figures 4 and 5, it is possible see the differences in the behaviors of both dummies' shoulders (Shoulder Force in Y).

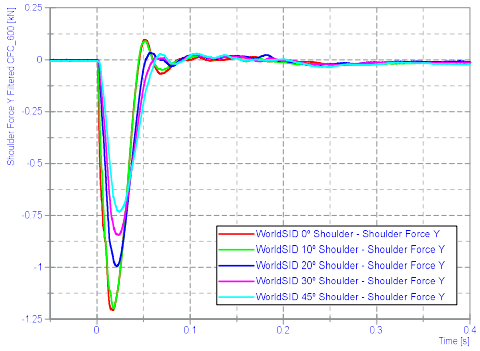

Figure 4. WorldSID Shoulder Force in Y. Comparison by impact angle (Shoulder impact tests)

In the case of the EuroSID Iogical trend that may be found in the results from the WorldSID is not present. When using the ES-2, the values of the Shoulder Force do not show clear signs of increasing or decreasing depending on the impact angle. This fact highlights the scarce development of the EuroSID II shoulder in comparison with that of the WorldSID together with its low reliability when tested under oblique loading conditions.

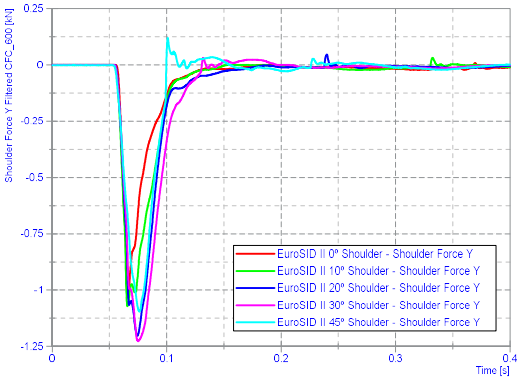

Figure 5. EuroSID II Shoulder Force in Y. Comparison by impact angle (Shoulder impact tests)

3.2 Thorax Impact Test Results

In the case of thorax impact test results, the same three comparative test graphs have been done, in order to show the impact that the impact angle has on the studied rib. In this case, the analyzed channel has been the Middle Thoracic Rib displacement and, in the case of WorldSID, its rotation. In this way, the direct impact point behavior has been studied.

In the following graphs it may be observed that the maximum rib displacement diminishes when the impact angle increases, in both dummies. However the EuroSID II Rib Displacement graph (Figure 6) does not follow a well-defined trend, as many of its curves count with more than one peak. Nevertheless, it may be seen that in remarkably oblique test conditions, the ES-2 rib displacement values are minor than 7.5 mm, which is considered to be a very low rib displacement value.

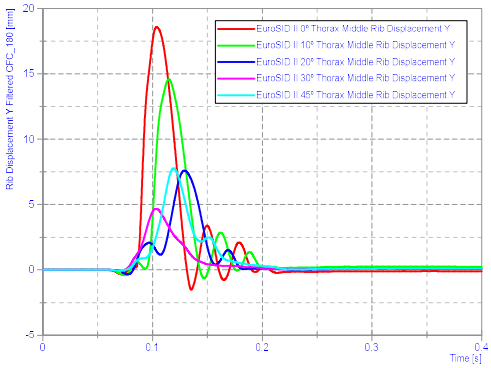

Figure 6. EuroSID II Middle Rib Displacement in Y Comparison (by Impact Angle) in Thorax Impact Tests

In the case of WorldSID (See Figure 7); however, the same trend as in the Shoulder Impact Tests has been followed, where the rib displacement values gradually decrease when the impact angle increases.

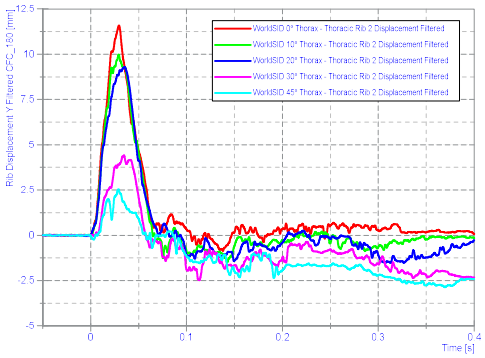

Figure 7. WorldSID Middle Rib Displacement in Y Comparison (by Impact Angle) in Thorax Impact Tests

Note that, in this case, the graph showing the differences in the rib rotation depending on the impact angle (Figure 8) shows a very clear trend. In the thorax impact phase, there are no unexpected results as the only positive rib displacement values that were obtained were in the 0º Impact Test and they were negligible (+2.4º). This suggests that, if the resultant rib displacement were calculated, the gap between the resultant displacement curves would be greatly reduced.

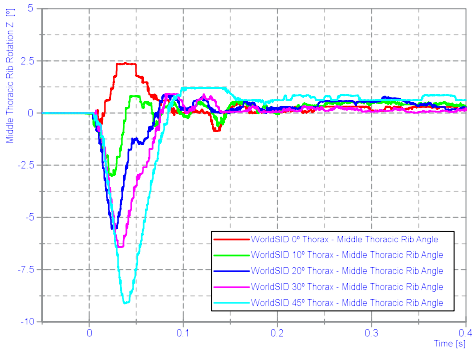

Figure 8. WorldSID Middle Rib Rotation in Z Comparison (by Impact Angle) in Thorax Impact Tests

On the other hand, the following results from the middle rib rotation in Z show that when the thoracic rib behavior is studied, lower initial positive rotations are found. This leads to the conclusion that part of the positive rotation that was achieved in the Upper Thoracic Rib (Shoulder Impact) was due to the arm rotation.

Figure 1. Comparison between both dummies' middle rib impact points in the 10º Thorax Impact Test

Furthermore, it has been observed that in thorax impacts using the WS, part of the pendulum energy was dissipated by moving the arm away from the impact direction. When using the EuroSID II, this does not happen as the dummy's seating position and the shape of its arm force the pendulum to impact directly upon the ribcage, underneath the arm.

Consequently, the energy absorption occurs only by means of rib deflection. Figure 9 shows the differences between the pendulum impact points when using both dummies in the same test setup.

4 Summary/Conclusions

The ES-2 and the WS are two advanced side impact dummies that count with remarkable differences between them. To start with, their anthropometry and construction characteristics force the two dummies to have variable responses to the same external impacts. This occurs due to the inequality in the interaction between the pendulum that has been used for the testing, and the dummy; as well as the influence of the rotation in Z on both dummies.

On the other hand, clear variances have been found between the shoulder and thorax tests. In the first case, the WS showed major values in all rib intrusion results due to the pressure of the dummy's arm against the ribcage. Nevertheless, in thorax impact tests, the ES-2 showed higher intrusion values than the WS. These results were obtained due to the fact that in the ES-2 tests, the pendulum impacted directly on the ribcage instead of impacting on the arm of the dummy and moving it away (dissipating in this way, part of the energy from the impact).

To conclude, the author would like to highlight that this study represents the first phase of a long-term WorldSID study that is to be carried out in the near future. Further testing and analysis of this particular dummy will be accomplished in the near future.

5 Definitions/Abbreviations

EuroSID II / ES-2	European Side-Impact Dummy II
WorldSID / WS	Worldwide Side Impact Dummy
Euro NCAP	European New Car Assessment Programme
AOP	Adult Occupant Protection

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