Evaluation of the Biofidelity of the WorldSID and the ES-2 on the basis of PMHS data

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ABSTRACT

Under the European Side Impact Dummy Biomechanics and Experimental Research (SIBER) project, a 50th percentile WorldSID pre-production dummy was evaluated in several configurations. Heidelberg type sled tests and accident reconstruction tests were conducted to verify the biofidelity, durability and repeatability. The sled test configurations consist of padded flat wall and padded pelvis offset. Under the same sled test condition, BASt tested the ES-2 dummy as well for comparison. For the biofidelity rating, the results were analysed compared with PMHS data using the cumulative variance. In addition, two accident reconstructions were conducted to analyse the WorldSID performance for different accident severities.

Keywords: Sled Test, Accident Reconstruction, WorldSID, Biofidelity, Dummies

The WorldSID is designed to simulate a real vehicle occupant under the same side impact crash condition. The full body sled tests described in this paper were conducted to verify the biofidelity of a pre-production WorldSID dummy by comparing the results to specification defined by PMHS (Post Mortem Human Subject) tests, using the same test procedure and configuration. To compare the dummy readings to human occupant behaviour, biofidelity criteria were quantified for the full body sled tests.

METHOD SLED TEST

The sled tests were performed according to the Heidelberg type sled tests with PMHS of Yoganandan (2002, 2003). The sled bench was mounted on a trolley and the complete test device was decelerated by a steel bending rig. The adjustment of the required delta v (velocity) was set by considering the sled velocity, the dummy velocity and the time of impact of the dummy to the wall. The test speeds were 6.7 m/s and 8.9 m/s. Due to the problems in robustness of the WorldSID as seen during the first sled tests against the rigid wall at a speed of 6.7 m/s the rigid tests and some of the high speed tests had to be cancelled. Overall 5 tests with the WorldSID and 6 tests with the ES-2 have been carried out (**Table 1**). The tests were carried out with both dummies to have a basis for comparison. The results of the dummy sled tests were compared with the measurements taken from PMHS tests. Therefore the results of 36 cadaver tests from the Medical College of Wisconsin (MCW) and the National Highway Traffic Safety Administration (NHTSA) were used (Maltese et al., 2003).

The dummies were seated on a bench covered with Teflon sheet (length 1.2 m) to reduce the friction which would otherwise lead to leaning of the dummy. The tests were performed with arms of the dummy in the lowest position, such that the arm was interposed between the thorax and the load wall. To avoid tilting of the dummy during the accelerating process of the test, the dummy was supported by a cardboard-bar. The trolley platform carrying the bench was also equipped with an impact wall. **Fig. 1** shows a schematic of the bench and the load wall. **Fig. 2** shows 450 mm pre-set distance between the load wall and the WorldSID, same for all the sled tests. The impact wall was composed of separate impact plates for the thoracic, abdominal, pelvic and the leg regions. Each plate was equipped with load cells to measure the impact forces of the different body regions of the dummy. The thorax and the abdomen plate were each equipped with two load cells, the pelvis plate with four and the leg plate with three load cells. Two configurations of the load wall (flat wall and pelvis offset of 110 mm) were used for testing (**Table 1**).

Table 1. Configuration of Tests Performed

Test condition	WorlSID Tests	ES-2 Tests
PLF (padded low speed flat wall, 6.7 m/s)	2	2
PLP (padded low speed pelvis offset, 6.7 m/s)	2	2
PHF (padded high speed flat wall, 8.9 m/s)	1	2

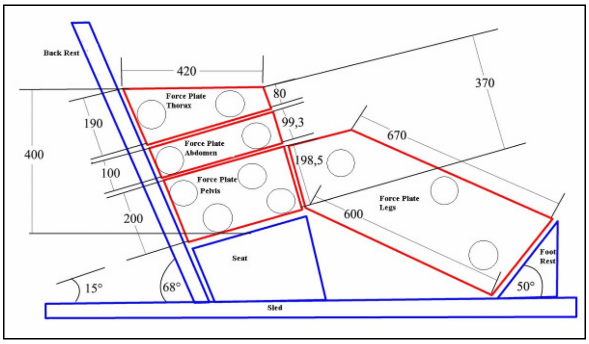

Fig. 1 – Schematic of the Side Impact Sled with Load Cells on Each Plate for Measuring the Impact Forces

Fig. 2 – View of the Sled Buck and the Load Wall mounted on the Trolley Platform

Since the ribs were damaged in a less severe low speed rigid flat wall test, the test configuration with the 110 mm thoracic offset, together with all other rigid wall test, was cancelled due to the potential damage of the ribs under such loading condition. To properly calculate the loading plate force, single axial accelerometer was installed on each plate to remove the force generated by the inertia of the plate itself. To prevent shoulder from contacting the upper edge of the thorax plate, the plate was set to 400 mm high vertically, which is the same as in the PMHS tests. The positioning of the dummy was according to the PMHS tests with the Frankfort plane horizontally, the legs parallel to the midsagittal plane. Each test configuration included padding material on the load wall plates with a thickness of 100 mm (Ethafoam LC200, compressive stiffness 103 kPa). The dummy contacted the wall without significant changes in the relative positions between the different body segments. In order to improve the accuracy of the calculation of the dummy impact speed, the impact time t_0 of each body segment has been recorded individually by using the copper foil sheets mounted on both the dummy body segment and the load wall plate, similar to the contact switch.

The sled was equipped with four tri-axial accelerometers on each corner of the sled. The WorldSID was equipped with 72 total channels, including upper spine acceleration (T1), lower spine acceleration (T12), thoracic and abdominal rib accelerations, thoracic and abdominal rib deflections, etc. The same signals except for the abdominal deflection were recorded and compared for the ES-2 dummy. The positive x-acceleration was along the posterior-anterior direction, positive y-axis acceleration was along the left-right axis, and positive z-axis acceleration was along the superior-inferior direction as seen in the PMHS tests performed by Yoganandan (2002, 2003).

The data was collected according to the SAE J211 specifications. The WorldSID data was recorded and stored by using the in-dummy system 'TDAS G5'. For the contact foils, the load cells, the load plates and the accelerometers of the sled, an external data acquisition mounted on the sled was used. The same external data acquisition unit was used for ES-2 tests. The filter classes used for the dummy signals are shown in **Table 2**. The data preparation was according to the PMHS tests mentioned before. All data was recorded with a sampling frequency of 10 kHz. Due to the fact that the results of the PMHS tests were available in a special data format, for comparison of the results the data of the dummy sled tests had to be adapted by sub-sampling at a frequency of 3.2 kHz.

Table 2. Filter Classes of the Signals

Signal	Filter Class
Load cell forces	CFC* 1000
Acceleration spine (T1, T12)	CFC 180
Acceleration pelvis	CFC 1000
Acceleration ribs	CFC 1000
Acceleration ribs	FIR** 100
Deflection ribs	CFC 600

*) CFC (Channel Frequency Class); **) FIR (Finite Impulse Response)

The data was filtered and then normalized with respect to the mass of the tested dummies according to the method presented by NHTSA (Maltese et al., 2003). The sled test data was analysed and compared to the corridors derived from the cadaver tests conducted by Medical College of Wisconsin and NHTSA. The biofidelity rating method used in this research is the "Cumulative Variance" (Morgan, Marcus and Eppinger), shown in **Table 3**.

Table 3. Calculation Method for the Biofidelity Rating

$CV = \sum_{t=0}^{T} [a_1(t) - a_2(t+\Delta t)]^2$	CV	Cumulative Variance
	t	Time
$CCV = \frac{\sum_{t=0}^{T}\sum_{i=1}^{n} [a_i(t) - MCR(t)]^2}{n-1}$	T	Time of the last measured value
	$a_1(t)$	Value of data set 1 at time t
	$a_2(t)$	Value of data set 2 at time t
$DCV = \sum_{t=0}^{T} [a_1(t) - MCR(t+\Delta t)]^2$	CCV	Cadaver Cumulative Variance
	$a_i(t)$	Value of cadaver data set at time t
$BR = \frac{DCV}{CCV}$	MCR(t)	Mean cadaver response at time t
	DCV	Dummy Cumulative Variance
	BR	Biofidelity Rate

All tests were recorded by high speed cameras (frontal, top and onboard anterior view). Additionally pre and post test pictures were taken as well.

Since the padding manufacturer discontinued the production of the padding material, and only limited amount of the padding material was available for these tests, the pre-tests were conducted with the rigid flat wall low speed. During the pre-tests, a few durability problems were observed. In the second pre-test, the shoulder IR-TRACC (Infra-Red Telescoping Rod for the Assessment of Chest Compression) was cut, shown in **Fig. 3**. The IR-TRACC rod ends, which were attached to the ribs, were bent for the shoulder and all three thoracic ribs, shown in **Fig. 3**. All damaged parts were replaced.

Fig. 3 – Debonding of damping material on the ribs (left), IR-TRACC with cut cable (middle) and bent ball-joint (right)

After the pre test, the dummy ribs were disassembled and measured according to the procedure of the dummy manufacturer. Debonding of damping material was observed in several ribs (**Fig. 3**). All the ribs had plastic deformation and were out of the tolerance, given in the dummy manual. The damaged ribs were replaced using the undeformed ribs of the non-impact side.

RESULTS AND DISCUSSION

Fig. 4 shows the acceleration of the upper spine as an example for the comparison of the PMHS and the dummy curves of the WorldSID and the ES-2. The PMHS curves are displayed as upper and lower corridors (standard deviation) and mean curve. The curves of all tests can be found in the SIBER deliverable D8/D9 (Damm, Schnottale, 2004) or can be provided by the author.

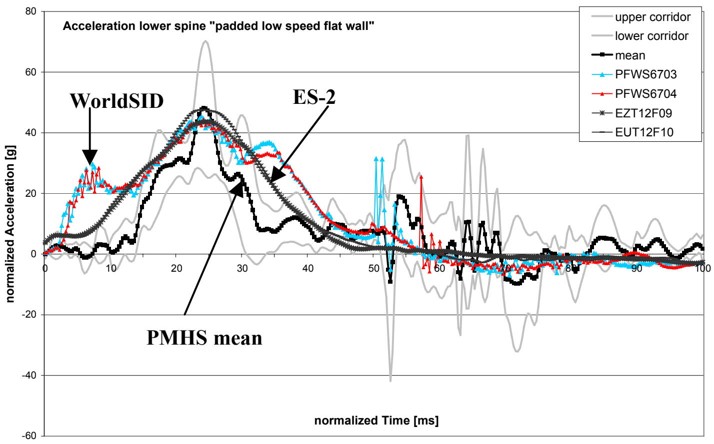

Fig. 4 - Example for the Comparison of the PMHS and Dummy curves

Test numbering: EUT12: abbreviation code for ES-2 results WS: abbreviation code for WorldSID results

In the following tables (**Table 4 – Table 7**) the biofidelity rates of the different body parts in the different tests can be seen. The rating is only possible for body regions and not as an overall-ranking of the full dummy. Due to the problem of selecting a weight factor for each body part, the comparison between NHTSA and ISO biofidelity rating is restricted. According to the biofidelity calculation method described in **Table 3**, and due to the very rough rating scheme used by Maltese et al., a more "detailed", grey colour coded rating scheme was generated and used to compare the results of the conducted sled tests with the underlying PMHS test. The rating scheme assesses the rating values according to BR (**Table 4**).

Table 4. Biofidelity Rating Scheme

Quality of the Biofidelity rating	Thresholds
excellent	0 – 0,7
good	0,7 – 1,5
adequate	1,5 – 5
marginal	5 – 12
weak	12 – 25
poor	25 – ∞

The dummy readings were compared with the results of the PMHS tests. For some body regions the results of only one PMHS were available. In these cases no biofidelity rating was calculated and marked as 'not applicable' in **Table 6**. In the ES-2 comparison tests also 'Deflection Abdomen' is marked as 'not applicable' due to the fact the ES-2 is not able to measure this criterion. A detailed breakdown of the results of the biofidelity rating per body region and test set-up is shown in **Table 5 – Table 7**.

Table 5. Biofidelity Rating WorldSID and ES-2 (Padded Low Speed Flat Wall Tests)

padded low speed flat wall (PLF)	Biofidelity rate **PFWS6703**	Biofidelity rate **PFWS6704**	Biofidelity rate **EUT12F09**	Biofidelity rate **EUT12F10**
Force Thorax	46.09	49.10	66.03	74.15
Force Abdomen	2.11	2.39	2.13	2.94
Force Pelvis	3.91	3.39	6.38	8.39
Acc upper Spine	1.43	1.41	1.08	1.61
Acc lower Spine	1.02	0.92	0.58	0.62
Acc upper Rib	10.99	8.84	3.06	3.28
Acc lower Rib	3.74	3.22	0.51	1.12
Acc upper Rib (FIR Filter)	7.68	5.93	1.21	1.43
Acc lower Rib (FIR Filter)	4.41	4.00	1.61	1.67
Acc Pelvis	3.80	3.91	4.63	5.01
Deflection upper Thorax	0.09	0.07	0.73	0.77
Deflection lower Thorax	0.16	0.08	0.60	0.65
Deflection Abdomen	1.95	1.96	not applicable	not applicable

Table 6. Biofidelity Rating WorldSID and ES-2 (Padded Low Speed Flat Wall Tests)

padded low speed pelvis offset (PLP)	Biofidelity rate **POWS6701**	Biofidelity rate **POWS6702**	Biofidelity rate **EUT12O04**	Biofidelity rate **EUT12O05**
Force Thorax	15.21	21.56	11.20	16.25
Force Abdomen	36.80	44.23	20.23	13.45
Force Pelvis	9.73	9.50	19.00	20.81
Acc upper Spine	2.80	2.94	4.47	5.24
Acc lower Spine	4.71	5.30	1.45	1.59
Acc upper Rib	3.46	3.06	1.24	1.05
Acc lower Rib	not applicable	not applicable	not applicable	not applicable
Acc upper Rib (FIR Filter)	14.09	13.57	4.08	3.73
Acc lower Rib (FIR Filter)	not applicable	not applicable	not applicable	not applicable
Acc Pelvis	7.28	7.39	10.47	12.71
Deflection upper Thorax	not applicable	not applicable	not applicable	not applicable
Deflection lower Thorax	not applicable	not applicable	not applicable	not applicable
Deflection Abdomen	not applicable	not applicable	not applicable	not applicable

Table 7. Biofidelity Rating WorldSID and ES-2 (Padded High Speed Flat Wall Tests)

padded high speed flat wall (PHF)	Biofidelity rate **PFWS8705**	Biofidelity rate **EUT12F08**	Biofidelity rate **EUT12F11**
Force Thorax	11.55	23.57	27.34
Force Abdomen	1.03	1.84	1.99
Force Pelvis	9.54	34.09	30.03
Acc upper Spine	0.93	0.53	0.60
Acc lower Spine	1.83	0.94	1.03
Acc upper Rib	1.13	0.57	0.58
Acc lower Rib	2.56	0.81	0.82
Acc upper Rib (FIR Filter)	1.97	1.16	0.94
Acc lower Rib (FIR Filter)	8.66	3.43	3.42
Acc Pelvis	1.72	2.55	2.45
Deflection upper Thorax	0.49	1.32	1.33
Deflection lower Thorax	0.30	0.62	0.59
Deflection Abdomen	3.03	not applicable	not applicable

In general, the WorldSID and ES-2 have similar biofidelity rating. The ES-2 acceleration biofidelity ratings are better than that of the WorldSID. However the WorldSID reproduces the behaviour of the PMHS with regard to the curve characteristics better than the ES-2. Even the oscillating peaks of the rib accelerations at the starting impact of the WorldSID are similar to those of the PMHS. The reason for the similar rating compared to the ES-2 results from the "sensibility" of the dummy. The effect of this sensibility can be seen in the peaks of the curve trace (over-oscillation). Especially the ribs tend to have strong oscillations at the time of the beginning of the impact. It seems that the damping of the ribs is not sufficient and the transfer functions between pelvis, spine and ribs have to be taken under consideration. This needs to be further investigated.

Regarding the rib deflection the WorldSID shows a 'good' to 'excellent' biofidelity rating and it is clearly better than the ES-2 rating. The repeatability of the test results of both dummies is on a very high level.

The analysis shows that all the data traces, especially the forces and the accelerations, had higher values in the dummy than these in PMHS. The rating results shows that the force measurements show "extreme" deviations for the measured forces between the dummy (either WorldSID or ES-2) and the PMHS, especially in the thorax region (**Table 5 – Table 7**). However, the rib deflections shows good comparison between the dummy and PMHS. It was also noticed that the forces at the load wall were higher for the dummy tests. Due to the data normalization, the dummy mass influence can be neglected. A few possible reasons could cause the difference. First, the stiffness of the load wall at BASt is very high, which may be stiffer than the setup used for the PMHS tests. Second, the higher forces measured at the load wall and the accelerations are indicating that the WorldSID and especially the ES-2 are stiffer than the human being. Volunteer tests performed under a different scope have shown clearly this difference (Lorenz et al., 1999).

The detailed test results with all curves can be found in the Deliverable report D8/D9 (Damm, Schnottale, 2004) of the SIBER project.

ACCIDENT RECONSTRUCTION

Two accident reconstructions were conducted within the SIBER project. Both accidents were taken from the UK CCIS (Co-operative Crash Injury Study) database.

RECONSTRUCTION 1 – MAZDA 121 AND FORD FIESTA

The first case to reconstruct was a Mazda 121 which was struck at the driver's side by a Ford Fiesta with a pre impact speed of 57 kmph. The Mazda stopped before the impact. The impact angle was 105°. There were four occupants in the target vehicle (Mazda 121). For the reconstruction, only the two occupants on the struck side had been simulated with the WorldSID at the driver's place and the ES-2 at the rear offside of the vehicle struck side. The 20 years old male driver as well as the rear passenger (20 years old male) had suffered serious injuries (**Table 8**).

Test configuration and equipment

The WorldSID was belted, the ES-2 unbelted. The seat of the rear passenger was non-adjustable; therefore the ES-2 was placed in a reasonable seating position. No information was available for the seating position of the driver except from photos of the deformed seats. Due to this fact a person of same size and weight was seated in the car and adjusted the seat to a practical position with regard to the angle and longitudinal position (10th notch from the front, seatback angle 26°, seat angle 17°). The head rest was adjusted to a suitable position for the driver (highest position).

The Ford Fiesta was equipped with a belted fully instrumented Hybrid III dummy on the drivers place. The seat was adjusted according to ECE-R94 with the seat in middle position and a seatback angle of 25°. The height of the seatbelt anchorage was adjusted to the second notch from the bottom.

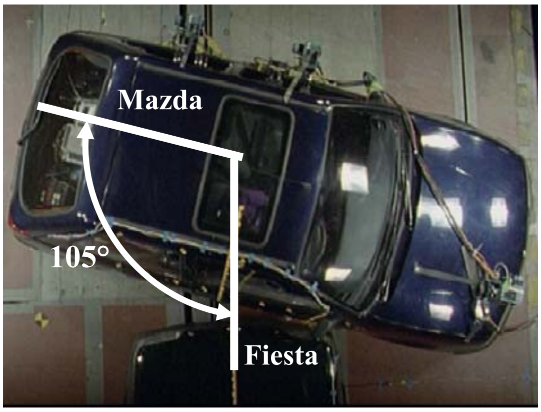

Fig. 5 – Top View Showing the Alignment of the Mazda and the Fiesta

Fig. 6 – WorldSID Positioned on the Mazda 121 Driver's Seat

The impact angle was 105° and the required impact velocity of the Ford Fiesta was 57.5 kmph. The Mazda 121 had no pre impact speed. The vehicle instrumentation consisted of nine accelerometer channels for the Fiesta and ten acceleration channels for the Mazda. The WorldSID recorded 72 channels and the ES-2 59 channels. The reconstruction was documented by six high speed cameras and pre and post test photos.

Test results

A comparison of the static deformations shows that the accident, especially with regard to the Mazda, is reconstructed very well (**Fig. 8**). The deformations are very similar regarding the deformation depth and the way of deformation. The curves of the Fiesta show some differences with regard to the left side of the vehicles (**Fig. 10**). It seems that the Fiesta of the accident had a bent rail which is not present in the reconstruction car. Therefore a difference in deformation depth is recorded. In the mid and the right side of the cars, the deformations are very similar.

Fig. 7 - Mazda of the Accident (left side) and of the Reconstruction (right side)

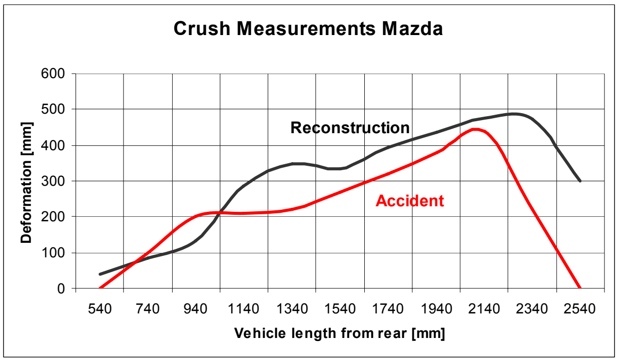

Fig. 8 - Deformations of the Mazda in Y-Direction
at the Height of 490mm from the Ground

Fig. 9 - Fiesta of the Accident (left side) and of the Reconstruction (right side)

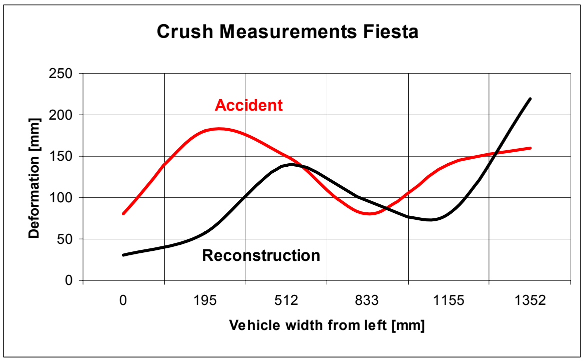

Fig. 10 - Deformations of the Fiesta in X-Direction
at the height of 400mm from the Ground

The most important injuries of the driver recorded in the Mazda and the according WorldSID readings of the reconstruction are shown in **Table 8**.

Table 8. Mazda 121: Driver Injuries and WorldSID Signals

Driver injuries:	**WorldSID readings:**	
AIS2: laceration of the spleen	Shoulder rib:	30 mm
AIS2: right superior pubic ramus fracture	Thorax ribs (2, 3, 4):	44 mm, 12 mm, 21 mm
AIS2: avulsion fracture anterior right sacrum	Abdomen ribs (5, 6):	41 mm, 70 mm
AIS2: small fracture right iliac bone	Lower Spine Acc.(T12):	108 g
AIS2: fracture to the transverse process 5^{th}	Pelvic Acc.:	85 g
lumbar vertebra	Pubic force:	2.3 kN

Due to the fact that the final injury risk curves of the WorldSID are not yet available, the revised draft curves, being proposed in 2005 and still under development by the ISO/SC12/WG6, have been taken into account to give a reflection of the accuracy of the WorldSID predicting the level of slight injuries in this reconstruction case.

The thoracic and abdominal deflection, the lower spine and pelvic acceleration and the pubic force risk curves are considered. The deflection of the upper thorax rib at 44 mm is according to a probability of 10 % to suffer an AIS3+ injury. The level of 12 mm and 21 mm (mid and lower thorax rib) are lying outside the risk function curve. No prediction can be made with the actual risk curves. For the abdominal rib deflection, 41 mm deflection results in a probability of 20 % to be injured at an AIS3+ level. The probability for an AIS3+ injury at 70 mm deflection is more than 80 %. Looking at the T12 acceleration, the probability for an AIS3+ is 80 %. For the pelvic acceleration it constitutes 68 %. For the pubic force of 2.3 kN the AIS3+ injury probability accounts for 92 %. Comparing these probabilities with the real injuries of the driver, the probability of suffering an AIS3+ injury was quite high at the abdomen, the lower spine and the pelvis region. But for this assumption it has to be taken into account the age of the occupant. The injury risk curves are set up for a 45 years old male person, but the driver of the car was a 20 year old male person with a good constitution. However the probabilities of 80 to 92 % for an AIS3+ injury in some regions seem to be predicted to high by the WorldSID.

The injuries of the passenger respectively the dummy readings of the ES-2 are not taken into account in this paper.

RECONSTRUCTION 2 – VAUXHALL ASTRA AND VAUXHALL CAVALIER

The second reconstruction case was based on an accident with a Vauxhall Astra as bullet and a Vauxhall Cavalier as target vehicle. In this accident both cars were moving, the pre impact speed of the Astra was 55 kmph and 32 kmph of the Cavalier. The Astra hit the driver's side with an impact angle of 90°. This collision was much more severe than the first case looking at the Cavalier, with fatal injuries to the driver (47 years old male) and severe injuries to the front seat passenger (20 years old female). The WorldSID was placed on the driver's seat of the Cavalier and the ES-2 on the passenger's front seat. Both dummies were belted, although the occupants in the accident might not have been belted. However the influence of wearing a belt is secondary in a side impact. In addition there was no evidence of occupant interaction in the accident.

Test configuration and equipment

No information was available for the seating position of the driver and the front passenger except the photos of the seats after the accidents. Due to the occupant's size and weight (driver of the Cavalier), which is very similar to the size and weight of the WorldSID, the seat was adjusted to the Euro NCAP seating position. For the passenger, the size and the height were not known. Therefore the seat was positioned in the same way. The Astra was equipped with a belted fully instrumented Hybrid III dummy on the driver's place. The seat was adjusted according to ECE-R94 with the seat in middle position and a seatback angle of 24°.

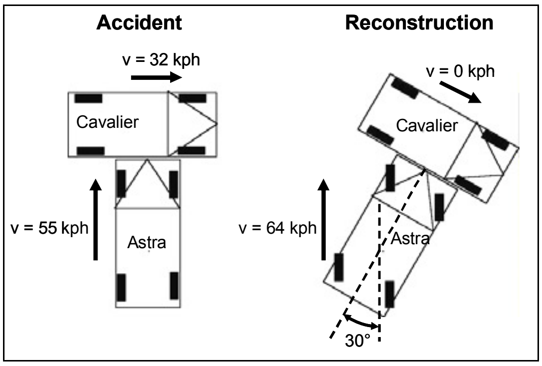

Fig. 11 - Sketch of the Parameters of the Accident and the Reconstruction

At this stage, it was not possible to perform a side impact crash with both cars moving at the crash test facility. Therefore the decision was taken to reconstruct this case by keeping the target car (Cavalier) stationary and the bullet vehicle (Astra) moving in crabbed mode (**Fig. 11**). A vector analysis was done on the data of the accident reconstruction (pre impact velocities and the impact angle). Due to the small difference in mass between both vehicles, the kinetic energy aspect was negligible. The results of the analysis led to a pre impact speed of 64 kmph for the Astra at an impact angle of 30° (**Fig. 11**). The Astra was equipped with five tri-axial and two one-axial accelerometers, the Cavalier had four tri-axial and two one-axial accelerometers. The WorldSID recorded 72 channels and the ES-2 59 channels. Nine high speed cameras and pre and post test photos were used to document the test.

Test results

In the following section the deformation levels of both vehicles can be seen.

Fig. 12 - Deformations of the Astra: Accident (left side) and Reconstruction (right side)

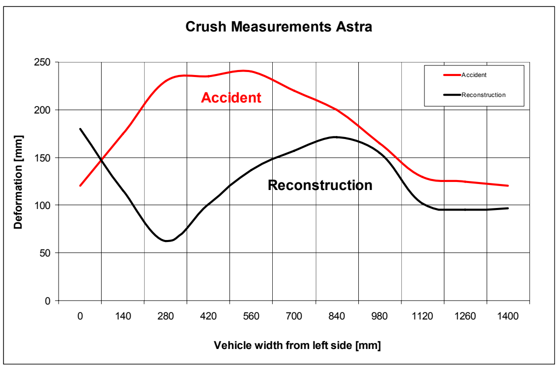

Fig. 13 - Deformations of the Astra in X-Direction at the Height of 460mm from the Ground

Fig. 14 - Deformations of the Cavalier: Accident (left side) and Reconstruction (right side)

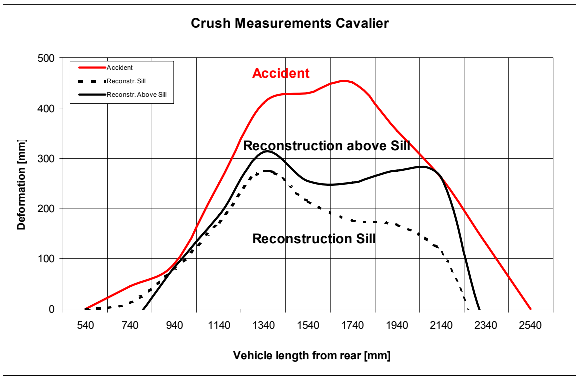

Fig. 15 - Deformations of the Vauxhall Cavalier in Y-Direction at the Height of 260mm above Ground

The alignment of the cars was corresponding to the input parameters of the reconstruction. However, it seems that the Astra hit the Cavalier slightly further to the front in the real accident, which led to a hard contact between the longitudinal of the Astra and the A-pillar of the Cavalier. Due to this misalignment between the impact location of the accident and the reconstruction the Astra slid away from the A-pillar of the Cavalier. This might be a reason for the smaller deformation in the accident car at the height of the measurement. The other supporting reason for this statement is the unbent longitudinal rail on the right side of the Astra compared for the Astra of the accident. However the tendency of the deformation of the 'reconstruction-Cavalier' is in line with the accident car except the maximum deformation depth. With regard to the deformation of the Astra there are differences on the left side of the vehicles. These points can be taken into account, if the reconstruction would be performed again.

The most important injuries of the driver recorded in the Cavalier and the according WorldSID readings of the reconstruction are shown in **Table 9**.

Table 9. Vauxhall Cavalier: Driver Injuries and WorldSID Signals

Driver injuries:	**WorldSID readings**:	
AIS5: fractured ribs (right 2nd - 10th, left 2nd - 8th) with collapsed left lung due to haemothorax	Shoulder rib (1):	66 mm (reached shoulder rib stop for ca. 13 ms)
	Thorax ribs (2, 3, 4):	50 mm, 44 mm, 43 mm
AIS5: transverse rupture of descending aorta just below the arch	Abdomen ribs (5, 6):	54 mm, 46 mm
	Lower Spine Acc.(T12):	79 g
AIS4: bilateral lung contusions	Pelvic Acc.:	76 g
	Pubic force:	1.4 kN

Taking the injury risk curves for the WorldSID, the probability for an AIS3+ varies from 10 to 20 % for the thorax rib deflections. For the abdominal deflection, the probability results in 30 to 53 %. Looking at the accelerations of the lower spine and the pelvic, the probability for an AIS3+ injury is 50 respectively 48 %. For the pubic force, the level is lower with a probability of 20 %. Although no injury risk curve is available for the shoulder, the deflection seems to be correctly reflected by the high rib deflection of 66 mm.

Regarding the deflections of the thorax ribs, the prediction of the injury risk of the WorldSID seems to be too low. For the abdomen ribs, the predicted injury risk is according to the injury level of the driver. Also the lower spine and pelvis acceleration are in line with the loading conditions. The low risk of a pelvic fracture is correctly predicted by the WorldSID.

The injuries of the passenger respectively the dummy readings of the ES-2 are not taken into account in this paper.

CONCLUSIONS

SLED TESTING

Overall speaking, the WorldSID can be seen as a good concept for a high biofidelity side impact dummy. It shows characteristic reactions close to the PMHS, especially regarding the curve traces. But in most cases the reaction is too sensible, in particular regarding the rib acceleration. The results of the rib accelerations show that the WorldSID still needs “fine tuning” to reduce the sensibility at the time of the initial impact. The damping factors of the ribs seem to be too low and need further investigation. At the moment the manufacturer has changed the damping material of the ribs due to durability and availability problems. The new material ought to have a better overall performance and has to be considered in further tests.

The performance of the thoracic and abdominal rib deflections is very good, lying very close to the PMHS mean curve.

The repeatability was quite good during the test series, even though more tests would consolidate this statement. During other testing with SIBER project, the dummy showed good repeatability as well.

The durability of the WorldSID needs to be improved, especially the IR-TRACC cable protection and the joint between the IR-TRACCs and the rib. The overall all cable routing needs to be improved to avoid damage during the test. For the production version of the WorldSID, the shoulder IR-TRACC has been replaced by a string-potentiometer.

The in-dummy data acquisition system in the WorldSID pre-production version is quite new. The experience showed that it has many advantages, although it still needs to be improved in reliability, durability and heat reduction. The heat generated by the measuring instrumentation and the data acquisition system raises the dummy temperature and therefore affects the dummy performance.

ACCIDENT RECONSTRUCTION

According to the input parameters, both reconstructions were performed successfully. Especially in the first case, the deformation of the target vehicle is very close to the accident. The readings of the WorldSID showed some differences in comparison to the victim in the accident car resulting in a prediction of a higher injury level. Vice versa the second reconstruction showed differences with regard to the deformations of the vehicles, but the dummy readings tend to reflect most of the driver’s injuries adequately.

Comparing the WorldSID results of both tests it can be seen that the WorldSID detects the higher loads in the pelvic region in the first reconstruction, as well as the higher loading in the thoracic region in the second case correctly. Regarding the handling of the WorldSID, no fundamental problems were found. The heating issue of the in-dummy data acquisition system in the thorax needs to be addressed. Different from the sled tests, no damages occurred during the real world loading conditions of the accident reconstructions.

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