COMPARISON BETWEEN OLD AND NEW WORLDSID 50TH PERCENTILE MALE SHOULDER CLEVIS DESIGNS

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ABSTRACT

WorldSID 50th percentile male is the latest state-of-the-art Side Impact Dummy that has been developed in order to enhance its similarity to human body performance in a side impact crash test scenario. Recently, the dummy manufacturer has released a new version of the Shoulder Clevis and Arm for WorldSID. This new shoulder joint improves several known problems from the previous design (especially arm positioning difficulties and excessive ease to move due to suit tension). However, the remarkable differences in the design may also lead to different arm and shoulder kinematics.

Several OEMs have performed crash and sled tests at IDIADA using this new WorldSID shoulder design. The results from these tests have led to believe that there could be a potential difference in the achieved results depending on the tested shoulder and arm. Because of this IDIADA has an ongoing research project that aims to check the behavior of these parts through back-to-back testing.

This paper includes the results found from several Pendulum tests that were performed at IDIADA using one dummy but two different shoulder clevis and arms. Some differences have been found when evaluating the reproducibility of these results. However, the authors are aware that these results may be due to the test mode that has been used and because of this; further testing will be done (including both Static Deployment Testing and Side Sled testing).

BACKGROUND

Side Impact Crashes are the second most frequent type of crashes (after frontal crashes) that take place throughout the world. For example, Side Impact Crashes were 25% of the total amount of fatal accidents that took place in 2015 in the US [1]. This information has been taken from the IIHS (Insurance Institute for Highway Safety) which has one of the largest databases, in relation to real-world severe crash incidents, throughout the world. Other sources of information [2] indicate that the before mentioned tendency is similar to that of Europe, where it is stated that Side Impact tests correspond to approximately one quarter of the total amount of serious-to-fatal injuries.

It is for this reason that it is very important to develop Safety Systems that prevent Occupants from injuries during Side Impact Crashes. Because of this, and due to the fact that previous side Impact Dummies had quite low Biofidelity Ranking values [3], the WorldSID 50th percentile male dummy was developed.

Since its release, WorldSID has been added in several consumer and regulation tests. The first instritution to adopt the use of WorldSID was Euro NCAP, who included it in its Side Impact Tests (Oblique Side Pole and Side AE-MDB test in 2015. On the 23rd December 2015 the oblique pole test with WorldSID 50th became in force for ADR 85/00 although it is not going to be mandatory in MA, MB and MC new model vehicles until the 1st November 2017 [4]. WorldSID is also expected to become mandatory to be used in UN R135 as part of the EU type approval in 2020 [5]. In the United States, the latest Request for Comments on the USNCAP announcement indicates that this dummy will be used in 2019/2020 [6].

In March 2016, the Anthropomorphic Test Device (ATD) supplier released a new WorldSID 50th percentile shoulder clevis and arm [7]. These parts had been designed by the supplier in conjunction with the WorldSID ISO Task Group in order to solve some recurring issues that could be found in previous versions of this part. The new Shoulder Clevis counts with larger holes and plunger ball. Images of the old (top) and new (bottom) shoulder clevis designs may be found in Figure 1:

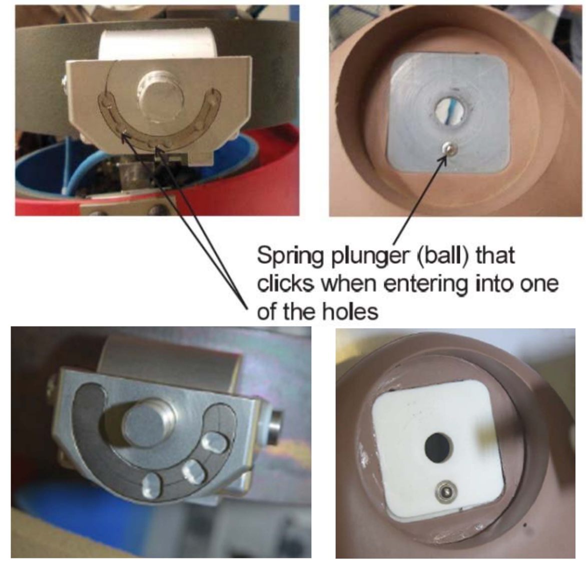

Figure 1. Images of the Old WorldSID 50th Percentile Shoulder Clevis Design (top) and the new one (bottom)

For the time being, both the old and the new shoulder clevis and arm components are considered to be indistinctively acceptable by Euro NCAP. However in 2018 Euro NCAP will only accept the use of the new shoulder clevis design. Many OEMs had already started their development with the old WorldSID Shoulder design and need to know the differences they may find with the new clevis as it will be the one to be used in the official testing program.

Recently, several development tests using both WorldSID shoulder versions have been performed at IDIADA. The results from these tests have lead to OEMs doubting on the consistency in the results found when using one version or the other. The arm movement that is achieved when using both shoulder joints seems to be slightly different which may lead to differences in the testing results.

OBJECTIVE

Arm movement is a critical factor for the development of Side Impact Passive Safety systems in order to enhance vehicle safety. This fact is due to the fact that the interaction between arm and side airbag highly defines the intrusion levels seen by the occupant's ribcage. Because of this, this study has been carried out in order to check the performance differences found between the two versions of the WorldSID shoulder clevis via back-to-back testing.

The results of these tests will be used to evaluate the differences between parts, if existing; identify the consequences of the new shoulder clevis implementation and validate if they can be used indistinctively without finding test result disparities.

Finally, a basic repeatability analysis of both shoulder clevis has also been done. However, the authors are aware that there is a limited data set in order to do this evaluation (2 repetitions per test mode) and the results can only give a preliminary conclusion.

METHODOLOGY

In order to evaluate the differences between the above mentioned shoulder joints, several pendulum tests were performed at IDIADA (similar configuration to [8], [9]). These tests were done in the same test setup, using the same WorldSID dummy but changing the shoulder joint and arm. Note that all tests were carried out twice to ensure repeatability.

The pendulum tests were carried out using the Standard 23.4 kg pendulum rig (Standard pendulum for male dummy calibration). Given that the objective of these tests was not to correlate the results with a crash test, but to obtain an extensive data set in different test configurations two random test speeds were chosen. These speeds correspond to the impactor release heights of: 1 metre and 1.5 metres.

Due to the fact that, WorldSID is not able to sit freely without a backrest as it is too flexible and bends forwards, it was decided to carry out all Pendulum tests with the dummy seated on the WorldSID Standard Calibration bench. In this way, the seating position was kept constant in all tests. Also, in order to assimilate the studied test mode to that of a Euro NCAP Pole Test, the pendulum impact angle was of 75º. In all tests the arm was positioned in the same way as in the Euro NCAP Protocol.

On the other hand, as it was believed that the main areas of interest when studying WorldSID's arm movement and overall performance are found under high loading of the shoulder and thoracic ribs; these two areas were chosen as impact points. In Test Set-Up 1 the pendulum hit against the Shoulder Bolt whilst in Test Set-Up 2 the Impact Point was the Mid Thoracic Rib.

Images showing the test set-up may be found in Figures 2 found below:

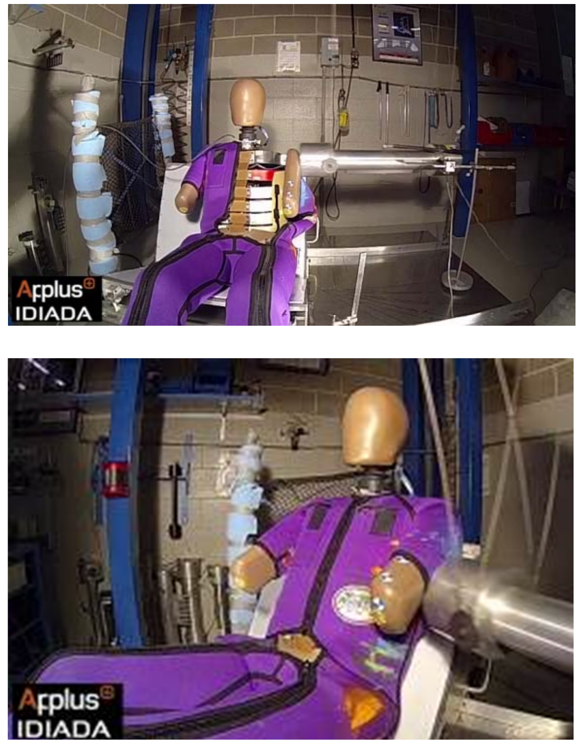

Figure 2. Images of pendulum test set-ups in Position 1 (Shoulder Impact – Top) and Position 2 (Thorax Impact – Bottom)

The test matrix that was followed in this first phase of the project may be found in Table 1:

Test Mode	Veh.	Clevis	Test
75º. Suit On. Arm in test position. Speed 1. Shoulder Bolt = Pos.1	1	1	1
		1	2
		2	1
		2	2
75º. Suit On. Arm in test position. Speed 2. Shoulder Bolt= Pos.1	2	1	1
		1	2
		2	1
		2	2
75º. Suit On. Arm in test position. Speed 1. Mid Thoracic Rib = Pos. 2	1	1	1
		1	2
		2	1
		2	2
75º. Suit On. Arm in test position. Speed 2. Mid Thoracic Rib = Pos. 2	2	1	1
		1	2
		2	1
		2	2

Table 1.
Pendulum Test Matrix

RESULTS

The data from this study show the comparison between the results of the WorldSID 50th percentile using two different level shoulder joints. This data will be useful in order to validate if both designs are comparable and show consistent results. This conclusion can be helpful in order to decide the feasibility of using both versions indistinctively for future side impact testing protocols.

Preliminary analysis of the test results from the above mentioned pendulum tests have shown differences between the values obtained when using one WorldSID shoulder clevis or another. As shown in graphs 3 to 7, the values achieved from testing the new shoulder clevis (red and burgundy curves) tend to have a greater amplitude than the green curves (corresponding to the old shoulder clevis design).

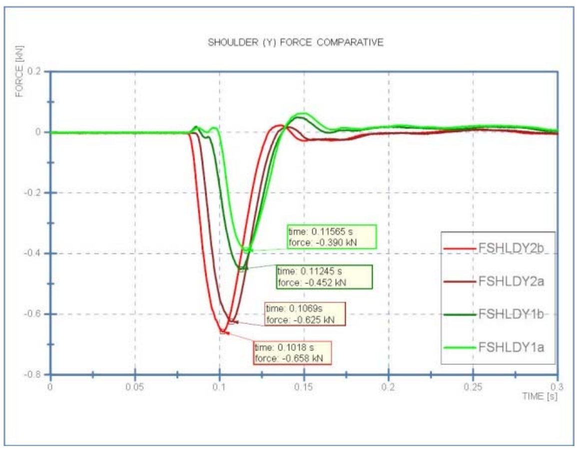

Figure 3. Shoulder Force in Y Test Mode: Mid Thoracic Rib Impact Point – Height 1m

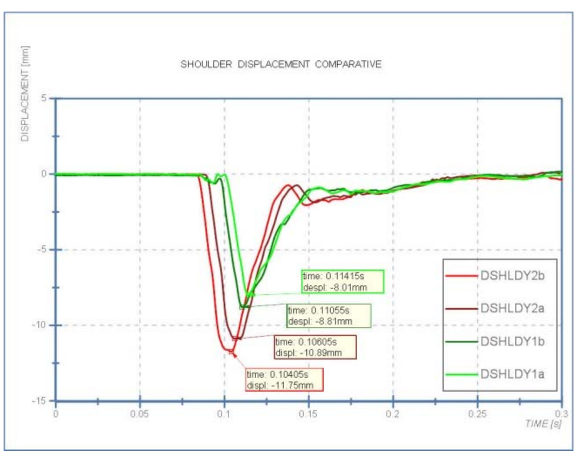

Figure 4. Shoulder Displacement Test Mode: Mid Thoracic Rib Impact Point – Height 1m

Figure 5. Shoulder Rotation in Z Test Mode: Mid Thoracic Rib Impact Point – Height 1m

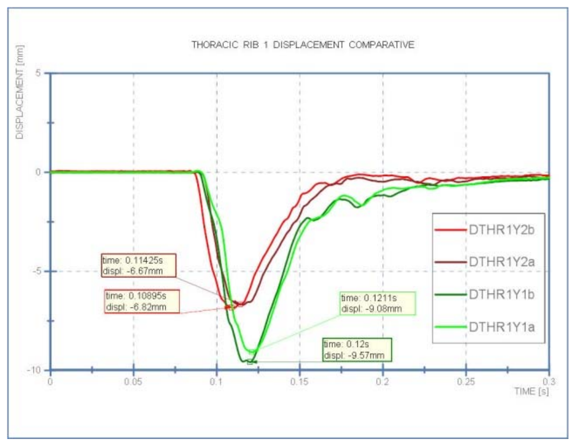

Figure 6. Upper Thoracic Rib Displacement Test Mode: Mid Thoracic Rib Impact Point – Height 1m

Figure 7. Upper Thoracic Rib Rotation Test Mode: Mid Thoracic Rib Impact Point – Height 1m

Given these results, it was decided to evaluate the Repeatability and Reproducibility of the test results. The evaluation of these results were done by evaluating the coefficient of variation percentage (CV%). The coefficient of variation shows the extent of variability in relation to the mean of the population [10]. The formula that has been used for this calculation is as shown below in (Equation 1):

$$CV\% = \frac{\sigma}{\mu} \cdot 100 \qquad \textbf{(Equation 1)}$$

Where σ is the standard deviation and µ corresponds to the mean.

The CV% was calculated using the data for each test mode (both repetitions of each arm) in order to evaluate the repeatability of each arm. Following to this, the global statistical values were calculated in order to assess the reproducibility level between arms. These results were then graded according the categorical categorization found bellow:

Category	CV% Level
CV% ≤ 5%	Excellent
5% < CV% ≤8%	Good
8% < CV% ≤ 10%	Marginal
CV% >10%	Unacceptable

Table 2.
Coefficient of Variation (CV%) Categorical Scale

As shown Annex A of this paper, the results from this evaluation show Good or Excellent results for repeatability. However, when comparing the results from both arms, unacceptable levels of variability are found. Nevertheless, if this data is analyzed in detail, it can be seen that most statistical anomalies correspond to the test done in Position 2 at 1 m height. For this reason, the authors believe that there must be a specific problem with this particular test that can be misleading during the data analysis.

DISCUSSION AND LIMITATIONS

As to the limitations of this project, it is important to highlight that the test modes that have been studied are very simplified scenarios that cannot fully represent a full vehicle crash test. However, for the purpose of this study, the main objective has been to identify the difference between the two studied shoulder clevis designs and not to correlate these results with those from crash and sled testing. The number of test repetitions that has been performed is also low. Further test repetitions would be needed in order to complete the repeatability analysis.

Also, due to time constraints, the only results that have been included in this Written Paper have been those corresponding to the first phase of the project (pendulum tests). The authors are aware that these tests are the less representative tests when compared to a real crash scenario and the most inadequate test modes to simulate real occupant arm interaction with vehicle interiors and restraint systems and because of this, further testing will be performed (see Section "Next Steps and Future Work" from this document) and more results will be presented during the Oral Presentation of this paper.

CONCLUSIONS

The preliminary results from this study have shown that some differences may be found when using one shoulder clevis and arm, or another. However, the authors believe that these differences may be due to dummy-pendulum positioning variability or the speed tolerance used in these tests. Because of this, further testing activities will be performed, as explained in the section Next Steps and Future Work from this paper. Most of the statistical anomalies that have been found are mainly related with the test in position 2 (Impact Point: Mid Thoracic Rib) where the pendulum was released from a height of 1m test. In particular, the values for the rib displacements seem to have the highest variability.

NEXT STEPS AND FUTURE WORK

In order to ensure data completeness and that the test results are representative of real crash scenarios, additional activities will be done so as to perform an in-depth comparison between both WorldSID Shoulder Clevises, These activities will be split in several phases, as explained below:

Phase II – Static Deployment Tests

In the second phase of this project, a series of back-to-back static deployment tests will be performed. Two different vehicles will be used for phases II and III of this study. Vehicle I is a large Pick-up while Vehicle II is a small vehicle. The reason behind using these two vehicles is to compare the effect of the change in the shoulder joint that is being used when there is a high intrusion (small car in Euro NCAP Pole Test Mode) versus a low intrusion load case (Pick-up car in Euro NCAP AE-MDB Test Mode). One of the options that is being discussed in order to evaluate this difference more precisely is to move the vehicle door trim closer to the dummy so that the restraint system deploys once the vehicle intrusion level has been simulated.

With these considerations in mind, the test matrix that will be followed for this phase will be as follows:

Test Mode	Veh.	Clevis	Test
Pole Test Condition	1	1	1
		1	2
		2	1
		2	2
Side AE-MDB		1	1
		1	2
		2	1
		2	2
Pole Test Condition	2	1	1
		1	2
		2	1
		2	2
Side AE-MDB		1	1
		1	2
		2	1
		2	2

Table 3.
Future Work – Static Deployment Test Matrix

Phase III – Side Sled Tests

In the third phase of the project, IDIADA will perform Side Sled Tests in order to evaluate the differences in the injury results that are found when testing using a WorldSID with the first design of shoulder clevis and the latest design. By performing Side Sleds, it will be possible to achieve a better picture of the situation that will be found in full-scale crash testing whilst ensuring a better test performance repeatability and a minor economic impact for the OEM. The test matrix to be followed in this phase is currently being defined by the project members and the OEM that has partnered with IDIADA for this work.

Phase IV - Comparison of the results

Lastly, before reaching the project closure; the authors would like to compare the results found through this research project and several development tests that are being performed in IDIADA's crash and sled test facilities. In this way, it will be possible to evaluate whether the conclusions found in the project are in line with other OEM experiences and evaluate the impact of the results from a global and objective point of view.

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ANNEX 1: TEST SUMMARY

KN	TEST	Repetitivity standard dev.	%CV	CV quality	ARM1 a	ARM1 b	ARM2 a	ARM2 b	Repetitivity standard dev.	%CV	CV quality	GLOBAL STATISTICS Average	Standard dev.	%CV	CV quality
FSHLDYmin	POS1 1m	0,00	0,77%	Excellent	-0,56	-0,56	-0,62	-0,66	0,02	2,61%	Excellent	-0,6008	0,0424	**7,05%**	Good
	POS1 1,5m	0,00	0,38%	Excellent	-1,16	-1,15	-1,23	-1,19	0,02	1,83%	Excellent	-1,1827	0,0322	**2,72%**	Excellent
	POS2 1m	0,03	7,35%	Good	-0,39	-0,45	-0,62	-0,66	0,02	2,61%	Excellent	-0,5314	0,1128	**21,24%**	Unnacceptable
	POS2 1,5m	0,03	3,20%	Excellent	-0,79	-0,84	-0,81	-0,83	0,01	1,65%	Excellent	-0,8158	0,0209	**2,56%**	Excellent

mm	TEST	Repetitivity standard dev.	%CV	CV quality	ARM1 a	ARM1 b	ARM2 a	ARM2 b	Repetitivity standard dev.	%CV	CV quality	GLOBAL STATISTICS Average	Standard dev.	%CV	CV quality
DSHLDYmin	POS1 1m	0,09	0,89%	Excellent	-10,82	-10,63	-10,88	-11,74	0,43	3,80%	Excellent	-11,0175	0,4272	**3,88%**	Excellent
	POS1 1,5m	0,11	0,44%	Excellent	-25,06	-25,28	-26,04	-25,28	0,38	1,48%	Excellent	-25,4150	0,3719	**1,46%**	Excellent
	POS2 1m	0,40	4,76%	Excellent	-8,01	-8,81	-10,89	-11,75	0,43	3,80%	Excellent	-9,8650	1,5131	**15,34%**	Unnacceptable
	POS2 1,5m	0,68	4,19%	Excellent	-15,56	-16,92	-14,92	-15,41	0,25	1,62%	Excellent	-15,7025	0,7417	**4,72%**	Excellent

mm	TEST	Repetitivity standard dev.	%CV	CV quality	ARM1 a	ARM1 b	ARM2 a	ARM2 b	Repetitivity standard dev.	%CV	CV quality	GLOBAL STATISTICS Average	Standard dev.	%CV	CV quality
DTHR1Ymin	POS1 1m	0,07	0,88%	Excellent	-8,06	-7,92	-6,68	-6,86	0,09	1,33%	Excellent	-7,3800	0,6153	**8,34%**	Marginal
	POS1 1,5m	0,15	0,81%	Excellent	-19,27	-18,96	-17,18	-17,96	0,39	2,22%	Excellent	-18,3425	0,8275	**4,51%**	Excellent
	POS2 1m	0,25	2,63%	Excellent	-9,57	-9,08	-6,67	-6,82	0,08	1,11%	Excellent	-8,0350	1,3027	**16,21%**	Unnacceptable
	POS2 1,5m	0,07	0,41%	Excellent	-18,41	-18,56	-16,55	-17,84	0,65	3,75%	Excellent	-17,8400	0,7917	**4,44%**	Excellent

		Repetitivity			ARM1		ARM2		Repetitivity			GLOBAL STATISTICS			
deg	TEST	standard dev.	%CV	CV quality	a	b	a	b	standard dev.	%CV	CV quality	**Average**	**Standard dev.**	**%CV**	**CV quality**
RTHR1Zmin	POS1 1m	0,07	1,89%	Excellent	-3,78	-3,64	-3,36	-3,16	0,10	3,07%	Excellent	-3,4850	0,2410	**6,91%**	Good
	POS1 1,5m	0,26	3,92%	Excellent	-6,27	-6,78	-4,93	-5,88	0,47	8,75%	Marginal	-5,9676	0,6781	**11,36%**	Unnacceptable
	POS2 1m	0,07	1,83%	Excellent	-3,90	-3,76	-3,37	-3,17	0,10	3,06%	Excellent	-3,5500	0,2930	**8,25%**	Marginal
	POS2 1,5m	0,04	0,36%	Excellent	-9,89	-9,82	-9,38	-8,77	0,31	3,36%	Excellent	-9,4650	0,4463	**4,72%**	Excellent

Statistic Anomalies → Test in Position 2 – 1m

		Repetitivity			ARM1		ARM2		Repetitivity			GLOBAL STATISTICS			
	TEST	standard dev.	%CV	CV quality	a	b	a	b	standard dev.	%CV	CV quality	**Average**	**Standard dev.**	**%CV**	**CV quality**
POS2 1m	FSHLDY	0,03	7,35%	Good	-0,39	-0,45	-0,62	-0,66	0,02	2,61%	Excellent	-0,5314	0,1128	**21,24%**	Unnacceptable
	DSHLDY	0,40	4,76%	Excellent	-8,01	-8,81	-10,89	-11,75	0,43	3,80%	Excellent	-9,8650	1,5131	**15,34%**	Unnacceptable
	RSHLDZ	0,25	9,17%	Marginal	2,46	2,95	1,08	1,31	0,12	9,62%	Marginal	1,9491	0,7784	**39,94%**	Unnacceptable
	DTHR2Y	0,22	3,60%	Excellent	-6,19	-5,76	-3,00	-3,01	0,00	0,17%	Excellent	-4,4900	1,4928	**33,25%**	Unnacceptable
	RTHR2Z	0,05	2,16%	Excellent	-2,60	-2,49	-1,64	-1,53	0,05	3,47%	Excellent	-2,0650	0,4831	**23,40%**	Unnacceptable
	DTHR1Y	0,25	2,63%	Excellent	-9,57	-9,08	-6,67	-6,82	0,08	1,11%	Excellent	-8,0350	1,3027	**16,21%**	Unnacceptable
	RTHR1Z	0,07	1,83%	Excellent	-3,90	-3,76	-3,37	-3,17	0,10	3,06%	Excellent	-3,5500	0,2930	**8,25%**	Marginal