SIDE IMPACT TEST PROCEDURE FOR CHILD RESTRAINT SYSTEMS
REVIEW OF EXISTING METHODS AND PROPOSALS FOR CONTINUATION

HEIKO JOHANNESEN\textsuperscript{1}, CEEH HUIJSKENS\textsuperscript{2}, BRITTA SCHNOTTALE\textsuperscript{3}, VOLKER SCHINDLER\textsuperscript{4}
\textsuperscript{1}Technische Universität Berlin (TUB), Berlin, Germany; \textsuperscript{2}TNO Automotive, Delft, Netherlands; \textsuperscript{3}Bundesanstalt für Straßenwesen, Bergisch Gladbach, Germany

ABSTRACT

Although accident analysis shows that lateral impact accidents continue to be dangerous for children in cars, no procedure to test side impact performance of child restraint systems (CRS) has been agreed on yet in Europe. In this paper, the existing four side impact test methods of ISO/TRL, ADAC, TUB and TNO are compared against full-scale MDB tests according to ECE R95 and EuroNCAP with respect to impact input and dummy readings. It is necessary that the finally agreed test procedure will be able to cope with today’s and future CRS, especially with ISOFIX and CRS which offer the possibility to pretension the car belt.

Keywords: child restraint systems, side impacts, procedures

ACCIDENT STATISTICS show that lateral impacts are still dangerous for children, especially for those sitting at the struck side [Langwieder, 1996]. To improve the performance of child restraint systems (CRS) in side impacts, a definition of test procedures which represent the real-world accidents is necessary. This paper describes the most important characteristics of side impact accidents. In addition different test procedures are assessed regarding these main characteristics. This paper is intended to support the current work of ISO WG 1 concerning the development of a side impact test procedure for CRS.

BOUNDARY CONDITIONS

There are different kinds of CRS types. Besides the differences of forward facing (FF) and rearward facing (RF) the fixation of the CRS and the child can be different. The following types can be found on today’s market: belt fixed CRS with integral harness for the child (FF mainly 5-point-harness, RF mainly 3-point-harness), booster with/without backrest (CRS and child restrained with car belt), ISOFIX (rigid) connection of CRS and car with integral harness for the child. For the belted CRS the usage of pretensioning devices which reduce the belt slack of the car belt are becoming more popular.

In accidents in general, but especially in lateral impacts, the most vulnerable body region is the head. The assessment of good head protection necessitates the definition of the worst-case condition. Worst-case in this context means, that the child’s head is located close to the point of maximum intrusion, which is the B-pillar in ECE R95 tests. This would lead to an assumed seating position of FF seats in the front passenger seat and of RF seats in the rear seat bench. Although these configurations may be unusual in some countries and not allowed in others, it is important to assess FF and RF CRS with test conditions of the same severity. For an appropriate head protection it is necessary that the side structure of the CRS contains the head during the impact. The “head containment” criterion helps to analyse this capability.

ANALYSIS OF FULL-SCALE TESTS

Full-scale tests – mainly ECE R95 and EuroNCAP tests – are analysed to describe the child safety relevant behaviour of cars in lateral impacts. The most important injury inducing mechanism in lateral impacts is the intrusion of the side structure. This intrusion can be described by velocity and depth.
Fig. 1 shows intrusion velocities and intrusion depths of different cars manufactured between the late eighties and beginning of the 21st century. For the analysis it has to be taken into account that intrusion depth and velocity are normally lower at the rear seat. In addition, both are normally lower in newer cars, which means that most of the higher values are from older cars. Car-to-car impact intrusion depths and intrusion velocities depend on the striking car. It is obvious that the intrusion velocity can be higher than in MDB (movable deformable barrier) tests, e.g. intrusion velocities above 12 m/s were measured with a big car striking a small family car.

The side structure of the target vehicle shows a v-shape damage after the impact (as demonstrated below in chapter Assessment of Procedures) irrespective of the test procedure.

In addition to the vehicle related measurements the child dummy readings are of interest. Fig. 2 shows a comparison of head and chest acceleration in different cars and different seats.

**SIDE IMPACT TEST PROCEDURES**

There are different side impact sled test procedures for CRS in Europe. These are all based on different stages of a proposal developed within the ISO Child Safety Working Group. The procedures are: the current ISO proposal as it is implemented by TRL, the ADAC procedure, the TNO procedure and the TUB procedure.

CURRENT ISO PROPOSAL: The main property of this test procedure is the hinged door concept where an ECE R44 test bench is mounted in an angle of 90° on a sled [ISO, 2004], which was originally proposed by TRL. During the sled deceleration the hinged door intrudes. This procedure
offers the possibility to simulate the main mechanisms of lateral collisions (acceleration of the struck car and intrusion of the struck side structure).

The CRS is positioned with a distance of 300 mm of its centreline from the hinged door. The test procedure takes into account the worst-case scenario for both, RF and FF CRS, by positioning the hinge at the side of the feet. The sled deceleration is defined by a delta-v corridor representing an overall delta-v of 25 km/h. The hinged door concept transfers the translational into a rotational intrusion. The angular velocity for RF CRS of $13 \pm 1$ rad/s corresponds to a translational intrusion velocity at the point of the head of about $12 \pm 1$ m/s. The intrusion depth is limited to 250 mm. The door is built as a double shaped panel. The hinge line is vertical to the seat cushion, so the movement is not parallel to the ground.

In the first DIS voting in 2004 the ISO proposal was not approved. The main reason for this was the missing validation especially for FF CRS.

ADAC PROCEDURE: The ADAC tests take place in a body in white of a VW Golf [Gauss, 2002]. The body is mounted on a sled at an angle of 80° and is equipped with a fixed door. The angle of 80° should cause an additional head movement in frontal direction. Therefore it is more difficult to pass the head containment criterion for FF CRS. The body in white is mounted in the same way to the sled for FF and RF CRS. In the ADAC procedure a fixed door is used, i.e. no intrusion is simulated. The sled is decelerated from an initial velocity of 25 km/h at a level of 15 g.

TNO PROCEDURE: The TNO procedure also uses the hinged door concept first proposed by TRL. The main difference to the ISO proposal is that the door is simulated by a flat panel.

TUB PROCEDURE: The TUB procedure also uses the hinged door concept. The main difference to the ISO proposal is that the door is simulated by a single shaped panel with a vertical hinge line. In addition the seat backrest and the upper belt anchorage point for FF CRS and the ISOFIX anchorage points are movable in y-direction, representing the seat and B-pillar displacement in full-scale tests. Other differences concerning sled acceleration and angular velocity are of less importance.

ASSESSMENT OF PROCEDURES

All procedures, except the one from ADAC reproduce intrusion. The main differences concern the shape and hinge of the intruding door. The comparison of static crush in MDB tests and the geometry of the intruding panels (see Fig. 3) shows that the double shaped ISO panel intrudes in an unrealistic way – the onset of the simulation of deformation is too late and too fast for both (RF and FF) configurations. In addition is the behaviour of the profile quite aggressive. Finally it has to be mentioned that due to the inclined hinge line in the ISO and the TNO procedure the upper edge of the panel does not move parallel to the ground, while it does with the vertical hinge line of TUB.

A realistic assessment of CRS in lateral impact requires the simulation of intrusion defined by intrusion velocity, intrusion depth and intrusion shape, what has already been stated by Lundell [1998]. In addition it is necessary that the procedure is applicable for all kinds of CRS at a comparable severity level, i.e. RF as well as FF, belted (with and without pretensioning) as well as ISOFIX. Especially for the FF scenario the intruding panel overtravels the original outboard belt anchorage points and the outboard ISOFIX anchor. In case of the TUB procedure these points are movable in y-
direction to avoid any interactions between the panel and the anchorage points. This kinematic is much closer to reality. If pretensioning is applied to the “car-belt” or if the ISOFIX arms do not bend during impact, there would be an unfavourable interaction between panel and seat using fixed anchorage points.

The global test severity of the procedures differs too. While ADAC rates a head acceleration below 32 g as good and above 76 g as poor [Gauss, 2002] the head acceleration in tests using the hinged door method is seldom well below 100 g (ISO results based on [LeClaire, 2004]). This means that the loads applied in the ADAC tests are below the average, while the hinged door procedures correlate with the worst-case cars mentioned in Fig. 2.

Additional analysis of hinged door tests in non-worst-case conditions showed that it is more difficult to fulfil the head containment criterion in these tests. This is caused by the point of first contact between CRS and door panel. In the non-worst case tests a forward movement of the head is induced by the impact at the seat back.

DISCUSSION AND CONCLUSION

For validation of the ISO proposal an appropriate number of MDB tests is available. However, tests to analyse the dynamic behaviour of ISOFIX CRS and CRS with car belt tensioners are still missing. This is a serious gap because a considerable part of the CRS market will be covered by these seats in the future.

From other studies it is known that in severe lateral impacts the intrusion, especially the intrusion velocity, is the injury inducing factor. This means, that an appropriate side impact procedure for CRS has to simulate intrusion.

The ISO double shaped panel causes an aggressive contact with the CRS and does not reflect the intrusion shape of lateral impact tests, while a single shaped panel does. In addition the use of fixed ISOFIX anchorages seem to cause problems and there will be an unwanted interaction of the seatbelt with the panel, when a seat with pretensioning device is used. Finally it has to be stated that it is important to test RF and FF CRS with the same severity, which means that it is necessary to validate both worst-case configurations before defining a standard.

The Comparison of MDB tests with the proposed test procedures with hinged door shows a high severity of the sled tests, which correspond to worst-case cars. However, car-to-car tests proved the adequate severity of these sled tests.

Due to the hinged door concept, it will be more difficult to pass the head containment criterion in non-worst-case conditions. Therefore it seems reasonable to conduct additional test for RF and FF CRS in non-worst-case conditions.

ACKNOWLEDGEMENT

Parts of the full-scale tests described in this paper are co-financed by the European Commission within the NPACS-Project. The authors thanks IDIADA for providing their test results.

REFERENCES

Gauss, C.; Klanner, W.; “Das Kindersitz-Testverfahren der europäischen Automobilclubs im Vergleich zur Euro NCAP Bewertung”; Innovative Kinderschutzsysteme im Pkw, Cologne, 2002

International Organisation for Standardisation (ISO); Road vehicles – Child restraint systems – “Side impact test method”; ISO/DIS 14646; SIS, Sweden, 2004

