

Technical University of Berlin
Automotive Engineering



ISO TC22 / SC12 / WG1 / TF1

Short Report

**Forward Component in ISO Side Impact
Test Procedure for CRS**

Heiko Johannsen
Rajiv A. Menon (The Children's Hospital of
Philadelphia, US)

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2 Methodology

The methodology for answering the question followed a three steps approach. The first step was to analyse the importance of the forward component based on accident data.

For the second step test results of FMVSS 214 and USNCAP tests were analysed. Both test procedures for the assessment of the side impact protection of passenger cars utilise a barrier simulating a forward component by crabbed motion of the MDB.

Finally the influence of a forward component in the current proposal for the Side Impact Test Procedure for CRS was assessed by numerical simulation using MADYMO.

3 Results

3.1 Accident Statistics

The accident data used for this study was coming from different sources. At the first stage data from the literature were reviewed.

The EEVC working group for side impact protection (WG13) based on GIDAS and CCIS data of all kinds of occupants concluded that perpendicular and angled side impacts are of the same share, while the perpendicular side impact seems to be more severe than the angled one [Lowne, 2001].

GDV analysed 69 international side impact accidents (collected within ISO TC22/SC12/WG1) with the involvement of children. The perpendicular type of accident was predominant (56%) in this sample, see Figure 1.

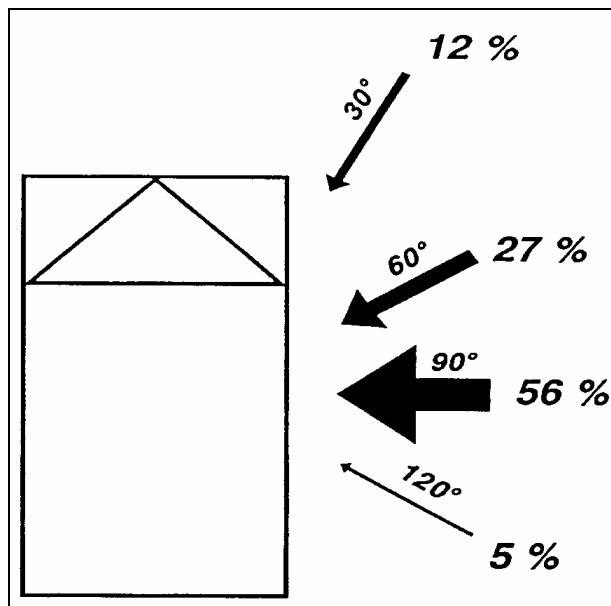


Figure 1: Impact directions in GDV data set [Langwieder, 1996]

Accident data collected in the EU funded CHILD project indicated that angled side impacts from the rear are the most severe ones, due to the likely contact between head and C pillar [Lesire, 2006].

The EEVC result indicated that there might be a different outcome, when comparing occupants of different injury severity levels. In addition the GDV showed that there seems to be a difference for adults and children. Therefore accident data of the GIDAS (German In Depth Accident Study), Volvo databases as well as data from the US Partners for Child Passenger Safety Crash Investigation Database were used.

For these analyses the PDOF (principle direction of force) system was used. In this system the direction of force is coded in a clock-wise system. Frontal impacts from -15 to 15° are coded as 12 o'clock; impacts from 15 to 45° are coded as 1 o'clock, see Figure 2. The coding is either based on calculation (e.g. GIDAS) or on estimation (e.g. VOLVO).

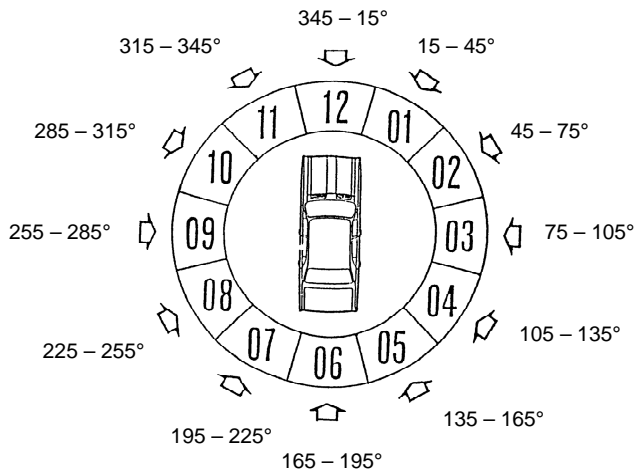


Figure 2: PDOF system

3.1.1 GIDAS

The analysed GIDAS data set included accidents from the Hanover and the surrounding area as well as Dresden and the surrounding area of the years 1999 to 2005. In total 192 children involved in side impact accidents were included.

The analysis shows, that the number of child occupants involved in side impacts is too small to allow statistically significant results. However, the data indicates that there is almost an equal share of side impacts with and without forward component taking into account all occupants, see Figure 3. Looking at children only, there are some more involved in side impacts with forward component than without. However, taking into account the accident severity, perpendicular side impacts seem to be more important for children who are killed or seriously injured (KSI).

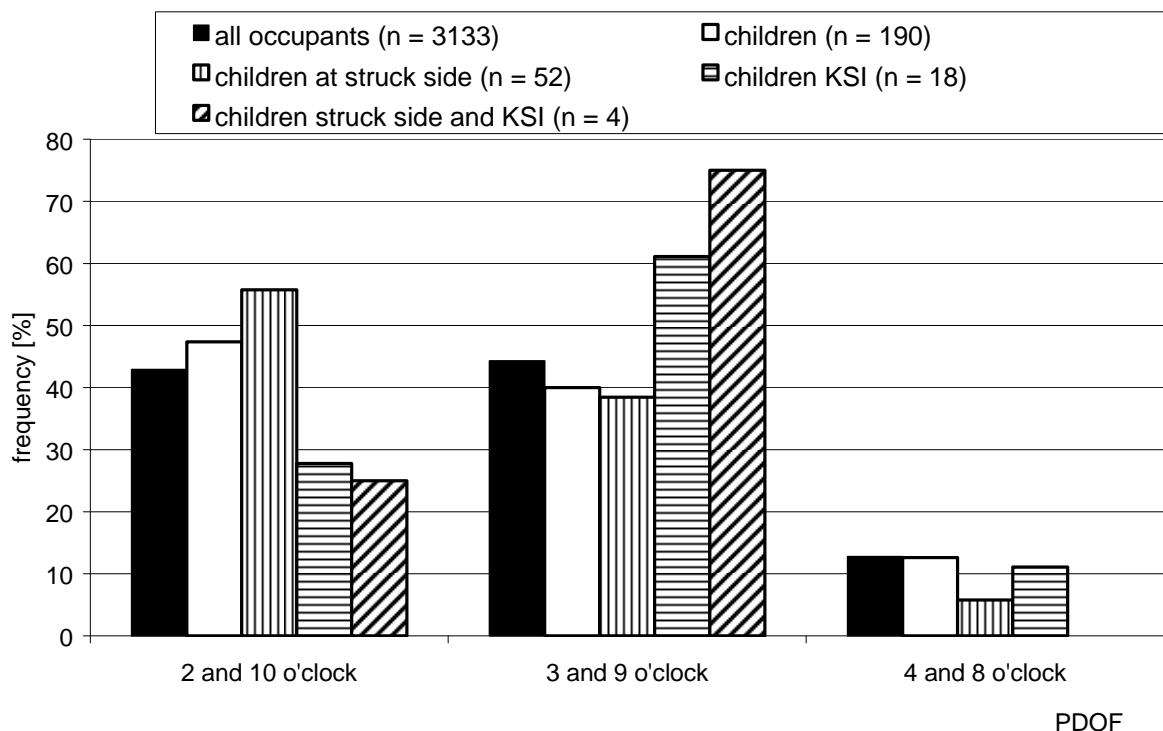


Figure 3: Impact directions in GIDAS database

3.1.2 Volvo Data

The analysed Volvo data set includes accidents with involvement of Volvo cars from the years 1976 to 2006. In total 708 children with an age below 12 years involved in lateral impact accidents sitting at the rear seat were considered.

As already seen in the German accident data, the number of cases is too small for statistically significant results. However, the data shows the same tendency as recognised in the GIDAS data. Side impacts with forward component are almost of the same share as those without. When taking into account the injury severity (defined by MAIS) purely lateral impacts seem to me more severe than side impact accidents with forward component, see Figure 4. The impact direction in the Volvo data set is estimated.

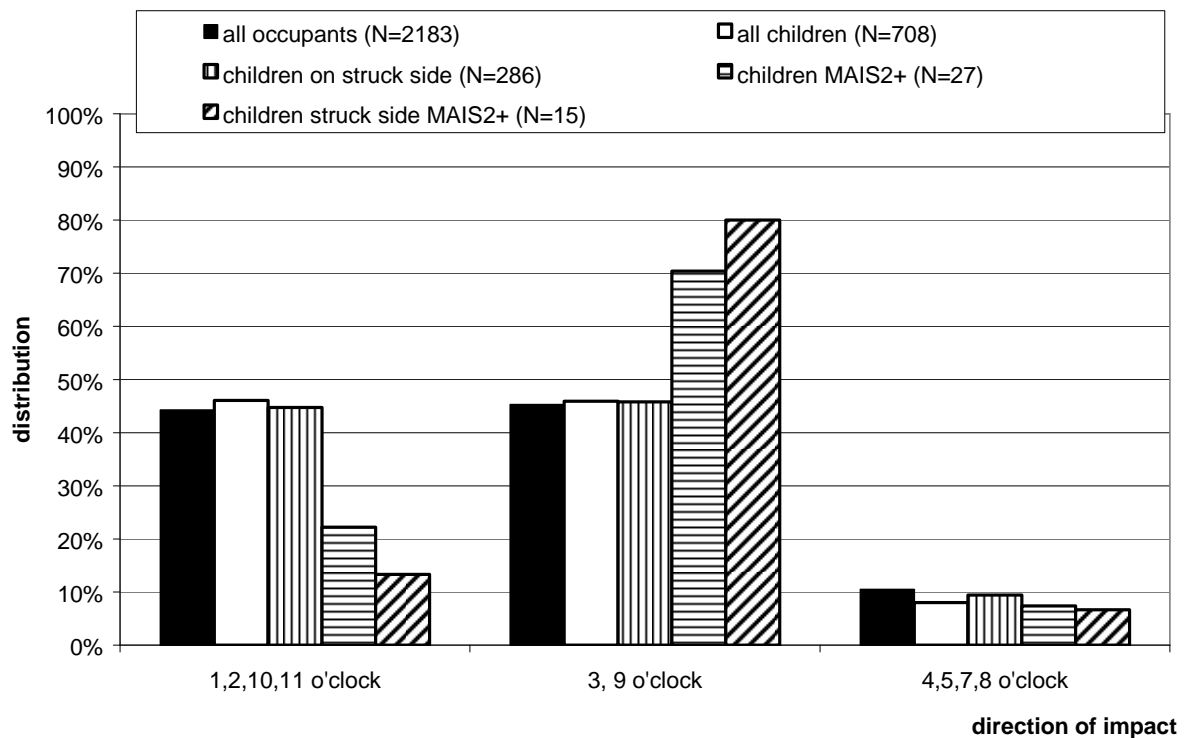


Figure 4: Impact directions in Volvo database

3.1.3 Data of the Partners for Child Passenger Safety

The data of the Partners for Child Passenger Safety includes accidents of the years 1998 to 2006 with involvement of at least one child with an age equal or below 15 years. Only cars of the model year 1990 or newer are considered. The data were collected in 15 of the 51 states of the US and the District of Columbia and analysed by The Children's Hospital of Philadelphia and the University of Pennsylvania.

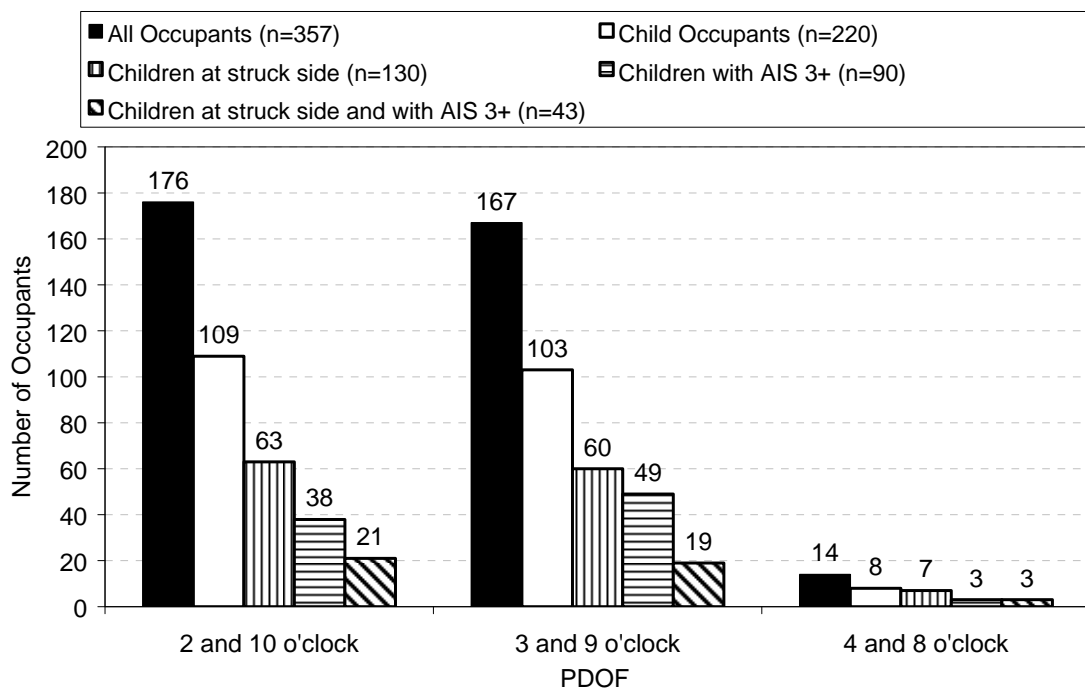


Figure 5: Impact directions in Partner for Child Passenger Safety data set

The data shows a nearly equal share of accidents with and without forward component independent from the occupant age, seating position with respect to the impact side and injury severity level, see Figure 5. However, while accidents with forward component occur slightly more often than those without, the share of perpendicular impacts amongst the group “children with AIS 3+” is slightly higher.

3.1.4 Synthesis of Accident Analysis

The possibility to draw conclusions based on the analysed accident data is limited as the number of involved children is too small to allow statistically significant results. However, there is a clear tendency amongst all studies, that the more severe accidents are more often perpendicular ones.

Due to the analysis in the PDOF system, perpendicular accidents include accidents with impact angles between 75 and 105° or 255 to 285°, respectively. That means that small deviations from the perpendicular were not taken into account.

3.2 Analysis of Car Side Impact Tests with Forward Component

The US side impact test procedures for cars, FMVSS 214 and US-NCAP side impact test procedure are reproducing a forward component by a moveable crabbed barrier, which simulates the longitudinal component of the striking and struck car in one motion, see Figure 6.

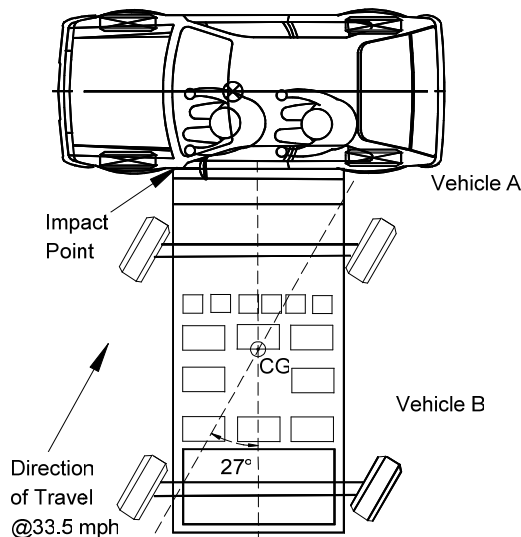


Figure 6: Impact configuration according to FMVSS 214 [NHTSA, 2003]

Taking into account the assumption that these test procedures are validated against real world side impacts analysis of test data enables to assess the forward component based on these tests.

NHTSA is publishing test results via their web site [NHTSA, 2007]. For both test procedure 20 most recent data were analysed. The velocity change is computed using the tunnel acceleration.

3.2.1 FMVSS 214

For the analysed FMVSS 214 tests the average lateral velocity change is approx. 6.2 m/s, while the longitudinal velocity change is approx. 1.2 m/s, see Figure 7. That means that the forward component is approx. 20% of the lateral component. Transferring this to the side impact sled test it would result in an angle of the test bench to the travel direction of the sled of 11°.

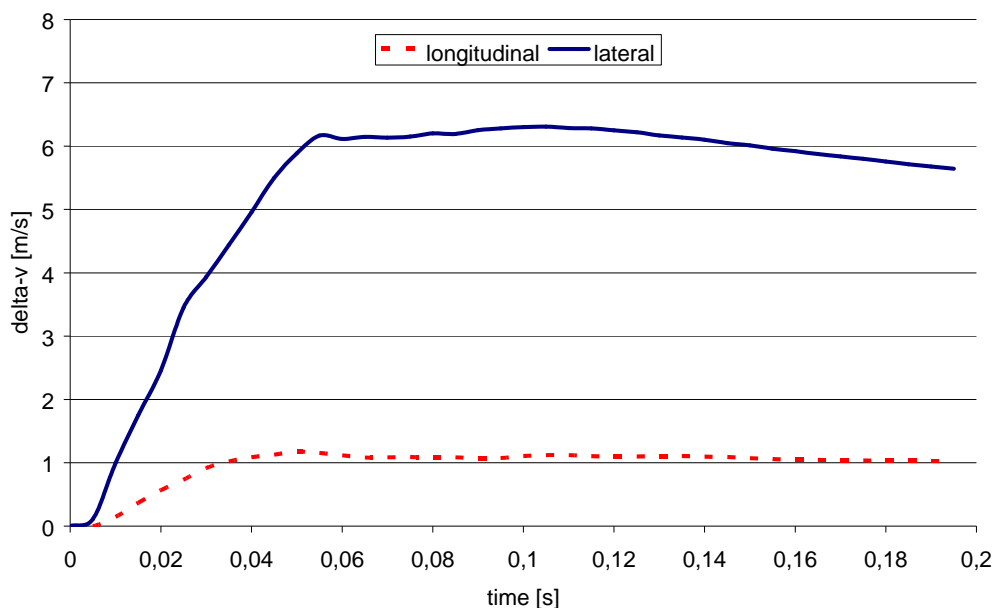


Figure 7: Velocity change in FMVSS 214 tests in lateral and longitudinal direction

3.2.2 US-NCAP

For the analysed US NCAP tests the average lateral velocity change is approx. 6.7 m/s, while the longitudinal velocity change is approx. 1.2 m/s, see Figure 8. That means that the forward component is approx. 18% of the lateral component. Transferring this to the side impact sled test it would result in an angle of the test bench to the travel direction of the sled of 10°.

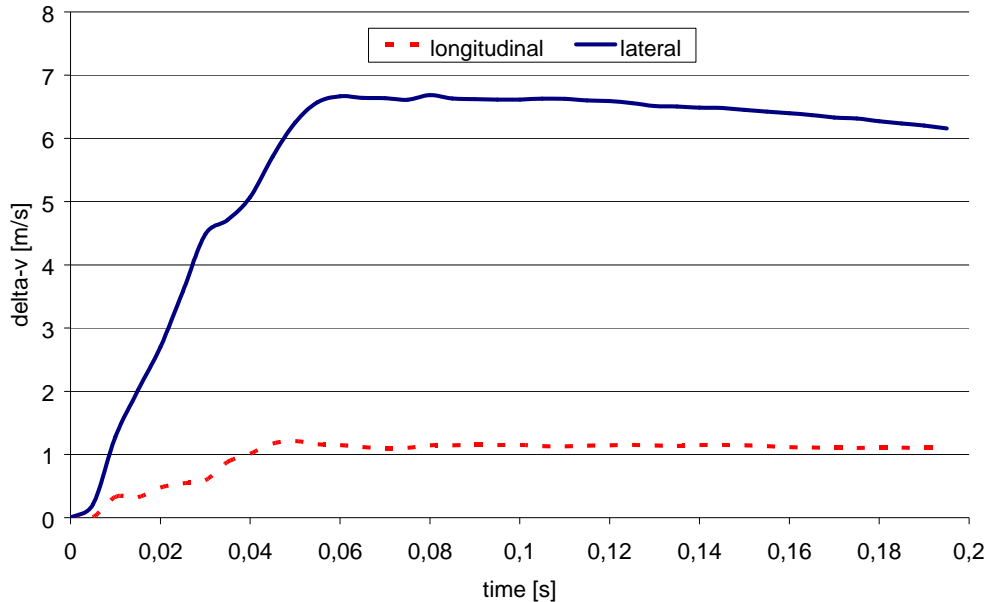


Figure 8: Velocity change in US-NCAP lateral tests in lateral and longitudinal direction

3.2.3 Synthesis of Car Test Results

The results of the analysed FMVSS 214 and US-NCAP lateral tests indicate an impact angle of 10°. The crabbed barrier test procedure was validated a long time ago (crabbed barrier was introduced in FMVSS 214 in 1990) taking into account accident data of adults. In addition the computing of the forward component from the tunnel acceleration includes minor mistakes (e.g., takes not into account the rotation of the test car). Therefore the results are suitable for an indication only.

3.3 Analysis of the Influence of the Forward Component

The main influence of a forward component is probably a forward excursion of the head making the fulfilment of the head containment criterion more challenging. From the theoretical point of view it is possible to compute the maximum possible forward excursion of the head based on the forward component taking into account the time to maximum head acceleration (being not more than 40 ms), the maximum delta-v at 40 ms (5 m/s) and the impact angle, see Table 1. However, this calculation does not take into account friction between head and CRS after the first contact and the interaction between chest and head based on the coupling through the neck. Therefore the theoretical values are likely overestimated.

impact angle	5°	10°	15°	20°
theoretical head forward excursion	17 mm	35 mm	52 mm	68 mm

Table 1: Theoretical head forward excursion due to different impact angles

To further analyse the influence of the forward component on the test results, numerical simulation runs with MADYMO were conducted using an FF harness type CRS and a Q3 model.

For the simulation two different ways of introducing the forward component were used. For the first one the amount of resultant acceleration was kept constant. That means that the acceleration in sled X direction and dummy Y direction was reduced. For the second option the component in sled X direction was kept constant and a certain amount of Y direction was added.

The visual analysis show limited difference between 0° and 20° conditions, see Figure 9.

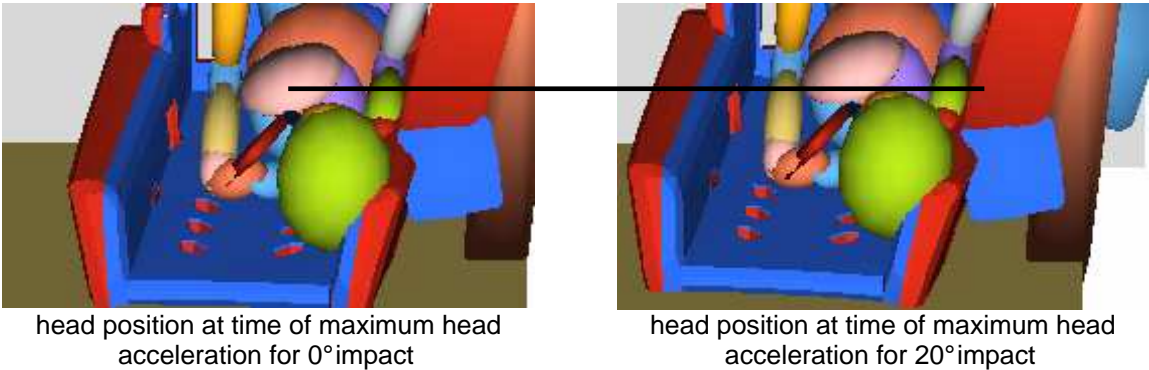


Figure 9: Head position at time of maximum head acceleration in different impact conditions

Taking into account the forward excursion of the head in the purely lateral impact of 9 mm, the difference for angled impacts is 17 mm in 20° impact condition, see Figure 10.

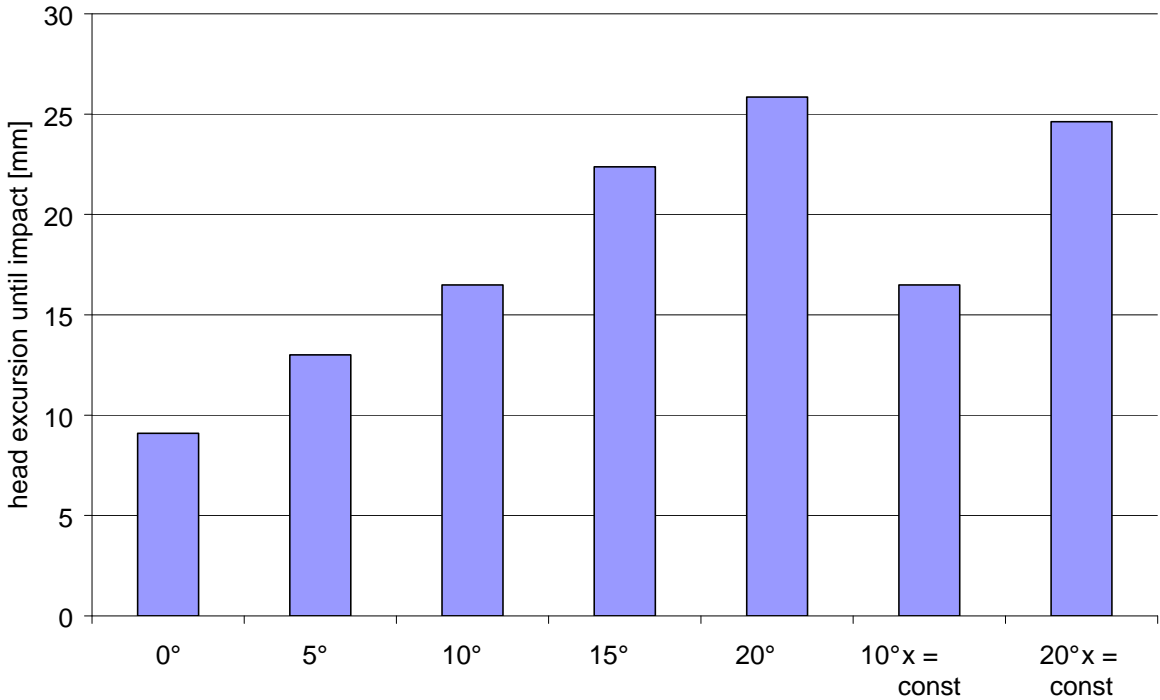


Figure 10: Change in head excursion depending on the impact angle

Looking at the head acceleration, there is almost no influence of the impact angle to the dummy readings, see Figure 11.

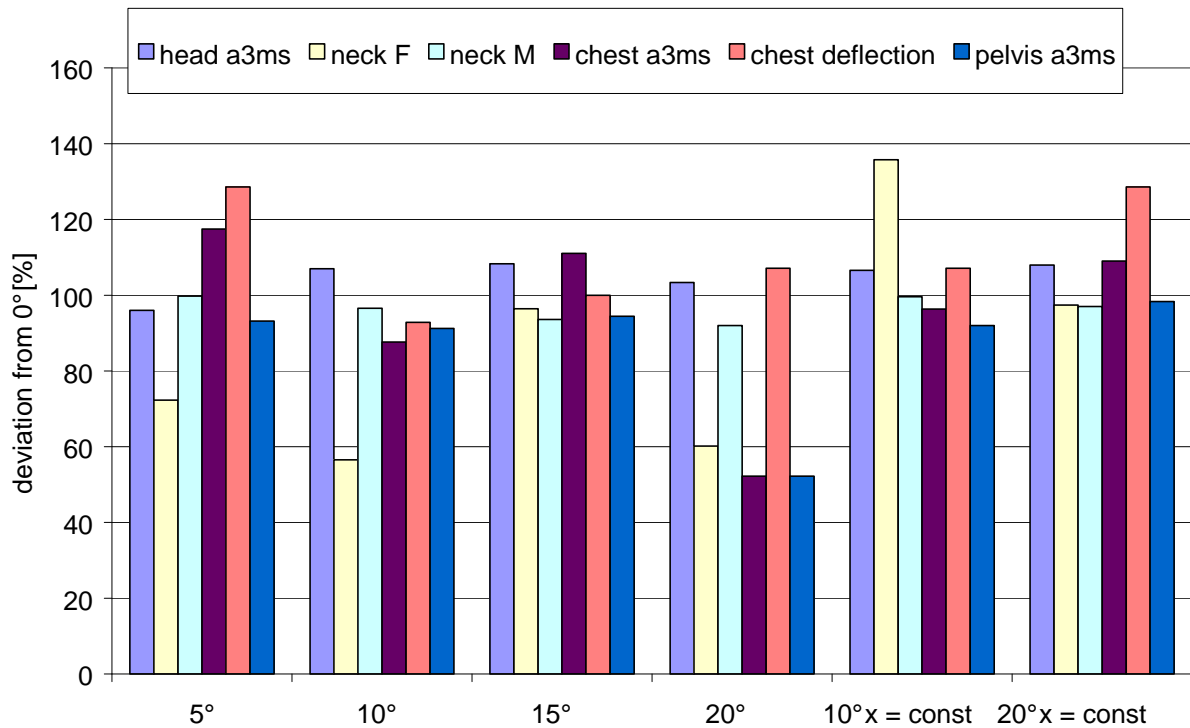


Figure 11: Change in dummy readings depending on the impact angle

The other body regions do not show a clear trend. Depending on the impact angle the loads are sometimes higher and sometimes higher compared to the 0° impact.

4 Conclusions

The current specification of the draft ISO Side Impact Test Procedure simulates a purely lateral impact although it is widely agreed that the struck car is subject to an angled acceleration due to its initial speed.

The main expected influence of a forward component would be an increase in head forward component. This would require more emphasis on the head containment criterion.

Analysis of accident data from different sources indicates that the purely lateral impact (due to the accident data coding with $\pm 15^\circ$ deviation) is more dangerous than angled ones.

Analysing test data from FMVSS 214 and US NCAP lateral impact tests indicate an impact angle of approx. 80° from the front, being 10° from the purely lateral impact direction.

Combining the results from accident analysis and analysis of the car tests it seemed to be sensible to look at impact angles of 0 to 20° from the side. This analysis was done by numerical simulation using MADYMO using a forward facing CRS and a Q3.

The observed change in head excursion is small (17 mm for 20° compared to 0°). In addition the dummy readings do not change in a significant way. Therefore it is not sensible to include any forward component to this test procedure. The conclusion would probably be different for side impact test procedures not representing intrusion, due to a timing issue.

5 Bibliography

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