Analysis of the EUROSID in 21 Full Scale Side Impact Tests

Rainer Hoefs, FAT Working Group Biomechanics

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1. Introduction

In spring 1987, the 'Biomechanics' working group of the FAT decided to perform a series of side impact tests with the object of investigating the EUROSID performances under full-scale test conditions. The full-scale side impact results published in the report of the EC commission on the EUROSID development /1/ were not detailed enough to allow the dummy to be evaluated under conditions of primary concern for automotive manufacturers. To ensure comparability with previous investigations /2, 3/ the same vehicle type was used for all tests.

2. Test program

The project is composed of two test programs with different objectives. The first series of side impact tests aimed at assessing the 'biofidelity' of the EUROSID was performed by the Institute of forensic medicine of the Heidelberg University by order of FAT.

The second test program consisted of side impact tests conducted jointly by the TNO Road Vehicles Research Institute and FAT to examine the dummy's suitability under various test configurations.

2.1 FAT 'Heidelberg' program

15 tests were performed by Heidelberg University using the CCMC barrier /4/ to simulate the impacting vehicle and an Opel Kadett body as the impacted car. All test parameters such as ground clearance, point of impact, seat adjustment and seating position were adopted as they were from previous FAT tests, see /2/ for more details. The only parameter to be varied was the impact speed: six tests were performed at 5o km/h, five at 45 km/h and the remaining four at 4o km/h.

14 tests furnished results suitable for evaluation whereas one of the 45 km/h tests could not be evaluated for failure of the measuring equipment.

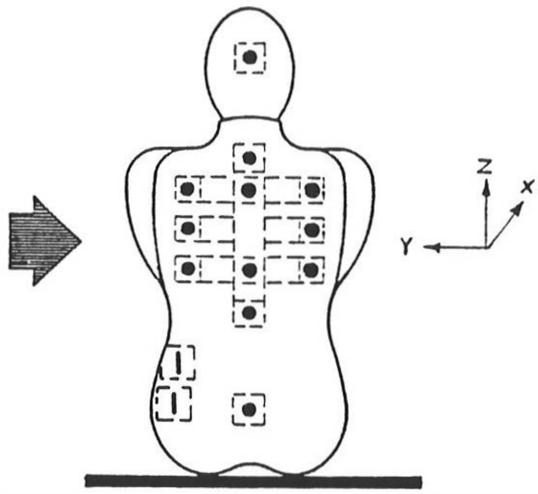
The dummy to be tested was the EUROSID, which was procured by CCMC and made available to FAT. Following the 8th test the dummy was calibrated by TNO. After each test a thorough visual check had been performed.

2.2 FAT - TNO cooperation

Three impact tests each were carried out by TNO Road Vehicles Research Institute, Delft, with the CCMC barrier and the NHTSA barrier /5/ simulating the impacting vehicle. The vehicle hit was always an Opel Kadett. The CCMC barrier impacted at an angle of 9o° while the NHTSA tests used a crabbed barrier. The test configurations have been described in detail in /6/.
The dummy used was TNO's own 1987 production prototype EUROSID. The dummy was calibrated before the test series and thoroughly visually inspected after each test.

3. Dummy measuring points

In addition to the standard measuring equipment additional pickups were installed to ensure comparability with the measured results of other dummies and to obtain the required data for biofidelity evaluation. The measuring points are shown in **Figure 1**.



	transducer	direction
Head	triaxial accelerometer	x,y,z
Upper spine T1	triaxial accelerometer	x,y,z
Upper rib left	uniaxial accelerometer	y
front	uniaxial accelerometer	x
right	uniaxial accelerometer	y
	displacement transducer	
Middle rib left	uniaxial accelerometer	y
right	uniaxial accelerometer	y
	displacement transducer	
Lower rib left	uniaxial accelerometer	y
front	uniaxial accelerometer	x
right	uniaxial accelerometer	y
	displacement transducer	
Lower spine T12	uniaxial accelerometer	y
Abdomen	3 switches	
Pelvis	triaxial accelerometer	x,y,z
-pubic symp.	force transducer	
-iliac wings	strain gauges	

Figure 1: EUROSID measuring equipment

4. Results

These test series supplied information on questions of general interest such as durability, reproducibility, handling etc. In addition, potential users received an answer to their urgent question whether the EUROSID in its actual configuration is a reliable test instrument.

4.1 Results of the Heidelberg test

Visual inspection of the dummy after completion of the 15 tests did not reveal any damages. Placing the dummy into and removing it from the vehicle did not cause any major handling problems but it is something of a disadvantage that the dummy is not allowed to be suspended by the head for transportation.

The conversion from left-hand to right-hand side impact configuration is far more complicated than implied in the EUROSID manual. Special care is required when mounting the abdominal switch in order to ensure its orderly measuring function. Apparently, the cable arrangement has been intended for left-hand impacts only.

The dummy acceleration and force measurements did not cause any difficulties. The measured results make sense and compare favourably with those obtained from similar tests. Great problems, however, occurred during the measurement of the rib deformations and abdominal forces (switch functions), which will be described in detail in the following.

In 12 out of 14 tests the rib deformation curves showed deficiencies. Different positive and/or negative offsets were measured after the impact (**Figure 2**).
The deformation curve shows sudden minima which cannot be produced by an impact (**Figure 3**).

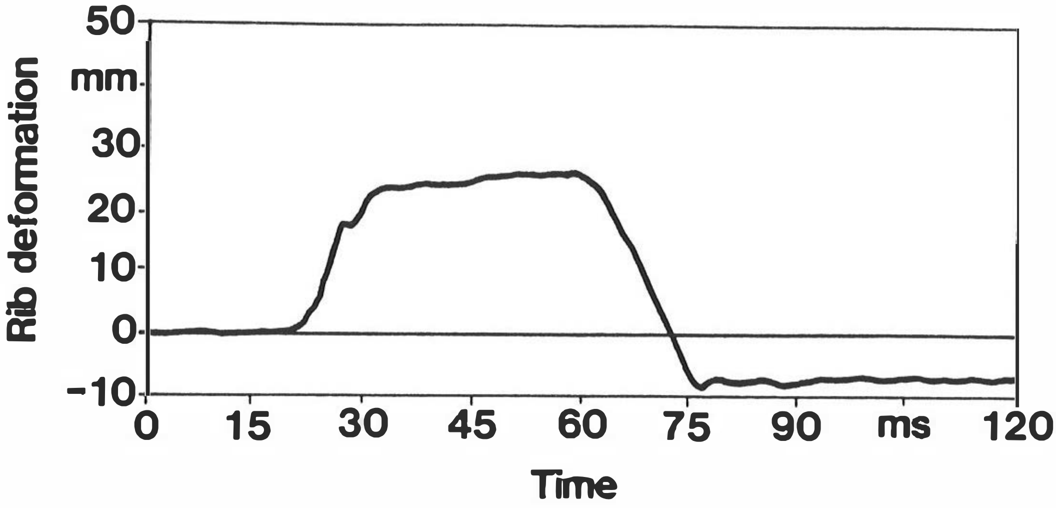


Figure 2: Example of a negative rib deformation offset

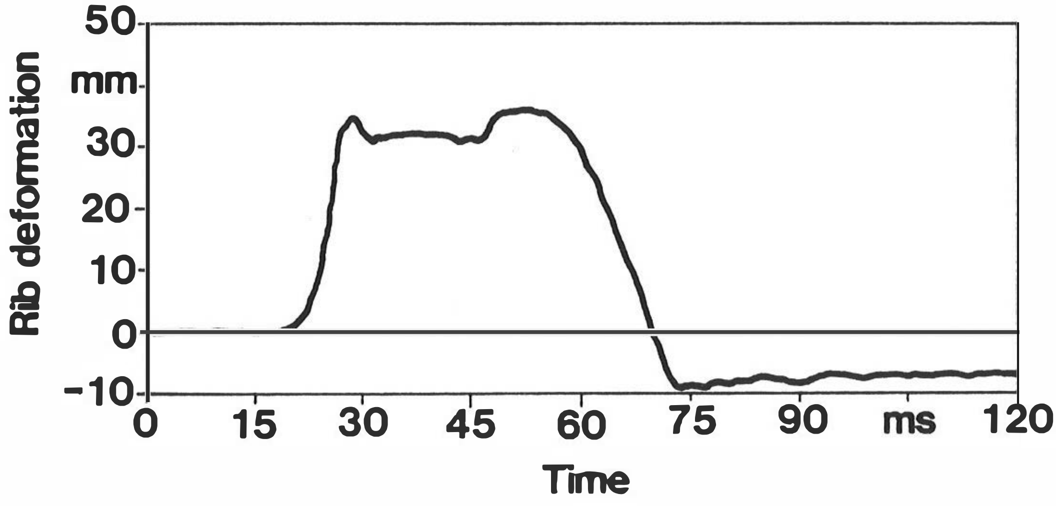


Figure 3: Examples of rib deformation curve minima

Several curves show constant maxima for durations of 15 to 2o ms (Figure 4).

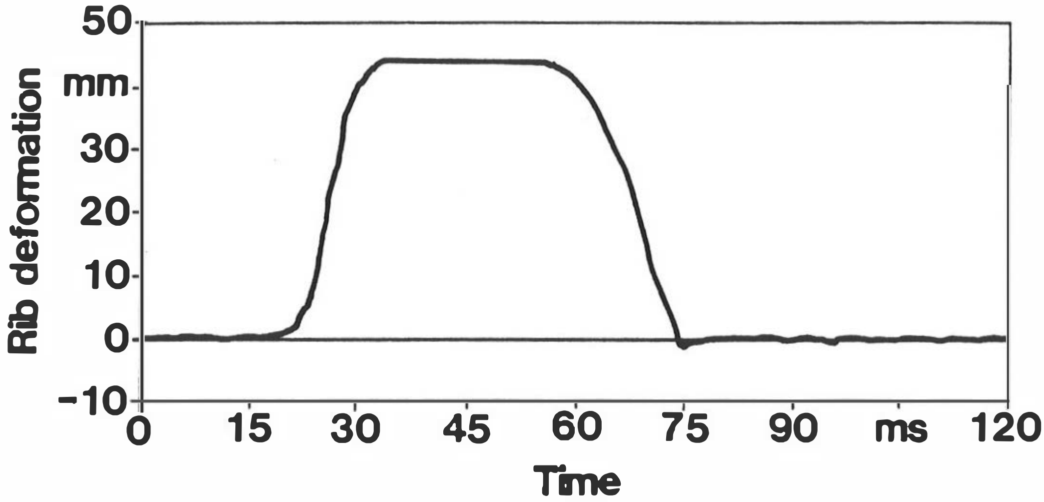


Figure 4: Example of a constant rib deformation maximum

This phenomenon seems to be caused by Coulomb's friction resulting in random measurements unsuited for the evaluation of rib deformations. The two results showing offsets after the tests are due to failures of the optoelectronic deformation elements. The measured values could be corrected only because additional rib acceleration measurements had been performed allowing to determine the rib deformation by double integration and use of a 'TNO correction procedure'.

The function of the abdominal contact switches is not plausible either. At each of the three test speeds (4o, 45, 5o km/h) switches 1 and 3 closed at least once while the directly loaded switch 2 was never found to close.

At some measuring points excessively great scatters were observed so that no reliable statements on the compliance or non-compliance with given load values were possible. **Table 1** lists the mean values and standard deviations recorded at some of the measuring points.

			mean value	standard deviation	mean value	standard deviation	mean value	standard deviation
Impact speed		(km/h)	49.95	0.42	44.40	0.50	40.33	0.20
Deformation Upper Rib	max	(mm)	38.37	6.39	43.42	2.12	36.07	6.36
Deformation Middle Rib	max	(mm)	44.47	3.25	44.47	0.12	43.19	4.09
Deformation Lower Rib	max	(mm)	46.80	2.04	42.14	2.27	46.48	3.81
Acceleration T 1 res	3 ms	(g)	116.34	12.98	96.12	17.50	96.79	10.36
Acceleration T 12 res	3 ms	(g)	117.81	10.36	93.21	6.02	95.18	5.59
Acceleration Pelvis res	3 ms	(g)	112.49	9.09	89.59	11.94	84.65	5.58
Iliac Wing Force Impacted Side	max	(kN)	3.18	0.65	1.54	0.32	2.07	0.10
Iliac Wing Force Opposite Side	max	(kN)	0.54	0.16	0.84	0.55	0.32	0.07
Pubic Force	max	(kN)	5.54	0.40	6.42	1.23	5.19	1.06

Table 1: Mean values and standard deviations at some measuring points (CCMC tests)

To evaluate the dummy's sensitivity to different impact energies a detailed analysis of the mean values obtained at 4o, 45 and 5o km/h has been performed taking into account dummy/vehicle contact speeds of 11 m/s to 14 m/s. The results of this analysis are uninterpretable: In some cases, high loads occur at low speeds and the rib deformations are apparently independent of the impact speed (**Figure 5**).

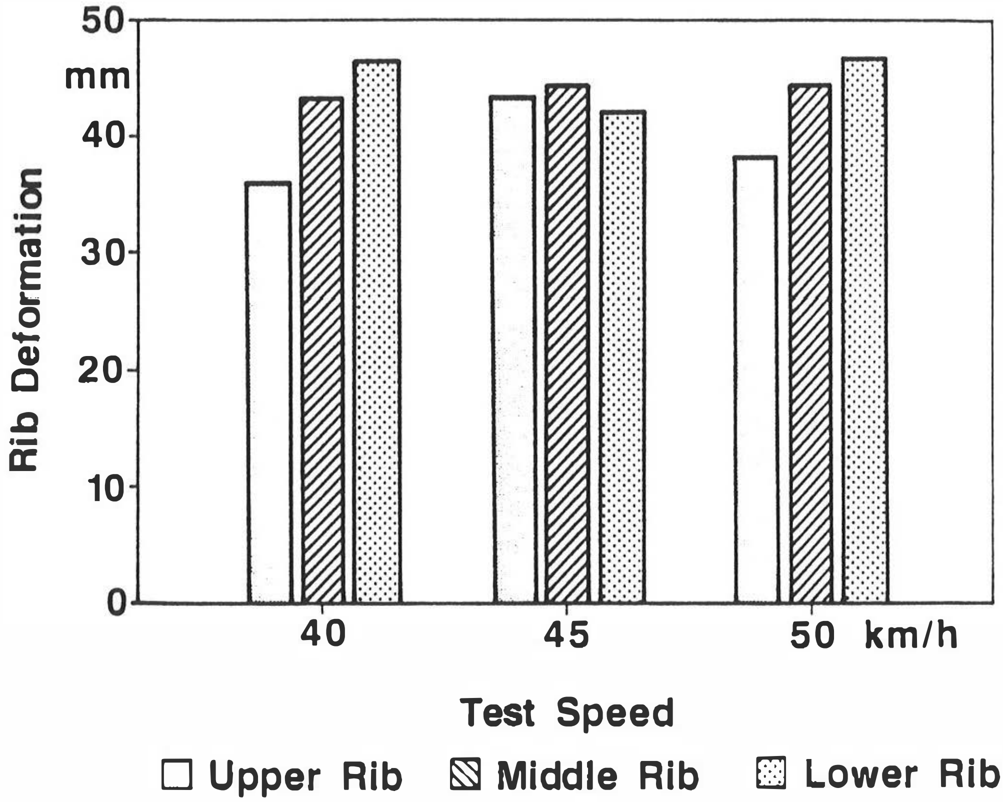


Figure 5: Examples of dummy rib structure sensitivity

4.2 Results of FAT-TNO joint test program

The dummy passed 5 tests undammaged; in the 6th test the neck broke and the head fell off after the rebound phase.

During this series of tests the same failures occurred as described under item 4.1 even though a different dummy was used and the tests were performed by a different institute applying a different measuring technique. Examples are shown in **Figures 6 + 7**.

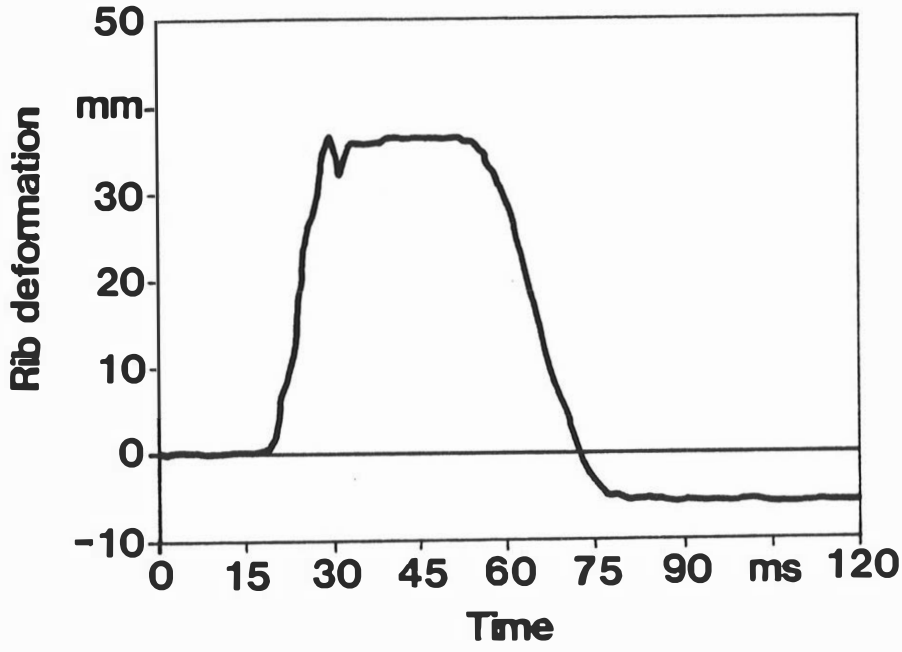


Figure 6: Negative offset after testing

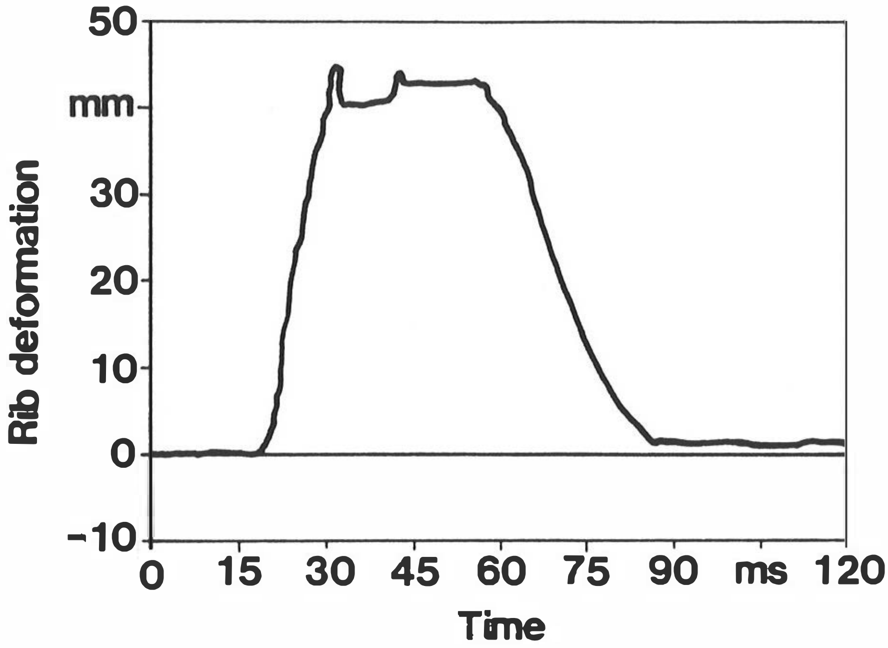


Figure 7: Sudden deformation curve drop

In two of three tests with the CCMC deformation element the center abdominal switch recorded a contact. When using the NHTSA element no closing of the contacts was registered even though high abdominal forces had been expected due to the indirect load produced by the bumper through the door. The forces acting on the pelvis as well as the accelerations at the pelvis center of gravity, at thoracic vertebra no. 12, and at the lower rib are partly significantly higher than those measured with the CCMC element so that the response of the abdominal switches cannot be understood.

Also in this test series some measuring points show considerable scatters. This means that even three identical tests do not furnish any reliable information on the compliance or non-compliance with the stipulated load limits (**Table 2**).

			mean value	standard deviation	mean value	standard deviation
			C C M C		N H T S A	
Deformation Upper Rib	max	(mm)	44.24	2.43	21.48	NA*
Deformation Middle Rib	max	(mm)	45.25	1.46	26.70	4.69
Deformation Lower Rib	max	(mm)	46.21	1.07	26.07	3.68
Acceleration T 1 res	3 ms	(g)	59.66	6.96	86.33	6.13
Acceleration T 12 res	3 ms	(g)	98.68	9.21	112.73	17.72
Acceleration Pelvis res	3 ms	(g)	117.47	9.43	151.00	20.61
Iliac Wing Force Impacted Side	max	(kN)	4.19	0.46	4.46	1.49
Iliac Wing Force Opposite Side	max	(kN)	1.08	0.12	0.89	0.20
Pubic Force	max	(kN)	9.24	2.45	19.30	2.91

* Data available from two tests only

Table 2: Mean values and standard deviations at selected measuring points (NHTSA tests)

4.3 Heidelberg tests versus FAT-TNO tests (CCMC tests)

This comparison was meant to find out whether there are any differences between the results obtained with different EUROSID dummies at different test institutes under identical test conditions (reproducibility). The test conditions have been found to be reproducible. The criteria used for comparison were the deceleration of the barrier simulating the impacting car and the door intrusion of the impacted vehicle.

As can be seen in **Figures 8 + 9**, there is no great difference between the measured results which means that the CCMC deformation element and the vehicle structure furnish load values of the same order of magnitude. Consequently, the differences between the dummy values are due to different behaviours of the two EUROSID dummies.

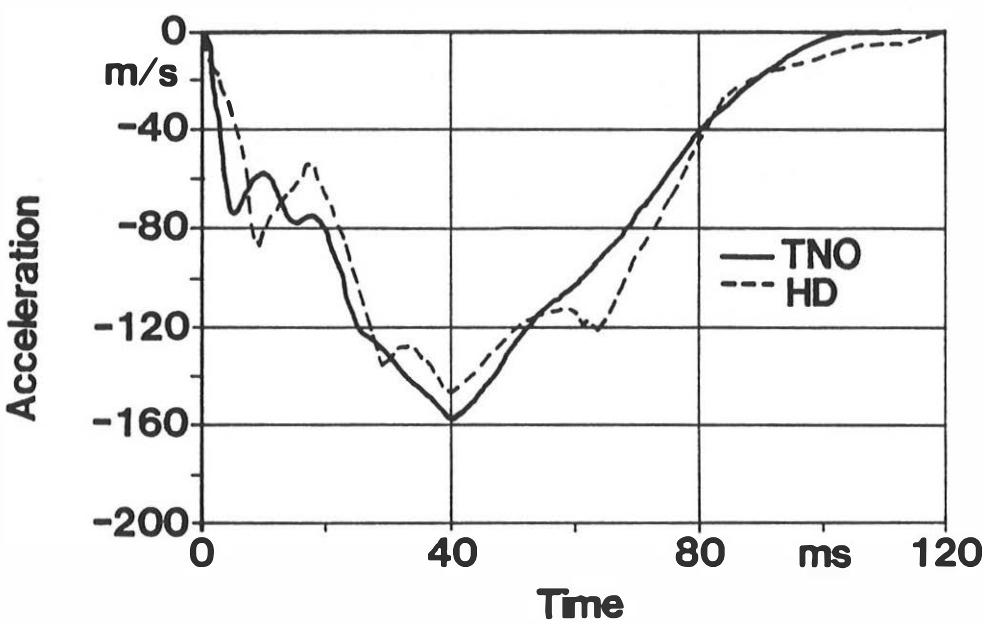


Figure 8: Comparison of the CCMC barrier deceleration/time histories

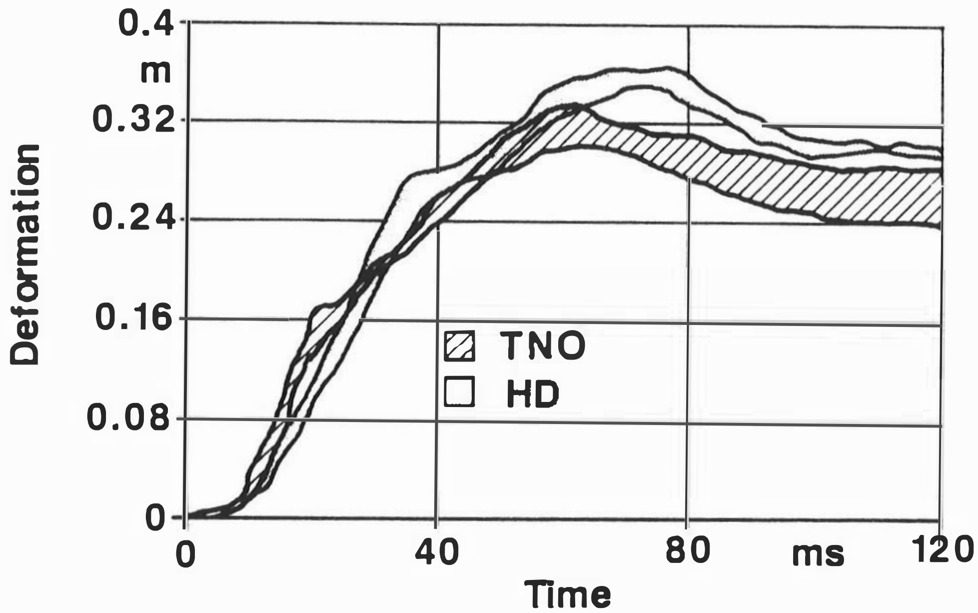


Figure 9: Door intrusion time histories of the Opel Kadett vehicles

5. Conclusions

The evaluation of the EUROSID dummy after a total of 21 full-scale side impact tests shows that the dummy in its present configuration is unsuited for compliance development testing. The quality of the measuring instruments at the ribs and abdomen does not meet the standards applied in automotive industry.

The rib design must be changed so as to eliminate any Coulomb's friction effects. The factors responsible for the pelvis force scatters must be eliminated as well.

The above-mentioned deficiencies must be remedied before continuing to use the EUROSID. The dummy producers will have to prove that the modifications are efficient, providing the users with a reliable test device. Additionally, it is to be demonstrated in full-scale tests that the dummy is responsive to structural changes or padding modifications.

6. References

1 The European Side-Impact Dummy 'EUROSID'
Commission of the European Communities, 1986
Report EUR 1o779 EN

2 Belastbarkeitsgrenzen und Verletzungsmechanik des angegurteten Fahrzeuginsassen beim Seitenaufprall, Phase I;
FAT-Schriftenreihe Nr. 36

3 See 2, Phase II; FAT-Schriftenreihe Nr. 6o

4 The CCMC Mobile Deformable Barrier for Lateral Collision Testing;
CCMC Working Group Crashworthiness; 1oth ESV-Conference, Oxford, 1985

5 Preliminary Regulatory Impact Analysis - New Requirements for Passenger Cars to Meet a Dynamic Side Impact Test, FMVSS FMVSS 214; U.S. Department of Transportation, DOT HS 8o7 22o
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6 FAT-TNO Cooperation in EUROSID Side Impact Tests;
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