CRASH TEST VARIABILITY
DUMMY AND VEHICLE RESPONSES

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ABSTRACT

Eight frontal rigid barrier impact tests with one car type were carried out on the test facility of the BASt. The tests were performed in accordance with the draft regulation of the Group of Rapporteurs on Crashworthiness (GRCS) of the Economic Commission for Europe concerning occupant protection in the event of head collisions.

The goal of the test series was to determine the variances of the measured values on the vehicle and on the dummies.Measurements on the vehicle revealed coefficients of variation for the individual values at 2 - 7%. In the case of the measured values for the dummies, a distinction is to be made as to whether they were assumed to have impacted against parts of the vehicle interior or not. Without impact the coefficients of variation of the HIC and SI protection criteria were 10-13%. If an interior impact takes place, the corresponding measured values are, of course, higher. For the head accelerations (maximum values and the 3 ms values) of the dummy in the driver's seat, coefficients of variation of 19 and 13% were measured, while a value of 22% was measured for the HIC. For the thorax the corresponding values for acceleration were 45 and 30% and for the SI they were 33%. In the right femur of the dummy in the passenger's seat, there was an impact between the knee and the instrument panel in every test. In this case the coefficient of variation was 28%.

Knowing the variances of crash test results, design limits can be established to achieve that, in standard tests, dummy measuring values remain within a defined probability below the legal performance criteria limits.

Although the number of tests conducted for statistical analyses is still too low, some design limits are specified in the assumption of a normal distribution of the measuring data.

INTRODUCTION, OBJECTIVE

Regarding the reproducibility of data measured for standardized collision tests, very different data were obtained from different sources.
The BASt has so far conducted two test series with a relatively high number of test configuration repeats. In a research project to determine the interaction loads of vehicle occupants in various impact situations [1][1], the vehicle-ve-

[1] *Number in parentheses designate references at end of paper*

hicle collision configurations were each repeated five times.Deviations from the mean values of 20 to 70% were observed, depending on the collision situation.
As part of the studies conducted by the Forschungsverbund Biomechanik (KOB) [2], a real accident simulated by the Peugeot-Renault Association in three preliminary, dummy and cadaver tests was simulated by three dummy tests conducted by the BASt. The measured scatter ranges were of the same order of magnitude as those of the interaction tests.
Compared with the car to car collision, the vehicle collision against the rigid wall represents a very much simplified type of test which could be expected to produce narrower scatter ranges for the measured values. An examination of available literature reveals that only a small number of research studies have so far been published on the subject "scatter of measured values in standard collision tests".

As part of the studies for the CCMC (Comité des Constructeurs d'Automobiles du Marché Commun), various test series known as "round-robin tests" were conducted by the members of the Federation. The results were published e.g. at the 6th and 7th ESV Conference. Despite the often high number of tests performed, a specific test configuration with a specific vehicle type was not repeated more than three times.

Under the guidance of the FORD/USA [3], three different laboratories conducted 33 full scale air bag tests with a single vehicle type.Since various test configurations were also applied here (9 side impact tests, 24 tests against the rigid 30° and 90° barrier), each collision type was only examined some three or four times. Different statistical methods were applied to obtain the estimate of variance. The work was conducted with the objective of determining producers' design limits and working limits from the performance criteria in the Federal Motor Vehicle Safety Standards (FMVSS 208) and the ranges of scatter to be expected.
The approach was as follows:
[Design limit] = [Upper tolerance limit] - k*[Standard deviation].
The limit values obtained depend considerably on the assumptions made (e.g. number of degrees of freedom of test type) and the statistical methods applied to determine the k-values and the standard deviation.

Crash test results represent on the one hand data distributed in some form or other (e.g. Gaussian distribution) and on the other hand discrete data caused by failures of subsystems of the car (e.g. head impacts which are not observed in all tests). The statistical calculation of the required number of random sampling tests leads to such a high number of tests that they could probably never be conducted [4]. Indeed, even a test of normal or log-normal distribution of the measured data requires around 30 - 50 tests to be conducted, depending on the assumptions made and the methods employed [4].

The presented study had the objective of conducting as many, for the most part identical, tests as possible and to use these to determine reliable, experimentally derived ranges of scatter which are as reliable as possible. Time and cost considerations meant that the number of tests had to be restricted to eight.

TEST METHODOLOGY

The tests were conducted according to the regulation draft for a "global test" as drawn up by the Economic Commission for Europe, Group of Rapporteurs on Crashworthiness (ECE/GRCS) [5]. The test vehicles were driven at a speed of 50 km/h against a rigid barrier whose face was set at an angle of 30° (around a vertical axis) to the plane which is perpendicular to the longitudinal axis of the vehicle, so that the driver side of the test vehicle struck the face of the barrier first. The Opel Kadett D produced from 1979 - 1985 was selected for the test vehicle. 1 - 2 year-old second-hand vehicles were used in order to minimise costs.

The mass of the prepared test vehicles (excluding dummies) was 835±5kg. Two 50% male dummies calibrated according to US-specification PART 572 were positioned in the front seats. In all tests the same dummy was located on the same seat. The front seats were shifted 50 mm to the front from the rearmost seat position, in accordance with [5]. Filming of the tests, transducer calibration, as well as filtering, transmission and analysis of the measured data were performed in accordance with the valid regulations and standards. Evaluation of the test vehicle behaviour was not restricted to ECE/GRCS criteria, but also included:

- Requirements of the GRCS draft,
- Additional requirements:
- Comparison with the criteria of ECE regulations 33; 12 [6],
- Presentation of the most important variables for vehicle accelerations (mean deceleration, maximum deceleration, length of deceleration),
- Measurement of the permanent crush of 13 measuring points on the front of the vehicle.

The following criteria were used for assessing the dummy measured values:

- Performance criteria limits of the GRCS draft:
  - Head: HIC < 1000, but calculated here solely for the duration of contact
  - Thorax a_{res} < 60 g/3 ms
  - Femur: Longitudinal forces < 10kN
  - Abdomen: No submarining

- Additional measured values often used in scientific literature
  - Head: HIC, without impact, a_{res} max, a_{res}/3 ms
  - Thorax a_{res} max, SI
  - Pelvis: a_{res} max, a_{res}/3 ms
  - Belt forces: Shoulder belt top and bottom, lap belt left and right on both dummies.

RESULTS

As already mentioned above, 8 tests is a very low figure for a statistical evaluation. The following variables are required in order to be able to characterise single-dimension frequency distributions [4]:

- Dimensions for the mean value of a distribution,
- Dimensions indicating the variability of the distribution,
- Dimensions specifying the deviation of a distribution from the standard Gaussian distribution.

The standard distribution is widely used in the technology sector to describe frequency distributions. The measuring results of this study cannot be tested for standard Gaussian distribution e.g. by means of the CHI^2 fitting test [4] due to the low number of tests involved. For most criteria, however, there is nothing to suggest that the normal Gaussian distribution should not be assumed, this normal distribution is therefore being used to characterise the frequency distribution of the various measured values. The following dimensions are used in the tables in describing the distributions of the individual parameters:

- Arithmetic mean ($\bar{x}$), $[\bar{x} = \Sigma x^i / N]$

- Standard deviation (SD), $\left[\sqrt{\frac{(\bar{x} - x)^2}{N - 1}}\right]$

- Coefficient of variation (CV), $[^s/_x \; 100 \; [\%]]$

- Minimum and maximum (min., max.).

Vehicle-Related Measurements

The test speed of 50 km/h (+0, -2 km/h) required in the draft standard [5] could be achieved very accurately with measured values of between 49.9 and 50.0 km/h. The final position of the test vehicle revealed a lateral displacement of around 0.5 to 0.8 m to the right of the starting direction.

Vehicle Deformation

The deformations of the vehicle front were recorded using a measurement frame by determining the displacement of 13 target points, see Fig. 1.

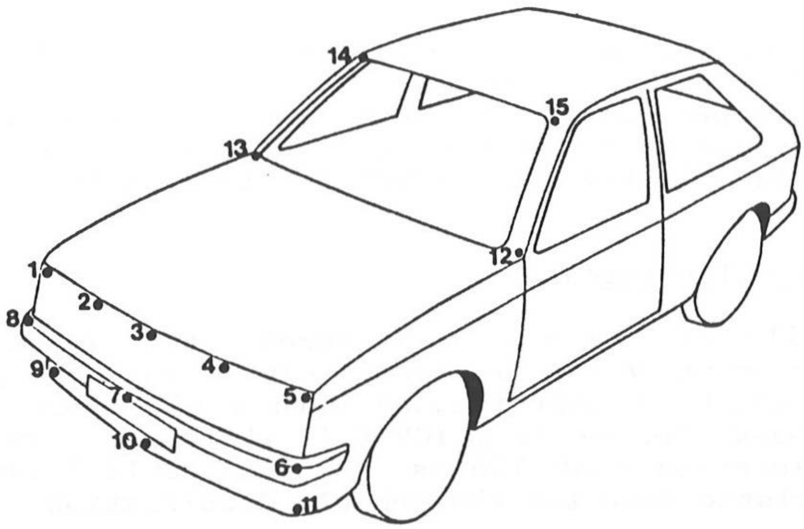

Fig. 1 : Position of the target points for determining the deformations of the vehicle front

Due to the fact that individual non-supporting metal or plastic body parts spring back towards their original position (elastic property), not all test points are directly suitable for providing a correct measurement of the residual vehicle deformations.
These encompass test points with a low displacement of 15 mm - 30 mm, and points 1,8,9 which display the highest CV(53 -75%).
The displacements in the test points on the left-hand side of the vehicle, see Table 1, are considerably more pronounced, in line with the test constellation.

The CV here are around 2 - 10%, while the points showing the largest displacement of 576 and 583 mm (6 and 11) have a CV of around 2 - 4%.

Table 1: Distribution Characteristics of the Horizontal Displacements (in mm) of Selected Test Points

Test Point	4	5	6	7	10	11
min.	277	437	561	274	204	544
max.	335	569	533	283	251	606
$\overline{x}$	309	473	576	282	233	583
SD	19	46	10	6	16	21
CV (%)	6	10	2	2	7	4

Table 1A in the Appendix provides a summary of all measured values. The further results are presented in the same way. Selected test parameters variables and their dispersion measures are summarised in the tables in the text. All measured values are contained in the corresponding tables in the Appendix.

Vehicle Accelerations

The profile of the resultant acceleration of the vehicle's centre of gravity can be adequately described by an oblique triangle which is superimposed with a vibration of around 80 Hz. The peak lies at 35 g (CV 6%), the base - the duration of the deceleration - at 125 ms (CV 2%). Table 2 summarises the characteristic data for the vehicle deceleration.

Table 2: Characteristic Values of the Resultant Vehicle Acceleration

Parameter	$\bar{a}$ (g)	ΔT (ms)	a_{max} (g)	$T(a_{max})$ (ms)	Δv (m/s)
$\bar{x}$	11.3	125	35.3	79	14.6
SD	0.24	2.9	2.3	6.7	0.2
CV (%)	2	2	6	8	2

$\bar{a}$ = Mean acceleration
ΔT = Duration of acceleration
a_{max} = Maximum acceleration
$T(a_{max})$ = Time of maximum acceleration after start of crash
Δv = velocity change via integration of acceleration

Since the horizontal penetration of the steering column according to ECE 12 could only be determined from high speed filming with a high degree of uncertainty and the deformations of the passenger compartment were very low (the measured values were well below the limit values specified in ECE regulation 33) these variables will not be discussed in any greater detail.

Dummy Measured Values

As a result of the rotation and lateral displacement of the test vehicles, the passengers also experience a considerable lateral acceleration to the right towards the end of the vehicle deceleration (unlike in 0% longitudinal crashes). Slight contact between the steering wheel and the head of the driver dummy was suspected in two tests, and additional contact between the thorax and the steering wheel in another test. However, none of these contacts could be proven. Analysis of the tests using film recordings proved very difficult since, according to the ECE/GRCS draft, all windows have to be fitted

and in closed position and no cameras are allowed to be attached to the vehicle.
Tables 3 and 4 summarise the head loading values for the driver and passenger dummies. Since no contact could be proved with certainty, the HIC was not determined according to the ECE/GRCS draft regulation (for duration of contact only), but instead for the entire duration of the resultant acceleration (FMVSS 208).

Table 3: Head Loading Values of Driver Dummy

a_x, a_y, a_z - acceleration components

Parameter	a_{res} max. (g)	a_{res}/3 ms (g)	HIC	a_x max. (g)	a_y max. (g)	a_z max. (g)
min.	48	45	545	-42	+ 4	-34
max.	80	62	940	-61	18	-59
$\overline{x}$	57	51	682	-51	—*	-43
SD	11	7	152	5.8	—*	8.6
CV (%)	19	13	22	12	—*	20

* see text

Table 4: Head Loading Values of Passenger Dummy

a_x, a_y, a_z - acceleration components

Parameter	a_{res} max. (g)	a_{res}/3 ms (g)	HIC	a_x max. (g)	a_y max. (g)	a_z max. (g)
min.	40	38	422	-26	-10	-30
max.	52	51	589	-42	-26	-43
$\overline{x}$	44	43	509	-34	-16	-35
SD	4	4	68	5.9	5.0	4.0
CV (%)	9	10	13	17	31	11

The mean head accelerations and the HIC values for the driver are higher than for the passenger (the respective values are 51 g and 43 g for the 3 ms values). This was due partly to the fact that in a number of cases, namely tests 6 and 8, slight contact was suspected between the driver's head and the steering wheel, and partly because the movements of the two front-seat dummies were different as a result of the vehicle rotation. This is revealed in the list of characteristic values for the individual components of the head accelerations. While the passenger displays maximum values of around 35 g in x and z directions of acceleration and 16 g in the y direction of acceleration, the corresponding values for the driver were 51 g and 43 g in x and z directions. The lateral accelerations of the driver's head could not be characterised with certainty. The ranges of scatter of the resultant head acceleration values were also considerably higher for the driver than for the passenger [CV of 19% (max.) and 13% (3 ms value) for the driver and 9% and 10% respectively for the passenger]. The CV of the driver dummy HIC is around 22%, and that of the passenger dummy around 13%. If tests number 6 and 8 are ignored, however, the CV of the HIC for the driver and passenger dummies are almost identical (see Appendix, Table 3B).

Tables 5 and 6 provide summaries of the <u>thorax loading values</u> for the driver and passenger dummies.

<u>Table 5:</u> Thorax Loading Values of the Driver Dummy

Parameter	a_{res} max. (g)	a_{res}/3 ms (g)	SI	a_x max. (g)	a_y max. (g)	$a_z$max (g) 1.max.	2.max.
min.	35	34	208	-32	- 8	-13	13
max.	96	71	502	-39	-15	-19	21
$\overline{x}$	46	41	280	-36	-13	-16	17
SD	21	12	93	2.3	2.3	2.5	2.7
CV (%)	45	29	33	6	18	16	17

<u>Table 6:</u> Thorax Loading Values of the Passenger Dummy

Parameter	a_{res} max. (g)	a_{res}/3 ms (g)	SI	a_x max. (g)	a_y max. (g)	$a_z$max. (g) 1.max.	2.max.
min.	39	38	282	-30	-23	-10	10
max.	44	43	363	-37	-31	-19	18
$\overline{x}$	42	40	315	-33	-26	-15	14
SD	2	2	32	3.0	2.5	3.3	3.4
CV (%)	5	4	10	9	10	22	25

The mean thorax accelerations of the driver were higher than those of the passenger - namely 46 g (max.) and 41 g (3 ms values) as opposed to 42 g and 40 g respectively. Once again, the transverse accelerations were more pronounced for the passenger than for the driver. The vertical accelerations are characterised by two maximum values with different signs. The belted dummies are first accelerated downwards and are then thrust upwards again.
Here, too, the ranges of scatter for the resultant driver accelerations of 45% and 29% lie considerably over those of the passenger (5% and 4% respectively). The large differences in the CV are primarily attributable to the values of one test (No. 6) in which the thorax was suspected of coming into contact with the steering wheel.
If one disregards the results of test No. 6, the ranges of scatter are once again more or less equal (see Appendix, Table 5B).

Table 7 shows the longitudinal forces on the femur for the driver and passenger dummies. The vehicle motion and the frictional forces between the dummies and the seats caused both dummies to rotate to the left in relation to the vehicle, so that both dummies moved forwards in the vehicle with their right legs first.
Knee impact with high forces acting on the femur were therefore observed primarily in the right-hand leg.

Table 7: Maximum Longitudinal Forces on the Femur of the Driver and Passenger Dummies

Parameter	Longitudinal Forces on Femur (kN)			
	Driver Dummy		Passenger Dummy	
	left	right	left	right
min.	0.5	1.0	0.8	4.8
max.	4.4	6.1	3.6	9.2
$\overline{x}$	1.5	3.8	1.5	6.0
s	1.4	2.4	1.1	1.7
CV (%)	94	63	74	28

Tables 8A, 9A, 10A and 11A in the Appendix provide a summary of the pelvic loads and the belt forces for the driver and passenger dummies.

Since the forces acting on the femur also react on the pelvis and the belt forces, it is best to examine these parameters together.

The high scatter levels of 94 and 74% observed in the forces in the left-hand femurs of the driver and passenger can be explained by the fact that knee impact only occurred in one or two tests. If knee impact occurs in every test (in the passenger dummy), however, the variances are considerably lower at 28%. The forces in the femur were higher in the passenger dummy than in the driver dummy due to the larger displacement experienced by the passenger dummy: namely 6.0 $\pm$ 1.7 kN , of the driver dummy 3.8 $\pm$ 2.4 kN respectively.

The <u>pelvic accelerations</u> were also correspondingly higher in the passenger dummy: 47 - 48 g compared to 35 g. The occasional knee impacts in the passenger dummy also resulted in higher scatter levels in the pelvic accelerations (see e.g. <u>Table 4</u>, test 8). Nevertheless, the coefficients of variance remain below 10%. The level of the longitudinal force on the femur also had a significant effect on the passenger's lap belt. A supporting force acting on the dummy's knee lowers the lap belt force (see tests 2 and 8, Tables 4 and 14). High variance levels of 29 and 64% were therefore observed at the lap belt test point near the belt buckle. The scatter levels in the shoulder belt were around 6 - 11%.

Conclusions

The dispersion measures determined can be used for estimating design limits. The standard deviation, the coefficient of variance and its scatter factors p can be used to describe specific ranges - "confidence intervals" - with the limits (e.g. for a specified standard deviation) $x \pm p \cdot s$ in which a given percentage of measured values is to be expected. Assuming a standard Gaussian distribution, the value for p is 1.645 for a one sided confidence interval of 95% (95% of all expected measured values lie below the scatter range limit). If the upper limit value is set, for example, to a performance criterion which is defined in standards and regulations and which must not be exceeded on dummies, this allows estimated values to be specified for development goals (design limits). Table 8 summarises the estimated values for a number of performance criteria using the variances determined in this investigation. Because is it not known what happens to the scatter of test results when a prototype car is modified in the develop phase: does the standard deviation remain constant or does the coefficient of variation remain constant, for both dispersion measures development goals (design limits) are calculated. It is necessary to point out, however, that only one vehicle type was used. It is therefore not possible to state whether characteristic scatter levels with the same standard deviation or same coefficient of variance would be obtained for other vehicles with other mean values (x).

Table 8: Estimated Values for Protection Criteria Measured on Dummies (Calculated with Various x and s which are not rounded off)

Dummy part		Driver dummy Head	Thorax	Femur		Passenger dummy Head	Thorax	Femur	
Performance criterion		HIC = 1000	60 g/ 3 ms	10 kN left	right	HIC = 1000	60 g/ 3 ms	10 kN left	right
Deve-lopment goals	SD = const.	751	40.0	7.7	6.1	887	57	8.1	7.3
	VC = const.	732	40.4	-*	-*	819	56	-*	6.9

* Values cannot be specified since CV is too high

Higher scatter factors p are obtained for larger confidence intervals, e.g. p = 2.326 for 99%; p = 3.090 for 99.9%. The development goals are to be set correspondingly lower for larger confidence intervals.
There are a number of indications that the measured values for the dummy, e.g. HIC and 3 ms values, do not follow a strict standard distribution. Physical factors relating to vehicles today (vehicle deceleration path, passenger compartment dimensions) mean that HIC values for vehicle occupants are generally not below around 250, while high values are possible for impacts against more rigid vehicle structures. Furthermore, the HIC values and, to a less extent, the 3 ms values are governed by the form of the acceleration curve. The fact that the maximum resultant acceleration assumes a power of 2.5 in the HIC calculation means that significant deviations from a standard distribution (e.g. a log-normal distribution) are possible. Suitable average values with appropriate variances can then result in different, generally somewhat lower, estimated values for the development goals.
Suitable transformation methods have not yet been introduced. It therefore appears necessary to continue examining the statistical methodological problems relating to impact test variance.

Summary

8 vehicle crash tests were performed at the crash-test facility of the BASt in accordance with the draft regulation drawn up by the Group of Rapporteurs on Crashworthiness (GRCS) of the Economic Commission for Europeconcerning frontal impact.

The project had the goal of determining the dispersion ranges of measured values for vehicles and dummies involved in frontal impact crash tests at a speed of 50 km/h against the rigid 30° barrier.

The measured values for the vehicle revealed coefficients of variance for the individual values which, at 2 - 7%, were well below a 10% level. When examining the measured values for the dummies, it is important to differentiate whether an impact against inner parts of the vehicle was suspected or not. Disregarding the tests with suspected impact against inner parts, coefficients of variance of around 10% and in some cases significantly lower levels, were revealed in the head, thorax and pelvic accelerations. The coefficients of variance of performance criteria HIC and SI were 10 - 13%.

If impact occurs between

- head and steering wheel (driver)
- thorax and steering wheel (driver)
- knee and instrument panel (driver and passenger),

the corresponding measured values are naturally higher. The standard deviations of the measured values are higher if these impacts cannot be observed in all tests. Coefficients of variation of 19 and 13% were measured for the head accelerations (maxima and 3 ms values) and 22% for the HIC for the driver dummy. The corresponding values for the thorax amounted to 45 and 30% for the acceleration and 33% for the SI. These high ranges of scatter were due to the fact that, in one test, the dummy was displaced forwards an unusually large distance due to an inefficient belt, this resulting in contact between the thorax and steering wheel.
In each test, impact was observed between the right-hand knee of the passenger dummy and the instrument panel. The coefficient of variance here was 28%.
The question as to how the scatter of the measured values in full scale impact tests is to be considered in legal regulations still requires clarification.

References:

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[5] Economic Commission for Europe, Draft Regulation: Uniform Provisions Concerning the Approval of Private (Passenger) Cars With Regard to the Protection of the Occupants on the Event of Head-On Collisions, GRCS TRANS,SC 1, WP 29 R. 23 of 9.5.1980 and 10.6.1981

[6] ECE regulations

APPENDIX:

Table 1A: Horizontal Displacement of the Deformation Test Points (see Fig. 1 for Position of Points)

Test Point / Test No.	1	2	3	4	5	6	7	8	9	10	11	12	13
1	7	58	119	277	569	561	277	-28	3	251	544	24	2
2	7	51	155	315	518	593	288	-13	11	244	560	43	9
3	23	76	123	285	437	581	274	-5	56	231	590	26	6
4	27	86	153	321	451	564	276	-17	57	204	606	27	2
5	17	26	143	335	457	573	282	-20	22	220	579	23	7
6	13	55	144	307	457	577	289	-2	7	242	596	33	7
7	9	40	144	315	444	578	284	-20	28	228	591	24	3
8	13	60	244	319	449	582	288	-15	36	244	594	19	-2
$\bar{x}$ / SD	15/ 7	57/ 19	153/ 39	309/ 19	473/ 46	576/ 10	282/ 6	-15/ 8	28/ 21	233/ 16	583/ 21	27/ 7	4/ 4
CV (%)	51	33	25	6	10	2	2	56	76	7	4	27	85

Table 2A: Characteristic Data of Resultant Vehicle Deceleration

Parameter / Test No.	Mean deceleration (g)	Duration of deceler. (ms)	Maximum deceleration (g)	Instant of max. deceler. (ms)	Δv* (m/s)
1	11.2	126	35.3	79	14.8
2	11.0	129	34.6	69	14.7
3	11.1	128	36.4	86	14.7
4	11.6	122	38.9	85	14.8
5	11.4	124	31.1	69	14.9
6	11.7	121	34.6	81	14.3
7	11.2	127	36.7	82	14.3
8	11.4	124	36.7	83	14.6
$\bar{x}$/SD	11.3/0.24	125/2.9	35.5/2.3	79/6.7	14.6/0.2
CV (%)	2	2	6	8	2

*Δv - Change of speed in test, determined from the integral of the acceleration signal

Table 3A: Characteristic Data of Head Accelerations of the Dummy in the Driver's Seat, Maximum Values and Times After Start of Impact

Measuring Variable / Test No.	x-acceleration		y-acceleration*		z-acceleration	
	max. (g)	time (ms)	max. (g)	time (ms)	max. (g)	time (g)
1	-56	118	+ 5	-	-46	85
2	-48	127	+7/-4	-	-41	87
3	-47	126	+ 4	-	-34	88
4	-49	122	+9/-5	-	-36	101
5	-53	116	+4	-	-37	102
6	-51	115	+18	106	-59	106
7	-42	133	+4/-6	-	-42	87
8	-61	116	+11/-7	-	-52	103
$\bar{x}$ / SD	-51/5.8	122/6.5	-	-	-43/8.6	95/8.8
CV (%)	12	5	-	-	20	9

* Curve cannot be characterised clearly

Table 3B: Head Accelerations for Driver Dummy without Tests 6 and 8

Measuring Variable	Head acceleration (g)		HIC
	ares max.	ares / 3 ms	
$\bar{x}$	52	47	607
SD	4.9	2.4	71
CV %	9	5	12

Table 4A: Characteristic Data of Head Accelerations of the Dummy in the Passenger Seat, Maximum Values and Times After Start of Impact

Measuring Variable / Test No.	x-acceleration max. (g)	time (ms)	y-acceleration max. (g)	time (ms)	z-acceleration max. (g)	time (g)
1	-40	131	-10	122	-32	81
2	-32	132	-16	122	-35	111
3	-42	135	-11	124	-38	119
4	-29	137	-15	132	-35	114
5	-29	130	-18	130	-34	106
6	-39	130	-14	130	-33	89
7	-26	134	-18	136	-30	112
8	-36	133	-26	132	-43	115
$\bar{x}$ / SD	-34/5.9	133/2.5	-16/5.0	129/5.2	-35/4	106/14
CV (%)	17	2	31	4	12	13

Table 5A: Characteristic Data of Thorax Accelerations of the Dummy in the Driver's Seat, Maximum Values and Times After Start of Impact

Measuring Variable / Test No.	x-acceleration max. (g)	time (ms)	y-acceleration max. (g)	time (ms)	z-acceleration max.1(g)	time1(g)	max.2(g)	time2(g)
1	-39	82	-14	88	-16	79	17	121
2	-34	76	-14	91	-13	74	17	121
3	-32	78	-15	103	-13	77	15	119
4	-36	90	-8	109	-18	74	13	116
5	-38	93	-12	91	-14	74	21	95
6	-35	91	-13	83	-19	77	18	104
7	-36	84	-15	91	-19	71	18	106
8	-38	85	-12	91	-15	68	13	101
$\bar{x}$ / SD	-36/2.3	85/6.2	-13/2.3	93/8.4	-16/2.5	74/3.5	17/2.7	110/10
CV (%)	6	7	18	9	16	5	17	9

Table 5B: Thorax Accelerations for Driver Dummy without Test 6

Measuring Variable	Thorax acceleration (g) ares max.	Thorax acceleration (g) ares / 3 ms	SI
$\bar{x}$	39	37	248
SD	3	2.5	25
CV %	8	7	10

Table 6A: Characteristic Data of Thorax Accelerations of the Dummy in the Passenger Seat, Maximum Values and Times After Start of Impact

Measuring Variable / Test No.	x-acceleration		y-acceleration		z-acceleration			
	max. (g)	time (ms)	max. (g)	time (ms)	max.1 (g)	time1(g)	max.2(g)	time2(g)
1	-37	81	-23	83	-15	76	18	110
2	-33	82	-26	90	-10	79	10	110
3	-32	90	-24	91	-12	79	16	111
4	-30	89	-25	90	-14	79	14	111
5	-31	73	-31	93	-19	74	11	99
6	-37	79	-25	82	-15	70	12	114
7	-30	86	-24	97	-18	78	10	111
8	-36	89	-27	106	-19	72	18	110
$\bar{x}$ / SD	-33/3.0	84/6.0	-26/2.5	92/7.7	-15/3.3	76/3.5	14/3.4	110/4.4
CV (%)	9	7	10	8	22	5	25	4

Table 7A: Maximum Longitudinal Forces on Femur for the Driver and Passenger Seats

Measuring Variable / Test No.	Forces on femur max. (kN) Driver left	right	Forces on femur max. (kN) Passenger left	right
1	2.7	6.1	1.1	4.8
2	4.4	7.7	0.8	8.0
3	0.9	2.4	0.7	4.8
4	0.8	5.5	0.8	5.9
5	1.1	3.1	1.0	5.0
6	0.8	1.4	1.2	5.1
7	0.5	1.0	3.6	5.3
8	0.5	3.1	3.1	9.2
$\bar{x}$ / SD	1.5/1.4	3.8/2.4	1.5/1.1	6.0/1.7
CV (%)	94	63	74	28

Table 8A: Characteristic Data of Pelvic Accelerations of the Dummy in the Driver's Seat, Maximum Values and Times After Start of Impact

Measuring Variable / Test No.	x-acceleration max. (g)	time (ms)	y-acceleration max. (g)	time (ms)	z-acceleration max. (g)	time (g)
1	-32	73	-21	77	30	98
2	-27	76	-12	87	29	98
3	-27	79	-14	101	28	102
4	-31	77	-15	98	29	101
5	-31	79	-14	87	31	98
6	-30	79	-20	83	33	99
7	-31	84	-15	84	28	102
8	-30	76	-15	84	31	103
$\bar{x}$ / SD	-30/1.9	78/3.2	-16/3.1	88/8	30/1.7	100/2.1
CV (%)	6	4	20	9	6	2

Table 9A: Characteristic Data of Pelvic Accelerations of the Dummy in the passenger Seat, Maximum Values and Times After Start of Impact

Measuring Variable / Test No.	x-acceleration max. (g)	x-acceleration time (ms)	y-acceleration max. (g)	y-acceleration time (ms)	z-acceleration max. (g)	z-acceleration time (g)
1	-43	74	-21	74	32	93
2	-34	88	-22	84	30	95
3	-33	80	-20	86	27	102
4	-34	84	-22	89	28	109
5	-35	81	-20	84	35	97
6	-38	66	-24	70	33	96
7	-40	84	-23	83	31	104
8	-39	92	-27	91	38	96
x̄ / SD	-37/3.5	81/8.1	-22/2.3	83/7.2	32/3.6	99/5.5
CV (%)	10	10	10	9	11	6

Table 10A: Summary of the Maximum Belt Forces for the Driver's Seat

Measuring Variable / Test No.	Max. belt forces (kN) 1	2	3	4	Mean Values (kN) Shoulderbelt 1/2	Lapbelt 3/4
1	6.5	6.2	7.9	7.5	6.35	7.7
2	6.2	5.3	8.1	6.7	5.75	7.4
3	5.3	5.0	6.5	6.9	5.15	6.7
4	6.4	5.4	6.6	6.4	5.9	6.5
5	6.6	5.4	7.3	7.6	6.0	7.45
6	6.4	5.9	9.0	7.3	6.15	8.15
7	6.1	def.	2.5	6.6	—	4.55
8	7.8	5.1	6.2	6.4	6.45	6.3
x̄ / SD	6.4/ 0.7	5.5/ 0.4	6.8/ 2.0	6.9/ 0.5	6.0/ 0.4	6.8/ 1.1
CV (%)	11	8	29	7	7	16

with belt force test points

Table 11A: Summary of the Maximum Belt Forces for the Passenger Seat

Measuring Variable / Test No.	Max. belt forces (kN) 1	2	3	4	Mean values (kN) Shoulder belt 1/2	Lap belt 3/4
1	8.2	4.6	5.8	10.7	6.4	8.25
2	8.0	4.2	4.5	6.5	6.1	5.5
3	7.0	4.5	1.0	9.6	5.75	5.3
4	7.5	4.2	5.4	9.7	5.85	7.55
5	7.3	4.4	2.7	12.3	5.85	8.85
6	7.4	4.5	7.8	8.5	5.95	8.15
7	8.0	4.3	7.1	9.5	6.15	8.3
8	7.3	5.1	0.3	7.4	6.2	3.85
$\overline{x}$ / SD	7.6/ 0.4	4.5/ 0.3	4.3/ 2.8	9.3/ 1.8	6.0/ 0.2	7.0/ 1.8
CV (%)	6	6	64	20	4	26

with belt force test points