A NEW NECK INJURY CRITERION CANDIDATE FOR REAR-END COLLISIONS TAKING INTO ACCOUNT SHEAR FORCES AND BENDING MOMENTS

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ABSTRACT

It is generally accepted today that the cervical spine of a car occupant who is involved in a low-speed rear end impact may suffer from soft tissue neck injuries leading to long-term impairment. Therefore, to assess the risk of sustaining such injuries is a major issue in traffic safety, and various neck injury criteria are being discussed for this purpose.

In this study a new candidate for such an injury predictor, called Nkm, was developed. Results from a total of 37 sled tests with various car front seat models were evaluated to validate the new criterion. These results indicate that the new criterion offers the possibility to assess the kinematic phase of forward motion of a rear-end collision. In contrast, the NICmax which was also calculated for these tests allows to evaluate the retraction phase only. Furthermore, the influence of the seat design on its protective potential could be related to the Nkm values obtained.

INTRODUCTION

Considerable attention has been given to the subject of soft tissue neck injuries sustained during low speed rear-end collisions [Ferrari 1999]. Much of this attention has been focused on the biomechanical assessment in terms of injury criteria as they relate to occupant protection. Such criteria are indispensable for automotive design.

Since seats are the primary structure in direct contact with a car occupant, considerable research has been done to evaluate various concepts for safety seating systems that could, for instance, reduce the risk of neck injuries. Yet, for seat design in terms of crashworthiness not many design requirements are stipulated and only few neck injury criteria are available that could be used in seat development to obtain information about the crash performance of the seat.

To date, mainly three different neck-related criteria are proposed: NIC [Boström et al. 1996], Nij [Klinich et al. 1996, Kleinberger et al. 1998] and IV-NIC [Panjabi et al. 1999].

Hereof the NIC is probably the most widely used procedure to assess low-intensity neck loading. It assumes pressure aberrations inside the cervical fluid compartments that occur due to a swift extension-flexion motion (S-shape) in the early stage of a rear-end impact to be the injury causing phenomenon [Svensson et al. 1993]. By definition it correlates the relative acceleration and velocity of the occipital condyles vs. the first thoracic vertebra. However, limitations exist [cf. e.g. Boström et al. 2000, Muser et al. 2000] suggesting that only values obtained within approximately the first 150 ms of the crash are reasonable. Thus, solely the retraction phase can be evaluated using the NIC.

With regard to the Nij criterion, one finds that it was proposed to assess severe neck injuries in frontal impacts including those with air bag deployment. For low speed rear-end impacts the criterion turned out not to be a good measure [Linder et al. 2000]. Nonetheless, the underlying concept for the Nij [Prasad and Daniel 1984], i.e. the idea of combining loads and moments seems to be a reasonable approach when addressing neck injuries. Although the knowledge about mechanisms which may cause soft tissue neck injuries is still limited, it is commonly believed that the relative motion of head and neck influence the injury mechanism [e.g. Ferrari 1999, Walz and Muser 1995, Penning 1992]. Here combinations of loads and moments are observed, for instance, during S-shape formation, where the upper neck is exposed to shear force and a sagittal bending moment [e.g. Deng et al. 2000].

However, regarding the inability of the Nij to assess low-speed rear-end collision, the question is whether the forces and moments implemented in the Nij definition are chosen appropriately for this purpose. In particular the axial forces measured at the upper neck load cell of a dummy have to be dealt with carefully with respect to the accuracy of the measurement.

Significant inaccuracies can be introduced due to a lack of biofidelity of most dummies of today. None of the current dummies is, for example, capable of simulating inter-vertebral displacements. This can be seen clearly from the fact that, in all dummy types, pin joints are used to connect the vertebrae. Hence, additional axial forces are measured because the unphysiologic design of the dummy neck does not allow the head to move backwards without rotation.

Regarding the IV-NIC, this criterion is defined as the ratio of the intervertebral motion under traumatic loading and the physiological range of motion. However, using dummies the evaluation of the IV-NIC is impossible due to the limitations in dummy design as mentioned above. In addition, the criterion is neither validated nor is there a threshold level proposed.

In summary, only the NIC has proven its applicability to assess low speed rear-end collisions; yet, it might not be sufficient to have just one suitable criterion. In particular, as this criterion can not be used to analyse the motion of the neck during the entire collision, one should have other measures at hand to evaluate phenomena that occur later in time. Especially the rebound phase needs attention [Muser et al. 2000]. Other seat properties than during retraction phase have a major influence in this phase and thus influence the risk of sustaining injuries.

Consequently, the proposal of a new injury criterion candidate did not aim at replacing another criterion, but to provide additional information and allow further assessment of an impact.

NEW CRITERION CANDIDATE Nkm

Based on the hypothesis that a neck protection criterion for rear-end collisions should take into account a linear combination of loads and moments, a new criterion called Nkm is proposed. This approach is similar to the definition of the Nij criterion for frontal impact [Kleinberger et al. 1998] and thus the newly proposed Nkm can be regarded as a modification thereof.

However, with respect to possible injury mechanisms in rear-end collisions, sagittal shear forces rather than axial forces are regarded as the critical load case. Thereby it is assumed that shear forces could potentially be harmful to the facet joints, in particular in the upper neck region [Yang et al. 1997, Deng et al. 2000]. The combination with the sagittal bending moment accounts for a constellation which is often found in the cervical spine, e.g. during S-shape formation. It is assumed that the strain of the upper neck facet joints can be amplified by accompanying bending moments. Whereas, in the human, axial compression/tension forces are considered to influence the amount of shear [Yang et al. 1997], they are afflicted with inaccuracies in the dummy measurements as explained above. Hence, they were not explicitly included here.

The Nkm criterion was defined according to the following equation:

$$N_{km}(t) = \frac{F_x(t)}{F_{int}} + \frac{M_y(t)}{M_{int}} \qquad (1.)$$

where Fx(t) and My(t) are the shear force and the flexion/extension bending moment, respectively. Both values should be obtained from the load cell positioned at the upper neck. Fint and Mint represent critical intercept values used for normalization.

Distinguishing positive shear, negative shear, flexion and extension, the Nkm criterion identifies four different load cases: Nfa, Nep, Nfp and Nea. The first index represents the bending moment (f: flexion, e: extension) and the second indicates the direction of the shear force (a: anterior, i.e., in positive x-direction, p: posterior, i.e., in negative x-direction). The sign convention according to SAE J211/2 was used. Consequently, positive shear forces measured at the upper neck load cell indicate that the head is moved backwards relative to the uppermost cervical vertebra.

The intercept values used to calculate the criterion are shown in table 1 which exhibits the human tolerance levels for the causation of AIS1 neck injury. These values were identified on the basis of volunteer experiments [Mertz and Patrick, 1993] and suggest tolerance levels up to which no injury is expected. For the maximum shear level tolerated, no difference was found with respect to the direction of the sagittal shear force.

Generally, we believe that for the use in an injury criterion, the ratio between a pair of loading conditions is more important than the actual values. Whereas the values used for normalisation could, if needed, be corrected indirectly by adjusting the threshold value, the ratio implies more fundamental aspects and should therefore be chosen very carefully. Thus, it might well

Table 1.

Intercept values for calculating Nkm

load case	value	
extension	47.5 Nm	Goldsmith and Ommaya, 1984 Mertz and Patrick, 1993
flexion	88.1 Nm	
negative and positive shear	845 N	

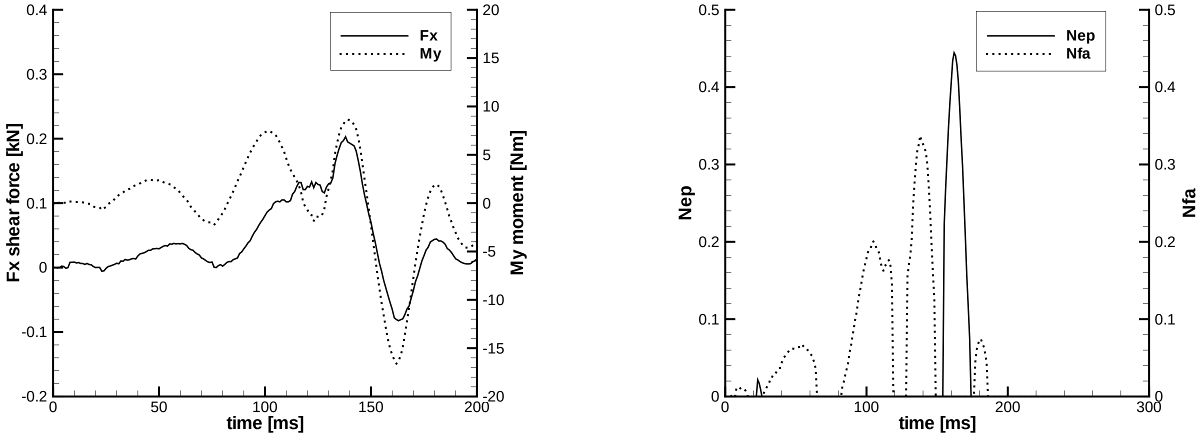

Figure 1. Example for the Nkm calculation: the left hand side shows the data recorded for the shear force and the sagittal bending moment. Shear and flexion and extension are determined, normalised by the according intercept values, and then the corresponding loading cases are added. Finally, the maxima of the curves obtained are taken to be the Nkm values. The right hand side shows the result for the Nfa (here 0.337) and the Nep (here 0.444).

be possible that the values proposed here for the test conditions as described have to be revised when using other test configurations, for example an other dummy type.

A correction for the loads and torques measured [Prasad et al. 1997] which accounts for the difference of the location of the upper neck load cell and the head/neck joint of the anthropomorphic test devices was not included. The effect of such a correction was found to be small and did not influence the comparability of the criterion under consideration.

For the computation of the Nkm values, first the two bending modes and the two load types under investigation are identified, then the load curves measured are divided by the according intercept value. Finally, the Nkm values are obtained by adding the adequate shear force and moment curves, while keeping the time scale unchanged, and determining the maximum of the resulting curve. Hence, the Nep represents the maximum value in time when extension and negative shear occur simultaneously and the Nfa gives the analog value for flexion and positive shear. However, it is necessary to check whether the results obtained are reasonable with respect to the crash test performed. If, for instance, one of the Nkm values calculated occurs at a point in time which is not

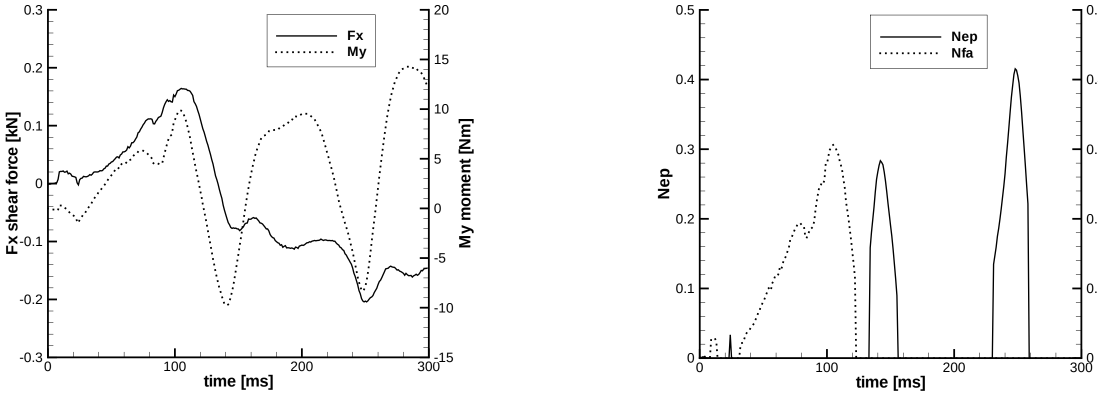

Figure 2. Another example for the Nkm calculation. However, in this case it was noted that, with respect to the sled test performed, the results obtained were no longer relevant for times greater 210 ms. Thus the Nep peak caused by this effect has to be neglected in favour of the next-to-highest peak prior in time. Therefore the final Nep values in this example reads 0.283 (at 142 ms).

relevant for the test (e.g. at the end of the rebound phase when the dummy is already restrained by the seat belt), the next-to-highest peak prior to that point in time has to be taken. Figures 1 and 2 illustrate the calculation procedure.

With regard to a critical Nkm value, 1.0 was used taking into account that either a moment or a shear force exceeding the intercept value produces a risk of sustaining neck injuries. A finer scale for better differentiation of the outcome is currently discussed.

MATERIAL AND METHODS

In order to validate the proposed criterion candidate, 37 sled tests (performed in collaboration with Autoliv (Germany) GmbH and the German Insurance Association (GDV)) were evaluated. A total of 31 different recent front seat models were tested. Of these seats six models were equipped with a whiplash protection system, i.e., either a system that moves the head restraint forward and upward during the collision (pro-tech device) [Wiklund et al. 1998] or a system that makes use of a special recliner which allows controlled deformation during the acceleration phase [Lundell et al. 1998]. All tests were carried out in the same manner according to the test procedure for the evaluation of the injury risk to the cervical spine in a low speed rear-end impact proposed for the ISO/TC22 N 2071 and ISO/TC22/SC10, respectively [Muser et al. 1999].

The seats were mounted on the sled and adjusted such that the angle of the seat ramp and the recliner read 12°±1° and 25°±2°, respectively. Adjustments were made using an H-point machine according to SAE J 826.

As anthropomorphic test devices (ATDs), a Hybrid III 50%ile male dummy equipped with a TRID neck, and, for one test, a BioRID dummy, were used. The dummies were positioned in the seat according to the procedures for frontal impact tests (cf. ECE R 94). The head must not be inclined forward prior to the test, i.e., the x axis of the head accelerometer has to be parallel with respect to the horizontal.

ATDs with standard instrumentation plus upper neck load cell were used. For this study the forces in x and z direction and the bending moment around the y axis recorded at the upper neck (C1 level) were important.

The head restraint of each seat was adjusted vertically until its top aligned with the top of the ATD's head. In case this was impossible (due to seat design) the position closest to the one aimed at was chosen.

The crash pulse used for the sled tests presented here, is shown in Figure 3. It was of trapezoidal shape with an average sled deceleration of 6±1g and with rise and fall times of 10-20 ms. Hence, the resulting Δv of the sled was 15±1 km/h.

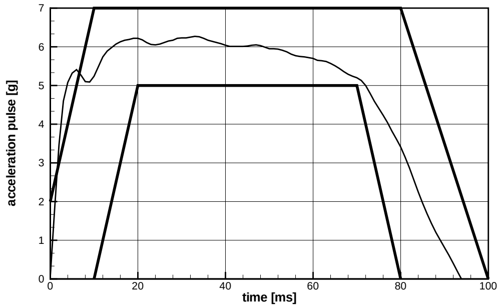

Figure 3. Corridor for the sled acceleration pulse and crash pulse as recorded for one of the tests.

Repeatability tests were performed by means of testing three identical seat models under identical conditions. Additionally, in one of these tests the TRID neck was replaced by another TRID neck to check for the influence of different testing equipment.

For each sled test, the neck injury criteria NICmax and Nkm were reported. While the Nkm was obtained as explained above, the NICmax was calculated on the basis of the following equation:

$$NIC(t) = 0.2 \cdot a_{rel}(t) + (v_{rel}(t))^2 \qquad (2.)$$

where arel and vrel denote for the relative acceleration and velocity of the occipital condyles and the C7/T1 position, respectively. NICmax is then taken as the maximum value of the NIC(t) curve during the first 150 ms (retraction phase). Furthermore, the maximum values for Fx and My are presented along with d, the initial horizontal gap between head and head restraint prior to the test. The characteristics to assess seat elasticity by means of the rebound velocity of the head c.g. and the rebound velocity of the first thoracic vertebra according to Muser et al. [2000] are also given.

RESULTS

For all sled tests performed the NICmax as well as the Nkm were determined. The results are shown in Tables 2, 3, and 4 in the Appendix.

Results for the Nfp were excluded for the evaluation in this study. The case of flexion plus posterior shear was, for the seats tested here, found in the belt restraint phase mainly, i.e. when the dummy was restrained by

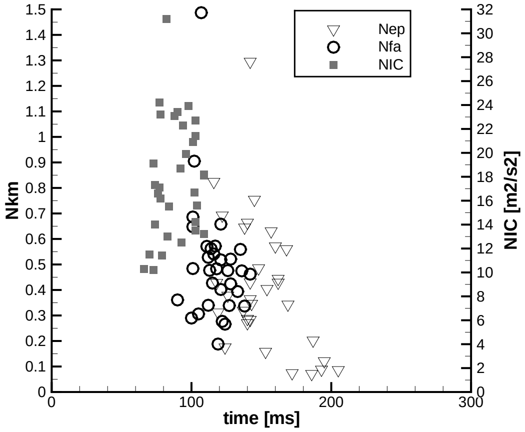

Figure 4. Results for the Nkm and the NICmax of all seats presented in Table 2.

the seat belt. However, the test set-up did not reproduce a realistic car environment with correct belt geometries for each seat; the belt was solely included to secure the ATD at the end of the rear-end impact. Hence, all values obtained after belt contact were excluded and thus no Nfp values are presented.

The sample of seats (Table 4) showed an average NICmax of 18.1±5.0 (average±SD) with a minimum value of 10.2 obtained for a seat with a whiplash protective device. Less than a third of seats tested reached a NICmax below the proposed threshold value of 15 m2/s2.

Computing the Nkm (Table 2), Nep values of 0.410±0.263 were obtained. With regard to those seats including an anti-whiplash system the Nep values were much smaller reaching values as low as 0.071. Just evaluating these seats an Nep of 0.233±0.145 was obtained indicating a smaller spread as the overall evaluation.

The maximum Nep value observed was 1.295 and as such exceeds the suggested threshold. Remarkably, the same seat for which this maximum Nep values was obtained, reached also the maximum Nfa value of 1.487 whereas its NICmax was 16.2.

Calculating the Nfa values for the whole sample led to an average of 0.499±0.231. Seats with a whiplash protection system did not perform significantly better than average. The Nea values evaluated to be 0.245±0.154 with a maximum of 0.765 for the same seat for which the highest Nep and Nfa values were found. The minimum Nea was obtained for a seat with whiplash protection system.

With regard to the points in time at which the criteria determined were established (Fig. 4), it can be seen that the NICmax values are found earlier in time as the Nkm peak values. The average time value for the NICmax was 89 ms±13 ms. Nfa values were always recorded before the according Nep values. On average the Nfa and the Nep occurred at 117 ms±13 ms and 151 ms±24 ms, respectively. Nea values were found at 128 ms±23 ms. While the NICmax and the Nfa values were lying in a quite close interval, the standard deviation for the Nep and Nea values indicated a wider spread.

The influence of changes to the seat design on the outcome of the injury criteria under consideration, was analysed by blocking the whiplash protective device and by introducing an additional head cushion. As expected, higher values for all criteria were obtained when the whiplash protection system was not functioning. The use of the head cushion resulted in lower NICmax values as well as in lower Nkm values, but one single Nep value.

Evaluation of tests XC and XD discloses the difference between using a Hybrid III/TRID dummy and a BioRID dummy. The NICmax value on the one hand turned out to be higher for the BioRID (Table 4), but the Nkm values on the other hand were clearly reduced for that dummy type (Table 3).

The repeatability tests performed (Table 3), gave values of 26.4±1.5 for the NICmax, 0.073±0.040 for the Nep, 0.497±0.017 for the Nfa, and 0.228±0.025. Differences were in particular recorded for changing the TRID neck.

DISCUSSION AND CONCLUSION

A total of 37 sled tests served as basis for the validation of the newly proposed neck injury criterion Nkm. For comparison the NICmax, My, Fx, d, and the elasticity characteristics were also evaluated.

Describing the Nkm data, a reasonable dispersion allowing differentiation and classification can be noticed. For the tests performed, the range of Nkm values obtained covers an interval including values that exceed the suggested critical value. From the tables provided, the relation between the Nkm values and the moments and shear forces used for its calculation becomes obvious. It can also be seen that the maximum moment is often obtained in the vicinity of the maximum shear force, and thus justifying the linear combination chosen. However, due to the constraint that moments and shear forces have to be recorded simultaneously to contribute to the Nkm, the timing is not equal to that of the maxima.

In this study, we focus on the Nep and Nfa values, as those seem to be the most relevant cases. With respect to the Nea values, it was noted that these values are generally much lower than the accompanying Nep values. Cases in which the Nea was found to be higher than the Nep indicated that the head rotates significantly before it contacts the head restraint. Reasons were detected to be either a large head to head restraint distance or seat failure (e.g. collapse of the recliner, height adjustment or head restraint).

Low Nep values were in particular recorded for seats equipped with a whiplash protection system. This indicates that these seats reduce backward shear and extension motion simultaneously. Although the according NICmax values are, generally speaking, low, a "good" Nep does not necessarily correlate to a "good" NICmax.

In addition, a small distance of head to head restraint is advantageous to gain a low Nep as well as it was found that the seat back geometry influences the Nep values.

In contrast, a direct influence of such anti-whiplash devices on the Nfa was not observed. This fact can possibly be attributed to other seat design properties like the seat elasticity.

Consequently, low Nep values do not necessarily have to be associated with low Nfa values. Low values for both parameters should be aimed at.

Analysing the tests with an additional head cushion indicated better values for all criteria evaluated except for one Nep value which can not be explained at this stage. The blocking of the whiplash protective device was also recognized by changing Nkm and NICmax values.

With regard to the points in time at which the Nkm values occurred, the results indicated that Nfa values were obtained in the phase of forward motion, i.e. after the retraction phase which is described by the NICmax and thus after head to head restraint contact. Nep values were recorded following the Nfa towards the end of the rebound phase.

The comparison of the Nkm outcome for a TRID neck dummy to a BioRID dummy revealed lower values for the latter. This can be attributed to the extended range of movement of the neck that the BioRID dummy offers. The neck is allowed to deform in a more physiological way and hence lower shear forces are recorded. With regard to the NICmax, higher translational acceleration of the head relative to the torso is measured, because the deformation of the BioRID neck prevents early rotation of the head. Consequently NICmax values are higher for the BioRID while Nkm values are lower. However, using the TRID and the according intercept values as recommended in the proposal might overestimate Nkm values. Therefore the choice of a smaller critical threshold value might have to be considered in future.

With respect to the repeatability tests, the variations determined from this small sample indicate that especially the changing of the TRID neck introduced greater changes towards higher values and later timing. This can in part be explained by the fact that changes on the ATD have a more direct influence on the kinematics and, of course, by differences of the neck due to manufacturing, storing and handling.

In summary, a new candidate for a neck injury criterion, called Nkm, was presented. It takes into account shear forces and bending moments at the occipital condyles. Sled test experiments were used to validate the Nkm criterion. It was shown that the Nkm values characterize the forward movement, i.e. the rebound phase. As such the Nkm gives additional information to that gained by the NICmax which accounts for the earlier phase only.

Furthermore, different characteristics of the seat design can be quantified with the different Nkm values at hand. These might be very helpful with respect to the ongoing discussion about the design principles for the "perfect" car seat [Parkin et al. 1995].

However, as for all injury criteria developed on the basis of ATDs, one has to be aware that to a certain extent dummy properties due to a lack of biofidelty are influencing the measurements. As long as the cause of injury is unknown, injury criteria will therefore always lack a justification as they have to assume a correlation between the measurements and the symptoms reported. This also influences the critical threshold value of the Nkm for which a final conclusion can not be given yet. A test using a BioRID dummy revealed differences which indicate that it might possibly be useful to chose either different intercept values or a different threshold value for this ATD. Further experience is needed to corroborate the initial findings presented here.

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APPENDIX

Table 2.

Results for the sagittal bending moments, the shear forces and the according Nkm values of the seats tested. An asterix (*) denotes a seat with "whiplash protection system". In test G, an additional head cushion was mounted to seat F. In test S, the same was done for seat O. In test O, the protective device of seat J was blocked.

Test	My				Fx				Nkm					
	max.flex.	t	max.ext.	t	max a	t	max p	t	Nep	t	Nfa	t	Nea	t
	Nm	ms	Nm	ms	N	ms	N	ms		ms		ms		ms
A	18.3	116	13.7	138	307	114	60	166	0.319	137	0.572	117	0.255	133
B*	7.6	125	6.7	103	152	124	38	226	0.071	186	0.266	124	0.206	104
C	15.8	111	23.3	167	356	138	65	170	0.560	168	0.559	135	0.386	161
D	10.7	127	20.2	147	300	126	147	239	0.485	148	0.476	126	0.364	142
E	8.9	64	5.2	90	1227	107	1079	142	1.295	142	1.487	107	0.765	91
F	17.9	122	15.3	141	266	121	159	239	0.364	142	0.518	121	0.259	137

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G	11.4	108	17.9	141	180	113	110	197	0.430	142	0.340	112	0.289	134
H	8.6	139	16.6	162	203	138	82	163	0.444	162	0.337	138	0.194	154
I	28.3	101	21.8	122	309	101	200	123	0.692	122	0.686	101	0.050	113
J*	22.4	112	9.3	140	232	112	79	175	0.287	140	0.528	112	0.051	131
K*	20.5	131	10.6	169	207	136	102	169	0.343	169	0.475	136	0.031	83
L	7.7	123	30.1	146	220	128	102	145	0.754	145	0.339	127	0.453	139
M	5.5	120	15.8	154	187	124	62	155	0.404	154	0.277	122	0.232	145
N*	9.2	120	2.4	203	71	118	100	213	0.086	205	0.188	119	0.019	98
O	13.8	114	24.5	137	270	113	113	139	0.645	138	0.477	113	0.288	129
P	14.9	90	28.3	116	162	90	199	113	0.824	116	0.361	90	0.100	145
Q	12.3	116	23.4	156	252	128	119	157	0.630	157	0.424	128	0.255	145
R	6.3	111	19.8	161	348	141	112	230	0.429	162	0.462	142	0.407	159
S	9.9	104	9.8	141	164	105	107	183	0.283	142	0.306	105	0.154	133
T	10.9	100	6.8	125	141	100	34	159	0.175	124	0.290	100	0.131	80
AA	23.1	103	16.3	126	328	101	74	159	0.378	126	0.648	101	0.302	123
AB	17.8	117	4.5	147	287	116	82	193	0.074	172	0.541	116	0.188	94
AC	35.9	102	11.8	119	420	102	112	188	0.312	119	0.905	102	0.162	115
AD*	19.6	128	13.1	151	252	129	50	189	0.202	187	0.521	128	0.315	151
AF*	23.0	116	5.0	153	254	114	73	193	0.158	153	0.562	114	0.022	141
AH	20.1	112	10.4	139	290	111	94	184	0.270	140	0.571	111	0.213	87
AI	18.7	101	16.2	118	229	101	73	167	0.428	118	0.484	101	0.125	111
AM	10.4	245	15.6	155	318	137	102	223	0.088	193	0.402	121	0.416	131
AN	13.1	118	21.7	159	282	118	98	161	0.571	160	0.483	118	0.275	149
AO	21.9	122	14.9	143	345	121	79	217	0.346	143	0.658	121	0.256	138
AQ	12.9	195	26.0	139	286	115	124	176	0.664	140	0.427	115	0.362	131
AR	10.4	249	12.1	158	304	133	106	228	0.121	195	0.394	133	0.323	155

Table 3.

Results for the sagittal bending moments, the shear forces and the according Nkm values of the seats tested. Tests AJ, AK, and AL represent the repeatabilty tests. Here the same seat model was used for all three tests. Additionally, in test AL the TRID neck used in all other tests was replaced by another TRID neck. Tests XC and XD were performed with the same seat, but using a Hybrid III/TRID dummy in test XC and a BioRID dummy in test XD

Test	My				Fx				Nkm					
	max.flex.	t	max.ext.	t	max a	t	max p	t	Nep	t	Nfa	t	Nea	t
	Nm	ms	Nm	ms	N	ms	N	ms		ms		ms		ms
AJ	14.0	113	8.2	147	276.9	116	99.0	216	0.057	174	0.483	113	0.218	143
AK	15.6	111	7.9	146	293.1	114	86.5	206	0.043	174	0.516	111	0.210	143
AL	15.6	114	10.9	149	270.4	116	98.1	216	0.119	180	0.491	116	0.256	146
XC	9.8	95	29.3	153	266.2	131	232.0	241	0.692	154	0.321	95	0.487	147
XD	6.8	123	6.9	211	55.6	127	132.3	211	0.302	211	0.142	124	0.044	169

Table 4.

Results for the horizontal distance (head to head restraint) measured prior to the test, the NICmax, and the elasticity as evaluated. Number 999 indicates that it was impossible to determine the according value.

Test	Distance	NIC		Elasticity (rebound velocity)			
	d	NICmax	t	v_head	t	v_T1	t
	mm	m2/s2	ms	m/s	ms	m/s	ms
A	95	23.4	90	3.0	190	2.2	166
B*	45	10.3	66	2.3	999	1.6	999
C	55	20.9	101	2.9	999	2.0	999
D	85	19.9	96	2.1	233	1.9	999
E	50	16.2	78	2.4	218	1.8	220
F	120	22.7	103	2.8	232	2.1	999
G	50	15.5	84	3.1	206	2.0	197
H	45	13.5	103	1.3	999	1.2	297
I	58	24.2	77	3.0	162	1.8	168
J*	115	17.1	77	2.7	193	2.0	194
K*	60	12.5	93	2.2	255	1.8	257
L	90	18.2	109	1.2	297	1.3	297
M	110	16.7	102	1.9	255	1.8	246
N*	75	10.2	73	2.8	218	2.1	213
O	100	23.1	88	3.1	186	2.0	191
P	65	17.3	74	2.7	190	1.7	191
Q	65	22.3	94	4.1	199	2.5	202
R	95	18.1	109	3.6	221	2.0	230
S	55	16.6	76	3.1	182	2.0	187
T	30	11.5	70	3.5	160	2.7	162
AA	50	19.1	73	3.4	165	2.2	169
AB	70	13.0	83	3.5	192	2.5	194
AC	100	23.2	78	1.4	199	1.2	205
AD*	90	13.2	109	0.9	999	0.8	999
AF*	85	14.0	74	2.9	195	2.1	195
AH	65	11.4	79	3.4	182	2.4	185
AI	90	31.2	82	3.3	167	2.1	165
AJ	100	25.0	97	3.4	210	2.3	214
AK	100	26.3	97	3.5	207	2.4	210
AL	110	28.0	100	3.6	212	2.3	217
AM	105	15.6	104	3.3	222	2.0	223
AN	80	21.4	103	2.5	238	1.7	238
AO	110	23.9	98	2.7	217	2.0	219
AQ	35	18.7	92	3.5	179	2.0	182
AR	105	14.2	103	3.3	225	1.9	229
XC	35	18.4	101	3.2	209	2.1	308
XD	50	26.2	96	4.5	200	2.8	180