TECHNICAL REPORT

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Road vehicles — Injury risk curves for evaluation of occupant protection in side impact

Véhicules routiers — Courbes de risques de blessures pour l'évaluation de la protection des occupants en choc latéral

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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ISO/TS 12350 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 12, *Passive safety crash protection systems*.

Road vehicles — Injury risk curves for evaluation of occupant protection in side impact

1 Scope

This Technical Report provides injury risk curves for the evaluation of occupant protection in side impacts on road vehicles. The measurements are performed on two lateral impact dummies, EuroSID 1 and BioSID, which present acceptable levels of biofidelity response in accordance with ISO/TR 9790 and are used in tests carried out according to ISO 10997.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO TR 9790, *Road vehicles — Anthropomorphic side impact dummy — Lateral impact response requirements to assess the biofidelity of the dummy*

ISO 10997, *Passenger vehicles — Side impact with deformable moving barrier — Full scale test*

3 Symbols and abbreviated terms

For the purposes of this document, the following symbols and abbreviated terms apply.

F_{adj}	Force, adjusted
F_{org}	Force, original
F_{abdo}	Force, abdomen
$F_{abdo\ in}$	Force, abdomen, interior
$F_{abdo\ ex}$	Force, abdomen, exterior
F_{pubis}	Force, pubis
F_{impact}	Force, impactor
v_{cad}	Impact velocity, cadaver
v_{dum}	Impact velocity, dummy
a_{adj}	Acceleration, adjusted
a_{org}	Acceleration, original
a_{spine}	Acceleration, spine
a_{lspine}	Acceleration, lower spine
a_{pelvis}	Acceleration, pelvis
δ_{adj}	Displacement, adjusted

δ_{org}	Displacement, original
V^*C_{adj}	Viscous criterion, adjusted
V^*C_{org}	Viscous criterion, original
V^*C_{abdo}	Viscous criterion, abdomen
V^*C_{max}	Viscous criterion, maximal
AIS	Abbreviate injury scale
AIS_{ht}	Abbreviate injury scale, hard thorax
$AIS_{ht\ adj}$	Abbreviate injury scale, hard thorax, adjusted
AIS_{max}	Abbreviate injury scale, maximal
$AIS_{max\ abdo}$	Abbreviate injury scale, maximal, abdomen
AIS_{intern}	Abbreviate injury scale, internal organs
AIS_{aorta}	Abbreviate injury scale, aorta
AIS_{abdo}	Abbreviate injury scale, abdomen
AIS_{pelvis}	Abbreviate injury scale, pelvis
AIS_{thor}	Abbreviate injury scale, thoracic
$AIS_{thor\ cad}$	Abbreviate injury scale, thoracic, cadaver
n_{FRadj}	Number of fractured ribs, adjusted
n_{RForg}	Number of rib fractures, original
AGE_{cad}	Age of cadaver

4 Methodology

The biomechanical bases are those selected and described in the ISO/TR 9790. Cadaver data (test conditions, subject characteristics and injuries) are provided in Tables 1 to 29 of the present Technical Report.

Corresponding tests are performed with EuroSID 1 and BioSID dummies under the same test conditions as those applicable to cadavers. Dummy test responses are also provided in the tables.

Cadaver injuries are then correlated to dummy responses to establish injury risk assessment, with the following adjustments.

4.1 Velocity

The dummy criteria are normalised by the velocity in order to match cadaver test velocities:

$$F_{adj} = F_{org} \times v_{cad} / v_{dum}$$

$$a_{adj} = a_{org} \times v_{cad} / v_{dum}$$

$$\delta_{adj} = \delta_{org} \times v_{cad} / v_{dum}$$

$$V^*C_{adj} = V^*C_{org} \times (v_{cad} / v_{dum})^2$$

4.2 Level of injury

4.2.1 For the hard thorax and abdomen, the following scale is used:

AIS_{ht} 2 = n_{FRadj} 1 to 3

AIS_{ht} 3 = n_{FRadj} 4 to 8

AIS_{ht} 4 = n_{FRadj} > 9 or 2 rib fractures on 4 consecutive ribs

4.2.2 For the thorax, rib fractures and internal organ injuries are considered separately.

Additional curves for “6+ fractured ribs” are provided in order to take into account the differences between living occupants and cadavers. This level should be considered as an AIS 3+ for living people.

4.2.3 For the abdomen, only AIS_{max} (rib fractures and internal organs) is considered.

4.2.4 For the pelvis, all levels of fractures are considered.

4.3 Age adjustment

4.3.1 Hard thorax and abdomen[1]

The number of fractured ribs (n_{FR}) is adjusted to 45 years with a scale factor of 0,2 n_{FR} per year:

$$n_{FRadj} = n_{FRorg} - 0{,}2\ (AGE_{cad} - 45)$$

4.3.2 Internal organ (thorax and abdomen)

No adjustment.

4.3.3 Pelvis

Evans[2] reports a decrease of about 20 % of ultimate bending stress between the ages of 24 and 79. Failure forces, accelerations and deflections being proportional to ultimate stress, they can be adjusted to 45 years, with a scale factor of 0,4 % a year:

$$F_{adj} = F_{org} / [1 - 0{,}004 \times (AGE - 45)]$$

$$a_{adj} = a_{org} / [1 - 0{,}004 \times (AGE - 45)]$$

$$\delta_{adj} = \delta_{org} / [1 - 0{,}004 \times (AGE - 45)]$$

4.4 Statistical analysis

Taking into account the small number of test data, the certainty method, described by Mertz[3], was used to compute injury risk curves.

For each cadaver, the corrected level of injury is associated with the corrected criteria measured on the dummy during a test in the same conditions. It is assumed that a relation exists between the criteria and the level of injury.

For a prescribed level of criteria, a group is composed (the certainty group) to include only those specimens it is known for certain either would or would not have experienced a level of injury at this level of criteria. The probability of injury at the given level of criteria is then estimated by calculating the ratio of the number of specimens that would have experienced the level of injury to the total number of specimens in the certainty group.

To ascertain whether a specimen would or would not have experienced a level of injury at a given level of criteria, one assumes that if someone sustains a level of injury at a given level of criteria, he/she will also sustain at least the same level of injury at a higher level of the criteria. The values obtained are then analysed numerically using regression techniques. Results of regressions are provided in Clause 6.

5 Test data

Test data from the literature (see Bibliography) are provided in Tables 1 to 29, including test conditions, cadaver characteristics and injuries with the corresponding dummy tests (EuroSID and BioSID references), and dummy test responses.

5.1 Thorax

5.1.1 Pendulum impact — 23,4 kg

See Tables 1 to 4.

Table 1 — Test results from [4]

Test No.	AGE	v m/s	n_{RF}	n_{RFadj}	$AIS_{ht\ adj}$	AIS_{intern}	AIS_{max}	EuroSID reference	BioSID reference
76T062	69	4,3	7	2,2	2	(5)	2	113a	114a
77T071	60	4,3	0	0	0	1	1	113a	114a
77T074	60	4,3	2	0	0	0	2	113a	114a

Table 2 — Test results from [5]

Test No.	AGE	v (m/s)	n_{FR}	n_{FRadj}	$AIS_{ht\ adj}$	AIS_{intern}	AIS_{max}	EuroSID reference	BioSID reference
Viano17	29	5,5	0	0	0	0	0	113a	114a
Viano29	52	5,2	0	0	0	0	0	113a	114a
Viano36	37	4,0	0	0	0	0	0	113a	114a
Viano40	64	3,62	2	0	0	0	0	113a	114a
Viano41	64	3,8	0	0	0	0	0	113a	114a
Viano4	63	5,99	4	0,4	0	0	0	113b	114b
Viano5	38	6,48	3	4,4	3	0	3	113b	114b
Viano7	66	6,73	5	0,8	0	0	0	113b	114b
Viano9	64	6,71	5	1,2	2	0	2	113b	114b
Viano11	40	6,71	5	6	3	0	3	113b	114b

Table 3 — Results from EuroSID 1 tests [6], [7]

Ref	Test reference	v (m/s)	δ (mm)	V^*C (m/s)
113a	Viano	4,4	39,1	0,5
113b	Viano	6,5	53,4	1,14
113c	Viano	9,3	61	2,03
113d	ACEA (UTAC)	4,3	33	0,36
113e	ACEA (UTAC)	6,7	50	0,9

Table 4 — Results from BioSID tests [6], [7]

Ref	Test reference	v (m/s)	δ (mm)	V^*C (m/s)
114a	Viano	4,4	33,4	0,31
114b	Viano	6,5	58	0,78
114c	Viano	9,3	76	2,17
114d	ACEA (UTAC)	4,3	32	0,32
114e	ACEA (UTAC)	6,7	60	1,03

5.1.2 Lateral drops

See Tables 5 to 7.

Table 5 — Test results from [8]

Test No.	AGE	Drop height (m)	Impact surface	Arm position	n_{RF}	n_{RFadj}	$AIS_{ht\ adj}$	AIS_{intern}	AIS_{max}	EuroSID reference	BioSID reference
APR104	70	1	rigid	up	14	9	4	0	4	—	—
APR105	47	1	rigid	up	13	12,6	4	0	2	—	—
APR111	52	1	rigid	20° fwd.	5	3,6	2	0	2	122b	123b
APR155	42	1	rigid	20° fwd.	0	0,6	0	0	0	122b	123b
APR120	51	2	APR pad	20° fwd.	13	11,8	4	0	3	122c	123c
APR121	57	2	APR pad	20° fwd.	4	1,6	2	0	2	122c	123c
APR122	42	2	APR pad	20° fwd.	0	0,6	0	0	0	122c	123c

Table 6 — Results from EuroSID 1 tests [9]

Ref	Test reference	Drop height (m)	Impact surface	Arm position	δ (mm)	V^*C (m/s)
122a	Harigae	0,5	rigid	20° fwd	19,7	0,1
122b	Harigae	1	rigid	20° fwd	33,9	0,29
122c	Harigae	2	padded	20° fwd	42,6	0,37

Table 7 — Results from BioSID tests [9]

Ref	Test reference	Drop height (m)	Impact surface	Arm position	δ (mm)	V^*C (m/s)
123a	Harigae	0,5	rigid	20° fwd	15,1	0,06
123b	Harigae	1	rigid	20° fwd	27,7	0,21
123c	Harigae	2	padded	20° fwd	27,7	0,21

5.1.3 Sled tests

See Tables 8 to 11.

Table 8 — Test results from [1]

Test No.	AGE	v (m/s)	Impact surface	n_{FR}	n_{FRadj}	$AIS_{ht\ adj}$	AIS_{intern}	AIS_{max}	EuroSID reference	BioSID reference
H-82-015	18	6,5	rigid	2	7,4	3	1	3	133a	134a
H-82-018	28	6,5	rigid	9	12,4	4	3	4	133a	134a
H-82-019	47	6,5	rigid	7	6,6	3	3	3	133a	134a
H-82-014	22	9,1	rigid	12	16,6	4	4	4	133b	134b
H-82-016	21	8,75	rigid	8	12,8	4	2	4	133b	134b
H-82-021	48	8,8	padded	13	12,4	4	4	4	133c	134c
H-82-022	50	9,1	padded	15	14	4	4	4	133c	134c

Table 9 — Test results from [10]

Test No.	AGE	v (m/s)	Pad thickness (mm)	n_{RF}	n_{RFadj}	$AIS_{ht\ adj}$	AIS_{aorta}	AIS_{max}	EuroSID reference	BioSID reference
SIC 04	69	9,1	rigid	22	17,2	4	0	4	133b	134b
SIC 07	66	6,7	rigid	16	11,8	4	0	4	133a	134a
SIC 10	60	8,8	152	5	2	2	0	2	—	—
SIC 14	60	9,4	102	18	15	4	0	4	—	—
SIC 15	43	8,9	102	0	0,4	0	0	0	—	—
SIC 16	58	8,9	76	26	23,4	4	0	4	—	—
SIC 17	65	8,9	152	2	0	0	0	0	—	—

Table 10 — Results from EuroSID-1 tests [9], [7]

Ref	Test reference	v (m/s)	Impact surface	δ (mm)	V^*C (m/s)
133a	Harigae	6,8	rigid	40,2	0,6
133b	Harigae	8,9	rigid	52,1	1,24
133c	Harigae	8,9	padded	54,7	0,98
133d	ACEA (Heidelberg)	6,7	rigid	32	—
133e	ACEA (Heidelberg)	8,9	APR pad	43	—

Table 11 — Results from BioSID tests [9], [7]

Ref	Test reference	v (m/s)	Impact surface	δ (mm)	V^*C (m/s)
134a	Harigae	6,8	rigid	51,1	0,68
134b	Harigae	8,9	rigid	65,8	1,5
134c	Harigae	8,9	padded	65,4	1,32
134d	ACEA (Heidelberg)	6,7	rigid	40	—
134e	ACEA (Heidelberg)	8,9	APR pad	22,5	—

5.2 Abdomen

5.2.1 Abdomen requirement 1 — Drop tests

See Tables 12 to 14.

Table 12 — Test results from [11]

Test No.	AGE	Drop height (m)	Impact surface	Arm position	Armrest height (mm)	n_{FR} on impact side (ribs 8 to 12)	AIS_{abdo} (internal organ)	EuroSID reference	BioSID reference
APR205	62	1	hardwood	20° fwd.	31	0	0	212a	213a
APR219	68	1	hardwood	20° fwd.	41	—	0	212a	213a
APR206	66	1	hardwood	20° fwd.	51	2	4	212a	213a
APR215	52	2	hardwood	20° fwd.	31	3	5	212b	213b
APR216	56	2	hardwood	20° fwd.	51	3	5	212b	213b
APR210	—	1	polystyrene	20° fwd.	51	1	3	—	—
APR211	—	1	polystyrene	20° fwd.	53	0	0	—	—
APR212	—	1	polystyrene	20° fwd.	55	—	0	—	—
APR213	—	2	polystyrene	20° fwd.	55	2	3	—	—

Table 13 — Results from EuroSID 1 tests [9], [7]

Ref	Test reference	Drop height (m)	Impact surface	Arm position	Armrest height (mm)	a_{lspine} (g)	F_{abdo} (kN)
212a	Harigae	1	rigid	without	41	45,6	5,93
212b	Harigae	2	rigid	without	41	92,5	11,44
212c	ACEA (TNO)	2	rigid	without	41	—	—

Table 14 — Results from BioSID tests [9], [7]

Ref	Test reference	Drop height (m)	Impact surface	Arm position	Armrest height (mm)	a_{lspine} (g)	F_{abdo} (kN)
213a	Harigae	1	rigid	without	41	33,2	—
213b	Harigae	2	rigid	without	41	75,8	—
213c	ACEA (TNO)	2	rigid	without	41	—	—

5.2.2 Abdomen requirement 2 — Sled tests

See Tables 15 and 16.

Table 15 — Test results from [10] and [12]

Test No.	AGE	v (m/s)	Pad thickness (mm)	AIS_{abdo} on impact side (ribs 8 to 12)	AIS_{abdo} internal organ	EuroSID reference	BioSID reference
SIC 04	69	9,1	rigid	3	2	—	223b
SIC 07	66	6,7	rigid	0	0	—	223a
SIC 10	60	8,8	152	0	0	—	223c
SIC 14		9,4	102	—	2	—	—
SIC 15	43	8,9	102	0	0	—	223d
SIC 16	58	8,9	76	3	4	—	223e
SIC 17	65	8,9	152	0	0	—	223c

NOTE No data are available at present for results from EuroSID 1 tests.