

The Adjustment of the Railway Vehicle Interior Passive Safety to Conform to the European Crashworthiness Requirements



Mobility Networks Logistics

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Content:

1. Background
2. Structural Passive Safety and Interior Passive Safety – a Consistent Approach
3. Crash Pulse Related Passive Safety Basic Elements
4. SICHER REISEN (Safe Travelling) – Project Results as to Railway Interior Design
 - 4.1 Reference Crash Pulse
 - 4.2 Protection Criteria (Injury Criteria)
 - 4.3 Sled Tests Results (Example)
5. Conclusions

1. Background

Two main conditions for crashworthy railway vehicles were defined by previous railway research:

- 1) Guarantee of the structural integrity to maintain the occupant's survival space.
- 2) Reduction of occupant's risk to get injured by secondary collisions with the vehicle interior.

Whereas the basis for structural crashworthiness European regulations (TSI HS RST, EN 15227) was provided by the EC-funded projects SAFETRAIN and SAFETRAM, up to now no consistent basis for railway vehicle interior passive safety is available.

Consequently, the German BMWi-funded project SICHER REISEN (Safe Travelling) was launched in 2004 aiming at the national preparation of the expected EC research to adjust the railway vehicle interior passive safety to the TSI- / EN crashworthiness requirements.

2. Structural Passive Safety and Interior Passive Safety – a Consistent Approach

To prevent the identified principal causes of occupant injuries in train / tram accidents

- loss of survival space and
- secondary impacts

by effective measures, a consistent approach of structural passive safety and interior passive safety is required.

The key to solve the second problem “secondary impacts” in a consistent manner is the crash pulse. It works as the “mediator” between structural crashworthiness and interior passive safety.

From there, an important problem to be solved by the SICHER REISEN project was to find out a suitable way for a TSI- and EN- conformable crash pulse solution relating to crashworthy rolling stock.

3. Crash Pulse Related Passive Safety Basic Elements

Crashworthiness requirements which provide a level of protection consistent with the probable collision risks and achieved by addressing the most common types of collision causing injuries and fatalities in Europe:

- *EN 15227 “Railway applications – Crashworthiness requirements for railway vehicle bodies”*
- *Technical specification for interoperability relating to the rolling stock subsystem (TSI HS RST).*

These structural requirements shall among other things:

- *Reduce the risk of derailment*
- *Reduce the risk of over-riding.*

In case of the design collision scenarios, crashworthy rail vehicles can be regarded as remaining on the tracks!

3. Crash Pulse Related Passive Safety Basic Elements

European railway vehicle categories (EN 15227, Table 1)

Category	Definition	Examples of vehicle types
C-I	Vehicles designed to operate on TEN routes, international, national and regional networks (which have level crossings)	Locomotives, coaches & fixed units
C-II	Urban vehicles designed to operate only on a dedicated railway infrastructure, with no interface with road traffic	Metro vehicles
C-III	Light rail vehicles designed to operate on urban or regional networks, in track-sharing operation, and interfacing with road traffic	Tram trains, periurban tram
C-IV	Light rail vehicles designed to operate on dedicated urban networks interfacing with road traffic	Tramway vehicles

3. Crash Pulse Related Passive Safety Basic Elements

European railway design collision scenarios outline (EN 15227, Table 2)

Design collision scenario	Collision obstacle	Operational characteristics of requirement	Collision Speed - km/h				Collision partner and conditions
			C-I	C-II	C-III	C-IV	
1	Identical train unit	All systems	36	25	25	15	Identical train unit
2	80-tons wagon	Mixed traffic with vehicles equipped with side buffers.	36	Na	25	n.a.	See Annex C.2 for wagon specification
	129-tons regional train	Mixed traffic with vehicles with a central coupler	na	Na	10	na	See Annex C.3 for representation of regional train
3	15-tons deformable obstacle	TEN & similar operation with level crossings	$V_{lc} - 50$ ≤ 110	na	25	na	See Annex C.4 for representation of large obstacle
	3-tons rigid object	Urban line not isolated from the road traffic.	na	na	na	25	See Annex C.5 for representation of obstacle
4	Small, low obstacle	Obstacle deflector requirements to be achieved	See table 3	See table 3	See table 3	na	If the risk due to this scenario is broadly acceptable no obstacle deflector is required, as defined below.

4. SICHER REISEN (Safe Travelling) – Project Results as to Railway Interior Design

4.1 Reference Crash Pulse

Analysis of the influences of common C-I configurations (DB-trains)



1. RE (1x cab car 53 T + 4x coach 53 T + 1x locomotive 82 T)



2. EC / IC (1x locomotive 84 T + 8x coach 49 T + 1x cab car 49 T)



3. EMU (1x cab car 42 T + 2x intermediate car 19 T + 1x cab car 41 T)

Train configuration 3 generates the highest mean deceleration in the design collision scenario 3 (EN 15227).

4.1 Reference Crash Pulse

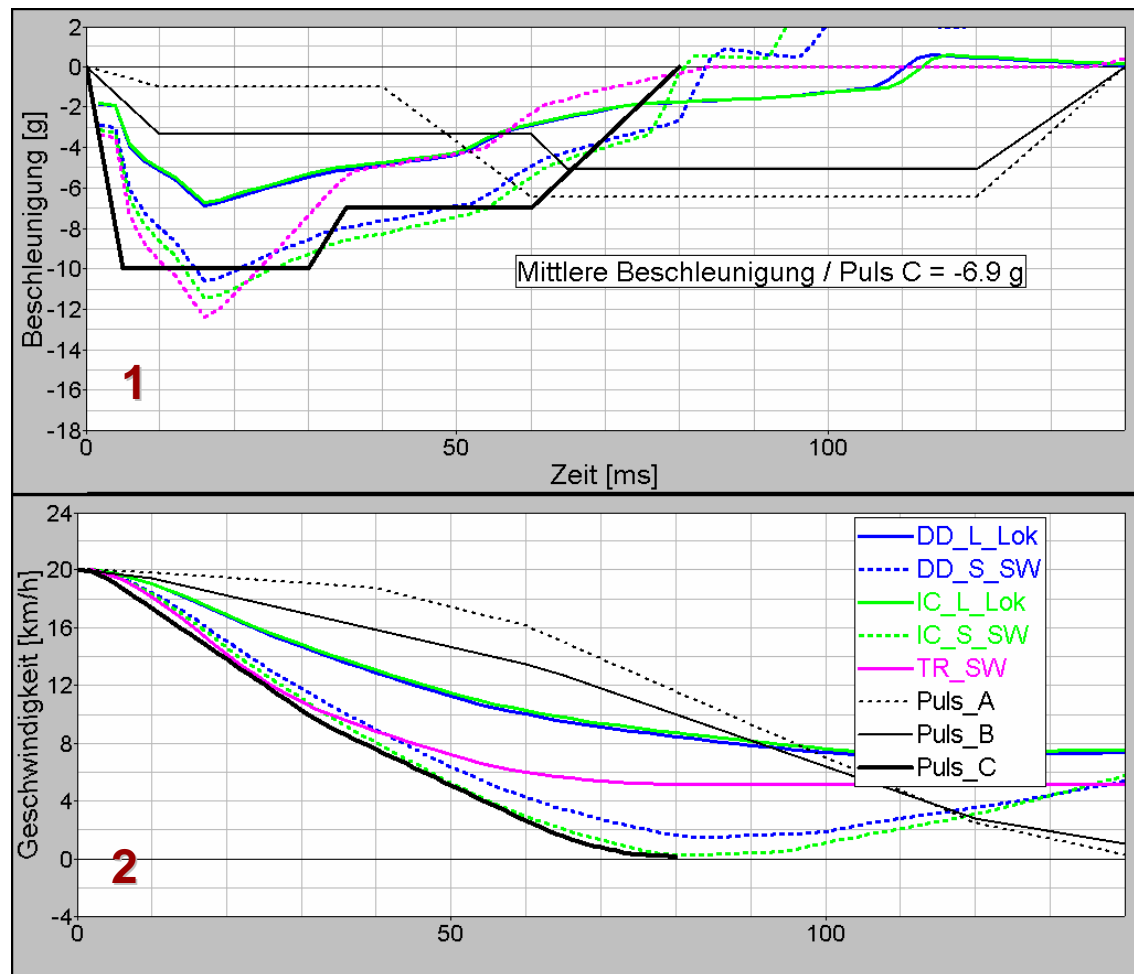
1. Acceleration – time curves and pulse C derived from DB train configurations on scenario 3 (EN 15227) conditions.

For comparison: pulses A and B on scenarios 1 and 2 conditions.

2. Collision speed – time curves on the same conditions.

Conclusion:

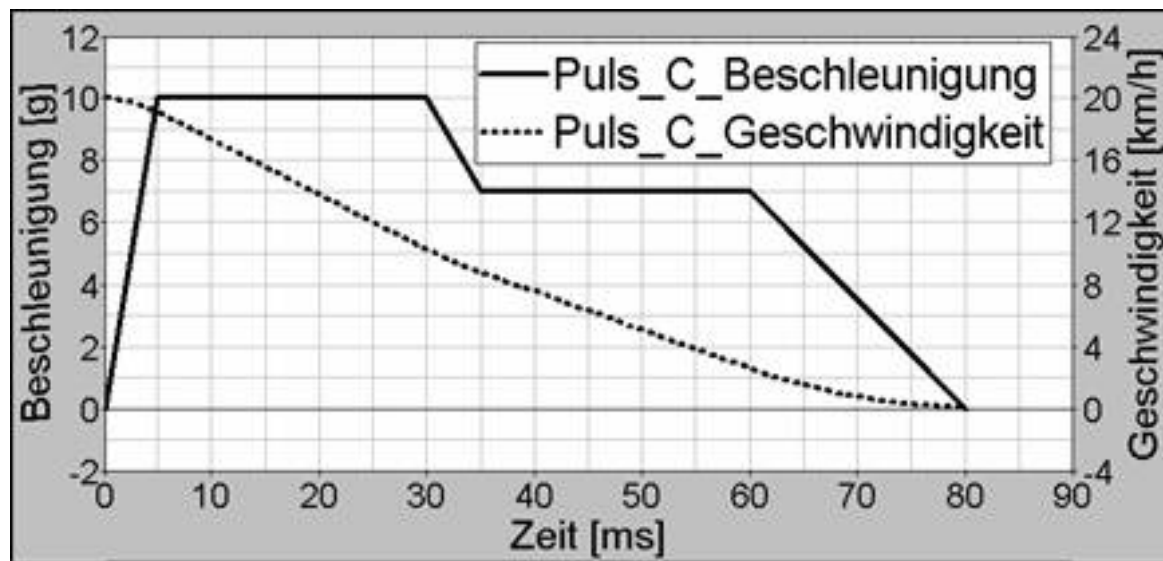
Pulse C = worst case.



4.1 Reference Crash Pulse

Pulse C is the recommended reference crash pulse, defined on the basis of an initial speed = 20 km/h.

This reference crash pulse covers the TSI- / EN- design collision scenarios 1-3 and is applicable for all common train configurations of the EN 15227 category C-I.



Zeit [ms]	Beschleunigung [g]
0	0
5	10
30	10
35	7
60	7
80	0

Crash pulse mean acceleration value: 6,9 g

Crash pulse time: 80 ms

4.2 Protection Criteria (Injury Criteria)

In case of a collision, for effective passenger and crew protection from injuries caused by secondary collisions with the interior, not only the knowledge about the crash pulse is necessary.

Part of the body		Limit
Head	HIC	500
	a(max) [g]	80
Neck	in flexion [Nm]	190
	in extension [Nm]	-57
Chest	[mm]	50
Femur	right [kN]	-7,58
	left [kN]	-7,58
Knee	right [mm]	15
	left [mm]	15
Tibia	right [-]	1,3
	left [-]	1,3

The availability of protection criteria is necessary for designing the vehicle interior in terms of passive safety as well.

As a project result, it is recommended to maintain the injury criteria provided by the SAFETRAIN project. At a HIC = 500 adjusted to railway conditions the limiting values of the guideline ECE-R 94 are suitable considered.

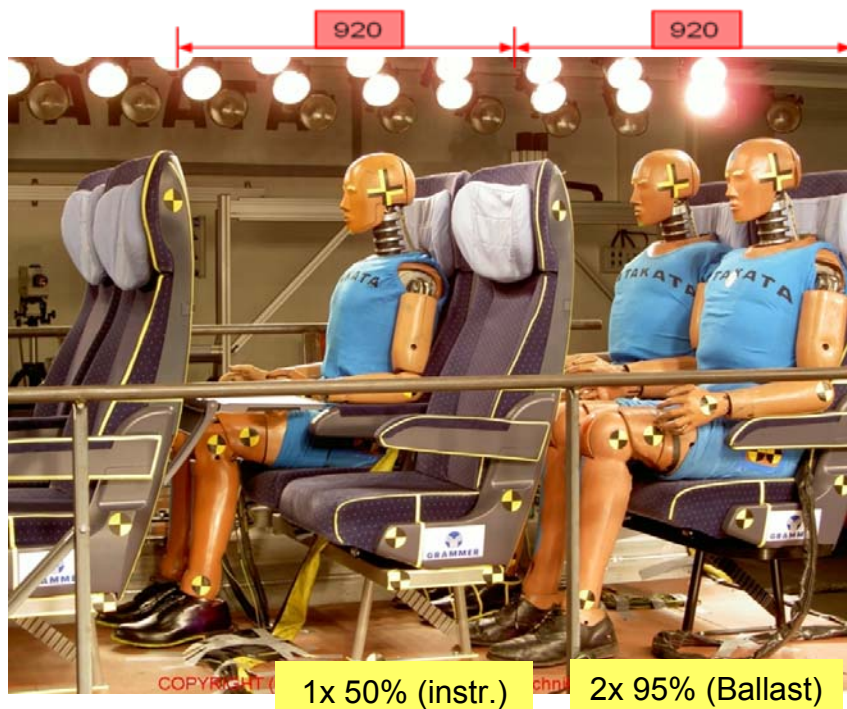
Open items: Abdomen injury criteria and suitable dummies for abdomen impact measurements.

4.3 Sled Tests Results (Example)

ICE 3 seat configuration (2nd class) mounted on a car-body segment. Floor structure slightly modified. Seat attachment components replaced by parts with high plastic deformation. Sled test crash pulse: Pulse C.

Seats & dummy position before test:

...after test:



4.3 Sled Tests Results (Example)

Sled test results evaluation:

All limiting values of the injury criteria are kept.

Most of the results (green marked) point at remarkable passive safety reserves.

			Grenzwert SICHER REISEN	Ergebnis 50% H-III	Ergebnis 50% H-III Prozent
Kopf	HIC 15	[-]		240	
	HIC 36	[-]	500	240	48,0%
	a _{3ms}	[g]	80	65,3	81,7%
	a _{max}	[g]		81,7	
Halskräfte (NIC)	+F _X	[kN]	1,1 @ 45 ms	0,27 @ 45 ms	24,5%
Halsmomente (NIC)	+F _{X max}	[kN]		0,85	
	-F _X	[kN]		-	
	-F _{X max}	[kN]		-1,183	
	+F _Z	[kN]	2,9 @ 35 ms	0,35 @ 35 ms	12,1%
	+F _{Z max}	[kN]		1,153	
	-F _Z	[kN]	-1,1 @ 30 ms	-0,41 @ 30 ms	37,3%
	-F _{Z max}	[kN]		-1,858	
Halsmomente (NIC)	+M _{Y flex.}	[Nm]	190	67,9	35,7%
	-M _{Y ext.}	[Nm]	-57	41,1	72,6%
Hals Nij	N _{TF}	[-]	1	0,2619	26,2%
	N _{CF}	[-]	1	0,3008	30,1%
	N _{TE}	[-]	1	0,2423	24,2%
	N _{CE}	[-]	1	0,5596	56,0%
Brust	a _{3ms}	[g]	60	18,4	30,7%
	a _{max}	[g]		23,2	
	s _{max} (TCC)	[mm]	50	4,27	8,5%
	VC	[m/s]	1	0,0255	2,5%
Becken	a _{3ms}	[g]		42,1	
	a _{max}	[g]		54,8	
Oberschenkel rechts links	-F _{Z max}	[kN]	-7,58	-6,16	81,3%
	-F _{Z max}	[kN]	-7,58	-5,77	76,1%
Knieverschieb. rechts links	s _{max}	[mm]	15	0,96	6,4%
	s _{max}	[mm]	15	3,15	21,0%
Schienbein	Tibia-Index upper left	[-]	1,3	0,30	23,1%
	Tibia-Index upper right	[-]	1,3	0,31	23,8%
	Tibia-Index lower left	[-]	1,3	0,23	17,7%
	Tibia-Index lower right	[-]	1,3	0,18	13,8%

5. Conclusions

1. The structural passive safety and interior passive safety objectives have to be realised by a consistent approach.
2. Crashworthiness requirements which provide a level of protection consistent with the probable collision risks and achieved by addressing the most common types of collision causing injuries and fatalities in Europe are available.
3. As a result of the SAFETRAIN project, the relevant requirements on passive safety of motor cars, e.g. biomechanical limiting values and injury criteria (guideline ECE-R 94) can be applied. The HIC should be railway conformable adjusted to 500.
4. The SICHER REISEN reference crash pulse covers the TSI- / EN-design collision scenarios 1-3 and is applicable for all common train configurations of the EN 15227 category C-I.

Crash pulses for categories C-II...C-IV are still open items.

5. Conclusions

5. The present European standards for passenger passive safety can also be met with railway seats.
6. Even more complex railway seats do not exceed the limiting values of injury criteria if the seat is adapted accordingly.
7. The well-known materials can be used further in connection with controlled energy absorption.
8. An useful result of all tested unidirectional ICE 3 seat configurations:
No seat belts necessary!

The SICHER REISEN project has provided a suitable way to improve the train occupant passenger safety but could not include all problems to be solved.

Therefore, the current EC project SAFEINTERIORS can be built up on these results to continue the previous research work purposeful.

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THANK YOU!

