Relevance of the IIHS Small Overlap Crash Test in Europe

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Abstract Modern cars often perform poorly in the new small overlap crash test of the Insurance Institute for Highway Safety (IIHS). This frontal impact replicates what happens, when only the front corner of the vehicle collides with another vehicle or an object such as a pillar or a tree. European vehicle manufacturers criticise that the IIHS small overlap crash test would not be relevant based on accident statistics and that two-way traffic collisions could not be reproduced with a rigid barrier. The DTC Dynamic Test Center AG in Switzerland did research on the relevance of the IIHS small overlap crash test in Europe. Therefore the reproducibility of the IIHS barrier in comparison with real two-way traffic collisions was examined. Three tests were performed with a randomly chosen Renault Scénic II using different test configurations. In a fourth test was the influence of the vehicle slip off from the barrier analysed implemented by design modifications on the test vehicle. Loads of the anthropomorphic test device (ATD) placed on the driving seat were measured during each test to draw conclusions on biomechanical stress and occupant protection. The results obtained show that a collision of real two-way traffic collision can be reproduced on a rigid barrier if the impact velocity is adapted on the involved vehicles. If a car is not designed for the IIHS small overlap crash test, speed reduction by main absorbing elements could be marginal and therefore significantly increase the biomechanical stress on the occupant. It has been shown that the vehicle slip off from the barrier could decrease the biomechanical stress but requires a frontal-/ side impact adapted restraint system. The front wheel must be prevented from penetrating the occupant foot well. To avoid injury risks of likely secondary collision further measures such as multifunctional airbags with sufficient residual energy should be taken. With regard to the analysed tests the conclusion was drawn that a slip off from the barrier in combination with necessary adaptations could decrease the injury risk. It can be concluded that the IIHS small overlap crash test is relevant for Europe due to the identified key gaps for occupant protection.

Keywords Relevance of the IIHS Small Overlap Crash Test, IIHS Small Overlap, IIHS Small Overlap Crash In Comparison to the Two-way Traffic Collision, Two-way

Traffic Collision, IHS Small Overlap Crash Test Modified Vehicle, IIHS Small Overlap Crash with Reduced Velocity, IIHS Small Overlap Crash Slip Off, Dynamic Test Center AG

1. Introduction

With support from Renault, the Baloise Insurance and the AGU Working Group on Accident Mechanics the DTC Dynamic Test Center AG of Switzerland researched the relevance of the IIHS small overlap crash tests in Europe. The crash investigation will show whether and how well a two-way traffic collision can be reproduced on the rigid IIHS barrier and with which challenges the vehicle manufacturers are faced by the IIHS small overlap crash test. The randomly chosen Renault Scénic II was used as test vehicle.

2. Relevance Regarding Real Accident

The Baloise Insurance analysed relating to the research their accidents internally regarding the overlap. It has been shown that every 5th frontal accident occurs with small overlap in Switzerland (Fig 1 and 2).[1] The consequences are dramatic regarding occupant injury due to strong deformation of the passenger compartment. Accident reports were picked up by chance in December 2012. The vehicle deformations were very close to the tested vehicles on the rigid IIHS barrier.

The longitudinal bars of the vehicles are ineffective due to the small overlap. The front wheel is separated from the suspension and pressed into the foot well (Fig 1 and 2). Thereby only very little energy can be reduced. The passenger compartment collapses if cars cannot slip off sufficiently due to the blocking.

The statistics of the Baloise Insurance as well as the accident images clearly show that the IIHS small overlap crash test shows a gap in the safety concept of present vehicles.

Figure 1. Accident A5 Twann [2]

Figure 2. Pictures of really crashed cars in Dezember 2012 [2]

3. Test configurations

Within the DTC investigations on the IIHS small overlap four crash tests were conducted.

The specifications of the IIHS were applied for the small overlap crash test (Fig. 3). [3]

- 25 % overlap to a rigid barrier
- Impact velocity 64.4 +/- 1 km/h
- ATD HIII 50% on driving seat

Differing from the IIHS requirements the parking brake was not applied after any test.

Figure 3. Vehicle at the rigid IIHS Barrier [6]

3.1. DTC 150 Renault Scénic II, acc. to IIHS

The first crash test DTC 150 (Fig. 4) with a Renault Scénic II was performed according to the IIHS standards. The aim of the test was to study the behaviour of the selected vehicle and to obtain basis of comparison for a two-way traffic collision between two vehicles (DTC 151).

Figure 4. Renault Scénic II at the rigid IIHS Barrier

3.2. DTC 151 Two-way Traffic Collision

A two-way traffic collision between a Renault Scénic II and a Land Rover Freelander (Fig. 5) was examined. The focus was on how well the structure and occupant loads on the Renault Scénic can be depicted by the IIHS small overlap crash test against a real accident. It could be determined that the impact should be conducted with at least 100 km/h relative velocity by using simulations of the accident analysis.

Figure 5. Renault Scénic II against Landrover Freelander

This simulation has also shown that the two vehicles will slip off each other. Therefore, the energy input into the vehicle structure cannot be substantially enhanced by increasing the impact speed of the Renault Scénic II. The crash test was performed with 104.8 km/h speed and an overlap of 25% against a stationary Land Rover Freelander. The Land Rover Freelander was loaded on his gross vehicle weight with mass dummies and additional weight.

3.3. DTC 149 Renault Scénic, IIHS with Reduced Velocity

Despite the high relative speed of 104.8 km/h the

vehicles slipped off each other at the two-way traffic collision. Because the damage severity with the chosen vehicle pairing at the two-way traffic collision turned out to be less severe than expected the third crash test, DTC 149 (Fig. 6), examines the damage severity on the Scénic II at reduced speed against the IIHS barrier. At the Renault Scénic II was a collision-induced velocity change of about 40 km/h detected.

Figure 6. Renault Scénic II at the IIHS barrier

The impact velocity of the crash test DTC 149 has been reduced to 46 km/h to initiate at the rigid IIHS barrier a similar energy absorption in the front structure. This reduction only applies to the tested vehicle pairing Renault Scénic II - Land Rover Freelander. For other vehicles the corresponding impact velocity against the IIHS small overlap barrier can change depending on the body structure, vehicle mass, the stability of the passenger compartment and the longitudinal bar position.

3.4. DTC 152 Ford Mondeo Modified, According to IIHS

At the example of a modified Ford Mondeo the approach of a slip off was examined (Fig. 7). Therefore the vehicle had been modified with steel profiles (Fig. 8) so that it slips off from the IIHS small overlap barrier and that the left front wheel is pushed inward before the passenger compartment impacts on the IIHS small overlap barrier.

Figure 7. Modified Ford Mondeo at the IIHS barrier

The modifications (Fig. 8) only serve to force the vehicle slipping off the rigid barrier. These implemented interventions in the front structure are not practicable in the

present version. But they represent the two needed measures to achieve a slipping in the IIHS small overlap crash test. The vehicle has been modified with various steel sections so that by the impact on the IIHS small overlap barrier a hooking can be avoided and that the wheel is pressed inward before the passenger compartment hits the IIHS small overlap barrier.

Figure 8. Vehicel structure at the impact area

This crash test and the variant chosen should show the necessary modifications so that the car can slip off from the IIHS barrier. The primary concern is the effect of these measures on the occupant load. It should however also demonstrate what movement of the vehicle after the primary impact is to be expected. It should be noted that the vehicle was not designed for the Euro-NCAP due to the model age and the equipped airbags.

Pre-tests with similar vehicle models (Fig. 9, 10 and 11) have shown that the cabins of this generation have a strong tendency to collapse in the IIHS small overlap crash test with 64 km/h.

Figure 9. DTC 145 Nissan 100 NX

Figure 10. DTC 146 Alfa Romeo 156

Figure 11. DTC 148 Subaru Legacy

4. Results

4.1. DTC 150 Renault Scénic II, According to IIHS

The vehicle hits the IIHS small overlap barrier with 65.2 km/h and an overlap of 25%. The Renault Scénic II grazed with the left longitudinal bar along the barrier and reduced only slightly energy (Fig. 12). Also the left front wheel was torn off and pushed back against the foot well. The passenger compartment and the IIHS small overlap barrier finally form one block. The car did not slip off and came almost to a standstill on the barrier. The vehicle started to rotate around the z-axis.

Figure 12. The left longitudinal bar doesn't hit the barrier

The passenger compartment collapsed due to the hard impact (Fig. 13). The foot well of the driver was severely

deformed because the left front wheel was pushed into it. As a result increased loads were measured in the legs of the driver ATD. The passenger compartment deformed in such an extent that the dashboard on the left, the steering column and the steering wheel had been pressed into the interior. The restraint systems such as airbags and belt tensioners were triggered.

Figure 13. The passenger compartment collapses

The acceleration during the first 40 ms is on a low level (Fig. 14), compared with the impact after that to the vehicle compartment.

During the complete impact duration a strong rotation takes place (Fig. 15).

A very high injury risk must be expected on the lower extremities for the occupant on the driving seat (Fig. 16). The ATD head still hits the front airbag despite the rotative movement of the vehicle, the resulting direction of movement of the driver ATD and the displacement of the steering column, (Fig. 18). The restraint systems such as seat belts, belt tensioners and airbags developed their protective effects.

The compressive loads on the right femur resulted higher due to the lateral displacement of the dashboard pushing the right knee of the dummy into the steering column (Fig. 17). The biomechanical limits according to ECE-R 94 (frontal crash) were not exceeded on the ATD. [4]

Figure 14. Vehicle loads

Figure 15. Vehicle rotation

Head		biomechanical limits		Regulation										
ares peak	59.8													
ares 3 ms max	51.9	80	g	ECE-R 94										
HIC36 max	308	1000		ECE-R 94										
Neck						Injury severity								
NIC	Diagramm Duration of Loading over Given Force / ms: Neck Shear Force unterhalb der roten Linie				ECE-R 94									
NIC	Diagramm Duration of Loading over Given Force / ms: Axial Tensile Force unterhalb der roten Linie				ECE-R 94									
My flexion	45.7	Nm	190	Nm	ECE-R 94	0% - 40%	40% - 80%	80% - 100%	>100%	of biomedical limits				
My extension	-19.3		-57	Nm	ECE-R 94	injury unlikely	medium	high	injury likely					
Thorax											Head	medium		
TCC	11.1	mm	50	mm	ECE-R 94						Upper Neck	injury unlikely		
V*C	0.0	m/s	1.0	m/s	ECE-R 94						Thorax	medium		
ares peak	39.6	g	60	g	FMVSS 208						Lumbar	injury unlikely		
ares 3ms max	38.4	g									Pelvis	high		
Lumbar											Femur ri	high	Femur le	medium
Fz (stretch)	1556.4	N									Knee ri	not evaluated	Knee le	not evaluated
Fz (comp.)	-1379.9	N	-6700	N	ETSO-C127a						Tibia ri	injury unlikely	Tibia le	high
Pelvis														
ares peak	84.7	g												
ares 3ms max	70.1	g	80	g	FMVSS 208									
Femur														
FFC right	Diagramm Duration of Loading over Given Force / ms: Femur right Axial Compressive Force unterhalb der roten Linie				ECE-R 94									
FFC left	Diagramm Duration of Loading over Given Force / ms: Femur left Axial Compressive Force unterhalb der roten Linie				ECE-R 94									
Knee														
s-Gleit ri	not measured	mm	15	mm	ECE-R 94									
s-Gleit le	not measured	mm	15	mm	ECE-R 94									
Tibia														
TCFC right	2424.0	N	8000	N	ECE-R 94									
TCFC left	1716.4	N	8000	N	ECE-R 94									
Ti right	0.3		1.3		ECE-R 94									
Ti left	1.1		1.3		ECE-R 94									

Injury severity

0% - 40%	40% - 80%	80% - 100%	>100%	of biomedical limits
injury unlikely	medium	high	injury likely	

Head medium

Upper Neck injury unlikely

Thorax medium

Lumbar injury unlikely

Pelvis high

Femur ri high

Femur le medium

Knee ri not evaluated

Knee le not evaluated

Tibia ri injury unlikely

Tibia le high

Figure 16. Loads on driver ATD

Figure 17. Reduced driver foot well

Figure 18. Marks of the dummy head on the airbag

4.2. DTC 151 Two-way Traffic Collision Renault Scnic II – Landrover Freelander

The Renault Scnic II hits the stationary Land Rover Freelander with 104.8 km/h and an overlap of 25%. The Renault Scnic II slipped with its left longitudinal bar, far away from the longitudinal bar of the Land Rover Freelander, only through soft structural body parts (Fig. 19). The wheels provided with their suspensions some resistance. Nevertheless, the longitudinal deceleration during the first 32 ms were on average 4.8 g, which is more than twice as high as in the barrier impact.

Figure 19. The longitudinal bars do not participate

Nevertheless up to this point neither belt tensioners nor airbags were deployed (Fig. 19). The battery ejected by the deformation of the front structure and separated from the vehicle.

The closer the two passenger compartments came, the stronger they started to slip off. At the moment of the mutual contact of the passenger compartments, the belt tensioners and airbags of both vehicles were deployed (Fig. 20). The left front wheels of both vehicles are demolished and pushed against the driver side foot well.

The collision-induced change in velocity in the x-direction was for the Scénic 38.1 km/h (Fig. 21) and for the Freelander 27.1 km/h (Fig. 22). the Renault Scénic II separated from the Land Rover Freelander with 66.7 km/h (Fig. 21). The Scénic started to swerve due to the momentum of the collision and the lacerated left front wheel. If there were a secondary collision in this situation, the frontal passive safety devices such as belt tensioners and airbags would already have been triggered. In addition there are vehicles on the market where the function of the airbag control unit is not ensured long enough with disconnected battery. If there were a secondary side collision, the ignition of the side airbags must be guaranteed at the very least.

In the release phase of the two vehicles after slipping off, the Renault Scénic II rotated significantly less around the z-axis than in crash DTC 150 (Fig. 23).

The loads measured on the ATD (Fig. 24) were well below the biomechanical limits according to ECE-R 94 (frontal crash).[4]

The driver foot well of the vehicle was slightly indented. On the instrument panel is shown a mark of the left ATD leg (Fig. 25). The legs of the ATD were not trapped. The dummy head was well supported by the airbag (Fig. 26) in spite of vehicle rotation around the z-axis and the lateral displacement due to the slipping off. The belt tensioner and the airbag could exert their protective effects very well.

Figure 20. The vehicles slip off each other

Figure 21. Vehicle loads Renault Scénic II

Figure 22. Vehicle loads Land Rover Freelander

Figure 23. Vehicle rotation of Renault Scénic II

Head		biomechanical limits		Regulation	
ares peak	43.5	g			
ares 3 ms max	42.4	g	80	g	ECE-R 94
HIC36 max	289		1000		ECE-R 94
Neck					
NIC		Diagramm Duration of Loading over Given Force / ms: Neck Shear Force unterhalb der roten Linie			ECE-R 94
NIC		Diagramm Duration of Loading over Given Force / ms: Axial Tensile Force unterhalb der roten Linie			ECE-R 94
My flexion		39.5	Nm	190	Nm
My extension		-15.2	Nm	-57	Nm
Thorax					
TCC		9.8	mm	50	mm
V* $\dot{C}$		0.0	m/s	1.0	m/s
ares peak		30.1	g		
ares 3ms max		29.0	g	60	g
Lumbar					
Fz(stretch)		1027.4	N		
Fz(comp.)		-1616.2	N	-6700	N
Pelvis					
ares peak		33.5	g		
ares 3ms max		33.0	g	80	g
Femur					
FFC right		Diagramm Duration of Loading over Given Force / ms: Femur right Axial Compressive Force unterhalb der roten Linie			ECE-R 94
FFC left		Diagramm Duration of Loading over Given Force / ms: Femur left Axial Compressive Force unterhalb der roten Linie			ECE-R 94
Knee					
s-Gleit ri.		not measured	mm	15	mm
s-Gleit le.		not measured	mm	15	mm
Tibia					
TCFC right		1232.0	N	8000	N
TCFC left		1165.4	N	8000	N
Tt right		0.3		1.3	
Tt left		0.5		1.3	

Injury severity				
0% - 40%	40% - 80%	80% - 100%	>100%	of biomedical limits
injury unlikely	medium	high	injury likely	

Head

Upper Neck

Thorax

Lumbar

Pelvis

Femur ri

Knee ri

Tibia ri

medium

medium

medium

injury unlikely

medium

injury unlikely

not evaluated

injury unlikely

Injury severity

0% - 40%	40% - 80%	80% - 100%	>100%	of biomedical limits
injury unlikely	medium	high	injury likely	

Head	medium
Upper Neck	medium		
Thorax	medium		
Lumbar	injury unlikely		
Pelvis	medium		
Femur ri	injury unlikely		Femur le injury unlikely
Knee ri	not evaluated		Knee le not evaluated
Tibia ri	injury unlikely		Tibia le injury unlikely

Figure 24. Loads on driver ATD, Renault Scénic II

Figure 25. Driver foot well

Figure 26. Dummy head marks on the airbag

4.3. DTC 149 Renault ScÉnic, IIHS with Reduced Velocity

The vehicle hits the IIHS small overlap barrier with 46.7 km/h and an overlap of 25% (Fig. 27). The Renault ScÉnic II grazed with the left longitudinal bar along the barrier. The longitudinal deceleration during the first 40 ms was 2.5 g on average.

Figure 27. Vehicle loads

Figure 28. Vehicle rotation

The rotation rate was quite on same level as on the test with the higher impact velocity DTC 150 (Fig. 15 and 28).

Neither the belt tensioners nor the airbags were deployed at this low level of deceleration (Fig. 29). The battery was ejected by the deformation of the front structure and separated from the vehicle.

Figure 29. The longitudinal bar slides past the barrier

The car did not slip off. The left front wheel was pressed into the driver foot well and the passenger compartment has blocked on the IIHS small overlap barrier. The belt tensioners and airbags were deployed (Fig. 30). By the acting rotation of the vehicle around the z-axis, caused by the collision, the movement of the ATD turns to the vehicle outside (Fig. 33). The vehicle rotated more than 60° and stopped three feet away from the barrier.

Figure 30. Blocking of the compartment with the barrier

The passenger compartment has well resisted the impact on the rigid barrier (Fig. 30). The deformation of the driver door shows that the limit of the energy input in the structure of the vehicle was reached at the low overlap of 25%. Because the longitudinal bar slid past the IIHS small overlap barrier, the defined deformation zone was almost ineffective. The energy of the impact could due to the two-way collision against the Land Rover Freelander matched impact speed of 46 km/h be absorbed through the front outer structure, the left suspension and mainly by the blocking of the passenger compartment. Thereby the passenger compartment remained mainly intact.

Marks of the ATD legs are shown on the instrument panel (Fig. 32). The dummy legs were not trapped. The loads measured on the ATD (Fig. 31) were well below the biomechanical limits according to ECE-R 94 (frontal crash).[4]

Head		biomechanical limits		Regulation	
ares peak	106.4 g				
ares 3 ms max	70.8 g	80 g		ECE-R 94	
HIC36 max	331	1000		ECE-R 94	
Neck					
NIC	Diagramm Duration of Loading over Given Force / ms: Neck Shear Force unterhalb der roten Linie			ECE-R 94	
NIC	Diagramm Duration of Loading over Given Force / ms: Axial Tensile Force unterhalb der roten Linie			ECE-R 94	
My flexion	28.8 Nm	190 Nm		ECE-R 94	
My extension	-25.3 Nm	-57 Nm		ECE-R 94	
Thorax					
TCC	6.8 mm	50 mm		ECE-R 94	
V* <i>C</i>	0.0 m/s	1.0 m/s		ECE-R 94	
ares peak	39.5 g				
ares 3ms max	38.5 g	60 g		FMVSS 208	
Lumbar					
Fz (stretch)	1040.4 N				
Fz (comp.)	-1062.9 N	-6700 N		ETSO-C127a	
Pelvis					
ares peak	48.0 g				
ares 3ms max	46.7 g	80 g		FMVSS 208	
Femur					
FFC right	Diagramm Duration of Loading over Given Force / ms: Femur right Axial Compressive Force unterhalb der roten Linie			ECE-R 94	
FFC left	Diagramm Duration of Loading over Given Force / ms: Femur left Axial Compressive Force unterhalb der roten Linie			ECE-R 94	
Knee					
s-Gleit ri.	not measured	mm	15 mm	ECE-R 94	
s-Gleit le.	not measured	mm	15 mm	ECE-R 94	
Tibia					
TCFC right	2141.8 N	8000 N		ECE-R 94	
TCFC left	1719.2 N	8000 N		ECE-R 94	
Ti right	0.4	1.3		ECE-R 94	
Ti left	0.5	1.3		ECE-R 94	

0% - 40%	40% - 80%	80% - 100%	>100%	of biomedical limits	
injury unlikely	medium	high	injury likely		

Head

Upper Neck

Thorax

Lumbar

Pelvis

Femur ri

Knee ri

Tibia ri

high

medium

medium

injury unlikely

medium

injury unlikely

not evaluated

injury unlikely

injury unlikely

injury unlikely

not evaluated

injury unlikely

Injury severity

0% - 40%	40% - 80%	80% - 100%	>100%	of biomedical limits
injury unlikely	medium	high	injury likely	

Head	high	
Upper Neck	medium	
Thorax	medium	
Lumbar	injury unlikely	
Pelvis	medium	
Femur ri	injury unlikely	Femur le injury unlikely
Knee ri	not evaluated	Knee le not evaluated
Tibia ri	injury unlikely	Tibia le injury unlikely

Figure 31. Loads on driver ATD

Figure 32. Reduced driver foot well

Figure 33. Dummy head on the airbag

4.4. DTC 152 Ford Mondeo Modified, Test According to IIHS

With the example of a Ford Mondeo was examined how the occupant loads develop if the vehicle was designed to slip off the barrier.

The vehicle impacts with 65.2 km/h and an overlap of 25% on the IIHS small overlap barrier. First, the vehicle glided along the barrier with the left longitudinal bar to the extra fitted profile (Fig. 34). Thereby much more energy was absorbed than in the tests DTC 149 and 150. With the modified structure, the vehicle started to slip off the IIHS small overlap barrier and the front wheel was pressed inwards. The restraint systems such as airbags and belt tensioners were triggered.

Figure 34. The front structure is pushed away from the barrier

The passenger compartment deformed only slightly because the vehicle was forced to slip off the barrier (Fig. 36). This can be traced back to the old model year.

The ATD moves in consequence of the vehicle movement obliquely forward to the outside.

Due to the slip off the remained speed was 30 km/h after the collision (Fig. 35).

Due to the vehicle slipping off the IIHS small overlap barrier the passenger compartment remained largely intact. Furthermore the left front wheel was prevented from being hooked and torn off (Fig. 39). The rotation rate around the z-axis was first low and changed then the direction (Fig. 37). It should be noted that the structure of the vehicle is not designed for the Euro-NCAP due to its old model age (compare Fig 8 to 10).

Figure 35. Vehicle loads

Figure 36. Different slip off kinematics

Figure 37. Vehicle rotation

Head			biomechanical limits			Regulation		
ares peak	36.1	g						
ares 3 ms max	35.2	g	80	g			ECE-R 94	
HIC36 max	227		1000				ECE-R 94	
Neck						Injury severity		
NIC	Diagramm Duration of Loading over Given Force / ms: Neck Shear Force unterhalb der roten Linie						ECE-R 94	
NIC	Diagramm Duration of Loading over Given Force / ms: Axial Tensile Force unterhalb der roten Linie						ECE-R 94	0% - 40%40% - 80%80% - 100%>100%of biomedical limits
My flexion	75.9	Nm	190	Nm			ECE-R 94	injury unlikelymediumhighinjury likely
My extension	-13.8		-57	Nm			ECE-R 94	
Thorax						Headmedium		
TCC	9.5	mm	50	mm			ECE-R 94	
V*ΔC	0.0	m/s	1.0	m/s			ECE-R 94	
ares peak	28.7	g						Upper Neckinjury unlikely
ares 3ms max	27.3	g	60	g			FMVSS 208	
						Thoraxmedium		
Lumbar						Lumbarinjury unlikely		
Fz (stretch)	865.9	N						
Fz (comp.)	-353.2	N	-6700	N			ETSO-C127a	
						Pelvisinjury unlikely		
Pelvis								
ares peak	33.4	g						
ares 3ms max	31.8	g	80	g			FMVSS 208	
Femur						Femur riinjury unlikelyFemur leinjury unlikely		
FFC right	Diagramm Duration of Loading over Given Force / ms: Femur right Axial Compressive Force unterhalb der roten Linie						ECE-R 94	
FFC left	Diagramm Duration of Loading over Given Force / ms: Femur left Axial Compressive Force unterhalb der roten Linie						ECE-R 94	
Knee						Knee riinjury unlikelyKnee leinjury unlikely		
s-Gleit ri.	not measured	mm	15	mm			ECE-R 94	
s-Gleit le.	not measured	mm	15	mm			ECE-R 94	
Tibia						Tibia riinjury unlikelyTibia leinjury unlikely		
TCFC right	1491.7	N	8000	N			ECE-R 94	
TCFC left	1513.3	N	8000	N			ECE-R 94	
Ti right	0.7		1.3				ECE-R 94	
Ti left	0.4		1.3				ECE-R 94	

Figure 38. Loads on driver ATD

The ATD did not hit the front airbag due to its transverse movement and the lateral movement of the vehicle (Fig. 40). The vehicle used was equipped with first-generation airbags without side airbags. The measured ATD loads (Fig. 38) were compared to the previous crash tests generally the lowest and substantially below the biomechanical limits according to ECE-R 94 (frontal crash).[4]

Figure 39. Largely intact passenger compartment and foot well

Figure 40. The front airbag was missed

5. Interpretation and Analysis

5.1. IIHS Small Overlap Crash (DTC 150) in Comparison With the Two-way Traffic Collision (DTC 151)

Figure 41. Passenger compartment after IIHS small overlap Crash DTC 150

Figure 42. Passenger compartment after two-way traffic collision DTC 151

The left longitudinal bars of the vehicles could not be supported in both types of collisions due to the small overlap of 25%, and were therefore not involved in the energy absorption. The upper longitudinal bar below the fender of the Renault Scénic II is barely deformed. A hard impact on the passenger compartment at the bottom of the A-pillar was not observed in the two-way traffic collision. Nevertheless, the impact energy, until the passenger compartment was involved respectively until the slip off, could be reduced so that the survival space for the occupants remained largely intact. In tendency the structural loads from the two-way traffic collision (DTC 151) are comparable with those from the small overlap IIHS crash test (DTC 150) at 64 km/h. The deformations and the occupant loads in the two-way traffic collision (DTC 151) were significantly lower at the pelvis and lower extremities

than the impact on the rigid barrier because of the slip off and the thereby missing impact of the passenger compartment on the Land Rover Freelander, (Fig. 41 and 42).

The impact speed of IIHS small overlap crash test against the rigid barrier is settled too high in comparison with the two-way traffic collision between a Renault Scénic II and a Land Rover Freelander.

5.2. IIHS Small Overlap Crash with Reduced Velocity (DTC 149) in Comparison With the Two-way Traffic Collision (DTC 151)

The Renault Scénic II hooked to the barrier at the IIHS small overlap crash test with reduced velocity. The left longitudinal bar was not hit by the rigid barrier. The upper longitudinal bar underneath the fender was in contrast to the oncoming traffic collision (DTC 151) with the Land Rover Freelander completely deformed. The impact energy could be mainly absorbed up to the passenger compartment despite the small overlap, so that the survival space for the occupant is still largely intact. The driver side foot well was similar to the two-way traffic collision (DTC 151) slightly deformed by the torn off wheel.

Figure 43. Overlay of both vehicle deformations IIHS Barrier DTC 149 (violet) and two-way traffic DTC 151 (green)

Figure 44. View from the top

The measured pressure in the left leg of the ATD was slightly higher than in the right leg. The measured loads were in both tests well below the biomechanical limits (Fig

42 and 43) according to ECE-R 94 (frontal crash).[4] Only the 3 ms head acceleration was slightly higher compared to the oncoming traffic collision. This could be substantiated by higher collision induced velocity change on one hand, and, on the other hand by the higher rotation of the vehicle about the z-axis (DTC 149: 11.0° / DTC 151: 5.2°) and thus an unfavorable support of the head to the front airbag.

0%-40% 40%-80% 80%-100% >100% of biomedical limits
Injury unlikely medium high Injury likely

Figure 45. Passenger compartment after two-way traffic collision DTC 151

Figure 46. Passenger compartment after IIHS small overlap Crash with reduced velocity DTC 149

The crash test DTC 149 has shown that the structure- and occupant loads of the two-way traffic collision between the Renault Scénic II and a Land Rover can be simulated on the IIHS rigid barrier. The impact velocity had to be reduced to 46 km/h for the Renault Scénic II.

5.3. Slip off (DTC 152) in Comparison of the Energy Absorption on the Rigid Barrier (DTC 149 & DTC 150)

The Ford Mondeo has slipped off the IIHS small overlap barrier after the deformation of the front structure because of the additionally implemented structure parts. A hard

impact on the passenger compartment at the bottom of the A-pillar was not observed so that the survival space for the occupants remained largely intact. Airbag and belt tensioners were triggered. The restraint systems could develop their protective effect only conditionally. The driver dummy missed the front airbag due to its inertia caused by the abrupt slip off and the resulting lateral movement of the vehicle. But thanks to the belt retention the head did not hit the instrument panel or the vehicle structure. The Ford Mondeo has much narrower space in the foot well in comparison with the Renault Scénic II. Therefore slightly increased loads were measured on the legs of the ATD. The measured loads were all over the Body the lowest and well below the biomechanical limits according to ECE-R 94 (frontal crash).[4]

The deformations and the occupant loads in the collision were because of the slip off and the thereby missing impact of the passenger compartment on the small overlap barrier significantly lower than in the crash tests DTC 149 and DTC 150 (Fig. 47, 48 and 49), at which the vehicles have hooked into the IIHS small overlap barrier.

0%-40% 40%-80% 80%-100% >100% of biomedical limits
Injury unlikely medium high Injury likely

Figure 47. Driver compartment after IIHS small overlap crash with slip off DTC 152

Figure 48. Driver compartment after IIHS small overlap crash with reduced velocity DTC 149

Figure 49. Driver compartment after IIHS small overlap crash DTC 150

The modified Ford Mondeo has shown a similar behaviour by the slip off on the IIHS barrier as in collision tests with safety barriers and crash cushions. This specific analysis showed the following results: [5]

While the specified limits for safety barrier tests are significantly exceeded at hooking with the rigid barrier (DTC 150), they can be observed by slipping off (DTC 152).

How the constructive measures, which enable a slip off on the small overlap crash test can be integrated into the

front structure has to be determined type-specific by the vehicle manufacturers. It must be ensured that the structural adaptations do not have adverse effects on other accident scenarios. The front airbag is no longer hit optimal due to the lateral movement of the vehicle. Side airbags as first protective measure would be more effectively. A contact with the instrument panel and the A-pillar has certainly to be prevented by a corresponding airbag.

The vehicle still has kinetic energy after the primary impact and skids possibly further on the roadway. The already activated passive safety features would be exhausted and no more or only insufficiently available if a second collision occurs. Reusable tensioners and airbags could solve the problem. The tests have shown that the vehicle battery could be separated already very early during the crash. Without battery current airbag control units are only a very short time active. Although the right side airbag would be still applicable, it must be ensured that safety systems could still be released in a second collision seconds after the primary impact.

The vehicle brake should respond automatically and the vehicle brought as quickly as possible to a standstill because it cannot be steered in all probability (VW Golf VII multi collision brake [7]).

Figure 50. ASI evaluation DTC 152

Figure 51. ASI evaluation DTC 150

Impacttest EN 1317	Acceleration severity index ASI	Theoretical head Impact velocity THIV
Limit value	A: 0 – 1.0	max. 33.0 km/h for safety barriers
	B: 1.1 – 1.4	max. 44.0 km/h for crash cushions
	C: 1.5 – 1.9	
IIHS slip off DTC 152	1.6 = C (Fig. 50)	39.1 km/h = crash cushions passed
IIHS DTC 150	2.0 = fail (Fig. 51)	51.4 km/h = fail

6. Conclusion

The studies clearly show that the small overlap crash test reveals some gaps in the design of passive safety concepts of modern vehicles. The actual number of accidents, accident images and victims substantiate the relevance of such an impact constellation. The tests carried out have shown that two-way traffic collision between two vehicles can be reproduced accurately enough on the rigid IIHS barrier. The high settled collision velocity of the IIHS test is confirmed in a certain way by the real accidents. From the present perspective the strategy of slipping off seems to be target-aimed to handle a small overlap crash with such a high velocity on a rigid barrier, energetically and structurally uninfluenced and without affect the vehicle performance at other equally frequent types of collisions. The occupant protection could be extended to additional situations.

Glossary

- A. AGU Working Group on Accident Mechanics
- B. IIHS The Insurance Institute for Highway Safety IIHS
- C. Euro-NCAP The official site of the European new car assessment programme -
- D. DTC Dynamic Test Center AG
- E. DTC XY Test number by the Dynamic Test Center AG

- F. HIII 50% A specific type of Dummy
- G. ECE-R 94 Economic Commission for Europe, internationally agreed common technical requirements for motor vehicles, Occupant protection at frontal impact
- H. Impacttest EN 1317 European standards for restraint systems on roads
- I. ASI Acceleration severity index according to EN 1317
- J. THIV Theoretical head Impact velocity according to EN 1317
- K. ATD Anthropomorphic Test Device

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- [4] ECE-R 94: Insassenschutz bei Frontalaufprall
- [5] EN 1317: Rückhaltesysteme an Strassen
- [6] SAFETY COMPANION 2013, carhs.training gmbh
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