



Dynamic Test Center AG
Centrum für Dynamische Tests AG
Centre de Tests Dynamiques SA

Relevance of the IIHS small overlap crashtest in Europe

- DTC 149 small overlap crashtest Renault Scénic II with reduced speed
- DTC 150 IIHS small overlap crashtest Renault Scénic II
- DTC 151 crashtest two-way traffic Renault Scénic II – Landrover Freelander
- DTC 152 IIHS small overlap crashtest principle study Ford Mondeo modified

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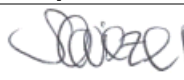
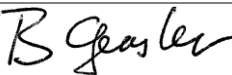
- Baloise Insurance
- Renault
- AGU Working Group on Accident Mechanics

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1 Abstract

Modern cars often perform poorly in the new small overlap crash test of the Insurance Institute for Highway Safety (IIHS). This frontal impact demonstrates what happens, when only a small part of the front of the vehicle collides with another vehicle or even with an object such as a pillar or a tree.

Although today's cars reach five stars on the Euro-NCAP and thus the maximum, they clearly fail the IIHS small overlap crash test. The reason for these different results is that the test configuration has changed. While the Euro-NCAP crash test is carried out at 64 km/h and 40 % overlap to a deformable barrier, impacts the car on the IIHS small overlap crash with the same velocity with only 25 % overlap to a rigid barrier. Thereby the longitudinal bars, one of the most important deformable elements for the frontal impact, aren't being used by most cars because they lie outside of the 25 % overlap or they slip off on the bending radius of the barrier. If a car isn't designed for the IIHS small overlap crash, the front wheel will be pulled off and pushed into the driver foot space, without an essential reduction of the velocity. Due to the very high residual energy, the passenger cabin finally collapses in the area of the A-pillar because of the blocking on the rigid barrier. In addition to the high injury risk of the lower extremities the protection of the upper body and the head with the airbag are not optimal due to the lateral displacement and rotations.

The European vehicle manufacturer criticises that the IIHS small overlap crash test from the point of view of accident statistics isn't relevant and that a collision of two-way traffic could not be reproduced with a rigid barrier. Analysis of the Baloise Insurance showed that every fifth frontal accident on Swiss roads occurs with a small overlap. This might be the same on European roads. The daily accident occurrence shows similar images of damages, as can be seen from the IIHS small overlap crash test.

The DTC Dynamic Test Center AG in Switzerland researched on a chosen at random Renault Scénic II with four crash tests, how precise a collision on two-way traffic between two cars can be reproduced on the rigid IIHS barrier and which design modifications should be implemented on the IIHS small overlap crash test for a better occupant protection. The results showed that a collision on two-way traffic between two cars can be reproduced on a rigid barrier with good results. To reproduce real accident events the impact velocity should be adapted to the involved cars. From where we stand it seems to be target-aimed to pass the IIHS small overlap crash test successfully, that the cars can slip away from the barrier and furthermore prevent the front wheel from being pushed into the foot space. If the structure is designed for a slip away, a corresponding adapted restraint system is needed because of the resulting front-/side collision. Concerning the post collision velocity and the risk of a secondary collision, additional measures should be taken such as multifunctional airbags, sufficient residual energy for the airbag control unit or automatic brake activation.

2 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 for 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. As a test vehicle the Renault Scénic II was used, thereby the choice was random. In the first test, DTC 150, the Scénic was driven against the rigid barrier, according to the instructions of the IIHS. For comparison, the Scénic collides in a second crash test, DTC 151, in a collision with oncoming traffic and an overlap of 25% against a Land Rover Freelander. 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, examines the damage severity on the Scénic at reduced speed against the IIHS barrier. Furthermore, a modified Ford Mondeo was driven against the rigid barrier according to the instructions of the IIHS. This crash test and the variant chosen should show what modifications are necessary so that the car can slip away 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.

3 Relevance regarding real accident

In connection to the research, the Baloise Insurance analysed their accidents internally regarding the overlap. It has been shown that in Switzerland every 5th frontal accident occurs as a small overlap. The consequences regarding occupant injury due to severe deformation of the passenger cell are dramatic. In December 2012 accident reports were picked up by chance. The vehicle deformations matched up very well with the tested vehicles on the rigid IIHS barrier.



Fig. 1 Accident A5 Twann



Fig. 2 Pictures of really crashed cars in Dezember 2012

Due to the small overlap the longitudinal bars of the vehicles are missed, the front wheels are separated from the suspension and pressed into the foot well. Thereby only very little energy can be reduced. If cars can't slide away sufficiently, the passenger compartment collapses 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 in today's vehicles.

4 Test configuration

In the context of the DTC crash investigation for IIHS small overlap, four crash tests were conducted.

For the small overlap crash test the specifications of the IIHS crash tests were applied.

- 25 % overlap to a rigid barrier
- Impact velocity 64.4 +/- 1 km/h
- Dummy HIII 50% at the driver's designated seating position

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

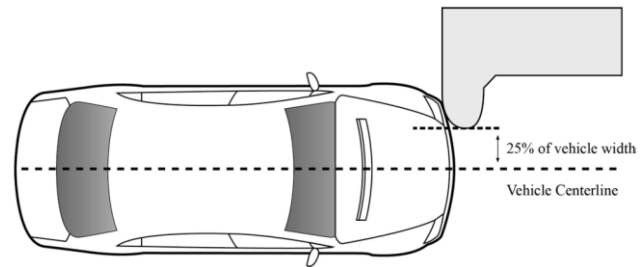


Fig. 3 Vehicle at the rigid IIHS Barrier

4.1 DTC 150 Renault Scénic II, acc. to IIHS

The first crash test DTC 150 with a Renault Scénic II was carried out according to the instructions of the IIHS. The aim of the test was to study the behaviour of the selected vehicle in the small overlap IIHS Crash Test and also to compare the two-way traffic collision between two vehicles (DTC 151).

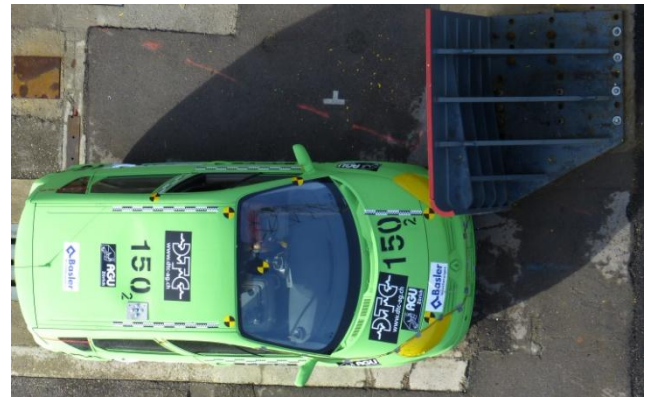


Fig. 4 Renault Scénic II at the rigid IIHS Barrier

4.2 DTC 151 two-way traffic collision

A two-way traffic collision between a Renault Scénic II and a Land Rover Freelander 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. By using simulations of the accident analysis it could be determined that the impact should be conducted with at least 100 km/h relative velocity.



Fig. 5 Renault Scénic II against Landrover Freelander

This simulation also showed that the two vehicles will slide off each other. Therefore, the energy input into the vehicle structure can't be substantially increased by further increase of the impact speed of the Renault Scénic II. The crash test was performed with 104.8 km/h speed and with coverage 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.

4.3 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. At the Renault Scénic II a collision-induced change in velocity of about 40 km/h was detected.



Fig. 6 Renault Scénic II at the IIHS barrier

To initiate at the rigid IIHS barrier a similar energy absorption in the front structure, the impact velocity of the crash test DTC 149 have been reduced to 46 km/h. This reduction applied only 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.

4.4 DTC 152 Ford Mondeo modified, according to IIHS

At the example of a modified Ford Mondeo the approach of slipping off was examined. Therefore the vehicle had been modified with steel profiles so that it can slip off the IIHS small overlap barrier and that the left front wheel is pushed inward before the passenger compartment meets the IIHS small overlap barrier.

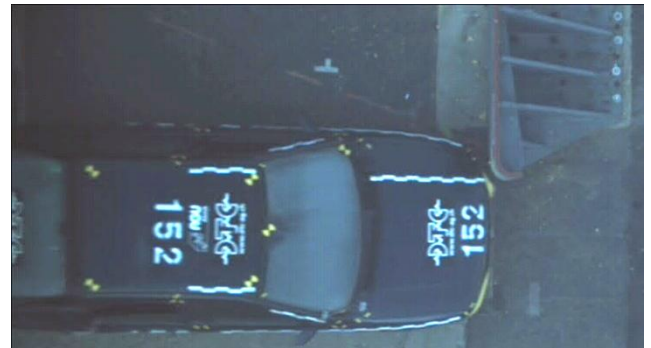


Fig. 7 Modified Ford Mondeo at the IIHS barrier

It should be noted that the vehicle was not designed for the Euro-NCAP due to the old model age and that it was only equipped with front airbags of first generation. Pretests with similar old vehicle models have shown that the cabin of this generation have a strong tendency to collapse in the IIHS small overlap crash Test with 64 km/h.



Fig. 8 DTC 145 Nissan 100 NX



Fig. 9 DTC 146 Alfa Romeo 156



Fig. 10 DTC 148 Subaru Legacy

5 Result

5.1 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 in which only slightly energy is reduced. Also the left front wheel torn off and was pushed back against the foot well. The passenger compartment and the IIHS small overlap barrier finally form one block. The car didn't slide off and almost came to standstill on the barrier. The vehicle started to rotate about the z-axis.



Fig. 11 The left longitudinal bar doesn't hit the barrier

The passenger compartment collapses due to the hard impact. Because the left front wheel bends to the driver's foot well, it was severely deformed. As a result there were increased loads measured in the legs of the driver dummy. The passenger compartment deformed in such an extent that the dashboard to the left, the steering column and the steering wheel had been pressing into the interior. The restraint systems such as airbags and belt tensioners were triggered.



Fig. 12 The passenger compartment collapses

A very high injury risk to the lower extremities at the driver's place must be expected. Despite the rotative movement of the vehicle, the resulting direction of movement of the driver dummy and the displacement of the steering column, the dummy head still hits the front airbag. The restraint systems such as seat belts, belt tensioners and airbags could develop their protective effect.

Because of the lateral displacement of the dashboard, the right knee of the dummy hit into the steering column, this results the higher pressure loads of the right femur. The biomechanical limits are not exceeded at the whole body.



Fig. 13 Reduced driver foot well



Fig. 14 Marks of the dummy head at the airbag

5.2 DTC 151 Two-way traffic collision Renault Scénic II – Landrover Freelander

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



Fig. 15 The two longitudinal bars do not participate in the collision

Nevertheless up to this point neither pretensioners nor airbags were deployed. 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 slide off. At the moment of the mutual contact of the passenger compartments, the belt tensioners and airbags from both vehicles were deployed. The left front wheels of both vehicles are demolished and pushed against the driver's side foot well.



Fig. 16 The vehicles slide off each other

In the release phase of the two vehicles after slipping off, the Renault Scénic II rotated significantly less around the z-axis than in the crash DTC 150. The collision-induced change in velocity in the x-direction was for the Scénic 38.1 km/h and for the Freelander 27.1 km/h. the Renault Scénic II separated from the Land Rover Freelander with 66.7 km/h. Because of the momentum from the collision and the lacerated left front wheel the Scénic begins to swerve. If there were a secondary collision in this situation, the frontal passive safety devices such as belt tensioners and airbags would already be consumed. In addition there are vehicles on the market where the function of the airbag control units isn't ensured long enough with disconnected battery. If there is a successive side collision, the ignition of the side airbags must be guaranteed at the least.

The driver foot well of the vehicle was slightly indented. On the instrument panel, a color print of the left dummy leg is shown. The driver's legs weren't trapped. The dummy head was well supported by the airbag in spite of vehicle rotation around the z-axis and the lateral displacement due to the sliding off. The two belt tensioners and the airbag could exert their protective effects very well. The measured loads were all over the body well below the biomechanical limits.

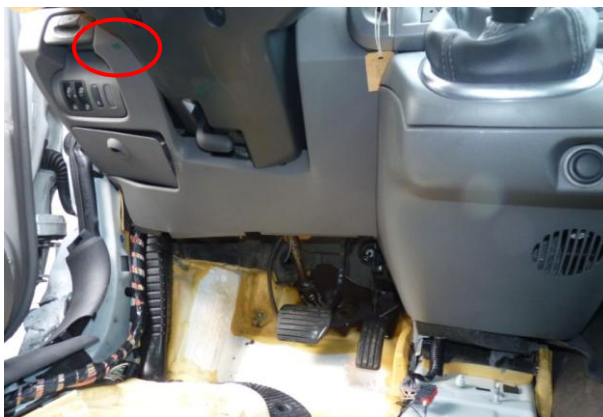


Fig. 17 Driver foot well



Fig. 18 Dummy head tracks on the airbag

5.3 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%. The Renault Scénic II grazed with the left longitudinal bar along the barrier. The longitudinal deceleration during the first 40 ms averages 2.5 g. Neither the pretensioners nor the airbags were deployed at this low level of deceleration. The battery ejected by the deformation of the front structure and separated from the vehicle.



Fig. 19 The longitudinal bar slides past the barrier

The car didn't slip off. The left front wheel was pressed into the driver's foot well and the passenger compartment has blocked on the IIHS small overlap barrier. The belt tensioners and airbags were deployed. By the acting rotation of the vehicle around the z-axis, caused by the collision, the movement of the dummy turns to the vehicle outside. The vehicle rotated more than 60° and stops three feet away from the barrier.



Fig. 20 Blocking of the compartment with the barrier

The passenger compartment has well resisted the impact onto the rigid barrier. The deformation of the driver's door shows that the limit of the energy input in the structure of the vehicle is reached at the low overlap of 25%. Because the longitudinal bar slid past the IIHS small overlap barrier, the defined deformation zone was mostly ineffective. Because of the two-way collision against the Land Rover Freelander matched impact speed of 46 km/h, the energy of the impact could be absorbed through the front outer structure, the left suspension and mainly by the blocking of the passenger compartment. Thereby the passenger compartment remained largely intact. On the instrument panel, color prints of the dummy legs are shown. The driver's legs weren't trapped. The measured loads were all over the body well below the biomechanical limits.



Fig. 21 Reduced driver foot well



Fig. 22 Dummy head on the airbag

5.4 DTC 152 Ford Mondeo modified, test according to IIHS

At the example of a Ford Mondeo, it was examined how the occupant load develops if the vehicle were designed so that it no longer blocks on the barrier but slips off.

The modifications only serve to force the vehicle sliding off the rigid barrier. These implemented interventions in the front structure are not practicable in the present version. But they represent the two measures, which are necessary for a sliding in IIHS small overlap crash tests. The vehicle has been modified with various steel sections so that by the impact to 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.

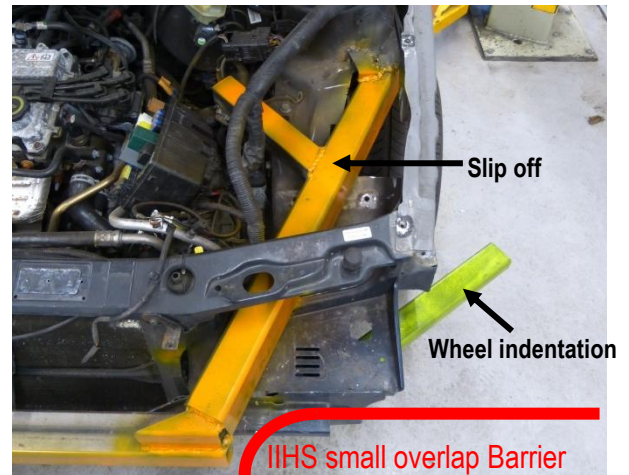


Fig. 23 Vehicel structure at the impacting area

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



Fig. 24 The front structure is pushed away from the barrier by the gains

Because of the slipping off of the vehicle on the barrier the passenger compartment couldn't hook and therefore it deformed only slightly. This can be traced back to the old model year.

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

The vehicle loses only part of the energy by slipping off and has a remaining speed of 30 km/h after the collision.



Fig. 25 Different slip off kinematics

By slipping off of the vehicle on the IIHS small overlap barrier the passenger compartment remained largely intact. Furthermore it was prevented that the left front wheel got hooked and torn off. It should be noted that the structure of the vehicle is not designed for the Euro-NCAP (compare Fig 8 to 10) due to its old model age.

Due to the lateral movement of the vehicle and the transverse movement of the dummy, he did not hit the front airbag. The used vehicle was equipped with first-generation airbags and no side airbags. The measured loads were, compared to the preceding crash tests, generally the lowest and at the whole body substantially below the biomechanical limits.



Fig. 26 Mostly intact passenger compartment and foot well



Fig. 27 The front airbag was missed

6 Interpretation und analysis

6.1 IIHS small overlap crash (DTC 150) in comparison to the two-way traffic collision (DTC 151)

The left two 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. By the Renault Scénic II, also the upper longitudinal bar below the fender 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 for the most part 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. Because of the slipping off and the thereby missing impact of the passenger compartment on the Land Rover Freelander (DTC 151), the deformations and the occupant loads in the two-way traffic collision were significantly lower at the pelvis and lower extremities than the impact of the rigid barrier.

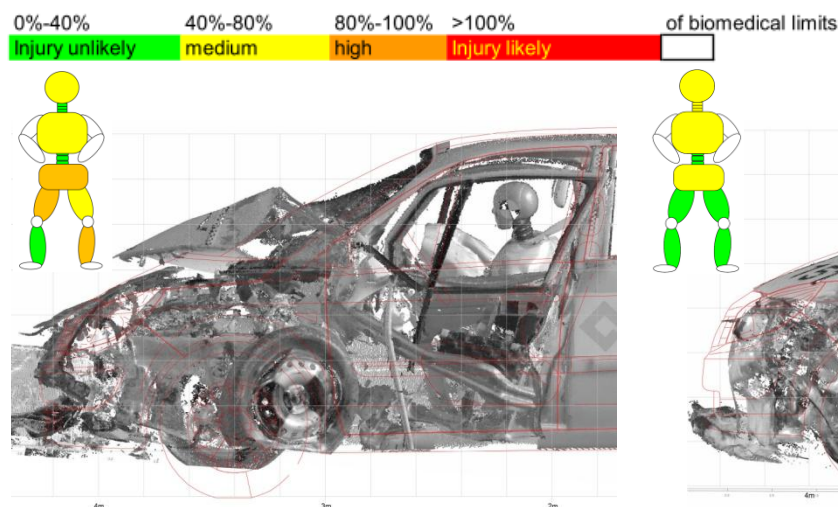


Fig. 28 Passenger compartment after IIHS small overlap Crash DTC 150

Fig. 29 Passenger compartment after two-way traffic collision DTC 151

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

6.2 IIHS small overlap crash with reduced velocity (DTC 149) in comparison to the two-way traffic collision (DTC 151)

The Renault Scénic II at the IIHS small overlap crash test with reduced velocity hooked to the barrier. 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. Despite the small overlap the impact energy could be mainly absorbed up to the passenger compartment, so that the survival space for the occupant is still largely intact. Similar to the two-way traffic collision (DTC 151) the driver's side foot well was lightly deformed by the broken wheel.

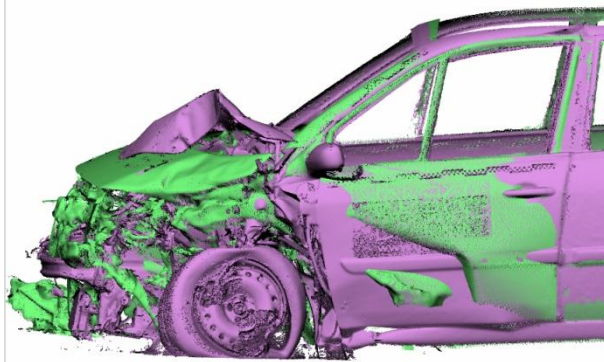


Fig. 30 Overlay of the both vehicle deformation IIHS Barrier DTC 149 (violet) und two-way traffic DTC 151 (green)

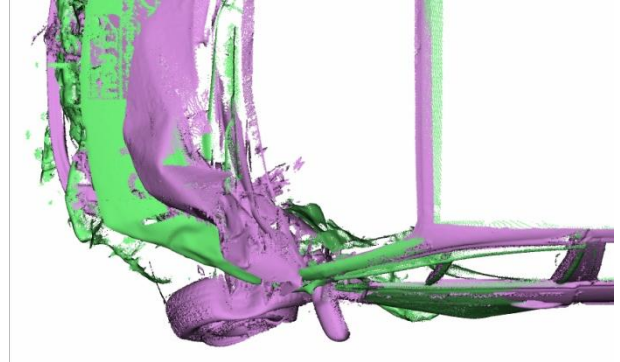


Fig. 31 View from the top

In the left leg of the driver dummy the measured pressure was slightly higher than in the right leg. The measured loads were in both tests on the whole body well below the biomechanical limits. Only the 3 ms head acceleration was slightly higher compared to the oncoming traffic collision. This can be established on one hand, due to the higher collision induced velocity change and secondly due to the higher rotation of the vehicle about the z-axis (DTC 149: 11.0° / DTC 151: 5.2°) and therefor is an unfavorable support of the head to front airbag.

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



Fig. 32 Passenger compartment after two-way traffic collision DTC 151



Fig. 33 Passenger compartment after IIHS small overlap Crash with reduced velocity DTC 149

The crash test DTC 149 has shown that the structure- and occupant load of the two-way traffic collision between the Renault Scénic II and a Land Rover can both be simulated at the IIHS rigid barrier. For the Renault Scénic II that would require a reduced impact velocity of 46 km/h.

6.3 Slip off (DTC 152) in comparison of the energy absorption at the rigid barrier (DTC 149 & DTC 150)

After the deformation of the front structure the Ford Mondeo has slipped off the IIHS small overlap barrier because of the additional built-in structure parts. A hard impact to the passenger compartment at the bottom of the A-pillar did not happen, 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, but only conditionally. By the sudden slip off and the resulting lateral movement of the vehicle the driver dummy missed the front airbag due to its inertia. But thanks to the belt retention the head did not hit the instrument panel or the vehicle structure. In comparison to the Renault Scénic II, the Ford Mondeo has much narrower space in the foot well. Therefore slightly elevated pressures were measured in both legs of the driver dummy. The measured loads were all over the Body the lowest and well below the biomechanical limits.

Because of slipping off and the thereby missing impact of the passenger compartment on the small overlap barrier the deformations and the occupant loads in the collision have been significantly lower than in the crash tests DTC 149 and DTC 150, at which the vehicles have hooked with the IIHS small overlap barrier.

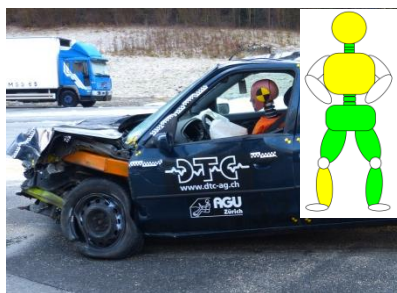


Fig. 34 Driver compartment after IIHS small overlap crash with slip off DTC 152



Fig. 35 Driver compartment after IIHS small overlap crash with reduced velocity DTC 149

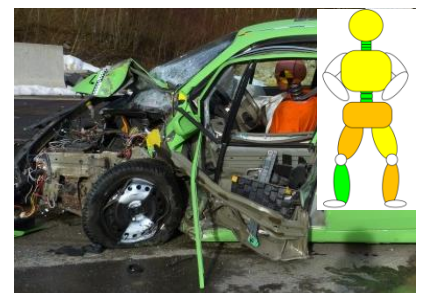


Fig. 36 Driver compartment after IIHS small overlap crash DTC 150

The modified Ford Mondeo has shown a similar behaviour at the sliding on the IIHS barrier as in collision tests with safety barriers and crash cushions. This specific analysis showed the following results:

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

While the specified limits for safety barriers 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 slipping off of the vehicle at small overlap crash test, can be integrated into the front structure has to be determined type-specific by the vehicle manufacturer. It must be ensured that the structural adaptations do not have adverse effects for other accident types. Because of the lateral movement of the vehicle the front airbag is no longer hit optimal. Side airbags as first measure of protection would be more effectively. A contact with the instrument panel and the A-pillar has certainly to be prevented by a corresponding airbag.

Post collision, the vehicle still has kinetic energy, and skids possibly further on the roadway. If a second collision occurs the already activated passive safety features would be exhausted and no more or only insufficiently available. Reusable tensioners and airbags could fix the problem. The vehicle battery would be possibly separated already very early. 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 can still be released in a second collision seconds after the primary impact.

Because the vehicle cannot be steered with a high probability and having brought to a standstill, the vehicle brake should respond automatically and as quickly as possible (VW Golf VII multi collision brake).

7 Conclusion

The studies clearly show that the small overlap crash test reveals some gaps in the design of passive safety concepts of today's 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 may be reproduced accurately enough on the rigid IIHS barrier. The settled high collision velocity of the IIHS test is confirmed in a certain way by the real accidents. To handle a slight overlap crash at such a high velocity onto a rigid barrier, energetically and structurally uninfluenced and without affect the vehicles performance at other equally frequent types of collision, from today's perspective the strategy of slipping off seems to be effective. The occupant protection could be extended to other situations.