Ignacio Lazaro, Thorsten Adolph, Robert Thomson, Nicolas Vie, Mathias Stein, Heiko Johannsen

SEVENTH FRAMEWORK PROGRAMME

FIMCAR
VI – Off-Set Test Procedure: Updated Protocol

FIMCAR
frontal impact and compatibility assessment research

The FIMCAR project was co-funded by the European Commission under the 7th Framework Programme (Grant Agreement no. 234216).

The content of the publication reflects only the view of the authors and may not be considered as the opinion of the European Commission nor the individual partner organisations.

This article is
published at the digital repository of Technische Universität Berlin:
URN urn:nbn:de:kobv:83-opus4-40854
[http://nbn-resolving.de/urn:nbn:de:kobv:83-opus4-40854]

It is part of
FIMCAR – Frontal Impact and Compatibility Assessment Research / Editor:
Heiko Johannsen, Technische Universität Berlin, Institut für Land- und Seeverkehr. – Berlin: Universitätsverlag der TU Berlin, 2013
ISBN 978-3-7983-2614-9 (composite publication)

CONTENT

EXECUTIVE SUMMARY

The off-set assessment procedure potentially contributes to the FIMCAR objectives to maintain the compartment strength and to assess load spreading in frontal collisions. Furthermore it provides the opportunity to assess the restraint system performance with different pulses if combined with a full-width assessment procedure in the frontal assessment approach. Originally it was expected that the PDB assessment procedure would be selected for the FIMCAR assessment approach. However, it was not possible to deliver a compatibility metric in time so that the current off-set procedure (ODB as used in UNECE R94) with some minor modifications was proposed for the FIMCAR Assessment Approach. Nevertheless the potential to assess load spreading, which appears not to be possible with any other assessed frontal impact assessment procedure was considered to be still high. Therefore the development work for the PDB assessment procedure did not stop with the decision not to select the PDB procedure.

As a result of the decisions to use the current ODB and to further develop the PDB procedure, both are covered within this deliverable. The deliverable describes the off-set test procedure that will be recommended by FIMCAR consortium, this corresponds to the ODB test as it is specified in UN-ECE Regulation 94 (R94), i.e. EEVC deformable element with 40% overlap at a test speed of 56 km/h. In addition to the current R94 requirements, FIMCAR will recommend to introduce some structural requirements which will guarantee sufficiently strong occupant compartments by enforcing the stability of the forward occupant cell.

With respect to the PDB assessment procedure a new metric, Digital Derivative in Y direction - DDY, was developed, described, analysed, and compared with other metrics. The DDY metric analyses the deformation gradients laterally across the PDB face. The more even the deformation, the lower the DDY values and the better the metric's result.

In order analyse the different metrics, analysis of the existing PDB test results and the results of the performed simulation studies was performed. In addition, an assessment of artificial deformation profiles with the metrics took place. This analysis shows that there are still issues with the DDY metric but it appears that it is possible to solve them with future optimisations. For example the current metric assesses only the area within 60% of the half vehicle width. For vehicles that have the longitudinals further outboard, the metric is not effective.

In addition to the metric development, practical issues of the PDB tests such as the definition of a scan procedure for the analysis of the deformation pattern including the validation of the scanning procedure by the analysis of 3 different scans at different locations of the same barrier were addressed. Furthermore the repeatability and reproducibility of the PDB was analysed. The barrier deformation readings seem to be sensitive with respect to the impact accuracy.

In total, the deliverable is meant to define the FIMCAR off-set assessment procedure and to be a starting point for further development of the PDB assessment procedure.

1 INTRODUCTION

1.1 FIMCAR Project

For the real life assessment of vehicle safety in frontal collisions the compatibility (described by the self and partner-protection level) between the opponents is crucial. Although compatibility has been analysed worldwide for years, no final assessment approach was defined. Taking into account the EEVC WG15 and the FP5 VC-COMPAT project activities, two test approaches are the most promising candidates for the assessment of compatibility. Both are composed of an off-set and a full overlap test procedure. However, no final decision was taken. In addition, another procedure (tests with a moving deformable barrier) is under discussion in today's research programmes.

Within the FIMCAR project, different off-set, full overlap and MDB test procedures will be analysed to be able to propose a compatibility assessment approach, which will be accepted by a majority of the involved industry and research organisations The development work will be accompanied by harmonisation activities to include research results from outside the consortium and to disseminate the project results taking into account recent GRSP activities on ECE R94, Euro NCAP etc.

The FIMCAR project is organised in six different RTD work packages. Work package 1 (Accident and Cost Benefit Analysis) and Work Package 5 (Numerical Simulation) are supporting activities for WP2 (Offset Test Procedure), WP3 (Full Overlap Test Procedure) and WP4 (MDB Test Procedure). Work Package 6 (Synthesis of the Assessment Methods) gathers the results of WP1 – WP5 and combines them with car-to-car testing results in order to define an approach for frontal impact and compatibility assessment.

1.2 Objective of this Deliverable

The objective of this deliverable is to summarise the FIMCAR activities regarding the off-set assessment procedure and to present the FIMCAR final off-set assessment procedure. In detail the following items are covered:

- Final off-set test protocol
- Reporting of crash test data
- Reporting of the Repeatability and Reproducibility analysis
- Analysis of test severity
- Proposal for off-set assessment criteria and metric
- Analysis of scanning issues for the PDB

1.3 Structure of this Deliverable

The deliverable starts with the definition of the FIMCAR off-set assessment procedure and the justification for its selection. Chapter 3 summarises the FIMCAR off-set test results, followed by further developments of the PDB procedure (metric development, PDB scanning procedure, analysis of test severity).

2 PROTOCOL FOR OFF-SET TEST PROCEDURE

The FIMCAR decision of an off-set test procedure consisted of maintaining the ODB test as it is specified in UN-ECE Regulation 94 (R94), i.e. EEVC deformable element with 40% overlap at a test speed of 56 km/h with no load cell wall or barrier assessments. An additional requirement on vehicle intrusions is proposed to ensure that all vehicles have a stable occupant compartment.

The main reasons for selecting the **Offset Deformable Barrier (ODB)** for the offset test procedure are:

- ODB guarantees that current level of compartment strength will be maintained for all vehicles
- Used in legislated and consumer tests in many countries
- Provides a softer pulse compared to the full width (FW) test
- Harmonization potential
- PDB without reliable compatibility metrics was not acceptable for a majority of FIMCAR members

The addition of a requirement for A-Pillar deformations to be less than 50 mm will guarantee sufficiently strong occupant compartments by enforcing the stability of the forward occupant cell. There is no explicit requirement for compartment stability in the current R94 that ensures a minimum level for Europe. Euro NCAP tests tend to promote stronger compartment designs than R94 but this is not a mandatory test.

The ODB test, as it is specified in R94, is characterized by an overlap of 40% impacting in driver’s side at a test speed of 56 km/h [EEVC 2013]. The deformable barrier used in this test was developed by the European Enhanced Vehicle Safety Committee (EEVC) in the 90’s, its characteristics in terms of stiffness corresponds to a passenger car developed during this period. The details of the test and assessment protocol for the proposed Off-set test are described in the Annex A of this report.

For vehicles developed after the implementation of the R94 the barrier is bottomed out in almost every test, as consequence of the barrier bottoming out, the main impact occurs with the rigid wall, therefore, the ODB test leads to a severe loading of the structures and, in particular, to the cabin intrusions.

Hybrid III (HIII) ATD’s are used to evaluate the self-protection of the vehicle which is assessed through the dummy injury values. The HIII measures the likely injuries in this type of crash. In addition to the HIII assessment, the residual rearward displacement of the A-Pillar (adjacent to the upper hinge of the front door) will be measured. The A-Pillar intrusion gives an indication of the integrity of the passenger compartment. Large displacements are usually associated with catastrophic collapse of the roof, driver's door and floorpan. A-Pillar displacements greater than 50 mm in the ODB 56 km/h test are considered as a potential control for passenger compartment integrity.

3 SUMMARY OF TESTS PERFORMED

3.1 PDB Tests

Two off-set candidates were evaluated in WP2, the ODB and PDB test procedures, as described in D2.1 [Lazaro 2013]. The PDB was identified at the start of the project as the one with more potential to evaluate the issues and priorities defined in FIMCAR, but still some open issues need be addressed, see Figure 3.1.

FIMCAR's consortium identified 8 main priorities to be addressed for frontal impact protection, see Figure 3.1. Not all these priorities are necessarily needed to be evaluated in an off-set procedure if it is combined with the full width test in a common frontal impact protection assessment. The main issues that are expected to be evaluated in an off-set procedure are the load spreading issues (Structural Interaction) and the self-protection in regards to compartment strength. In addition, the combination of a full width and off-set test provide a possibility to evaluate the restraint system for different pulses.

Figure 3.1 summarises the list of issues to be addressed by the frontal impact protection assessment test procedures. Both off-set test candidates were evaluated with respect to these priorities and the PDB was identified as the one with more potential to address the below described priorities.

	Structural Interaction		Front End Force / Deformation		Compartment Integrity		Restraint System	
	Alignment	Load Spreading	Deforma-tion force	Energy Absorption	Sufficient for self-protection	Enhanced for light vehicles	Different pulses	Restraint Capacity
Priority	1	1	2	1	1	2	1	1
Can be addressed by? (FIMCAR conclusions)								
ODB	N	N	N	-	Y	N	-	-
PDB	Y	?	Y	-	?	Y	-	-

Metric development **Test procedure characteristics**

Figure 3.1: FIMCAR priorities and off-set candidates.

Regarding the two off-set candidates, only the PDB has the potential to assist in evaluating structural alignment (load spreading). The PDB provides the final deformed shape of the barrier at the end of crash. That gives an indication about how the tested vehicle will interact with a partner vehicle in case of a car-to-car collision.

After the initial analyses performed within WP2, some of the issues in Figure 3.1 needed to be further investigated. In case of the ODB, as its potential to address the compartment integrity issue was limited, there were no additional items to be proved or reviewed. Therefore, the FIMCAR off-set test series was focused on the PDB test procedure.

Although the PDB also gives the possibility of assessing the front-end forces of the tested vehicle, which may be desirable for assessing force level matching between vehicles, the accident data in WP1 did not indicate that this issue was a high priority for current FIMCAR activities.

The main issues to be addressed in the PDB test campaign were:

- Structural Interaction (Load spreading)
- Compartment integrity (Sufficient for self-protection)

A total of 7 PDB tests were performed in WP2. Table 1 shows the complete test matrix and the main objective of each test. In addition to the above objectives, this testing program will support the final development of the assessment procedure and support the repeatability and reproducibility (R&R) evaluation of the PDB approach.

Table 1: PDB Test matrix.

Vehicle to test	Laboratory	Test Date	Test configuration	Objective	Partner-protection
Supermini 2	FIAT	Jun 2011	PDB60	Test severity validation (self-protection) and comparison with other test modes (FWRB and MPDB)	Good performance expected
City Car 1	UTAC	Sep 2011	PDB60	Comparison with Supermini 2 in terms of the vehicle performance	Good performance expected
Supermini 1	PSA	Nov 2011	PDB60	Test severity validation (self-protection) and validation of the compatibility assessment	Marginal performance expected
Supermini 2	BASt	Jan 2012	PDB60	Repeatability issues	Good performance expected
Supermini 2	BASt	Apr 2012	PDB60	Repeatability issues	Good performance expected
SUV 1	IDIADA	May 2012	PDB60	Test severity validation (self-protection) and validation of the compatibility assessment	Good performance expected
Small family Car 1 (SFC 1)	IDADA	Jun 2012	PDB60	Test severity validation (self-protection) and validation of the compatibility assessment	PASS/FAIL limit investigation

A detailed test report and analysis of these 7 tests can be found in Annex E of this deliverable. The main objective of FIMCAR's off-set testing activities was addressing the different issues pointed out by the project, as well as answering to the R&R issues of the PDB test procedure.

In order to address the compartment strength issues the following items were analysed.

3.1.1 Pulse

The vehicle test pulse for all the tests was measured at the B-pillar base. The vehicle pulse gives an estimation of the test severity in terms of deceleration. A higher deceleration will indicate a higher severity of the test. The duration of the pulse will serve as an indicator of the severity, shorter durations will suggest higher severities.

Figure 3.2 shows the vehicle pulse of all the PDB tests performed. The graph shows the tendency that the small vehicles have the highest deceleration peak (i.e. City Car 1, Supermini 1 and Supermini 2) compared to the heavy ones. In particular, a significantly lower peak was observed for the heavy vehicle (SUV 1). The mid-size car, SFC 1, is located in between both categories of vehicles.

A similar trend is observed in terms of pulse duration. Vehicles with higher deceleration peaks reached 0 m/s earlier than vehicles with lower peak. A significant difference is observed between the SUV 1 and the small vehicles, in particular Supermini 2 and City Car 1. In all cases an equivalent delta velocity (DV) is observed.

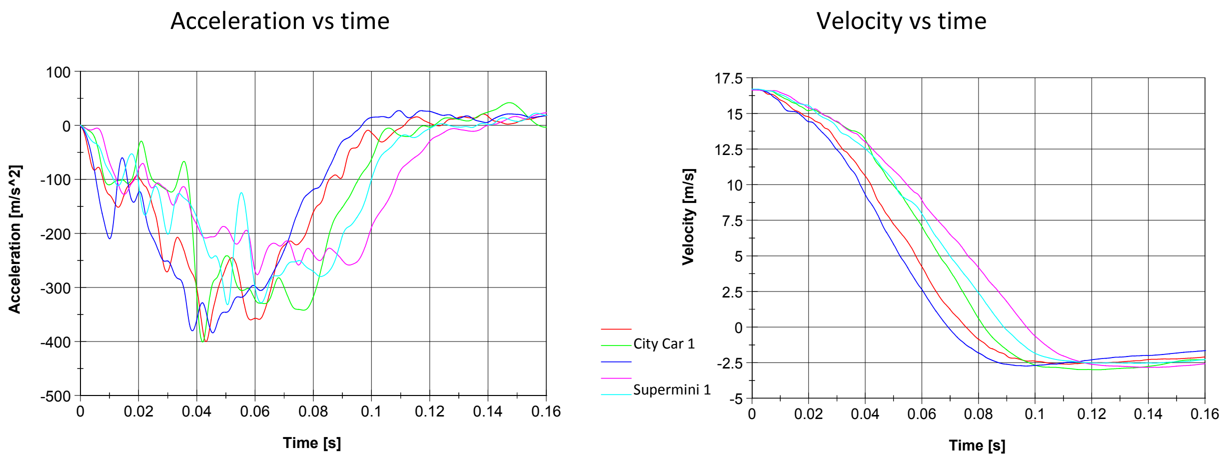


Figure 3.2: Tested vehicles pulse.

Parameters like the *max mean acceleration*, Equation 3.1, also serves to evaluate the level of severity and compare the severity of different test procedures and between vehicles.

$$max\ mean\ acc = \frac{max\ Delta\ V}{time\ to\ max\ DeltaV}$$

Equation 3.1: Max mean acc.

The max mean acceleration of the different PDB tests has been compared. The results are summarised in Figure 3.3. The Supermini 2 shows a significantly higher value compared to the others, the lowest value is the SUV 1, followed by the SFC 1. Therefore, we can confirm that the Supermini 2 test was more severe in terms of deceleration pulse compared to the others.

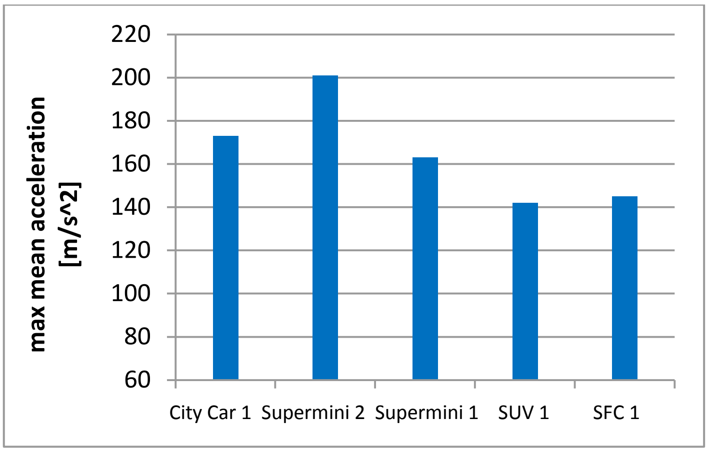


Figure 3.3 Tested vehicles max mean acceleration.

The Supermini 2 PDB test achieved even higher decelerations than the corresponding Euro NCAP [Euro NCAP 2013] test. As result, a high mean acceleration is also observed in the PDB test, 205 compared to 177m/s^2. Although no data was available, it is expected that the R94 test will record a significantly lower value than the other two tests.

The PDB pulse is generated by the deformation of both barrier and vehicle, with similar contributions from each of them. In the Euro NCAP test, the ODB barrier's contribution is significantly lower than the vehicle's. On the other hand, in the Euro NCAP test the vehicle sill is loaded while in the PDB test no deformation is observed in this area.

Euro NCAP test PDB test

Figure 3.4 Supermini 2 PDB vs. Euro NCAP

No deformation of the sill load path was observed in all PDB tests performed in WP2, independent from the type of tested vehicle. In Figure 3.4 we can appreciate the local deformation of the Euro NCAP test at the sill area. The deformation suggests a loading in the structure and, as consequence, the contribution of the load path to the deceleration pulse.

3.1.2 Intrusions

The residual displacement of structural components in the passenger compartment provides an indication of the level of self-protection offered by the tested vehicle, i.e. the A-pillar rearward displacement. The passenger compartment will be loaded during the crash and the A-pillar will be displaced rearwards. In other words, the intrusions can be interpreted as a direct indication of the response of the vehicle the passenger loading. The A-pillar intrusion, or lack of, will indicate a level of self-protection of the tested vehicle.

The European vehicles influenced by Euro NCAP (almost all vehicles today in Europe) produce a very low A-pillar rearward displacement in any off-set test (R94, Euro NCAP or PDB). This is also the case for the vehicles that were tested against the PDB in FIMCAR, in all cases below 30 mm. Figure 3.5 shows the results of the A-pillar intrusions for these vehicles.

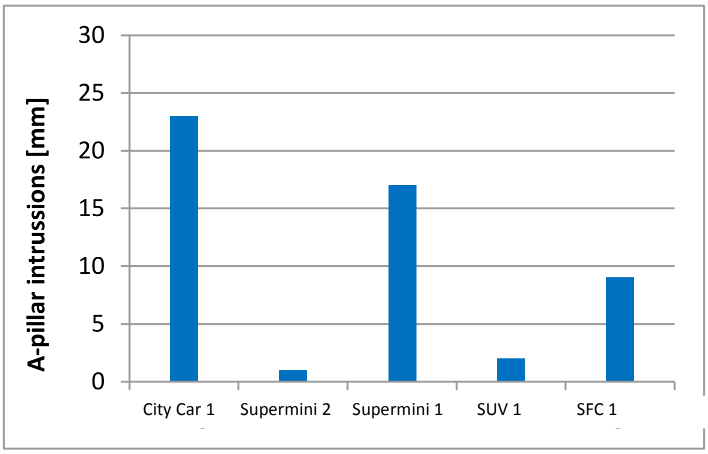


Figure 3.5: Tested vehicles A-Pillar intrusion.

3.1.3 Dummy Loadings

The dummy injuries are a direct indication of the level of self-protection provided by the tested vehicle. The protection provided by the car during the frontal impact test is measured by the ATD, HIII 50%tile male dummy, as it is specified by today's ECE R94 frontal off-set test [EEVC 2013].

In WP2 tests, the injury parameters are compared to the Euro NCAP [Euro NCAP 2013] scale in order to provide an estimation of the level of protection provided by the vehicle and compare the PDB severity to the Euro NCAP rating.

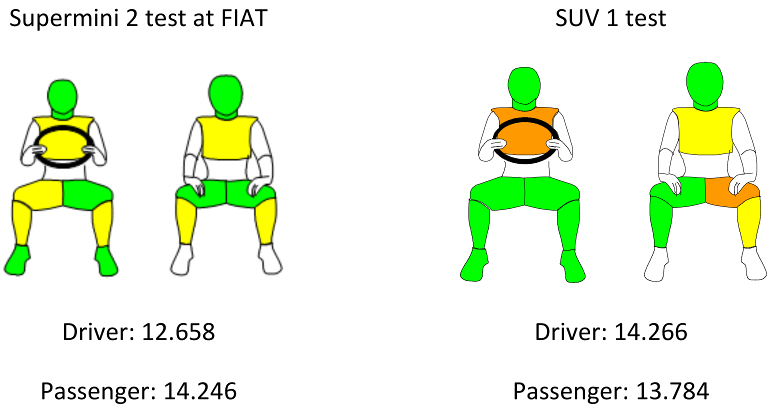


Figure 3.6 PDB tests dummy results.

The figure above shows the dummy results of two PDB tests performed by WP2, Supermini 2 and SUV 1. After the vehicle analysis, it was concluded that the main dummy injuries were caused by the deceleration pulse. In both PDB tests the passenger compartment was stable and negligible intrusions were measured. Therefore, we can conclude that no injury was caused by intrusions.

In general, we can state that higher dummy injuries will be caused by the deceleration pulse and will occur at the time of maximum B-Pillar deceleration. As shown in the dummy results comparison, high injuries were recorded in the Supermini 2 compared to the SUV 1, which also achieved a higher deceleration pulse

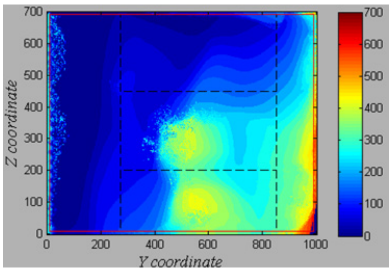
It has to be taken into account that all tested vehicles are equipped with different restraint systems that have developed for the R94 and Euro NCAP test conditions. The Supermini 2 is equipped with a double seatbelt pre-tensioner and knee airbag, while a single pre-tensioner an no knee airbag is available in the SUV 1, however better results were obtained in the SUV 1 crash test.

As the PDB test represents a more severe test for the Supermini 2 compared to the Euro NCAP one (conclusion from vehicle pulse analysis) high injury values were obtained in the PDB compared to the test performed by Euro NCAP, 12.6 and 15.1 points [Euro NCAP 2013], respectively.

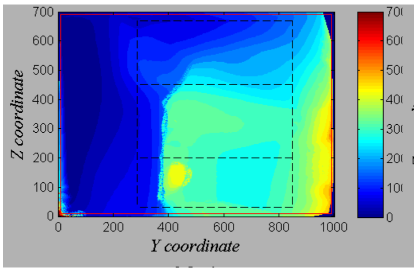
The PDB scanning was also analysed in order to evaluate the structural interaction of the vehicle (load spreading)

3.1.4 PDB Scanning

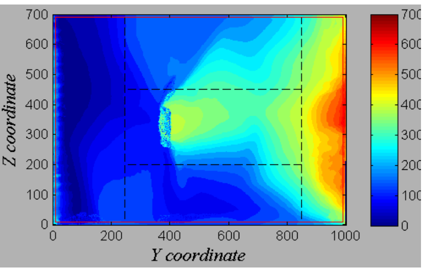
The PDB will serve to investigate the level of partner-protection provided by the tested vehicle. In particular, the PDB assessment will focus on load spreading issues. This structural interaction issue has been identified by the FIMCAR consortium as a Priority 1 issue. The PDB scans obtained in WP2 were included in the development of the PDB metrics.



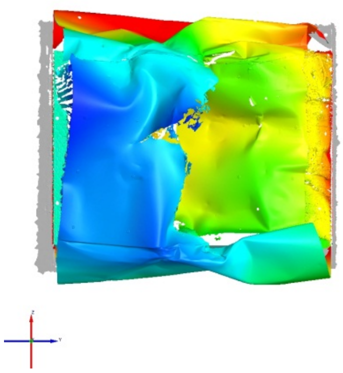
City Car 1



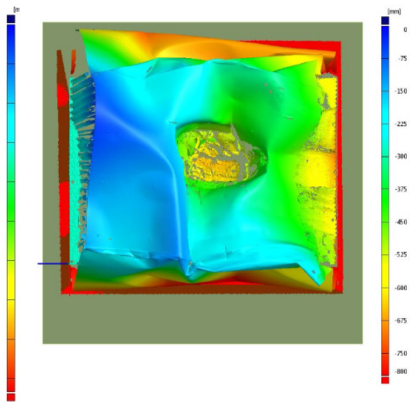
Supermini 2 at FIAT



Supermini 1



SUV 1



SFC 1

Figure 3.7: PDB scans.

The further development of the PDB metric can be found in Section 4.1 of this report. The development will focus on the load spreading metric between the longitudinals which has been defined as Priority for FIMCAR project.

3.2 Car-to-Car Tests

Three series of car-to-car crash tests will support the off-set assessment proposal and the PDB metric (PASS/FAIL definition) proposed by WP2 and will also support the final validation of the PDB metric, the test series are:

- Supermini 2, aligned and misaligned
- Supermini 1, aligned and misaligned
- SUV 1 vs. SFC 1, aligned and misaligned and SUV 2 vs. SFC 1 aligned

The main issues to be addressed in these car-to-car series are the underride/override issue, evaluated in the comparison between aligned and misaligned situations. The fork effect can be analysed in the aligned conditions, where no underride was present.

The compatibility issue is detected when one of the two tested vehicles will be performing poorly compared to the opposite vehicle, when the collision partner is an identical model, or a reference test. For the FIMCAR project a reference crash for the car-to-car tests was the Euro NCAP test results.

Supermini 2 showed a compatible situation in both aligned and misaligned car-to-car tests, details can be found in FIMCAR report D6.1 (Car-to-Car test results) [Sandqvist 2013]. Therefore, the Supermini 2 test series suggests that the tested vehicle should be a clear PASS the load spreading metric.

In the Supermini 1 case, the aligned car-to-car test presented acceptable results for both tested cars. On the other hand, the misaligned situation showed a bad performance in the lowered car compared to the other vehicles (aligned and raised), which was identified as an “incompatible” situation. High injuries for the diver and high vehicle intrusions were measured (single vehicle in all car-to-car test series with A-Pillar intrusions above 50 mm). The main issue observed in this misaligned situation was the underride of the raised vehicle into the lowered one, refer to D6.1. However, the “compatible” situation spotted in the aligned Supermini 1 and the underride situation in the misaligned suggests that the Supermini 1 should PASS the load spreading metric.

The PEAS of the Supermini 1 worked well in alignment conditions. Therefore, the Supermini 1 should PASS the metric. The absence of SEAS, or other structures to support vertical load spreading, can be identified as the main issue causing the “incompatible” situation in the misaligned test.

Finally, the last car-to-car test series showed better results in the SUV 1 vs. SFC 1 (aligned and misaligned) compared to the SUV 2 vs. SFC 1 (aligned), this last test was classified as an “incompatible” situation. The main reason for this “incompatible” situation observed in the SUV2- SFC 1 tests seems to be a fork effect.

In conclusion, the SUV 1 will be a clear PASS vehicle, while the SUV 2 and SFC 1 need to be further evaluated in order to understand the final reason of the fork effect and the main responsible of the “incompatible” situation.

4 FURTHER DEVELOPMENT OF PDB PROTOCOL

The fundamentals of the assessment method using the PDB off-set test have been defined in D2.1 [Lazaro 2013]. However, because the metric still needs to be developed further and validated, the majority of the FIMCAR members decided to propose the current ODB test procedure for the FIMCAR test approach.

It should be noted that work to develop compatibility metrics for the PDB test continued within the project because the majority of FIMCAR members believe that the PDB test has potential for compatibility assessment in the longer term.

4.1 Further Development of Metric

Different metrics assessing the depth of barrier deformation and distribution of deformations have been investigated in FIMCAR. During the initial development phase of the PDB metric, the development was supported by a database of 37 PDB tests at 60 km/h, tests performed in previous research projects (e.g. VC-Compat). WP2 has contributed to this database with 7 additional tests. Therefore, a total 44 cases were available to develop this metric.

The barrier deformation of these tests was analysed and taken as a reference for metric development. In a first stage, the barriers were classified following a subjective approach, gathering the barriers that suggest a good performance in compatibility, a detailed explanation about the subjective classification can be found in FIMCAR deliverable D2.1 [Lazaro 2013].

The PDB methodology consists of assessing the barrier deformation. The PDB vertically divided in zones as shown in Figure 4.1.

The area for assessing the PEAS has been identified as the priority for evaluating the load spreading (first priority in the evaluation).

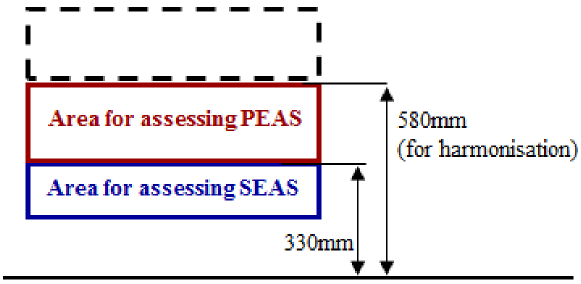


Figure 4.1: PDB areas of assessment.

This assessment area should include the common interaction zone (CIZ) of Part 581 (406 to 508 mm from ground). With this objective WP2 has defined different options for the load spreading evaluation. The 330 to 580 mm from ground area has been harmonized with the FW methodology. This area also includes the CIZ of Part 581.

The PDB metric calculations follow the steps:

- PDB scan: *.stl file as the result
  - The deformation of the PDB barrier is digitized into a graphic file using the .stl format

- PDB scanning pre-processing: Two methods investigated “Ray Tracing” (VTI) and “Deformation Projection” (TNO)
  - The Ray Tracing procedure is used to address the potential for barrier folding and pockets in the deformed barriers. Ray Tracing uses the deepest deformed points when more than one surface in along the x axis is encountered for the same y&z coordinates.
  - Deformation Projection was a procedure to convert all x coordinates into an orthogonal y&z coordinate system. This procedure was part of the Ray Tracing procedure and not required as a separate procedure. Details of the methods are provided below.
- Criteria calculation: Load path detection and Load Spreading characteristics
  - The objective values calculated from the barrier deformations were reviewed and compared to the subjective calculations. Different criteria were developed and a summary is provided in Section 4.1.2
- Metric calculation: PASS/FAIL threshold definition

Different scan methodologies have been used in FIMCAR project. Details of the PDB scan comparisons using these methodologies are described in section 5.2.2 of this report.

Different pre-processing methods have been investigated in FIMCAR. Figure 4.2 shows an example of PDB scan pre-process using the “Ray Tracing” method (right image of Figure 4.2) and the “Deformation Projection” method (left image of Figure 4.2)

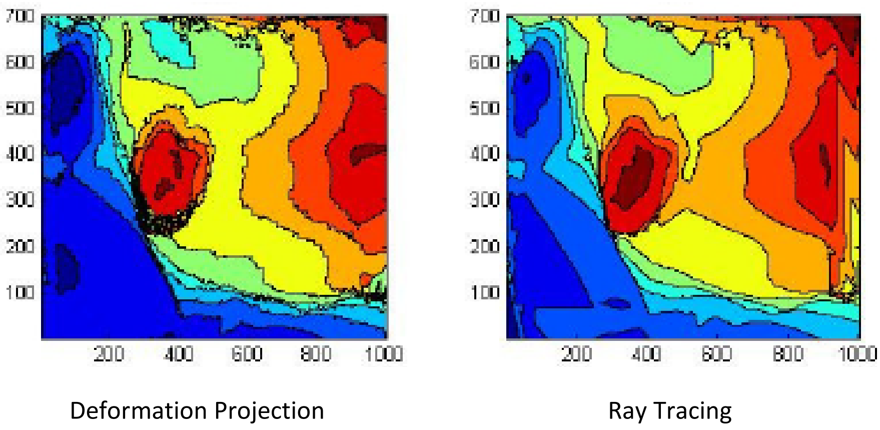


Figure 4.2: PDB pre-processing methods.

As shown in Figure 4.2, both pre-processing methods, present reasonably consistent results for deformation. The Ray Tracing procedure developed at VTI provided a more consistent filtering of the data and made metrics based on deformation gradients less susceptible to small (under 3 mm) tears or folds. After the confirmation that both presented methodologies provided similar results, VTI method was adopted for further PDB analysis.

Different scanning methodologies have been used in FIMCAR project. Both laser scanning and photographic methods were used. The results of the PDB scan comparisons are given described in Section 5.2.2 of this report.

4.1.1 Load Path Detection (Longitudinal Deformation)

The aim of the criteria is to identify front-end structures, which are able to deform the barrier in a significant manner. The load path will be evaluated by the barrier deformation. The 3D measurements of the barrier will allow the identification of the vehicle load paths.

The load path detection will be assessed by the Longitudinal Deformation of the barrier. The Longitudinal deformation (d) criterion has been developed using statistical characteristics of the deformation within a defined zone, taking coefficients of the barrier longitudinal deformations.

The parameter and limits can also be used to limit the front-end stiffness controlling the maximum deformation of the barrier. Proposals for this criterion were presented in FIMCAR Deliverable D2.1 [Lazaro 2013]. Due to the priority of compatibility issues in the FIMCAR project (Figure 3.1) no further investigation was carried out for stiffness matching during the final development phase of the PDB protocol.

4.1.2 Load Spreading

The aim of this criterion is to assess the load spreading characteristics of a specific load path. This criterion is identified as a key issue for FIMCAR. Therefore, its development is particularly important for the project. Several different concepts were explored and evaluated in the second half of the project.

4.1.2.1 Maximum Sub-zone Displacement

One approach to load spreading used the area of investigation for horizontal load spreading divided horizontally in a total of N equal sub-zones as shown in Figure 4.3. The vertical limits of overall area will be fixed (e.g. 330 to 580 mm from ground). The horizontal limits and in consequence the final size of the sub-zones will differ in function of the width of the vehicle.

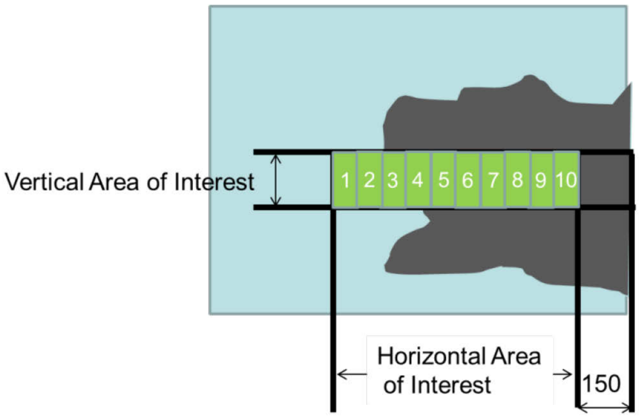


Figure 4.3: Subzone definition.

Dividing the area of analysis in sub-zones allows investigating the horizontal load spreading over the total area of investigation. Further analysis of the sub-zones has been done in terms of differences of the longitudinal deformations among the different sub-zones.

Different parameters can be calculated from these N sub-zones:

- D is the average of longitudinal deformation of the complete area
- Di (i=1 to N) is the average of longitudinal deformation for the i sub-zone
- q%ile i (i=1 to N) is the q%ile of longitudinal deformation for the i sub-zone

Several criteria have been developed and investigated using the above mentioned parameters, some examples are:

- D/Di gives an estimation of the horizontal variation of the i sub-zone compare to the total average
- ei=D-Di is the deviation of a sub-zone from the overall average of deformation

Vehicles that have a good horizontal load distribution should have similar deformations in each sub-zone. Therefore criteria that promote small deviations among the subzones should promote better structural interactions.

4.1.2.2 Change in Horizontal Slope – Digital Derivative Y

Good horizontal load distribution should produce an even distribution of PDB deformation across the width of the vehicle. One indicator of the load spreading should therefore be the absence of sudden changes in the slope of the barrier deformation in the lateral direction. If one considers the average depth at every horizontal segment of a barrier deformation within the assessment area as shown in Figure 4.4, the deformation vs horizontal position graphs can be plotted as shown under the PDB deformation plots. The displacement graphs can be further processed so that each horizontal position is associated with the slope in of deformation in the y direction. The Digital Derivative in Y (DDY) is an indicator to how smooth the barrier is deformed. Figure 4.4 (left side) shows an example of a relatively smooth barrier deformation with few abrupt displacement changes while the right side of Figure 4.4 indicates more localised deformations and thus poor horizontal load spreading.

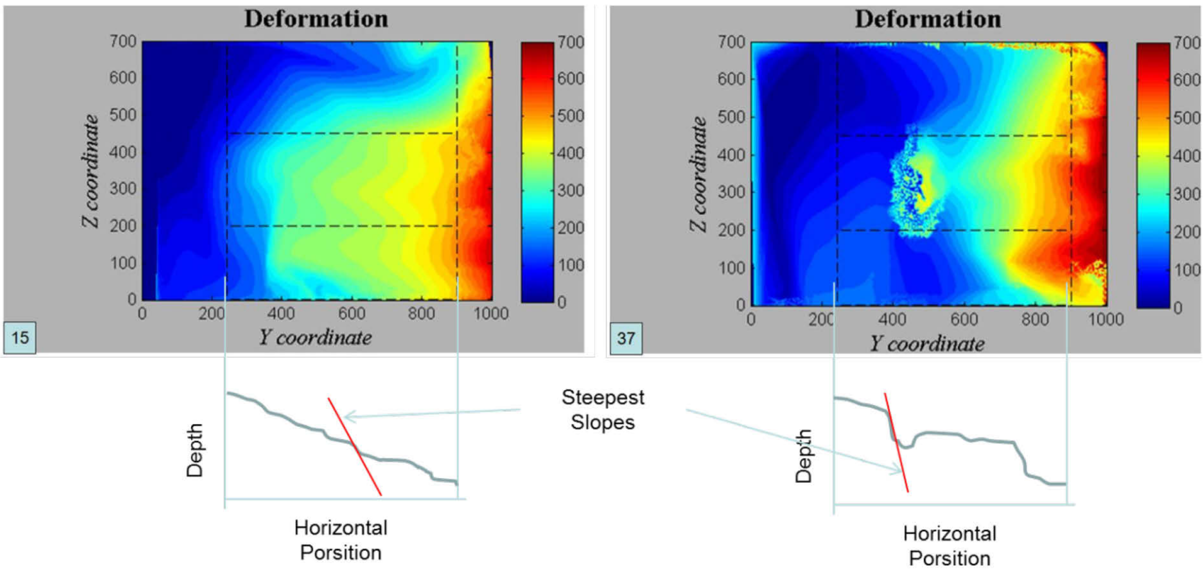


Figure 4.4: Horizontal slopes.

The DDY metric

During the review of the results, the DDY calculation over the entire horizontal area of investigation emerged as the best candidate to evaluate the Load Spreading issue. This parameter guarantees the independency of the metric to the vehicle mass. At the same time, it represents a relatively easy approach as no need of additional divisions of the assessment area is necessary.

$$\text{For } y=1 \text{ to } Ny,\ z=1 \text{ to } Nz \qquad DDY(y,z) = \left|\frac{X(y,z)-X(y-1,z)}{\text{mesh size}}\right|$$

Equation 4.1: DDY equation.

Regarding the metric development different options were investigated:

- Lateral limit: UTAC proposal (W/2-100mm), 80%, 70% and 60% of vehicle width
- Vertical definition: CIZ of Part 581 and Row 3&4
- DDY criteria: max DDY, 99%ile DDY and standard deviation of DDY
- Mesh dimensions: 1,3,5,10 mm

The 99%ile DDY calculated in the defined area gives an estimation of the homogeneity of the barrier. Lower values will correspond to small variations in the analysed area, therefore more homogeneous vehicle deformation.

Figure 4.5 summarizes the lateral limits of the area of investigation, which is fixed at 150 mm from the centre of the vehicle and extends laterally to the side of the tested vehicle. These dimensions are constant for left-hand or right-hand drive cars.

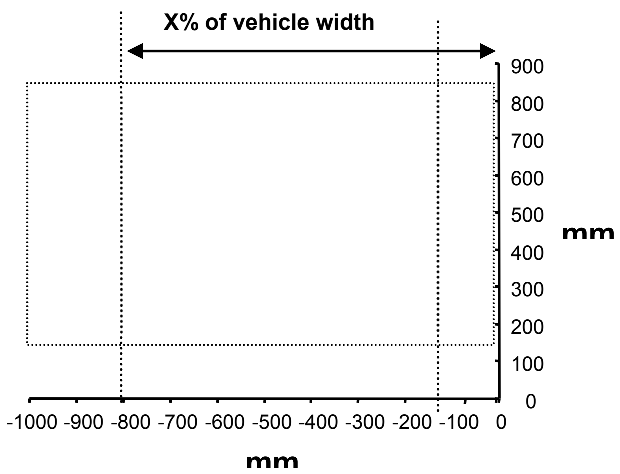


Figure 4.5: Lateral limits.

The assessment areas consisting of 330-580 mm (Row 3&4 in the FW test), 60% vehicle width and 99%ile DDY provided the best correlation with the subjective classification and showed acceptable R&R results. Figure 4.6 shows the subjective classification as described in FIMCAR Deliverable D2.1 [Lazaro 2013] against the 99%ile DDY criterion in the evaluation area (Row 3&4 and 60%). The subjective classification grouped the studied cases in three different groups. These groups identify different horizontal load spreading cases due to the architecture and can be summarised as:

- G1: Group 1, Cases that should PASS a horizontal load spreading metric
- G2: Group 2, Borderline cases that required a specific evaluation
- G3: Group 3, Cases that should FAIL a horizontal load spreading metric

It is important to note that Figure 4.6 shows the initial analysis results as described in the original FIMCAR Deliverable D2.2. However, in the review process it appears that some results are incorrect. The updated results are shown in Chapter 4.6 below.

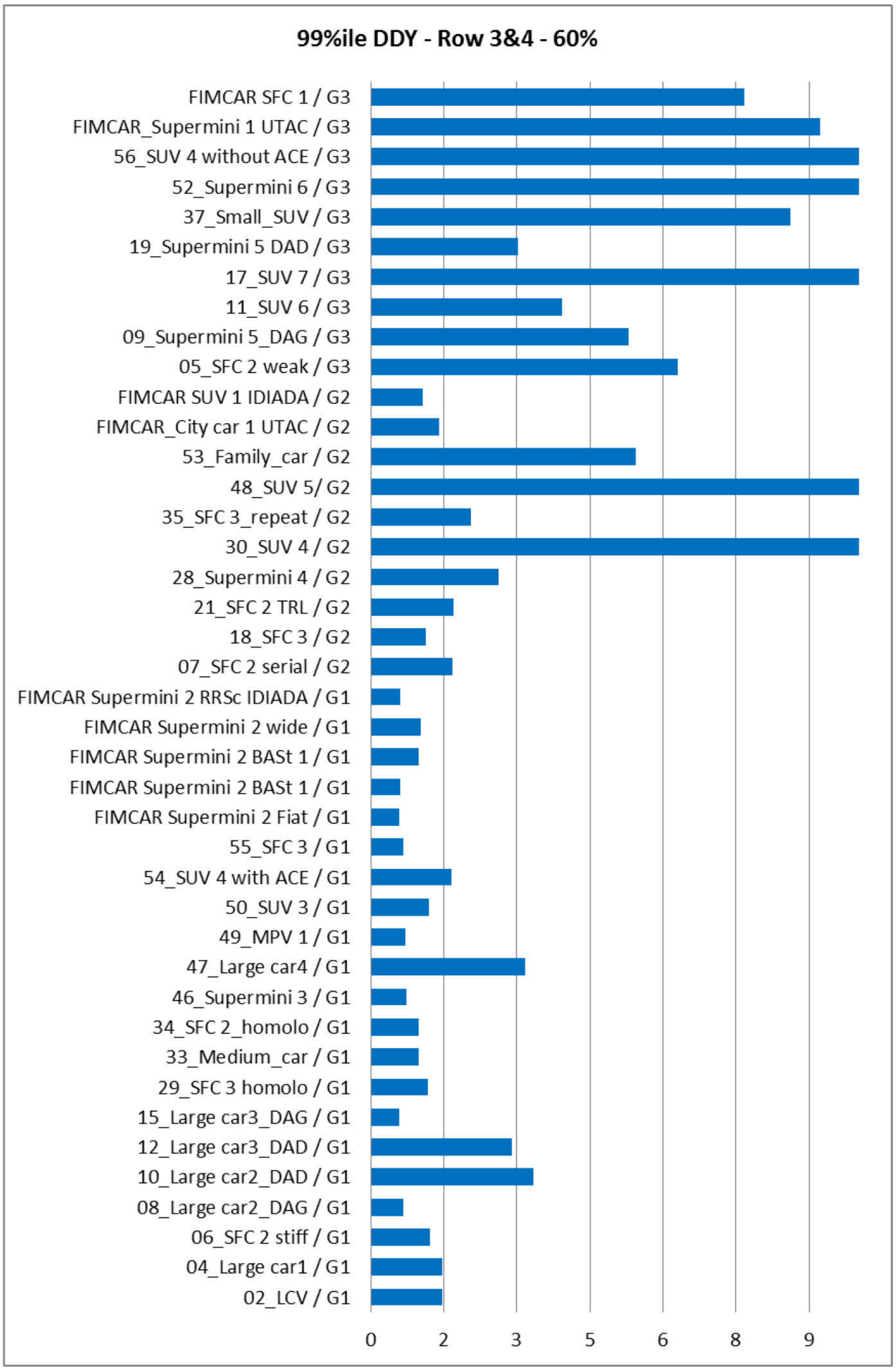


Figure 4.6: Initial 99% DDY, Row 3&4, 60%.

The results were analysed and the following cases were investigated for the 99%ile DDY criteria.

- <u>PASS/FAIL threshold must be consistent with subjective classification.</u>

The 99%ile DDY criterion with a threshold value of 3.5 could discriminate between vehicle with an even (homogeneous) deformation pattern, G1, and barrier with localised holes, G3. There were some borderline cases that should be reviewed but the criteria had a good sensitivity to discriminate vehicles according to the subjective rating.

- <u>Repeatability in terms of value for the R&R study in WP2 (Supermini 2).</u>

The criterion showed a good repeatability for the different tests of the Supermini 2, values around 0.60, well below the proposed limit. This confirms the good performance expected by the FIMCAR Supermini 2.

- Additional R&R of previous projects, only PASS/FAIL.

An acceptable R&R in terms of PASS/FAIL assessment was found for the cases studied in previous projects. All R&R cases for previous projects showed the same PASS/FAIL result, except the left and right hand versions (Case 9 and 19 in Figure 4.7) for one vehicle. In one case the hole was smoother that the other and as a consequence one passes the metric and the second fails. This difference arises due to the asymmetric drivetrain structures in the vehicle and should be considered in a “worst case” condition for testing.

- Studies of “modified” vehicles also taken into account.

The proposed metric also showed a consistent result in the “modified” vehicles studies. Vehicle 54 was a redesign of vehicle 56 for compatibility and the modifications introduced in the vehicles were reflected by the metric and correlated with the PASS/FAIL results.

4.1.3 Conclusions

The structural interaction has been defined as a main issue for improving the partner-protection of a vehicle. The vertical location of the load paths, assessed by the longitudinal deformation of the barrier, can provide an estimation of the risk that the tested vehicle will be interacting with the opponent car. However this is better addressed in the structural alignment metric in the FWDB test [Adolph 2013].

The contribution of the SEAS has been defined as an added value to contribute in partner-protection issues. In the first stages of FIMCAR, 50 to 65% of longitudinal deformation, or mean deformation, have been identified as the most promising parameters to detect the load paths [Lazaro 2013]. This metric was not further investigated as the priority for the last year in FIMCAR was to develop a horizontal load spreading criterion.

The load spreading in the CIZ has been also identified as a main issue to be addressed by the PDB procedure. Several proposals for assessing the characteristics of the load spreading have been investigated in FIMCAR. The criterion with the best correlation to subjective vehicle ranking has been obtained using the slope of the deformations in the Y direction. The assessment parameter is the 99%ile DDY calculated in the Row 3&4 investigation area and with an outer vertical limit of 60%. The Row 3&4 area is harmonized with the FW metrics, while the 60% of the vehicle width ensures the involvement of a significant part of PEAS in the assessment. This assessment width captures the crossbeam performance between the longitudinals for European cars.

The objective of this criterion is to address compatibility issues like the small overlap and the fork effect.

4.2 Artificial PDB Profiles

The evaluation of the PDB assessment metrics was initially carried out by the deformation patterns coming from PDB and MPBD crashes. The subjective analysis enabled the FIMCAR group to distinguish between clear effects like holes and homogenous footprints. The result of this process was the subjective classification of the tested vehicles into three groups, see

FIMCAR Deliverable D2.1 [Lazaro 2013]. However, sometimes the metric results were not clearly understood and it was assumed that the combination of different compatibility characteristics were interpreted differently in the metrics than in the subjective assessment. In particular the BDA software provides one value containing the assessment of different characteristics like maximum intrusion depth and homogeneity intrusion depth in specific areas. In order to separate different characteristics (i.e., intrusion depth, number of load paths, homogeneity and deformed areas that are within investigations zones and those that exceed the investigation zones) independently, artificial deformation profiles were developed. The main objective was to create simple deformation patterns addressing the following specific frontal impact compatibility issues of the PDB:

- Intrusion depth
- Vertical load spreading
- Horizontal load spreading
- Homogeneity (in terms of proportion of deformed area within a specific area)

Based on a re-meshed cladding plate of the FEM PDB model, 47 artificial profiles where created. In addition to the evaluation of the BDA software the most promising assessment metrics developed within FICMAR (Homogeneity Value and Smooth Deformation Index - SDI), see [Lazaro 2013], and DDY were analysed too. A summary of all artificial profiles and the corresponding assessments is shown in Annex F.

The following analysis is based on the artificial profiles shown in Annex F. Qualitative information about the geometry and the assessment by BDA software, Homogeneity value and DDY can be found there. It is important to know that the DDY metric was developed relative late in the project and that this metric addresses only the homogeneity within a specific area (Area of Interest – AoI). The artificial profiles were not designed to address this kind of homogeneity. That is why the DDY assessments alter between 20.1 and 0.0 depending on whether or not the deformation is within the AoI. Thereby 0.0 means that the deformation is completely within the AoI and 20.1 indicate that the deformation exceeds the borders of the AoI. Therefore the DDY values are not taken into account in the following analysis. As a result of this it needs to be stated that the DDY metric needs to be improved to better cope with deformation profiles that exceed the AoI as homogeneity exceeding the width of the longitudinals was considered to be important for small overlap compatibility.

The visualisation of the assessments of BDA software and Homogeneity value is given in relation to the mean value of the corresponding group. This means that values > 1.0 indicate increasing scores and values < 1.0 indicate decreasing scores. The BDA software assessment uses the Partner Protection Score (PPS) which is a combined rating for all frontal impact compatibility issues listed above. The higher this value, the better is the assessment of the compatibility. The Homogeneity value is intended only to address the homogeneity of the deformation within the AoI. The higher the Homogeneity value, the more homogenous is the deformation pattern.

4.2.1 Sensitivity Analysis – Intrusions

The intrusion depth should not have an influence on the homogeneity assessments. The main reason is that heavier vehicles generally produce deeper intrusions than lighter vehicles even though they can have comparable load spreading. If the assessment results strongly depend on the vehicle mass, the corresponding metric needs to be revised because on the one hand it is very difficult for light vehicles to create a specific intrusion depth and for heavy vehicles it could be a problem to reduce the maximum intrusion depth. Figure 4.7 are examples of identical PDB profiles except for deformation depth and Figure 4.8 are the resulting evaluations.

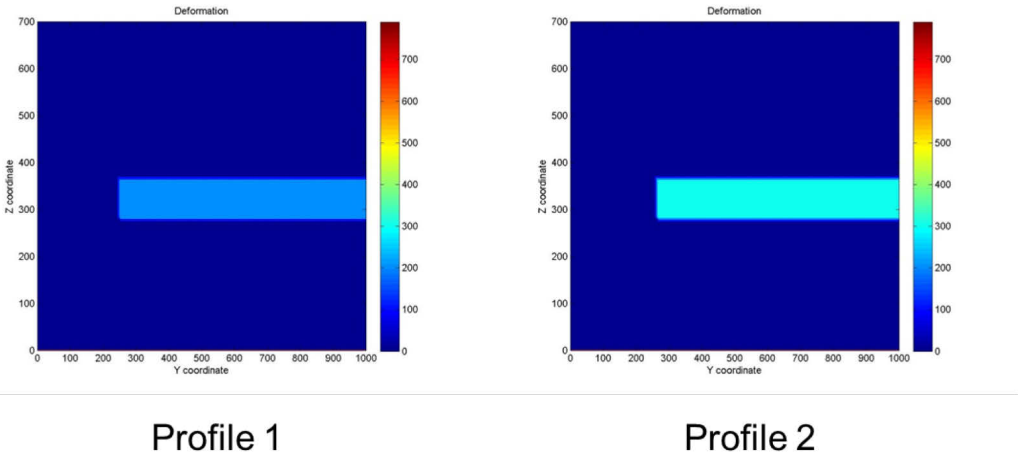


Figure 4.7: Intrusion depth – variation of the maximum intrusion (300mm to 400mm) within the middle area of the PDB (only minor differences are expected).

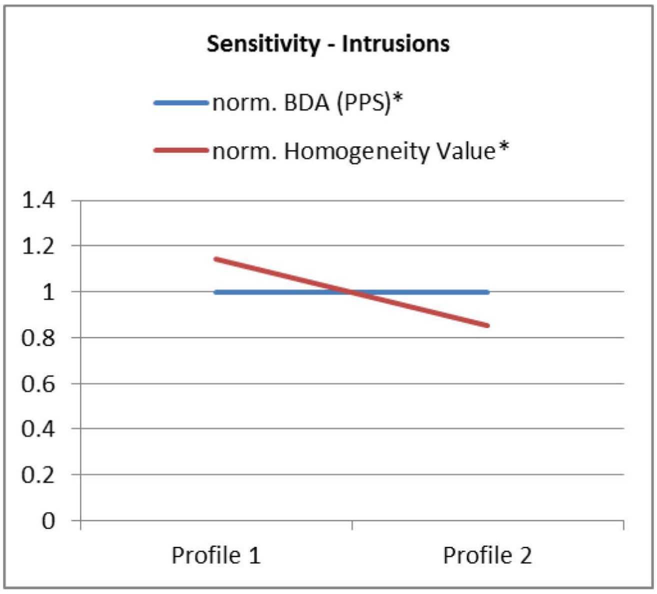


Figure 4.8: Dependency on intrusion depth of PDB metrics.

According to the assessment corridors for intrusions into the PDB (see [Lazaro 2013]) which were initially defined for the first assessment metric proposed by UTAC, the results show no dependency on the intrusion depth because both values are within the range of maximum rating. A comparison with other artificial profiles show (e.g. Profile 7 and Profile 38 in Annex F) that the scoring of the intrusions works correctly and the scoring changes in dependency on the computed values. However, the Homogeneity value also changes, even though the deformed area does not, which indicates a dependency on the intrusion depth too.

4.2.2 Sensitivity Analysis – Vertical Load Spreading

Vertical load spreading within LCW Row 3 and Row 4 (330 mm to 580 mm above the ground) is mainly addressed by the FWB test procedures. Additionally the assessment of forces in Row 2 (205 mm to 330 mm above the ground) takes lower load paths into account. While the analysis of loads applied to the LCW is restricted by the relative rough resolution due to the load cell array, the PDB offers the potential to analyse the deformation continuously. Furthermore the whole front of the PDB is theoretically capable to be analysed. Thereby the area can be divided into sub areas which correspond e.g. to the rows of the LCW. The assessment metrics should be able to distinguish between the impacted areas shown in Figure 4.9. In terms of the BDA software there are assessment corridors defined addressing the intrusion depth in the upper, middle and lower area of the PDB. Depending on the impact location and the intrusion depth the PPS should vary. The Homogeneity value only addresses deformations in the middle and lower area. A further criterion is the vertical load spreading within the area of LCW Row 3 and Row 4. Because the FWB cannot precisely detect the impact location within Row 3 and Row 4 the PDB should be able to provide information about the vertical load spreading within this area. Figure 4.10 shows how both metrics are detecting differences in when the lower load path is present with the Homogeneity Value being more sensitive to the presence of the lower load path.

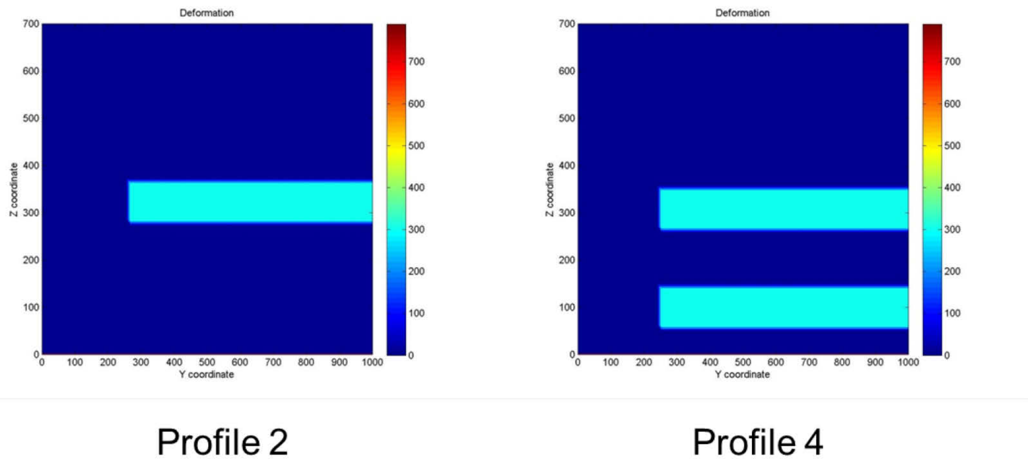


Figure 4.9: Vertical Load Spreading – variation of the impact location, only middle area (left), middle and lower area (right) (Profile 4 should be rated better than Profile 2).

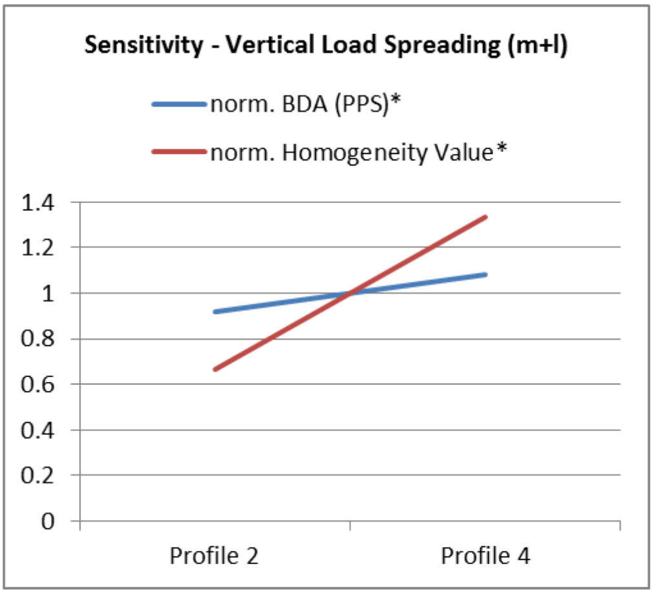
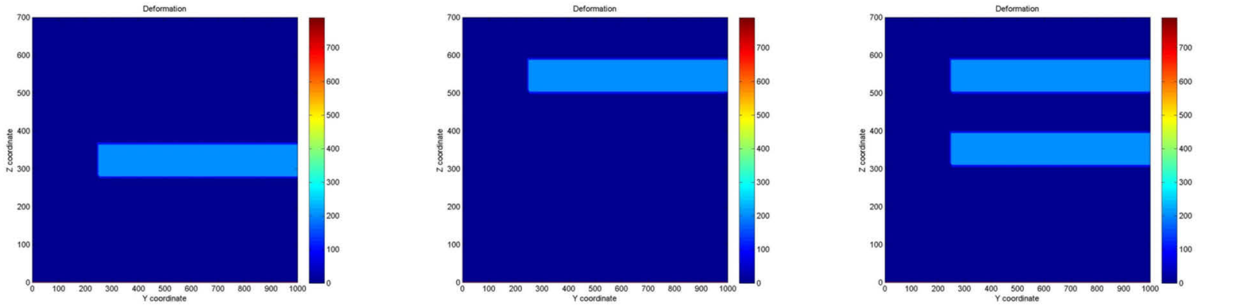


Figure 4.10: Dependency on vertical load spreading in middle and lower area of PDB metrics.



Profile 1 Profile 34 Profile 37

Figure 4.11: Vertical Load Spreading – variation of the impact location, only middle area (left), only upper area (middle), middle and upper area (right) (Profile 34 should be rated worst because load spreading is mainly required in the middle area and below).

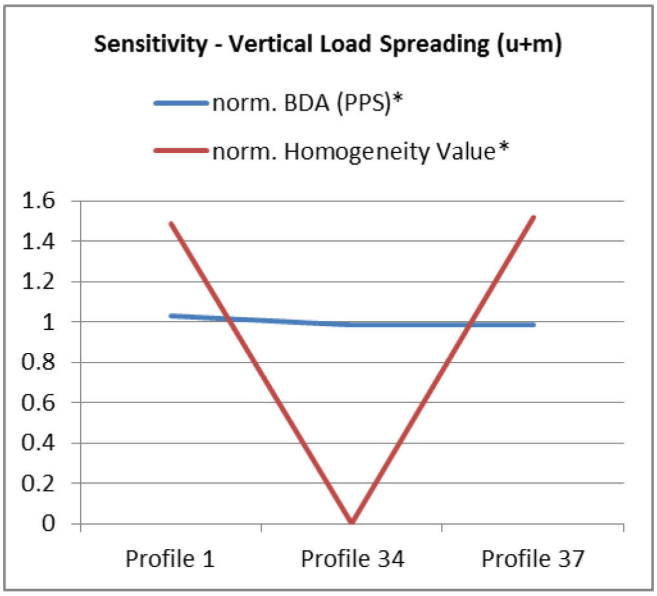


Figure 4.12: Dependency on vertical load spreading in middle and upper area of PDB metrics.

The artificial profiles clearly show that the Homogeneity value does not take into account the upper area, see Figure 4.11and Figure 4.11. Furthermore the same deformation in the middle area and additional deformation in the lower zone, see Figure 4.9 (Profile 2 and Profile 4), leads to a better assessment by the Homogeneity value Figure 4.10, because the intrusion depth within the lower area is only one part of the combined assessment criterion of the BDA software and thus the effect on the total PPS score is relative small compared to the Homogeneity value. The reason for the identical assessment of Profile 34 and 37 by the BDA software is that the homogeneity of Profile 34 is assessed with the maximum score while the deformation of the middle area results in zero points. In total the PPS value of both profiles is the same.

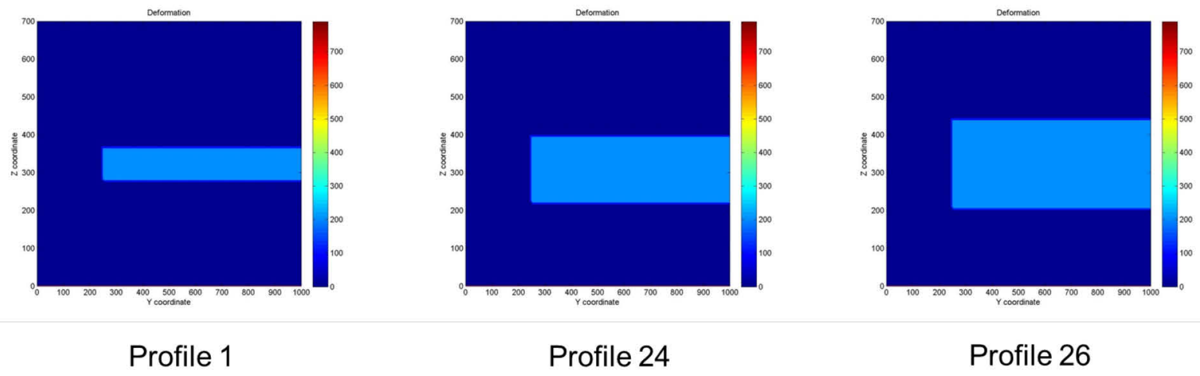


Figure 4.13: Vertical Load Spreading – variation of the impacted area within the LCW Row 3 and Row 4 (rating should improve from left to right).

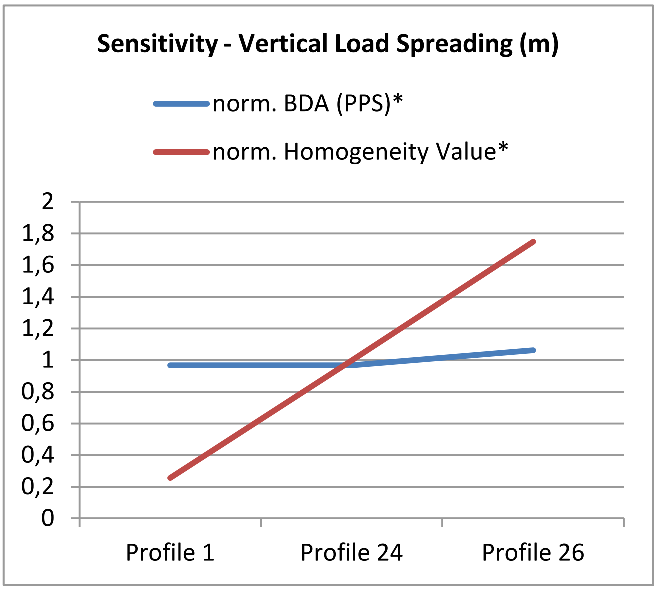


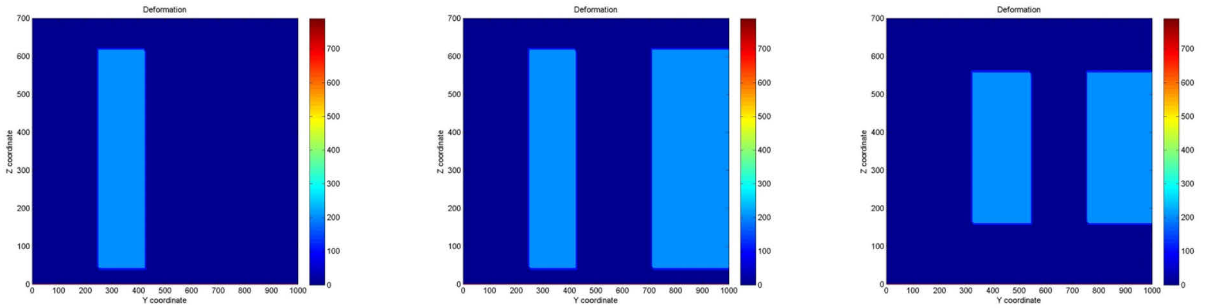
Figure 4.14 Dependency on vertical load spreading within the LCW Row 3 and Row 4 of PDB metrics.

Figure 4.14 shows a clear trend for the homogeneity value. The more area of LCW Row 3 and Row 4 was deformed (Figure 4.13), the better the Homogeneity assessment. The BDA software shows no clear dependency on the deformed area. The increased PPS for Profile 26 seems to be a result of a better assessment of the homogeneity within the middle area. In that case the deformed area exceeds the vertical borders because the middle area assessed by the BDA software (350 mm to 600 mm above the ground) does not corresponds to the

LCW grid (330 mm to 480 mm above the ground). This seems to affect the calculation of the TV value (which is used for both metrics) positively because the size of the deformed assessed area is larger.

4.2.3 Sensitivity Analysis – Horizontal Load Spreading

As already mentioned the PDB was the only test procedure that offers the potential to assess the horizontal load spreading. All other discussed test procedures and corresponding horizontal load spreading metrics were not able to assess the horizontal load spreading in an appropriate manner. The BDA software and the homogeneity value do not distinguish between the direction of load spreading (vertically or horizontally). However, if the intrusion depth is constant, an increasing horizontal size of deformation should affect the compatibility metrics positively. If the number of load paths is increased laterally, as in Figure 4.15, there is not a strong correlation between the area and metric output, Figure 4.16.



Profile 32 Profile 33 Profile 39

Figure 4.15: Horizontal Load Spreading I – variation of the impact location in upper, middle and lower area (Profile 33 should be rated best followed by 39 and 32).

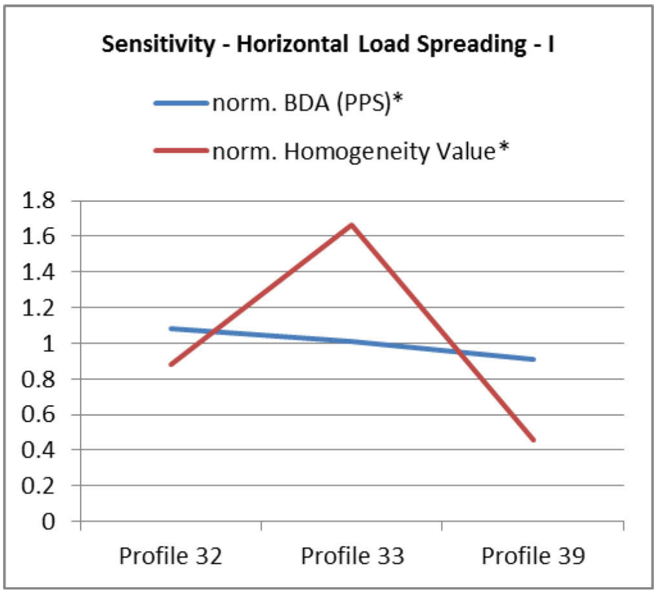


Figure 4.16: Dependency on horizontal load spreading in upper, middle and lower area of PDB metrics.

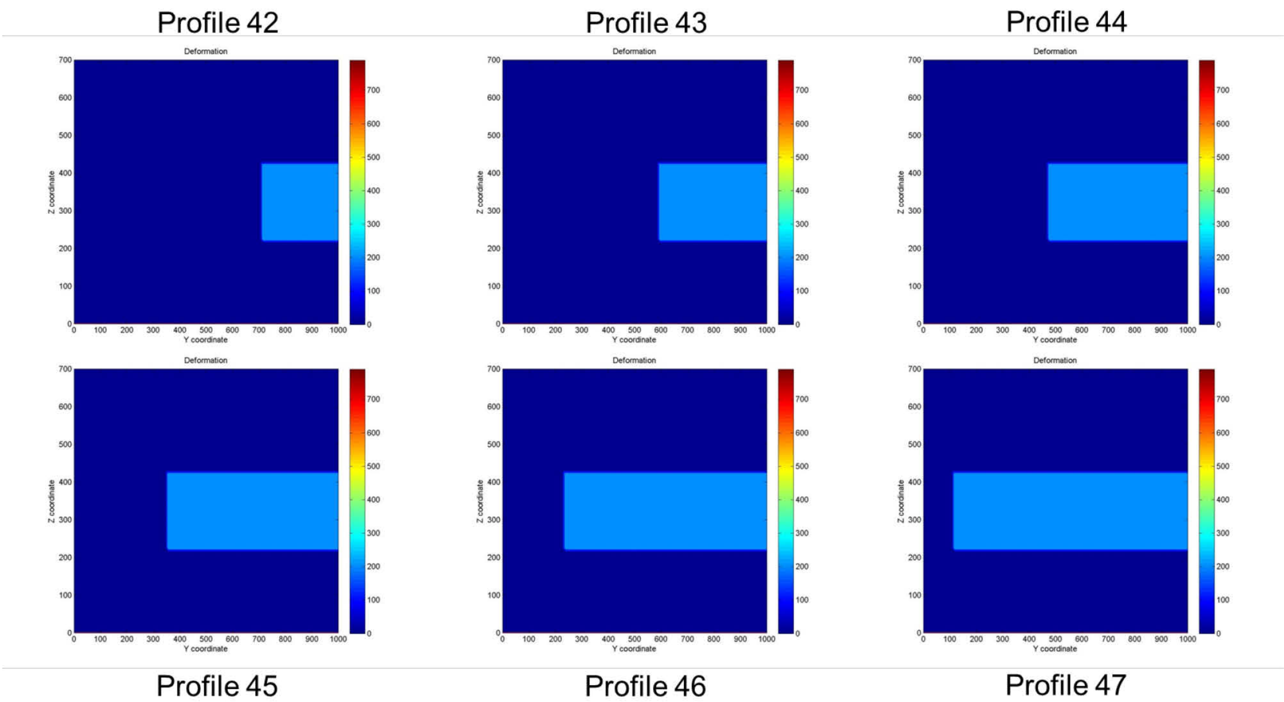


Figure 4.17: Horizontal Load Spreading II – variation of the deformed area within the middle area (rating should improve from left to right).

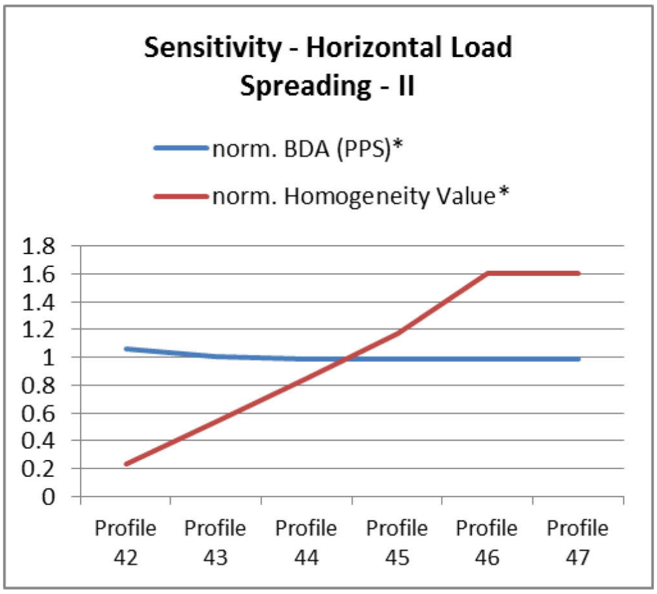
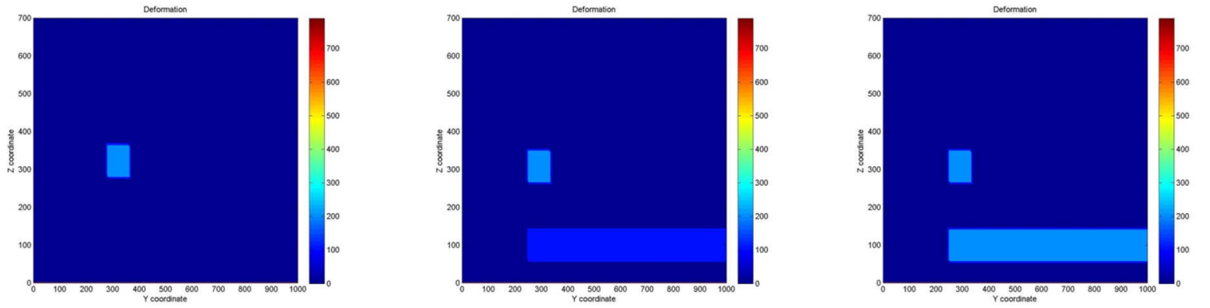


Figure 4.18. Dependency on horizontal load spreading within the middle area of PDB metrics.

These two examples (horizontal load spreading I and II) show the expected correlation of the deformed area and the Homogeneity value. The more area is deformed by one load path within the AoI, the better is the assessment. As expected, Figure 4.18 shows that increasing the area beyond the borders of the AoI results in a constant Homogeneity value. Regarding the BDA software assessment there is a poor correlation between deformed area and the computed PPS. The main reason for that behaviour could be the sensitivity of the TV value (used by BDA software to compute the homogeneity) to sharp edges. The more sharp edges, respectively, and the longer the sharp edges are, the higher is the TV value which results in poor assessment.

4.2.4 Sensitivity Analysis – Homogeneity

The homogeneity aspect should mainly address holes within the PDB which can be observed if the penetrating longitudinal is very stiff, due to the high vehicle mass or if the connection to other structures like cross beam or sub frame is not sufficient. As generally agreed, the presence of holes such as those found in Figure 4.19 is a good indicator of poor compatibility. For that reason the assessment metric should address this aspect and should be able to detect holes.



Profile 8 Profile 10 Profile 11

Figure 4.19. Homogeneity I – holes and variation of the deformed area within the lower area (Profile 8 should be rated worst, Profile 11 should be rated slightly better than Profile 10).

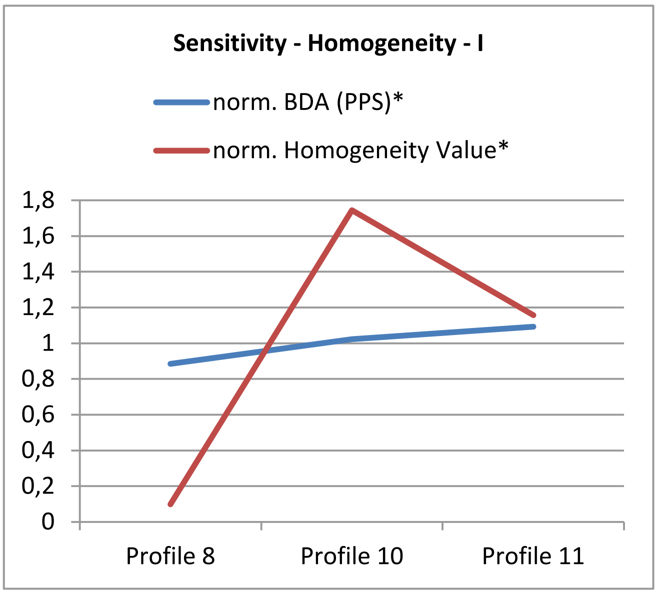


Figure 4.20: Dependency on holes and additional deformed lower area of PDB metrics.

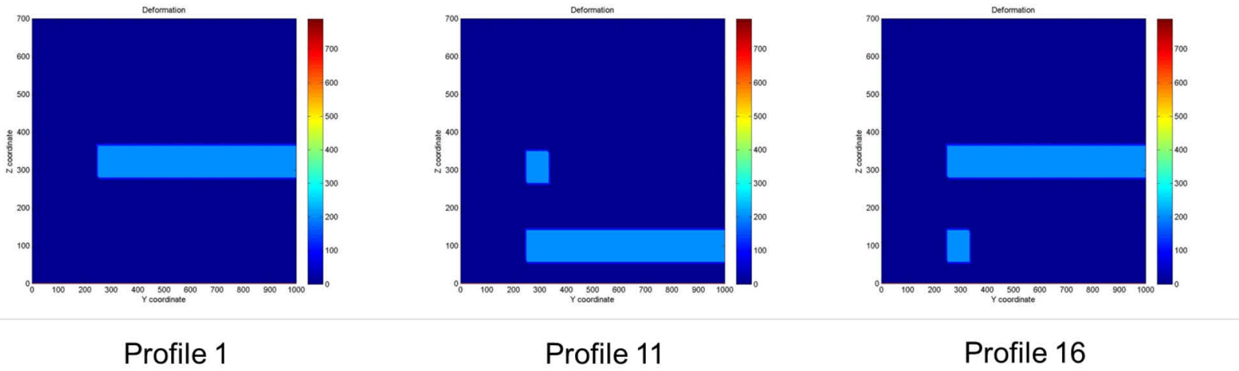


Figure 4.21: Homogeneity II – variation of the position of the hole (Profile 11 should be rated worst, Profile 16 should be rated similar to Profile 1).

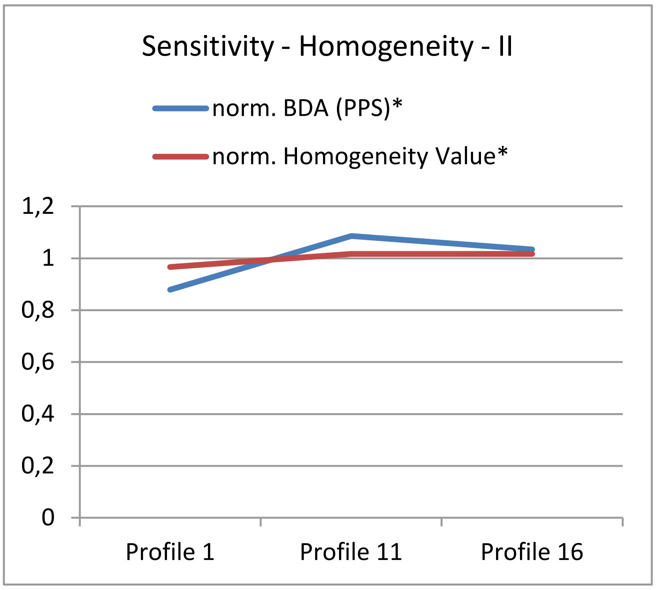


Figure 4.22: Dependency on the position of holes of PDB metrics.

The two examples based on Figure 4.19 and Figure 4.21 show contradicting results regarding the BDA software assessment. Figure 4.22 shows an increasing trend for the PPS for the profiles in Figure 4.21. But the reason for the positive assessment is the better rating of the deeper deformation in the lower area. The assessment will be worse if the influence of the intrusion depth is not eliminated (intrusion depth remains constant in Profiles 1, 11 and 16) and the main part of the deformation is within the middle area. This indicates again a problem of the TV value computation. The Homogeneity value also seems to be sensitive to the depth of the intrusion, because the Homogeneity value decreases see Figure 4.20. The Homogeneity value seems not to be sensitive to the location of the hole, see Figure 4.22 Therefore the metric cannot distinguish between the middle and lower area and if the hole is located in one of these areas.

Sensitivity Analysis – Vehicle Width

The analysis of the artificial profiles was conducted w.r.t. two different vehicle widths. The represented widths correspond to an average width of a small family car (average width = 1652 mm ➔ y_{min} = 274 mm) and an average width of an off road car (average width = 1842 mm ➔ y_{min} = 179 mm), see Figure 4.23.

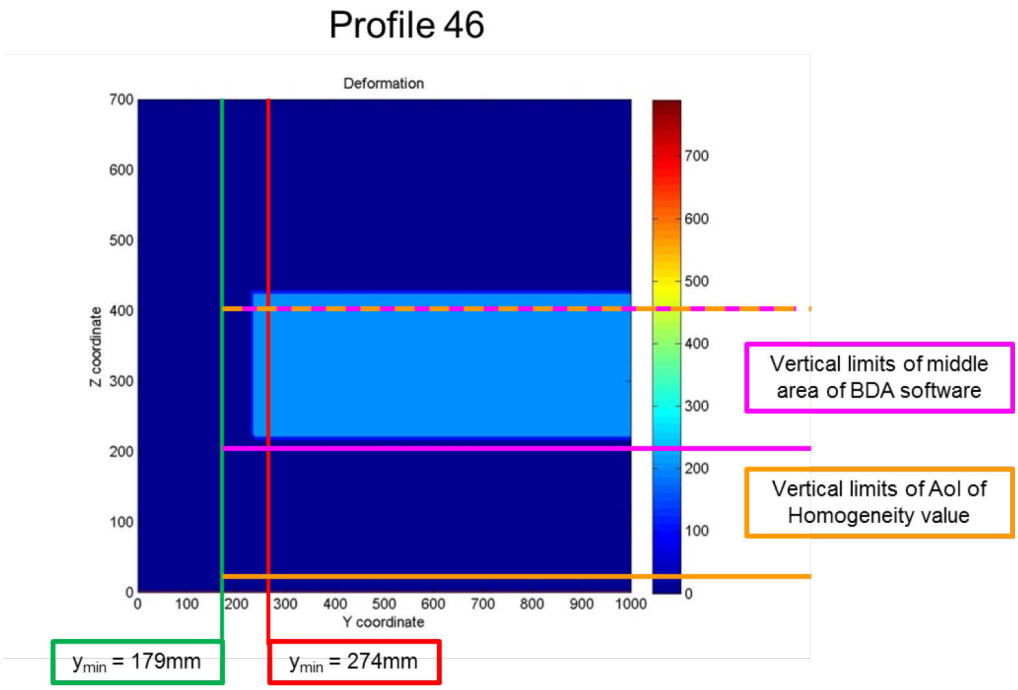


Figure 4.23: Different AoI depending on used vehicle width and assessment metric.

Regarding the constant deformation patterns of the artificial profiles, the assessments of the small family car should be better, because the deformations cover a larger proportion of the AoI than for the wider off road car. This should mainly have an effect on the homogeneity computation for Figure 4.23. In most of the cases the expected behaviour could be observed. However, regarding the assessments of Profile 42 to Profile 47, see Figure 4.24 unexpected results were computed.

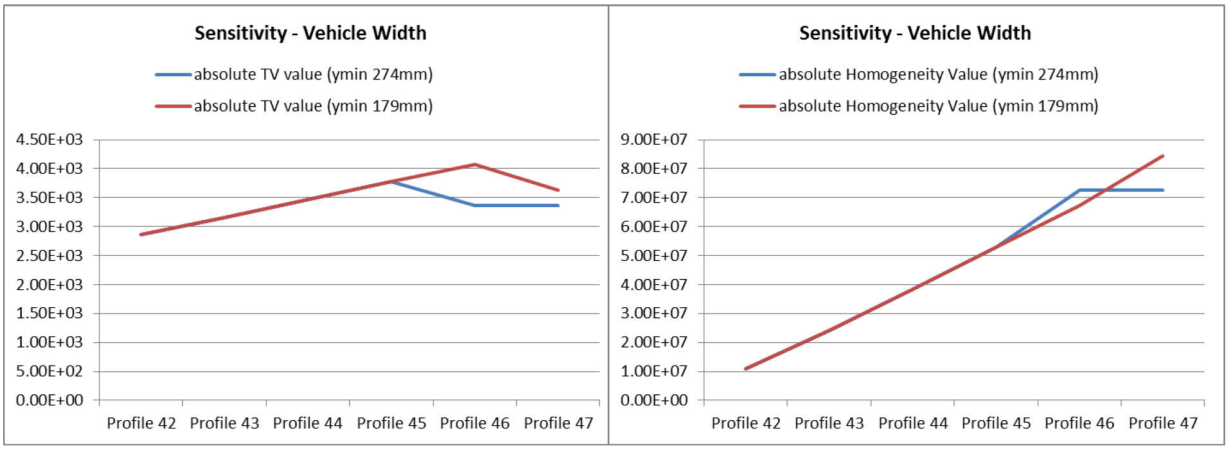


Figure 4.24: Absolute values for TV value (as part of the PPS) and Homogeneity value for different vehicle widths.

Figure 4.24 shows the trends of TV value (left) and Homogeneity value (right) for the two different vehicle widths. The main expectation was that the values are different depending on the vehicle width due to the changing AoI. This could not be confirmed. Both metrics compute the same values for Profile 42 to Profile 45. Profile 46 exceeds the limits of the AoI for the small family car (y_{min} = 274 mm). While the TV value decreases the Homogeneity value increases. This confirms former observations that the computation of the homogeneity in both metrics is interfered if the deformation exceeds the borders of the AoI.

4.2.5 Summary of Analyses of Artificial Profiles

Table 2 summarises the main findings of the analysis of the artificial profiles. Regarding these very simplified footprints, both investigated metrics seem not to be capable of addressing all compatibility issues. The main disadvantage is the dependency on the intrusion depth which is not acceptable because this indicates a relation to the vehicle mass. Another important factor is that both metrics were not able to detect holes. Although the Homogeneity value assessed holes worse, the metric could not distinguish where the hole was located because the metric used a combined AoI consisting of middle and upper area. However, an update of the principle seems to be possible to address this issue.

Table 2: Summary of assessment metric analysis of artificial profiles.

compatibility issue		**expected behaviour**	**BDA software**	**Homogeneity value**
intrusion depth		no dependency	-	-
vertical load spreading	upper and middle area	should be detected	+	-
	middle and lower area		+	-
	within the CIZ		-	+
horizontal load spreading			-	+
homogeneity (detection of holes)			-	-
horizontal load spreading in relation to vehicle width			-	-

„+“ – expected behaviour confirmed „-“ – expected behaviour not observed

The *artificial* profiles offered a good possibility to check the assessment metrics and to conduct sensitivity analyses. Thus it was possible to create footprints to address the specific compatibility issues and to check if the metrics assessment fits to the expected results. Prospective work should focus on the investigation of the DDY metric which could not be assessed with the created setup of artificial profiles. New created profiles should be used to improve the understanding of the homogeneity assessment and the hole detection

4.3 Analysis of PDB Model Deformation Pattern - Preparation of Numerical Simulation Output

The FIMCAR crash simulation programme was already described in FIMCAR Deliverable D2.1 [Lazaro 2013]. However, due to model quality issues at that time, the results were not available when D2.1 was finalised. However, before discussing the simulation results it is important to describe problems with the analysis of the PDB Model deformation.

The updated PDB model [Stein 2013/2] provided realistic deformation patterns especially in terms of material failure and lateral stiffness of the honeycombs. Due to the improved model sensitivity, analysis of structural modifications could be conducted. To assess the resulting footprint of the barrier the extraction of the cladding plate and (if needed) further parts, like the honeycomb, from the numerical output was necessary. Thereby an analogue procedure to the real scanning process was used to capture the deformations. However, even though the numerical PDB model was able to represent mechanisms like rupture of the cladding plate, the treatment of the crash solver to represent this behaviour lead to time consuming manual post-processing. The main reason is the treatment of material failure which is typically realised by deletion of individual elements in the area where rupture occurs or that the stress-strain calculation of these “deleted elements” is not further considered which can lead to unrealistic deformations of these elements, see Figure 4.25.

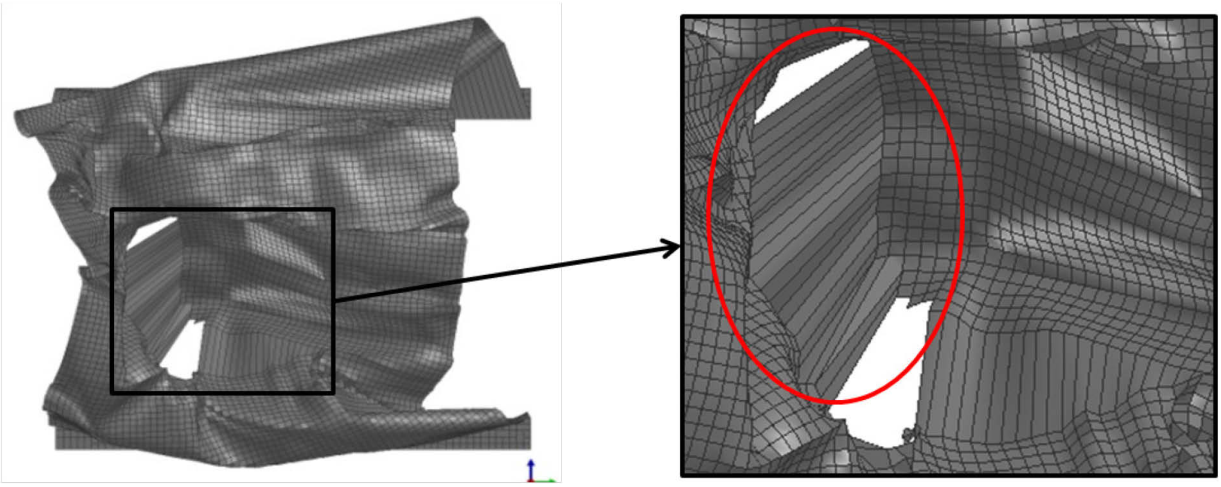


Figure 4.25: Unrealistic deformed elements due to material failure, because stress/strain calculation is not further considered.

In terms of the PDB model, the element elimination lead to the special case of “free nodes”, if neighboured elements will be eliminated which share a common node, see figure 4.24.

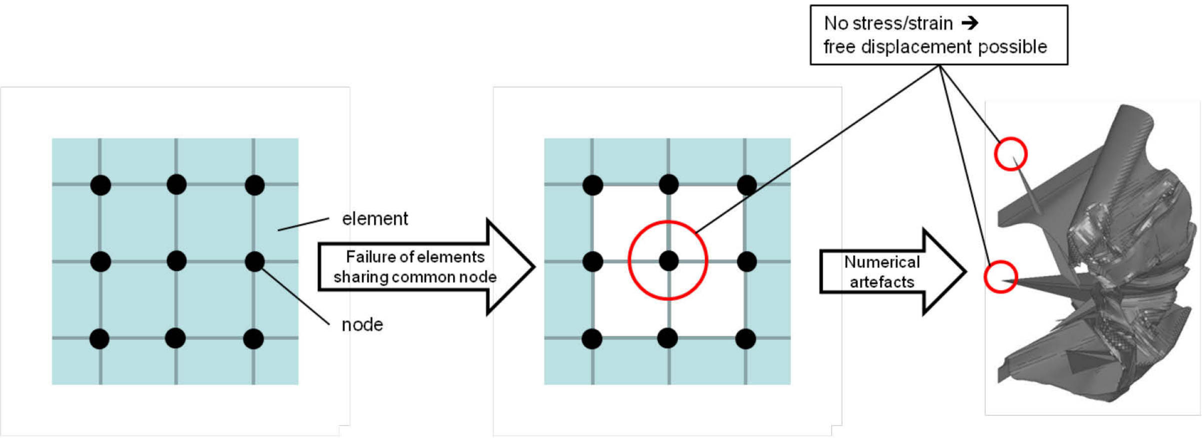


Figure 4.26: Creation of “free nodes” due to the treatment of material failure in the numerical PDB model.

These “free nodes” can move without any restriction because no reaction forces affect this node. This phenomenon can create numerical artefacts that complicate the post-processing. Figure 4.27 illustrates the magnitude of these numerical artefacts at the end of a simulation.

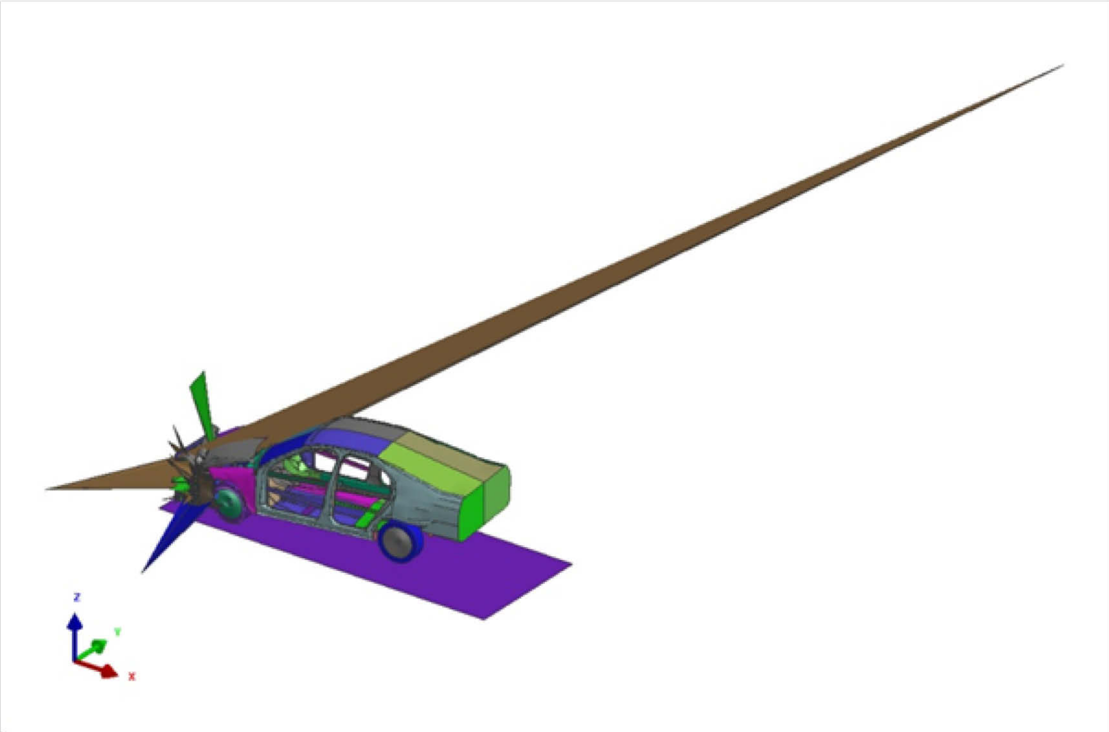


Figure 4.27: Large deformed elements at the end of the simulation due to material failure treatment.

Typically these elements and nodes are not taken into account in the post-processing. For the analysis of the barrier footprint the location of the nodes are crucial because they will be used to create the final STL file of the deformed cladding plate. Therefore a manual cleaning process is necessary to remove these nodes from the data and to prepare the output for the following assessment, see figure 4.26.

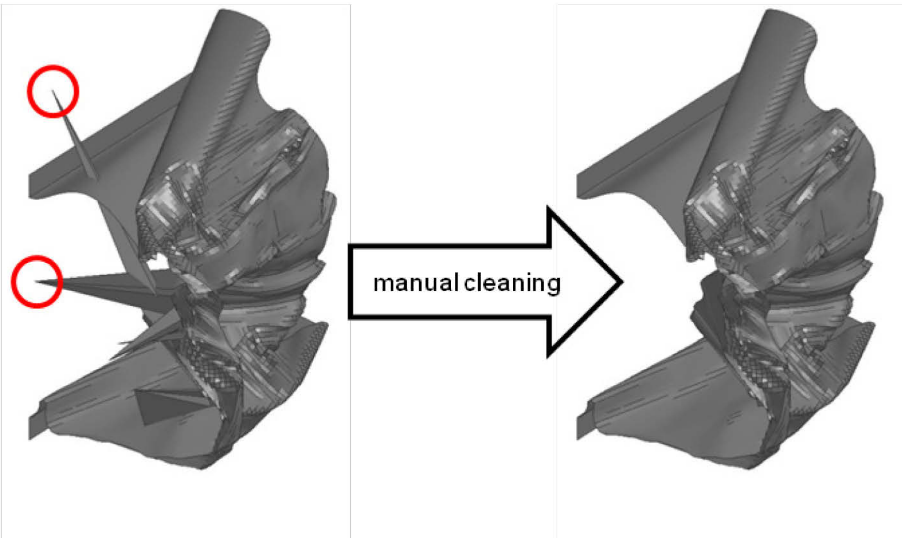


Figure 4.28: Manual cleaning of "deleted" elements.

The material failure also affects the accuracy of the final deformation. Comparable to the treatment of ruptures of the cladding sheet in the physical barrier the deformation of the honeycomb behind the cladding sheet needs to be considered to assess the barrier deformation for the FE model too. Even though, nodal information of coordinates of the deformed and failed cladding plate are available they are not sufficient to represent the exact shape of the hole. Based on the presence of nodal information in the area of the maximum intrusion, all investigated assessment metrics interpolate between these available nodes and the area where the cladding plate fails. Figure 4.29 shows an intruding PEAS (green) into the PDB. The detailed view (right) shows the difference of the shape of the PEAS and the deformed cladding plate due to element elimination.

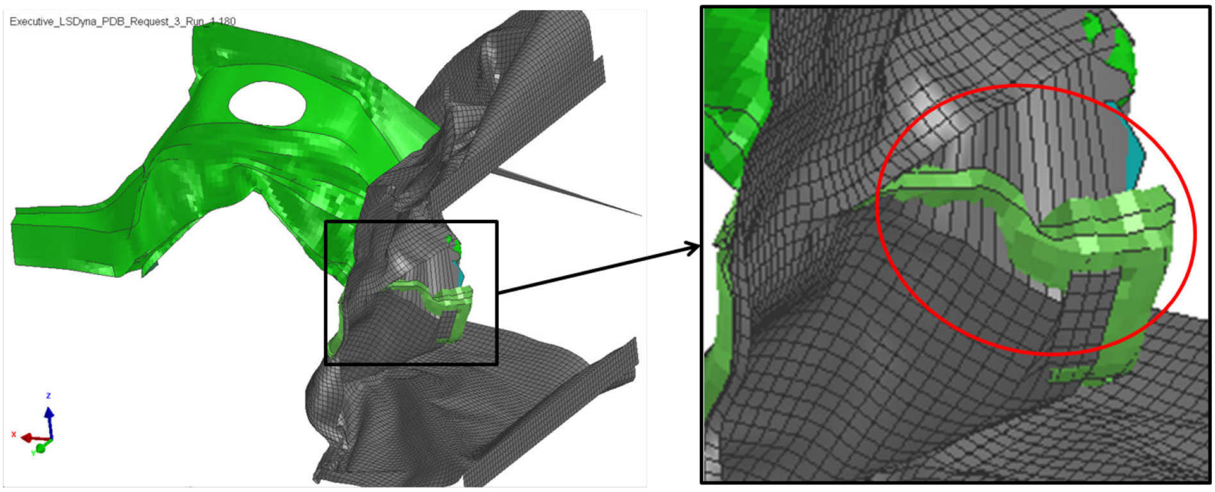


Figure 4.29: Representation of the shape of the intruding PEAS.

The first step to increase the accuracy was to extract the correct shape from the nodal information of the honeycomb elements too. This approach was considered not to lead to the desired results. On the one hand the missing information had to be extracted from a very high number of honeycomb elements which was very time consuming. On the other hand material failure was also observed for the honeycomb parts which lead to the same numerical artefacts as already described for the cladding plate.

Two possibilities were analysed to overcome this problem. The first was the implementation of so called “null shells”. These null shells are shell elements that can cover parts but do not have an influence on the results because no stress/strain calculation is considered. A typical application in numerical simulation is the creation of contact surfaces. However, because the null shells need to be connected to other parts (i.e., the nodes of the cladding plate) they also experience the same deformations. Therefore no additional information was created to better describe the final deformation pattern and reduce the manual post-processing. The second option was an additional plate in front of the cladding plate of the PDB. This additional plate was welded in specific areas to the cladding plate. The basic idea was to create some kind of contact surface with the colliding vehicle which does not have any failure mechanisms and behaves independently from the cladding plate but with the same characteristics. First simulations showed that this approach had the potential to improve the reproduction of the final deformation. Due to the mechanical properties of the additional cladding plate the overall behaviour of the PDB model altered (increased deceleration peak and time shift of maximum deceleration). Because it was not possible to clarify whether or not the altered behaviour is acceptable, this approach was also neglected.

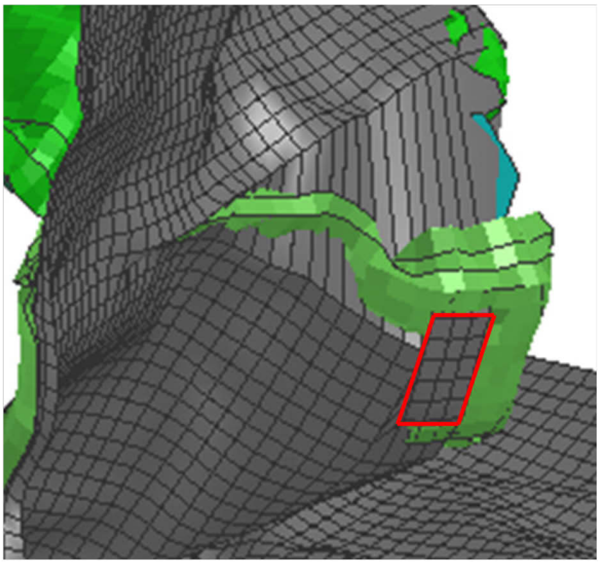


Figure 4.30: Finite elements (red marked) close to the maximum deformation depth for analysis of footprint.

To proceed with the numerical simulation tasks it was decided to accept the inaccuracy resulting from analysing only the cladding plate of the PDB. Figure 4.30 shows a group of nodes of the cladding plate (red marked) very close to the maximum intrusion. Nevertheless, due to the presence of those elements close to the deepest intrusion the assessments of the footprints were possible. Regarding the conducted sensitivity analysis and the simplified vehicle models, this procedure is acceptable. For the development process of a vehicle this method cannot be used. In particular, the prediction of the crash behaviour in frame of the homologation process is crucial, thus this inaccuracy cannot be tolerated. Due to a lack of appropriate post-processing procedures, the extraction of the real footprint from the numerical output remains a time consuming process.

4.4 PDB Sensitivity Analysis – PCM Simulations

The following section summarises the results of the sensitivity analysis of the PDB barrier. As described in Chapter 4.1.2 of FIMCAR Deliverable D2.1 [Lazaro 2013] the main objective of this investigation was, in particular, to analyse modifications of the PEAS and SEAS and the resulting metric assessments. Further parameters were the vehicle mass and the impact velocity. Therefore the parametric design of the PCM model “Executive” should be used to create the planned modifications. Depending on the simulation results, worst case and best case scenarios (combinations of different varied parameters) should be created and the crash performance should be verified in car-to-car simulations. However, it was not possible to finalise this task within the FIMCAR project. Nevertheless the analysis of the deformed PDB will be presented hereafter. All 45 modifications (Chapter 4.1.2 of FIMCAR Deliverable D2.1 [Lazaro 2013]) were rerun against the PDB version 2 FEM model, which had improved overall crash behaviour like rupture of the cladding plate.

A detailed overview of all results containing barrier footprints and assessment metric results can be found in Annex G. First preliminary results indicated that the effect on the footprints of the lower load path was too small. Therefore it was decided to improve the stiffness of the baseline model for all sub frame modifications. Figure 4.31 shows the footprints of the two baseline models.

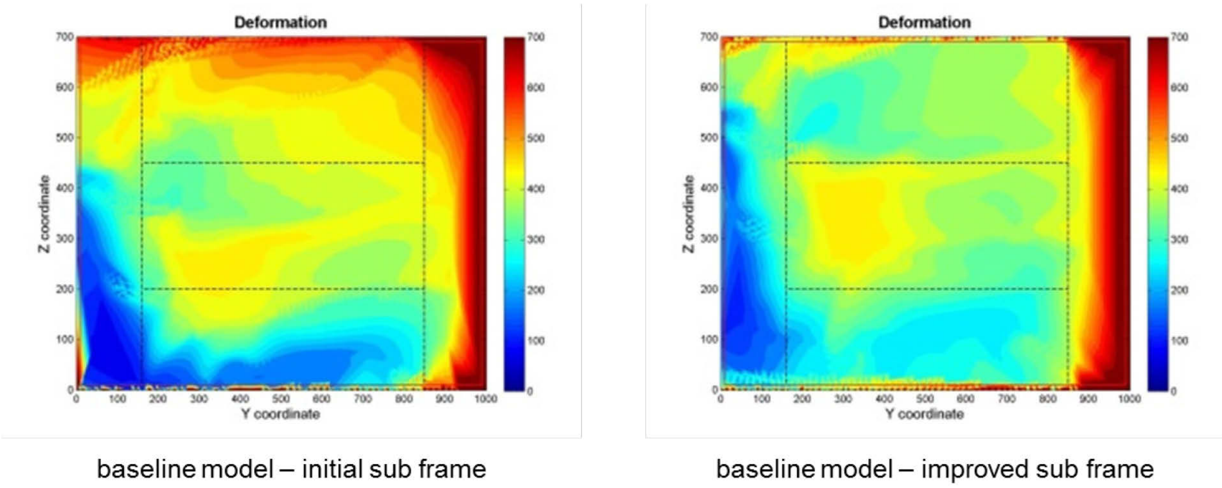


Figure 4.31: Footprints of baseline models with initial design of sub frame (left) and improved design (right).

Even though the sub frame still cannot be detected (initial position in x-direction is 100 mm behind the cross beam), it has a positive influence on the stability of the PEAS. Due to the design of the longitudinals, the whole PEAS tend to bend downwards during the impact against the PDB, see Figure 4.30.

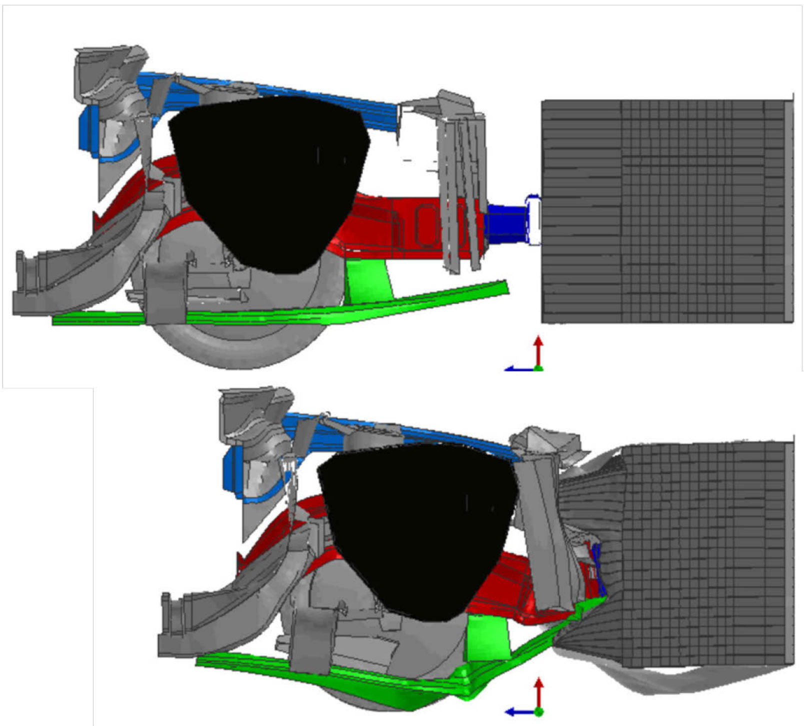


Figure 4.32: Downward bending of the longitudinal (red) during the impact against the PDB.

Due to this effect the resulting footprint of the longitudinal differs from its initial position (see Figure 4.30 upper and lower frame) for most of the Runs 01 to 25.

The following results of the assessment metrics are normalised to corresponding baseline model value of each criterion and are marked with "*". For PPS and Homogeneity value, values > 1.0 indicate increasing scores (better assessment w.r.t the baseline model) and values < 1.0 indicate decreasing scores (worse assessment w.r.t. the baseline model) because high values are intended to correlate well with good compatibility. In comparison high DDY values indicate a poor compatibility, therefore normalised DDY values < 1 indicate an improvement w.r.t. the baseline model. Additionally the computed DDY values are normalised to the preliminary threshold value of 3.5 and are marked with "**".

To understand the assessments of the three compatibility metrics it is important to know that the metrics assess different AoIs. The main difference is the lower horizontal dimension of the DDY assessment area because it takes into account only 60% of the half vehicle width. The distance between the longitudinals of the PCM Executive car is relative large. Therefore the main part of the footprint of the longitudinal is not taken into account. During the development of the DDY it was discussed to use the distance between outer edges of the longitudinals as a reference value for the calculation of the horizontal dimensions of the AoI, if the distance is larger than 60% of the vehicle width. This proposal was not used for the following analysis.

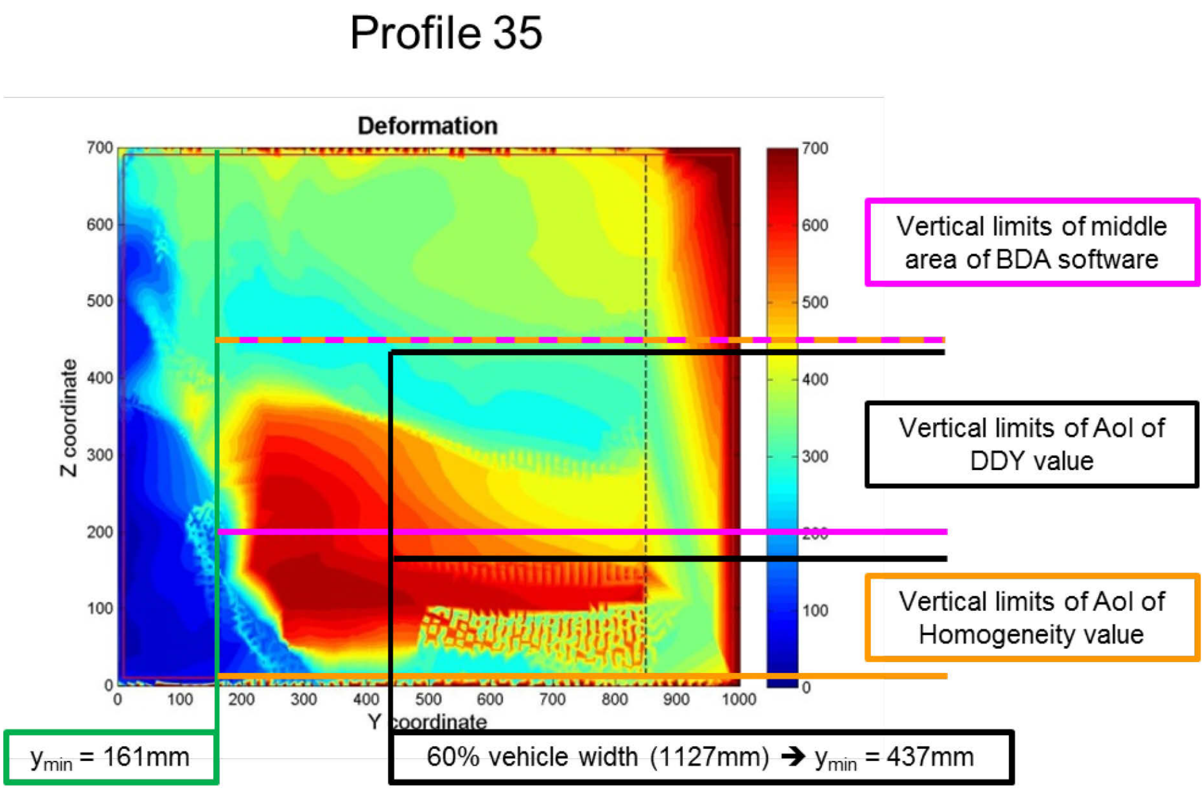


Figure 4.33: Different AoI depending on used assessment metric.

4.4.1 Sensitivity Analysis – Vehicle Mass

As already stated the vehicle mass should have minor effect on the compatibility metrics because otherwise vehicles are discriminated due their mass. Hence this is limited to the intrusion depth which is easier for heavier cars to achieve, the vehicle mass can have an influence on the homogeneity of the deformation pattern. Due to a higher vehicle mass it can happen that the interaction between engine and barrier becomes more relevant, which leads to a more homogenous footprint.

- Parameters:
  decreased mass - engine mass
  increased mass - cowl support and seat cross beam
  Run 01: m_{engine} - 200kg
  Run 02: m_{engine} - 100kg
  Run 03: m_{engine} = 430kg / $m_{vehicle}$ = 1904kg (basis model)
  Run 04: $m_{vehicle}$ + 100kg
  Run 05: $m_{vehicle}$ + 200kg

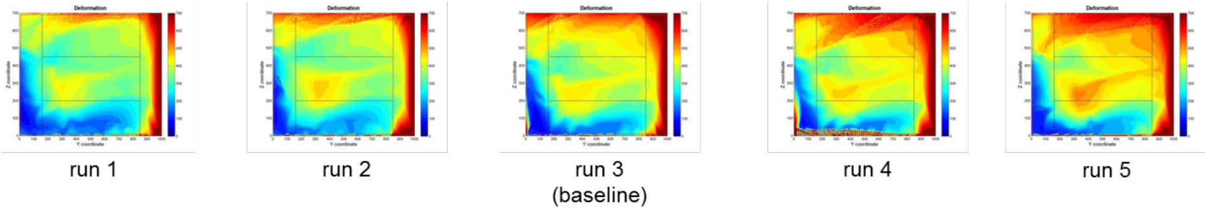


Figure 4.34: Barrier footprints depending on modified vehicle mass.

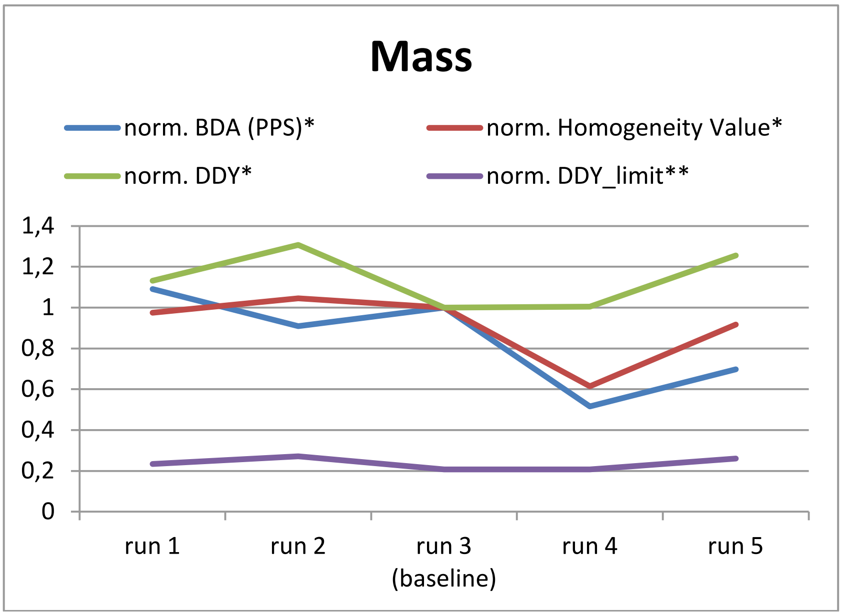


Figure 4.35: Metric assessment depending on modified vehicle mass.

In principle Figure 4.35 shows comparable results. The normalised DDY seems to show less sensitivity to vehicle mass than the BDA and Homogeneity Values. According to the DDY values in relation to the threshold value of 3.5 all vehicles offer a good load spreading. However, the influence of the engine can clearly be seen in Figure 4.34. While the footprints of run 1 and run 2 only show the longitudinal, the effect of the interaction with the engine becomes more relevant (run 4 and run 5).

4.4.2 Sensitivity Analysis – Impact Velocity

Small variations of the impact velocity should have hardly any influence on the metrics. In particular typical tolerances occurring in real crash tests must not lead to large differences in the assessment. To analyse the sensitivity on the vehicle speed the following variations were investigated.

- Parameter: initial velocity
  - Run 06: v = 56km/h
  - Run 07: v = 59km/h
  - Run 08: v = 60km/h (basis model)
  - Run 09: v = 61km/h
  - Run 10: v = 64km/h

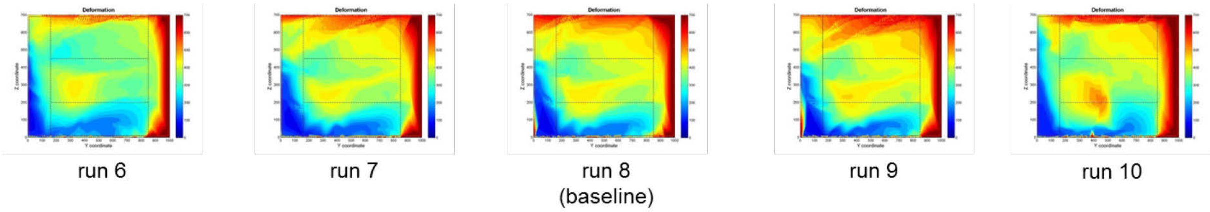


Figure 4.36: Barrier footprints depending on modified impact velocity.

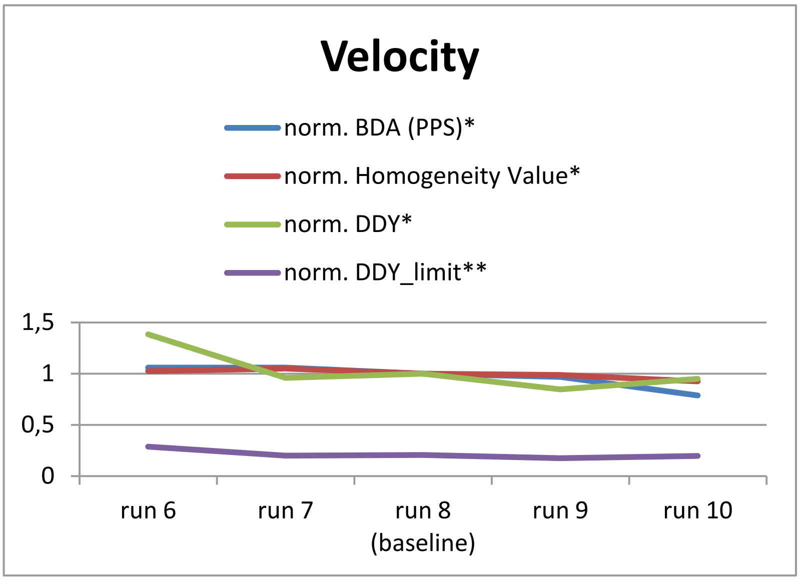


Figure 4.37: Metric assessment depending on modified impact velocity.

As expected the assessment results from all three metrics are virtually identical within ±1km/h (run 7 to run 10). Especially the Homogeneity value and the DDY value seem to be very robust against small variations of velocity.

4.4.3 Sensitivity Analysis – Cross Beam Stiffness

To improve the horizontal load spreading a strong cross beam was proposed to spread the loads e.g. from a centric pole impact to the longitudinals. The objective of the variation of the cross beam stiffness was to analyse if a stronger cross beam can be detected in the footprints and if the metrics are able to address the improved horizontal load spreading.

- Parameter: wall thickness
  - Run 11_w/o cross beam
  - Run 11: t = 0.10mm
  - Run 12: t = 0.90mm
  - Run 13: t = 1.80mm (basis model)
  - Run 14: t = 3.54mm
  - Run 15: t = 10.00mm

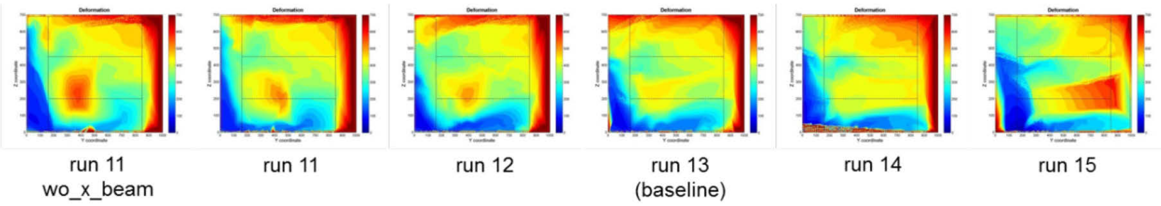


Figure 4.38: Barrier footprints depending on modified cross beam stiffness.

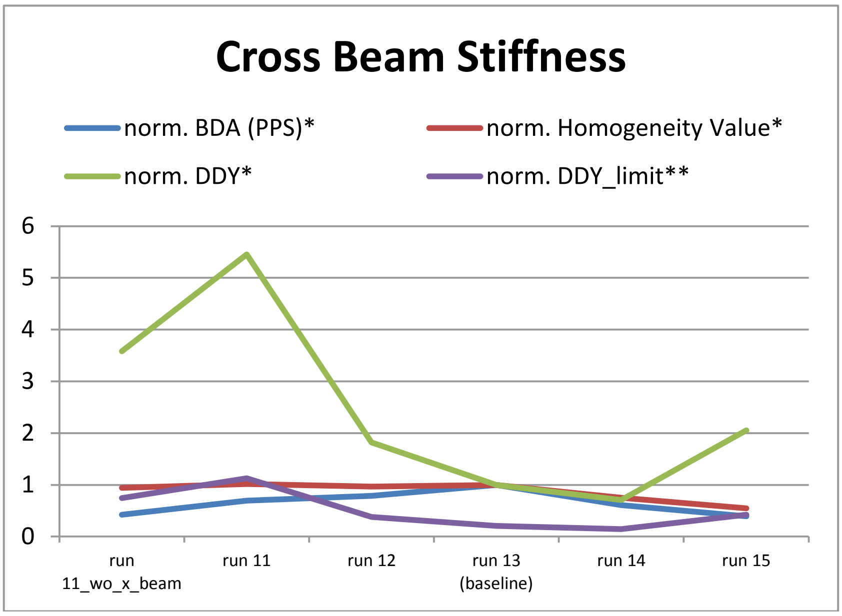


Figure 4.39: Metric assessment depending on modified cross beam stiffness.

Although the presence of a hole can clearly be seen in Figure 4.38 (Run 11 w/o cross beam and Run 11) only BDA software and DDY detect these holes. The Homogeneity value remains constant for all runs except Run 14 and Run 15. Regarding the horizontal load spreading only DDY value assessed run 14 better than the baseline run which was expected. However all Runs except Run 11 would pass the DDY metric. Run 11 without cross beam passes the metric because the longitudinal bends in outboard direction due to the missing connection between both longitudinals. Thus the longitudinal (and the hole resulting from the longitudinal without crossbeam) is not within the AoI of the DDY metric and was not assessed. As already explained above the issue could likely be solved if the metric considers 60% of the vehicle width or the real distance between longitudinals whatever is larger.

4.4.4 Sensitivity Analysis – Sub Frame x-direction

Several investigations were conducted to analyse the potential of the lower load path in a frontal crash [Park 2009; Stein 2013/1]. All studies indicated a positive trend regarding the forward position of the sub frame for cars that have a suitable connection between sub frame and PEAS (Primary Energy Absorbing Structures). Thus the PDB and the corresponding assessment metrics should be able to detect the presence of a lower load path which is mainly depending on the distance between cross beam and the sub frame.

- Parameter: distance of cross beam and sub frame in x-direction
  - Run 26: very reward ($x_{cross\ beam}$ + 500mm)
  - Run 27: reward ($x_{cross\ beam}$ + 300mm)
  - Run 28: medium ($x_{cross\ beam}$ + 100mm)

- Run 29: forward ($x_{cross\ beam}$)
- Run 30: very forward ($x_{cross\ beam}$ - 100mm) ➔ conflict with bumper

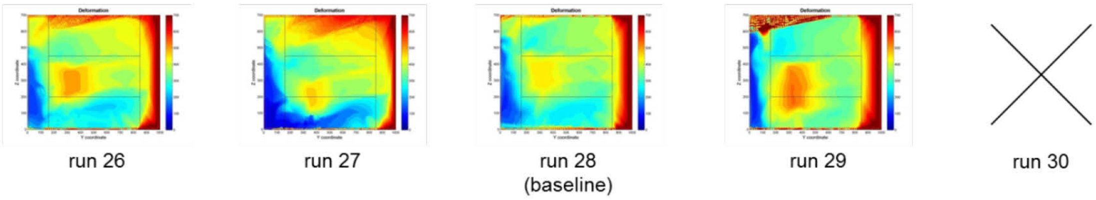


Figure 4.40: Barrier footprints depending on modified sub frame position in x-direction.

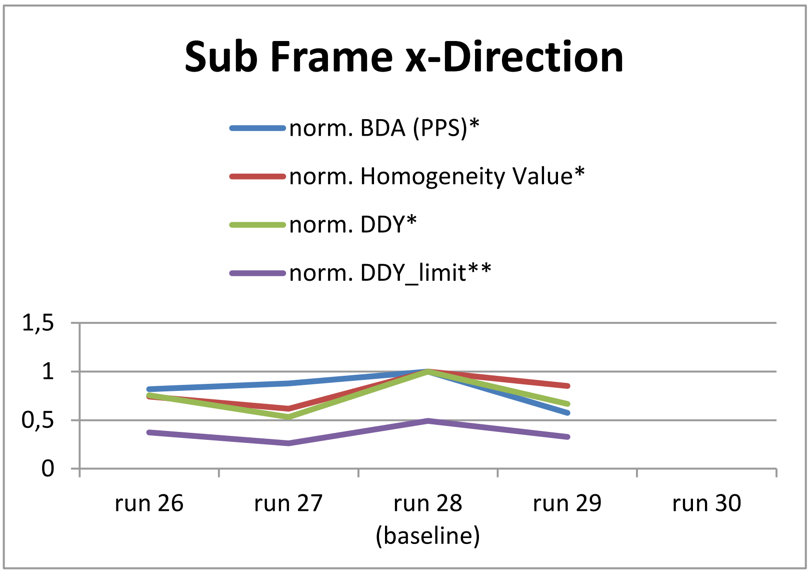


Figure 4.41: Metric assessment depending on modified sub frame position in x-direction.

This example shows contradicting results regarding the assessments. While PPS and Homogeneity value assess all modifications worse compared to the baseline model the normalised DDY value indicate improvements. The subjective assessment of the footprints correlates with the assessment of PPS and Homogeneity value. The main reason is the relative homogenous footprint in the centre of the barrier of the baseline run (Run 28, see Figure 4.40). W.r.t. Run 26 and Run 29 the deformation of the longitudinal is dominating which leads to the expectation of a reduced homogeneity. The main reason for the contradicting rating of the DDY metric is the smaller AoI which did not captured the holes.

4.4.5 Sensitivity Analysis – Sub Frame stiffness

To sustain the crash loads during a frontal impact a specific stiffness of the sub frame is needed. This can be influence either by the geometry of the sub frame or by the material used. In general it was expected that increasing sub frame stiffness should be detected by the metrics and should result in a better assessment than weak sub frames.

- Parameter: wall thickness
  - Run 31: t = 0.10mm
  - Run 32: t = 1.00mm
  - Run 33: t = 2.00mm (basis model)
  - Run 34: t = 4.00mm
  - Run 35: t = 10.00mm

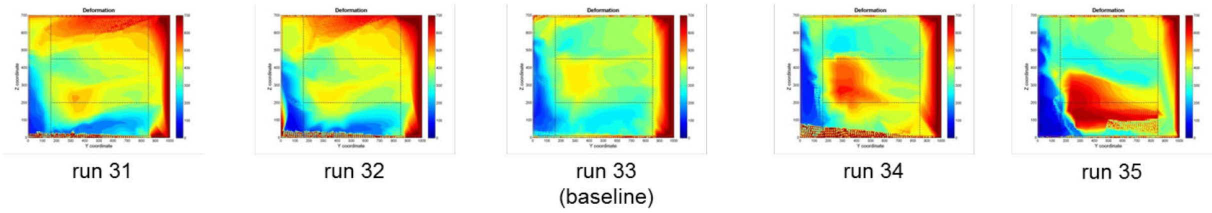


Figure 4.42: Barrier footprints depending on modified sub frame stiffness.

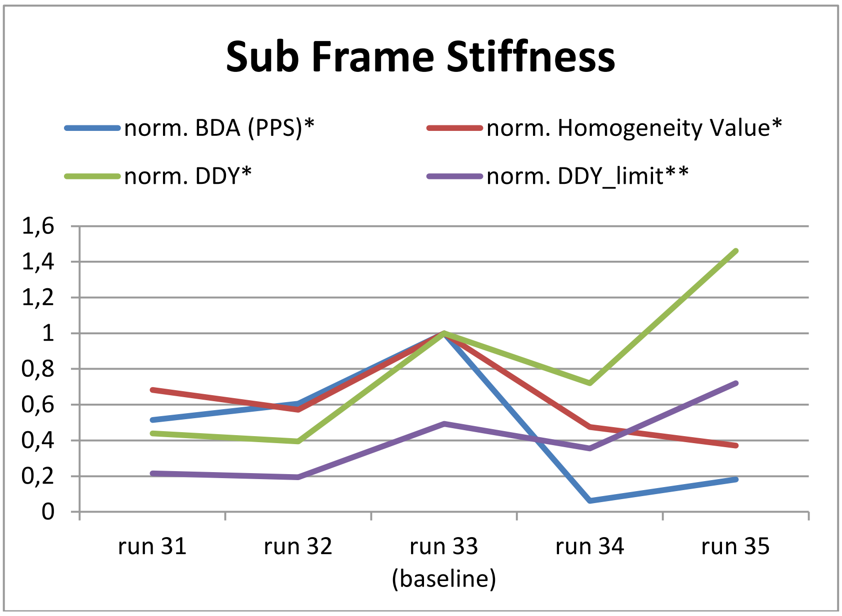


Figure 4.43: Metric assessment depending on modified sub frame stiffness.

The downward bending of the PEAS due to the reduction of the sub frame stiffness (Run 31 and Run 32, see Figure 4.42) was assessed better by PPS and Homogeneity value compared to the baseline model. The DDY value again assessed this as an improvement, because the main affected area is not within the AoI. Regarding the stiffer sub frame runs (Run 34 and Run 35, see Figure 4.42) the rating of the DDY tends be worse but is still below the preliminary threshold value of 3.5. PPS and Homogeneity value assess the stiff sub frame worse too. The reason for the poor assessment of all three metrics is that the stiff sub frame also reinforced the PEAS which lead to a very stiff beam structures resulting in a hole.

4.4.6 Summary PCM Simulations

In total 45 simulations were conducted with variations of 9 different parameters. The main objective was to run a sensitivity study to analyse the effects of structural modification of PEAS and SEAS as well as vehicle mass and impact velocity. The most important findings were shown and explained in detail. The analysis show that the metrics are robust against small variation of the impact velocity which is a finding addressing the R&R requirements. Further results are that the metrics are sensitive to modifications of PEAS and SEAS. However, not in all cases could the same trends be observed. In particular the detection of holes was not possible with all metrics because the AoI of the DDY value was too small to capture the deformations coming from the longitudinals.

The PCM models showed their potential to run a sensitivity study to analyse structural modifications. A large number of different footprints could be created and analysed to investigate the influence of specific changes in design and topology of the crash relevant structures. However the initial design of the models showed that the deformation mode of structures like the longitudinal was not suitable to investigate one specific parameter. Due to the downward bending of the longitudinal the overall crash performance partially showed completely different footprints. Therefore a clear correlation of the modification of one parameter with the metric assessments was not possible in all cases. Future work should focus on an improvement of the PCMs to better address structural changes.

Due to the contradicting results of the metric assessments of all three metric, no clear statement can be made. The results indicate that all metrics need to be revised and maybe modified. The current status does not allow the use of one of them e.g. within the vehicle development process. One possibility to improve the metrics is to further analysis the sensitivity to special effects like improved load spreading or the detection of lower load paths and the appropriate design (in terms of improved car-to-car crash behaviour). Another approach is the elimination of the sensitivity of the metrics on boundary effects as they seem to affect the results if the deformation exceeds the AoI.

4.5 GCM – PDB Simulations

In addition to the simulation results already presented in Chapter 4.1.1 in FIMCAR Deliverable D2.1 [Lazaro 2013] the metric assessments of BDA software, Homogeneity value and DDY metric will be described in the following section. The results focus on the comparison of the three metrics and their potential to assess load spreading within the Area of Interest (AoI) and the detection of holes. Due to the different load path concepts of each GCM category, the detection of the presence of the sub frame is analysed too. The computed values of the three assessment metrics and the corresponding footprints are summarised in Annex H.

The following results of the assessment metrics are normalised to the mean values of each criterion and are marked with "*", see Figure 4.42. For Homogeneity value (TV_upgrade), higher values indicate increasing scores (e.g. > 1.0 means better assessment w.r.t the mean value) and small values indicate decreasing scores (e.g. < 1.0 worse assessment w.r.t. the mean value) because high values are intended to correlate well with good compatibility. In comparison high DDY and TV values (homogeneity assessment by BDA software) indicate a poor compatibility, therefore normalised DDY and TV values < 1.0 indicate an improvement w.r.t. the corresponding mean value. Additionally the computed DDY values are normalised to the preliminary threshold value of 3.5 and are marked with "**".

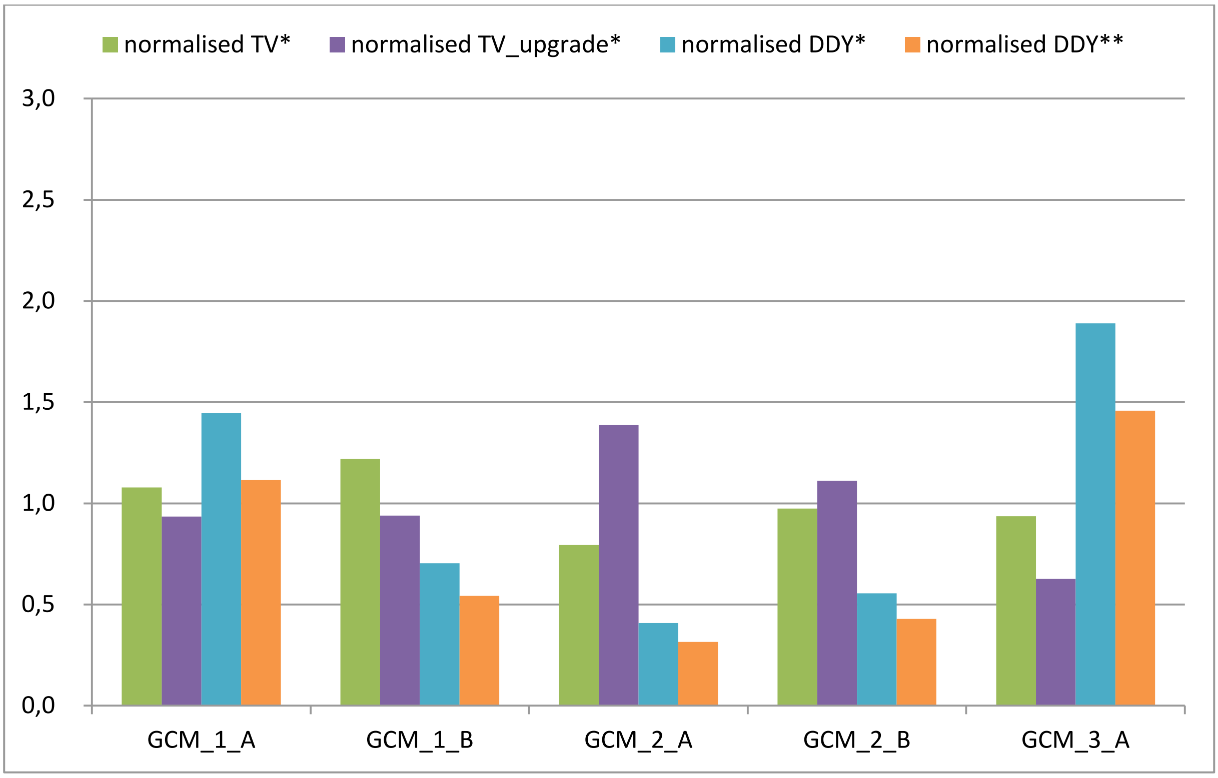


Figure 4.44: Normalised metric assessments of GCM simulations (in relation to mean value; ** in relation to proposed DDY threshold value of 3.5).*

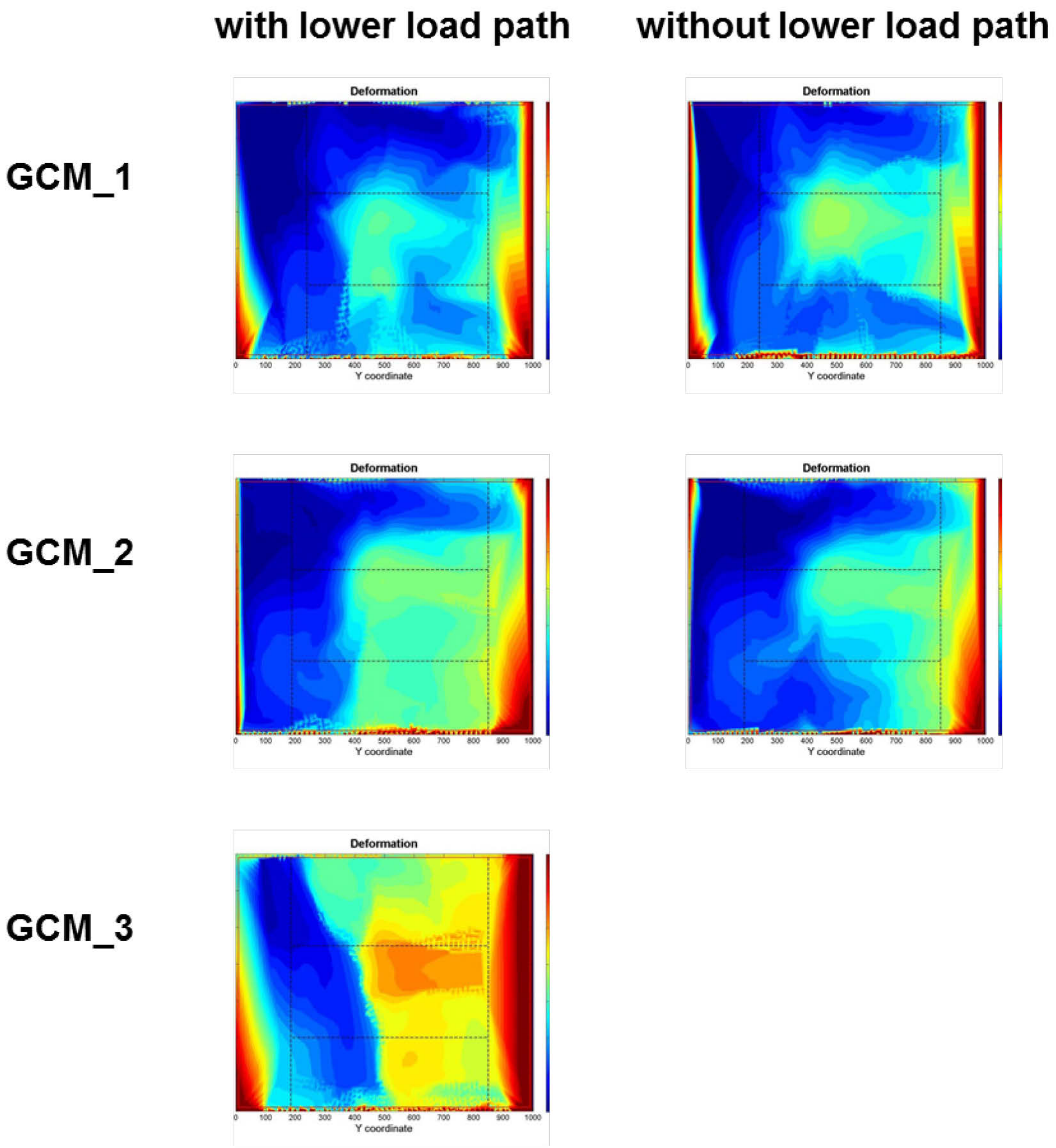


Figure 4.45: Barrier footprints of GCMs.

4.5.1 GCM_1

The subjective assessment of the GCM barrier footprints, Figure 4.45, would conclude that the lower load path improves the vertical load spreading and the hole (in the center of the barrier) due to the single load path disappears. The DDY metric clearly distinguish between both deformation patterns. The normalised values of DDY** indicate that the single load path GCM_1 fails the proposed DDY metric, while the same car model equipped with a sub frame passes. The Homogeneity values shows hardly any differences, thus this metric seems not to be capable to detect holes and to distinguish between the directions of the load spreading. The BDA software assesses the sub frame model better too. The main reason for that is the better assessment of the homogeneity (TV value). In total the difference of the PPS scores is higher because additional points are given due to the deeper intrusions in the lower area. That could be an indicator of the ability of the BDA metric to detect lower load paths.

4.5.2 GCM_2

Both footprints show a very homogeneous deformation pattern, see Figure 4.43. Due to the presence of a lower load path the deformed area of the lower area is larger than without the lower path. In particular, the Homogeneity value (TV upgrade) is higher for the sub frame model, however the DDY metric as well as the BDA software (TV value) assess the improved homogeneity too. However, the total assessment of the BDA software shows a contradicting trend. Because the intrusions of GCM_2_B (without lower load path) in the upper area are lower and the intrusions in the lower area are deeper the total PPS is higher for this model, see Annex H. The rating of the intrusion depth is part of the BDA software assessment and described in detail in FIMCAR Deliverable D2.1[Lazaro 2013].

4.5.3 GCM_3

Because there is only one load path concept available for GCM_3 no comparison to an Executive car without a lower load path can be made. Regarding the metrics all values indicate a relative poor assessment. Indeed, the TV value shows comparable results to the other GCM types but due to the deep intrusions the total PPS is worse too. The sensitivity to the intrusion depth was already identified in the analysis of the artificial profiles (Section 4.2.1). Subjectively, the footprint shows a homogenous deformation below the footprint of the cross beam. This indicates that GCM_3 potentially offers enough structures to activate the EAS (Energy Absorbing Structures) of a colliding vehicle. However, the difference between the non-deformed side and the deformed area (see Figure 4.44) seems to have an influence on the metric. W.r.t. the footprints coming from the calculation of Homogeneity value and DDY metric the deformations seem to be relatively smooth, see Figure 4.44.

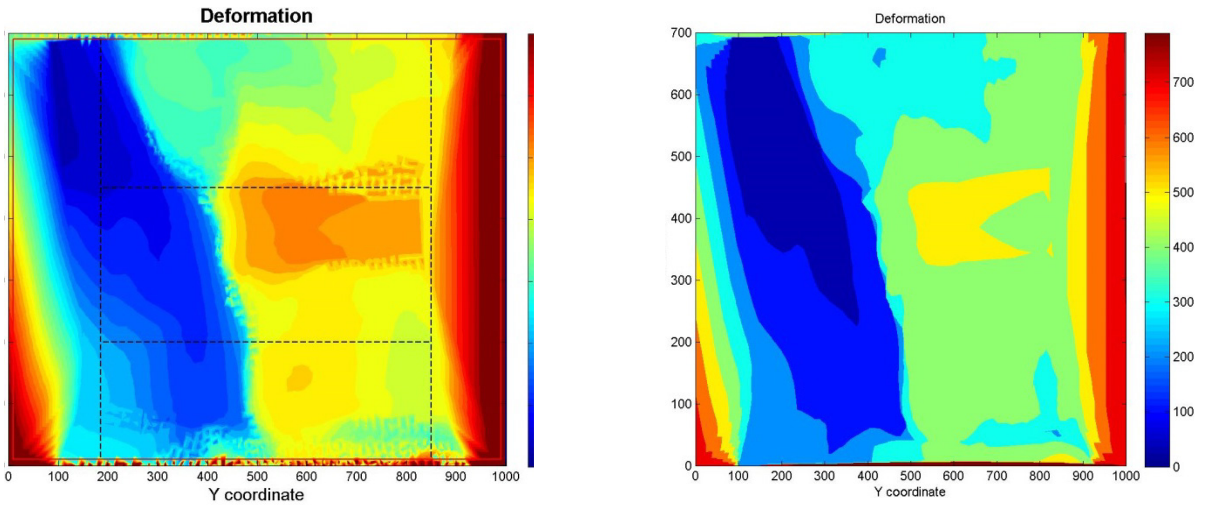


Figure 4.46: Barrier footprint of GCM_3 from BDA software (left) and Homogeneity value and DDY metric (right).

4.5.4 Conclusions GCM Simulations

The GCMs offered the possibility to compare detailed vehicle models with a generic design and different structural concepts. Thus the comparison of the three compatibility metrics regarding an improved load spreading, the presence of holes and the detection of a lower load path was possible. The analysis shows again the dependency on the vehicle mass, because heavier vehicles typically create deeper intrusions than lighter vehicles. However this investigation clearly shows that cars equipped with a lower load path are assessed better than the corresponding model without a sub frame. The additional load path eliminated the presence of holes and improved the homogeneity which could addressed by Homogeneity value and DDY metric

4.6 DDY Value – Updated Assessment Values

In addition to the description of the DDY metric and the overview of the initial vehicle assessments by this metric presented in Section 4.1.2.2, the rating was reviewed in particular to analyse the borderline cases. Figure 4.47, shows the updated DDY values (99%ile, LCW Row 3 and Row 4, 60% of half of the vehicle width) for the test candidates. All analysed test candidates and the corresponding metric assessments as well as the barrier footprints are summarised in Annex I.

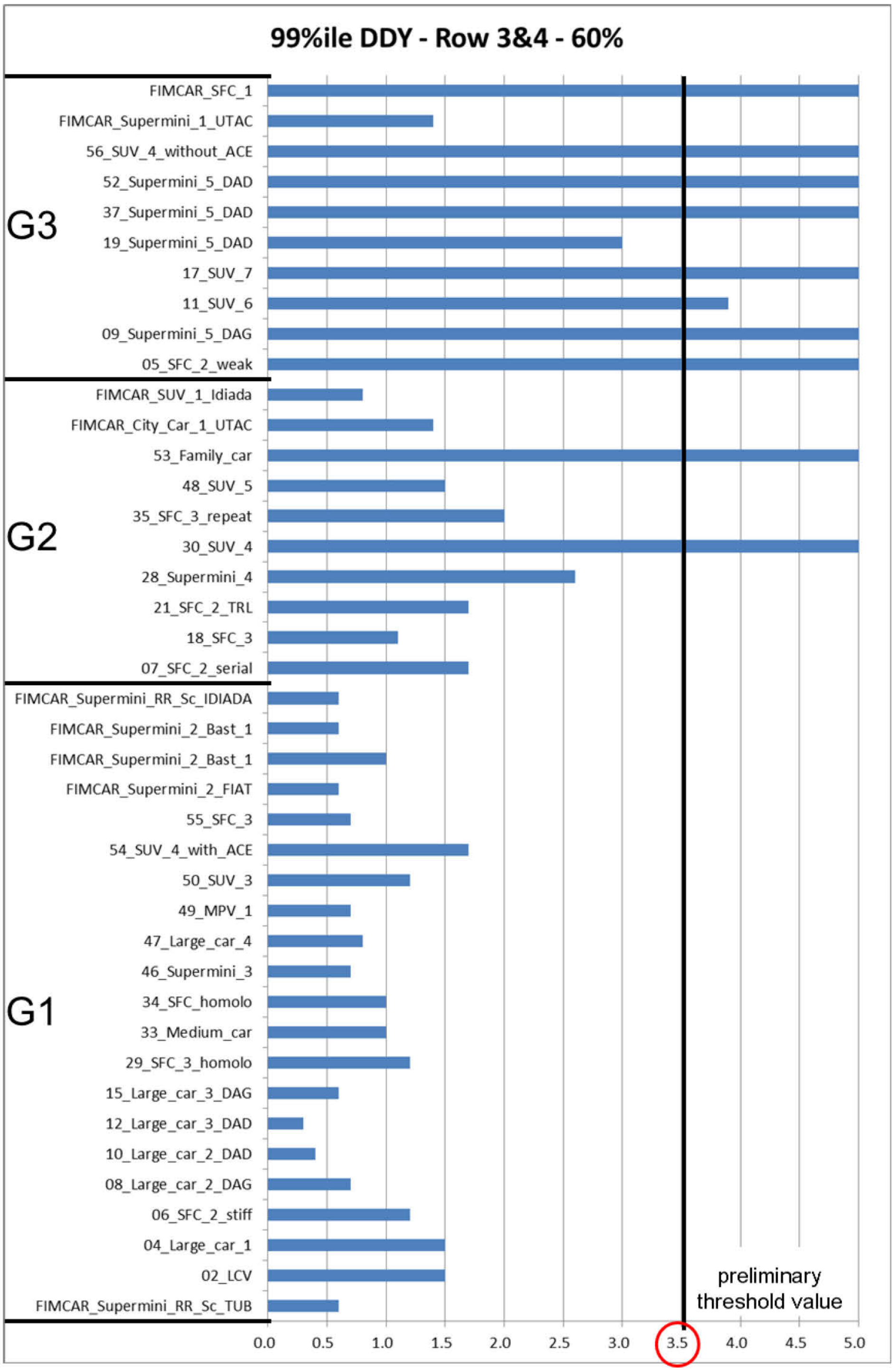


Figure 4.47: Updated summary of 99%ile DDY – Row 3&4 – 60% metric assessment.

4.6.1 Group 1

All reviewed DDY values are a little bit lower than the original assessment in Chapter 4.1.2.2. Therefore the borderline cars of the first comparison are now below the preliminary threshold value. Furthermore the difference between LHD and RHD tested vehicles (e.g. “10_Large_Family_Car_2” and “08_Large_Family_Car_2”) was reduced.

4.6.2 Group 2

Figure 4.46 shows the barrier footprints of the group 2 vehicles. The red highlighted footprints represent the vehicles that still fail the DDY metric. The yellow highlighted footprint shows a deformation pattern with a corrected DDY value, thus the corresponding vehicle passes the metric now.

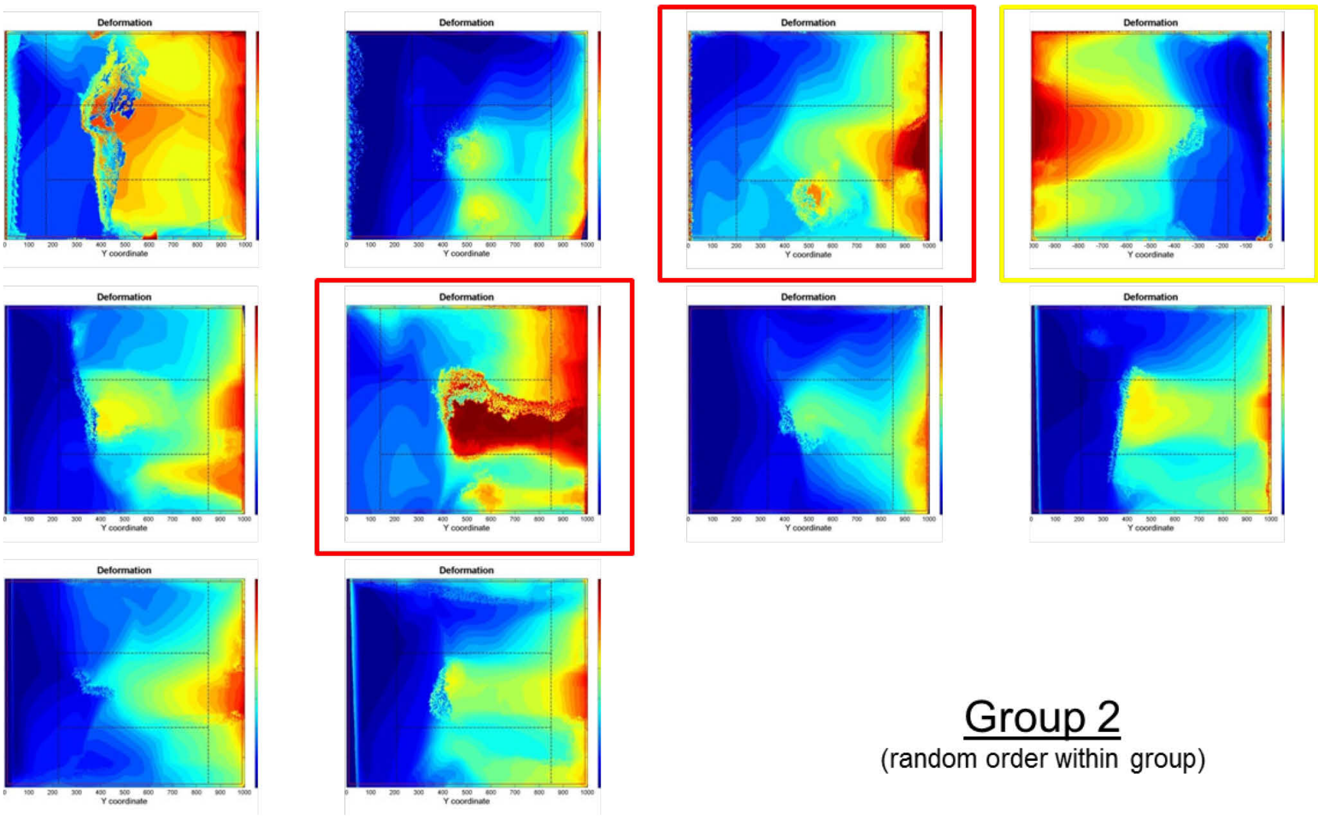


Figure 4.48: Barrier footprints of group 2 vehicles (fail ➔ red flag; pass after review ➔ yellow).

4.6.3 Group 3

Within group 3 there was a change of the pass/failed vehicles too. The yellow highlighted footprints, see Figure 4.47, represents a car that now passes the DDY metric. In comparison with the green highlighted footprint both deformations show the same characteristics which is now addressed by the assessment.

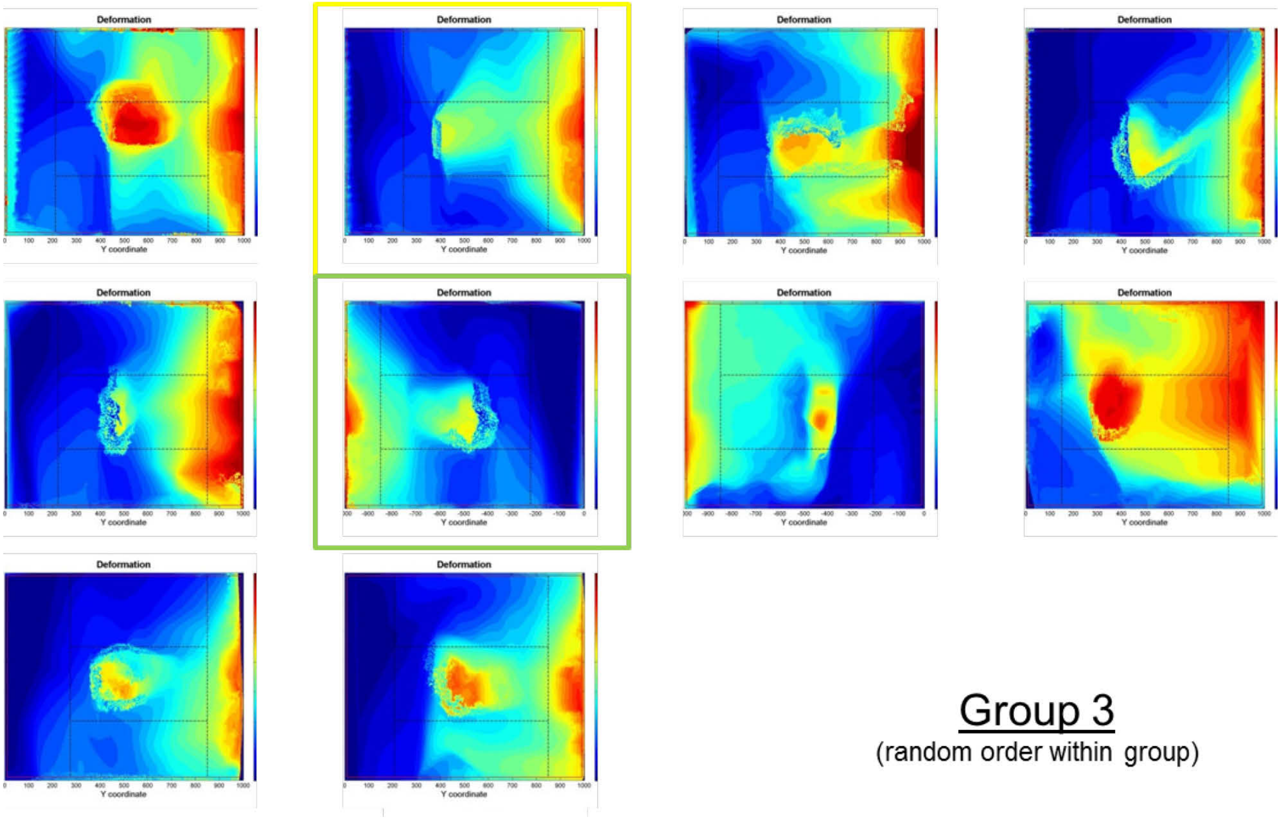


Figure 4.49: Barrier footprints of group 3 vehicles (pass ➔ green flag; pass after review ➔ yellow).

4.7 Comparison of Compatibility Metrics

To compare the three metrics (BDA software, Homogeneity value (TV_upgraded) and DDY metric) the mean value of the each metric was computed and all PDB test candidates and the corresponding assessments were summarised in relation to this mean value and are marked with "*", see Figure 4.48. For PPS (Partner Protection Score) and Homogeneity value (TV_upgrade), higher values indicate increasing scores (e.g. > 1.0 means better assessment w.r.t the mean value) and small values indicate decreasing scores (e.g. < 1.0 worse assessment w.r.t. the mean value) because high values are intended to correlate well with good compatibility. In comparison high DDY values indicate a poor compatibility, therefore normalised DDY values < 1.0 indicate an improvement w.r.t. the corresponding mean value.

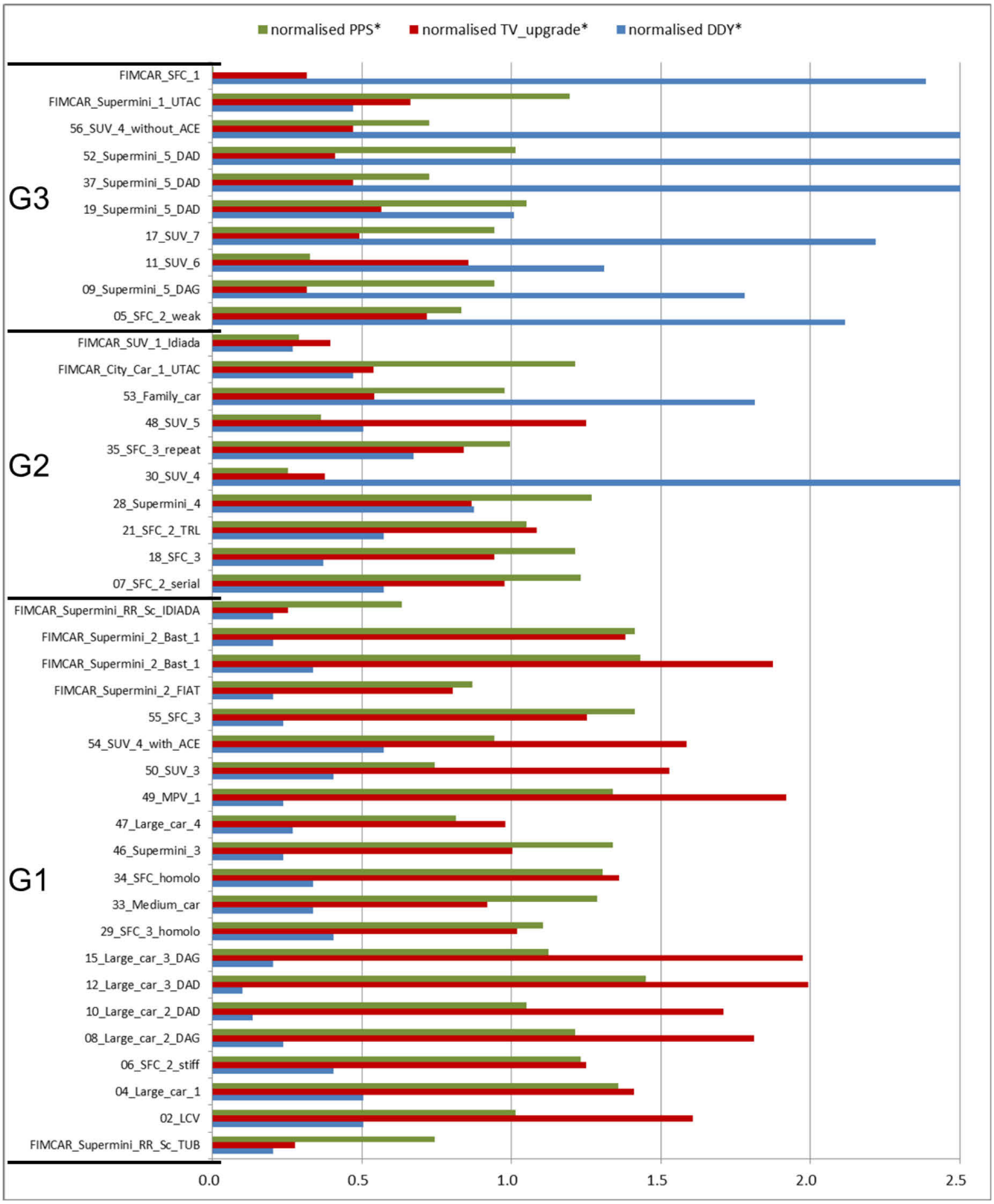


Figure 4.50: Comparison of metric assessments of PDB test candidates.

The DDY and Homogeneity values show the expected contradicting trends, see Figure 4.49. Furthermore, both metrics show a relative large spread. Thus, both metric are capable to clearly distinguish between group 1 and group 3 cars due to their higher, respectively lower normalised values. Indeed, the BDA software shows higher average values for group1 compared to group 3 too, but the difference is relative small, which complicates the definition of appropriate threshold values.

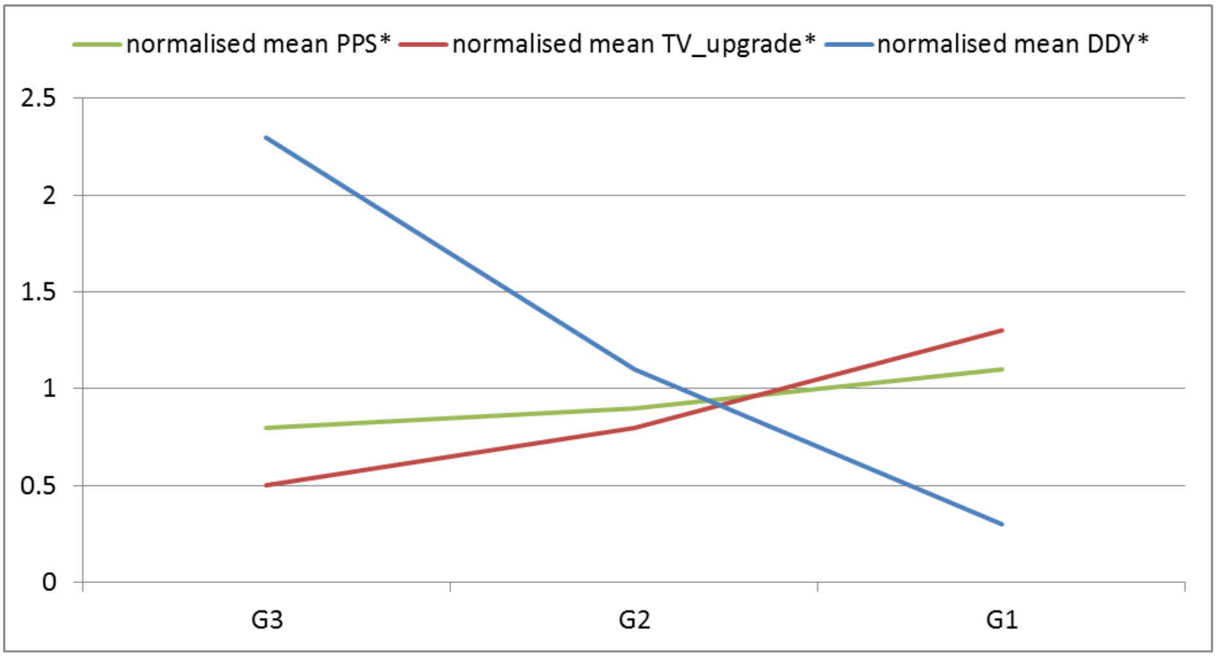


Figure 4.51: Normalised mean values of assessment metrics for group 3 to group 1 cars.

4.8 Definition of Test Severity / Velocity

The proposed test velocity in the PDB test is 60 km/h [Lazaro 2013], the proposed deformable element used in the PDB test aims to harmonise the test severity for different vehicle masses. While with the current deformable barrier used in ODB test (R94 and Euro NCAP) the test severity will increase with the mass of the tested vehicle.

A parameter to assess the severity of a test (or traffic accident) is the EES. In order to ensure the R94 severity an EES of 50 km/h for all type of vehicles will be required.

Details about the definition of the test severity and issues related to the PDB in terms of test severity can be found in Annex B of this deliverable. The main finding was that the PDB produces a more severe test for smaller vehicle, particularly those under 1500 kg than R94. The severity for heavier vehicles becomes less severe. There was not so much data for vehicles above 2000 kg and it was not possible to confirm the PDB would maintain current compartment requirements for all vehicles subject to R94.

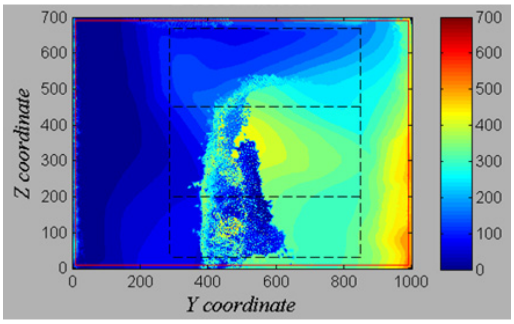
4.9 PDB Barrier Certification

As described in previous sections on this report, the compatibility assessment proposed with the PDB procedure will be based on the post-test, 3D measurements of the deformable barrier. Therefore, it is essential to define the deformable element and the post-test 3D measurements method. Both items are described in the annexure of this report.

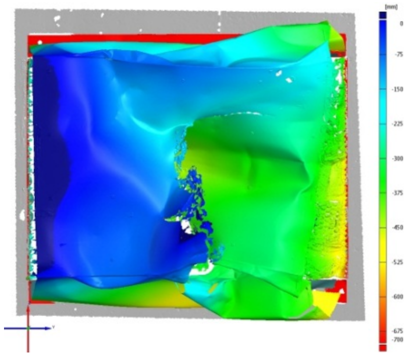
A key factor of the PDB test procedure will be the new proposed deformable element. The definition of this deformable element can be found in Annex 3 of this report. The proposed barrier will require a certification process to validate the behaviour of the deformable element. The certification of the deformable element will consist of a dynamic test to be performed by the barrier manufacturer.

4.10 Development of PDB Scan Procedure

The PDB scan can be performed with different technologies and the different methods have been investigated in WP2. Annex D of this deliverable describes the method proposed by UTAC, a faro arm with laser scanner.



UTAC scan method



IDIADA scan method

Figure 4.52: PDB scan methods.

Alternative methods can be used to conduct the PDB scan, Figure 4.52 shows the Supermini 2 barrier tested at FIAT scanned using two different methods, UTAC and IDIADA. Comparable results on PDB criteria were found using both methods. The analysis of differences in the scanning is described in the R&R section (Chapter 5.2).

During the FIMCAR's investigations, the PDB criteria has been calculated using a reference mesh with 1 mm resolution which is then averaged over 5 mm calculation zones. Therefore, PDB scan methods should provide a mesh size of at least 1 mm.

In the following section additional information to the scan procedure, see Annex D, will be given. The presented information is mainly the result of an interview with consulting engineers which were in charge with one of the repeatability scan of a PDB barrier.

4.10.1 Limitation of Scanning Process

One of the main questions regarding the R&R issues was, if the scanning process depends on the person, which is responsible for scanning the barrier. According to the consulting engineers the quality of the scanning method described in Annex D, does not depend on the user. User specific scanning (e.g. multiple scanning of the same area, horizontal or vertical movement of the scanner) will not affect the results. However, w.r.t. the presence of holes or covered pockets, the digitisation of theses geometries depends on the ability of the user in handling the scanner. Another important factor is the used contactless scanner system. Three relevant systems are listed below:

- structured light scanning
- manual 3D laser scanning (as described in Annex D)
- remote control profile scanning

Regarding footprints of PDB with deep or covered holes, the three systems offer different potentials to capture all necessary information to assess the deformation correctly.

4.10.2 Sensitivity of Scanning Process

Due to the fact that there is no commonly agreed procedure to scan 3D objects like the PDB there is also no information available how the scanning procedure can influence the digitisation of the deformed PDB and how the quality of a scan can be assessed. According to the consulting engineers, the quality of the scan can be ensured and compared by the following values:

- Calibration of scanner
  - Should be done before each scanning (or according to the agreement)
- Standard deviation
  - Automatically computed by the scanner system after the scanning process

Regarding to the standard deviation no thresholds are available distinguish between good or poor scans.

Potentially the 3D scanner systems offer different setups which can have an influence on the result. Most important settings are accuracy and resolution. Accuracy is the ability of the scanner system to sample the surface of an object and to measure surface irregularities. Resolution describes the level of detail of the output. A high-definition output contains more detailed information of the scanned object then a low definition output. While the accuracy of the scanner depends on the used system the user can choose between different setting to create the output and the corresponding resolution. Basically the user can define to take the highest resolution in all areas of the scanned surface. This method results in very large output files (STL files need to be in ASCII format to be workable by the PDB assessment tools) which are difficult to handle in post-processing and cause time consuming calculations. To avoid these disadvantages the scanner systems offer special user routines which automatically reduce the number of scanned points in smooth areas and adjust the number of necessary points in areas where a higher resolution is needed to capture the geometry. How these routines work and how they affect the digitisation process could not be clarified. In general a rule of thumb is used to scan 3D objects which is very familiar to signal processing applications: “the sampling rate of scanning should be 10 times higher than the needed resolution”. According to the experiences of the consulting engineers, the objects which were scanned w.r.t. this rule of thumb should provide R&R conform requirements.

In general the efficiency of the scanning process can be improved if the surface will be matted with special matting sprays, see Figure 4.53 . In that way reflections of the laser and low contrasts which interfere with the measurements can be avoided. As described in Annex D, matting of the surfaces is strongly recommended.

Figure 4.53: Mat surface (left) and bright surface (right) of PDB cladding plates.

4.10.3 Manipulation of Data

To avoid unintended manipulation of the data, possibilities to check the originality where discussed. Basically an STL file contains information about the position and the orientation of a vertex and the connection to a neighboured vertex. This information can be manipulated easily with typical pre-processors used for FEA or CAD applications. Simple checks like date of creation or modification enable the user to control the data. However as simple as the check of this as simple is the manipulation of those data. A further possibility is the cyclic redundancy check (CRC) to verify that there is no loss of data while digital transferring or saving the file. A high level of security guarantees a digital signature, but this feature is not provided by the STL format.

4.10.4 Improvement of PDB for Definition of Origin of Coordinate System

The localisation of the origin of the reference coordinate system is described in Appendix D. Due to deformations on the lower honeycomb edge of the non-impacted side of the PDB the positioning of the reference frame is relative inexact. In particular the localisation of the origin is part of the post-processing after the scanning. Depending on the accuracy of the scan it is nearly impossible for the user to define local axis on the barrier which are parallel to the global coordinate system. The results are small deviations especially regarding the measurement of intrusions into the PDB which can have an influence on the assessment metrics. To simplify the definition of the local coordinate system and therefore to improve the computations of the assessment metric it is proposed to add a rigid cube to the corner of the PDB, as shown in Figure 4.55 where the origin of the local coordinate system should be placed.

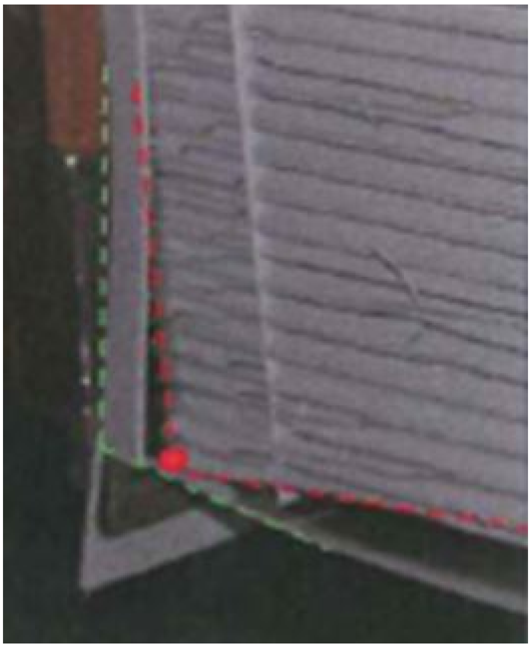
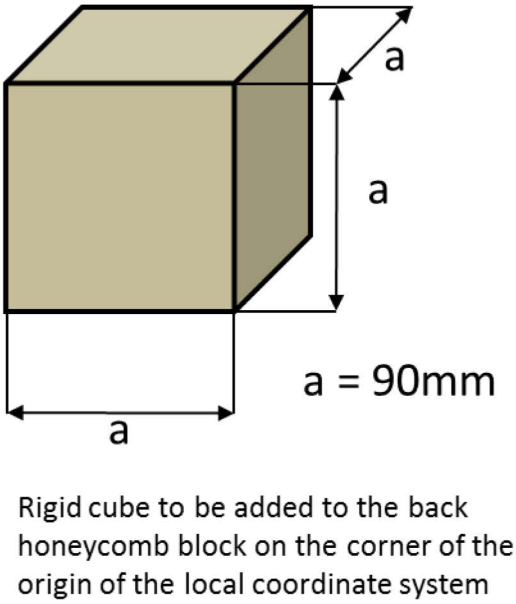


Figure 4.54: Localisation of origin of local coordinate system as described in Annex D.



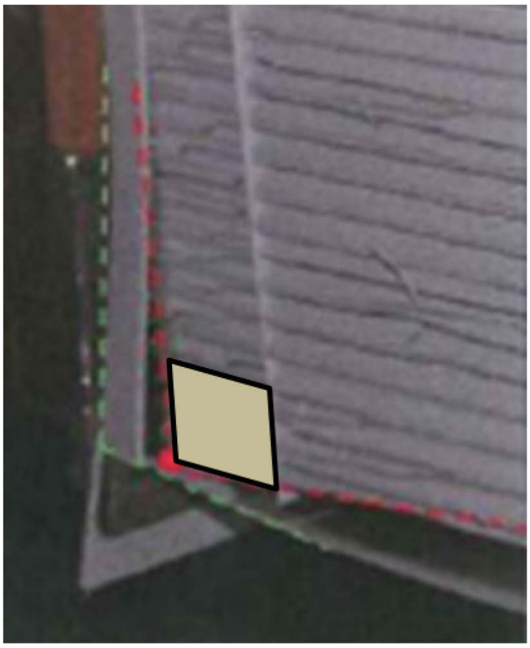


Figure 4.55: Proposal to improve the PDB with a rigid block to simplify the localisation of the local coordinate system.

As described in, the rigid cube can be added to the back honeycomb block of the PDB on the non-impacted side. The outer edges of the cube should be measurable by the scanner. Thus the user can clearly define the local coordinate system within the post-processing. This feature should improve the handling and the preparation of the STL files and should improve the scanning process to become more independent from the user.

4.10.5 Treatment of Folds – Ray Tracing

In some cases the footprint of the PDB showed a deformation pattern where some areas are covered by the cladding plate. This can be a result of failure mechanisms due to rupture of the cladding plate, or the vehicle rotates and pushed a pocket into the honeycombs or while removing a vehicle or components of a vehicle which stuck into the barrier. Figure 4.56 shows two examples.

Figure 4.56: Covered pocket due to rotation of the vehicle (left) and covered areas due to rupture of the cladding plate (right).

As already described these footprints can cause problems depending on the ability of the user to scan the whole surface but one of the main issues is the presence of multiple layers of the barrier (frontal view) due to folds. Figure 4.57 shows the corresponding interpretation of the PDB scans analysed with BDA software v1.0.

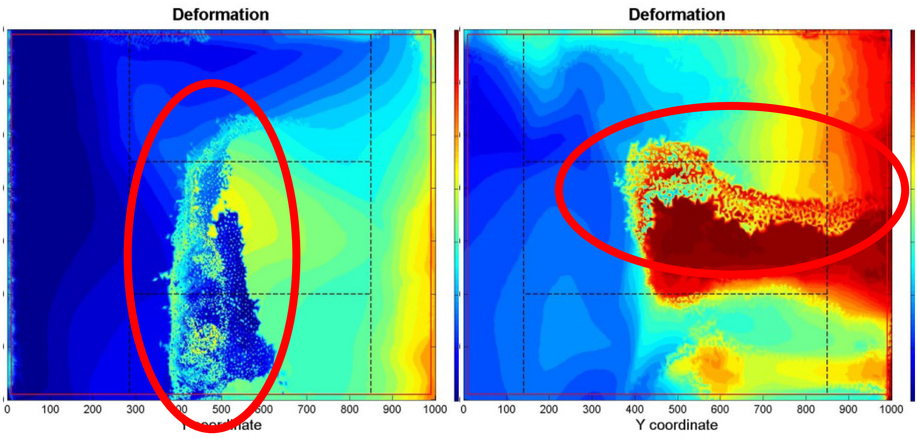


Figure 4.57: Interpretation of scans by BDA software v1.0 of covered pocket (right) and rupture of cladding plate (left).

The red circles in Figure 4.57show that during the scanning process the foremost layer was scanned too which causes interferences in the interpretation of the footprint and therefore influences the assessment by BDA software. The critical parameter is the calculation of the homogeneity of the deformed area which basically is analysed by the total variation of the gradient of the deformation of neighboured points. Folds as well as the geometry of honeycombs (if the cladding plate does not cover the honeycombs the laser goes into the honeycomb due to their orientation and the bottom of the corresponding PDB layer is measured) can cause “noise” within the area of interest and thus can make a correct assessment not possible.

To handle this problem two methods were developed and implemented into the Matlab scripts developed by VTI and TNO, see Chapter 4.1. The most promising approach to reduce interfering areas and to assess the real deformation depth was the ray tracing approach.

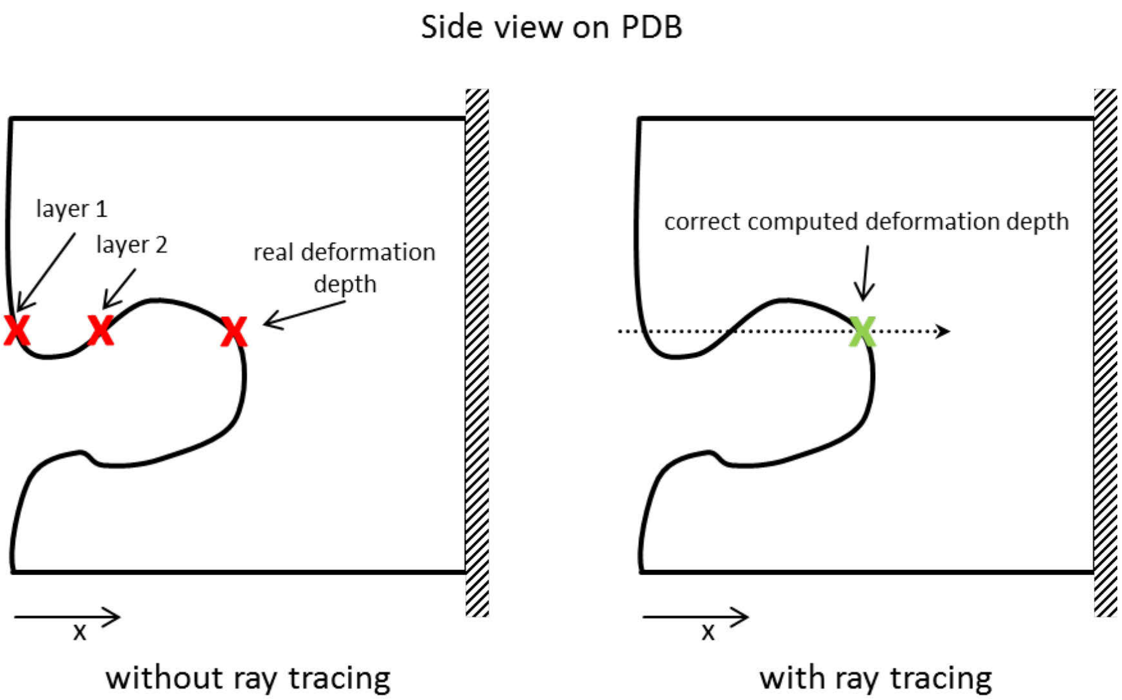


Figure 4.56: Principle of ray tracing.

Figure 4.56 shows basic idea of ray tracing. Mathematically a ray parallel to the x-axis detects multiple layers and only takes the highest x value (= deepest intrusion) into account. The following calculation steps, e.g. for homogeneity value or DDY metric, are based on the maximum x values. Thus no interferences influence the assessments negatively. Exemplarily Figure 4.57 shows the same PDB scans computed with ray tracing as already described in Figure 4.55.

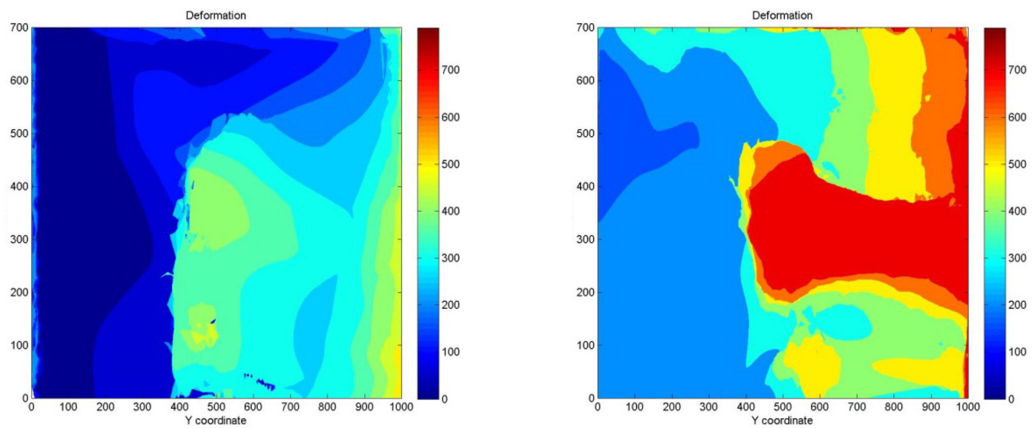


Figure 4.57: interpretation of scans analysed with ray tracing, covered pocket (left) and rupture of cladding plate (right) in comparison to the interpretation without ray tracing shown in Figure 4.55.

The ray tracing offers the possibility to scan the PDB after the crash and excludes multiple layers due to this kind of post-processing. Automatically the real deformation depth is computed by the ray tracing approach and ensures repeatable results. Another method is a user controlled scan, where covered areas are manually uncovered to scan the maximum intrusion into the barrier. But this method is very sensitive to the experience and the ability of the user and can cause belated deformations or rupture of the barrier. The manual post-processing after the scanning is the third possibility to remove folds or areas which can influence the assessment. This manual preparation of the data is very time consuming because there are no automatic algorithms known to delete multiple layers with FEA or CAD tools. Furthermore a manipulation of the STL data cannot be checked if this method is used.

5 VALIDATION OF PDB PROTOCOL

5.1 Validation of Concept

The validation of the PDB procedure involved different analyses of PDB tests performed in FIMCAR and the associated car-to-car test series. The aim of these studies was to show that a vehicle which exhibits underride and other “compatibility” problems in car-to-car tests will FAIL the metric and those which do not show any issue will be assessed appropriately by the PDB test metric and performance limits.

Clear examples of vehicles that should PASS the metric as result of the car-to-car tests are the Supermini 1 and Supermini 2. The Supermini 2 exhibits a “compatible” situation in the aligned and misaligned crash tests, while Supermini 1 showed a “compatible” situation in the aligned conditions (both cases OK the load spreading). Both vehicles were tested in WP2 and passed the structural alignment metric requirements.

The SUV 1 vs SFC 1 car-to-car tests have shown “compatible” situations, i.e. acceptable self-protection in tested cars as well as an equivalent passenger compartments for both vehicles. Those results apply for both, aligned and misaligned tests. On the other hand, the SUV 2 vs SFC 1 showed an “incompatible” situation, in this test the SFC 1 was locally deformed in the footwell area producing higher intrusions in the area and high inward pedal displacements.

From the PDB deformation, we can conclude that the SFC 1 will fail the metric. This result is in line with the SFC 1 vs. SUV 2 car-to-car test.

5.2 Repeatability and Reproducibility

5.2.1 Analysis of FIMCAR R&R Data

In order to investigate the R&R of the PDB, the FIMCAR consortium decided to take the Supermini 2 as a vehicle to be tested and analysed. As agreed by the FIMCAR consortium the R&R analysis includes three tests of an identical vehicle in two different FIMCAR laboratories.The tests were performed in two different laboratories, FIAT and BASt. The same Supermini 2 model, engine and vehicle option was used in all case, see Table 3.

Table 3: Supermini 2 Test matrix.

Vehicle to test	Laboratory	Test Date	Test configuration	Objective	Partner-protection
Supermini 2	FIAT	Jun 2011	PDB60	Test severity validation (self-protection) and comparison with other test modes (FWRB and MPDB)	Good performance expected
Supermini 2	BASt	Jan 2012	PDB60	Repeatability issues	Good performance expected
Supermini 2	BASt	Apr 2012	PDB60	Repeatability issues	Good performance expected

5.2.1.1 Description of the Supermini 2 Front Structure

The Supermini 2 is a super mini car equipped with two energy absorption structures (PEAS & SEAS) and an upper structure that includes a front-end connected to the radiator support at the bonnet leading edge area.

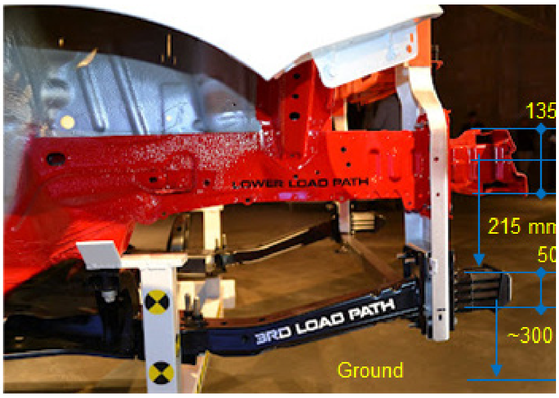


Figure 5.1: Supermini 2 front structure.

As shown in Figure 5.1 the centreline of the PEAS (in red) are positioned 565 mm above ground level which is inside the interaction area defined in FIMCAR (Rows 3&4, 330 to 580 mm). The SEAS lie between 300 to 350 mm above ground, therefore, partially interacting with the common interaction zone defined in FIMCAR. Both structures are longitudinally extended forward to the front-end of the car and incorporate steel cross beams, which are considered part of the front structure.

For the above mentioned front structure characteristics the Supermini 2 is considered a good candidate for compatibility. This assumption was checked and confirmed in FIMCAR. A set of car-to-car tests was performed in order to study the Supermini 2 performance in this kind of crash. Results of the Supermini 2 car-to-car tests can be found in FIMCAR Deliverable D6.1 [Sandqvist 2013].

Table 4: Supermini 2 R&R Test set-up.

Crash Lab.	Car model	Test #	Test mass [kg]	Velocity [km/h]	Ride height measurements		Impact point	
					Front [mm]	Rear [mm]	Horizontal [mm]	Vertical [mm]
FIAT	Super-mini 2	17292	1165	60.24	L 613 R 615	L 623 R 622	0	Up 10
BASt	Super-mini 2	FM02 OPDB	1165	60.01	L 622 R 619	L 614 R 615	Left 35	Up 12
BASt	Super-mini 2	FM03 OPDB	1164	60.08	L 634 R 633	L 618 R 620	Left 87	Low 7

The overlap of the two tests performed at BASt was above the tolerances (20 mm), however, no significant influence was identified on vehicle pulse, dummy reading and vehicle intrusions by the larger overlap. A significant effect on barrier deformation and further metric investigations is expected, however. In particular, for the BASt test no.2 (87 mm horizontal deviation to the left, overlap over 50%).

The pictures below show the Supermini 2 cars before and after tests performed at FIAT and BASt laboratories.

FIAT test | BASt test no.1 | BASt test no.2

Figure 5.2: Supermini 2 pre-test.

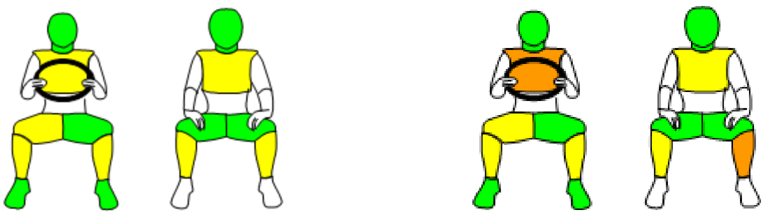
FIAT test BASt test no.1 BASt test no.2

Figure 5.3: Supermini 2 post-test.

In addition to the dummy results and vehilce intrusions, the PDB barrier of the three tests has been scanned and analyed. The objective is to investigate the R&R of the proposed compatibility metrics.

The non-firing of the safety restraint system of BASt test no.1 (FM02OPDB) makes the dummy results unrealistic and non-compareble with the other two Supermini 2 tests. Therefore, we can only compare the test performed at FIAT and the second test performed in BASt (FM03OPDB).

FIAT test BASt test no.2



Driver: 12.658 Driver: 11.932

Passenger: 14.246 Passenger: 13.487

Figure 5.4: Supermini 2 dummy readings.

Comparable results were obtained in terms of dummy values, Figure 5.4. As well as in terms of vehicle pulse and vehicle intrusions, Figures 4.15 and 4.16, respectivelly.

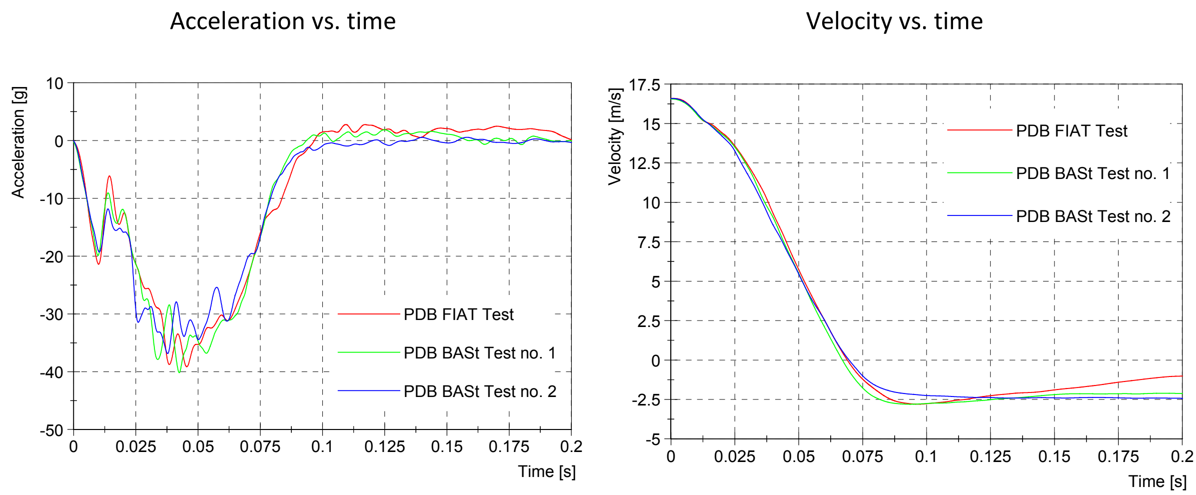


Figure 5.5: Supermini 2 Test pulse.

Minor A-Pillar intrusions were measured in all three tests, minor intrusions at the footrest area were recorded in all cases below 50 mm.

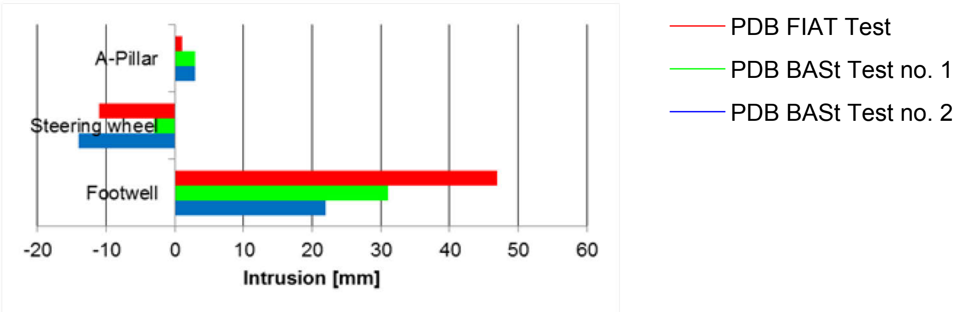
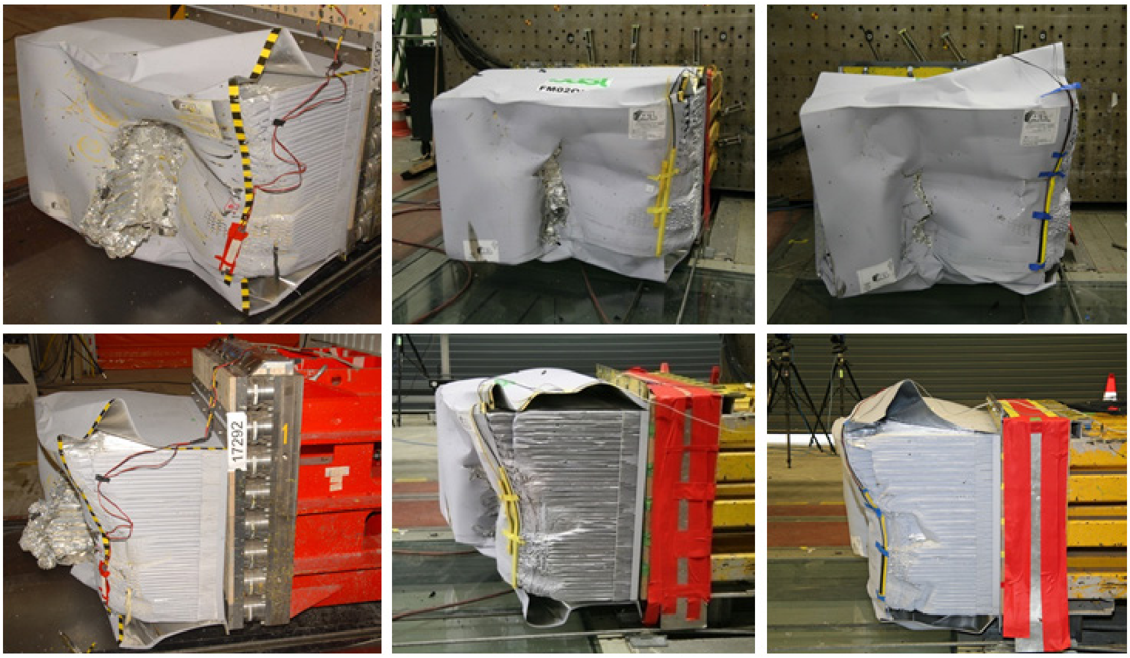


Figure 5.6: Supermini 2 intrusions.



FIAT test BASt test no.1 BASt test no.2

Figure 5.7: Supermini 2 PDB deformation.

In all the three cases, the lower load path has well deformed the barrier. The large vehicle overlap of BASt test no.2 can be observed in the barrier deformation.
Figure 5.8 gives an overview of the three R&R barrier footprints. It has to be noted that “Test 2 @ BASt” had a horizontal impact accuracy greater than the specified tolerance (horizontal overlap with PDB was higher than 50%) whereby the metrics were influenced. The subjective analysis of the footprints, see Figure 5.9, shows comparable deformation patterns. In particular, the repeatability tests (Test 1 and Test 2) show almost identical scans, disregarding the difference due to the wrong horizontal overlap.

Table 5 summarises the ratings of the three metrics. PPS and Homogeneity value assess "Test 3 @ Lab 2" worse compared to the other two tests. The high assessment by the BDA software for Test 1 is a result of additional assessment credits in the homogeneity rating, which is not the case in the other two tests. Furthermore, Homogeneity value and DDY metric are influenced by the larger horizontal overlap with the PDB, but the Homogeneity value indicates an improved compatibility while DDY indicates deterioration. However, the coefficient of variation shows relative high numbers for the deviation from the mean value for all three tests which indicates the importance of impact accuracy.

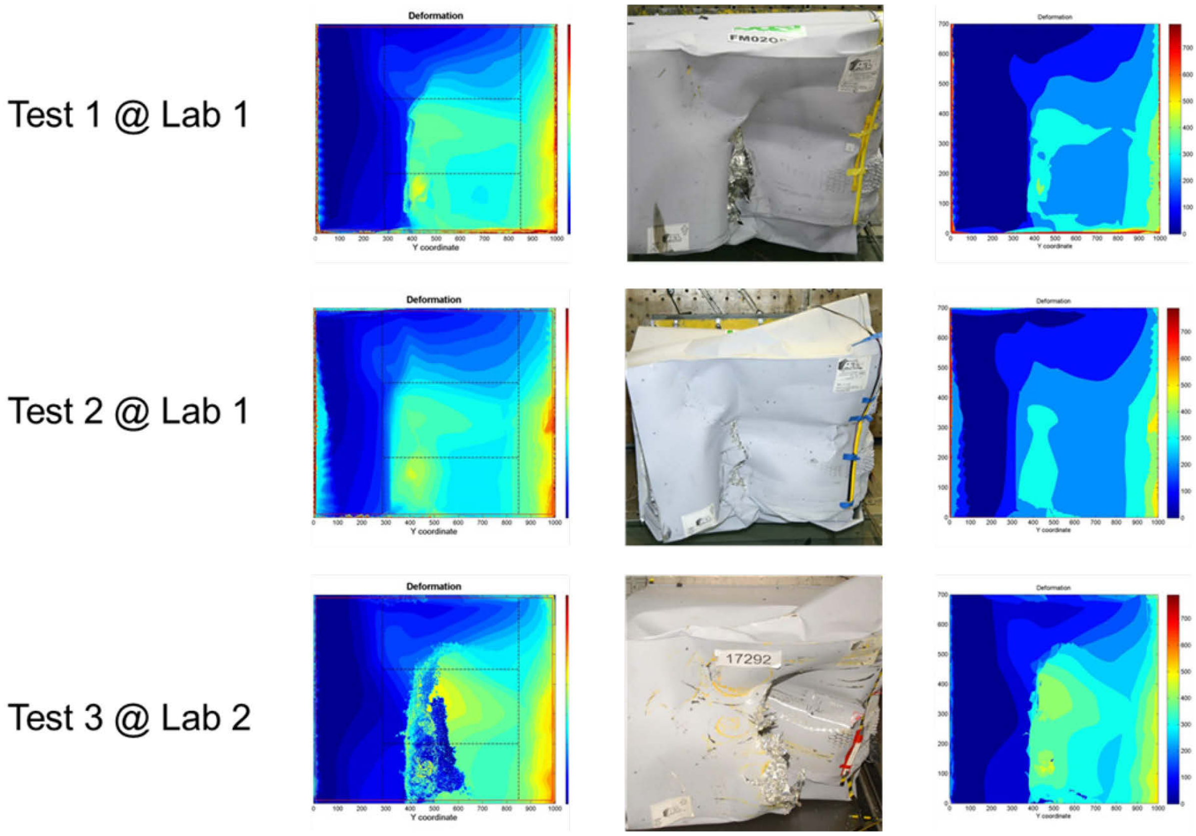


Figure 5.8:FIMCAR Supermini 2 PDB tests.

Table 5: Comparison of metric assessments of FIMCAR Supermini 2 PDB tests.

	PPS	Homogeneity value	DDY
Test 1 @ Lab 1	7.8	209,418,168	0.6
Test 2 @ Lab 1	5.6	284,247,959	1.0
Test 3 @ Lab 2	4.8	122,006,265	0.6
Mean value	6.1	205,224,131	0.7
Coefficient of Variation	25.6	39.6	31.5

Figure 5.9 shows the barrier footprints of the same PDB barrier scanned by different labs. Subjectively all three scans show identical results. The challenge of scanning this barrier was that parts of the deformation where covered by folds. As described in Section 4.10.1, the scanning of covered area depends on the experience of the user to capture the important areas. Table 6 summarises the ratings of the three scans of the same PDB. The DDY value is the same for all three scans while the Homogeneity value shows a very high value for “Scan 1”. Therefore the coefficient of variation indicates an unacceptable high variance of the three ratings. The assessment by the BDA software is acceptable and the rating by DDY is perfect, because there are no deviations.

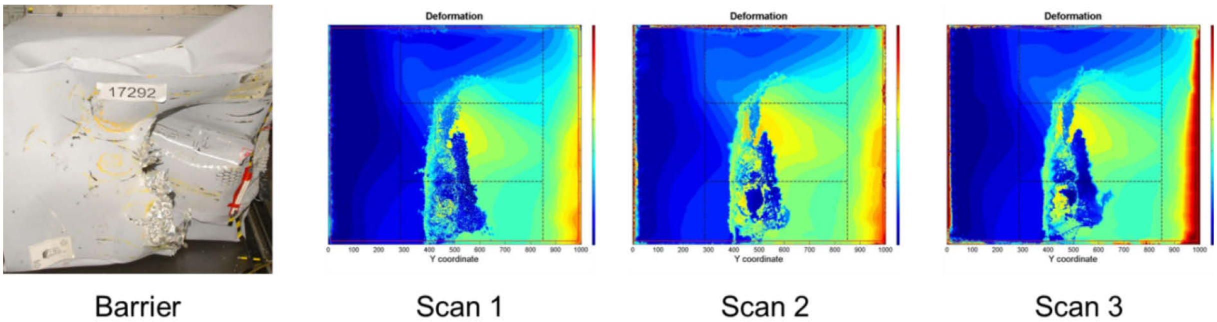


Figure 5.9: FIMCAR Supermini 2 PDB scans of the same barrier

Table 6: Comparison of metric assessments of FIMCAR Supermini 2 scans of the same barrier.

	PPS	Homogeneity value	DDY
Scan 1	4.8	122,006,265.00	0.6
Scan 2	3.5	38,180,200.00	0.6
Scan 3	4.1	41,828,238.00	0.6
Mean value	4.1	67,338,234.33	0.6
Median value	4.1	41,828,238.00	0.6
Coefficient of Variation	15.7	70.4	0.0

5.2.2 Conclusions R&R Analysis

Repeatable results were obtained in terms of vehicle performance, pulse and intrusions. The A-Pillar intrusions were below 5 mm for all three tests, the same range of A-Pillar intrusions in a Euro NCAP test.

A correct activation of the Safety Restraint System (SRS) was achieved in two of the three tests. In those cases the dummy injuries were well below R94 limits, repeatable results in terms of dummy values when a correct activation of the SRS was observed.

The R&R analysis of the metric assessments shows that the DDY metric is very robust in analysing barrier footprints of the same vehicle. It needs to be checked if the deviation of “Test 2 @ Lab 1” depends on the wrong horizontal overlap. The BDA software and the Homogeneity value seem not to be capable of fulfilling R&R requirements because the computed values differ too much. In terms of the PPS the assessments mainly depend on the intrusion depths. A review of the rating corridors for the intrusion depth is proposed.

6 CONCLUSIONS

In regards to the off-set test procedure, FIMCAR decided to propose the current R94 test procedure (without additional compatibility metrics) as FIMCAR's off-set test approach. The test will include additional structural requirements to ensure the passenger compartment stability during the crash test. Therefore, an equivalent test to the current ODB (R94) will be proposed for the off-set test procedure.

Because of the potential of the PDB to include compatibility metrics, WP2 has continued the PDB metric development until the end of FIMCAR project. The development focused on the assessment of the load spreading issue, which was defined as a Priority 1 issue by FIMCAR consortium.

The fundamentals of the assessment method using the PDB off-set test were defined in D2.1 [Lazaro 2013]. Different metrics have been investigated for assessing compatibility issues. The recently investigated metrics have shown reasonably good results in terms of correlation with a subjective assessment. The proposed metric is based on the DDY criterion which is a vehicle mass independent criterion. It is calculated from the PDB barrier's deformations. More specifically, it calculates the barrier's slope in the lateral (Y) direction and penalizes vehicles producing high slopes such as those occurring at the edges of holes. However, the metric still needs to be developed further and validated.

The full scale tests performed in WP2 shown that the PDB represents a reasonable severe test compared to the Euro NCAP test, which is considered the reference today in Europe. The vehicle pulse and dummy values measured in the tests performed in WP2 shown comparable results to the Euro NCAP reference. Further validation is needed for vehicles with masses over 2000 kg.

Finally, R&R issues have been analysed for the PDB test procedure. The study was conducted using the FIMCAR Supermini 2 PDB data. Three different tests were performed in two different FIMCAR laboratories showing repeatable results.

7 REFERENCES

[Adolph 2013] Adolph, T.; Edwards, M.; Thomson, R.; Stein, M.; Lemmen, P.; Vie, N.; Evers, W.; Warkentin, T: VIII Full-Width Test Procedure: Updated Protocol Development in Johannsen, H. (Editor): FIMCAR – Frontal Impact and Compatibility Assessment Research, Universitätsverlag der TU Berlin, Berlin 2013

[Delannoy 2005] Delannoy, P.; Castaing, P.; Martin, T.: "*Comparative Evaluation of Frontal Offset Tests to Control Self and Partner Protection*". 19th Enhanced Safety Vehicle Conference 2005. Paper Number: 05-0010 2005. http://www-nrd.nhtsa.dot.gov/pdf/esv/esv19/05-0010-O.pdf

[EEVC 2013] Enhanced European Vehicle-safety Committee 2013. www.eevc.org.

[Euro NCAP 2013] Euro NCAP. European New Car Assessment Programme 2013. www.euroncap.com

[Lazaro 2013] Lazaro, I.; Vie, N.; Thomson, R.; Schwedhelm, H.: V Off-set Test Procedure: Review and Metric Development in Johannsen, H. (Editor): FIMCAR – Frontal Impact and Compatibility Assessment Research, Universitätsverlag der TU Berlin, Berlin 2013

[Meyerson 2009] Meyerson, S.; Delannoy, P.; Guillaume, R.: "*Evaluation of Advanced Compatibility Frontal Structures Using the Progressive Deformable Barrier (PDB)*". 21st Enhanced Safety Vehicle Conference 2009. Paper Number: 09-0329 2009. http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0329.pdf

[Park 2009] Park, C.-K.; Thomson, R.; Krusper, A.; Kan, C.-D.: "*The Influence of Sub-Frame Geometry on a Vehicle's Frontal Crash Response*". 21st Enhanced Safety Vehicle Conference 2009. Paper Number: 09-0403. Stuttgart 2009. http://www-nrd.nhtsa.dot.gov/departments/esv/21st/

[Sandqvist 2013] Sandqvist, P.; Thomson, R.; Kling, A.; Wagström, L.; Delannoy, P.; Vie, N.; Lazaro, I.; Candellero, S.; Nicaise, J.L.; Duboc, F.: III Car-to-car Tests in Johannsen, H. (Editor): FIMCAR – Frontal Impact and Compatibility Assessment Research, Universitätsverlag der TU Berlin, Berlin 2013

[Stein 2013/1] Stein, M.; Johannsen, H.; Thomson, R.: "*FIMCAR – Influence of SEAS on Frontal Impact Compatibility*". 23rd Enhanced Safety Vehicle Conference. Paper Number: 13-0436 2013. http://www-nrd.nhtsa.dot.gov/pdf/esv/esv23/23ESV-000436.pdf

[Stein 2013/2] Stein, M.; Johannsen, H.; Puppini, R.; Friedemann, D.: IV – FIMCAR Models in Johannsen, H. (Editor): FIMCAR – Frontal Impact and Compatibility Assessment Research, Universitätsverlag der TU Berlin, Berlin 2013

8 GLOSSARY

ATD:	Anthropomorphic Test Device
AoI:	Area of Interest
CIZ:	Common interaction zone (as described in Part581 zone)
EES:	Estimate Equivalent Speed
EEVC:	European Enhanced Vehicle Safety Committee
Euro NCAP:	European New Car Assessment Programme
FW:	Full Width Frontal Impact
HIII:	Hybrid III test dummy
ODB:	Off-set Deformable
Part 581 zone:	Bumper zone according to FMVSS Part 581 Bumper Standard
PEAS:	Primary Energy Absorbing Structures
PDB:	Progressive Deformable Barrier
PPS:	Partner Protection Score (assessment result of BDA and PDB software)
R&R:	Repeatability and Reproducibility
SDI:	Smooth Deformation Index
SEAS:	Secondary Energy Absorbing Structures
SRS:	Safety Restraint System
VC-Compat:	EC funded project (FP5) Vehicle Crash Compatibility

ANNEX A: OFF-SET TEST AND ASSESSMENT PROTOCOL

TEST CONFIGURATION

In this annex the off-set test procedure proposed by FIMCAR is described. The deformable element of the trolley corresponds to the current UN-ECE-Regulation 94 test as well as impact speed and overlap taken into account the FIMCAR aim to at least maintain the current level of compartment strength. The addition of a requirement for A-pillar deformations to be less than 50 mm will guarantee sufficiently strong occupant compartments by enforcing the stability of the forward occupant cell. There is no explicit requirement for compartment stability in the current UN-ECE Regulation 94 that ensures a minimum level for Europe. Euro NCAP tests tend to promote stronger compartment designs than R94 but this is not a mandatory test.

The text reproduced below was prepared by FIMCAR in order to add intrusion requirements to the existing ECE-R 94.

CHANGES TO ECE-R 94

Chapter 5.2.8. (new)

The rearward movement of the A-post shall not be more than 50 mm

Annex 11 (new)

Intrusion Measurements

8.1 Before test

8.1.1 Remove the carpet, trim and spare wheel from the luggage compartment. The plastic trim or rubber seals that might influence the latching mechanism should be re-fitted once the intrusion measurements have been recorded. This is to ensure that any opening of the rear door during the impact is not caused by the omission of some part of the trim around the latching mechanism.

8.1.2 Locate the vehicle axis reference frame (see Figure A-1) centrally to the rear of the vehicle.

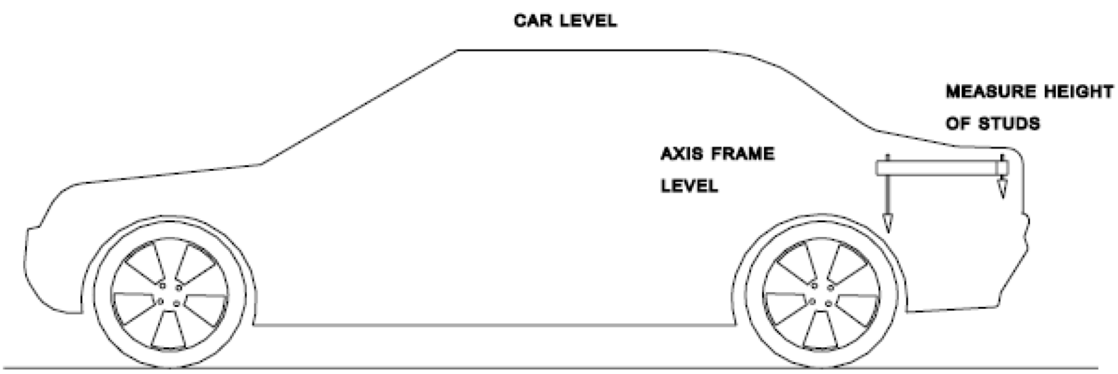


Figure A-1: Setting up axis reference frame.

8.1.3 Level the reference frame

8.1.4 Measure and record the stud heights of the reference frame. These will be used after the test to help reset the reference frame, if required.

8.1.5 If it is necessary to lean on the vehicle to reach the following points, the vehicle should be supported to maintain the ride heights during measuring.

8.1.6 Set up the vehicle co-ordinate axes in the 3D arm or similar device.

8.1.7 Mark and record the position of at least 5 datum points on the rear of the vehicle. These points should be on structures which are not expected to be deformed in the test and should be positioned such that they have wide spaced locations in three dimensions and can all be reached with the 3D measuring system in one position.

8.1.8 Working on the passenger side of the vehicle determine and mark the positions of the A-post which are
i) at a distance of 100 mm above the sill
ii) at a distance of 100 mm beneath the lowest level of the side window aperture.

8.1.9 All points should be as close as possible to the rubber sealing strip around the door aperture.

8.1.10 Measure and record the pre-impact positions of the two aperture points.

8.1.11 Working on the driver's side of the vehicle determine and mark the positions on the A-post which are
i) at a distance of 100 mm above the sill
ii) at a distance of 100 mm beneath the lowest level of the side window aperture.

8.1.12 All points should be as close as possible to the rubber sealing strip around the door aperture.

8.1.13 Measurement should be taken of the pre-impact positions of the door aperture points.

8.1.14 After test

8.1.15 Use any 3 of the 5 datum points at the rear of the vehicle, and their pre-impact measurements, to redefine the measurement axes.

8.1.16 If the axes cannot be redefined from any 3 of the datum points relocate the axis reference frame in the same position as in section 8.1.4. Set the studs of the frame to the same heights as in section 8.1.7 (Figure A-2). The frame should now be in the same position relative to the car as it was before impact. Set up measurement axes from the frame.

8.1.17 Record the post-impact positions of the B-post points on the passenger's side of the vehicle.

8.1.18 Compare the vertical co-ordinate of the B-post sill point before (section 8.1.8) and after (section 8.1.16) the test.

8.1.19 Find the angle θ that best satisfies the following equation: $z = -x'\sin\theta + z'\cos\theta$ for the B-post sill point (where z = pre impact vertical measurement and x',z'= post-impact longitudinal and vertical).

8.1.20 Working on the driver's side of the vehicle, record the door aperture points.

8.1.21 Transform the post impact longitudinal and vertical measurement (x',z') using the following equations.

$$\begin{pmatrix} X' \\ Z' \end{pmatrix} = \begin{pmatrix} \cos\vartheta & \sin\vartheta \\ -\sin\vartheta & \cos\vartheta \end{pmatrix} \begin{pmatrix} x' \\ z' \end{pmatrix}$$

8.1.22 Where ϑ is the angle determined in Section 8.1.19. X and Z should now be in the same frame of reference as the pre-impact measurements. [1]

8.1.23 From the pre-impact and adjusted post-impact data collected, determine the rearward movement of the A-post at waist level

8.1.24 Record these intrusion measurements in the test details.

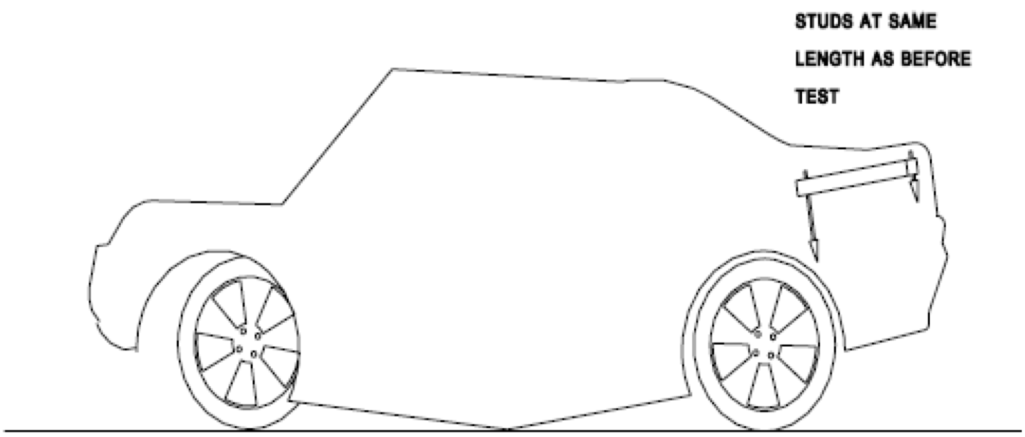


Figure A-2: Re-setting axis reference frame after test.

[1] This assumes that the point on the passenger B-post sill is not displaced vertically or laterally during the impact.

ANNEX B: PBD TEST SEVERITY

The definition of an appropriate severity level is crucial for any test procedure. According to the FIMCAR strategies, one of the boundary conditions to be considered for the definition of the test severity is that the current level of compartment strength shall not be reduced. The off-set test is the main candidate to assess compartment strength as it loads the structures only on one side of the vehicle. According to the FIMCAR goals, ECE R94 requirements were set as the reference.

In the literature, the severity level in an off-set test procedure was often expressed in EES or, in other words, the deformation energy dissipated by the test vehicle. However, EES calculation, especially for the ODB (ECE R94 and Euro NCAP) is based on various assumptions (e.g., constant energy dissipated by the barrier face independent of the test vehicle, rotational energy after the impact was neglected etc.). Furthermore the deformation energy does not necessarily reflect the requirements for the cabin strength. NHTSA analysed one car with different front structures tested in the PDB procedure. While the older one without advanced energy absorbing structures did not show any reduction in the door opening (i.e., A-pillar deformation) a small reduction in the door opening was observed the newer model. In contrast the calculated EES was slightly higher in the older car [Meyerson 2009].

To investigate the severity of an offset test, in particular the PDB test, several sources for the analysis of severity level were explored by FIMCAR.

COMPARISON OF TEST SEVERITY BY TESTS

In general the PDB aims at harmonising the severity level amongst vehicles of different masses. With the current barrier face the test severity increases with mass as the energy absorbed by the deformable element does linearly increase with the test weight, see Figure B-1.

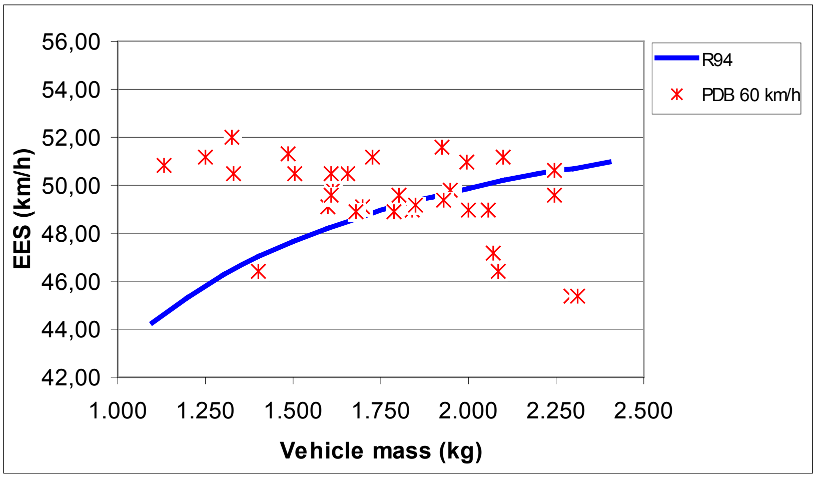


Figure B-1: Estimated EES in R94 and calculated EES in PDB tests [Lazaro 2013].

However, as the assumptions that lead to the EES estimation for the ECE R94 curve and the calculated PDB points may be misleading and cabin intrusion were compared.

UTAC analysed mean intrusion and mean acceleration in different left hand drive and right hand drive cars in ECE R94 tests, R94 tests with an increased test speed of 60 km/h (instead of 56 km/h) and PDB tests [Delannoy 2005]. Although the difference (between R94 and PDB) in mean intrusion was decreasing with the vehicle's weight up to approx. 1.750 kg, mean intrusion of the ECE R94 was at least almost maintained in the PDB tests, Figure B-2. Interestingly mean acceleration was significantly higher in all PDB tests independently of the test weight.

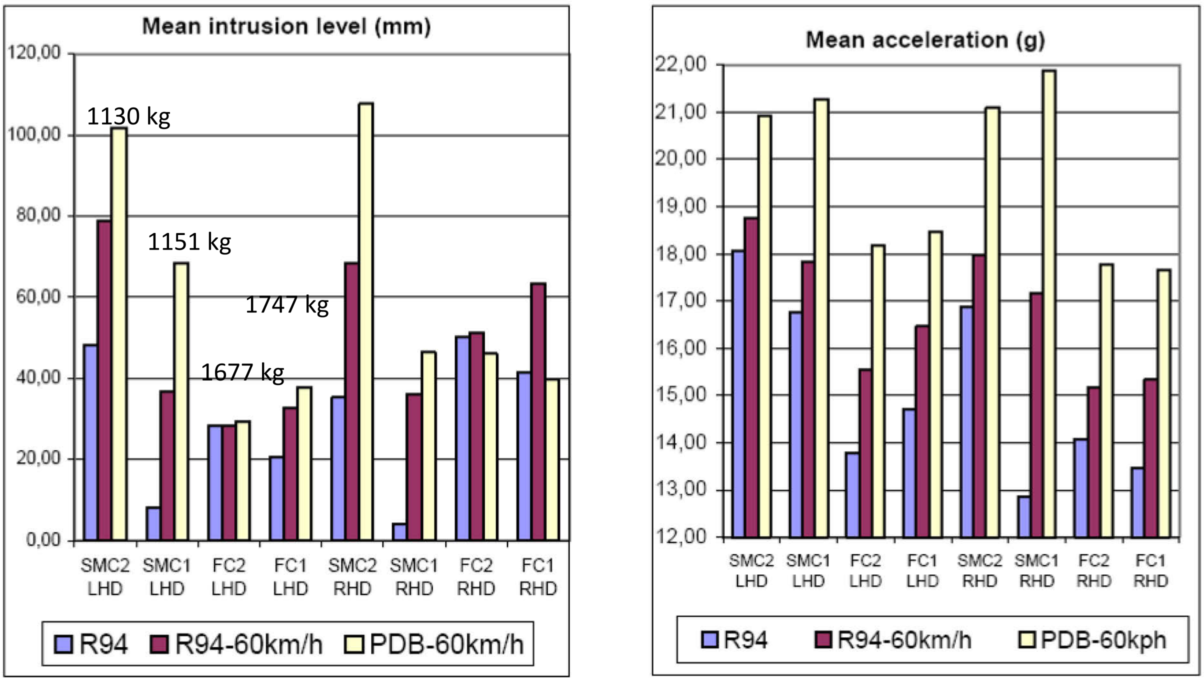


Figure B-2: Comparison of mean intrusion and mean acceleration in ECE R94, ECE R94 with increased test speed and PDB tests [Delannoy 2005].

Finally FIMCAR analysed published crash test data from the US to compare PDB and ECE R94 test conditions. Subject of the analysis were

- maximum cabin acceleration,
- mean cabin acceleration,
- intrusion at dashboard,
- intrusion at door waist level,
- intrusion at door sill level,
- intrusion in foot area.

For most of the cars, except the Ford FT250, intrusion was larger or equal in the PDB tests, see Figure B-3. As the FT250 is a body on frame vehicle, which is more like a truck than a passenger car, the results here are somehow irrelevant.

					Acceleration [G]		Intrusion [mm]			
Vehicle	Test Weight	LLP	Load case	Comments	Max	Mean	Dash	Door Waist	Door Sill	Foot area
Chevrolet Aveo	1433kg	NO	R94	ODB barrier bottoms out	28,7	8,9	52	62	5	38
			PDB		31,2	9,5	65	80	7	52
Ford Escape	1781kg	NO	R94	ODB barrier bottoms out	30,0	9,0	14	13	2	37
			PDB	Rupture / separation in barrier face	25,5	9,2	42	34	-1	42
Ford 500	1916kg	YES	R94	ODB barrier bottoms out	22,9 19,3 21,5	9,1 8,2 8,9	21 10 16	14 - 10	5 1 2	11 4 4
			PDB	Main rail penetrates PDB barrier	24,9 25,5 25,8	8,9 9,1 9,5	16 26 41	16 12 25	5 3 10	3 3 8
Saturn Outlook	2408kg	YES	R94	ODB barrier bottoms out	25,6	8,9	5	1	1	2
			PDB	Main rail penetrates PDB barrier	24,9	9,1	2	1	0	-1
Ford F250	3291kg	NO	R94	ODB barrier bottoms out	-	-	-	49 42	20 39	
			PDB	Main rail penetrates PDB barrier	-	-	-	12	3	

Key:

significantly better significantly worse no significant difference

tendency to be better but large scatter tendency to be worse but large scatter

Figure B-3: Comparison of acceleration and intrusion for PDB and ECE R94 tests.

As the test results show a blurred picture FIMCAR decided to add simulation activities to this analysis.

COMPARISON OF TEST SEVERITY BY SIMULATION

For the comparison of test severity between ECE R94 and PDB the Generic Car Models and a model of an actual SUV were used.

Advantages of modelling compared to testing are that the energy calculation is much more accurate and that intrusions can be measured dynamically and again more accurate. Furthermore it is possible to measure the loads applied to different parts of the models using concepts in the software called “section forces”.

The Generic Car Models GCM1A, GCM1B, GCM2A, GCM2B and GCM3 [Stein 2013] were used to compare average intrusion into the cabin, steering wheel intrusion, EES and max cabin acceleration for ECE R94 and PDB tests. Cabin intrusion is significantly higher in the PDB tests for the lighter models while it is smaller for the heavier models, see

Figure B-4 and Figure B-5. A similar trend but with smaller relative difference is visible for EES, see

Figure B-4. For the cabin acceleration no clear trend is visible.

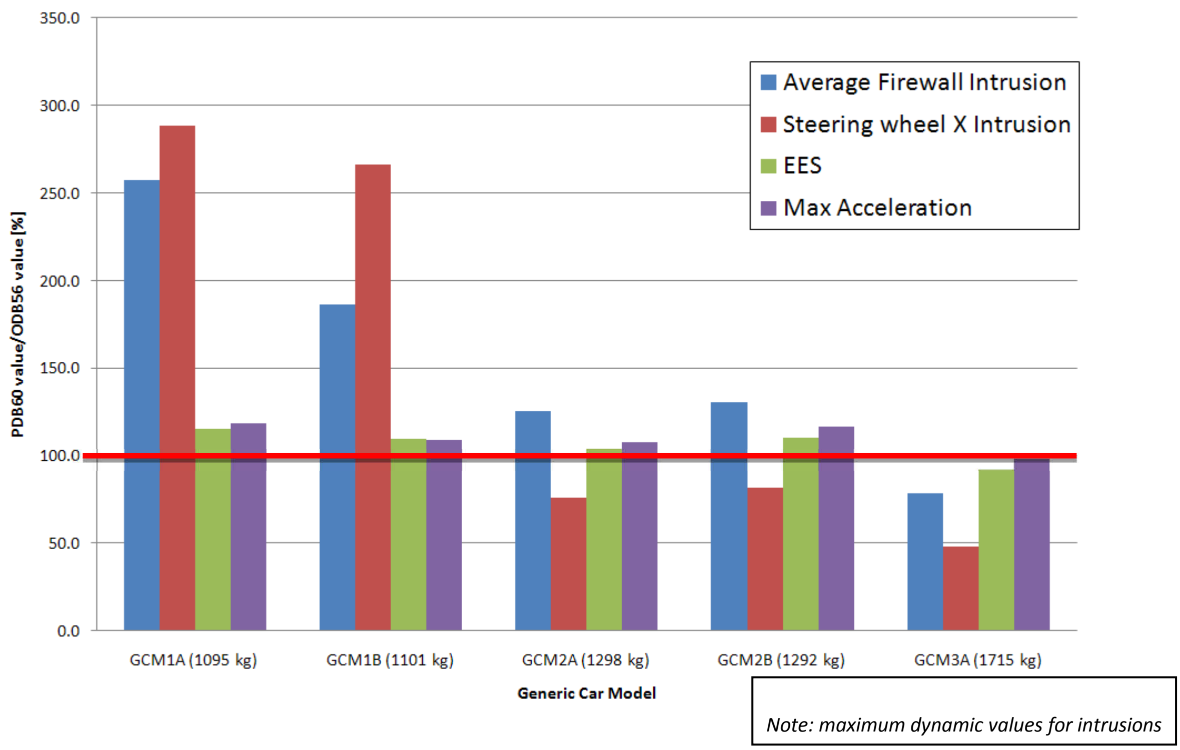


Figure B-4: Cabin intrusion, EES and acceleration for ECE R94 and PDB on GCM.

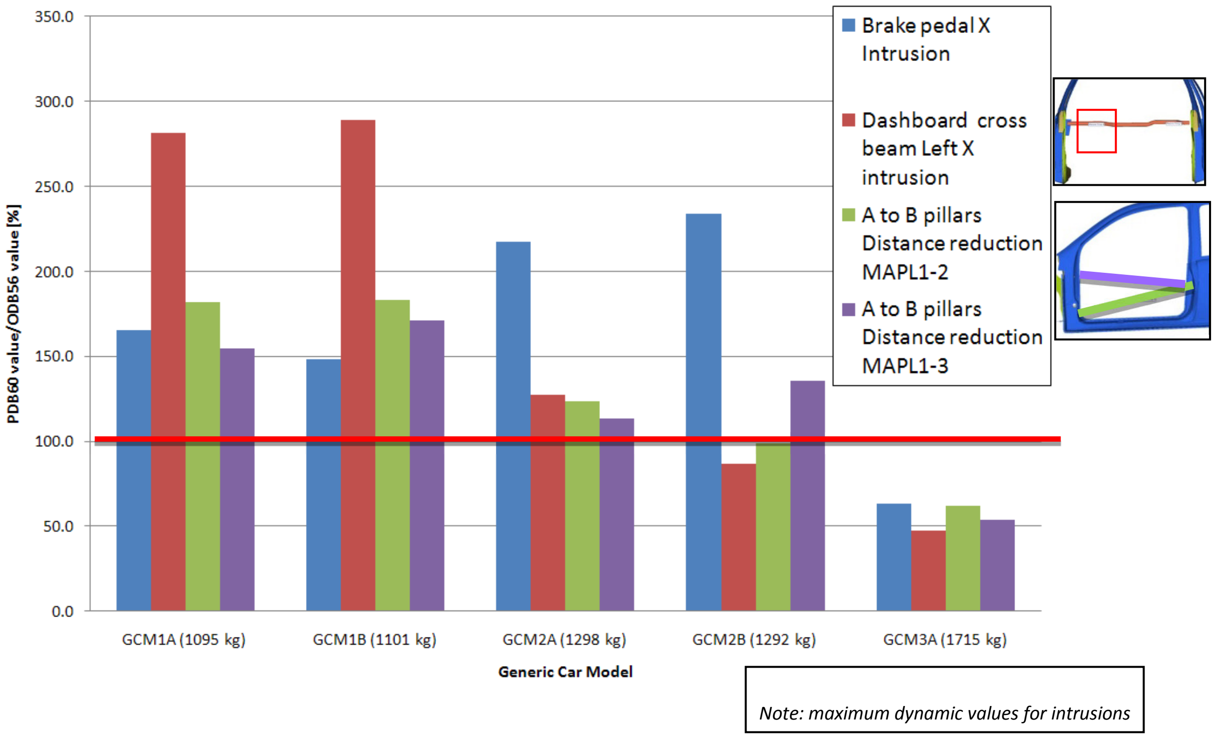
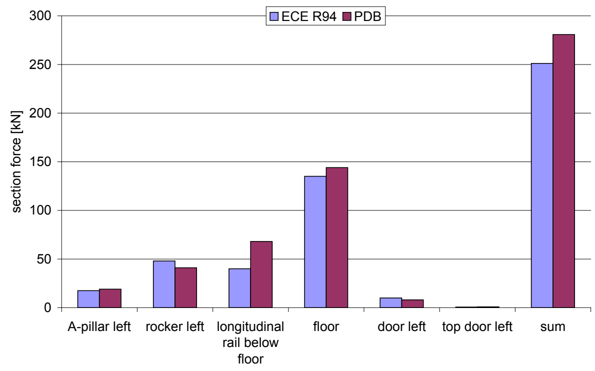
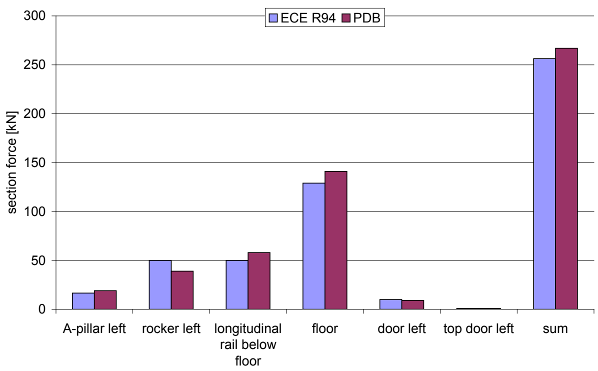


Figure B-5: Cabin intrusion at different locations for ECE R94 and PDB on GCM.

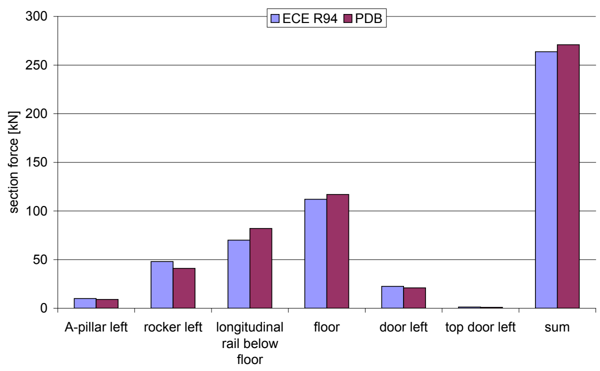
The comparison of section forces using the Generic Car Models show higher section forces and thus higher cabin loading in the ECE R94 test for lighter models and smaller section forces for the heavier ones. Another interesting aspect is that the section forces increase in the ODB test with a second load path (GCM1B and GCM2A) while in the PDB test it is the other way round, see Figure B-6.



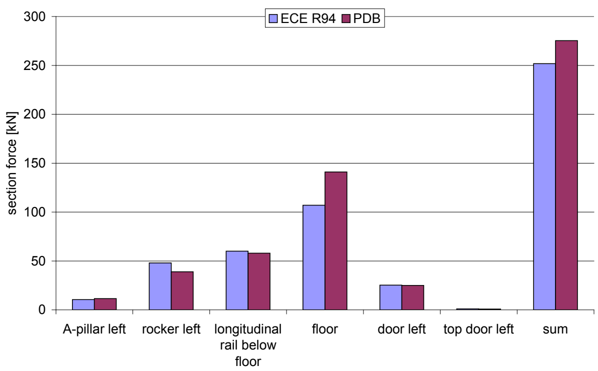
GCM1A



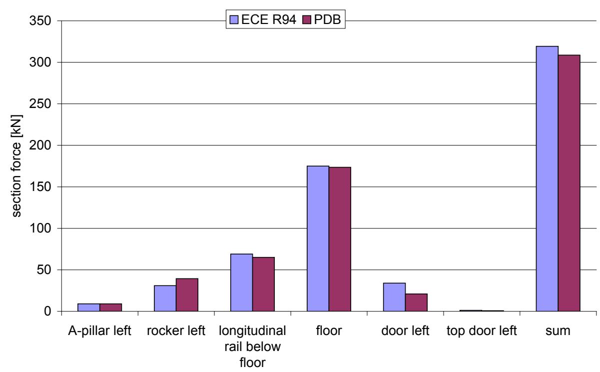
GCM1B



GCM2A



GCM2B



GCM3

Figure B-6: Section forces for ECE R94 and PDB on GCM.

Finally a model of an actual SUV was analysed. As the model showed a crossbeam failure that would likely result in failing of PDB metrics the model was improved to avoid the failure. Firewall intrusion of this 2.2 t car is larger in the ECE R94 tests, see Figure B-7.

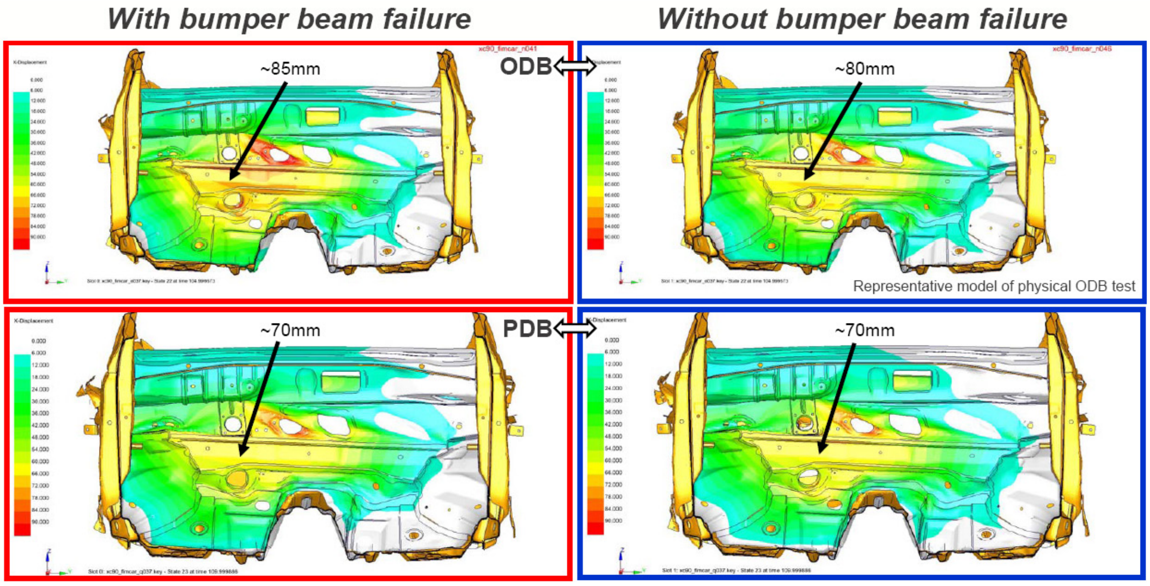


Figure B-7: Comparison of firewall intrusion in actual SUV model.

In summary the simulation results show a clear tendency of decreasing requirements for the PDB test with vehicle weight, see Figure B-8.

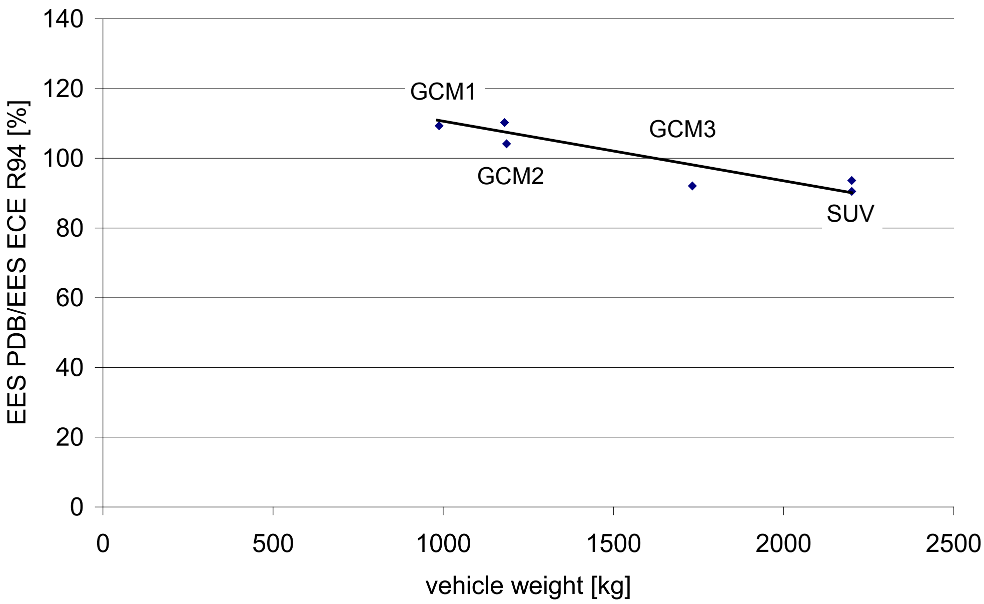


Figure B-8: EES dependency on vehicle weight.

CONCLUSION

According to the FIMCAR Deliverable D1.1 compartment strength issues in accident data mainly occur in car-to-HGV and car-to-object accidents. Furthermore compartment strength issues are not an isolated problem of small cars. That means that the car-to-barrier test for the assessment of compartment strength should somehow reflect this situation.

Most of the data presented indicate that the requirements for compartment strength are decreasing with vehicle weight when using a PDB test.

ANNEX C: PDB DEFINITION AND CERTIFICATION

CHARACTERISTICS OF THE DEFORMABLE BARRIER

The PDB deformable barrier is a stacking of three deformable aluminium honeycomb cores. The first (front deformable core, 250 mm thick) is designed to provide a constant load in depth. The second (progressive deformable core, 450 mm thick) is designed to provide a progressive load in depth. The third (back deformable core, 90 mm thick) is designed to provide a constant load in depth. Aluminium honeycomb cores are bonded together with different aluminium sheets forming a ready to use deformable barrier to be fixed on a rigid surface (wall, trolley).

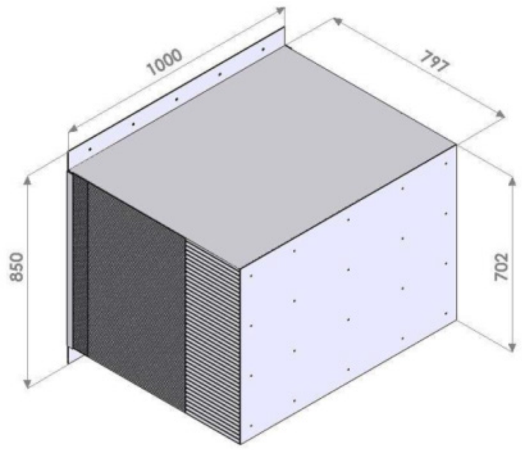


Figure C-1: PDB Barrier dimensions.

1. COMPONENT AND MATERIAL SPECIFICATIONS

The dimensions of the barrier are illustrated in Figure C-1 of this annex. The dimensions of the individual components of the barrier are listed separately below.

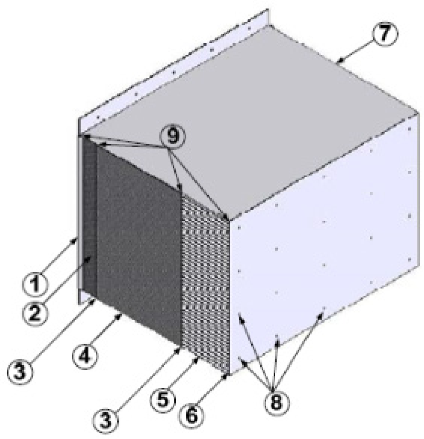


Figure C-2: PDB Barrier components.

The PDB barrier is composed of the following components:

(1) One back plate,

(2) One back deformable core,

(3) Two intermediate plates,

(4) One progressive deformable core,

(5) One front deformable core,

(6) One contact plate,

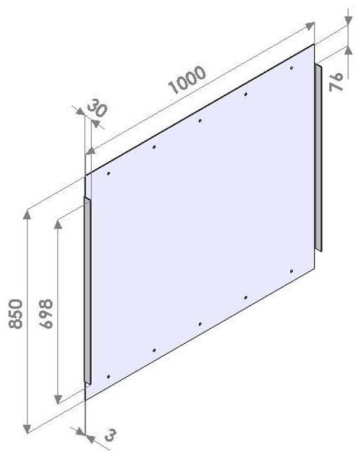
(7) One outer cladding,

(8) Blind rivets,

(9) Epoxy resin.

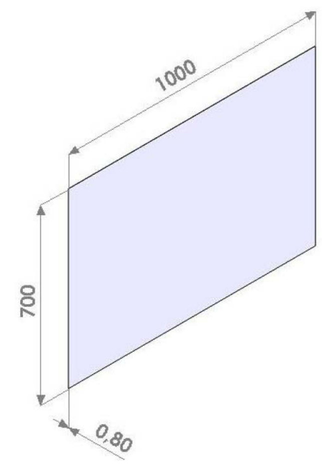
1.1. Back Plate geometrical and material characteristics (1)

The back plate is 1000 ± 2.5 mm wide and 850 ± 2.5 mm high. The thickness is 3 mm. The back plate is manufactured from Aluminium of 1050A H14.



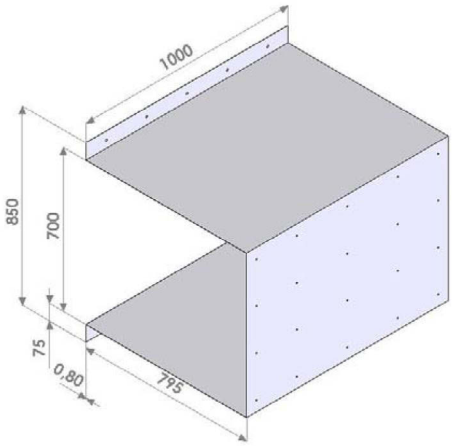
1.3. Contact plate geometrical and material characteristics (6)

The contact plate is 1000 ± 2.5 mm wide and 700 ± 2.5 mm high. The thickness is 1.5 mm. The contact plate is manufactured from Aluminium of 1050A H24.



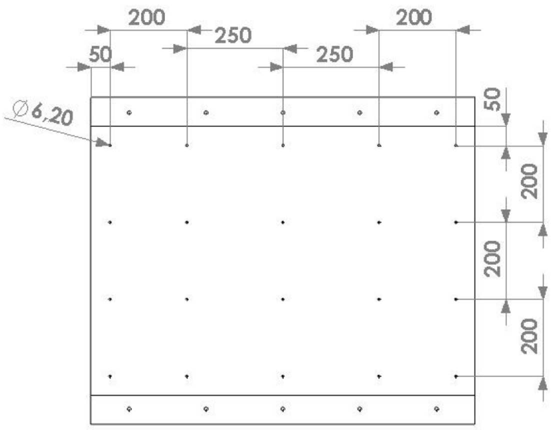
1.4. Cladding geometrical and material characteristics (7)

The cladding is 1000 ± 2.5 mm wide and 850 ± 2.5 mm high. The thickness is 0.8 mm. The cladding is manufactured from Aluminium of 5754 H22. The cladding has two mounting flanges of 75 mm allowing rigid wall mounting. Twenty 6.2 mm holes shall be drilled trough the outer cladding in order to accommodate front face blind rivets.



1.5. Rivets position (8)

Twenty blind rivets shall be used to improve the link between outer cladding and contact plate. Rivets shall be aluminium/steel blind rivets diameter 6 mm.



1.6. Adhesive (9)

The adhesive to be used shall be an Epoxy Resin type H9940 or equivalent.

1.7. Honeycomb deformable cores

Geometrical and material characteristics:

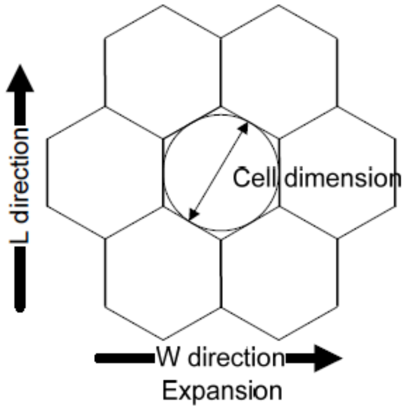
The PDB deformable barrier is a stacking of three deformable aluminium honeycomb cores and provides 4 different crushing strength areas (#1, #2, #3, #4) whose forms and positioning are shown below.

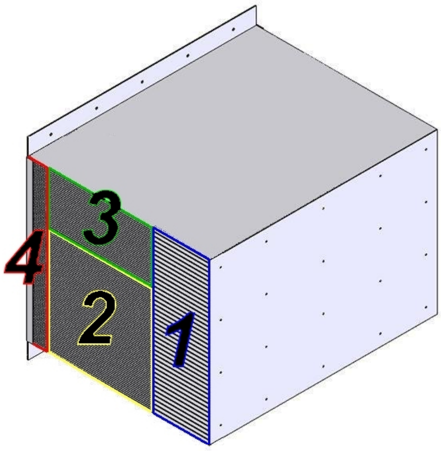
All honeycomb deformable cores shall be made of 3003 aluminium.

(a) The cell dimensions for the front block shall be 19.1 mm ± 15 percent.

(b) The cell dimensions for the intermediate block shall be 9.5 mm ± 15 percent.

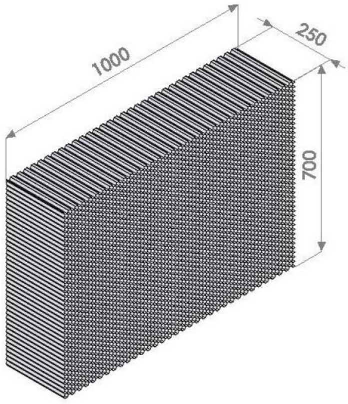
(c) The cell dimensions for the rear block shall be 6.3 mm ± 15 percent.





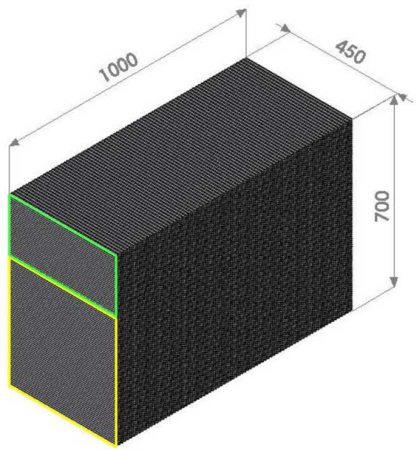
1.7.1. Front block (5)

The front block (area #1) shall be 700 ± 5 mm in L Direction, 1000 ± 5 mm in W direction and 250 ± 1 mm in T direction. The crushing characteristics of the front block are constant.



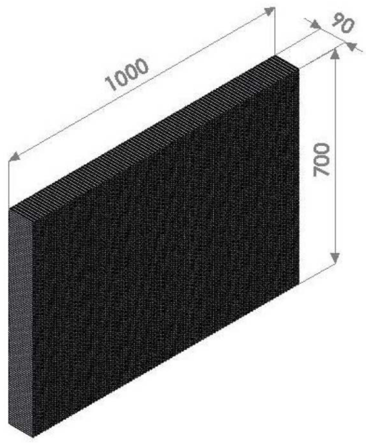
1.7.2. Progressive block (4)

The progressive block (area #2 and #3) shall be: 700 ± 5 mm in L direction, 1000 ± 5 mm in W direction and 450 ± 1 mm in T direction. The crushing characteristics of the progressive block present 2 different load paths. The lower load path #2, offers a progressive resistance in depth for first 350 mm and a constant resistance in depth for last 100 mm. The upper load path #3, offers a progressive resistance in depth for first 350 mm and a constant resistance in depth for last 100 mm.



1.7.3. Back block (2)

The back block (area #4) shall be 700 ± 5 mm in L direction, 1000 ± 5 mm in W direction and 90 ± 1 mm in T direction. The crushing characteristics of the front block are constant.



2. ALUMINIUM HONEYCOMB CERTIFICATION

The aluminium honeycomb blocks should be processed such that the force deflection-curve when statically crushed (according to the procedure defined below) is within the corridors defined for each of the three blocks. Samples taken from each batch of processed honeycomb core shall be tested.

2.1. Sample size

One sample for the front block (area #1): The sample size of the aluminium honeycomb for static tests shall be 200 mm in W direction x 200 mm in L direction x 250 mm in T direction for the front block.

Two samples for the progressive block: One sample for lower load path (area #2) and one sample for upper load path (area #3). The samples size of the aluminium honeycomb for static tests shall be at least 100 mm in W direction x 100 mm in L direction x 450 mm in T direction for the progressive block.

One sample for the back block (area #4): The sample size of the aluminium honeycomb for static tests shall be 100 mm in W direction x 100 mm in L direction x 90 mm in T direction for the back block.

2.2. Data collection and crush rate

The samples should be compressed between two parallel loading plates which are at least 20 mm larger than the block cross section. The compression speed shall be 100 mm/min, with a tolerance of 5 percent. The data acquisition for static compression shall be sampled at a minimum of 5 Hz. The static test shall be continued until the block compression is at least 80 percent of honeycomb core initial thickness.

2.3. Sample crush strength specification

The crush resistance curve for each block tested shall be included within the corridors defined below:

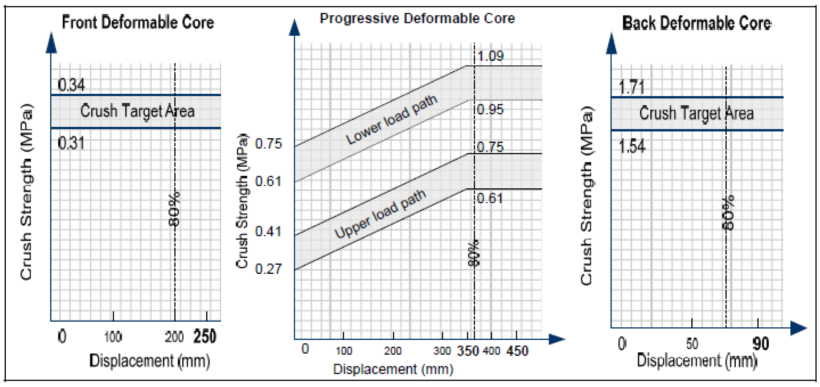


Figure C-2: Crush strength specification for the different cores.

3. ADHESIVE BONDING PROCEDURE

3.1. Immediately before bonding, aluminium sheet surfaces to be bonded shall be thoroughly cleaned using a suitable cleaning and degreasing solution**.** This is to be carried out as required to eliminate grease or dirt deposits. The cleaned surfaces shall then be abraded using 120 grit abrasive paper. Metallic/Silicon Carbide abrasive paper is not to be used. The surfaces shall be thoroughly abraded and the abrasive paper changed regularly during the process to avoid clogging, which may lead to a polishing effect. Following abrading, the surfaces shall be thoroughly cleaned again, as above. All dust and deposits left as a result of the abrading process shall be removed, as these will adversely affect bonding.

3.2. The adhesive should be applied to one surface only. In cases where honeycomb is to be bonded to aluminium sheet, the adhesive should be applied to the aluminium sheet only. A maximum of 0.5 kg/m_2 shall be applied evenly over the surface, giving a maximum film thickness of 0.5 mm.

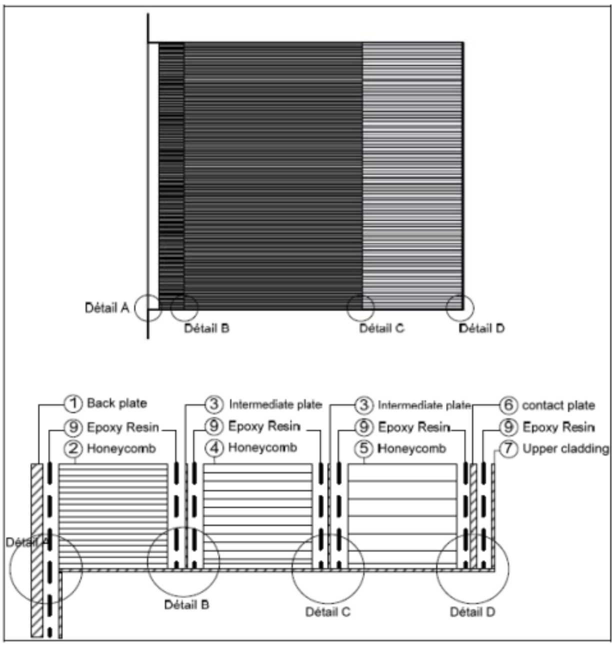


Figure C-3: Gluing detail among the different parts.

4. CONSTRUCTION

4.1. The main honeycomb blocks shall be bonded to the sheets with adhesive such that the cell axes are perpendicular to the sheets. The outer cladding shall be bonded to the contact plate. The upper and lower surfaces of the outer cladding sheet shall not be bonded to the honeycomb blocks but should be positioned closely to it. The cladding sheet shall be adhesively bonded to the back plate at the mounting flanges.

4.2. Clearance holes for mounting the barrier are to be drilled in the mounting flanges (shown in Figure C-4). The holes shall be of 9.5 mm diameter. Five holes shall be drilled in the top flange at a distance of 40 mm from the top edge of the flange and five in the bottom flange, 40 mm from the bottom edge of that flange. The holes shall be at 100 mm, 300 mm, 500 mm, 700 mm, and 900 mm from either edge of the barrier. All holes shall be drilled to ± 1 mm of the nominal distances. These holes locations are a recommendation only. Alternative positions may be used which offer at least the mounting strength and security provided by the above mounting specifications.

5. MOUNTING

5.1. The deformable barrier shall be rigidly fixed to the edge of a mass of not less than 7 x 10^4 kg or to some structure attached thereto. The attachment of the barrier face shall be such that the vehicle shall not contact any part of the structure more than 75 mm from the top surface of the barrier (excluding the upper flange) during any stage of the impact. The front face of the surface to which the deformable barrier is attached shall be flat and continuous over the height and width of the face and shall be vertical ± 1° and perpendicular ± 1° to the axis of the run-up track. The attachment surface shall not be displaced by more than **2** mm during the test. If necessary, additional anchorage or arresting devices shall be used to prevent displacement of the stationary barrier structure. The edge of the deformable barrier shall be aligned with the edge of the stationary barrier structure appropriate for the side of the vehicle to be tested.

5.2. The deformable barrier shall be fixed to the block by means of ten bolts, five in the top mounting flange and five in the bottom. These bolts shall be of at least 8 mm diameter. Steel clamping strips shall be used for both the top and bottom mounting flanges (see Figures C-3). These strips shall be 60 mm high and 1000 mm wide and have a thickness of at least 3 mm. The edges of the clamping strips shall be rounded-off to prevent tearing of the barrier against the strip during impact. The edge of the strip shall be located no more than 5 mm above the base of the upper barrier-mounting flange, or 5 mm below the top of the lower barrier-mounting flange. Five clearance holes of 9.5 mm diameter must be drilled in both strips to correspond with those in the mounting flange on the barrier (see paragraph 4.). The mounting strip and barrier flange holes may be widened from 9.5 mm up to a maximum of 25 mm in order to accommodate differences in back-plate arrangements and/or load cell wall hole configurations. None of the fixtures shall fail in the impact test. In the case where the deformable barrier is mounted on a load cell wall (LCW) it shall be noted that the above dimensional requirements for mountings are intended as a minimum. Where a LCW is present, the mounting strips may be extended to accommodate higher mounting holes for the bolts. If the strips are required to be extended, then thicker gauge steel should be used accordingly, such that the barrier does not pull away from the wall, bend or tear during the impact. If an alternative method of mounting the barrier is used, it should be at least as secure as that specified in the above paragraphs. **The ground clearance of the front part of the barrier shall be 150 mm.**

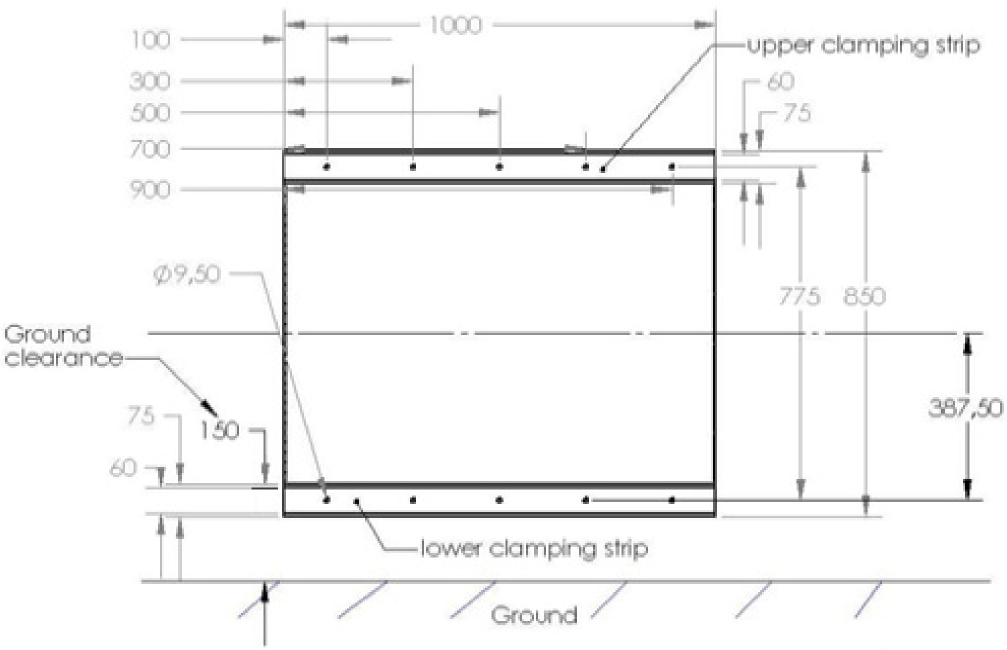


Figure C-4: barrier mounting and ground clearance.

6. CONFORMITY

For every year or 100 barriers faces produced, the manufacturer shall make two dynamic tests according to the method described below:

6.1. Test 1: Rigid wall impactor

6.1.1. Characteristics of the mobile barrier

6.1.1.1. The total mass shall be 1300 kg +/- 30 kg. The trolley shall be so constructed that no permanent deformation appears after the test. It shall be so guided that, during the impact phase, the deviation in the vertical plane does not exceed 5° and 2° in the horizontal plane.

6.1.1.2. The front and rear track width of the trolley shall be 1,500 ± 10 mm.

6.1.1.3. The wheelbase of the trolley shall be 3,000 ± 10 mm.

6.1.1.4. The centre of gravity shall be situated in the longitudinal median vertical plane within 10 mm, 700 ± 30 mm behind the front axle and 500 ± 30 mm above the ground. 6.1.1.5. The distance between the front face of the impactor and the centre of gravity of the barrier shall be 2,000 ± 30 mm.

6.1.2. Deformable barrier tested. The deformable barrier tested shall be representative of the series production of the barrier.

6.1.3. Attachment of the impactor

6.1.3.1. The impactor shall be firmly attached to the trolley in such a way that no relative displacement occurs during the test.

6.1.3.2. The angle between the longitudinal axis of the rigid wall and the direction of motion of the trolley shall be 0° ± 2°.

6.1.3.3. The impactor consists of a rigid block defined in Figure C-5. The material of the impactor must be in steel. The geometry of the impactor must respect the design in Figure C-5.

6.1.4. Attachment of the deformable barrier. The deformable barrier shall be fixed on a rigid wall as specified in paragraph 5.

6.1.5. Test configuration

6.1.5.1. The rigid wall shall overlap the right side of the barrier face by 700 +/- 20 mm in Y axis (Figure C-6).

6.1.5.2. The velocity of the trolley at the moment of the impact shall be 60 km/h -0/+1 km/h. If the test was performed at a higher impact speed and the test results meet the requirements, the test shall be considered satisfactory.

6.1.6. Measurement to be made on the trolley. The position of the transducers measuring the deceleration of the Centre of Gravity (COG) of the trolley during the impact shall be parallel to the longitudinal axis of the trolley (Channel Frequency Class (CFC) of 180).

6.1.7. Reference curve Global force vs. displacement. This displacement is obtained by integration of the deceleration curve of the COG of the trolley obtained. The global crush force is obtained by the multiplication of the trolley acceleration in CFC of 60 by its mass.

6.1.8. Equivalent method. A dynamometric wall behind the barrier may measure the crush force calculation. The global force shall be calculated by the sum of different load cell wall measurements. The sum shall be processed with a CFC 60 filter.

6.1.9. Certification. The force deflection curves of the barrier tested shall lie within the corridors defined in Figure C-8.

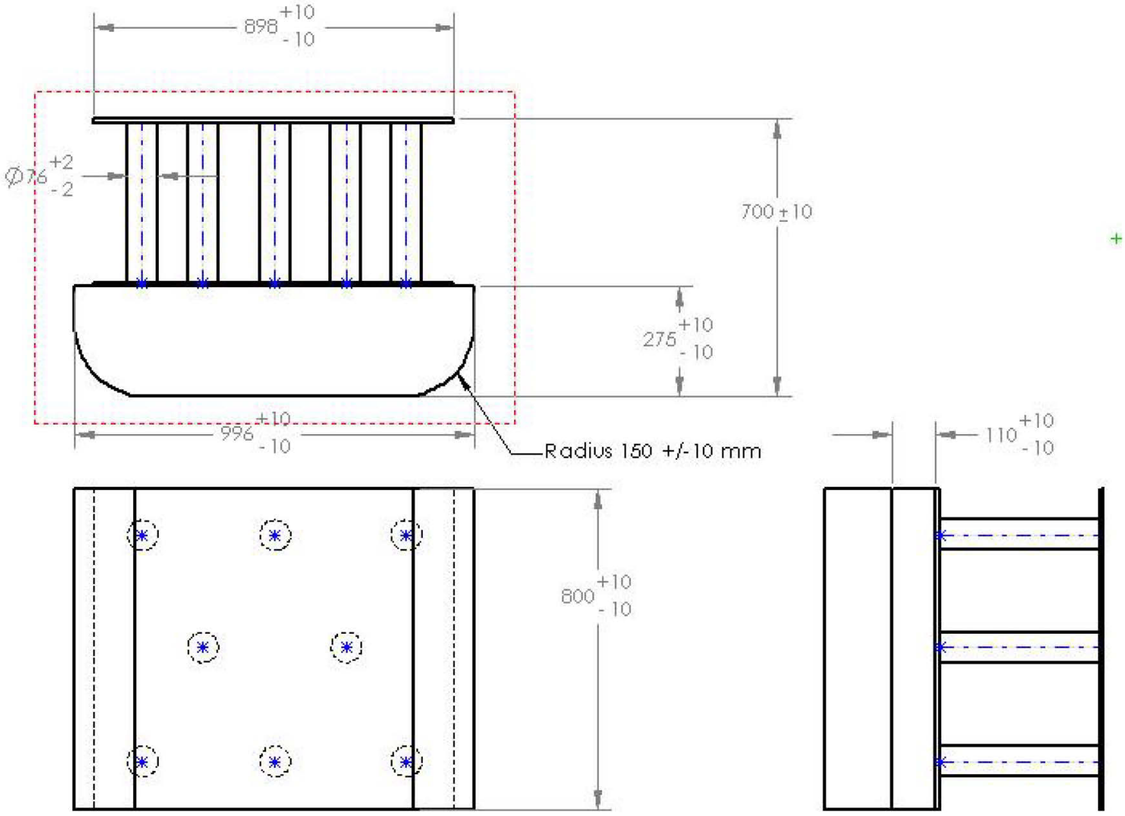


Figure C-5: Engineering drawings flat surface impactor.

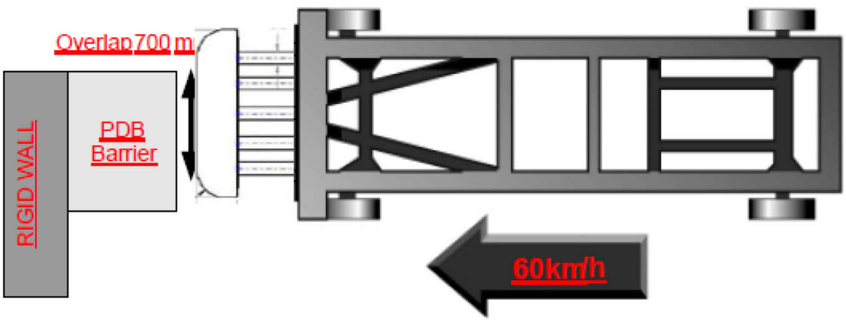


Figure C-6: test configuration flat surface impactor.

Figure C-7: Trolley with impactor.

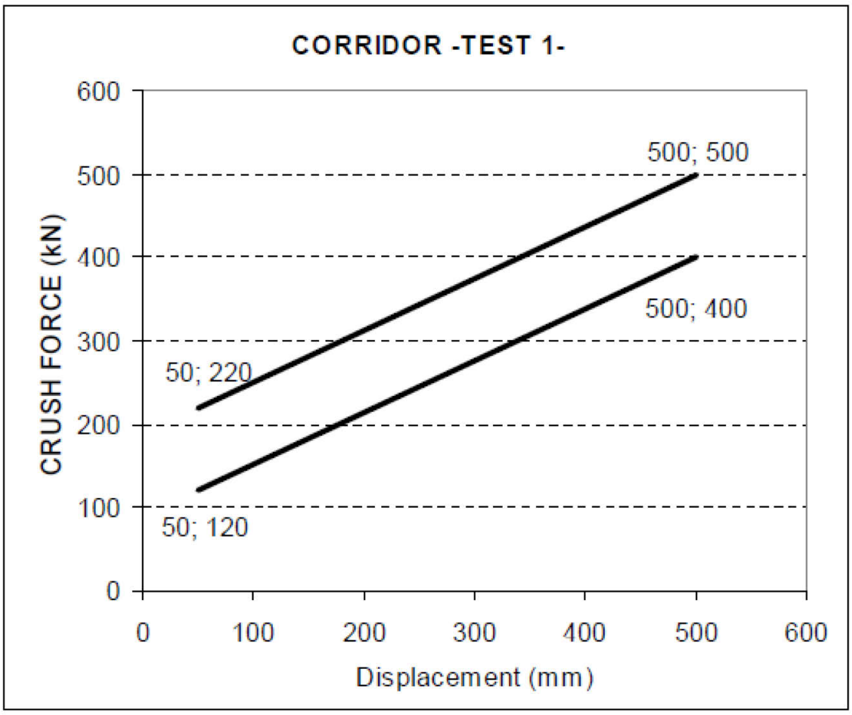


Figure C-8: Corridor.

6.2. Test 2: Rigid tubular impactor

6.2.1. Characteristics of the mobile barrier

6.2.1.1. The total mass shall be 1,300 kg +/- 30 kg. The trolley shall be so constructed that no permanent deformation appears after the test. It shall be so guided that, during the impact phase, the deviation in the vertical plane does not exceed 5° and 2° in the horizontal plane.

6.2.1.2. The front and rear track width of the trolley shall be 1,500 ± 10 mm.

6.2.1.3. The wheelbase of the trolley shall be 3,000 ± 10 mm.

6.2.1.4. The center of gravity shall be situated in the longitudinal median vertical plane within 10 mm, 950 ± 30 mm behind the front axle and 500 ± 30 mm above the ground.

6.2.1.5. The distance between the front face of the impactor and the center of gravity of the barrier shall be 2,100 ± 30 mm.

6.2.2. Deformable barrier tested. The deformable barrier tested shall be representative of the series production of the barrier.

6.2.3. Attachment of the impactor

6.2.3.1. The impactor shall be firmly attached to the trolley in such a way that no relative displacement occurs during the test.

6.2.3.2. The angle between the longitudinal axis of the rigid wall and the direction of motion of the trolley shall be 0° ± 2°.

6.2.3.3. The impactor consists of a rigid block defined in Figure C-9. The material of the impactor must be in steel. The geometry of the impactor must respect the design in Figure C-9.

6.2.4. Attachment of the deformable barrier. The deformable barrier shall be fixed on a rigid wall as specified in paragraph 5.

6.2.5. Test configuration

6.2.5.1. The rigid wall shall overlap the right side of the barrier face by 800 +/- 20 mm in Y axis (Figure C-10).

6.2.5.2. The velocity of the trolley at the moment of the impact shall be 60 km/h -0/+1 km/h. If the test was performed at a higher impact speed and the test results meet the requirements, the test shall be considered satisfactory.

6.2.6. Measurement to be made on the trolley. The position of the transducers measuring the deceleration of the Centre Of Gravity (COG) of the trolley during the impact shall be parallel to the longitudinal axis of the trolley (CFC of 180).

6.2.7. Reference curve Global force vs. displacement. This displacement is obtained by integration of the deceleration curve of the COG of the trolley obtained. The global crush force is obtained by the multiplication of the trolley acceleration in CFC of 60 by its mass.

6.2.8. Equivalent method. A dynamometric wall behind the barrier may measure the crush force calculation. The global force shall be calculated by the sum of different load cell wall measurements. The sum shall be processed with a CFC of 60 filter.

6.3. Validation

6.3.1. The force deflection curves of the barrier tested shall lie within the force corridors defined in Figure C-12.

6.3.2. The barrier face deformation shall lay within the deformation defined in Figure C-13.

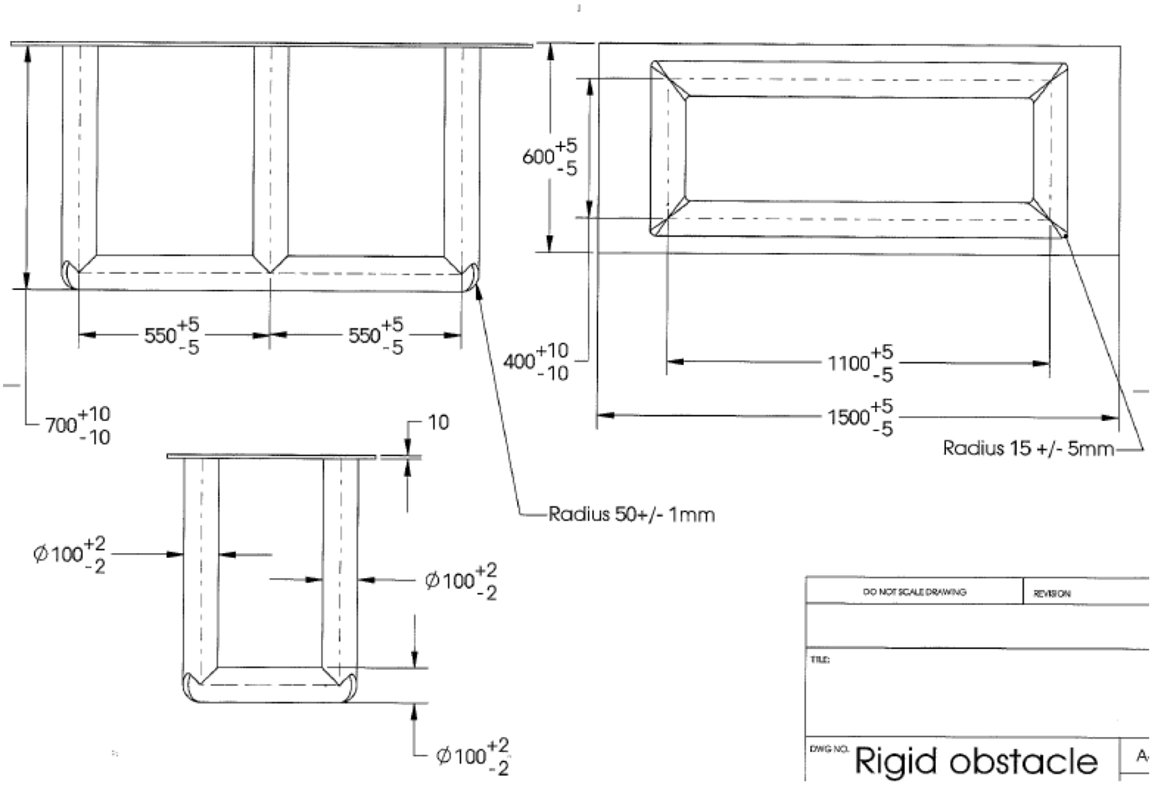


Figure C-9: Engineering drawing tube impactor.

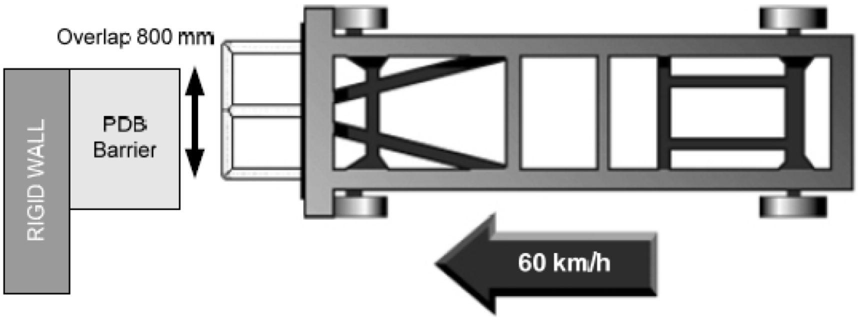


Figure C-10: Test set-up tube impactor.

Figure C-11: trolley with tube impactor.

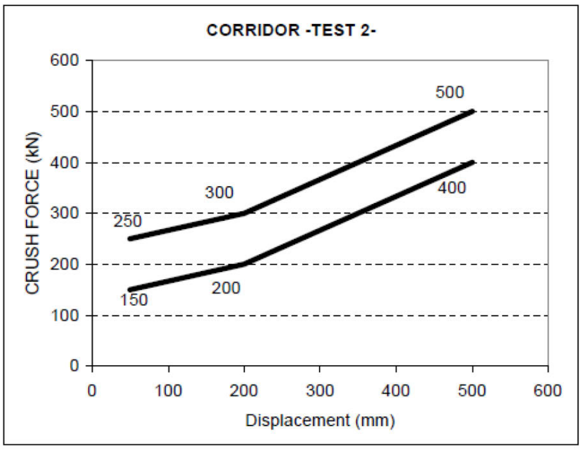


Figure C-12: Corridor tube impactor test.

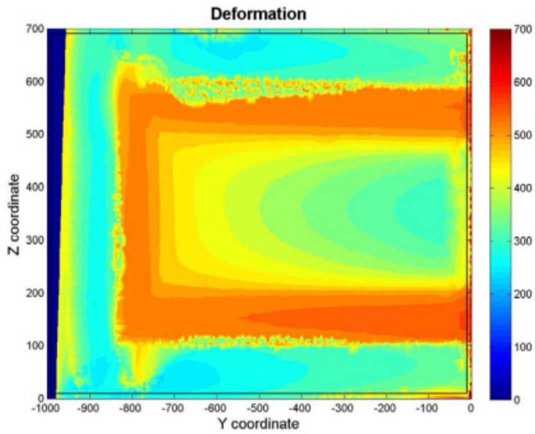


Figure C-13: barrier deformation tube impactor test.

ANNEX D: PDB SCAN PROCEDURE

The PDB deformed face digitization is a protocol based on 3D scanner facility to create a numeric picture of the deformed PDB face. The result of the digitization is a file with a specific format, allowing mathematical treatment with a specific barrier deformation analysis software.

EXAMPLE OF FACILITY

The facilities needed are composed of a 3D scanner, useable with a 3D arm facility.

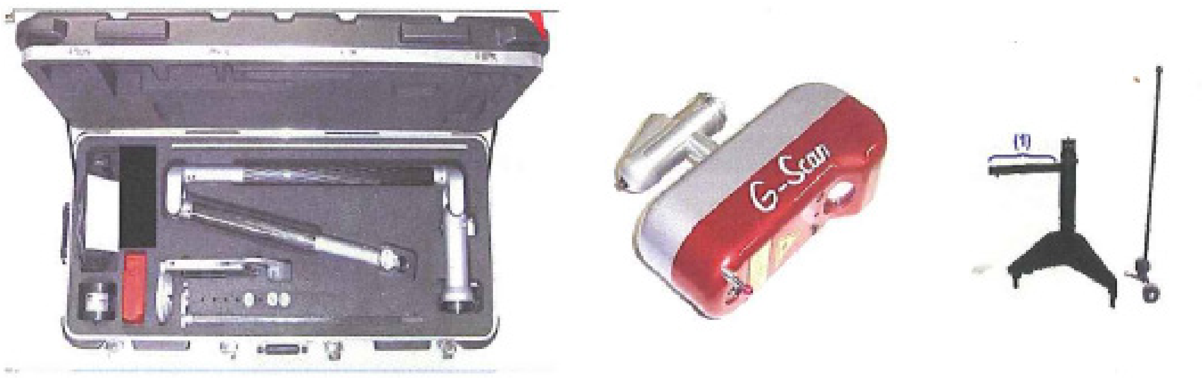


Figure D-1: Example of a 3D arm and 3D scanner.

POSITION OF BARRIER REFERENCE POINT

First, the digitization of the barrier is done by positioning the barrier on a reference surface, which it will remain exactly the same position throughout all the digitization. The barrier has to be temporary fixed or attached to the support. In Figure D-2, you can see an example to fix the barrier on rigid support. This reference position must be the same as the reference position taken to make an assessment on a car.

The ground must be as flat as possible and the fixation points must restrain the barrier to avoid any movements.

Figure D-2: PDB barrier positioning and fixation.

The reference point used as the origin is the lower, rear, corner opposite to the crash side. This corner has not been impacted during the crash, so there is no deformation of the honeycomb.


Frame origin

Figure D-3: Origin of the PDB

According to different front ends structures of vehicles to be tested, and reactions that occurs on PDB deformed face, the reference frame can be determined in two different cases due to the deformation of PDB back plate during the crash are seen in Figures D-4 and D-5:

- Back plate reference (intersections of green lines in Figure D-4&D-5) is not deformed. That occurs when honeycomb is still stuck to the back plate without space between both components. In that case, the origin frame must be taken from the back plate as close as possible from the honeycomb corner.

- honeycomb reference (intersection of red lines in Figure D-4&D-5). Occurs when interactions between vehicle and barrier make deformation on the back plate during the crash. This situation is often similar to a hole created on the deformed face PDB. In that case, the frame origin must be taken at the bottom corner of the honeycomb.

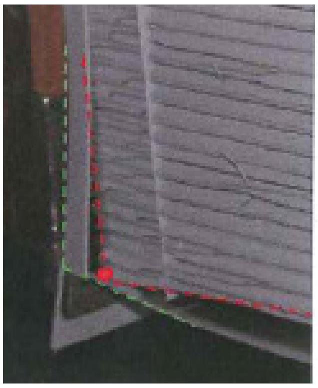


Figure D-4: Origin of PDB in cases the honeycomb seperates from the back plate

With the 3D tools, this origin frame must be determined by the intersection of the 3 straight lines of the honeycomb (see Figure D-5).

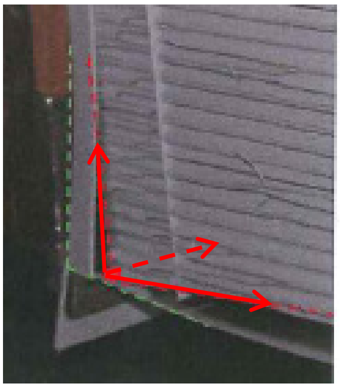


Figure D-5: Coordinate system of PDB in cases the honeycomb seperates from the back plate

SURFACES TO BE SCANNED

Main issues of PDB barrier analysis comes from the deformed front surface. Therefore the digitization must concern the front surface increased by 50 mm on all sides. In Figure D-6, the surface delimited by the red line plus 50 mm on the 4 sides is shown. The extra area is needed to be sure to catch all the involved front surface.

To be able to have the exact position of the front deformed surfaced of the deformed PDB, it is important to digitize the line from the origin frame to the deformed surface.

Result of the digitization is representing on Figure D-7.

Figure D-6: Front surface + 50 mm digitization area

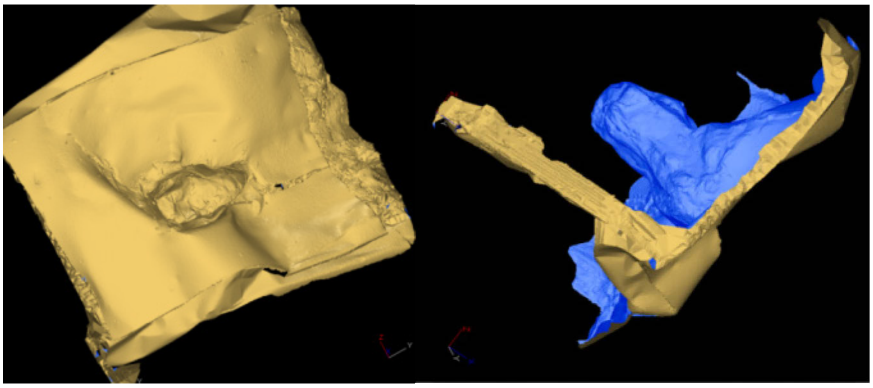


Figure D-7: digitize surface representation need to be performed.

The digitization of the front deformed PDB face is done with the scanner, following the same principle as painting an element with spray print. The quality of q deformed PDB's digitization comes from surface finish of deformed face and number of numeric points recorded.

Covering the aluminium barrier face with a matte paint facilitates the measurement of points with the scanner. On the other hand, the number of numeric points recorded result from the way the 3D scanner passes over the surfaces being scanned.

To guide a user when digitizing objects correctly, the 3D scanner is equipped with "a good position visualisation". This is composed of one red line which shows users the surfaces scanned, and a reference point as seen in Figure D-8.

Figure D-8: Positioning visualisation.

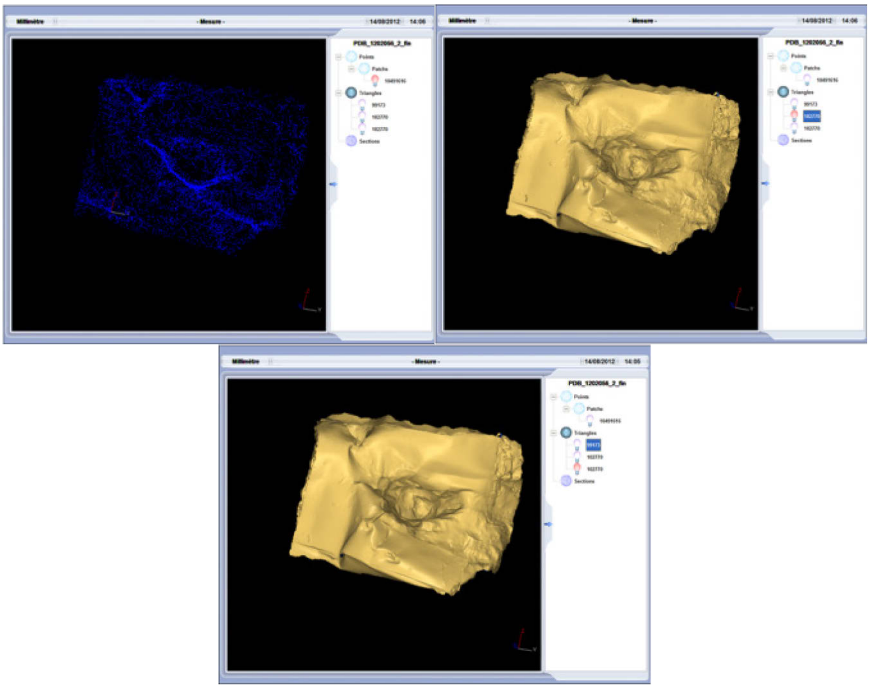
The digitization of the deformed PDB face consists in passing the scanner over all the front surface of the barrier. By crossing the various passages of the scan, it helps to have better quality digitization, according to the same principle of spray paint (Figure D-9)

Figure D-9: Scanning of all front surface areas.

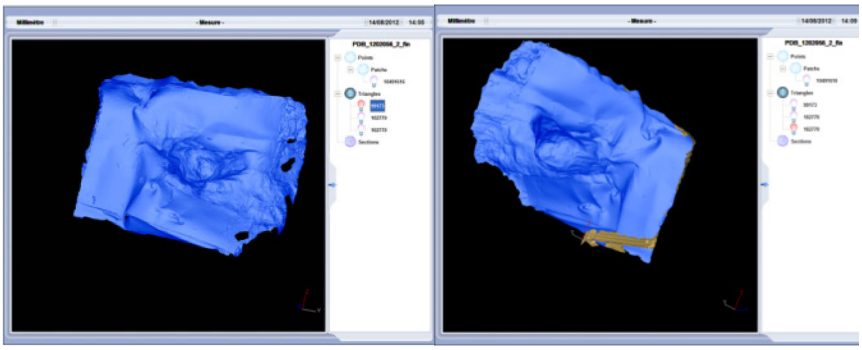
In some case, parts of a barrier are unreachable with the 3D scanner, especially when the deformed barrier has a hole. Depending to the size of this hole, the scanner may not be introduced in hole. In this situation it is necessary to scan a maximum surface with the 3D scanner equipped with a punctual sensor, identify missing points and record them by points clouds (Figure D-10).

Figure D-10: Manual digitation of points that cannot be scanned

3D scanner software is able to make triangular meshes of clouds points (Figure D-11) according to the precision settings. Depending on the precision, the deformed face of PDB barrier is more or less smooth.



PDB digitation from front view



PDB digitalisation from rear view

Figure D-11: PDB digitation from different views.

Deformed PDB face digitization is complete when the digitalization is able to represent the deformed face, with any holes, as few points as possible. Optimum digitization is a representation with no hole. Global representation of the result is available on Figure D-7.

GENERAL REMARKS

The number of required elements is estimated to be around 80 000 elements to have a good representation for the graphic representation, with main unit to respect

- Unit: mm,
- Means dimensions of elements close to 5mm,
- The coordinated of nodes are included in the following intervals in each axis:

For a left hand drive car

X: 0 ➔ 790mm

Y: 0 ➔ 1000mm

Z: 0 ➔ 700mm

For a right hand drive car

X: 0 → 790mm
Y: -1000 → 0mm
Z: 0 → 700mm

RULE

- the digitization must be performed without any intervention on the deformed face. All the deformations made on the barrier by the vehicle onto the barrier must be scanned. This rule is true before and also after digitizing the barrier.

DATA FILES STANDARD

Example of STL File format

Starting of stl file:

```
Solid

    Face normal -0.944588  -0.299744  0.133817

        Outer loop

            Vertex 699.199493  44.990338  464.111826

            Vertex 699.400769  40.254919  454.925475

            Vertex 704.398190  28.842159  464.637274

        Endloop

    endfacet

    Face normal -0.951527  -0.306960  -0.019296

        Outer loop

            Vertex 699.199493  44.990338  464.111826

            Vertex 704.398190  28.842159  464.637274

            Vertex 702.288054  34.774403  474.322900

        Endloop

    endfacet

    Face normal -0.340816  -0.858930  0.382210

        Outer loop

            Vertex 693.491814  48.491214  440.798902

            Vertex 684.318998  53.859586  444.683700

            .
```

.

.

End of stl file

ANNEX E: TEST REPORTS

Supermini 1 PDB 60 km/h @ UTAC

Supermini 2 PDB 60 km/h @ FIAT

Supermini 2 PDB 60 km/h @ BASt test 1

Supermini 2 PDB 60 km/h @ BASt test 1

Supermini 2 PDB 60 km/h @ BASt test 2

City Car 1 PDB 60 km/h @ UTAC

Small Family Car 1 PDB 60 km/h @ IDIADA

SUV 1 PDB 60 km/h @ IDIADA

9 SUPERMINI 1 PDB 60 KM/H @ UTAC

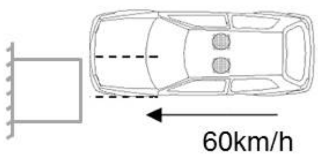
Offset Test
Supermini 1

AFFSEP1102784

Analysis and Report

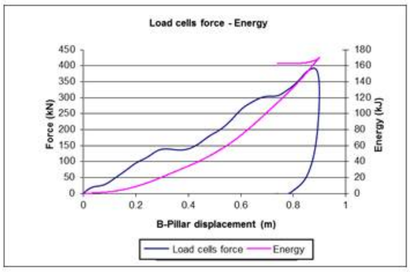
PDB Supermini 1

Test Date:	09, 2011
Location:	UTAC
Topic:	PDB-Test
Mass Ratio:	N/A
Test Number:	AFFSEP1102784
Test Protocol:	N/A

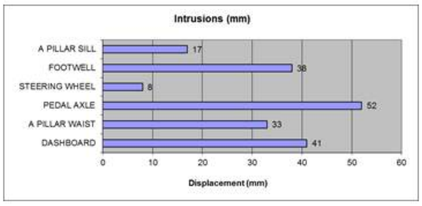


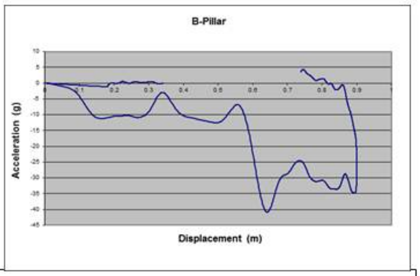
Vehicle 1:	Super Mini	Barrier: PDB v8
Brand/type:	Supermini 1	
Engine	1.4L, 4 cylinders	
Impact side:	Front left	
Speed:	60,48 km/h	
Overlap:	50 %	
Test mass:	1345 kg	
Dummy:	LHS – HIII 50% RHS – HIII 50%	

2- SELF PROTECTION : Structural analysis (1/2)



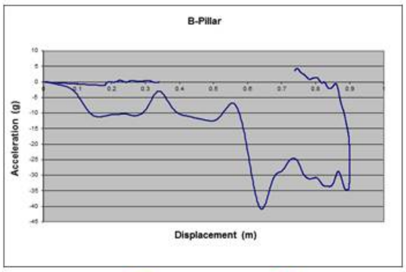
Average intrusion
36,2 mm up = 37mm low=35,7mm
Maximum force
392 kN
EES
48,7 km/h

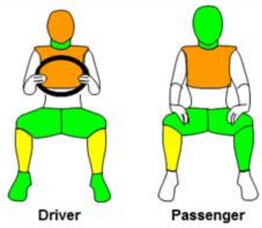




⇨ Medium compartment intrusion

2- SELF PROTECTION : Dummies (2/2)





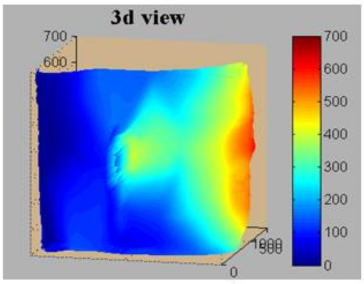
* Rating representation

		DRIVER	PASS	ECE R94
Head	HIC	502	338	<1000
	Criteria 3ms (g)	82,2	49,1	<80g
Upper Neck	NIC	<corridor		<corridor
	My (Nm)	24,8	27,2	<57 Nm
Chest	Deflexion (mm)	39,7	32,5	<50mm
	Viscous criterion	0,19	0,18	<1 m/s
Femur	Force	<corridor		<corridor
Knee	Left disp, (mm)	0,59	0,14	<15mm
	Right disp, (mm)	0,02	0,12	<15mm
Tibia Index	Left upper	0,54	0,33	<1,3
	Left lower	0,32	0,20	<1,3
	Right upper	0,44	0,41	<1,3
	Right lower	0,25	0,21	<1,3

Dummies criteria far from R94 limits

3- PARTNER PROTECTION ANALYSIS: PDB (1/2)





MAX DEFORMATION	VOLUME	ENERGY
405 mm	139 dm3	63,9 kJ

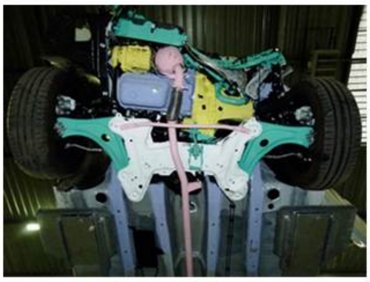
* Calculated with current formula

FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

3- PARTNER PROTECTION ANALYSIS: Front end (2/2)



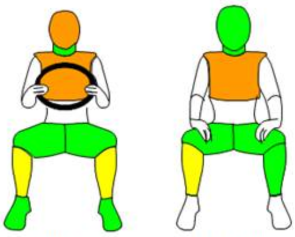

FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

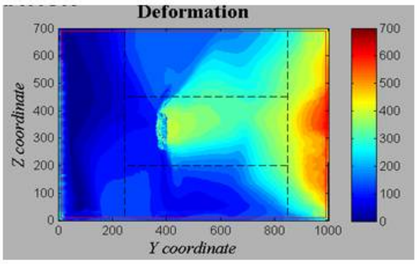
4- PARTNER AND SELF PROTECTION ASSESSMENTS

SELF

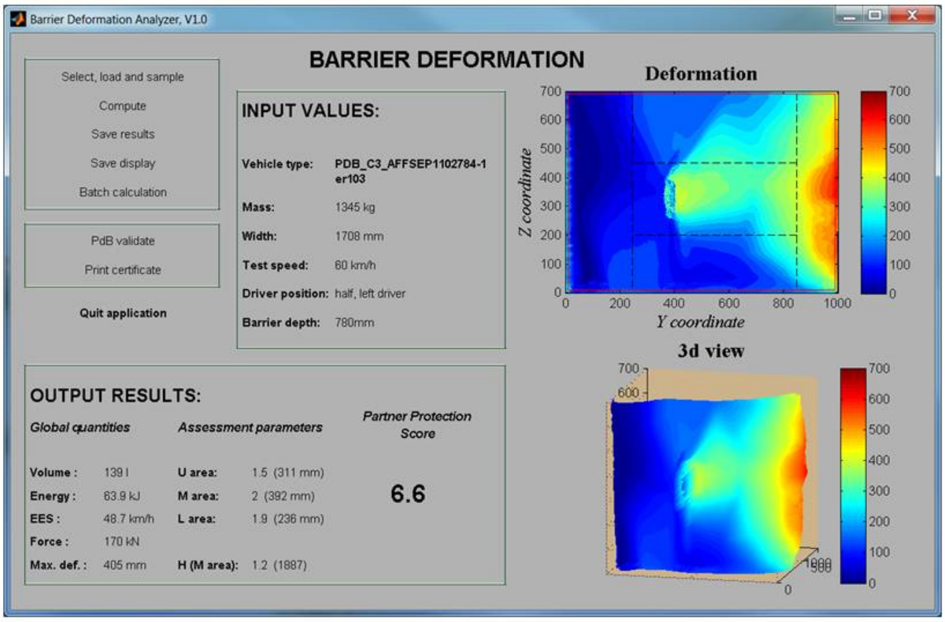
Graphe intrusion



PARTNER



4- BACK UP



10 SUPERMINI 2 PDB 60 KM/H @ FIAT

Offset Test
Supermini 1 2; PDB

Analysis and Report

Stefano Candellero (FIAT)

FIMCAR WP 2, 14th February 2012

FIMCAR
frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

Test comparison (test set-up´s)

PDB (60 kph)
Supermini 2: 1.2 Bz, LHD, POP
Barrier: PDB AFL v8.0 XT
Test weight: 1160 kg
Velocity: 60 kph

M-PDB (50 kph)
Supermini 2 : 1.2 Bz, LHD, POP
Trolley: TNO, v8.0 PDB
Test weight: 1160 kg (500), 1514 kg (Trolley)
Velocity: 50 kph (100 kph closing speed)

M-PDB (56 kph)
Supermini 2 : 1.2 Bz, LHD, POP
Trolley: TNO, v8.0 PDB
Test weight: 1225 kg (500), 1487 kg (Trolley)
Velocity: 56 kph (112 kph closing speed)

Eu-NCAP
Supermini 2 : 1.2 Bz, LHD, POP
Test weight: 1191 kg
Velocity: 64 kph

ECE94
Supermini 2 : 1.3 JTD, LHD *
Test weight: 1321 kg
Velocity: 56 kph

* ECE94 test was perfomed with a different engine and different restraint system

FIMCAR
frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

2

Biomechanical results in EuNcap rating form

SUMMARY	PDB 60 kph Driver	PDB 60 kph Passenger	MPDB 50 kph Driver	MPDB 50 kph Passenger
Head and Neck assessment	4.000	4.000	4.000	4.000
Chest assessment	3.129	2.957	2.429	3.757
Knee, Femur and Pelvis assessment	2.729	4.000	1.236	4.000
Lower Leg, Foot and Ankle Assessment	2.800	3.289	1.822	1.333
TOTAL	12.658	14.246	9.487	13.090
TOTAL FRONTAL	12.486		8.998	

SUMMARY	MPDB 56 kph Driver	MPDB 56 kph Passenger	EuNCAP Driver	EuNCAP Passenger
Head and Neck assessment	0.000	4.000	4.000	4.000
Chest assessment	1.771	0.729	3.820	3.940
Knee, Femur and Pelvis assessment	4.000	4.000	4.000	4.000
Lower Leg, Foot and Ankle Assessment	1.911	2.222	3.290	3.840
TOTAL	7.682	10.951	15.110	15.780
TOTAL FRONTAL	6.640*		15.110	

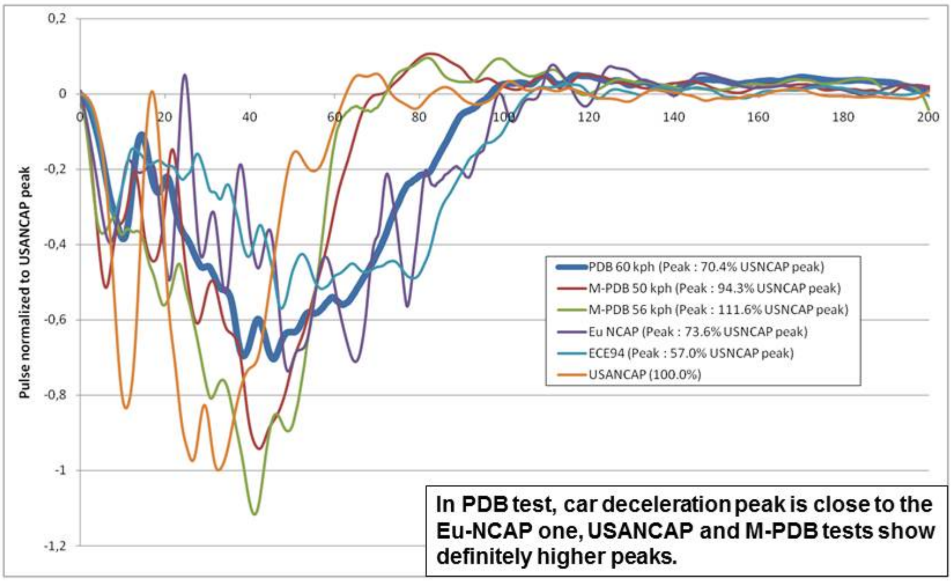
*: 0 points with test capping

ECE94 biomechanical results not comparable because the test was performed with a different restraint system (fitted on a version with a very low volume of sales – without kneebag)

Test	Compliance to ECE r94
PDB 60 kph	Compliant
MPDB 50 kph	Compliant
MPDB 56 kph	Not compliant (Head)
EuNCAP	Compliant

FIMCAR frontal impact and compatibility assessment research — SEVENTH FRAMEWORK PROGRAMME

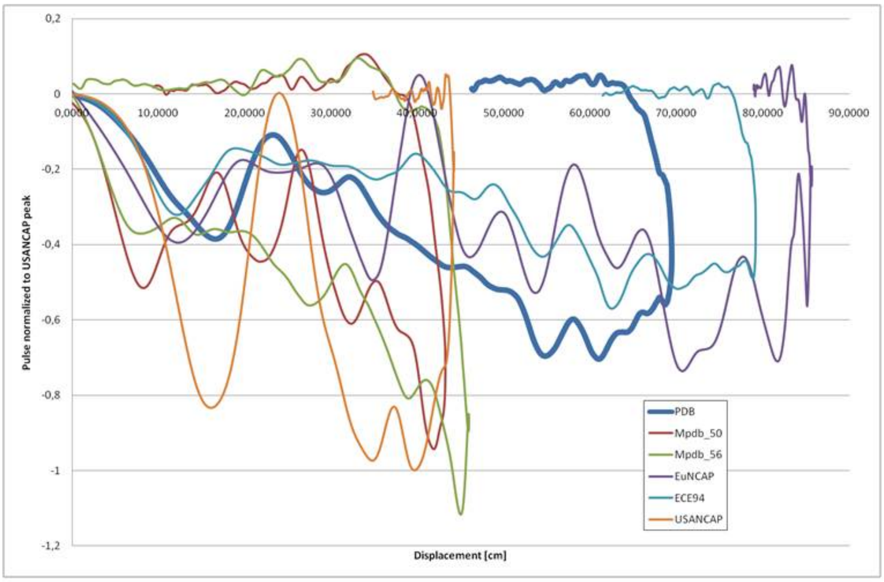
Normalized pulses



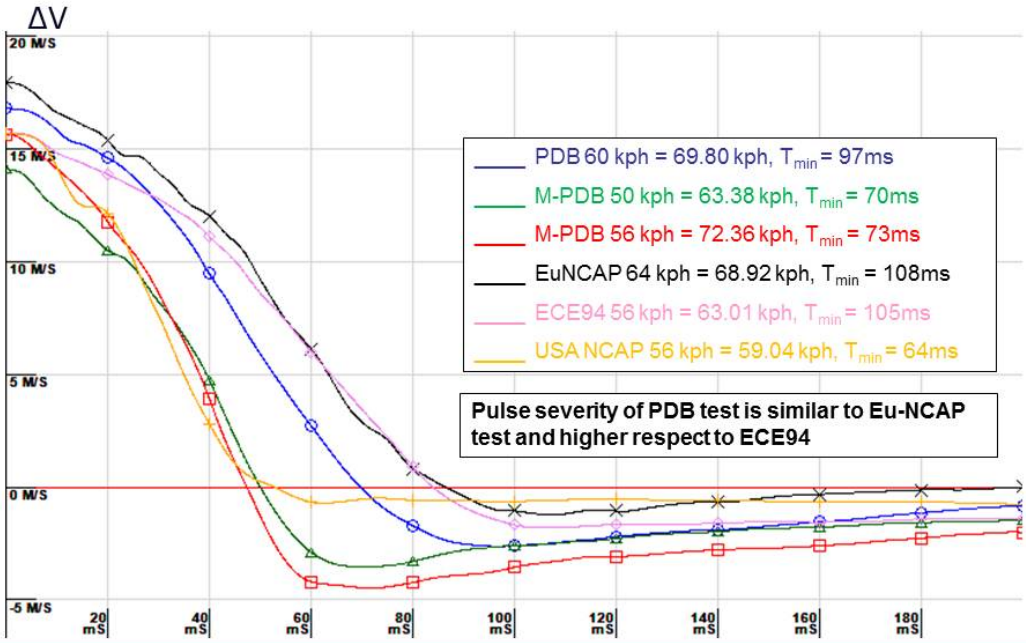
In PDB test, car deceleration peak is close to the Eu-NCAP one, USANCAP and M-PDB tests show definitely higher peaks.

FIMCAR frontal impact and compatibility assessment research — SEVENTH FRAMEWORK PROGRAMME

Pulse Vs. absolute car displacement



FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME



FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

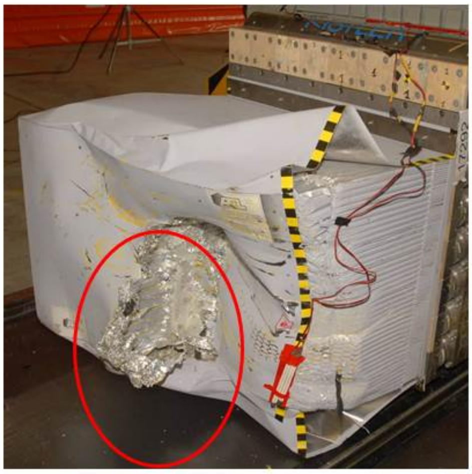
Static measurements

Frontal Impact	Rearw. Steering wheel displacment	Rearw. A pillar displacement	Rearward pedal fixation displacement	Rearw. Pedals displacement	Upward. Pedals displacement
Remarks	(mm)	(mm)	(mm)	(mm)	(mm)
PDB 60 kph	-11	1	47	-3 (accel)	-19 (accel)
M-PDB 50 kph	9	22	103	19 (accel)	-27 (brake)
M-PDB 56 kph	31	71	---	14 (clutch)	37 (clutch)
EuNCAP 64 kph	-4	7	68	1 (accel)	-21 (accel)
ECE94 56 kph	-13	1	37	-5 (accel)	-32 (accel)

PDB's level of intrusion is low and close to ECE94.

Barrier deformations (1/3)

PDB 60kph



Evident rupture in PDB barrier (similar to EEVC barrier in front Eu-NCAP test), instability is dangerous when using barrier scanning for rating (or others evaluations).

Barrier deformations (2/3)

MPDB 50 kph

Barrier static measurements expected from TNO

MPDB 56 kph

FIMCAR
frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

Barrier deformations (3/3)

EuNCAP

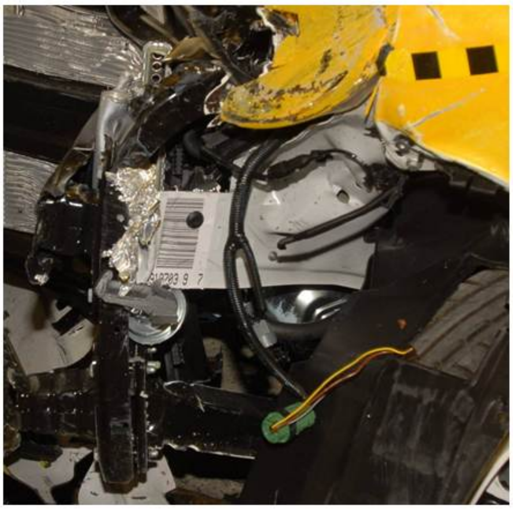
ECE94

FIMCAR
frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

Bumper-beam and longitudinals deformations (1/2)

PDB 60 kph



Bumper-beam and longitudinals deformations (2/2)

MPDB
50 kph

MPDB
56 kph

Longitudinals and third load path deformations

M-PDB 50kph

M-PDB 56kph

FIMCAR
fontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Longitudinals (PDB 60kph Vs. Eu-NCAP)

PDB 60kph

Eu-NCAP

PDB barrier stress less the longitudinals respect to EEVC barrier in Eu-NCAP test (loads on longitudinals aren't sufficient for longitudinal collapse).

FIMCAR
fontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

PDB 'Supermini 2'

Test Date: Location: Topic: Mass Ratio: Test Number: Test Protocol:	12/04/2012 BASt PDB-Test N/A **FM03OPDB** ECE R-94 with amend. ECE/TRANS /WP.29/GRS P/2007/17e				
		Vehicle: Type: Impact side: Speed: Offset: Test mass: Dummy:	Supermini 2 Front 60,08 km/h 50 % 1164 kg LHS – Hybrid III 50th RHS – Hybrid III 50th	Barrier: Impact accuracy: LCW/barrier ground clearance: Barrier dimensions:	PDB - AFL Prod101XT Version V8.0 Ser. No.: CP809413 87mm left (more overlap) 7 mm lower 153 mm left 149 mm right 1000 mm wide 700 mm high 790 mm long

Test objectives:
Test to check reproducibility of PDB testing procedure (to be compared to PDB-Test 17292 conducted at Fiat and PDB-Test FM02OPDB at BASt)

Test parameters

Vehicle data:

- **Vehicle: Supermini 2, *model year: 07/2010* (LHD)**
- **Vehicle identification no (VIN):**
- **Engine / Transmission: 1.2 l petrol / manual**
- **Test speed: 60.08 km/h**
- **Test weight: 1164 kg (FL/FR 343 / 327) (RL/RR 245 /249)**
- **Test impact accuracy:**
  lateral 87mm left (more overlap) and vertical 7 mm lower

Test vehicle status:

- **Safety systems: 3 point belt system with pretensioner (retractor & buckle) and load limiter, dual stage airbag driver/passenger, knee airbag driver, side and window airbag**
- **Wheels: steel, 175/65 R14, 2.2 bar**
- ***Ride height measurements:***
  FL: 634 mm, FR: 633 mm
  RL: 618 mm, RR: 620 mm

Pre-test Pictures
Vehicle

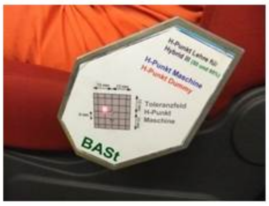
FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures
Barrier

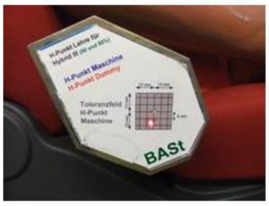
FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Additional Pre-test pictures

H-Point Driver



H-Point Passenger



Description of front-end structure

Three front load paths

- *Upper load path: Frontend assembly/radiator support at bonnet leading edge*
- *Lower load path: Longitudinals / crush can/ bumper crossbeam → PEAS*
- *3rd load path: Sub frame/crush can/crossbeam → SEAS*
- *Vertical connection between all load paths*

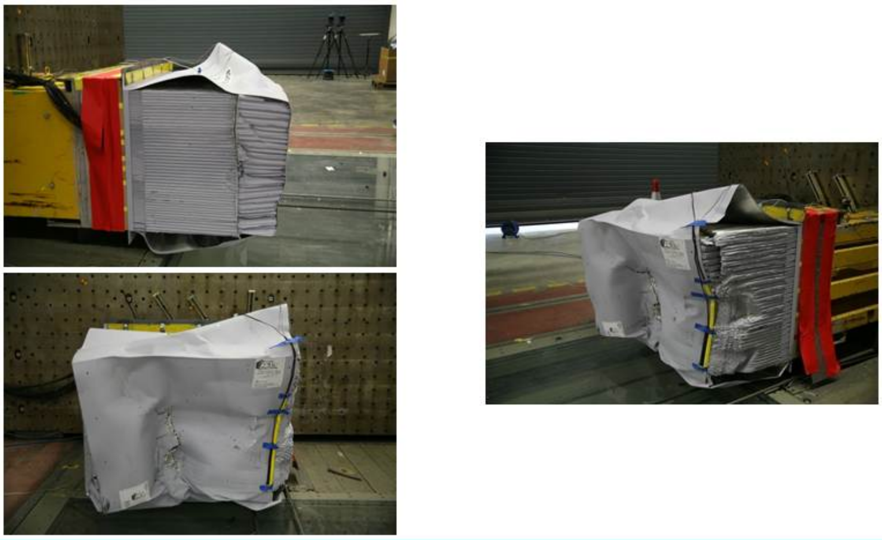
Dimensions [mm] (heights above ground)	Top height	Bottom height	Width	Depth
Engine	737	167	470	263
Gear Box	370	160	372	-
Higher Crossbeam	661	539	-	-
Lower Crossbeam	350	300	-	-
Subframe	-	210	560	-

Vehicle / barrier results

Post-test Pictures
Vehicle

Post-test Pictures
Front End Structure

Post-test Pictures
Barrier



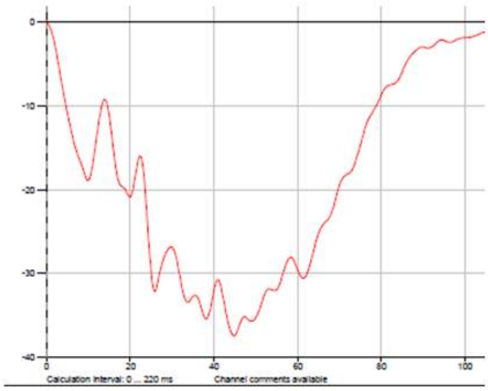
Additional Post-test pictures

Static deformation in x-direction

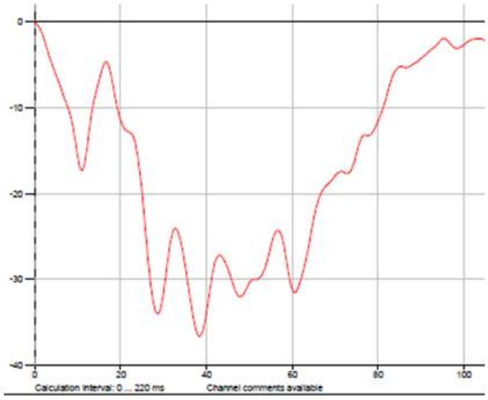
	Difference		
Location	x	y	z
A-post-RHS-waist	0,51	5,72	3,82
A-post-RHS-sill	1,44	4,77	2,26
B-post-RHS-waist	1,23	0,54	0,57
B-post-RHS-sill	0,17	0,69	0,46
A-post-LHS-waist	2,76	2,22	0,76
A-post-LHS-sill	0,74	1,69	0,30
B-post-LHS-waist	0,12	2,35	2,40
B-post-LHS-sill	0,60	2,04	2,05
Centre of the accelerator pedal	5,99	37,57	21,24
Centre of the brake pedal	27,46	2,33	12,16
Centre of the clutch pedal	88,10	7,05	30,39
Centre of the steering column	14,57	0,84	11,96

Vehicle Accelerations in X

A-Pillar lower left



A-Pillar lower right



FIMCAR frontal impact and compatibility assessment research

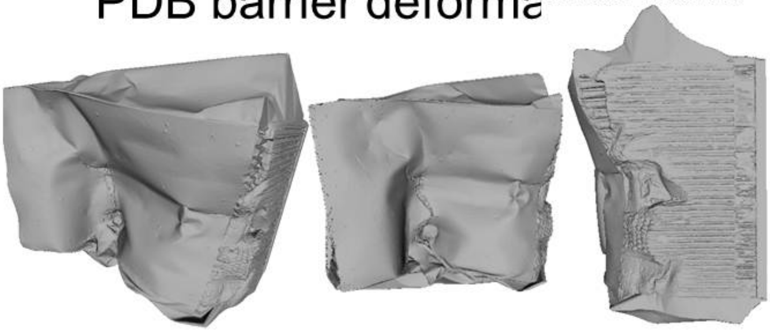
SEVENTH FRAMEWORK PROGRAMME

PDB barrier deformation results

FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

PDB barrier deforma



scans available in three resolution:
- high (1 mm)
- mid (2 mm)
- low (5 mm)

FIMCAR frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Dummy results

FIMCAR frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Dummy criteria Comparison

Supermini 2 PDB-Test 60km/h FM03OPDB

M03OPDB M03OPDB 012-04-12	Supermini 2	vs. PDB 50 Offset Frontal Impact Euro NCAP

Criterion	Driver SP 1 (H3)				Co-Driver SP 3 (H3)			
Head & Neck			4.000	★			4.000	★
Head								
HIC 36	934.16				355.22			
Acceleration Resultant	72.00	g	4.000	★	45.64	g	4.000	★
3ms cumulative	70.30	g			44.83	g		
Neck								
Shear Force Fx+	0.91	kN	4.000	★	0.43	kN	4.000	★
Shear Force Fx-	-0.38	kN	4.000	★	-0.30	kN	4.000	★
Tensile Force Fz+	1.86	kN	4.000	★	1.26	kN	4.000	★
Extension My-	-16.76	Nm	4.000	★	-16.16	Nm	4.000	★
Chest			1.966	★			2.947	★
Deflection	-36.24	mm	1.966	★	-29.37	mm	2.947	★
VC max	0.23	m/s	4.000	★	0.19	m/s	4.000	★
belt at upper diagonal belt Force	4.19	kN			3.97	kN		

FM02OPDB FM02OPDB 2012-01-26	Supermini 2	vs. PDB 50 Offset Frontal Impact Euro NCAP

Criterion	Driver SP 1 (H3)				Co-Driver SP 3 (H3)			
Femur & Knee			2.875	★			4.000	★
Left								
Femur Force Fz-	-0.66	kN	4.000	★	-0.53	kN	4.000	★
Knee Slider Displacement	-0.97	mm	4.000	★	-0.06	mm	4.000	★
Right								
Femur Force Fz-	-2.46	kN	4.000	★	-0.47	kN	4.000	★
Knee Slider Displacement	-8.53	mm	2.875	★	-0.18	mm	4.000	★
Tibia			3.091	★			2.540	★
Left								
Compression Upper Fz-	-1.26	kN	4.000	★	-2.51	kN	3.658	★
Compression Lower Fz-	-1.45	kN	4.000	★	-3.47	kN	3.023	★
Tibia Index Upper	0.46		3.745	★	0.73		2.540	★
Tibia Index Lower	0.24		4.000	★	0.44		3.819	★
Right								
Compression Upper Fz-	-1.91	kN	4.000	★	-1.62	kN	4.000	★
Compression Lower Fz-	-2.04	kN	3.975	★	-2.00	kN	4.000	★
Tibia Index Upper	0.60		3.091	★	0.51		3.510	★
Tibia Index Lower	0.25		4.000	★	0.43		3.875	★
Sum			11.932				13.487	

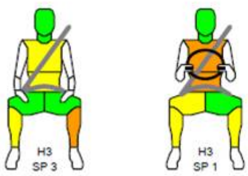
FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

Dummy criteria Comparison

PDB-Test 60km/h

Body Region	SP 1		SP 3	
Head & Neck	4.000	★	4.000	★
Chest	1.966	★	2.947	★
Femur & Knee	2.875	★	4.000	★
Tibia	3.091	★	2.540	★
Sum	11.932		13.487	



EuroNCAP ODB-Test 64 km/h

SUMMARY

Supermini 2

Adult Occupant Rating

★★★★★

Frontal Driver	
Head and Neck assessment	4.00
Chest assessment	3.82
Knee, Femur and Pelvis assessment	4.00
Lower Leg, Foot and Ankle assessme	3.29
Frontal Passenger	
Head and Neck assessment	4.00
Chest assessment	3.94
Knee, Femur and Pelvis assessment	4.00
Lower Leg assessment	3.84
Door Opening	0
OVERALL FRONT	15.11

FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

Firing times

- Driver Airbag:
  Stage 1 at 18,9 ms
  Stage 2 at 22,5 ms

11 SUPERMINI 2 PDB 60 KM/H @ BAST TEST 1

Offset Test
Supermini 2

FM02OPDB

Analysis and Report

Holger Schwedhelm,
Thorsten Adolph

FIMCAR WP 2, 30th May 2012

PDB 'Supermini 2'

Test Date:	26/01/2012
Location:	BASt
Topic:	PDB-Test
Mass Ratio:	N/A
Test Number:	**FM02OPDB**
Test Protocol:	ECE R-94 with amend. ECE/TRANS /WP.29/GRSP/2007/17e

Vehicle:	Supermini 2	Barrier:	PDB - AFL
Type:	(silver)		Prod101XT Version V8.0
Impact side:	Front		Ser. No.: CP0809401
Speed:	60,01 km/h	Impact accuracy:	35 mm left (more overlap)
Offset:	50 %		12 mm up
Test mass:	1165 kg	LCW/barrier	152 mm left
Dummy:	LHS – Hybrid III 50th	ground clearance:	151 mm right
	RHS – Hybrid III 50th	Barrier dimensions:	1000 mm wide
			700 mm high
			790 mm long

Test objectives:
Test to check reproducibility of PDB testing procedure (to be compared to PDB-Test 17292 conducted at Fiat)

Test parameters

Vehicle data:

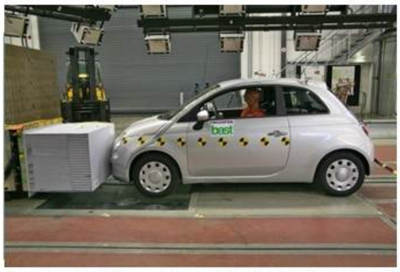
- Vehicle: Supermini 2, *model year: 05/2010* (LHD)
- Vehicle identification no (VIN):
- Engine / Transmission: 1.2 l petrol / manual
- Test speed: 60.01 km/h
- Test weight: F: 680 kg / R: 485 kg Total: 1165 kg
- Test impact accuracy:
  lateral 35 mm left (more overlap) and vertical 12 mm up

Test vehicle status:

- Safety systems: 3 point belt system with pretensioner (retractor & buckle) and load limiter, dual stage airbag driver/passenger, knee airbag driver, side and window airbag → airbag control unit did not fire
- Wheels: steel, 175/65 R14, 2.2 bar
- *Ride height measurements:*
  FL: 622 mm, FR: 619 mm
  RL: 614 mm, RR: 615 mm

fontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures
Vehicle




fontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures
Barrier

Additional Pre-test pictures

H-Point Driver

H-Point Passenger

Description of front-end structure

Three front load paths

- *Upper load path: Frontend assembly/radiator support at bonnet leading edge*
- *Lower load path: Longitudinals / crush can/ bumper crossbeam → PEAS*
- *3rd load path: Sub frame/crush can/crossbeam → SEAS*
- *Vertical connection between all load paths*

Dimensions [mm] (heights above ground)	Top height	Bottom height	Width	Depth
Engine	737	167	470	263
Gear Box	370	160	372	-
Higher Crossbeam	661	539	-	-
Lower Crossbeam	350	300	-	-
Subframe	-	210	560	-

Vehicle / barrier results

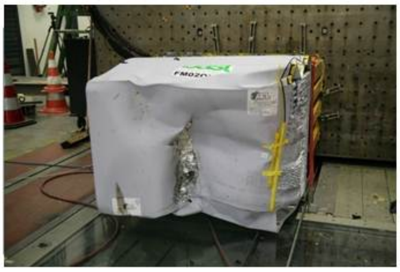
Post-test Pictures
Vehicle

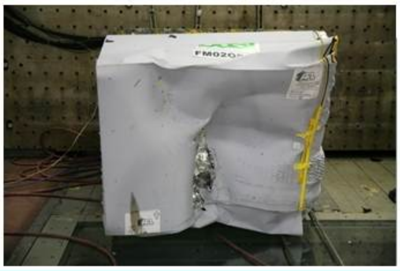
FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Post-test Pictures
Front End Structure

FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Post-test Pictures
Barrier



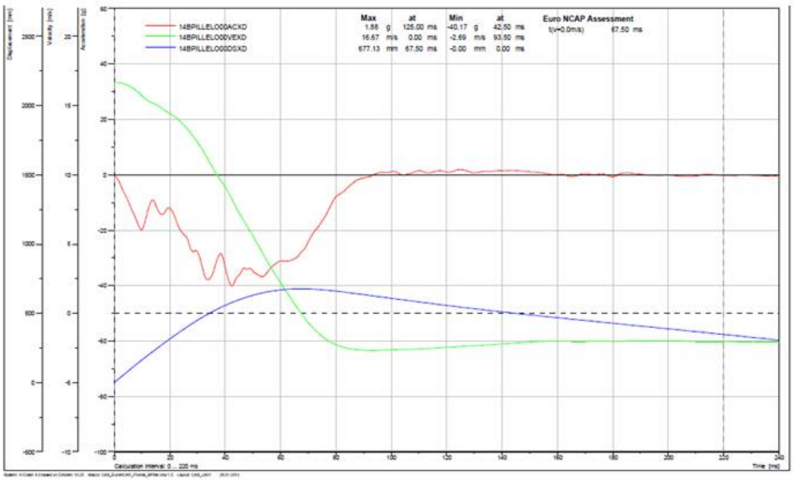


Additional Post-test pictures

Static deformation in x-direction

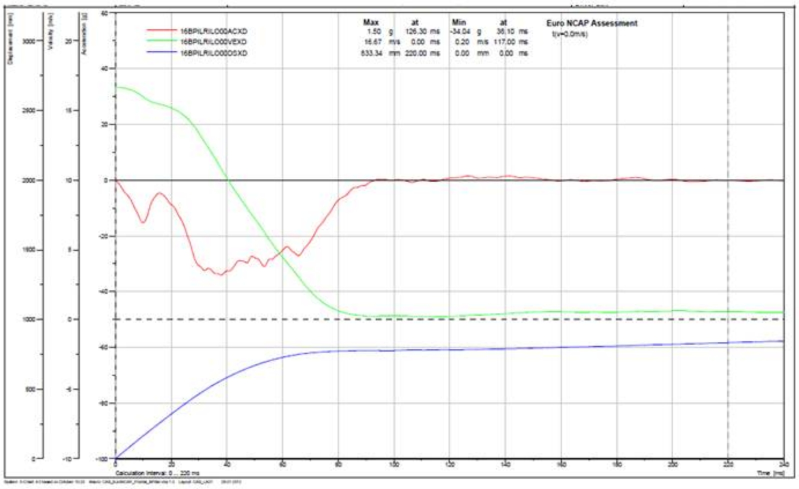
Location		Difference
A-pillar-waist	x	1,0
	y	3,1
	z	1,3
A-pillar-sill	x	0,1
	y	1,7
	z	1,9
B-pillar-waist	x	0,4
	y	0,1
	z	0,6
B-pillar-sill	x	0,3
	y	0,7
	z	0,7

Vehicle Accelerations/Velocities/Displacements B-Pillar Left Lower X



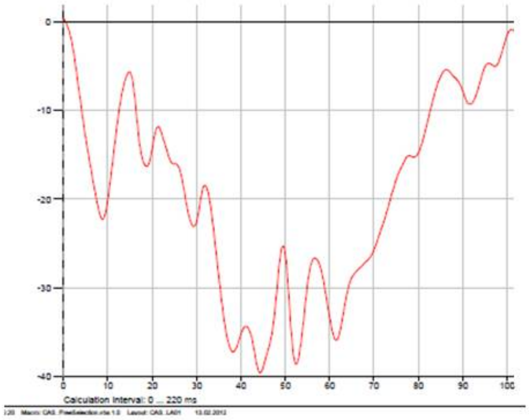
Vehicle Accelerations/Velocities/Displacements

B-Pillar right Lower X

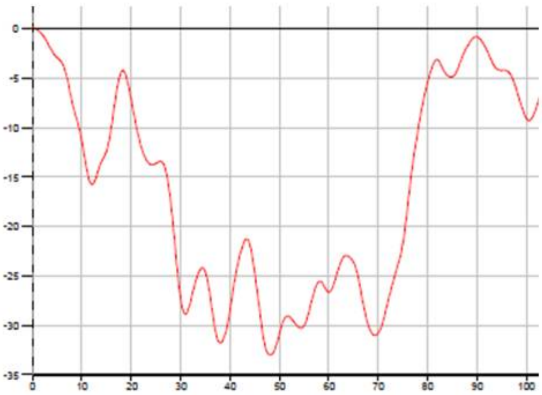


Vehicle Accelerations

A-Pillar middle left



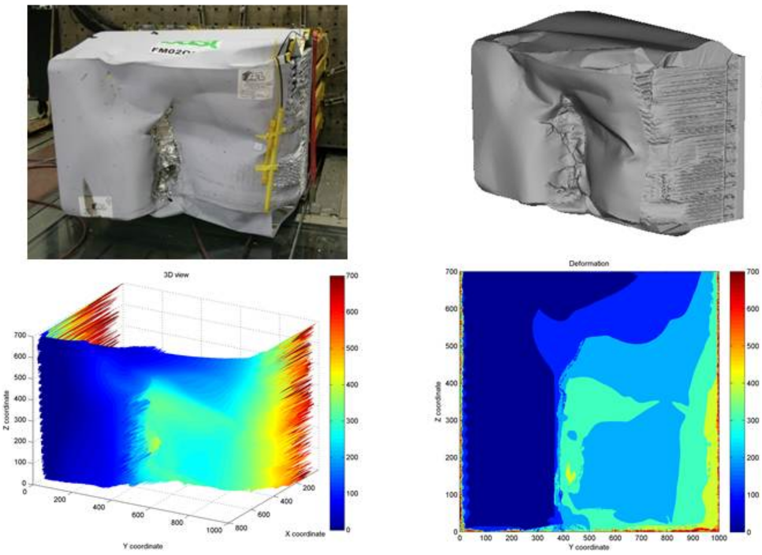
A-Pillar middle right



FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

PDB barrier deformation results

PDB barrier deformation scan



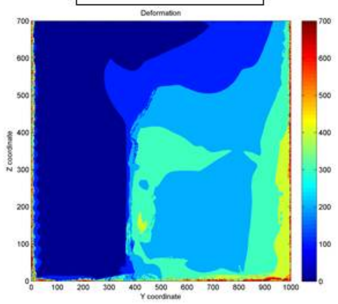
scans available in three resolution:

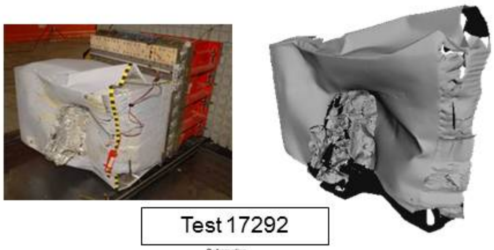
- high (1 mm)
- mid (2 mm)
- low (5 mm)

high resolution

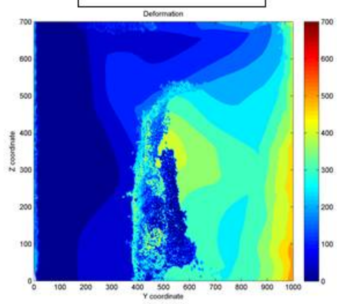
Comparison with test 17292

Test FM02OPDB





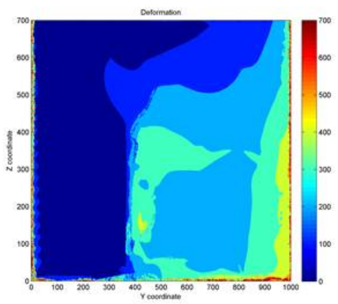
Test 17292



Metric evaluation/R&R

high resolution

Test FM02OPDB

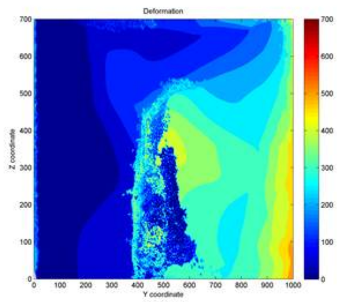


SDI (smooth deformation index):

Low resolution: 209,572
Mid resolution: 209,508
High resolution: 209,418

hardly any difference using different resolutions

Test 17292



SDI (smooth deformation index):

122,006 → scanning procedure and post-processing of stl-file needs to be checked

Dummy results

Dummy criteria Comparison

Supermini 2 PDB-Test 60km/h FM02OPDB

FM02OPDB
FM02OPDB
2012-01-26

Supermini 2 vs. PDB 50 Offset
Type of Test: Frontal Impact
Regulation: Euro NCAP

Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (H3)		
Head & Neck			0.000			0.000
Head						
HIC 36	2858.76		0.000	1863.88		0.000
Acceleration Resultant	169.61	g		247.68	g	
3ms cumulative	158.61	g	0.000	129.30	g	0.000
Neck						
Shear Force Fx+	0.40	kN	4.000	0.59	kN	4.000
Shear Force Fx-	-1.85	kN	4.000	-0.99	kN	4.000
Tensile Force Fz+	5.73	kN	0.000	2.79	kN	3.390
Extension My-	-74.56	Nm	0.000	-31.20	Nm	4.000
Chest			1.749			3.217
Deflection	-37.76	mm	1.749	-27.48	mm	3.217
VC max	0.30	m/s	4.000	0.13	m/s	4.000
belt at upper diagonal belt Force	3.91	kN		3.41	kN	

airbag control unit did <u>not</u> fire

FM02OPDB
FM02OPDB
2012-01-26

Supermini 2 vs. PDB 50 Offset
Type of Test: Frontal Impact
Regulation: Euro NCAP

Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (H3)		
Femur & Knee			0.000			4.000
Left						
Femur Force Fz-	-3.41	kN	4.000	-0.64	kN	4.000
Knee Slider Displacement	-0.46	mm	4.000	-0.20	mm	4.000
Right						
Femur Force Fz-	-3.76	kN	4.000	-0.05	kN	4.000
Knee Slider Displacement	-17.20	mm	0.000	-0.09	mm	4.000
Tibia			0.415			2.483
Left						
Compression Upper Fz-	-2.74	kN	3.508	-2.19	kN	3.874
Compression Lower Fz-	-2.69	kN	3.538	-3.05	kN	3.298
Tibia Index Upper	0.50		3.545	0.61		3.087
Tibia Index Lower	0.40		4.000	0.29		4.000
Right						
Compression Upper Fz-	-1.67	kN	4.000	-2.27	kN	3.823
Compression Lower Fz-	-1.65	kN	4.000	-2.89	kN	3.409
Tibia Index Upper	1.21		0.415	0.74		2.483
Tibia Index Lower	0.29		4.000	0.43		3.882
Sum			0.000			0.000

Dummy criteria Comparison

PDB-Test 60km/h

FM02OPDB
FM02OPDB
2012-01-26

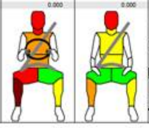
Fiat 500 vs. PDB 50 Offset
Frontal Impact
Euro NCAP

bast

Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (H3)			Worst Points
Head & Neck			0.000			0.000	0.000
Head							
HIC 36	2858.76		0.000	1663.68		0.000	0.000
Acceleration Resultant	169.61	g		247.68	g		
3ms cumulative	158.61	g	0.000	129.30	g	0.000	0.000
Neck							
Shear Force Fx+	0.40	kN	4.000	0.59	kN	4.000	4.000
Shear Force Fx-	-1.85	kN	4.000	-0.99	kN	4.000	4.000
Tensile Force Fz+	5.73	kN	0.000	2.79	kN	3.390	0.000
Extension My-	-74.56	Nm	0.000	-31.20	Nm	4.000	0.000
Chest			1.749			3.217	1.749
Deflection	-37.76	mm	1.749	-27.48	mm	3.217	1.749
VC max	0.30	m/s	4.000	0.13	m/s	4.000	4.000
belt at upper diagonal belt Force	3.91	kN		3.41	kN		
Femur & Knee			0.000			4.000	0.000
Left							
Femur Force Fz-	-3.41	kN	4.000	-0.64	kN	4.000	4.000
Knee Slider Displacement	-0.46	mm	4.000	-0.20	mm	4.000	4.000
Right							
Femur Force Fz-	-3.76	kN	4.000	-0.05	kN	4.000	4.000
Knee Slider Displacement	-17.20	mm	0.000	-0.09	mm	4.000	0.000
Tibia			0.415			2.483	0.415
Left							
Compression Upper Fz-	-2.74	kN	3.508	-2.19	kN	3.674	3.508
Compression Lower Fz-	-2.69	kN	3.538	-3.05	kN	3.298	3.298
Tibia Index Upper	0.50		3.545	0.61		3.087	3.087
Tibia Index Lower	0.40		4.000	0.29		4.000	4.000
Right							
Compression Upper Fz-	-1.67	kN	4.000	-2.27	kN	3.823	3.823
Compression Lower Fz-	-1.86	kN	4.000	-2.89	kN	3.409	3.409
Tibia Index Upper	1.21		0.415	0.74		2.483	0.415
Tibia Index Lower	0.29		4.000	0.43		3.882	3.882
Sum			0.000			0.000	0.000

Rating without modifiers

Points
4.000
2.670 - 3.999
1.330 - 2.669
0.001 - 1.329
0.000



airbag control unit did not fire

Results Passengers
Front
Vehicle 1

EuroNCAP ODB-Test 64 km/h

SUMMARY

Supermini 2

Adult Occupant Rating

Frontal Driver	
Head and Neck assessment	4.00
Chest assessment	3.82
Knee, Femur and Pelvis assessment	4.00
Lower Leg, Foot and Ankle assessme	3.29
Frontal Passenger	
Head and Neck assessment	4.00
Chest assessment	3.94
Knee, Femur and Pelvis assessment	4.00
Lower Leg assessment	3.84
Door Opening	0
OVERALL FRONT	15.11

Firing times

- No firing times have been recorded
- The Airbag and the seat belt pretensioner have not been fired due to replacement of airbag control unit foreseen for 5 seater vehicle model

FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Conclusions

- In the test the seat belt pretensioner and the airbag have not fired due to a failure in the replacement of the control unit
- Acceleration: 40 g at b-pillar, left
- Dummy values: Extremely high acceleration of the head but considerably low chest compression for the passenger

12 SUPERMINI 2 PDB 60 KM/H @ BAST TEST 2

Offset Test
Supermini 2 vs PDB

FM03OPDB

Analysis and Report

Holger Schwedhelm,
Thorsten Adolph

FIMCAR WP 2, 1st June 2012

FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

PDB 'Supermini 2'

Test Date:	12/04/2012
Location:	BASt
Topic:	PDB-Test
Mass Ratio:	N/A
Test Number:	**FM03OPDB**
Test Protocol:	ECE R-94 with amend. ECE/TRANS/WP.29/GRSP/2007/17e

Vehicle:	Supermini 2	Barrier:	PDB - AFL
Type:			Prod101XT Version V8.0
Impact side:	Front		Ser. No.: CP809413
Speed:	60,08 km/h	Impact accuracy:	87mm left (more overlap)
Offset:	50 %		7 mm lower
Test mass:	1164 kg	LCW/barrier	153 mm left
Dummy:	LHS – Hybrid III 50th	ground clearance:	149 mm right
	RHS – Hybrid III 50th	Barrier dimensions:	1000 mm wide
			700 mm high
			790 mm long

Test objectives:
Test to check reproducibility of PDB testing procedure (to be compared to PDB-Test 17292 conducted at Fiat and PDB-Test FM02OPDB at BASt)

FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

Test parameters

Vehicle data:

- Vehicle: Supermini 2, *model year: 07/2010* (LHD)
- Vehicle identification no (VIN):
- Engine / Transmission: 1.2 l petrol / manual
- Test speed: 60.08 km/h
- Test weight: 1164 kg (FL/FR 343 / 327) (RL/RR 245 /249)
- Test impact accuracy:
  lateral 87mm left (more overlap) and vertical 7 mm lower

Test vehicle status:

- Safety systems: 3 point belt system with pretensioner (retractor & buckle) and load limiter, dual stage airbag driver/passenger, knee airbag driver, side and window airbag
- Wheels: steel, 175/65 R14, 2.2 bar
- *Ride height measurements:*
  FL: 634 mm, FR: 633 mm
  RL: 618 mm, RR: 620 mm

FIMCAR frontal impact and compatibility assessment research

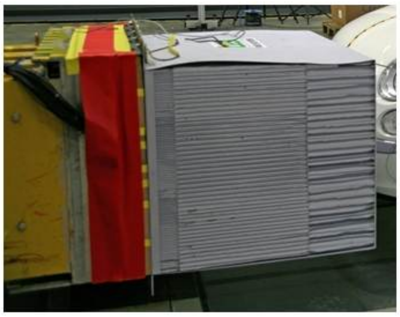
SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures Vehicle

FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

Pre-test Pictures
Barrier

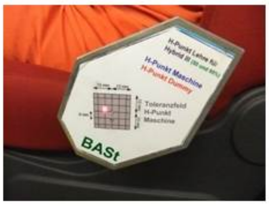



FIMCAR fontal impact and compatibility assessment research

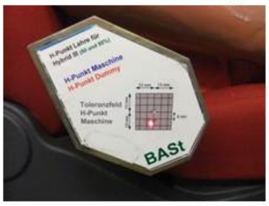
SEVENTH FRAMEWORK PROGRAMME

Additional Pre-test pictures

H-Point Driver



H-Point Passenger








FIMCAR fontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

Description of front-end structure

Three front load paths

- *Upper load path: Frontend assembly/radiator support at bonnet leading edge*
- *Lower load path: Longitudinals / crush can/ bumper crossbeam → PEAS*
- *3rd load path: Sub frame/crush can/crossbeam → SEAS*
- *Vertical connection between all load paths*

Dimensions [mm] (heights above ground)	Top height	Bottom height	Width	Depth
Engine	737	167	470	263
Gear Box	370	160	372	-
Higher Crossbeam	661	539	-	-
Lower Crossbeam	350	300	-	-
Subframe	-	210	560	-

Vehicle / barrier results

Post-test Pictures
Vehicle

Post-test Pictures
Front End Structure

Post-test Pictures
Barrier

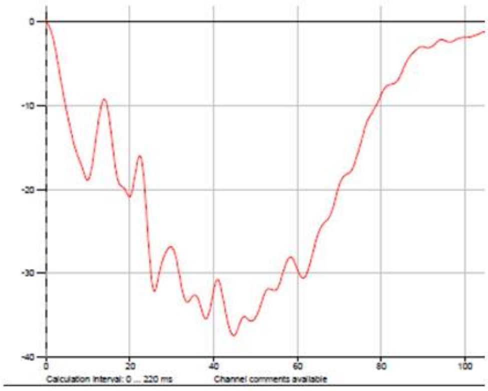
Additional Post-test pictures

Static deformation in x-direction

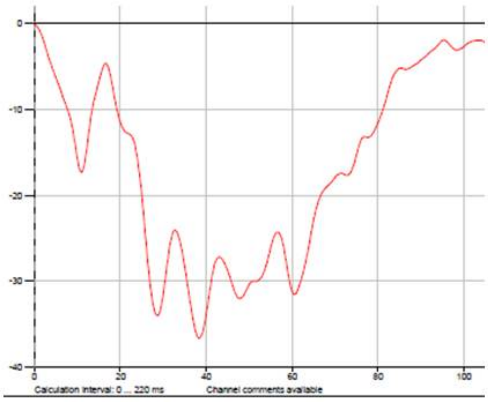
Location	Difference x	y	z
A-post-RHS-waist	0,51	5,72	3,82
A-post-RHS-sill	1,44	4,77	2,26
B-post-RHS-waist	1,23	0,54	0,57
B-post-RHS-sill	0,17	0,69	0,46
A-post-LHS-waist	2,76	2,22	0,76
A-post-LHS-sill	0,74	1,69	0,30
B-post-LHS-waist	0,12	2,35	2,40
B-post-LHS-sill	0,60	2,04	2,05
Centre of the accelerator pedal	5,99	37,57	21,24
Centre of the brake pedal	27,46	2,33	12,16
Centre of the clutch pedal	88,10	7,05	30,39
Centre of the steering column	14,57	0,84	11,96

Vehicle Accelerations in X

A-Pillar lower left



A-Pillar lower right



PDB barrier deformation results

PDB barrier deformation scan

scans available in three resolution:

- high (1 mm)
- mid (2 mm)
- low (5 mm)

Dummy results

Dummy criteria Comparison

Supermini 2 PDB-Test 60km/h FM03OPDB

M03OPDB
M03OPDB
012-04-12

Supermini 2 vs. PDB 50 Offset
Frontal Impact
Euro NCAP

Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (H3)		
Head & Neck			4.000			4.000
Head						
HIC 36	934.16			355.22		
Acceleration Resultant	72.00	g	4.000	45.64	g	4.000
3ms cumulative	70.30	g		44.83	g	
Neck						
Shear Force Fx+	0.91	kN	4.000	0.43	kN	4.000
Shear Force Fx-	-0.38	kN	4.000	-0.30	kN	4.000
Tensile Force Fz+	1.86	kN	4.000	1.26	kN	4.000
Extension My-	-16.76	Nm	4.000	-16.16	Nm	4.000
Chest			1.966			2.947
Deflection	-36.24	mm	1.966	-29.37	mm	2.947
VC max	0.23	m/s	4.000	0.19	m/s	4.000
belt at upper diagonal belt Force	4.19	kN		3.97	kN	

FM02OPDB
FM02OPDB
2012-01-26

Supermini 2 vs. PDB 50 Offset
Frontal Impact
Euro NCAP

Criterion	Driver SP 1 (H3)			Co-Driver SP 3 (H3)		
Femur & Knee			2.875			4.000
Left						
Femur Force Fz-	-0.66	kN	4.000	-0.53	kN	4.000
Knee Slider Displacement	-0.97	mm	4.000	-0.06	mm	4.000
Right						
Femur Force Fz-	-2.46	kN	4.000	-0.47	kN	4.000
Knee Slider Displacement	-8.53	mm	2.875	-0.18	mm	4.000
Tibia			3.091			2.540
Left						
Compression Upper Fz-	-1.26	kN	4.000	-2.51	kN	3.658
Compression Lower Fz-	-1.45	kN	4.000	-3.47	kN	3.023
Tibia Index Upper	0.46		3.745	0.73		2.540
Tibia Index Lower	0.24		4.000	0.44		3.819
Right						
Compression Upper Fz-	-1.91	kN	4.000	-1.62	kN	4.000
Compression Lower Fz-	-2.04	kN	3.975	-2.00	kN	4.000
Tibia Index Upper	0.60		3.091	0.51		3.510
Tibia Index Lower	0.25		4.000	0.43		3.875
Sum			11.932			13.487

Dummy criteria Comparison

PDB-Test 60km/h

Body Region	SP 1	SP 3
Head & Neck	4.000 *	4.000 *
Chest	1.966 *	2.947 *
Femur & Knee	2.875 *	4.000 *
Tibia	3.091 *	2.540 *
Sum	11.932	13.487

EuroNCAP ODB-Test 64 km/h

SUMMARY

Supermini 2

Adult Occupant Rating

Frontal Driver	
Head and Neck assessment	4.00
Chest assessment	3.82
Knee, Femur and Pelvis assessment	4.00
Lower Leg, Foot and Ankle assessme	3.29
Frontal Passenger	
Head and Neck assessment	4.00
Chest assessment	3.94
Knee, Femur and Pelvis assessment	4.00
Lower Leg assessment	3.84
Door Opening	0
OVERALL FRONT	15.11

Firing times

- Driver Airbag:
  Stage 1 at 18,9 ms
  Stage 2 at 22,5 ms

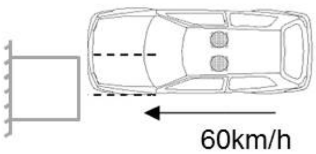
13 CITY CAR 1 PDB 60 KM/H @ UTAC

Offset Test
Citycar 1 vs PDB

AFFSEP1102347

Analysis and Report

PDB 'Citycar1'

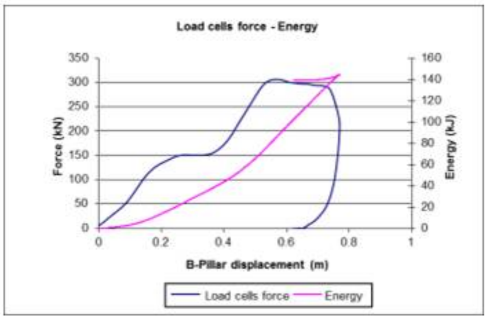
Test Date: Location: Topic: Mass Ratio: Test Number: Test Protocol:	09, 2011 UTAC PDB-Test N/A **AFFSEP1102347** N/A	

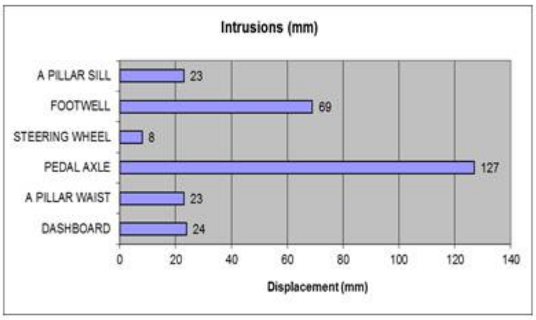
Vehicle 1: Brand/type: Engine Impact side: Speed: Overlap: Test mass: Dummy:	Super Mini Citycar 1 1.2L, 4 cylinders Front left 60,06 km/h 50 % 1168.0 kg LHS – HIII 50% RHS – HIII 50%	Barrier: PDB v8

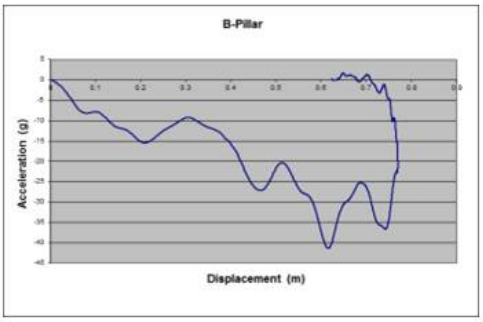
Test objective: Frontal crash to PDB with a 50% overlap at 60km/h

2- SELF PROTECTION : Structural analysis (1/2)

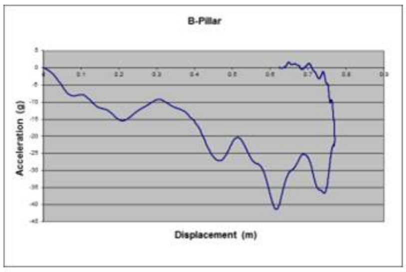
Average intrusion
53,2 mm up = 23,5mm low=73mm
Maximum force
306 kN
EES
50.4 km/h

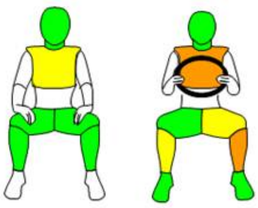






2- SELF PROTECTION : Dummies (2/2)





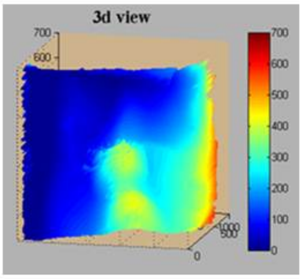
* Rating representation

		DRIVER	PASS	ECE R94
Head	HIC	506	442	<1000
	Criteria 3ms (g)	51,6	50,5	<80g
Upper Neck	NIC	<corridor		<corridor
	My (Nm)	45,8	19,3	<57 Nm
Chest	Deflexion (mm)	33	24,2	<50mm
	Viscous criterion	0,195	0,103	<1 m/s
Femur	Force	<corridor		<corridor
Knee	Left disp, (mm)	1,89	3,51	<15mm
	Right disp, (mm)	3,58	0,04	<15mm
Tibia Index	Left upper	0,38	0,23	<1,3
	Left lower	0,69	0,15	<1,3
	Right upper	0,81	0,36	<1,3
	Right lower	0,60	0,19	<1,3

Dummies criteria far from R94 limits

3- PARTNER PROTECTION ANALYSIS: PDB (1/2)





MAX DEFORMATION	VOLUME	ENERGY
425 mm	104 dm3	47,7 kJ

Homogeneous barrier deformation Deformation shape allows to see PEAS and SEAS

* Calculated with current formula

FIMCAR
frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

3- PARTNER PROTECTION ANALYSIS: Front end (2/2)





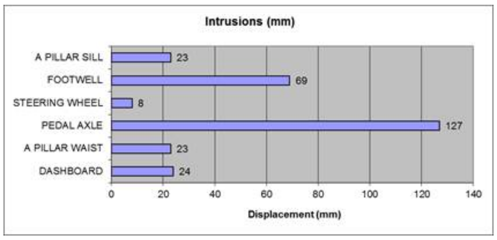
FIMCAR
frontal impact and compatibility assessment research

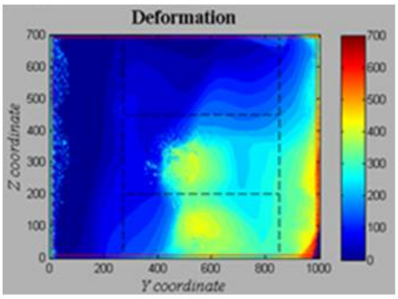
SEVENTH FRAMEWORK PROGRAMME

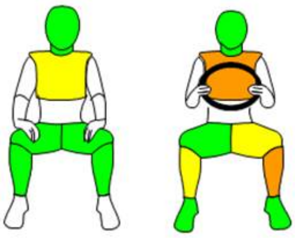
4- PARTNER AND SELF PROTECTION ASSESSMENTS

SELF

PARTNER



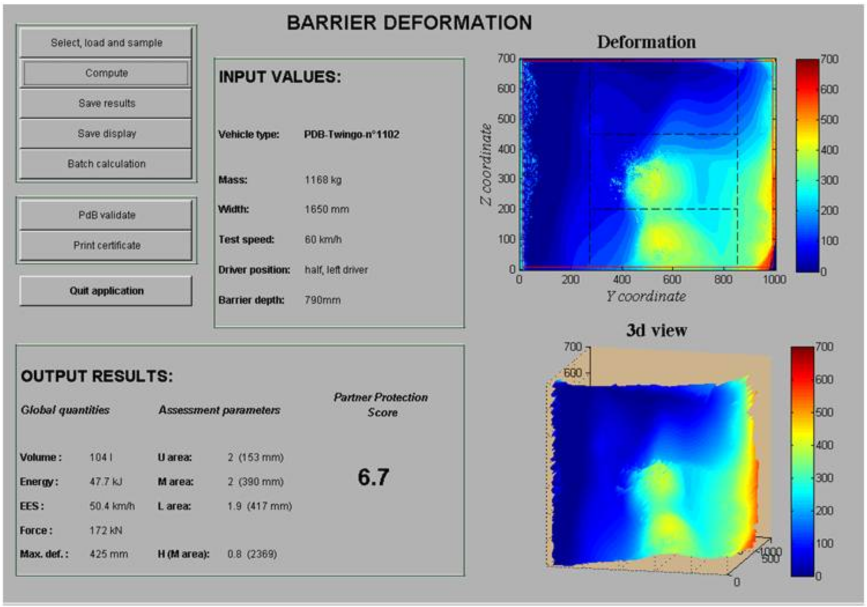




FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

4- BACK UP



FIMCAR frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

14 SMALL FAMILY CAR 1 PDB 60 KM/H @ IDIADA

SEVENTH FRAMEWORK PROGRAMME

WP2 testing activities
Small Family Car 1
PDB at IDIADA

frontal impact and compatibility assessment research

SEVENTH FRAMEWORK PROGRAMME

Small Family Car 1 PDB test

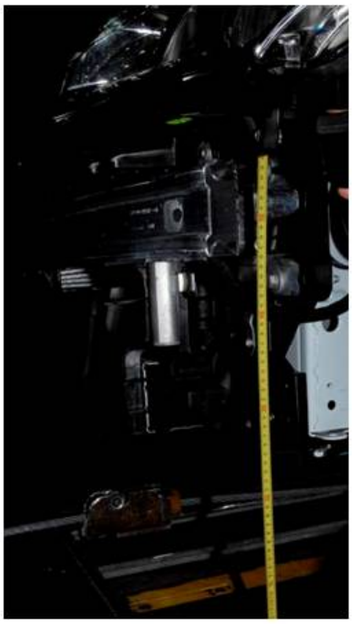
Test Date	June 28, 2012
Location	IDIADA
Topic	PDB
Mass Ratio	NA
Test Number	122611DF
Test Protocol	FIMCAR

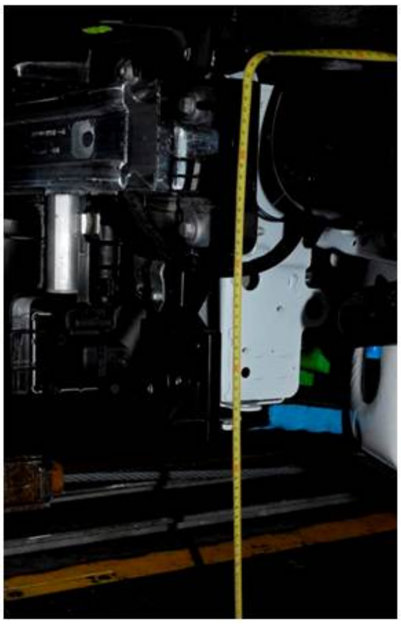
60 km/h

Vehicle 1:	Compact	Ride height measured at wheel arch:
Brand/type:	Small Family Car 1	
Impact side:	Front left	Front left: 679 mm
Speed:	60 km/h	Front right: 674 mm
Overlap:	50 %	
Test mass:	1490.0 kg	Rear left: 667 mm
Dummy:	LHS – HIII 50%	Rear right: 664 mm
	RHS – HIII 50%	

Test objective: Frontal crash to PDB with a 50% overlap at 60km/h

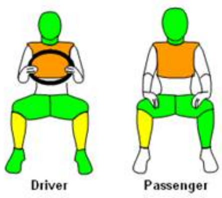
Small Family Car 1 PDB Test
Pre-Test measurements





PDB left impact test on Small Family Car 1

Test conditions
IDIADA test number: 122611DF
Vehicle: Small Family Car 1
Test Vehicle Mass: 1490.0 kg
Test velocity: 60.42 km/h



Euro NCAP modifiers not applied

SUMMARY	Driver	Passenger
Head and Neck assessment	4,000	4,000
Chest assessment	2,657	2,293
Knee, Femur and Pelvis assessment	4,000	4,000
Lower Leg, Foot and Ankle Assessment	3,800	3,733
TOTAL	14,457	14,026
Door Opening	0,00	
TOTAL FRONTAL	**14,026**	

Small Family Car 1 PDB Test
Pre-Test photos

Small Family Car 1 PDB Test
Static measurement results

- No door opening during the test.
- No door opening after the test.

STATIC MEASUREMENTS

+ve= up,aft,left

STEERING WHEEL	
Fore/aft displacement - mm	-26
Vertical displacement - mm	-14
Lateral displacement - mm	6

A PILLAR	
Waistline displacement - mm	9

PEDAL DISPLACEMENTS	
Brake Vertical displacement - mm	-30
Brake Horizontal displacement - mm	-29
Clutch Vertical displacement - mm	24
Clutch Horizontal displacement - mm	61
Accel Vertical displacement - mm	1
Accel Horizontal displacement - mm	29
MAXIMUM PEDAL MOVEMENT	
Brake vertical displacement - mm	-30
Clutch horizontal displacement - mm	61

DOOR APERTURE	
Waist level collapse - mm	-10
Sill level collapse - mm	-1

Small Family Car 1 PDB Test
Dummy results

Small Family Car 1

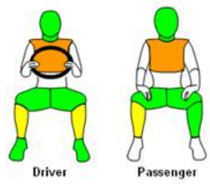
	Driver	Points	Passenger	Points
HEAD				
Peak resultant acceleration - g	48,94	4,000	56,07	4,000
HIC_{36}	387,26		471,60	
Resultant Acc. 3 msec exeedence - g	47,83		54,87	
Unstable airbag contact, Bottoming out or Hazardous deployme		0,000		0,000
Steering wheel displacement (-1) mm	-1	0,000		
Incorrect airbag deployment		0,000		0,000
Head Assessment		4,000		4,000
NECK				
Shear level exceeded - kN	0,47	4,000	0,30	4,000
duration of exceedence - ms	0		0,00	
Tension level exceeded - kN	0,78	4,000	1,17	4,000
duration of exceedence - ms	0		0,00	
Extension - Nm	11,30	4,000	10,33	4,000
Neck Assessment		4,000		4,000
Head and Neck Assessment		4,000		4,000
CHEST				
Compression - mm	31,40	2,657	33,95	2,293
Viscous criterion - m/s	0,17	4,000	0,12	4,000
Steering wheel contact (-1)		0,000		
A-Pillar displacement (-2) mm	2	0,000		
Unstable passenger compartment (-1)		0,000		
Shoulder belt load - kN	4,40		4,26	
Chest Incorrect Airbag Deployment Modifier		0,000		0,000
Chest Assessment		2,657		2,293

KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	0,0	4,000	1,0	4,000
Left Femur Compression level exceeded - kN	0,41	4,000	1,5	4,000
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Left Knee, Femur and Pelvis Assessment		4,000		4,000
Right Knee Slide - mm	0,2	4,000	0,2	4,000
Right Femur Compression level exceeded - kN	0,46	4,000	2,3	4,000
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Right Knee, Femur and Pelvis Assessment		4,000		4,000
Knee, Femur and Pelvis assessment		4,000		4,000
LOWER LEG				
Left compression - kN	1,77	4,000	1,99	4,000
Left Upper Tibia Index	0,42	3,911	0,26	4,000
Left Lower Tibia Index	0,28	4,000	0,28	4,000
Brake pedal vertical (-1) mm	-53	0,000		
Left Lower Leg assessment		3,911		4,000
Right compression - kN	2,30	3,800	1,97	4,000
Right Upper Tibia Index	0,38	4,000	0,46	3,733
Right Lower Tibia Index	0,21	4,000	0,16	4,000
Brake pedal vertical (-1) mm	-53	0,000		
Right Lower Leg assessment		3,800		3,733
FOOT and ANKLE				
Brake pedal horizontal displacement - mm	-58	4,000		
Footwell Rupture (-1)		0,000		
Pedal Blocking (-1)	22	0,000		
Foot and Ankle assessment		4,000		
Lower Leg, Foot and Ankle assessment		3,800		3,733

PDB left impact test on Small Family Car 1
Comparison results with Euro NCAP

PDB results (IDIADA)

Euro NCAP modifiers not applied



SUMMARY		
Head and Neck assessment	4,000	4,000
Chest assessment	2,657	2,293
Knee, Femur and Pelvis assessment	4,000	4,000
Lower Leg, Foot and Ankle Assessment	3,800	3,733
TOTAL	14,457	14,026
Door Opening	0,00	
TOTAL FRONTAL	14,026	

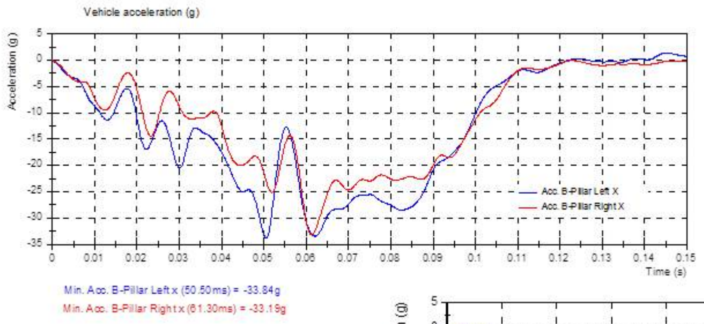
ODB results (Euro NCAP)

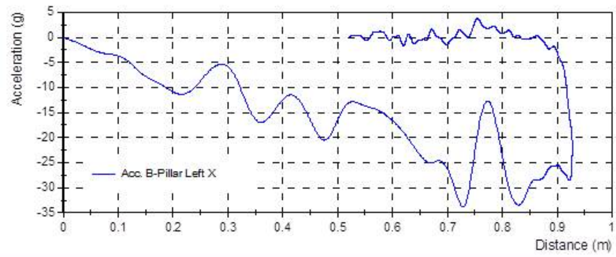
Euro NCAP modifiers applied

TOTAL FRONTAL 15,8

FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

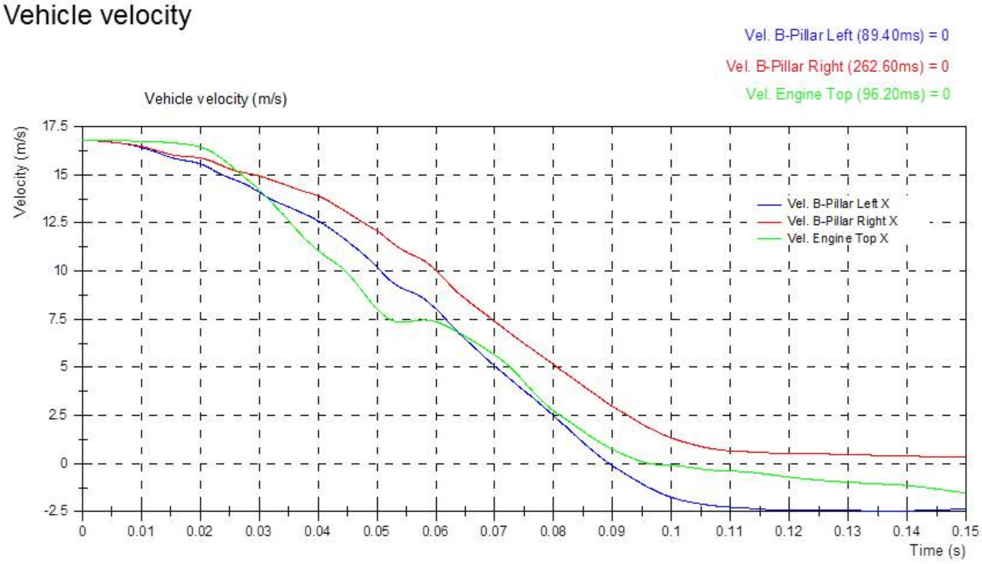
Small Family Car 1 PDB Test
Vehicle pulse





FIMCAR
frontal impact and compatibility assessment research
SEVENTH FRAMEWORK PROGRAMME

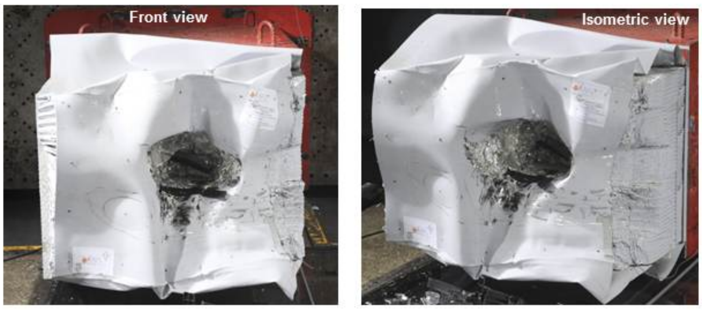
Small Family Car 1 PDB Test
Vehicle velocity

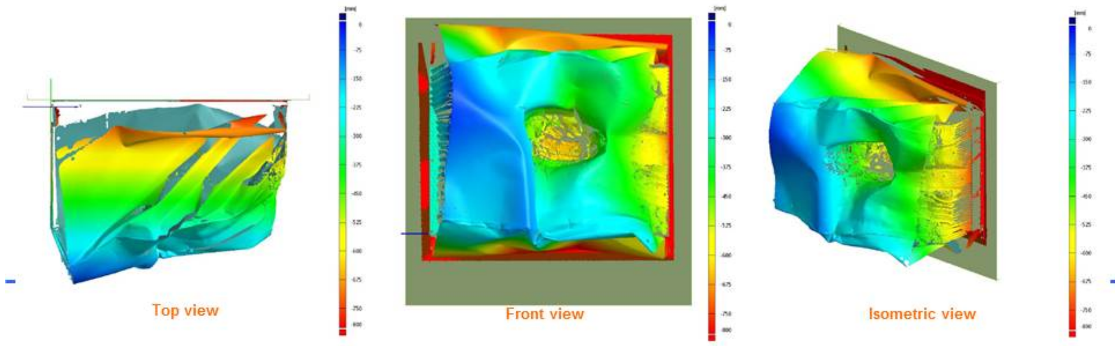


Small Family Car 1 PDB Test
Post-Test photos

Small Family Car 1 PDB Test
Post-Test photos (measurements)

Small Family Car 1 PDB Test
Barrier deformation





Small Family Car 1 PDB Test
Conclusions

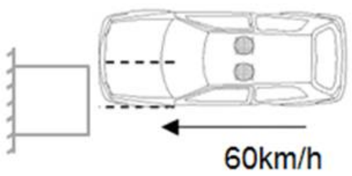
- Dummies injuries are below R94 limits
- A-Pillar waistline had only 9 mm rearward displacement
- PDB scan to be further analyzed

15 SUV 1 PDB 60 KM/H @ IDIADA

WP2 testing activities
SUV 1
PDB at IDIADA

SUV 1 PDB test

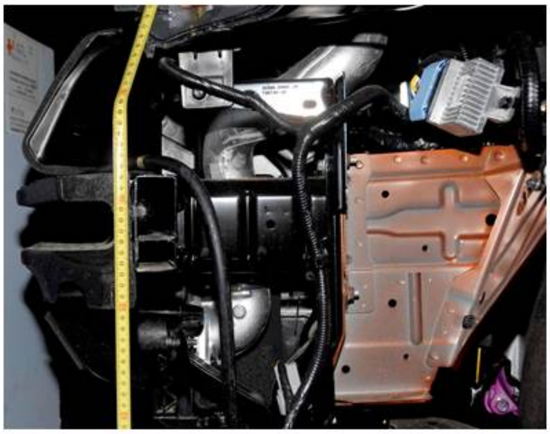
Test Date	May 28, 2012
Location	IDIADA
Topic	PDB
Mass Ratio	NA
Test Number	122201DF
Test Protocol	FIMCAR



Vehicle 1:	Off-road	Ride height measured at wheel arch:
Brand/type:	SUV 1	
Impact side:	Front left	Front left: 765 mm
Speed:	60 km/h	Front right: 772 mm
Overlap:	50 %	
Test mass:	1906.0 kg	Rear left: 760 mm
Dummy:	LHS – HIII 50%	Rear right: 760 mm
	RHS – HIII 50%	

Test objective: Frontal crash to PDB with a 50% overlap at 60km/h

SUV 1 PDB Test
Pre-Test measurements



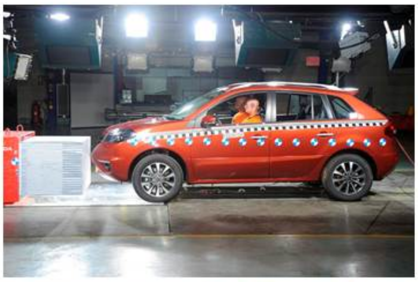
PDB left impact test on SUV 1

Test conditions
IDIADA test number: 122201DF
Vehicle: SUV 1
Test Vehicle Mass: 1906.0 kg
Test velocity: 60.34 km/h

Euro NCAP modifiers not applied

SUMMARY	Driver	Passenger
Head and Neck assessment	4,000	4,000
Chest assessment	2,266	3,389
Knee, Femur and Pelvis assessment	4,000	2,484
Lower Leg, Foot and Ankle Assessment	4,000	3,911
TOTAL	14,266	13,784
Door Opening	0,00	
TOTAL FRONTAL	**12,661**	

SUV 1 PDB Test
Pre-Test photos




SUV 1 PDB Test
Static measurement results

- No door opening during the test.
- No door opening after the test.

STATIC MEASUREMENTS

+ve= up aft left

STEERING WHEEL	
Fore/aft displacement - mm	-37
Vertical displacement - mm	-7
Lateral displacement - mm	-1

A PILLAR	
Waistline displacement - mm	2

PEDAL DISPLACEMENTS	
Brake Vertical displacement - mm	-53
Brake Horizontal displacement - mm	-58
Clutch Vertical displacement - mm	-11
Clutch Horizontal displacement - mm	22
Accel Vertical displacement - mm	-8
Accel Horizontal displacement - mm	10
MAXIMUM PEDAL MOVEMENT	
Brake vertical displacement - mm	-53
Brake horizontal displacement - mm	-58

DOOR APERTURE	
Waist level collapse - mm	-2
Sill level collapse - mm	-2

SUV 1 PDB Test
Dummy results

SUV 1

	Driver	Points	Passenger	Points
HEAD				
Peak resultant acceleration - g	37,15	4,000	37,41	4,000
HIC36	238,82		223,31	
Resultant Acc. 3 msec exeedence - g	36,41		36,03	
Unstable airbag contact, Bottoming out or Hazardous deployme		0,000		0,000
Steering wheel displacement (-1) mm	-1	0,000		
Incorrect airbag deployment		0,000		0,000
Head Assessment		4,000		4,000
NECK				
Shear level exceeded - kN	0,39	4,000	0,66	4,000
duration of exceedence - ms	0		0,00	
Tension level exceeded - kN	1,09	4,000	0,94	4,000
duration of exceedence - ms	0		0,00	
Extension - Nm	13,25	4,000	25,37	4,000
Neck Assessment		4,000		4,000
Head and Neck Assessment		4,000		4,000
CHEST				
Compression - mm	34,14	2,266	26,28	3,389
Viscous criterion - m/s	0,13	4,000	0,10	4,000
Steering wheel contact (-1)		0,000		
A-Pillar displacement (-2) mm	2	0,000		
Unstable passenger compartment (-1)		0,000		
Shoulder belt load - kN	5,85		5,89	
Chest Incorrect Airbag Deployment Modifier		0,000		0,000
Chest Assessment		2,266		3,389

	Driver	Points	Passenger	Points
KNEE, FEMUR and PELVIS				
Left Knee Slide - mm	0,2	4,000	9,4	2,484
Left Femur Compression level exceeded - kN	0,13	4,000	2,2	4,000
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Left Knee, Femur and Pelvis Assessment		4,000		2,484
Right Knee Slide - mm	0,0	4,000	0,3	4,000
Right Femur Compression level exceeded - kN	0,08	4,000	0,8	4,000
duration of exceedence - ms	0		0,0	
Variable contact (-1)		0,000		0,000
Concentrated loading (-1)		0,000		0,000
Incorrect airbag deployment		0,000		0,000
Right Knee, Femur and Pelvis Assessment		4,000		4,000
Knee, Femur and Pelvis assessment		4,000		2,484
LOWER LEG				
Left compression - kN	1,35	4,000	1,76	4,000
Left Upper Tibia Index	0,31	4,000	0,42	3,911
Left Lower Tibia Index	0,12	4,000	0,26	4,000
Brake pedal vertical (-1) mm	-53	0,000		
Left Lower Leg assessment		4,000		3,911
Right compression - kN	0,94	4,000	1,23	4,000
Right Upper Tibia Index	0,25	4,000	0,19	4,000
Right Lower Tibia Index	0,15	4,000	0,10	4,000
Brake pedal vertical (-1) mm	-53	0,000		
Right Lower Leg assessment		4,000		4,000
FOOT and ANKLE				
Brake pedal horizontal displacement - mm	-58	4,000		
Footwell Rupture (-1)		0,000		
Pedal Blocking (-1)	22	0,000		
Foot and Ankle assessment		4,000		
Lower Leg, Foot and Ankle assessment		4,000		3,911

PDB left impact test on SUV 1
Comparison results with Euro NCAP

PDB results (IDIADA)

Driver Passenger

Euro NCAP modifiers not applied

SUMMARY	Driver	Passenger
Head and Neck assessment	4,000	4,000
Chest assessment	2,266	3,389
Knee, Femur and Pelvis assessment	4,000	2,484
Lower Leg, Foot and Ankle Assessment	4,000	3,911
TOTAL	14,266	13,784
Door Opening	0,00	
TOTAL FRONTAL	**12,661**	

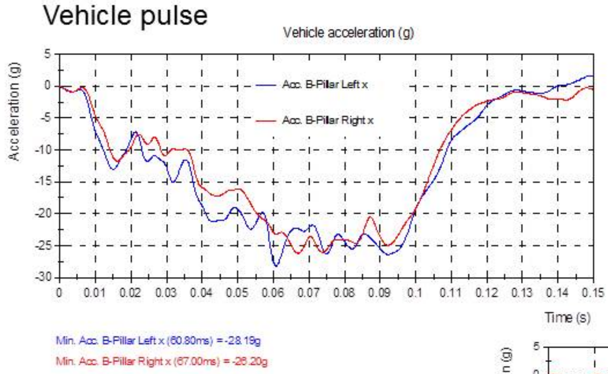
ODB results (Euro NCAP)

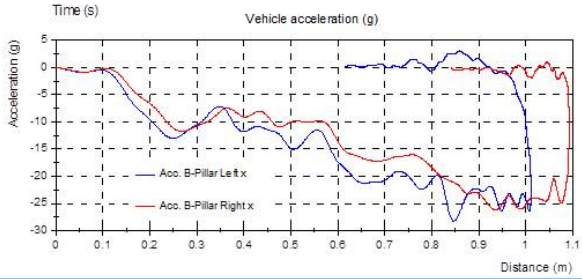
Frontal impact driver *Frontal impact passenger*

Euro NCAP modifiers applied

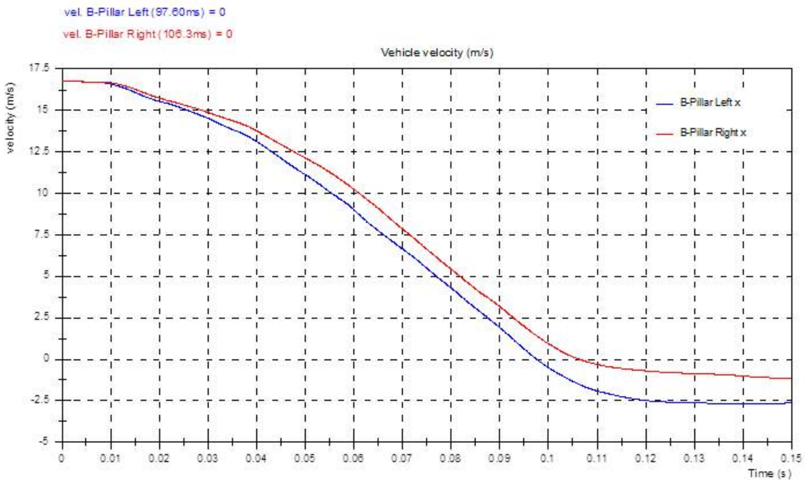
TOTAL FRONTAL 13,1

SUV 1 PDB Test
Vehicle pulse





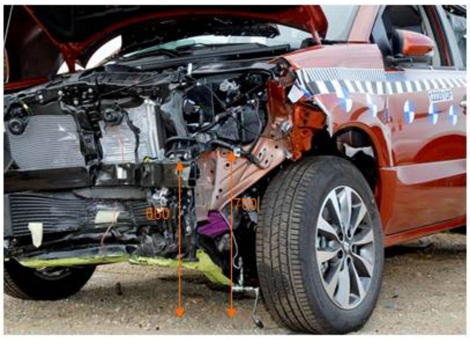
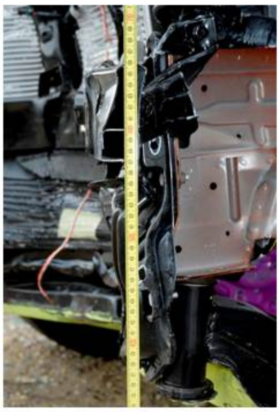
SUV 1 PDB Test
Vehicle velocity



SUV 1 PDB Test
Post-Test photos




SUV 1 PDB Test
Post-Test photos (measurements)


SUV 1 PDB Test
Barrier scan procedure

SUV 1 PDB Test
Barrier deformation

SUV 1 PDB Test
Conclusions

- Dummies injuries below R94 limits
- A-Pillar waistline only 2 mm rearward displacement
- PDB scan to be further analysed

ANNEX F: ARTIFICIAL PROFILES

Department of Automotive Engineering

FIMCAR

Artificial PDB Profiles

frontal impact and compatibility assessment research

- **To represent different vehicle widths two average values calculated with data from the structural database were used**
  - **Super Mini car: avarage width = 1652mm ➔ y_{min} = 274mm**
  - **Off Road car: avarage width = 1842mm ➔ y_{min} = 179mm**

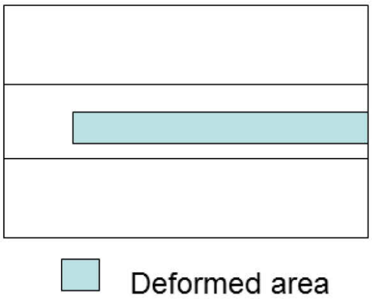
FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

- **PDB assessment metrics**
  - **BDA software v1.0**
  - **Homogeneity value (TV upgraded)**
    - A_{def}(40%)
    - Assessment of middle and lower area ➔ z_{min} = 30mm & z_{max} = 450mm
  - **DDY**
    - 60% of vehicle width
    - Assessment area w.r.t. LCW Row 3 and Row 4 (330mm-580mm) ➔ z_{min} = 180mm & z_{max} = 430mm
    - 99%ile DDY

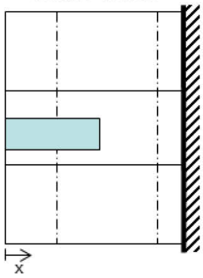
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

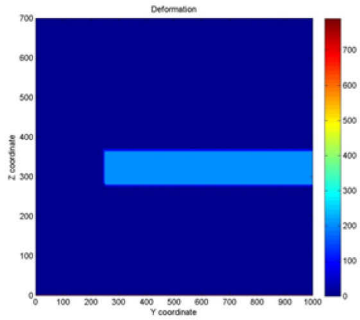
Profile 1

Front view



Side view





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	24	295	2	23	2	295	1.1	139	0	5258	5.1
179	24	295	2	23	2	295	1.1	139	0	5753	5.1

BDA software

y_{min}	M area + L area
274	13,784,463
179	13,656,662

Homogeneity value

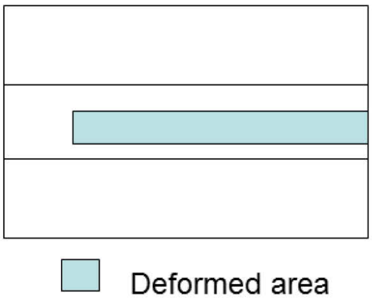
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

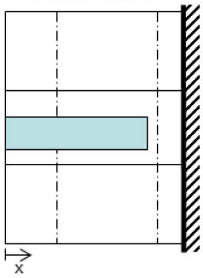
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

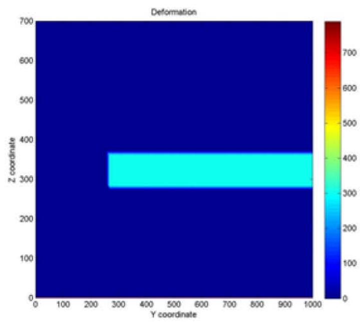
Profile 2

Front view



Side view





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	30	395	2	23	2	395	1.1	139	0	5264	5.1
179	30	395	2	23	2	395	1.1	139	0	5680	5.1

BDA software

y_{min}	M area + L area
274	10,279,939
179	9,916,783

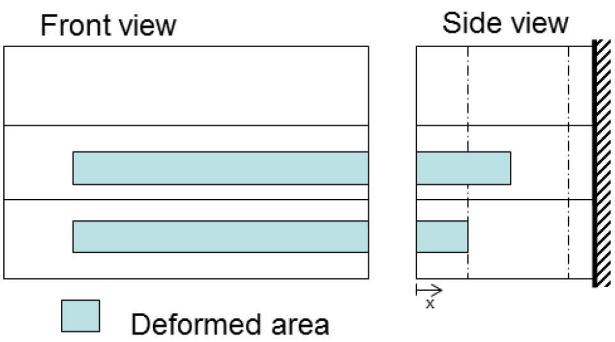
Homogeneity value

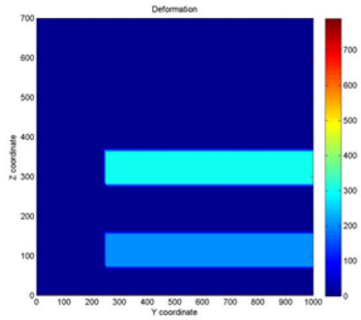
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Department of Automotive Engineering

Profile 3





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	51	395	2	23	2	395	2	295	0	5260	6
179	51	395	2	23	2	395	2	395	0	5755	6

BDA software

y_{min}	M area + L area
274	23,747,366
179	23,561,656

Homogeneity value

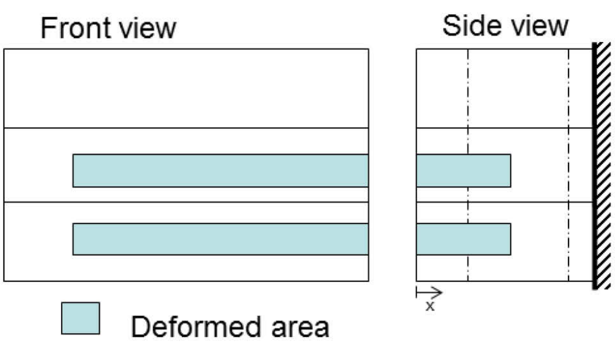
y_{min}	Row 3 + Row 4
274	0
179	0

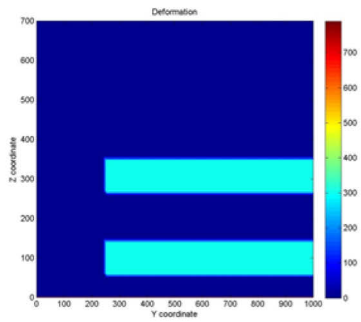
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 6

Department of Automotive Engineering

Profile 4





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	57	395	2	23	2	395	2	395	0	5240	6
179	57	395	2	23	2	395	2	395	0	5735	6

BDA software

y_{min}	M area + L area
274	20,559,878
179	20,366,140

Homogeneity value

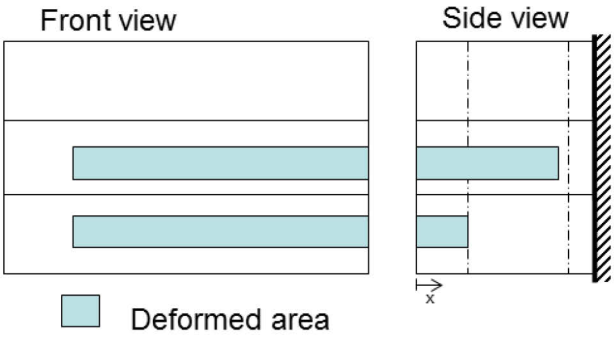
y_{min}	Row 3 + Row 4
274	0
179	0

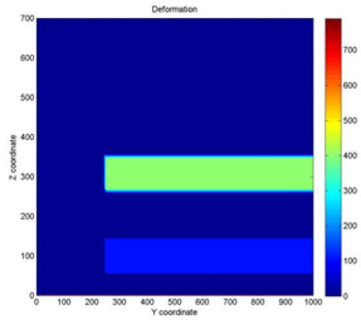
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 7

Department of Automotive Engineering

Profile 5





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	51	495	2	23	0.9	495	1.6	195	0	5241	4.5
179	51	495	2	23	0.9	495	1.6	195	0	5735	4.5

BDA software

y_{min}	M area + L area
274	8,196,167
179	8,119,866

Homogeneity value

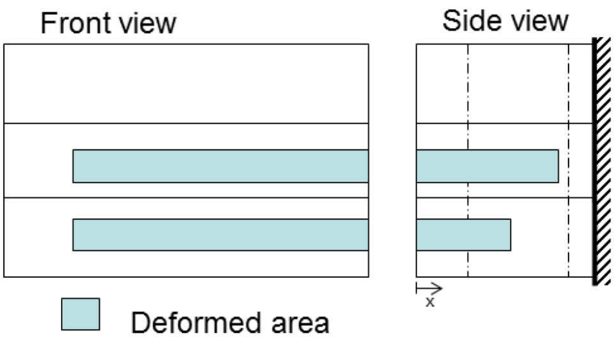
y_{min}	Row 3 + Row 4
274	0
179	0

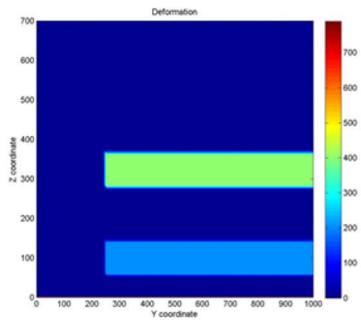
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 8

Department of Automotive Engineering

Profile 6





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	57	495	2	23	0.9	495	2	295	0	5261	4.9
179	57	495	2	23	0.9	495	2	295	0	5756	4.9

BDA software

y_{min}	M area + L area
274	21,579,290
179	21,352,871

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

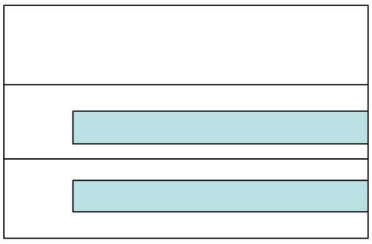
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 9

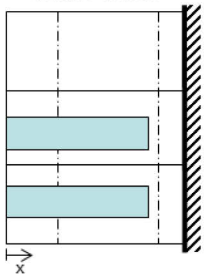
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

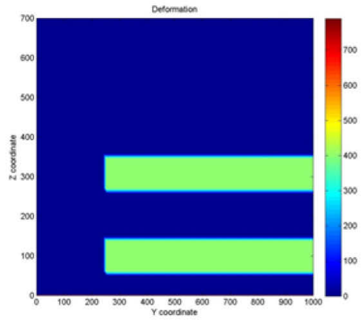
Profile 7

Front view



Side view





Deformed area

y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	71	495	2	23	0.9	495	1.5	495	0	5241	4.5
179	71	495	2	23	0.9	495	1.5	495	0	5737	4.5

BDA software

y_{min}	M area + L area
274	16,392,335
179	16,237,387

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

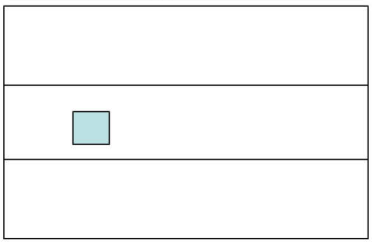
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 10

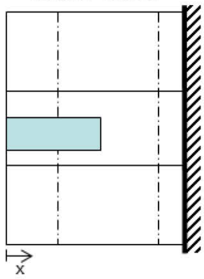
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

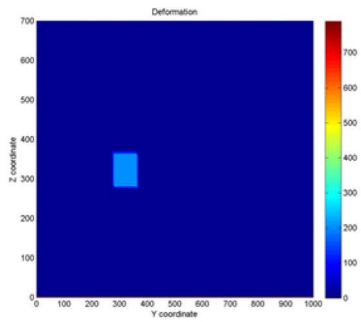
Profile 8

Front view



Side view





Deformed area

y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	7	295	2	23	2	295	1.1	139	0	3738	5.1
179	7	295	2	23	2	295	1.1	139	0	4109	5.1

BDA software

y_{min}	M area + L area
274	1,236,732
179	1,237,340

Homogeneity value

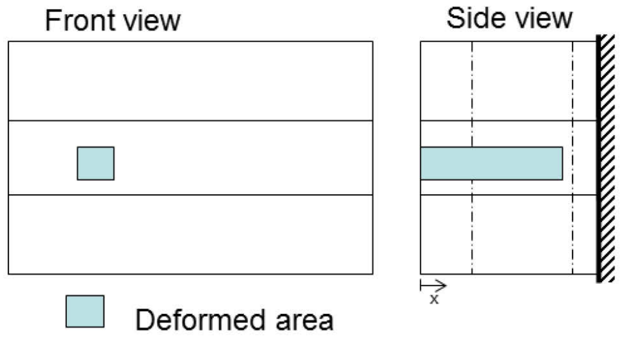
y_{min}	Row 3 + Row 4
274	0
179	0

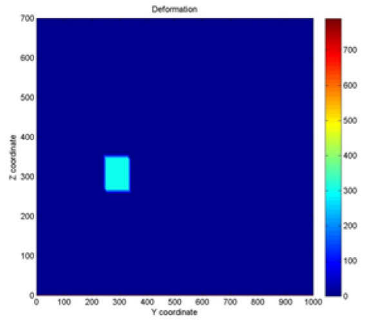
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 11

Department of Automotive Engineering

Profile 9





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	7	395	2	23	2	395	1.1	139	0.3	2951	5.4
179	7	395	2	23	2	395	1.1	139	0	4108	5.1

BDA software

y_{min}	M area + L area
274	725,859
179	922,839

Homogeneity value

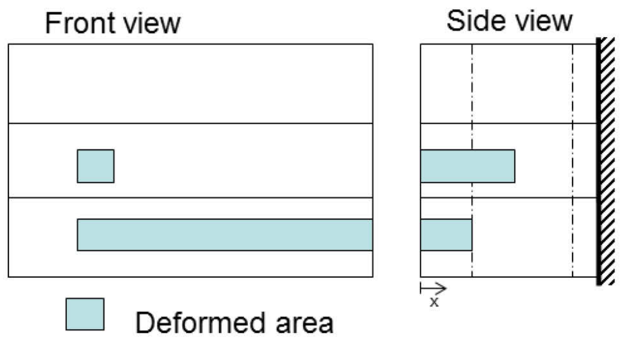
y_{min}	Row 3 + Row 4
274	0
179	0

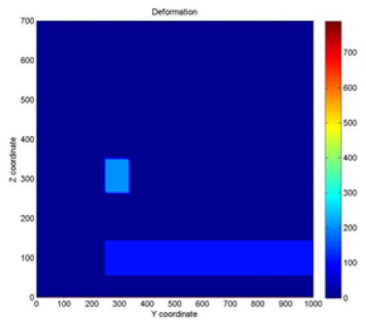
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 12

Department of Automotive Engineering

Profile 10





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	20	295	2	23	2	295	1.6	195	0.3	2950	5.9
179	20	295	2	23	2	295	1.6	195	0	4106	5.6

BDA software

y_{min}	M area + L area
274	21,865,918
179	20,952,283

Homogeneity value

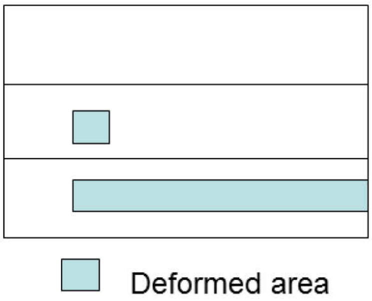
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

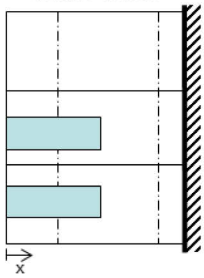
Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 13

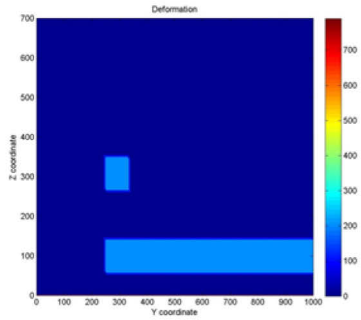
Profile 11

Front view



Side view





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	26	295	2	23	2	295	2	295	0.3	2950	6.3
179	26	295	2	23	2	295	2	295	0	4106	6

BDA software

y_{min}	M area + L area
274	14,498,970
179	14,433,905

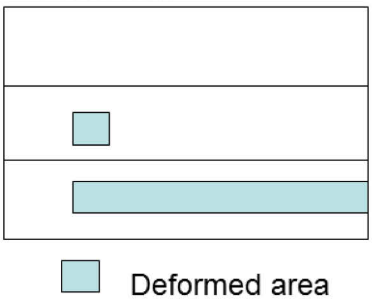
Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

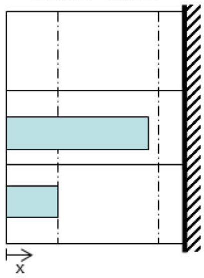
DDY

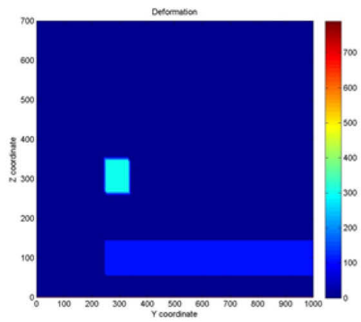
Profile 12

Front view



Side view





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	21	395	2	23	2	395	1.6	195	0.3	2951	5.9
179	21	395	2	23	2	395	1.6	195	0	4108	5.6

BDA software

y_{min}	M area + L area
274	25,464,133
179	22,497,779

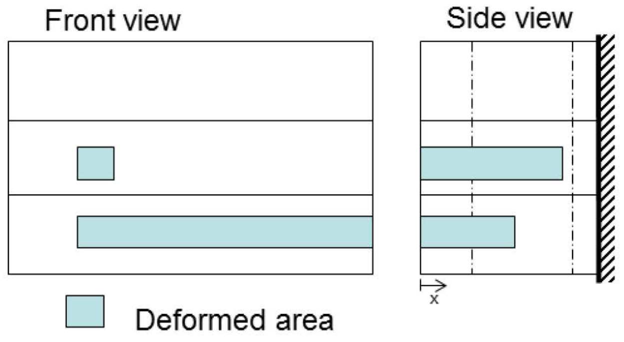
Homogeneity value

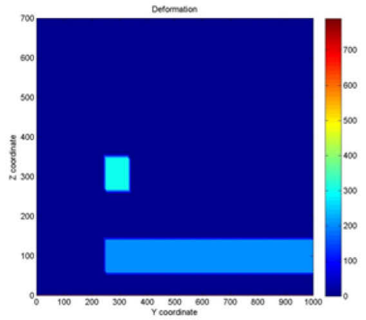
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Department of Automotive Engineering

Profile 13





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	27	395	2	23	2	395	2	295	0.3	2951	6.3
179	27	395	2	23	2	395	2	295	0	4108	6

BDA software

y_{min}	M area + L area
274	14,085,462
179	13,736,080

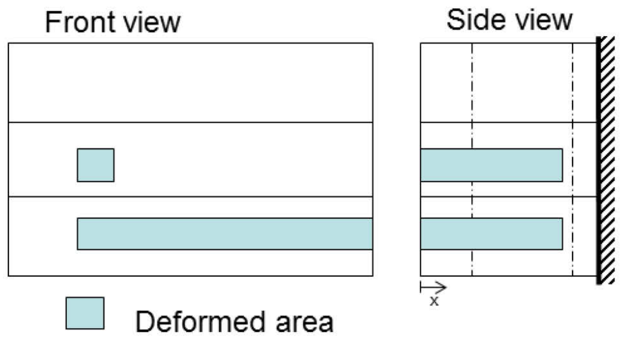
Homogeneity value

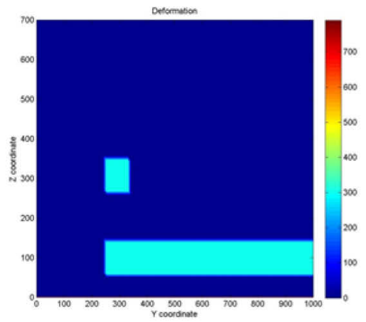
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Department of Automotive Engineering

Profile 14





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	34	395	2	23	2	395	2	395	0.3	2951	6.3
179	34	395	2	23	2	395	2	395	0	4108	6

BDA software

y_{min}	M area + L area
274	10,812,289
179	10,766,022

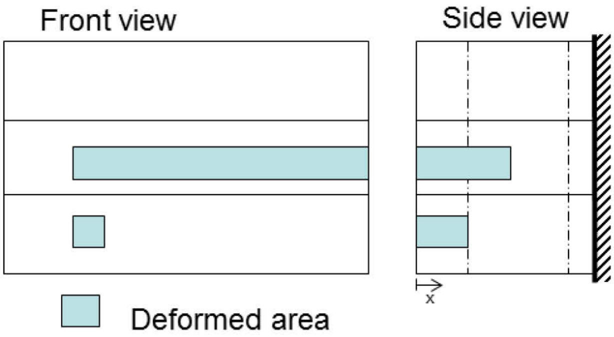
Homogeneity value

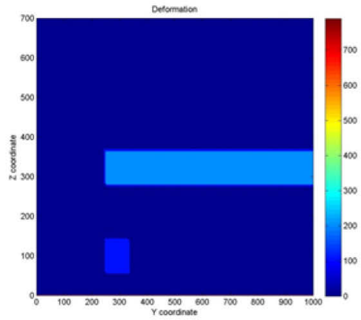
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Department of Automotive Engineering

Profile 15





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	26	295	2	23	2	295	1.6	195	0	5258	5.6
179	26	295	2	23	2	295	1.6	195	0	5753	5.6

BDA software

y_{min}	M area + L area
274	15,396,278
179	15,724,373

Homogeneity value

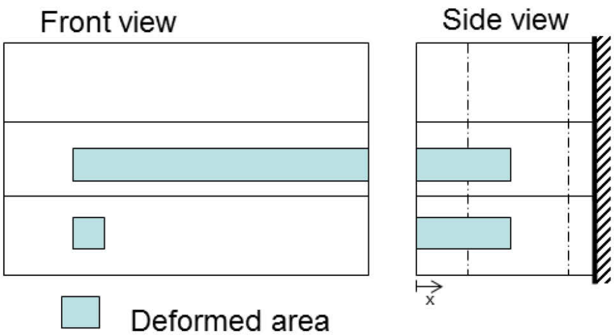
y_{min}	Row 3 + Row 4
274	0
179	0

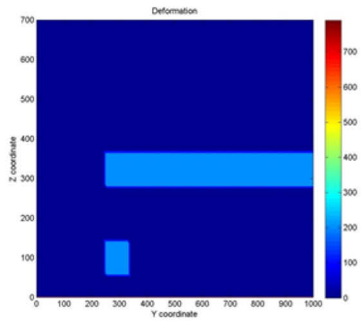
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 18

Department of Automotive Engineering

Profile 16





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	26	295	2	23	2	295	2	295	0	5258	6
179	26	295	2	23	2	295	2	295	0	5753	6

BDA software

y_{min}	M area + L area
274	14,501,685
179	14,440,103

Homogeneity value

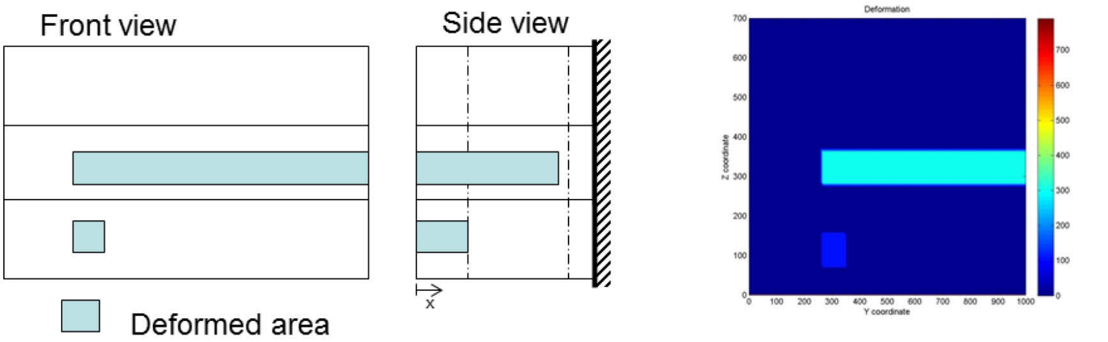
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 19

Department of Automotive Engineering

Profile 17



y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	32	395	2	23	2	395	1.6	195	0	5264	5.6
179	32	395	2	23	2	395	1.6	195	0	5680	5.6

BDA software

y_{min}	M area + L area
274	12,223,898
179	11,890,413

Homogeneity value

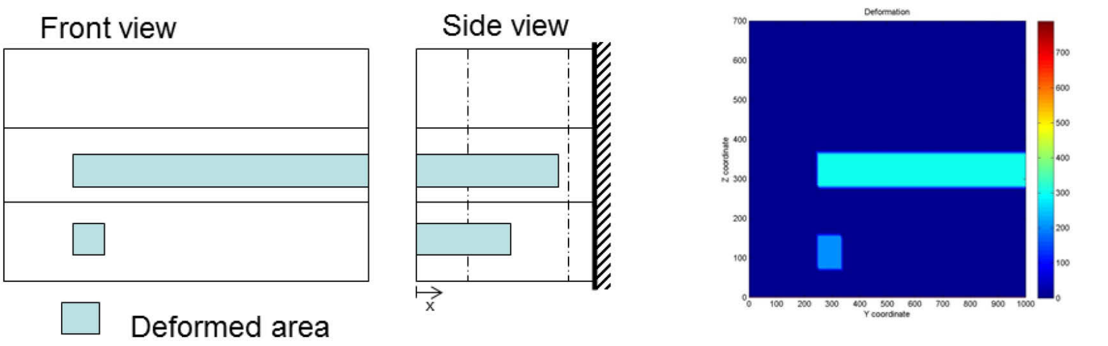
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 20

Department of Automotive Engineering

Profile 18



y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	33	395	2	23	2	395	2	295	0	5260	6
179	33	395	2	23	2	395	2	295	0	5755	6

BDA software

y_{min}	M area + L area
274	11,315,870
179	11,479,789

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

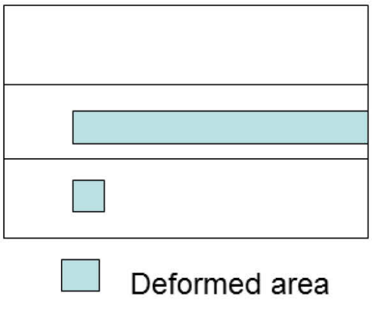
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 21

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

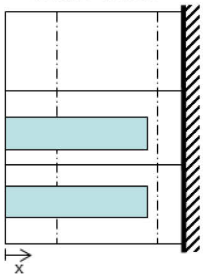
Profile 19

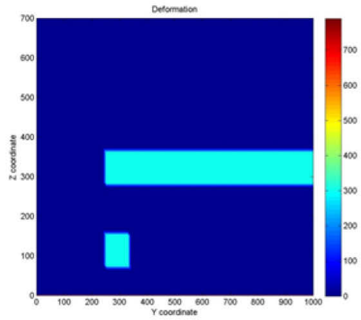
Front view



Deformed area

Side view





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	34	395	2	23	2	395	2	395	0	5260	6
179	34	395	2	23	2	395	2	395	0	5755	6

BDA software

y_{min}	M area + L area
274	10,814,675
179	10,768,078

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

DDY

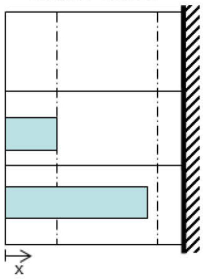
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

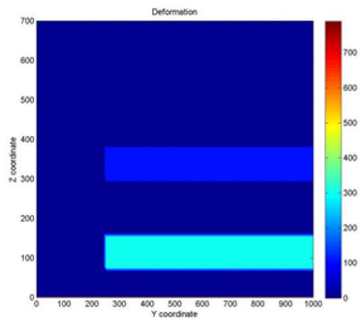
Profile 20

Front view

Deformed area

Side view





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
274	44	395	2	23	1.6	195	2	395	0	5254	5.6
179	44	395	2	23	1.6	195	2	395	0	5748	5.6

BDA software

y_{min}	M area + L area
274	29,508,035
179	29,114,740

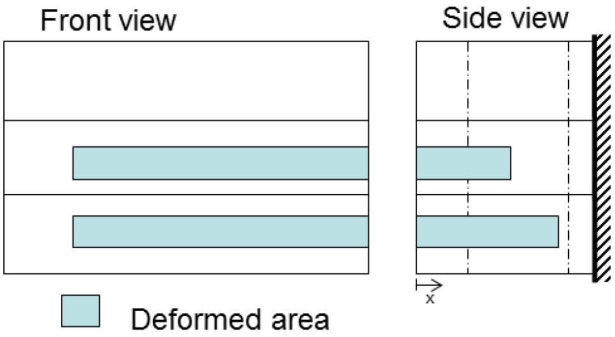
Homogeneity value

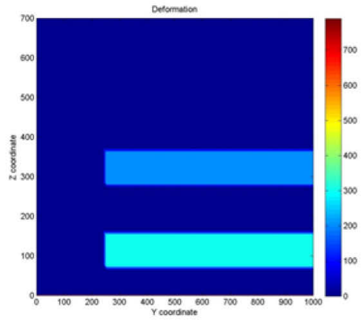
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Department of Automotive Engineering

Profile 21





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	51	395	2	23	2	295	2	395	0	5258	6
179	51	395	2	23	2	295	2	395	0	5753	6

BDA software

y_{min}	M area + L area
274	23,674,984
179	23,485,518

Homogeneity value

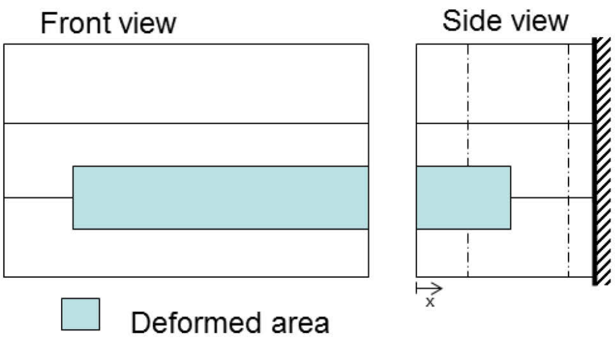
y_{min}	Row 3 + Row 4
274	0
179	0

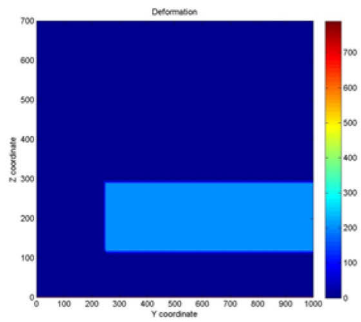
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 24

Department of Automotive Engineering

Profile 22





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	44	295	2	23	2	295	2	295	0.7	2527	6.7
179	44	295	2	23	2	295	2	295	0.3	2979	6.3

BDA software

y_{min}	M area + L area
274	53,354,537
179	49,439,924

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

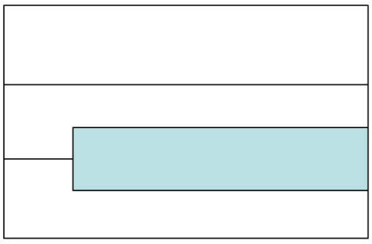
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 25

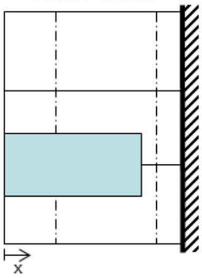
Department of Automotive Engineering

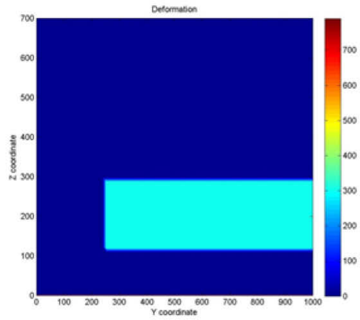
Profile 23

Front view



Side view





Deformed area

y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	58	395	2	23	2	395	2	395	0.7	2528	6.7
179	58	395	2	23	2	395	2	395	0.3	2980	6.3

BDA software

y_{min}	M area + L area
274	39,789,825
179	36,868,765

Homogeneity value

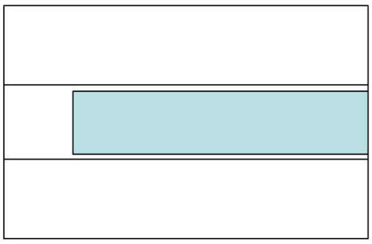
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

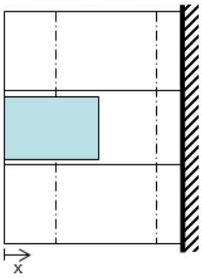
Department of Automotive Engineering

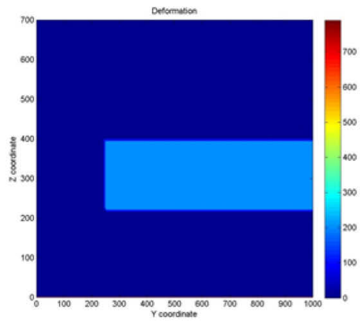
Profile 24

Front view



Side view





Deformed area

y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	44	295	2	23	2	295	1.1	139	0	3648	5.1
179	44	295	2	23	2	295	1.1	139	0	4269	5.1

BDA software

y_{min}	M area + L area
274	53,945,719
179	49,987,650

Homogeneity value

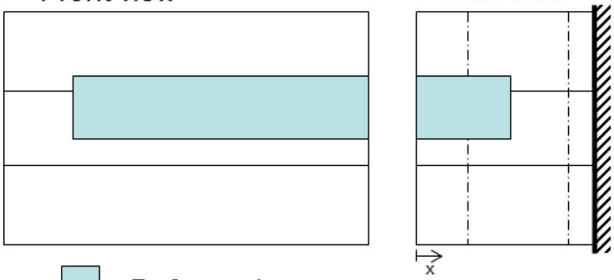
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

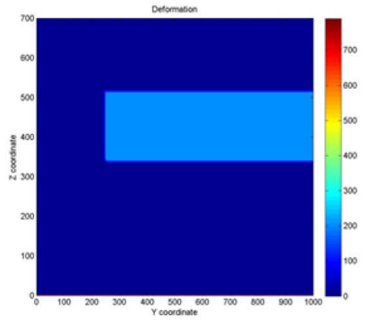
Department of Automotive Engineering

Profile 25

Front view | Side view



Deformed area



y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	44	295	1.8	295	2	295	1.1	139	0.9	2286	5.7
179	44	295	1.8	195	2	295	1.1	139	0.5	2761	5.3

BDA software

y_{min}	M area + L area
274	43,076,448
179	38,638,517

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

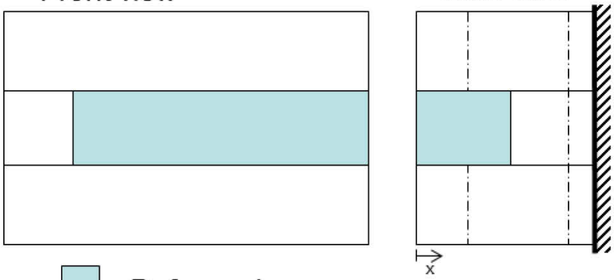
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 28

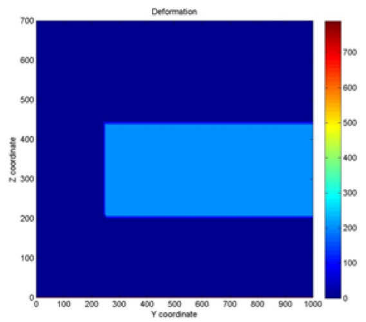
Department of Automotive Engineering

Profile 26

Front view | Side view



Deformed area



y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	57	295	2	23	2	295	1.1	139	0.5	2730	5.6
179	57	295	2	23	2	295	1.1	139	0	3418	5.1

BDA software

y_{min}	M area + L area
274	94,590,668
179	84,020,634

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

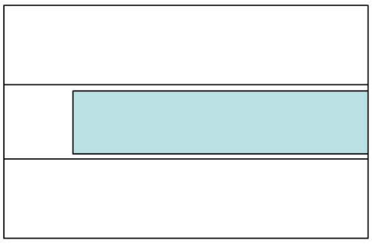
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 29

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

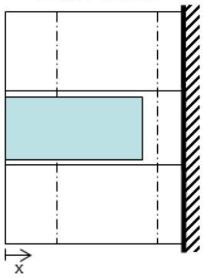
Profile 27

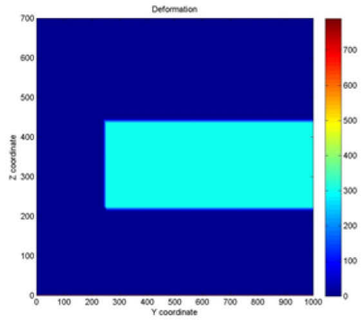
Front view



Deformed area

Side view





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	71	395	2	23	2	395	1.1	139	0.1	3208	5.2
179	71	395	2	23	2	395	1.1	139	0	3892	5.1

BDA software

y_{min}	M area + L area
274	62,034,281
179	55,677,304

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

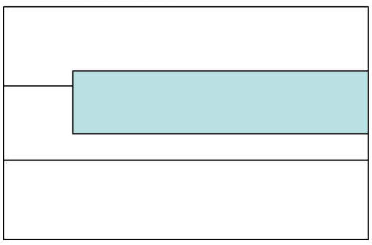
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 30

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

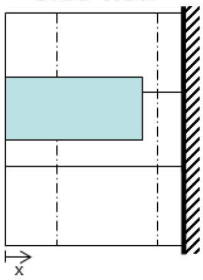
Profile 28

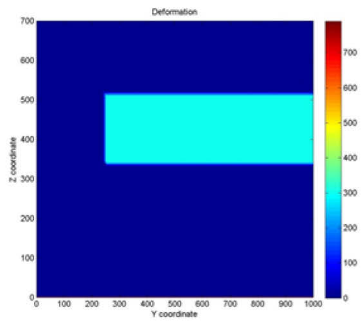
Front view



Deformed area

Side view





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	57	395	0.1	395	2	395	1.1	139	0.9	2287	4.1
179	57	395	0.1	395	2	395	1.1	139	0.5	2762	3.7

BDA software

y_{min}	M area + L area
274	32,124,809
179	28,814,103

Homogeneity value

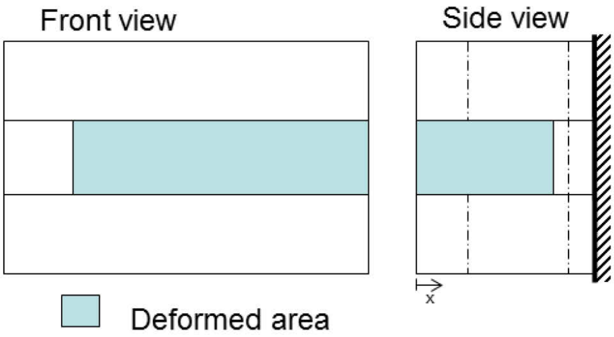
y_{min}	Row 3 + Row 4
274	0
179	0

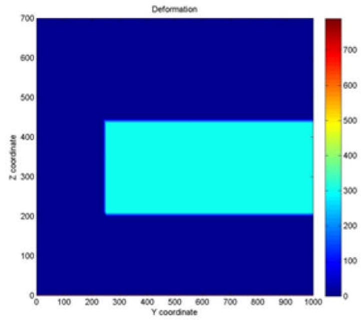
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 31

Department of Automotive Engineering

Profile 29





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	75	395	2	23	2	395	1.1	139	0.5	2731	5.6
179	75	395	2	23	2	395	1.1	139	0	3419	5.1

BDA software

y_{min}	M area + L area
274	70,542,193
179	62,656,710

Homogeneity value

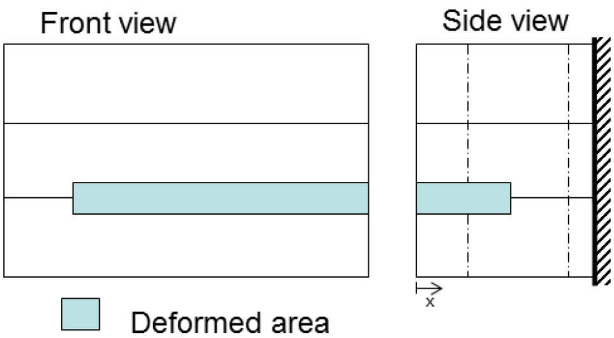
y_{min}	Row 3 + Row 4
274	0
179	0

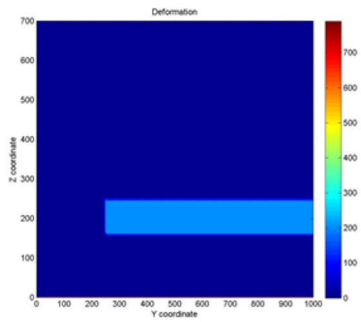
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 32

Department of Automotive Engineering

Profile 30





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	24	295	2	23	2	295	2	295	0	3571	6
179	24	295	2	23	2	295	2	295	0	3936	6

BDA software

y_{min}	M area + L area
274	13,784,463
179	13,656,623

Homogeneity value

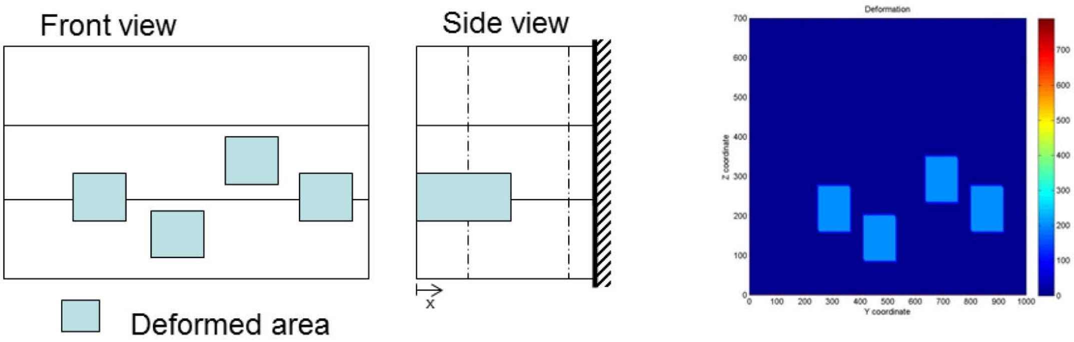
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 33

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

Profile 31



y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	21	295	2	23	2	295	2	295	0	5560	6
179	21	295	2	23	2	295	2	295	0	5984	6

BDA software

y_{min}	M area + L area
274	9,142,383
179	9,449,795

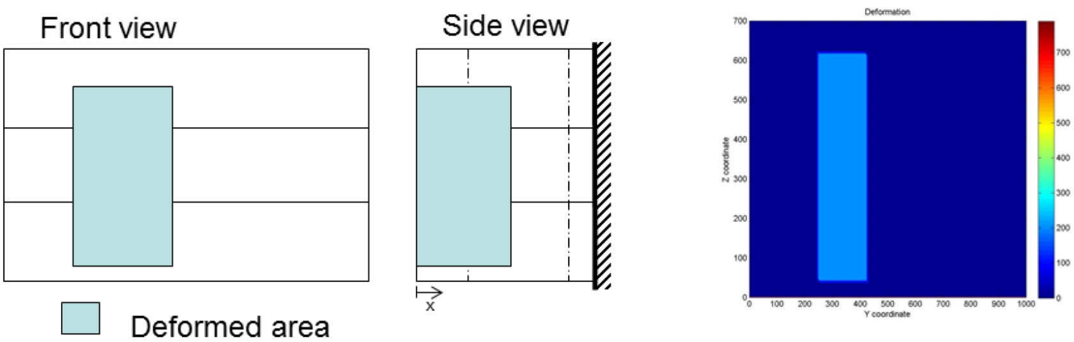
Homogeneity value

y_{min}	Row 3 + Row 4
274	20.1
179	20.1

DDY

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

Profile 32



y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	35	295	1.8	295	2	295	2	295	1.8	1297	7.5
179	35	295	1.8	295	2	295	2	295	0.8	2406	6.5

BDA software

y_{min}	M area + L area
274	40,496,337
179	32,291,821

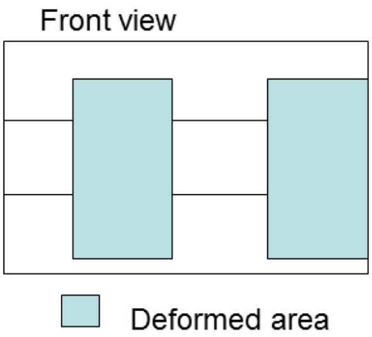
Homogeneity value

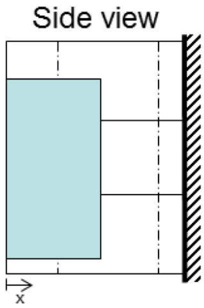
y_{min}	Row 3 + Row 4
274	0
179	0

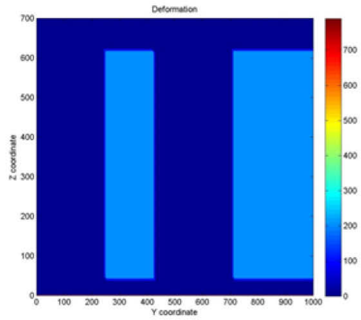
DDY

Department of Automotive Engineering

Profile 33







y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	85	295	1.8	295	2	295	2	295	1.3	1866	7
179	85	295	1.8	295	2	295	2	295	0.5	2690	6.3

BDA software

y_{min}	M area + L area
274	76,604,559
179	66,378,693

Homogeneity value

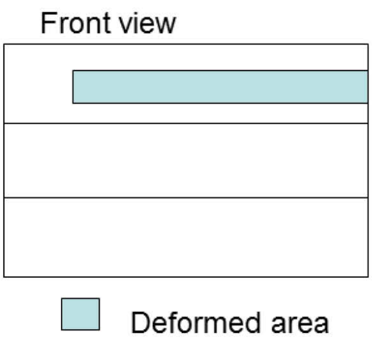
y_{min}	Row 3 + Row 4
274	20.1
179	20.1

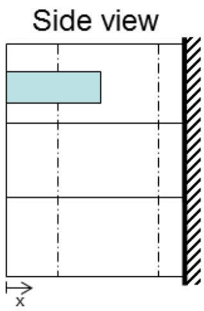
DDY

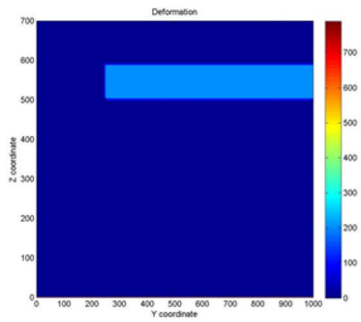
Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 36

Department of Automotive Engineering

Profile 34







y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	24	138	1.8	295	0	0	1.1	139	2	0	4.9
179	24	138	1.8	295	0	0	1.1	139	2	0	4.9

BDA software

y_{min}	M area + L area
274	0
179	0

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

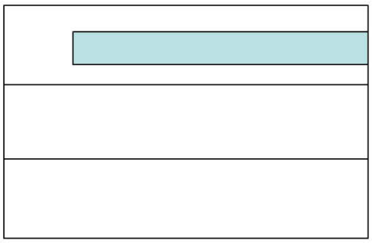
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 37

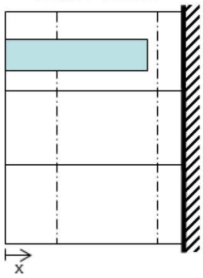
Department of Automotive Engineering

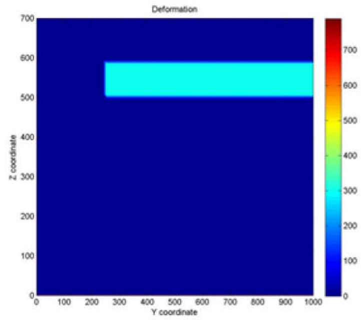
Profile 35

Front view



Side view





Deformed area

y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	31	184	0.1	395	0	0	1.1	139	2	0	3.2
179	31	184	0.1	395	0	0	1.1	139	2	0	3.2

BDA software

y_{min}	M area + L area
274	0
179	0

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

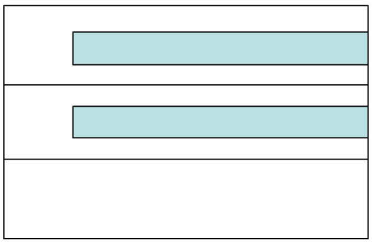
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 38

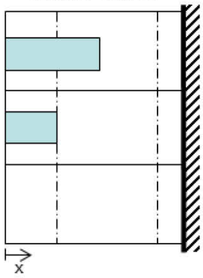
Department of Automotive Engineering

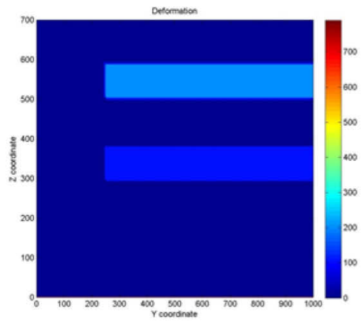
Profile 36

Front view



Side view





Deformed area

y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	37	195	1.8	295	1.6	195	1.1	139	0	5254	4.4
179	37	195	1.8	295	1.6	195	1.1	139	0	5748	4.4

BDA software

y_{min}	M area + L area
274	20,914,358
179	20,722,533

Homogeneity value

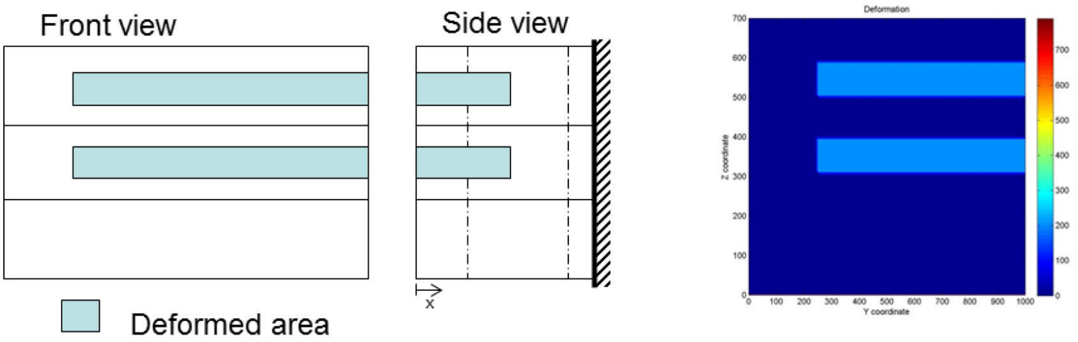
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 39

Department of Automotive Engineering

Profile 37



y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	44	295	1.8	295	2	295	1.1	139	0	5258	4.9
179	44	295	1.8	295	2	295	1.1	139	0	5740	4.9

BDA software

y_{min}	M area + L area
274	14,085,754
179	13,951,111

Homogeneity value

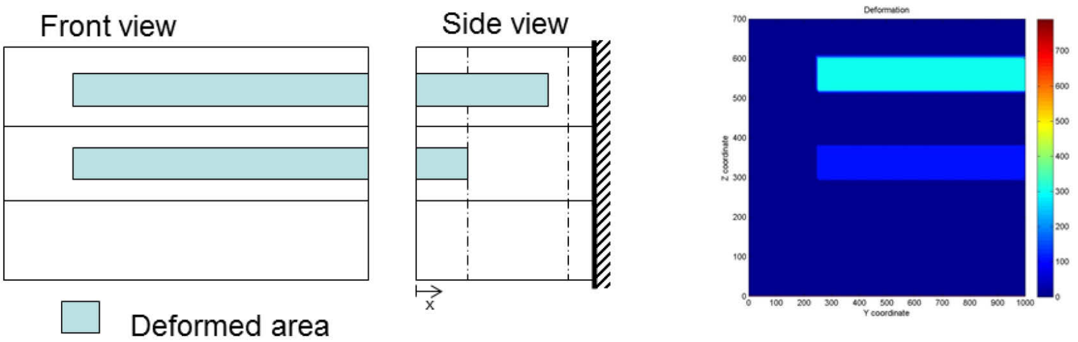
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 40

Department of Automotive Engineering

Profile 38



y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	44	195	0.1	395	1.6	195	1.1	139	0	5254	2.8
179	44	195	0.1	395	1.6	195	1.1	139	0	5748	2.8

BDA software

y_{min}	M area + L area
274	20,914,358
179	20,722,533

Homogeneity value

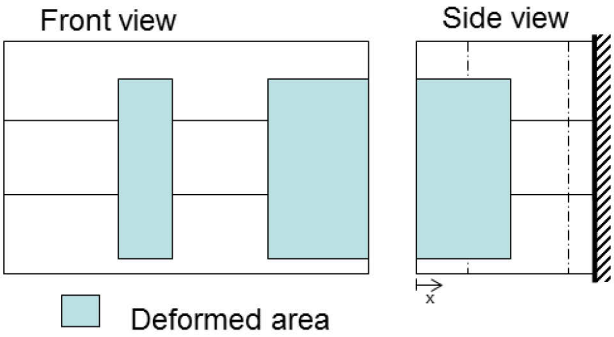
y_{min}	Row 3 + Row 4
274	0
179	0

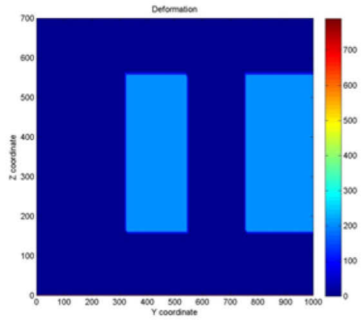
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 41

Department of Automotive Engineering

Profile 39





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	60	295	1.8	295	2	295	2	295	0.5	2690	6.3
179	60	295	1.8	295	2	295	2	295	0.5	2690	6.3

BDA software

y_{min}	M area + L area
274	20,914,358
179	43,597,516

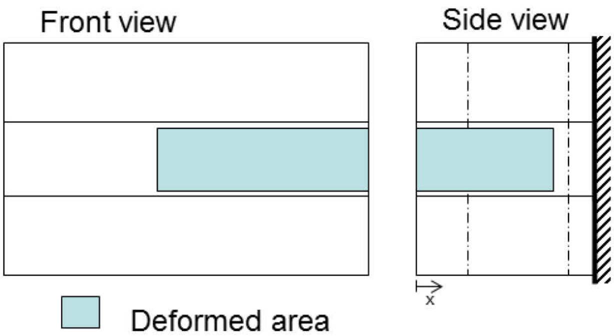
Homogeneity value

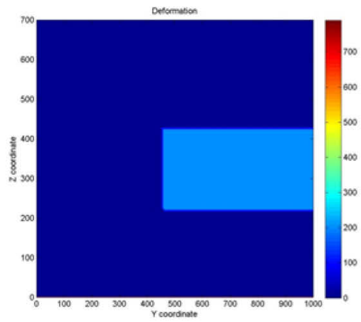
y_{min}	Row 3 + Row 4
274	20.1
179	20.1

DDY

Department of Automotive Engineering

Profile 40





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	38	295	2	23	2	295	1.1	139	0	3506	5.1
179	38	295	2	23	2	295	1.1	139	0	3506	5.1

BDA software

y_{min}	M area + L area
274	40,195,514
179	40,215,247

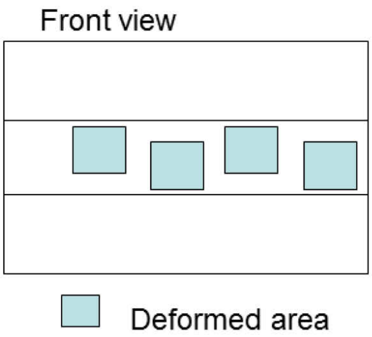
Homogeneity value

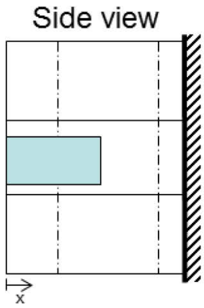
y_{min}	Row 3 + Row 4
274	0
179	20.1

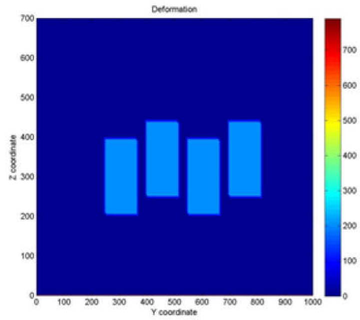
DDY

Department of Automotive Engineering

Profile 41







y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	32	295	2	23	2	295	1.1	139	0	7485	5.1
179	32	295	2	23	2	295	1.1	139	0	8076	5.1

BDA software

y_{min}	M area + L area
274	21,301,336
179	21,714,007

Homogeneity value

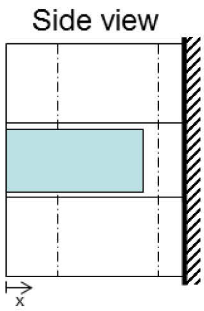
y_{min}	Row 3 + Row 4
274	20.1
179	20.1

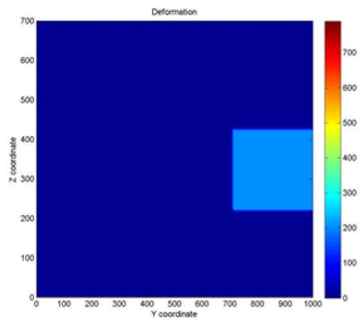
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 44

Department of Automotive Engineering

Profile 42





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	22	295	2	23	2	295	1.1	139	0.4	2864	5.5
179	22	295	2	23	2	295	1.1	139	0.4	2864	5.5

BDA software

y_{min}	M area + L area
274	10,764,362
179	10,769,647

Homogeneity value

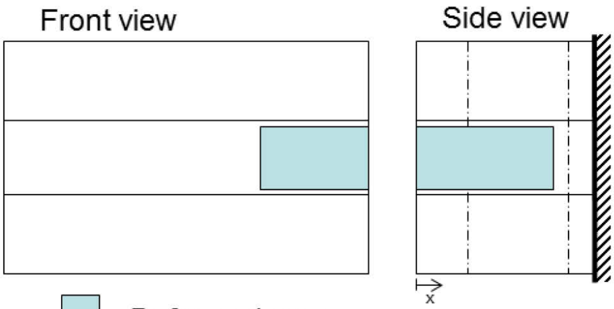
y_{min}	Row 3 + Row 4
274	20.1
179	20.1

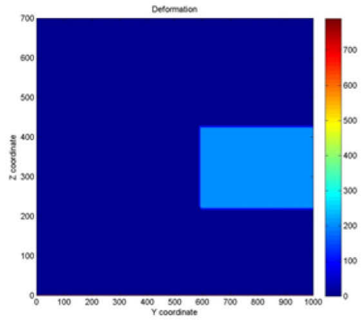
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 45

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

Profile 43





Deformed area

y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	30	295	2	23	2	295	1.1	139	0.1	3153	5.2
179	30	295	2	23	2	295	1.1	139	0.1	3153	5.2

BDA software

y_{min}	M area + L area
274	24,082,267
179	24,094,090

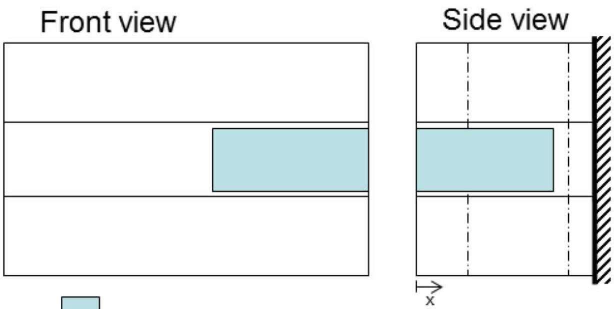
Homogeneity value

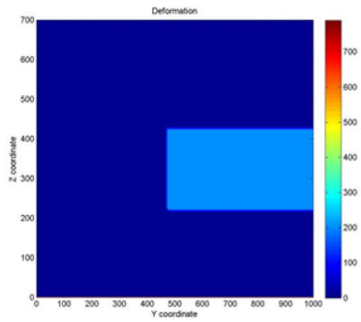
y_{min}	Row 3 + Row 4
274	20.1
179	20.1

DDY

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

Profile 44





Deformed area

y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	37	295	2	23	2	295	1.1	139	0	3467	5.1
179	37	295	2	23	2	295	1.1	139	0	3467	5.1

BDA software

y_{min}	M area + L area
274	38,380,647
179	38,399,489

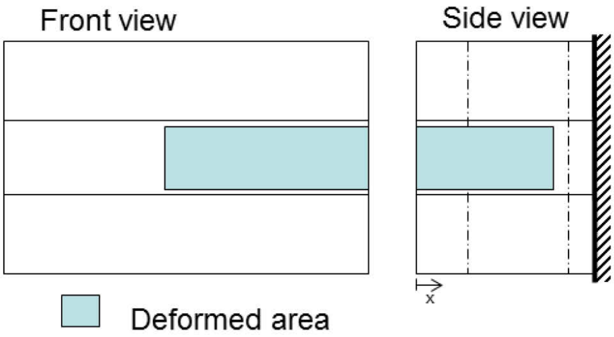
Homogeneity value

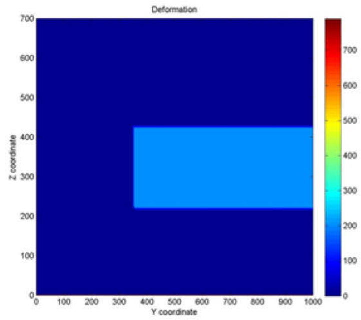
y_{min}	Row 3 + Row 4
274	0
179	20.1

DDY

Department of Automotive Engineering

Profile 45





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	44	295	2	23	2	295	1.1	139	0	3774	5.1
179	44	295	2	23	2	295	1.1	139	0	3774	5.1

BDA software

y_{min}	M area + L area
274	52,808,370
179	52,834,295

Homogeneity value

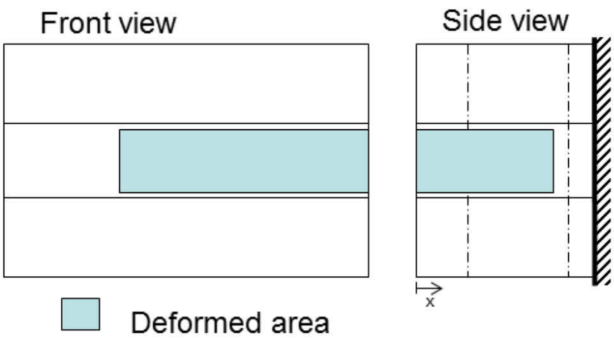
y_{min}	Row 3 + Row 4
274	0
179	0

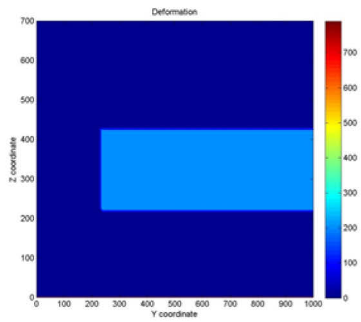
DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 48

Department of Automotive Engineering

Profile 46





y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	52	295	2	23	2	295	1.1	139	0	3368	5.1
179	52	295	2	23	2	295	1.1	139	0	4070	5.1

BDA software

y_{min}	M area + L area
274	72,506,864
179	67,413,612

Homogeneity value

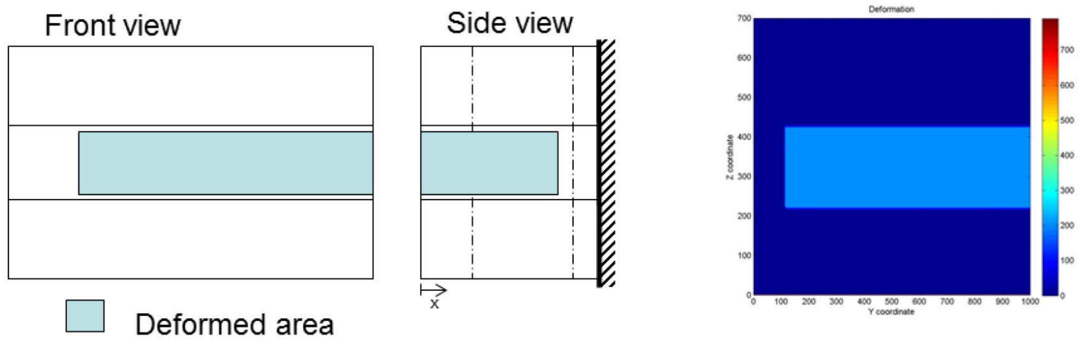
y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 49

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

Profile 47



y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
274	59	295	2	23	2	295	1.1	139	0	3368	5.1
179	59	295	2	23	2	295	1.1	139	0	3635	5.1

BDA software

y_{min}	M area + L area
274	72,506,864
179	84,465,461

Homogeneity value

y_{min}	Row 3 + Row 4
274	0
179	0

DDY

Mathias Stein FIMCAR – WP 2 – Artificial PDB Profiles 50

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

PDB metric results

- **Summary of BDA assessment:**

profile	y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
1	274	24	295	2	23	2	295	1.1	139	0	5258	5.1
	179	24	295	2	23	2	295	1.1	139	0	5753	5.1
2	274	30	395	2	23	2	395	1.1	139	0	5264	5.1
	179	30	395	2	23	2	395	1.1	139	0	5680	5.1
3	274	51	395	2	23	2	395	2	295	0	5260	6
	179	51	395	2	23	2	395	2	395	0	5755	6
4	274	57	395	2	23	2	395	2	395	0	5240	6
	179	57	395	2	23	2	395	2	395	0	5735	6
5	274	51	495	2	23	0.9	495	1.6	195	0	5241	4.5
	179	51	495	2	23	0.9	495	1.6	195	0	5735	4.5
6	274	57	495	2	23	0.9	495	2	295	0	5261	4.9
	179	57	495	2	23	0.9	495	2	295	0	5756	4.9
7	274	71	495	2	23	0.9	495	1.5	495	0	5241	4.5
	179	71	495	2	23	0.9	495	1.5	495	0	5737	4.5
8	274	7	295	2	23	2	295	1.1	139	0	3738	5.1
	179	7	295	2	23	2	295	1.1	139	0	4109	5.1
9	274	7	395	2	23	2	395	1.1	139	0.3	2951	5.4
	179	7	395	2	23	2	395	1.1	139	0	4108	5.1
10	274	20	295	2	23	2	295	1.6	195	0.3	2950	5.9
	179	20	295	2	23	2	295	1.6	195	0	4106	5.6

Department of Automotive Engineering

PDB metric results

- **Summary of BDA assessment:**

profile	y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
11	274	26	295	2	23	2	295	2	295	0.3	2950	6.3
	179	26	295	2	23	2	295	2	295	0	4106	6
12	274	21	395	2	23	2	395	1.6	195	0.3	2951	5.9
	179	21	395	2	23	2	395	1.6	195	0	4108	5.6
13	274	27	395	2	23	2	395	2	295	0.3	2951	6.3
	179	27	395	2	23	2	395	2	295	0	4108	6
14	274	34	395	2	23	2	395	2	395	0.3	2951	6.3
	179	34	395	2	23	2	395	2	395	0	4108	6
15	274	26	295	2	23	2	295	1.6	195	0	5258	5.6
	179	26	295	2	23	2	295	1.6	195	0	5753	5.6
16	274	26	295	2	23	2	295	2	295	0	5258	6
	179	26	295	2	23	2	295	2	295	0	5753	6
17	274	32	395	2	23	2	395	1.6	195	0	5264	5.6
	179	32	395	2	23	2	395	1.6	195	0	5680	5.6
18	274	33	395	2	23	2	395	2	295	0	5260	6
	179	33	395	2	23	2	395	2	295	0	5755	6
19	274	34	395	2	23	2	395	2	395	0	5260	6
	179	34	395	2	23	2	395	2	395	0	5755	6
20	274	44	395	2	23	1.6	195	2	395	0	5254	5.6
	179	44	395	2	23	1.6	195	2	395	0	5748	5.6

Department of Automotive Engineering

PDB metric results

- **Summary of BDA assessment:**

profile	y_{min}	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
21	274	51	395	2	23	2	295	2	395	0	5258	6
	179	51	395	2	23	2	295	2	395	0	5753	6
22	274	44	295	2	23	2	295	2	295	0.7	2527	6.7
	179	44	295	2	23	2	295	2	295	0.3	2979	6.3
23	274	58	395	2	23	2	395	2	395	0.7	2528	6.7
	179	58	395	2	23	2	395	2	395	0.3	2980	6.3
24	274	44	295	2	23	2	295	1.1	139	0	3648	5.1
	179	44	295	2	23	2	295	1.1	139	0	4269	5.1
25	274	44	295	1.8	295	2	295	1.1	139	0.9	2286	5.7
	179	44	295	1.8	195	2	295	1.1	139	0.5	2761	5.3
26	274	57	295	2	23	2	295	1.1	139	0.5	2730	5.6
	179	57	295	2	23	2	295	1.1	139	0	3418	5.1
27	274	71	395	2	23	2	395	1.1	139	0.1	3208	5.2
	179	71	395	2	23	2	395	1.1	139	0	3892	5.1
28	274	57	395	0.1	395	2	395	1.1	139	0.9	2287	4.1
	179	57	395	0.1	395	2	395	1.1	139	0.5	2762	3.7
29	274	75	395	2	23	2	395	1.1	139	0.5	2731	5.6
	179	75	395	2	23	2	395	1.1	139	0	3419	5.1
30	274	24	295	2	23	2	295	2	295	0	3571	6
	179	24	295	2	23	2	295	2	295	0	3936	6

Department of Automotive Engineering

PDB metric results

- **Summary of BDA assessment:**

profile	y_{min}	volume [l]	max def [mm]	U area		M area		L area		H (M area)		PPS
				score	def [mm]	score	def [mm]	score	def [mm]	score	TV	
21	274	21	295	2	23	2	295	2	295	0	5560	6
	179	21	295	2	23	2	295	2	295	0	5984	6
22	274	35	295	1.8	295	2	295	2	295	1.8	1297	7.5
	179	35	295	1.8	295	2	295	2	295	0.8	2406	6.5
23	274	85	295	1.8	295	2	295	2	295	1.3	1866	7
	179	85	295	1.8	295	2	295	2	295	0.5	2690	6.3
24	274	24	138	1.8	295	0	0	1.1	139	2	0	4.9
	179	24	138	1.8	295	0	0	1.1	139	2	0	4.9
25	274	31	184	0.1	395	0	0	1.1	139	2	0	3.2
	179	31	184	0.1	395	0	0	1.1	139	2	0	3.2
26	274	37	195	1.8	295	1.6	195	1.1	139	0	5254	4.4
	179	37	195	1.8	295	1.6	195	1.1	139	0	5748	4.4
27	274	44	295	1.8	295	2	295	1.1	139	0	5258	4.9
	179	44	295	1.8	295	2	295	1.1	139	0	5740	4.9
28	274	44	195	0.1	395	1.6	195	1.1	139	0	5254	2.8
	179	44	195	0.1	395	1.6	195	1.1	139	0	5748	2.8
29	274	60	295	1.8	295	2	295	2	295	0.5	2690	6.3
	179	60	295	1.8	295	2	295	2	295	0.5	2690	6.3
30	274	38	295	2	23	2	295	1.1	139	0	3506	5.1
	179	38	295	2	23	2	295	1.1	139	0	3506	5.1

Department of Automotive Engineering

PDB metric results

- **Summary of BDA assessment:**

profile	y_{min}	volume [l]	max def [mm]	U area		M area		L area		H (M area)		PPS
				score	def [mm]	score	def [mm]	score	def [mm]	score	TV	
41	274	32	295	2	23	2	295	1.1	139	0	7485	5.1
	179	32	295	2	23	2	295	1.1	139	0	8076	5.1
42	274	22	295	2	23	2	295	1.1	139	0.4	2864	5.5
	179	22	295	2	23	2	295	1.1	139	0.4	2864	5.5
43	274	30	295	2	23	2	295	1.1	139	0.1	3153	5.2
	179	30	295	2	23	2	295	1.1	139	0.1	3153	5.2
44	274	37	295	2	23	2	295	1.1	139	0	3467	5.1
	179	37	295	2	23	2	295	1.1	139	0	3467	5.1
45	274	44	295	2	23	2	295	1.1	139	0	3774	5.1
	179	44	295	2	23	2	295	1.1	139	0	3774	5.1
46	274	52	295	2	23	2	295	1.1	139	0	3368	5.1
	179	52	295	2	23	2	295	1.1	139	0	4070	5.1
47	274	59	295	2	23	2	295	1.1	139	0	3368	5.1
	179	59	295	2	23	2	295	1.1	139	0	3635	5.1

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

PDB metric results

- **Summary of Homogeneity value (TV upgraded) assessment:**

profile	y_{min}	M area + L area
1	274	13,784,463
	179	13,656,662
2	274	10,279,939
	179	9,916,783
3	274	23,747,366
	179	23,561,656
4	274	20,559,878
	179	20,366,140
5	274	8,196,167
	179	8,119,866
6	274	21,579,290
	179	21,352,871
7	274	16,392,335
	179	16,237,387
8	274	1,236,732
	179	1,237,340
9	274	725,859
	179	922,839
10	274	21,865,918
	179	20,952,283

profile	y_{min}	M area + L area
11	274	14,498,970
	179	14,433,905
12	274	25,464,133
	179	22,497,779
13	274	14,085,462
	179	13,736,080
14	274	10,812,289
	179	10,766,022
15	274	15,396,278
	179	15,724,373
16	274	14,501,685
	179	14,440,103
17	274	12,223,898
	179	11,890,413
18	274	11,315,870
	179	11,479,789
19	274	10,814,675
	179	10,768,078
20	274	29,508,035
	179	29,114,740

profile	y_{min}	M area + L area
21	274	23,674,984
	179	23,485,518
22	274	53,354,537
	179	49,439,924
23	274	39,789,825
	179	36,868,765
24	274	53,945,719
	179	49,987,650
25	274	43,076,448
	179	38,638,517
26	274	94,590,668
	179	84,020,634
27	274	62,034,281
	179	55,677,304
28	274	32,124,809
	179	28,814,103
29	274	70,542,193
	179	62,656,710
30	274	13,784,463
	179	13,656,623

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

PDB metric results

- **Summary of Homogeneity value (TV upgraded) assessment:**

profile	y_{min}	M area + L area
31	274	9,142,383
	179	9,449,795
32	274	40,496,337
	179	32,291,821
33	274	76,604,559
	179	66,378,693
34	274	0
	179	0
35	274	0
	179	0
36	274	20,914,358
	179	20,722,533
37	274	14,085,754
	179	13,951,111
38	274	20,914,358
	179	20,722,533
39	274	20,914,358
	179	43,597,516
40	274	40,195,514
	179	40,215,247

profile	y_{min}	M area + L area
41	274	21,301,336
	179	21,714,007
42	274	10,764,362
	179	10,769,647
43	274	24,082,267
	179	24,094,090
44	274	38,380,647
	179	38,399,489
45	274	52,808,370
	179	52,834,295
46	274	72,506,864
	179	67,413,612
47	274	72,506,864
	179	84,465,461

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering
berlin

PDB metric results

- **Summary of DDY assessment:**

profile	y_{min}	Row 3 + Row 4
1	274	0
	179	0
2	274	0
	179	0
3	274	0
	179	0
4	274	0
	179	0
5	274	0
	179	0
6	274	0
	179	0
7	274	0
	179	0
8	274	0
	179	0
9	274	0
	179	0
10	274	0
	179	0

profile	y_{min}	Row 3 + Row 4
11	274	0
	179	0
12	274	0
	179	0
13	274	0
	179	0
14	274	0
	179	0
15	274	0
	179	0
16	274	0
	179	0
17	274	0
	179	0
18	274	0
	179	0
19	274	0
	179	0
20	274	0
	179	0

profile	y_{min}	Row 3 + Row 4
21	274	0
	179	0
22	274	0
	179	0
23	274	0
	179	0
24	274	0
	179	0
25	274	0
	179	0
26	274	0
	179	0
27	274	0
	179	0
28	274	0
	179	0
29	274	0
	179	0
30	274	0
	179	0

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering
berlin

PDB metric results

- **Summary of DDY assessment:**

profile	y_{min}	Row 3 + Row 4
31	274	0
	179	0
32	274	0
	179	0
33	274	20.1
	179	20.1
34	274	0
	179	0
35	274	0
	179	0
36	274	0
	179	0
37	274	0
	179	0
38	274	0
	179	0
39	274	20.1
	179	20.1
40	274	0
	179	20.1

profile	y_{min}	Row 3 + Row 4
41	274	20.1
	179	20.1
42	274	20.1
	179	20.1
43	274	20.1
	179	20.1
44	274	0
	179	20.1
45	274	0
	179	0
46	274	0
	179	0
47	274	0
	179	0

ANNEX G: PCM SIMULATION RESULTS

Department of Automotive Engineering

FIMCAR

PCM Simulations – PDB metric results

Department of Automotive Engineering

Request 3

- **Task:**
  - Sensitivity analysis of the PDB assessment criteria
- **Investigation:**
  - Influence of different parameters on assessment criteria
- **PCM Executive:**
  - vehicle width: 1878mm
  - vehicle mass: 1904kg

Mathias Stein FIMCAR – WP 2 – Request 3 2

PDB metric results

- **PDB assessment metrics**
  - **BDA software v1.0**
  - **Homogeneity value (TV upgraded)**
    - A_{def}(40%)
    - Assessment of middle and lower area ➔ z_{min} = 30mm & z_{max} = 450mm
  - **DDY**
    - 60% of vehicle width
    - Assessment area w.r.t. LCW Row 3 and Row 4 (330mm-580mm) ➔ z_{min} = 180mm & z_{max} = 430mm
    - 99%ile DDY

Test Matrix

Comment	Priority	Parameter	Simulation no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46*)	47*)
				Influence on vehicle mass					Influence on vehicle speed					Influence on crossbeam stiffness					Influence on crossbeam height					Influence on crossbeam length					Influence on subframe x-direction					Influence on subframe stiffness					Influence on subframe height					Influence on subframe length					bad compatibility expected	good compatibility expected
decrease of mass: engine mass - increase of mass: add masses to vehicle parts	3	vehicle mass	given mass - 200 kg	x																																														
			given mass -100 kg		x																																									
			given mass			x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
			given mass +100 kg				x																																											
			given mass + 200 kg					x																																						
	3	vehicle speed	56 km/h						x																																					
			58 km/h							x																																				
			60 km/h	x	x	x	x	x			x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
			61 km/h									x																																		
			64 km/h										x																																	
stiffness modification: bending stiffness ==> wall thickness	1	crossbeam stiffness	very weak. W=--> 0											x																																			x	
			weak. W/2												x																															
			medium. W	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
			stiff. W* 2														x																													
			very stiff. W* 5															x																														x
	2	crossbeam height	very low. z = 350 mm																x																													
			low. 410 mm																	x																											
			medium. z = 475 mm	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x
			high. z = 540 mm																			x																										
			very high. z = 600 mm																				x																										x	
	2	crossbeam length (overlap corresponds to half of vehicle width)	very short: no overlap																					x																									x	
			short. overlap = (vehicle width - longitudinal width) / 16																						x																									
			medium. overlap = (vehicle width - longitudinal width) / 8	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
			long. overlap = (vehicle width - longitudinal width) / 6																								x																					
			very long. overlap = (vehicle width - longitudinal width) / 4																									x																					x
	2	subframe x-direction	very rearward. x crossbeam + 300 mm																										x																				x	
			rearward. x crossbeam + 200 mm																											x																			
			medium. x crossbeam + 100 mm	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		
			forward. x crossbeam																													x																	
			very forward. x crossbeam - 100 mm																														x																	x
stiffness modification: bending stiffness ==> wall thickness	1	subframe stiffness	very weak. W=--> 0																															x															x	
			weak. W/2																																x													
			medium. W	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x	x	x	x	x	x	x		
			stiff. W* 2																																		x											
			very stiff. W* 5																																			x											x
	2	subframe height	very low. z = 190 mm																																				x										
			low. z = 220 mm																																					x									
			medium. z = 265 mm	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x			x	x	x	x	x		x
			high. z = 310 mm																																							x							
			very high. z = 350 mm																																								x						x	
	2	subframe length	short. l = vehicle width * 40%																																									x					x	
			short. l = vehicle width * 55%																																										x				
			medium. l = vehicle width * 70%	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x				
			long. l = vehicle width * 85%																																												x			
			very long. l = vehicle width (wing width)																																													x		x

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

Test Matrix

- **Run 03 = basis model for parameters:**
  - Mass
  - Velocity
  - Cross beam stiffness
  - Cross beam height
  - Cross beam overlap
- **Run 33 = basis model for parameters:**
  - Sub frame x-direction
  - Sub frame stiffness
  - Sub frame height
  - Sub frame overlap

Influence of sub frame modifications in footprints were to low. So the basis model for the sub frame runs was adjusted.

Mathias Stein FIMCAR – WP 2 – Request 3 5

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

Test Matrix

- **Vehicle mass:**
  - Parameters:
    - decreased mass - engine mass
    - Increased mass - cowl support and seat cross beam

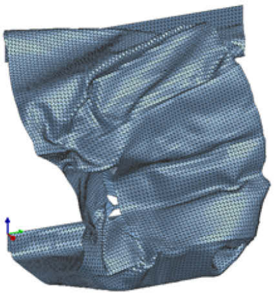
    - Run 01: m_{engine} - 200kg
    - Run 02: m_{engine} - 100kg
    - Run 03: m_{engine} = 430kg / $m_{vehicle}$ = 1904kg (basis model)
    - Run 04: $m_{vehicle}$ + 100kg
    - Run 05: $m_{vehicle}$ + 200kg

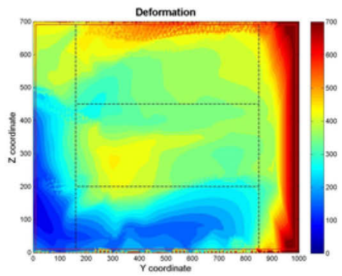
Mathias Stein FIMCAR – WP 2 – Request 3 6

Department of Automotive Engineering

PDB metric results

- **Vehicle mass:**
  - Run 01





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
246	439	0	530	1.7	431	2	402	0	925	3.6

BDA software

M area + L area
240,907,448

Homogeneity value

Row 3 + Row 4
0.82

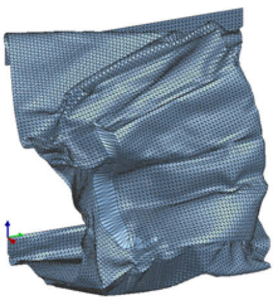
DDY

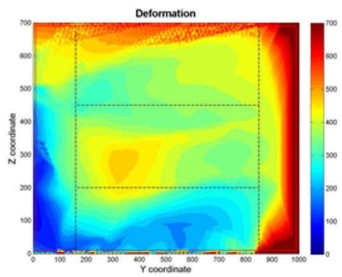
Mathias Stein FIMCAR – WP 2 – Request 3 7

Department of Automotive Engineering

PDB metric results

- **Vehicle mass:**
  - Run 02





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
263	499	0	569	1.2	469	1.8	438	0	849	3

BDA software

M area + L area
258,625,071

Homogeneity value

Row 3 + Row 4
0.95

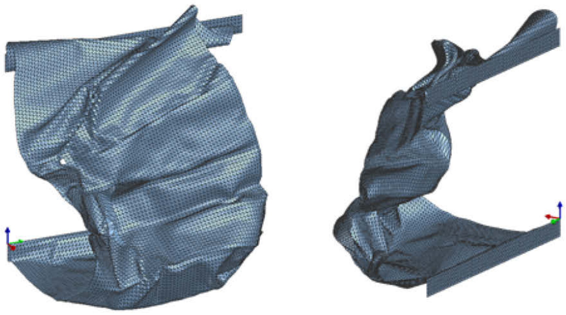
DDY

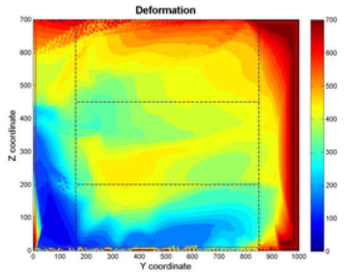
Mathias Stein FIMCAR – WP 2 – Request 3 8

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

PDB metric results

- **Vehicle mass:**
  - Run 03 – basis model





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
276	493	0	582	1.4	452	1.8	432	0	806	3.3

BDA software

M area + L area
247,266,229

Homogeneity value

Row 3 + Row 4
0.73

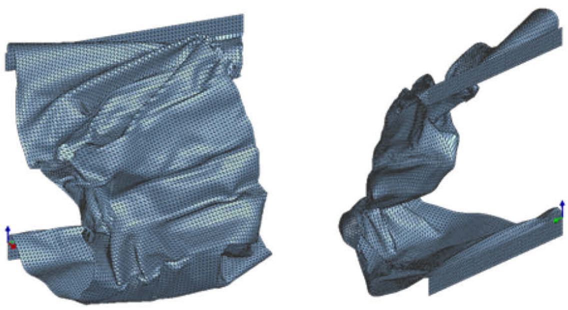
DDY

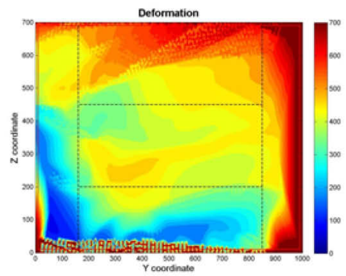
Mathias Stein FIMCAR – WP 2 – Request 3 9

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

PDB metric results

- **Vehicle mass:**
  - Run 04





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
298	770	0	639	1.3	465	0.4	708	0	728	1.7

BDA software

M area + L area
152,111,517

Homogeneity value

Row 3 + Row 4
0.73

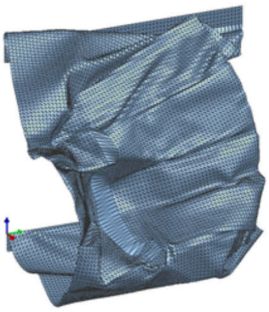
DDY

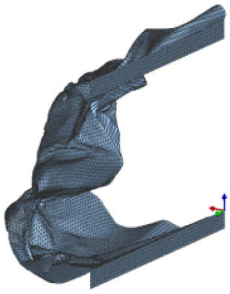
Mathias Stein FIMCAR – WP 2 – Request 3 10

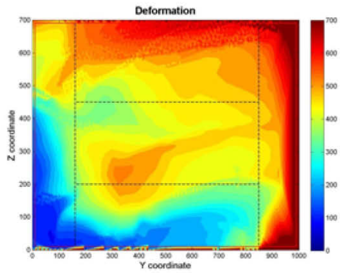
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

PDB metric results

- **Vehicle mass:**
  - Run 05







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
298	519	0	641	0.8	509	1.5	491	0	739	2.3

BDA software

M area + L area
226,780,112

Homogeneity value

Row 3 + Row 4
0.91

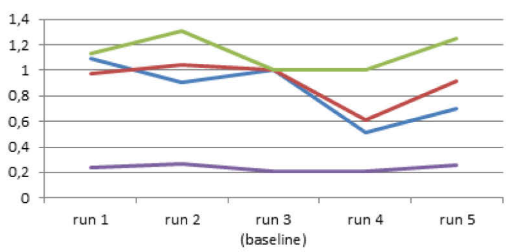
DDY

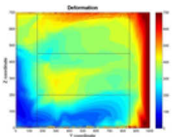
Mathias Stein — FIMCAR – WP 2 – Request 3 — 11

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

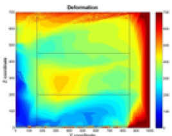
PDB metric results

- **Vehicle mass:**
  - Parameters:
    - decreased mass - engine mass
    - Increased mass - cowl support and seat cross beam
    - Run 01: m_{engine} - 200kg
    - Run 02: m_{engine} - 100kg
    - Run 03: m_{engine} = 430kg / $m_{vehicle}$ = 1904kg (basis model)
    - Run 04: $m_{vehicle}$ + 100kg
    - Run 05: $m_{vehicle}$ + 200kg

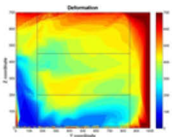




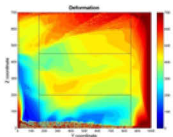
run 1



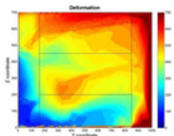
run 2



run 3 (baseline)



run 4



run 5

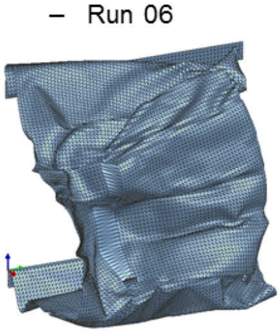
Mathias Stein — FIMCAR – WP 2 – Request 3 — 12

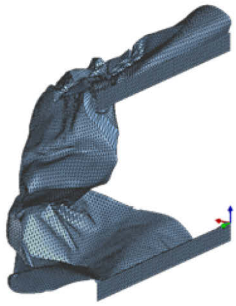
Test Matrix

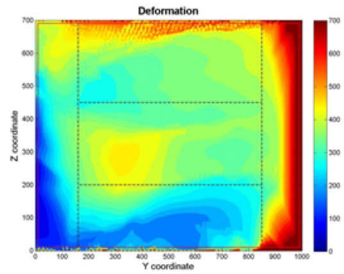
- **Vehicle speed:**
  - Parameter: initial velocity
    - Run 06: v = 56km/h
    - Run 07: v = 59km/h
    - Run 08: v = 60km/h (basis model)
    - Run 09: v = 61km/h
    - Run 10: v = 64km/h

PDB metric results

- **Vehicle speed:**
  - Run 06







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
246	486	0	545	1.5	446	2	406	0	929	3.5

BDA software

M area + L area
253,560,389

Homogeneity value

Row 3 + Row 4
1.00

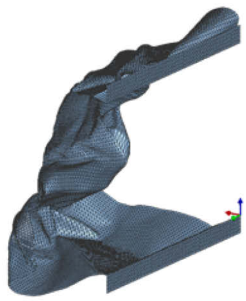
DDY

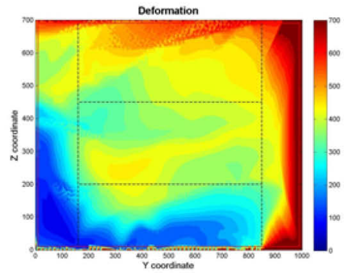
FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

PDB metric results

- **Vehicle speed:**





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
267	452	0	583	1.6	439	1.9	417	0	778	3.5

BDA software

M area + L area
259,503,701

Homogeneity value

Row 3 + Row 4
0.70

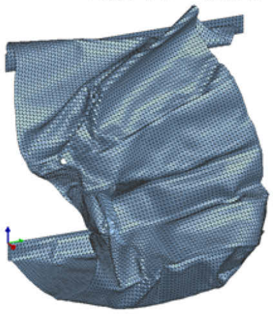
DDY

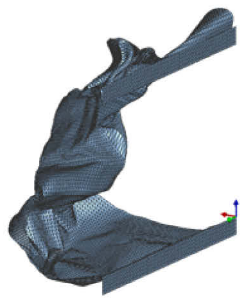
FIMCAR frontal impact and compatibility assessment research

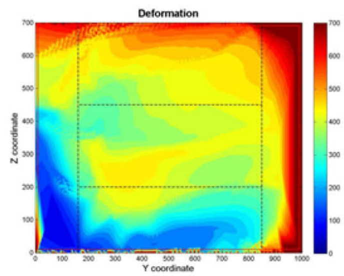
Department of Automotive Engineering

PDB metric results

- **Vehicle speed:**
  - Run 08 – basis model







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
276	493	0	582	1.4	452	1.8	432	0	806	3.3

BDA software

M area + L area
247,266,229

Homogeneity value

Row 3 + Row 4
0.73

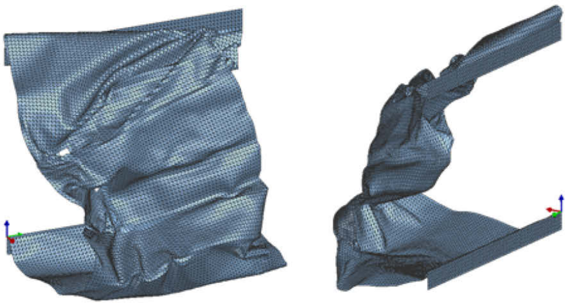
DDY

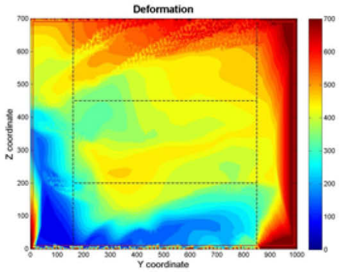
FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

PDB metric results

- **Vehicle speed:**
  - Run 09





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
284	470	0	622	1.4	457	1.8	441	0	710	3.2

BDA software

M area + L area
243,904,964

Homogeneity value

Row 3 + Row 4
0.61

DDY

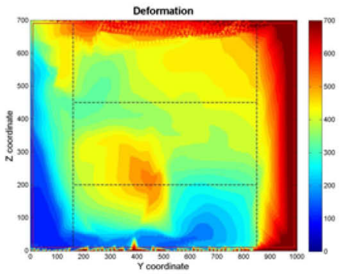
Mathias Stein FIMCAR – WP 2 – Request 3 17

FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

PDB metric results

- **Vehicle speed:**
  - Run 10



volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
308	516	0	656	1	490	1.6	481	0	708	2.6

BDA software

M area + L area
229,121,681

Homogeneity value

Row 3 + Row 4
0.69

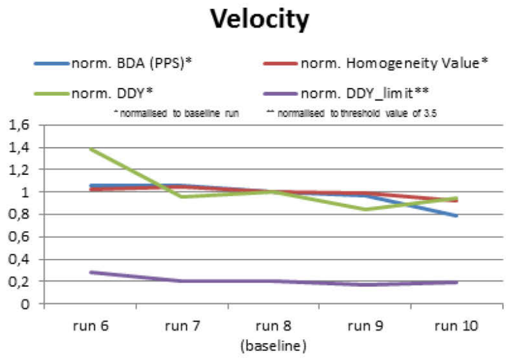
DDY

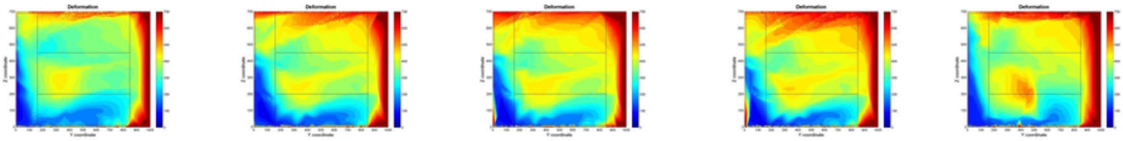
Mathias Stein FIMCAR – WP 2 – Request 3 18

FIMCAR frontal impact and compatibility assessment research Department of Automotive Engineering TU berlin

PDB metric results

- **Vehicle speed:**
  - Parameter: initial velocity
    - Run 06: v = 56km/h
    - Run 07: v = 59km/h
    - Run 08: v = 60km/h (basis model)
    - Run 09: v = 61km/h
    - Run 10: v = 64km/h





run 6 run 7 run 8 (baseline) run 9 run 10

FIMCAR frontal impact and compatibility assessment research Department of Automotive Engineering TU berlin

Test Matrix

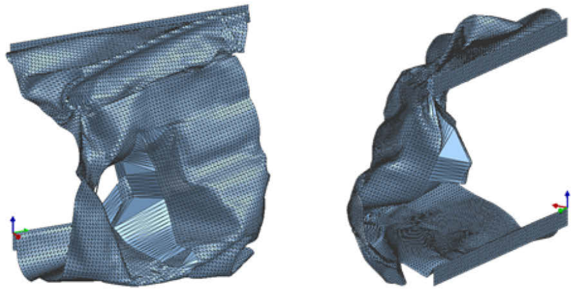
- **Cross beam stiffness:**
  - Parameter: wall thickness
    - Run 11_w/o cross beam
    - Run 11: t = 0.10mm
    - Run 12: t = 0.90mm
    - Run 13: t = 1.80mm (basis model)
    - Run 14: t = 3.54mm
    - Run 15: t = 10.00mm

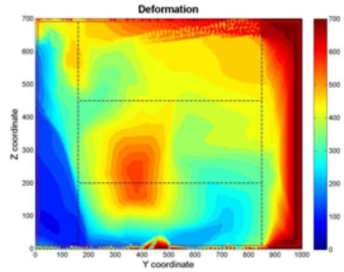
FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

PDB metric results

- **Cross beam stiffness:**
  - Run 11 – w/o cross beam





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
277	579	0	601	0.2	565	1.2	556	0	855	1.4

BDA software

M area + L area
232,385,559

Homogeneity value

Row 3 + Row 4
2.60

DDY

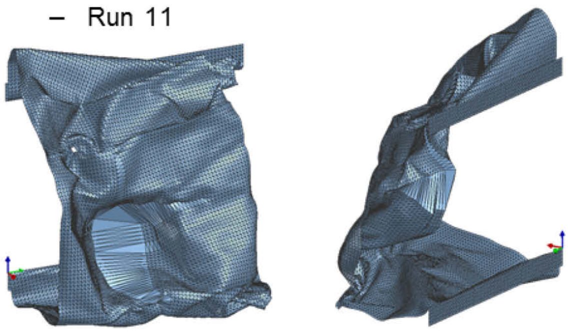
Mathias Stein FIMCAR – WP 2 – Request 3 21

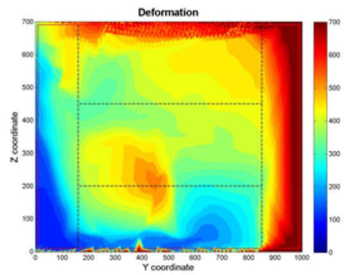
FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

PDB metric results

- **Cross beam stiffness:**
  - Run 11





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
278	523	0	614	0.8	508	1.5	499	0	765	2.3

BDA software

M area + L area
251,624,569

Homogeneity value

Row 3 + Row 4
3.95

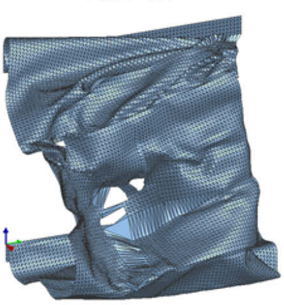
DDY

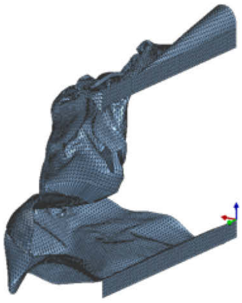
Mathias Stein FIMCAR – WP 2 – Request 3 22

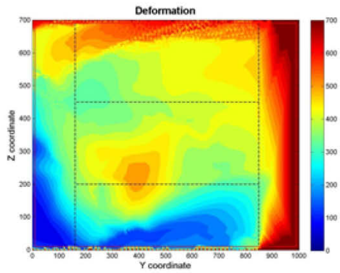
FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

PDB metric results

- **Cross beam stiffness:**
  - Run 12







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
277	500	0	589	1	493	1.6	481	0	689	2.6

BDA software

M area + L area
238,723,153

Homogeneity value

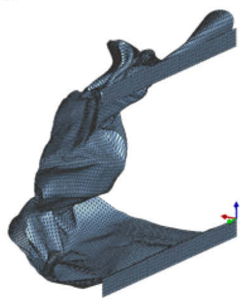
Row 3 + Row 4
1.32

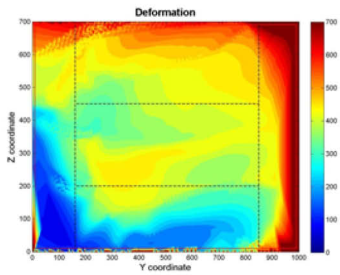
DDY

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

PDB metric results

- **Cross beam stiffness:**
  - Run 13 – basis model





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
276	493	0	582	1.4	452	1.8	432	0	806	3.3

BDA software

M area + L area
247,266,229

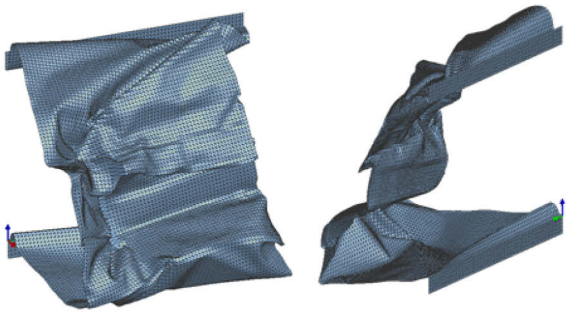
Homogeneity value

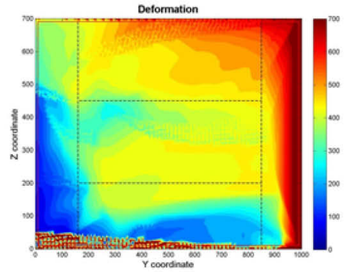
Row 3 + Row 4
0.73

DDY

PDB metric results

- **Cross beam stiffness:**
  - Run 14





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
280	744	0	576	1.6	439	0.4	708	0	1058	2

BDA software

M area + L area
186,052,136

Homogeneity value

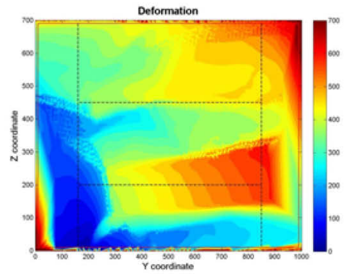
Row 3 + Row 4
0.51

DDY

Department of Automotive Engineering

PDB metric results

- **Cross beam stiffness:**
  - Run 15



volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
255	599	0	505	0	580	1.3	531	0	1673	1.3

BDA software

M area + L area
135,428,069

Homogeneity value

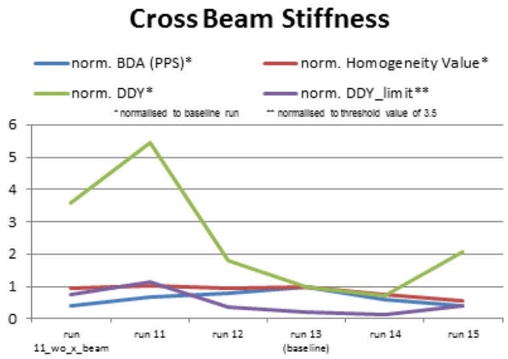
Row 3 + Row 4
1.49

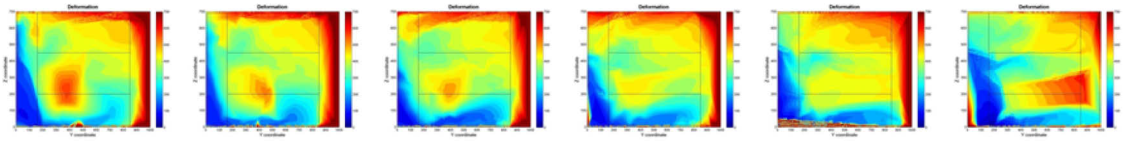
DDY

Department of Automotive Engineering

PDB metric results

- **Cross beam stiffness:**
  - Parameter: wall thickness
    - Run 11_w/o cross beam
    - Run 11: t = 0.10mm
    - Run 12: t = 0.90mm
    - Run 13: t = 1.80mm (basis model)
    - Run 14: t = 3.54mm
    - Run 15: t = 10.00mm





run 11 wo_x_beam | run 11 | run 12 | run 13 (baseline) | run 14 | run 15

Department of Automotive Engineering

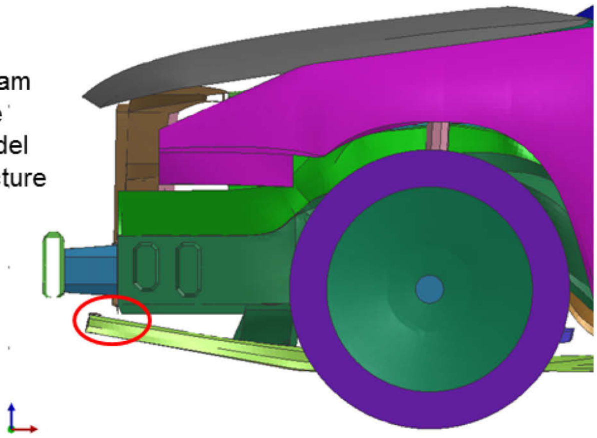
Test Matrix

- **Cross beam height:**
  - Parameter: distance from floor to middle point of cross section
    - Run 16: h = 350mm ➔ conflict with sub frame height in basis model
    - Run 17: h = 410mm
    - Run 18: h = 475mm (basis model)
    - Run 19: h = 540mm
    - Run 20: h = 600mm

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

PDB metric results

- **Cross beam height:**
  - Run 16
  - Conflict:
    - Further reduction of cross beam height not possible due to the sub frame height in basis model
    - (picture shows height of structure of run 17)

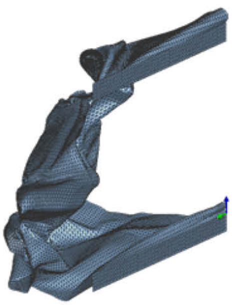


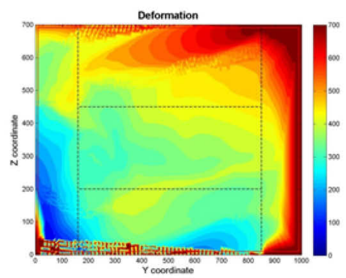
Mathias Stein FIMCAR – WP 2 – Request 3 29

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

PDB metric results

- **Cross beam height :**
  - Run 17





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
286	771	0	652	1.6	435	0.6	682	0	708	2.2

BDA software

M area + L area
224,350,944

Homogeneity value

Row 3 + Row 4
0.53

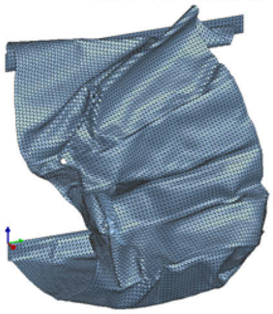
DDY

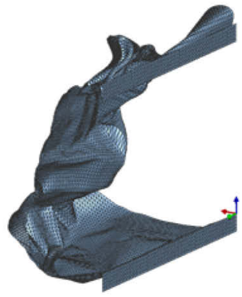
Mathias Stein FIMCAR – WP 2 – Request 3 30

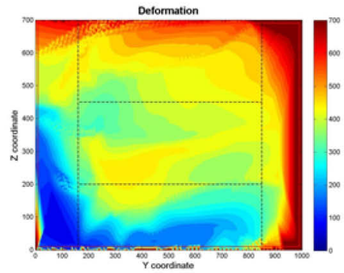
FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

PDB metric results

- **Cross beam height :**
  - Run 18 – basis model







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
276	493	0	582	1.4	452	1.8	432	0	806	3.3

BDA software

M area + L area
247,266,229

Homogeneity value

Row 3 + Row 4
0.73

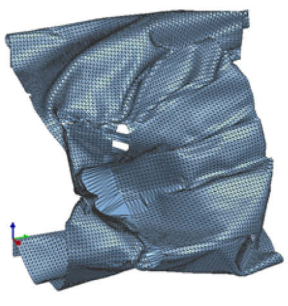
DDY

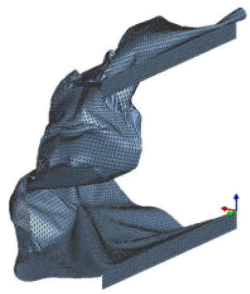
Mathias Stein FIMCAR – WP 2 – Request 3 31

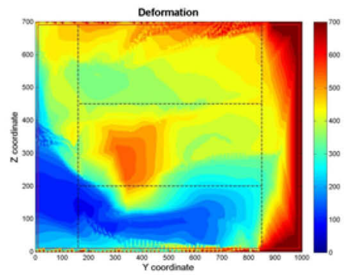
FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

PDB metric results

- **Cross beam height :**
  - Run 19







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
264	553	0	569	0.4	543	1.6	471	0	1230	2

BDA software

M area + L area
145,861,158

Homogeneity value

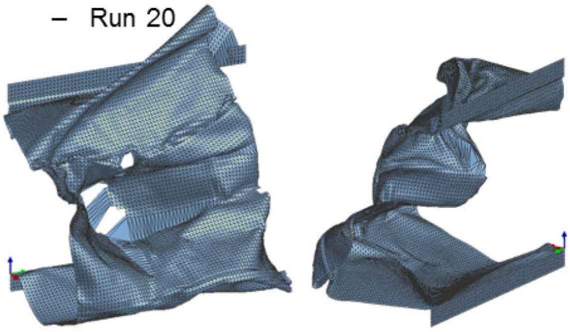
Row 3 + Row 4
2.51

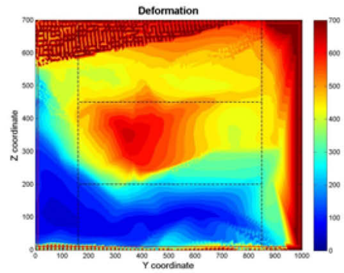
DDY

Mathias Stein FIMCAR – WP 2 – Request 3 32

PDB metric results

- **Cross beam height :**
  - Run 20





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
278	640	0	761	0	629	2	362	0	1482	2

BDA software

M area + L area
100,553,580

Homogeneity value

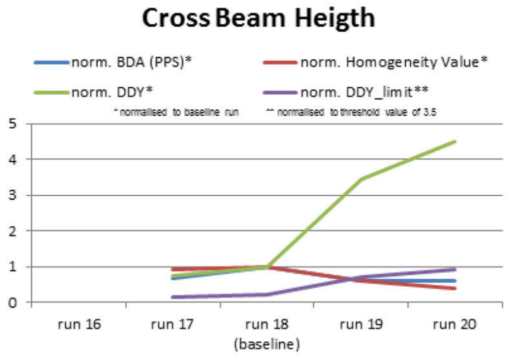
Row 3 + Row 4
3.25

DDY

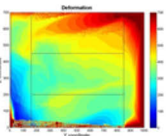
Department of Automotive Engineering

PDB metric results

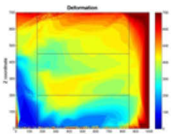
- **Cross beam height:**
  - Parameter: distance from floor to middle point of cross section
    - Run 16: h = 350mm ➔ conflict
    - Run 17: h = 410mm
    - Run 18: h = 475mm (basis model)
    - Run 19: h = 540mm
    - Run 20: h = 600mm



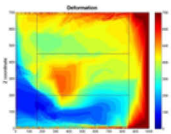
run 16



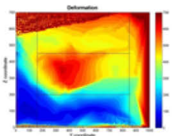
run 17



run 18 (baseline)



run 19



run 20

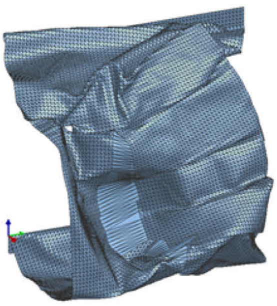
Test Matrix

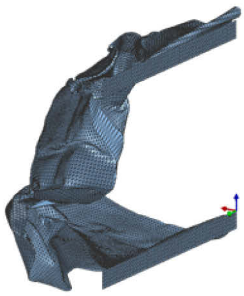
- **Cross beam width:**
  - Parameter: overlap (corresponds to half of vehicle width)
    - Run 21: very short (no overlap)
    - Run 22: short (vehicle width – longitudinal width)/16
    - Run 23: medium (vehicle width – longitudinal width)/8 (basis model)
    - Run 24: long (vehicle width – longitudinal width)/6
    - Run 25: very long (vehicle width – longitudinal width)/4

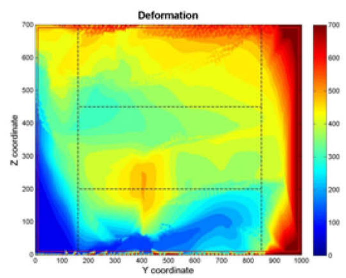
FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

PDB metric results

- **Cross beam width:**
  - Run 21







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
263	487	0	560	1.1	477	1.6	476	0	796	2.8

BDA software

M area + L area
184,468,910

Homogeneity value

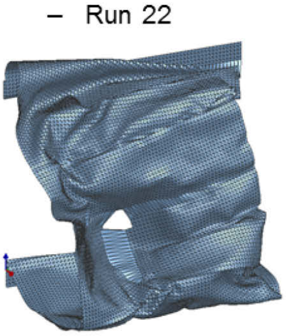
Row 3 + Row 4
1.18

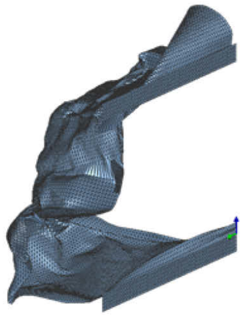
DDY

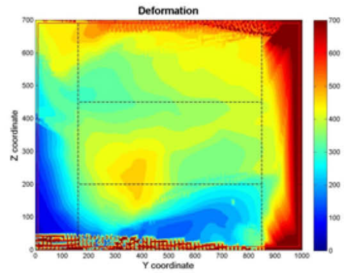
Department of Automotive Engineering

PDB metric results

- **Cross beam width:**
  - Run 22







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
272	772	0	574	1.2	469	0.3	732	0	734	1.5

BDA software

M area + L area
134,176,366

Homogeneity value

Row 3 + Row 4
1.11

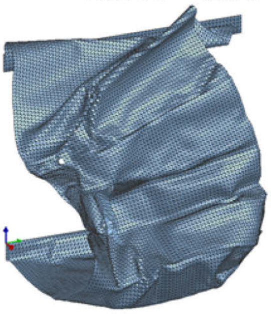
DDY

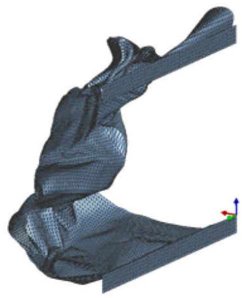
Mathias Stein FIMCAR – WP 2 – Request 3 37

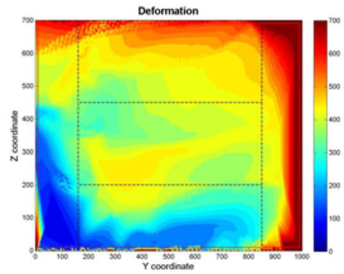
Department of Automotive Engineering

PDB metric results

- **Cross beam width:**
  - Run 23 – basis model







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
276	493	0	582	1.4	452	1.8	432	0	806	3.3

BDA software

M area + L area
247,266,229

Homogeneity value

Row 3 + Row 4
0.73

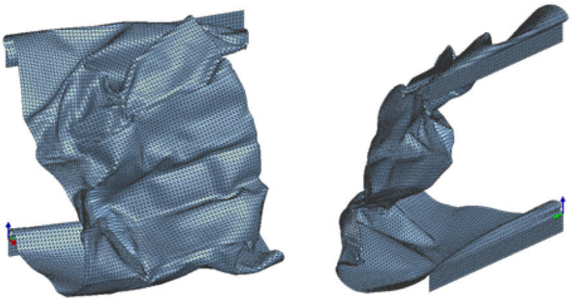
DDY

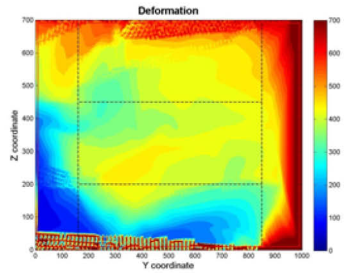
Mathias Stein FIMCAR – WP 2 – Request 3 38

Department of Automotive Engineering

PDB metric results

- **Cross beam width:**
  - Run 24





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
284	768	0	617	1.5	442	0.3	731	0	670	1.8

BDA software

M area + L area
137,949,267

Homogeneity value

Row 3 + Row 4
0.84

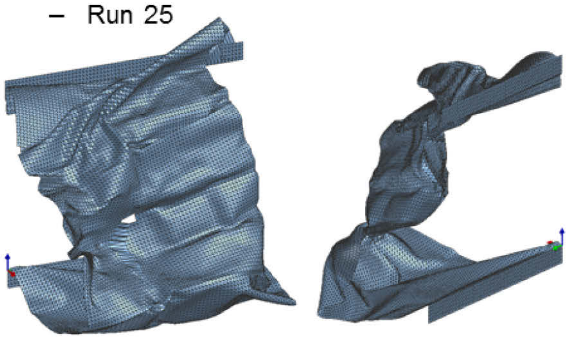
DDY

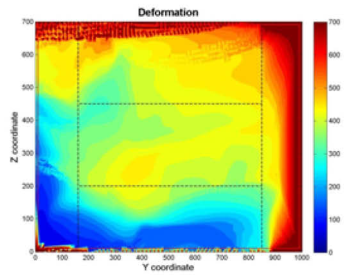
Mathias Stein FIMCAR – WP 2 – Request 3 39

Department of Automotive Engineering

PDB metric results

- **Cross beam width:**
  - Run 25





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
279	469	0	737	1.5	441	1.9	422	0	611	3.4

BDA software

M area + L area
267,457,337

Homogeneity value

Row 3 + Row 4
0.66

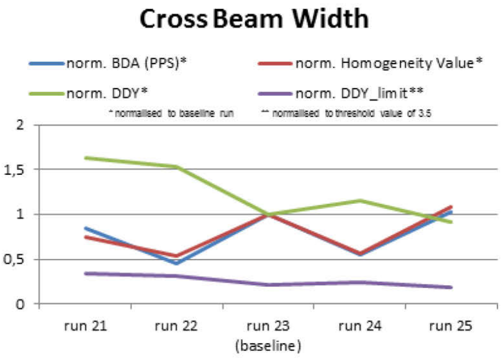
DDY

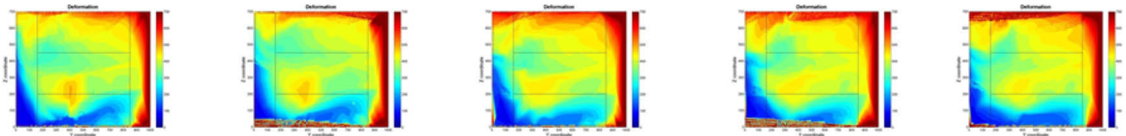
Mathias Stein FIMCAR – WP 2 – Request 3 40

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

PDB metric results

- **Cross beam width:**
  - Parameter: overlap (corresponds to half of vehicle width)
    - Run 21: very short (no overlap)
    - Run 22: short (vehicle width – longitudinal width)/16
    - Run 23: medium (vehicle width – longitudinal width)/8 (basis model)
    - Run 24: long (vehicle width – longitudinal width)/6
    - Run 25: very long (vehicle width – longitudinal width)/4





run 21 | run 22 | run 23 (baseline) | run 24 | run 25

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

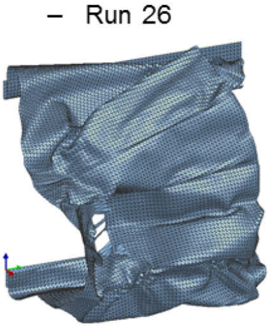
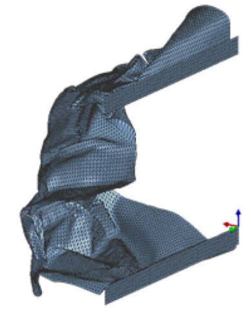
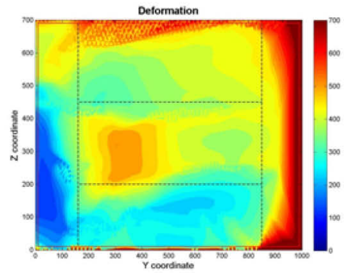
Test Matrix

- **Sub frame x-direction:**
  - Parameter: distance of cross beam and sub frame in x-direction
    - Run 26: very reward ($x_{cross\ beam}$ + 500mm)
    - Run 27: reward ($x_{cross\ beam}$ + 300mm)
    - Run 28: medium ($x_{cross\ beam}$ + 100mm)
    - Run 29: forward ($x_{cross\ beam}$)
    - Run 30: very forward ($x_{cross\ beam}$ - 100mm) ➔ conflict with bumper

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

PDB metric results

- **Sub frame x-direction:**
  - Run 26

volume [l]	max def [mm]	U area		M area		L area		H (M area)		PPS
		score	def [mm]	score	def [mm]	score	def [mm]	score	TV	
272	507	0	580	0.9	501	1.8	442	0	1101	2.7

BDA software

M area + L area
251,533,973

Homogeneity value

Row 3 + Row 4
1.30

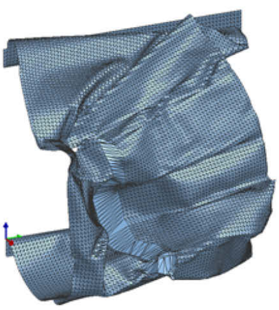
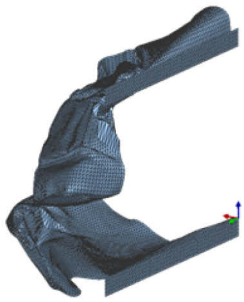
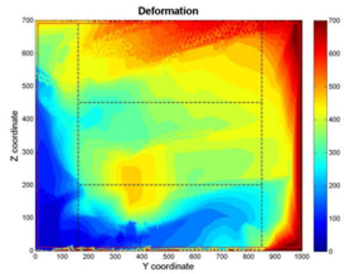
DDY

Mathias Stein FIMCAR – WP 2 – Request 3 43

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

PDB metric results

- **Sub frame x-direction:**
  - Run 27

volume [l]	max def [mm]	U area		M area		L area		H (M area)		PPS
		score	def [mm]	score	def [mm]	score	def [mm]	score	TV	
257	475	0	605	1.3	465	1.7	465	0	910	2.9

BDA software

M area + L area
209,567,010

Homogeneity value

Row 3 + Row 4
0.92

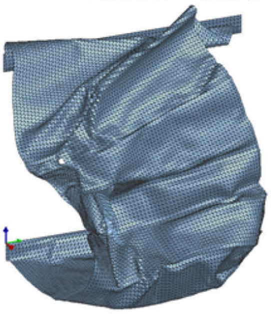
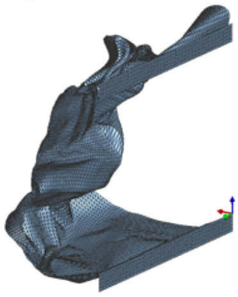
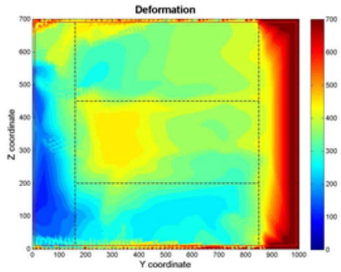
DDY

Mathias Stein FIMCAR – WP 2 – Request 3 44

Department of Automotive Engineering

PDB metric results

- **Sub frame x-direction:**
  - Run 28 – basis model (reinforced sub frame)

volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
276	493	0	582	1.4	452	1.8	432	0	806	3.3

BDA software

M area + L area
339,632,673

Homogeneity value

Row 3 + Row 4
1.73

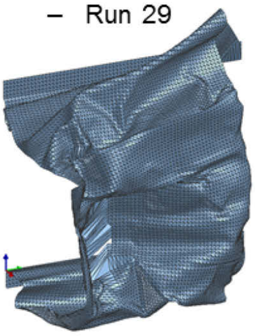
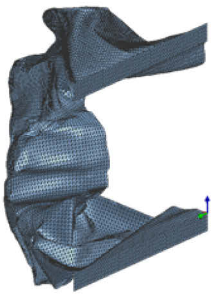
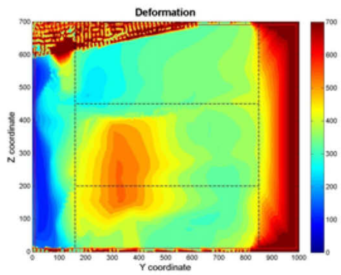
DDY

Mathias Stein FIMCAR – WP 2 – Request 3 45

Department of Automotive Engineering

PDB metric results

- **Sub frame x-direction:**
  - Run 29

volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
283	601	0	752	0.5	531	1.3	532	0	948	1.9

BDA software

M area + L area
289,406,184

Homogeneity value

Row 3 + Row 4
1.15

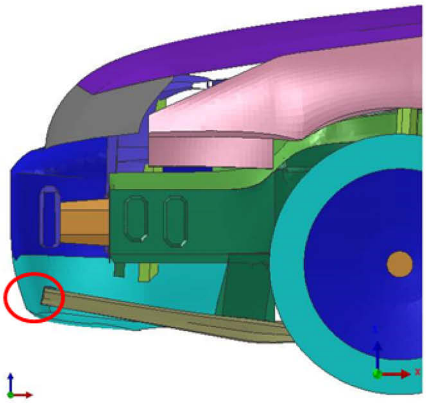
DDY

Mathias Stein FIMCAR – WP 2 – Request 3 46

Department of Automotive Engineering

PDB metric results

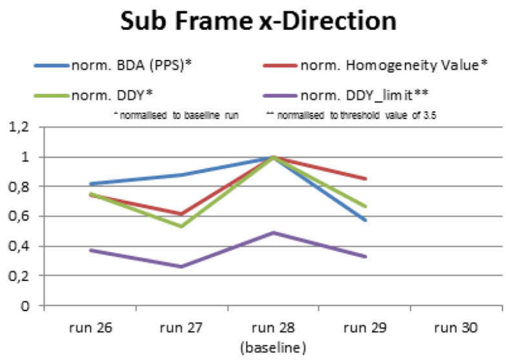
- **Sub frame x-direction:**
  - Run 30
  - Conflict:
    - Further displacement of sub frame not possible due to the bumper in basis model
    - (picture shows sub frame and bumper of of run 29)

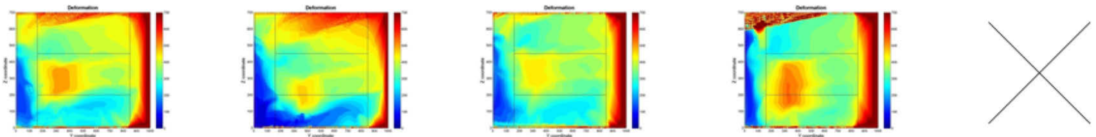


Department of Automotive Engineering

PDB metric results

- **Sub frame x-direction:**
  - Parameter: distance of cross beam and sub frame in x-direction
    - Run 26: very reward ($x_{cross\ beam}$ + 500mm)
    - Run 27: reward ($x_{cross\ beam}$ + 300mm)
    - Run 28: medium ($x_{cross\ beam}$ + 100mm)
    - Run 29: forward ($x_{cross\ beam}$)
    - Run 30: very forward ($x_{cross\ beam}$ - 100mm) ➔ conflict with bumper





run 26 run 27 run 28 (baseline) run 29 run 30

Department of Automotive Engineering

Test Matrix

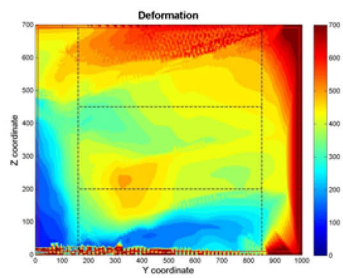
- **Sub frame stiffness:**
  - Parameter: wall thickness
    - Run 31: t = 0.10mm
    - Run 32: t = 1.00mm
    - Run 33: t = 2.00mm (basis model)
    - Run 34: t = 4.00mm
    - Run 35: t = 10.00mm

Mathias Stein FIMCAR – WP 2 – Request 3 49

Department of Automotive Engineering

PDB metric results

- **Sub frame stiffness:**
  - Run 31



volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
286	534	0	613	1.1	481	0.6	677	0	716	1.7

BDA software

M area + L area
231,924,454

Homogeneity value

Row 3 + Row 4
0.76

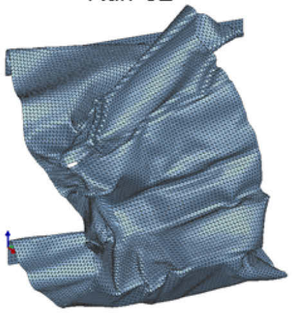
DDY

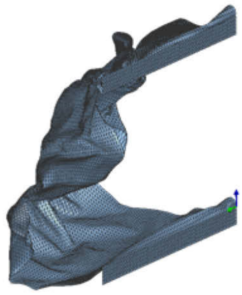
Mathias Stein FIMCAR – WP 2 – Request 3 50

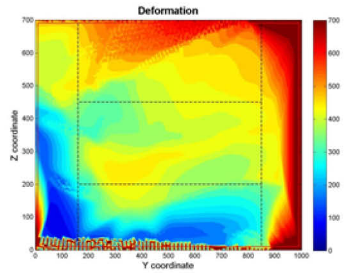
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering

PDB metric results

- **Sub frame stiffness:**
  - Run 32







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
283	762	0	612	1.4	450	0.6	675	0	772	2

BDA software

M area + L area
194,267,834

Homogeneity value

Row 3 + Row 4
0.68

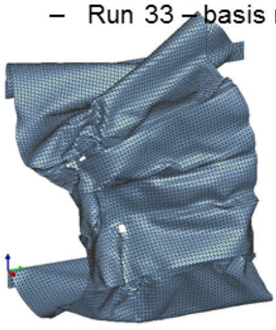
DDY

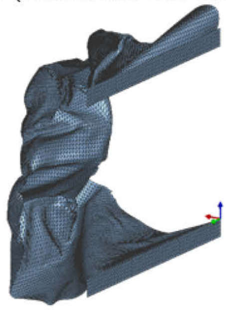
Mathias Stein FIMCAR – WP 2 – Request 3 51

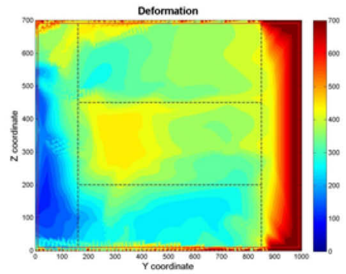
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering

PDB metric results

- **Sub frame stiffness:**
  - Run 33 – basis model (reinforced sub frame)







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
258	452	0	451	1.4	451	1.8	436	0	798	3.3

BDA software

M area + L area
339,632,673

Homogeneity value

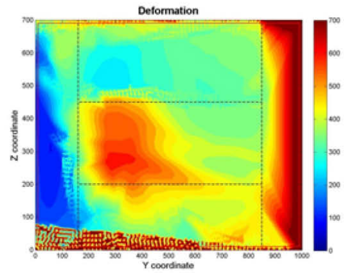
Row 3 + Row 4
1.73

DDY

Mathias Stein FIMCAR – WP 2 – Request 3 52

PDB metric results

- **Sub frame stiffness:**
  - Run 34



volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
281	765	0	473	0	588	0.2	746	0	1037	0.2

BDA software

M area + L area
161,169,098

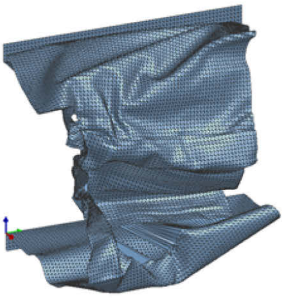
Homogeneity value

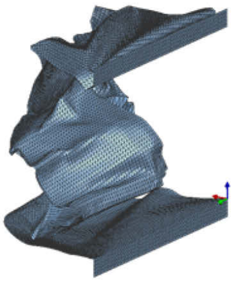
Row 3 + Row 4
1.24

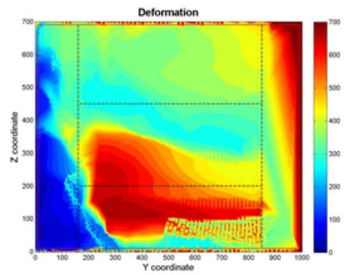
DDY

PDB metric results

- **Sub frame stiffness:**
  - Run 35







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
271	672	0	407	0	636	0.6	669	0	1540	0.6

BDA software

M area + L area
125,758,312

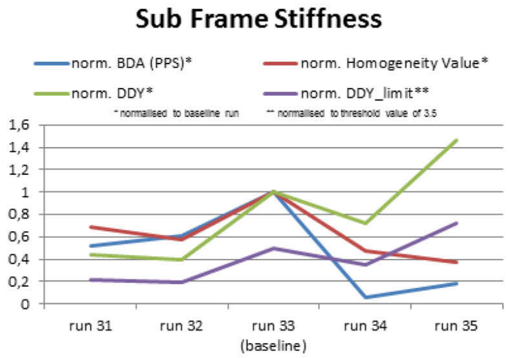
Homogeneity value

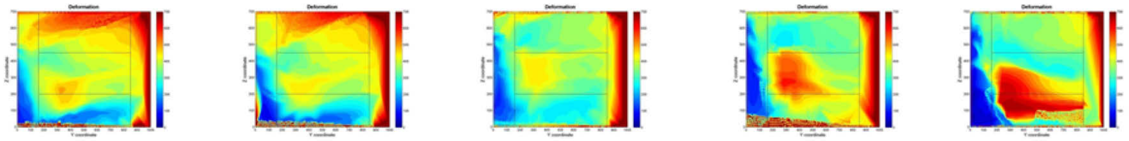
Row 3 + Row 4
2.52

DDY

PDB metric results

- **Sub frame stiffness:**
  - Parameter: wall thickness
    - Run 31: t = 0.10mm
    - Run 32: t = 1.00mm
    - Run 33: t = 2.00mm (basis model)
    - Run 34: t = 4.00mm
    - Run 35: t = 10.00mm





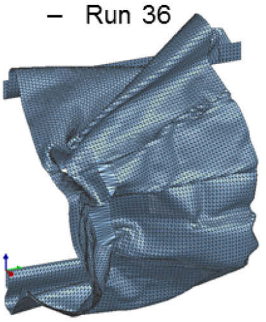
run 31 | run 32 | run 33 (baseline) | run 34 | run 35

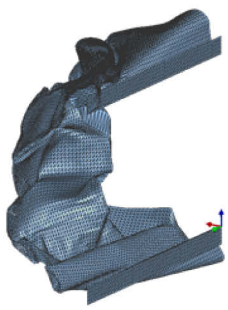
Test Matrix

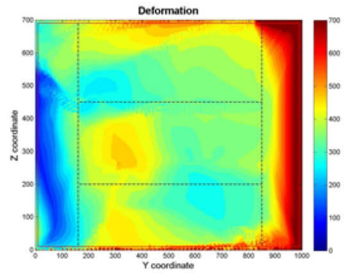
- **Sub frame height:**
  - Parameter: distance from floor to middle point of cross section
    - Run 36: h = 180mm
    - Run 37: h = 220mm
    - Run 38: h = 265mm (basis model)
    - Run 39: h = 310mm
    - Run 40: h = 350mm

PDB metric results

- **Sub frame height:**
  - Run 36







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
263	516	0	492	1.2	471	1.6	487	0	1106	2.8

BDA software

M area + L area
301,731,271

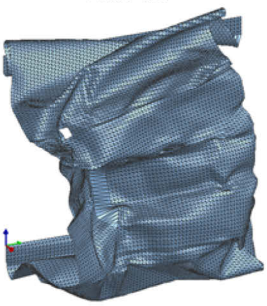
Homogeneity value

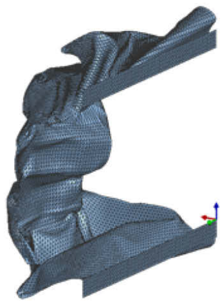
Row 3 + Row 4
1.17

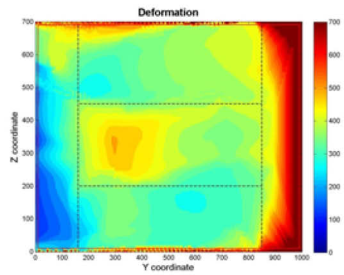
DDY

PDB metric results

- **Sub frame height:**
  - Run 37







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
266	519	0	498	1.1	479	1.9	413	0	918	3.1

BDA software

M area + L area
360,258,532

Homogeneity value

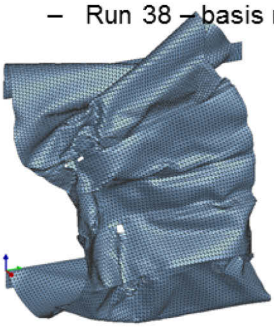
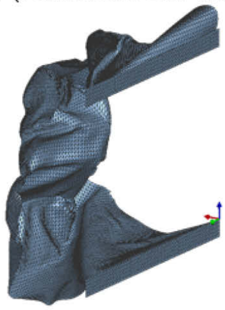
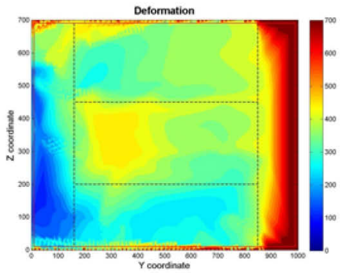
Row 3 + Row 4
0.95

DDY

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

PDB metric results

- **Sub frame height:**
  - Run 38 – basis model (reinforced sub frame)

volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
258	452	0	451	1.4	451	1.8	436	0	798	3.3

BDA software

M area + L area
339,632,673

Homogeneity value

Row 3 + Row 4
1.73

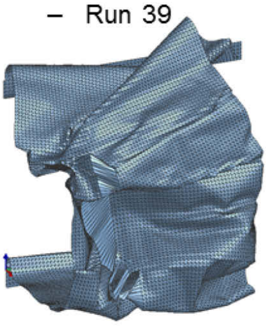
DDY

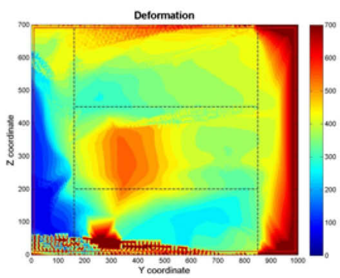
Mathias Stein FIMCAR – WP 2 – Request 3 59

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering

PDB metric results

- **Sub frame height:**
  - Run 39





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
276	770	0	529	0.4	542	0.2	750	0	1175	0.6

BDA software

M area + L area
97,203,135

Homogeneity value

Row 3 + Row 4
1.14

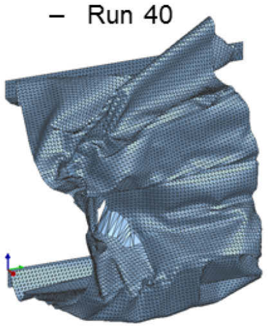
DDY

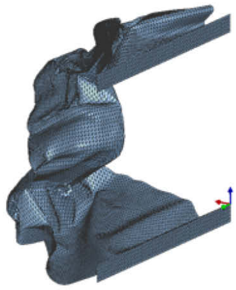
Mathias Stein FIMCAR – WP 2 – Request 3 60

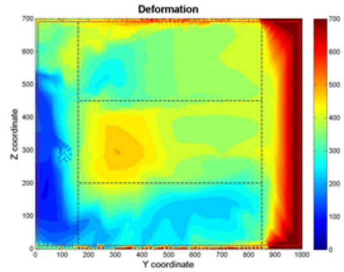
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering

PDB metric results

- **Sub frame height:**
  - Run 40







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
255	484	0	483	1.1	477	1.9	413	0	904	3.1

BDA software

M area + L area
294,283,927

Homogeneity value

Row 3 + Row 4
0.97

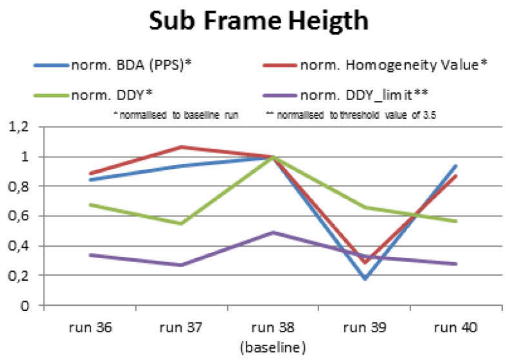
DDY

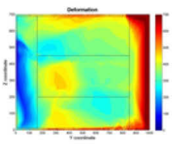
Mathias Stein FIMCAR – WP 2 – Request 3 61

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering

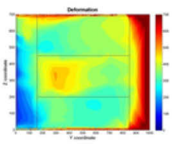
PDB metric results

- **Sub frame height:**
  - Parameter: distance from floor to middle point of cross section
    - Run 36: h = 180mm
    - Run 37: h = 220mm
    - Run 38: h = 265mm (basis model)
    - Run 39: h = 310mm
    - Run 40: h = 350mm

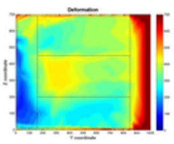




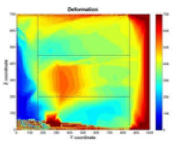
run 36



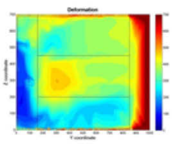
run 37



run 38 (baseline)



run 39



run 40

Mathias Stein FIMCAR – WP 2 – Request 3 62

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

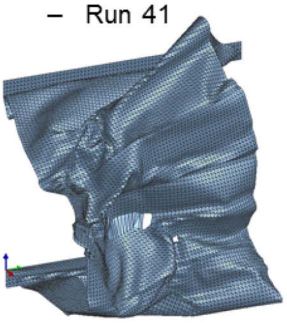
Test Matrix

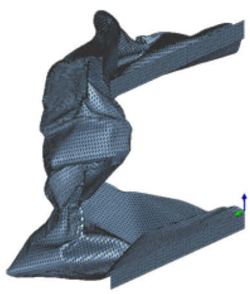
- **Sub frame width:**
  - Parameter: percentage of vehicle width
    - Run 41: vehicle width * 40%
    - Run 42: vehicle width * 55%
    - Run 43: vehicle width * 70% (basis model)
    - Run 44: vehicle width * 85%
    - Run 45: vehicle width * 100% (wing width) ➔ Conflict with shape of wings

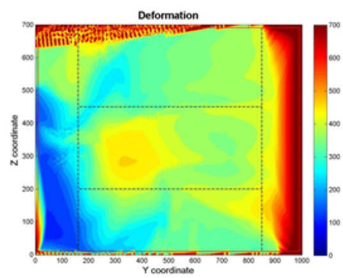
FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

PDB metric results

- **Sub frame width:**
  - Run 41







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
263	463	0	677	1.4	456	2	407	0	928	3.3

BDA software

M area + L area
308,284,332

Homogeneity value

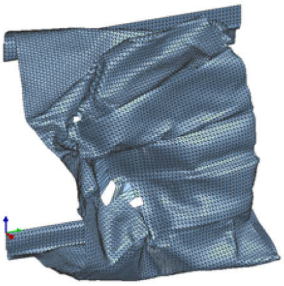
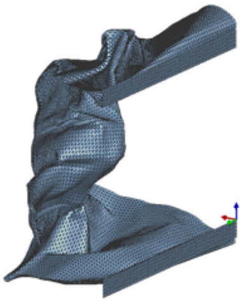
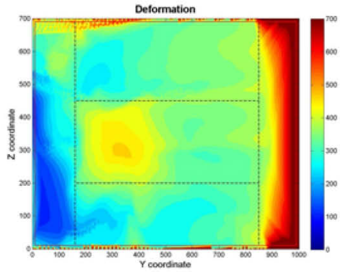
Row 3 + Row 4
1.38

DDY

Department of Automotive Engineering

PDB metric results

- **Sub frame width:**
  - Run 42

volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
249	462	0	483	1.4	458	2	376	0	827	3.4

BDA software

M area + L area
362,116,103

Homogeneity value

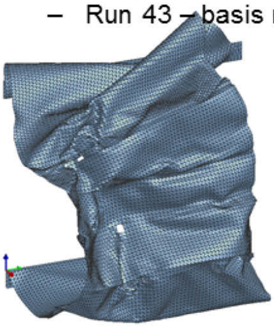
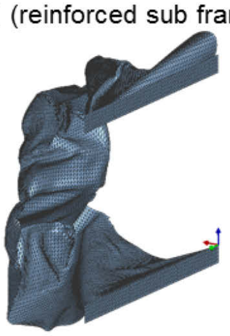
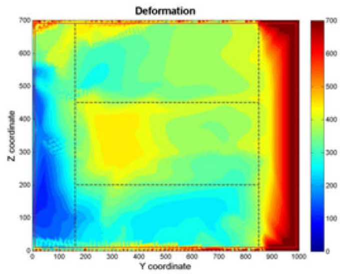
Row 3 + Row 4
0.96

DDY

Department of Automotive Engineering

PDB metric results

- **Sub frame width:**
  - Run 43 – basis model (reinforced sub frame)

volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
258	452	0	451	1.4	451	1.8	436	0	798	3.3

BDA software

M area + L area
339,632,673

Homogeneity value

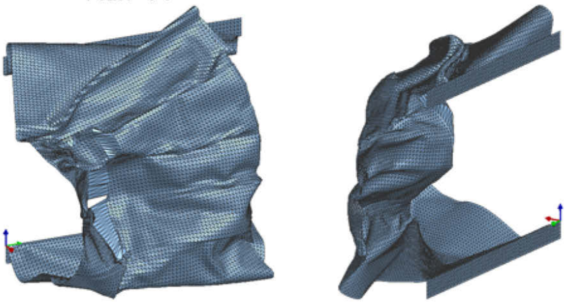
Row 3 + Row 4
1.73

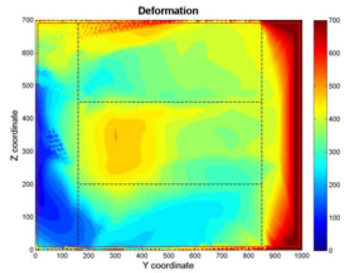
DDY

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering
berlin

PDB metric results

- **Sub frame width:**
  - Run 44





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
260	484	0	530	1.1	478	1.9	415	0	840	3.1

BDA software

M area + L area
318,586,976

Homogeneity value

Row 3 + Row 4
1.21

DDY

Mathias Stein FIMCAR – WP 2 – Request 3 67

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering
berlin

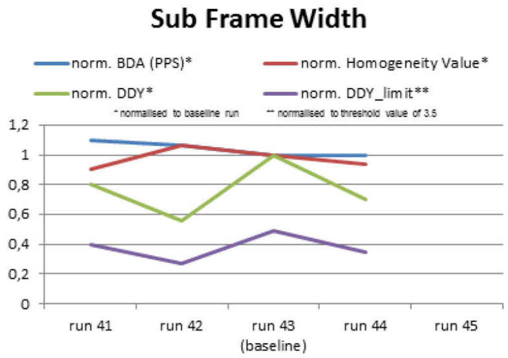
PDB metric results

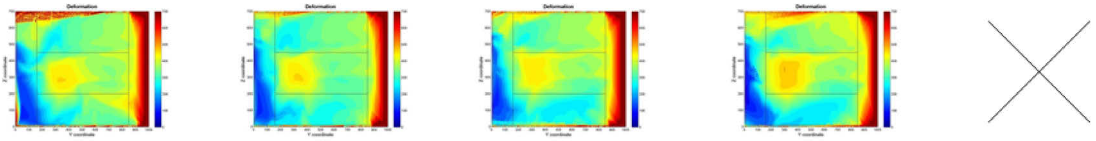
- **Sub frame width:**
  - Run 45
  - Conflict:
    - Sub frame width of Run 44 was the maximum width which was possible to create

Mathias Stein FIMCAR – WP 2 – Request 3 68

PDB metric results

- **Sub frame width:**
  - Parameter: percentage of vehicle width
    - Run 41: vehicle width * 40%
    - Run 42: vehicle width * 55%
    - Run 43: vehicle width * 70% (basis model)
    - Run 44: vehicle width * 85%
    - Run 45: vehicle width * 100% (wing width) ➔ Conflict with shape of wings





run 41 | run 42 | run 43 (baseline) | run 44 | run 45

PDB metric results

- **Summary of BDA assessment:**

parameter	modification	run	volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
mass (decrease of engine mass and increase of cowl support and seat cross beam mass)	- 200kg	1	246	439	0	530	1.7	431	2	402	0	925	3.6
	- 100kg	2	263	499	0	569	1.2	469	1.8	438	0	849	3
	= 430kg	3	276	493	0	582	1.4	452	1.8	432	0	806	3.3
	+ 100kg	4	298	770	0	639	1.3	465	0.4	708	0	728	1.7
	+ 200kg	5	298	519	0	641	0.8	509	1.5	491	0	739	2.3
velocity	56km/h	6	246	486	0	545	1.5	446	2	406	0	929	3.5
	59km/h	7	267	452	0	583	1.6	439	1.9	417	0	778	3.5
	60km/h	8	276	493	0	582	1.4	452	1.8	432	0	806	3.3
	61km/h	9	284	470	0	622	1.4	457	1.8	441	0	710	3.2
	64km/h	10	308	516	0	656	1	490	1.6	481	0	708	2.6
cross beam stiffness (wall thickness)		11_wo_x_beam	277	579	0	601	0.2	565	1.2	556	0	855	1.4
	0.10mm	11	278	523	0	614	0.8	508	1.5	499	0	765	2.3
	0.90mm	12	277	500	0	589	1	493	1.6	481	0	689	2.6
	1.80mm	13	276	493	0	582	1.4	452	1.8	432	0	806	3.3
	3.54mm	14	280	744	0	576	1.6	439	0.4	708	0	1058	2
	10.0mm	15	255	599	0	505	0	580	1.3	531	0	1673	1.3
cross beam height (distance between floor and middle point of cross section)	350mm	16						-					
	410mm	17	286	771	0	652	1.6	435	0.6	682	0	708	2.2
	475mm	18	276	493	0	582	1.4	452	1.8	432	0	806	3.3
	540mm	19	264	553	0	569	0.4	543	1.6	471	0	1230	2
	600mm	20	278	640	0	761	0	629	2	362	0	1482	2
cross beam width	very short	21	263	487	0	560	1.1	477	1.6	476	0	796	2.8
	short	22	272	772	0	574	1.2	469	0.3	732	0	734	1.5
	medium	23	276	493	0	582	1.4	452	1.8	432	0	806	3.3
	long	24	284	768	0	617	1.5	442	0.3	731	0	670	1.8
	very long	25	279	469	0	737	1.5	441	1.9	422	0	611	3.4

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

PDB metric results

• Summary of BDA assessment:

parameter	modification	run	volume [l]	max def [mm]	U area		M area		L area		H (M area)		PPS
					score	def [mm]	score	def [mm]	score	def [mm]	score	TV	
sub frame x-direction (measured from cross beam)	+ 500mm	26	272	507	0	580	0.9	501	1.8	442	0	1101	2.7
	+ 300mm	27	257	475	0	605	1.3	465	1.7	465	0	910	2.9
	+ 100mm	28	276	493	0	582	1.4	452	1.8	432	0	806	3.3
	0mm	29	283	601	0	752	0.5	531	1.3	532	0	948	1.9
	-100mm	30						-					
sub frame stiffness (wall thickness)	0.10mm	31	286	534	0	613	1.1	481	0.6	677	0	716	1.7
	1.00mm	32	283	762	0	612	1.4	450	0.6	675	0	772	2
	2.00mm	33	258	452	0	451	1.4	451	1.8	436	0	798	3.3
	4.00mm	34	281	765	0	473	0	588	0.2	746	0	1037	0.2
	10.0mm	35	271	672	0	407	0	636	0.6	669	0	1540	0.6
sub frame height (distance between floor and middle point of cross section)	180mm	36	263	516	0	492	1.2	471	1.6	487	0	1106	2.8
	220mm	37	266	519	0	498	1.1	479	1.9	413	0	918	3.1
	265mm	38	258	452	0	451	1.4	451	1.8	436	0	798	3.3
	310mm	39	276	770	0	529	0.4	542	0.2	750	0	1175	0.6
	350mm	40	255	484	0	483	1.1	477	1.9	413	0	904	3.1
sub frame width	very short	41	249	462	0	483	1.4	458	2	376	0	827	3.4
	short	42	258	452	0	451	1.4	451	1.8	436	0	798	3.3
	medium	43	260	484	0	530	1.1	478	1.9	415	0	840	3.1
	long	44	260	484	0	530	1.1	478	1.9	415	0	840	3.1
	very long	45						-					

Mathias Stein FIMCAR – WP 2 – Request 3 71

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

PDB metric results

• Summary of Homogeneity value (TV upgraded) assessment:

parameter	modification	run	M area + L area
mass (decrease of engine mass and increase of cowl support and seat cross beam mass)	- 200kg	1	240,907,448
	- 100kg	2	258,625,071
	= 430kg	3	247,266,229
	+ 100kg	4	152,111,517
	+ 200kg	5	226,780,112
velocity	56km/h	6	253,560,389
	59km/h	7	259,503,701
	60km/h	8	247,266,229
	61km/h	9	243,904,964
	64km/h	10	229,121,681
cross beam stiffness (wall thickness)		11_wo_x_beam	232,385,559
	0.10mm	11	251,624,569
	0.90mm	12	238,723,153
	1.80mm	13	247,266,229
	3.54mm	14	186,052,136
	10.0mm	15	135,428,069
cross beam height (distance between floor and middle point of cross section)	---	16	-
	410mm	17	224,350,944
	475mm	18	247,266,229
	540mm	19	145,861,158
	600mm	20	100,553,580
cross beam width	very short	21	184,468,910
	short	22	134,176,366
	medium	23	247,266,229
	long	24	137,949,267
	very long	25	267,457,337

parameter	modification	run	M area + L area
sub frame x-direction (measured from cross beam)	+ 500mm	26	251,533,973
	+ 300mm	27	209,567,010
	+ 100mm	28	339,632,673
	0mm	29	289,406,184
	- 100mm	30	-
sub frame stiffness (wall thickness)	0.10mm	31	231,924,454
	1.00mm	32	194,267,834
	2.00mm	33	339,632,673
	4.00mm	34	161,169,098
	10.0mm	35	125,758,312
sub frame height (distance between floor and middle point of cross section)	180mm	36	301,731,271
	220mm	37	360,258,532
	265mm	38	339,632,673
	310mm	39	97,203,135
	350mm	40	294,283,927
sub frame width	very short	41	308,284,332
	short	42	362,116,103
	medium	43	339,632,673
	long	44	318,586,976
	very long	45	-

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering

PDB metric results

- **Summary of DDY metric assessment:**

parameter	modification	run	Row 3 + Row 4
mass (decrease of engine mass and increase of cowl support and seat cross beam mass)	- 200kg	1	0.82
	- 100kg	2	0.95
	= 430kg	3	0.73
	+ 100kg	4	0.73
	+ 200kg	5	0.91
velocity	56km/h	6	1.00
	59km/h	7	0.70
	60km/h	8	0.73
	61km/h	9	0.61
	64km/h	10	0.69
cross beam stiffness (wall thickness)		11_wo_x_beam	2.60
	0.10mm	11	3.95
	0.90mm	12	1.32
	1.80mm	13	0.73
	3.54mm	14	0.51
	10.0mm	15	1.49
cross beam height (distance between floor and middle point of cross section)	---	16	-
	410mm	17	0.53
	475mm	18	0.73
	540mm	19	2.51
	600mm	20	3.25
cross beam width	very short	21	1.18
	short	22	1.11
	medium	23	0.73
	long	24	0.84
	very long	25	0.66

parameter	modification	run	Row 3 + Row 4
sub frame x-direction (measured from cross beam)	+ 500mm	26	1.30
	+ 300mm	27	0.92
	+ 100mm	28	1.73
	0mm	29	1.15
	- 100mm	30	-
sub frame stiffness (wall thickness)	0.10mm	31	0.76
	1.00mm	32	0.68
	2.00mm	33	1.73
	4.00mm	34	1.24
	10.0mm	35	2.52
sub frame height (distance between floor and middle point of cross section)	180mm	36	1.17
	220mm	37	0.95
	265mm	38	1.73
	310mm	39	1.14
	350mm	40	0.97
sub frame width	very short	41	1.38
	short	42	0.96
	medium	43	1.73
	long	44	1.21
	very long	45	-

ANNEX H: GCM SIMULATION RESULTS

Department of Automotive Engineering

FIMCAR

GCM Simulations – PDB metric results

Department of Automotive Engineering

GCMs – PDB metric results

- **Overview of the different GCMs:**

GCM	Vehicle Class	Lower Load Path available	Vehicle Width [mm]
GCM_1_A	Super Mini	no	1720
GCM_1_B		yes	
GCM_2_A	Small Family Car	yes	1822
GCM_2_B		no	
GCM_3_A	Large Executive	yes	1828

FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

GCMs – PDB metric results

- **PDB assessment metrics**
  - **BDA software v1.0**
  - **Homogeneity value (TV upgraded)**
    - $A_{def}(40\%)$
    - Assessment of middle and lower area ➔ z_{min} = 30mm & z_{max} = 450mm
  - **DDY**
    - 60% of vehicle width
    - Assessment area w.r.t. LCW Row 3 and Row 4 (330mm-580mm)
      ➔ z_{min} = 180mm & z_{max} = 430mm
    - 99%ile DDY

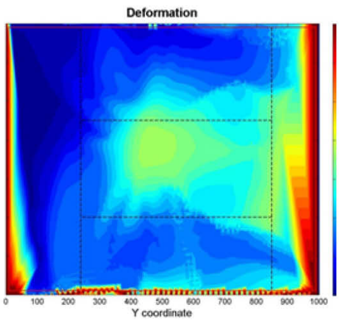
Mathias Stein FIMCAR – WP 2 – GCM vs. PDB 3

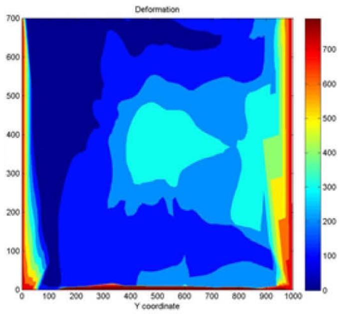
FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

GCMs – PDB metric results

- **GCM_1_A:**





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
156	379	1.3	323	2	376	1.3	529	0	1503	4.6

BDA software

M area + L area
185,244,384

Homogeneity value

Row 3 + Row 4
3.9

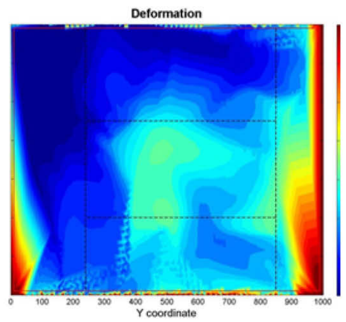
DDY

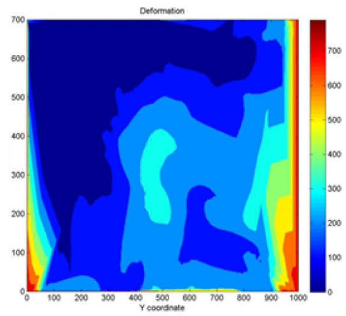
Mathias Stein FIMCAR – WP 2 – GCM vs. PDB 4

Department of Automotive Engineering

GCMs – PDB metric results

- **GCM_1_B:**





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
137	379	1.3	342	2	319	2	319	1.4	1699	7.4

BDA software

M area + L area
186,229,164

Homogeneity value

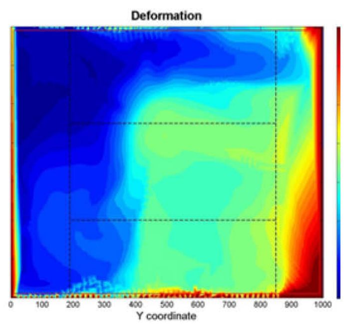
Row 3 + Row 4
1.9

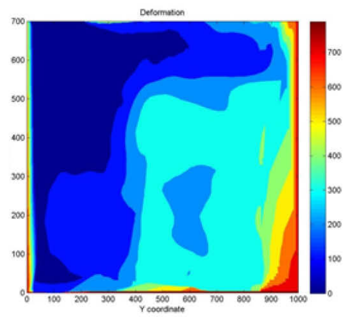
DDY

Department of Automotive Engineering

GCMs – PDB metric results

- **GCM_2_A:**





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
169	407	1	341	2	379	1.6	472	1.9	1106	6.5

BDA software

M area + L area
274,581,139

Homogeneity value

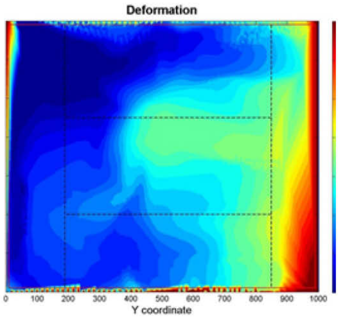
Row 3 + Row 4
1.1

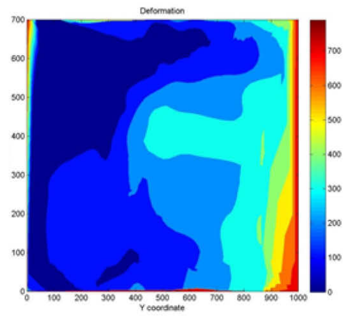
DDY

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

GCMs – PDB metric results

- **GCM_2_B:**





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
149	405	1.6	307	2	336	2	319	1.7	1357	7.3

BDA software

M area + L area
220,354,041

Homogeneity value

Row 3 + Row 4
1.5

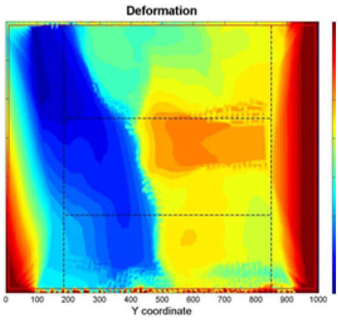
DDY

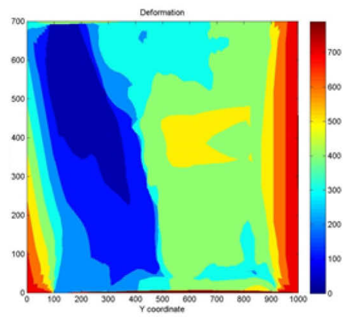
Mathias Stein FIMCAR – WP 2 – GCM vs. PDB 7

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

GCMs – PDB metric results

- **GCM_3_A:**





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
251	524	0	495	0.7	520	1.7	457	0	1304	2.4

BDA software

M area + L area
124,239,703

Homogeneity value

Row 3 + Row 4
5.1

DDY

Mathias Stein FIMCAR – WP 2 – GCM vs. PDB 8

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

GCMs – PDB metric results

- **Summary of BDA assessment:**

GCM	volume [l]	max def [mm]	U area		M area		L area		H (M area)		PPS
			score	def [mm]	score	def [mm]	score	def [mm]	score	TV	
GCM_1_A	156	379	1.3	323	2	376	1.3	529	0	1503	4.6
GCM_1_B	137	379	1.3	342	2	319	2	319	1.4	1699	7.4
GCM_2_A	169	407	1	341	2	379	1.6	472	1.9	1106	6.5
GCM_2_B	149	405	1.6	307	2	336	2	319	1.7	1357	7.3
GCM_3_A	251	524	0	495	0.7	520	1.7	457	0	1304	2.4

Mathias Stein FIMCAR – WP 2 – GCM vs. PDB 9

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

GCMs – PDB metric results

- **Summary of Homogeneity value (TV upgraded) assessment:**

GCM	M area + L area
GCM_1_A	185,244,384
GCM_1_B	186,229,164
GCM_2_A	274,581,139
GCM_2_B	220,354,041
GCM_3_A	124,239,703

Mathias Stein FIMCAR – WP 2 – GCM vs. PDB 10

Department of Automotive Engineering

GCMs – PDB metric results

- **Summary of DDY metric assessment:**

GCM	Row 3 + Row 4
GCM_1_A	3.9
GCM_1_B	1.9
GCM_2_A	1.1
GCM_2_B	1.5
GCM_3_A	5.1

ANNEX I: TEST PDB PROFILES

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering

FIMCAR

Vehicle PDB Profiles

FIMCAR
frontal impact and compatibility assessment research

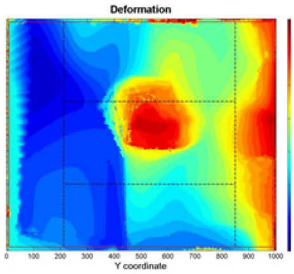
FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering

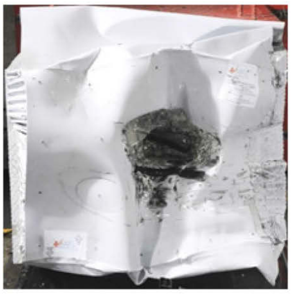
- **PDB assessment metrics**
  - **BDA software v1.0**
  - **Homogeneity value (TV upgraded)**
    - A_{def}(40%)
    - Assessment of middle and lower area ➔ z_{min} = 30mm & z_{max} = 450mm
  - **DDY**
    - 60% of vehicle width
    - Assessment area w.r.t. LCW Row 3 and Row 4 (330mm-580mm) ➔ z_{min} = 180mm & z_{max} = 430mm
    - 99%ile DDY

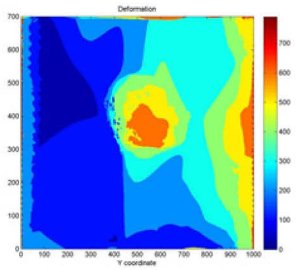
Mathias Stein *FIMCAR – WP 2 – Vehicle PDB Profiles* 2

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

- vehicle: FIMCAR_SFC_1
- vehicle width: 1775mm
- group: G3
- barrier depth: 790mm
- driver position: LHD







volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
200	646	0	545	0	638	2	304	1.2	1966	3.2

BDA software

M area + L area
47,915,147

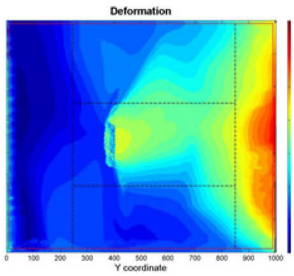
Homogeneity value

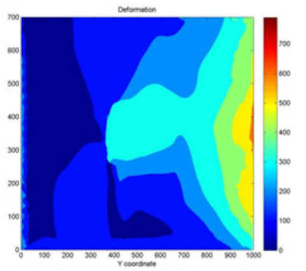
Row 3 + Row 4
7.1

DDY

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

- vehicle: FIMCAR_Supermini_1_UTAC
- vehicle width: 1708mm
- group: G3
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
146	415	1.3	321	2	402	2	246	1.3	1826	6.6

BDA software

M area + L area
100,495,224

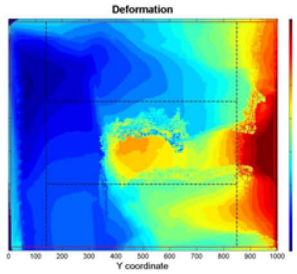
Homogeneity value

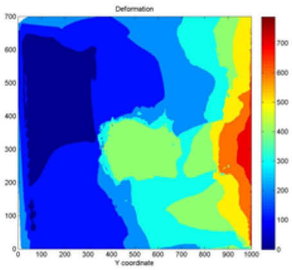
Row 3 + Row 4
1.4

DDY

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

- vehicle: 56_SUV_4_without_ACE
- vehicle width: 1920mm
- group: G3
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
185	579	1.3	320	0.8	504	1.8	431	0	3390	4

BDA software

M area + L area
65,332,503

Homogeneity value

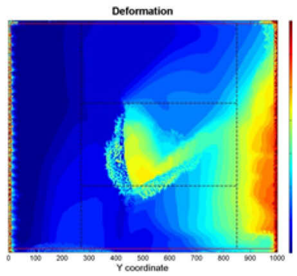
Row 3 + Row 4
17.3

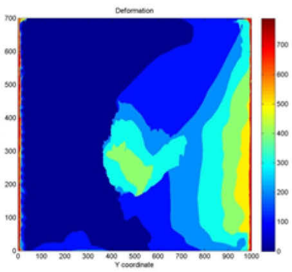
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 5

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

- vehicle: 52_Supermini_6
- barrier depth: 790mm
- driver position: LHD
- vehicle width: 1660mm
- group: G3





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
116	451	2	169	1.6	437	2	341	0	3819	5.6

BDA software

M area + L area
62,144,259

Homogeneity value

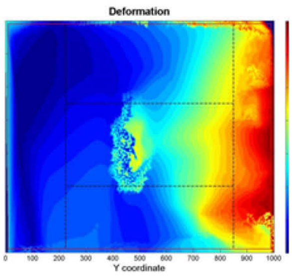
Row 3 + Row 4
10.0

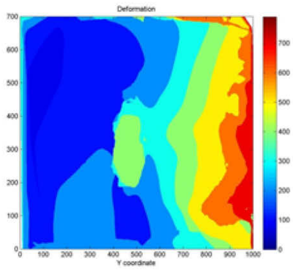
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 6

Department of Automotive Engineering

- vehicle: 37_Small_SUV
- vehicle width: 1815mm
- group: G3
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
157	570	1	339	1	489	1.8	430	0.1	3131	4

BDA software

M area + L area
71,464,524

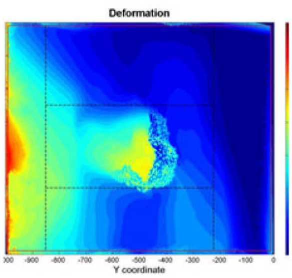
Homogeneity value

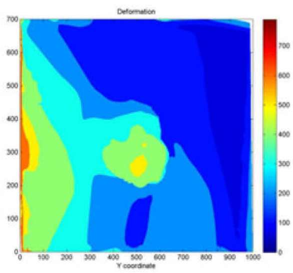
Row 3 + Row 4
8.6

DDY

Department of Automotive Engineering

- vehicle: 19_Supermini_5_DAD
- vehicle width: 1752mm
- group: G3
- barrier depth: 700mm
- driver position: RHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
110	433	2	170	1.8	419	2	265	0	3626	5.8

BDA software

M area + L area
85,738,397

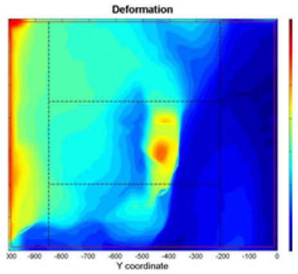
Homogeneity value

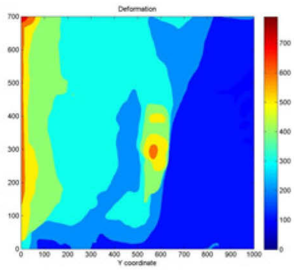
Row 3 + Row 4
3.0

DDY

FIMCAR frontal impact and compatibility assessment research Department of Automotive Engineering TU berlin

- vehicle: 17_SUV_7
- vehicle width: 1778mm
- group: G3
- barrier depth: 700mm
- driver position: RHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
137	537	1.6	303	0.9	500	2	358	0.7	2444	5.2

BDA software

M area + L area
74,689,634

Homogeneity value

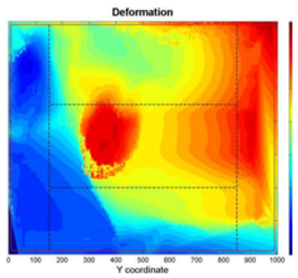
Row 3 + Row 4
6.6

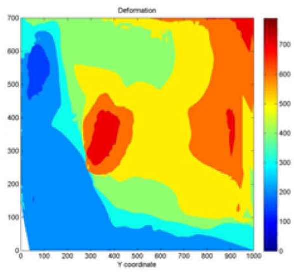
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 9

FIMCAR frontal impact and compatibility assessment research Department of Automotive Engineering TU berlin

- vehicle: 11_SUV_6
- vehicle width: 1898mm
- group: G3
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
252	629	0	509	0	624	1.8	431	0	1459	1.8

BDA software

M area + L area
129,748,335

Homogeneity value

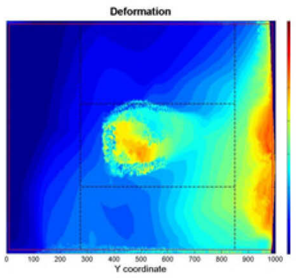
Row 3 + Row 4
3.9

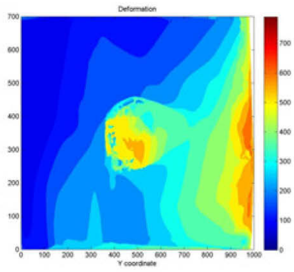
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 10

Department of Automotive Engineering

- vehicle: 09_Supermini_5_DAG
- vehicle width: 1649mm
- group: G3
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
117	502	2	184	1.2	474	2	300	0	3433	5.2

BDA software

M area + L area
47,775,587

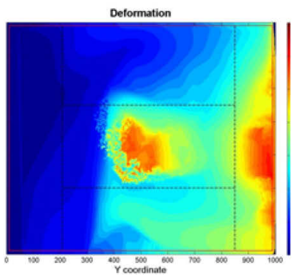
Homogeneity value

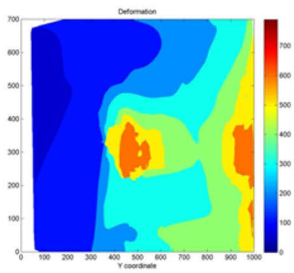
Row 3 + Row 4
5.3

DDY

Department of Automotive Engineering

- vehicle: 05_SFC_2_weak
- vehicle width: 1783mm
- group: G3
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
138	558	2	252	0.5	534	2	336	0.1	3160	4.6

BDA software

M area + L area
108,672,228

Homogeneity value

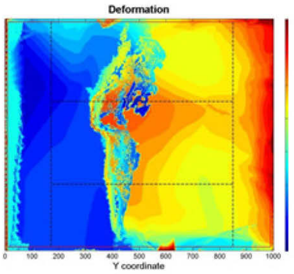
Row 3 + Row 4
6.3

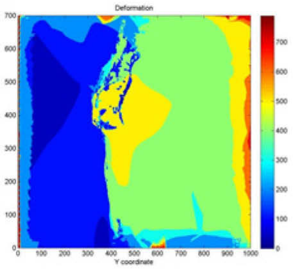
DDY

FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

- vehicle: FIMCAR_SUV_1_IDIADA
- vehicle width: 1855mm
- group: G2
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
228	582	0	548	0.1	568	1.5	495	0	3792	1.6

BDA software

M area + L area
59,929,260

Homogeneity value

Row 3 + Row 4
0.8

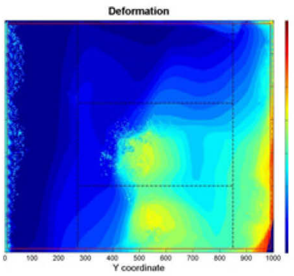
DDY

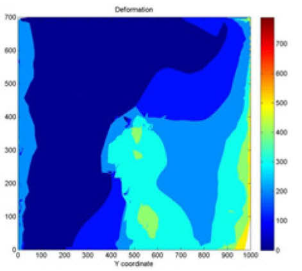
Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 13

FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

- vehicle: FIMCAR_City_Car_1_UTAC
- vehicle width: 1655mm
- group: G2
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
104	425	2	153	2	390	1.9	417	0.8	2373	6.7

BDA software

M area + L area
81,782,461

Homogeneity value

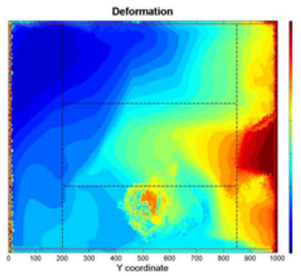
Row 3 + Row 4
7.4

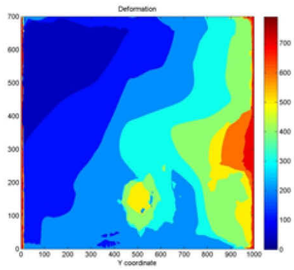
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 14

Department of Automotive Engineering

- vehicle: 53_Family_car
- vehicle width: 1798mm
- group: G2
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
189	589	1.6	302	0.7	518	1.4	513	1.7	1364	5.4

BDA software

M area + L area
82,156,892

Homogeneity value

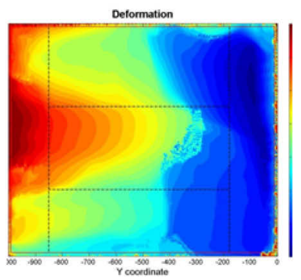
Row 3 + Row 4
5.4

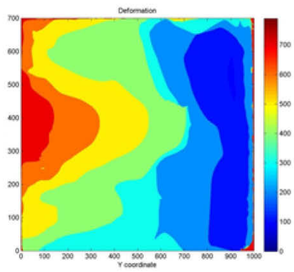
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 15

Department of Automotive Engineering

- vehicle: 48_SUV_5
- vehicle width: 1845mm
- group: G2
- barrier depth: 700mm
- driver position: RHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
212	591	0	477	0	577	2	367	0	1438	2

BDA software

M area + L area
189,619,514

Homogeneity value

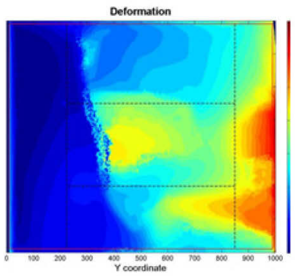
Row 3 + Row 4
1.5

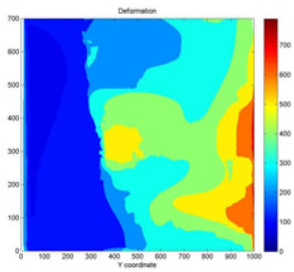
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 16

Department of Automotive Engineering

- vehicle: 35_SFC_3_repeat
- vehicle width: 1751mm
- group: G2
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
154	488	1.1	333	1.7	431	1.8	435	1	2207	5.5

BDA software

M area + L area
127,369,304

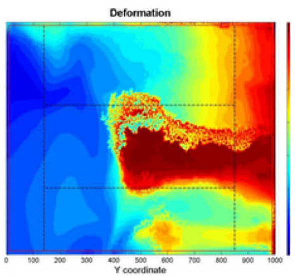
Homogeneity value

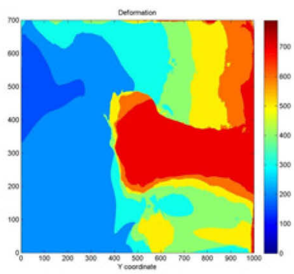
Row 3 + Row 4
2.0

DDY

Department of Automotive Engineering

- vehicle: 30_SUV_4
- vehicle width: 1920mm
- group: G2
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	TV	PPS
231	694	0	511	0	692	1.4	496	0	3599	1.4

BDA software

M area + L area
57,173,388

Homogeneity value

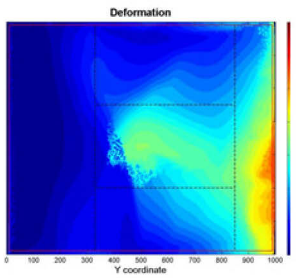
Row 3 + Row 4
15.7

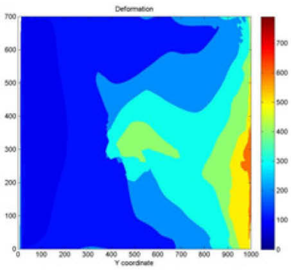
DDY

FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

- vehicle: 28_Supermini_4
- vehicle width: 1540mm
- group: G2
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
99	344	2	218	2	339	2	258	1	2135	7

BDA software

M area + L area
131,503,576

Homogeneity value

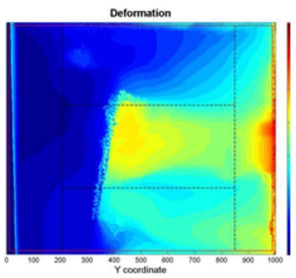
Row 3 + Row 4
2.6

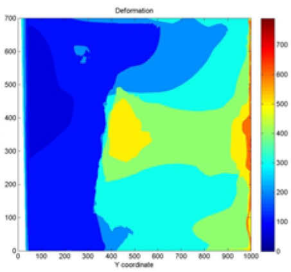
DDY

FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

- vehicle: 21_SFC_2_TRL
- vehicle width: 1783mm
- group: G2
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
133	446	1.1	336	1.6	439	2	303	1.2	1963	5.8

BDA software

M area + L area
164,611,553

Homogeneity value

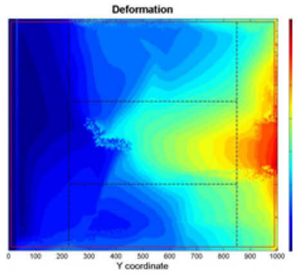
Row 3 + Row 4
1.7

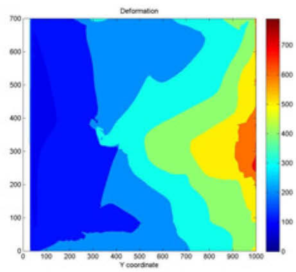
DDY

FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

- vehicle: 18_SFC_3
- vehicle width: 1752mm
- group: G2
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
137	468	2	280	1.4	457	2	304	1.4	1742	6.7

BDA software

M area + L area
143,076,073

Homogeneity value

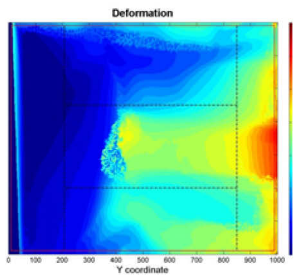
Row 3 + Row 4
1.1

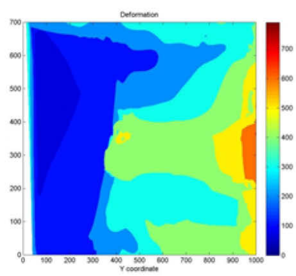
DDY

FIMCAR frontal impact and compatibility assessment research

Department of Automotive Engineering

- vehicle: 07_SFC_2_serial
- vehicle width: 1783mm
- group: G2
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
141	424	2	276	1.8	414	2	353	0.9	2237	6.8

BDA software

M area + L area
148,335,514

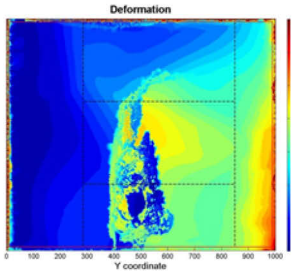
Homogeneity value

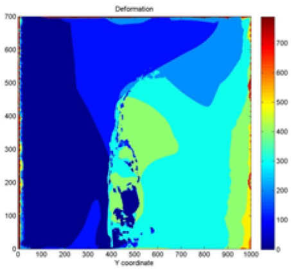
Row 3 + Row 4
1.7

DDY

Department of Automotive Engineering

- vehicle: FIMCAR_Supermini_2_RRSc_IDIADA
- vehicle width: 1627mm
- group: G1
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
156	479	0.4	376	3.5	465	1.9	428	0	3805	3.5

BDA software

M area + L area
38,180,200

Homogeneity value

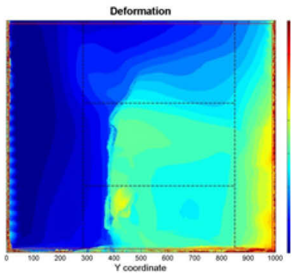
Row 3 + Row 4
0.6

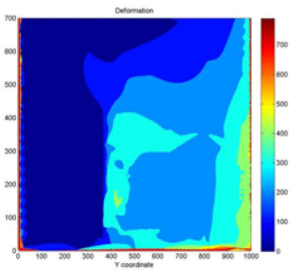
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 23

Department of Automotive Engineering

- vehicle: FIMCAR_Supermini_2_BASt_1
- vehicle width: 1627mm
- group: G1
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
131	411	2	259	2	326	2	407	1.8	1245	7.8

BDA software

M area + L area
209,418,168

Homogeneity value

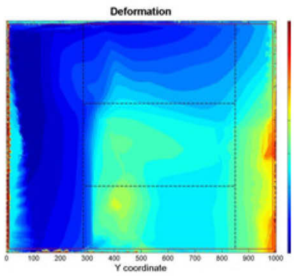
Row 3 + Row 4
0.6

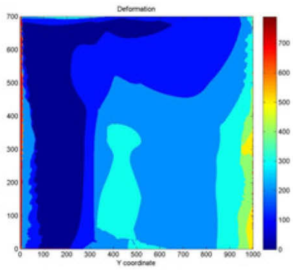
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 24

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

- vehicle: FIMCAR_Supermini_2_BASt_1
- vehicle width: 1627mm
- group: G1
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
143	392	2	234	2	324	2	383	1.9	1115	7.9

BDA software

M area + L area
284,247,959

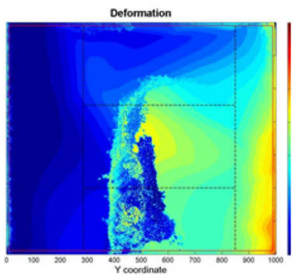
Homogeneity value

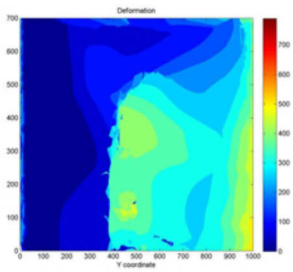
Row 3 + Row 4
1.0

DDY

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

- vehicle: FIMCAR_Supermini_2_FIAT
- vehicle width: 1627mm
- group: G1
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
125	482	1.1	335	1.8	422	2	401	0	3989	4.8

BDA software

M area + L area
122,006,265

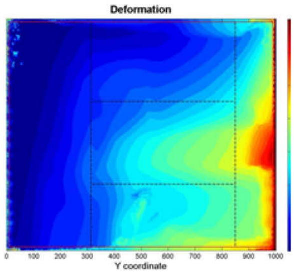
Homogeneity value

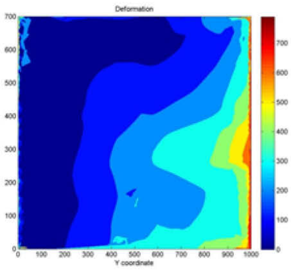
Row 3 + Row 4
0.6

DDY

Department of Automotive Engineering

- vehicle: 55_SFC_3
- vehicle width: 1572mm
- group: G1
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
129	413	2	196	2	398	2	347	1.9	1168	7.8

BDA software

M area + L area
190,144,805

Homogeneity value

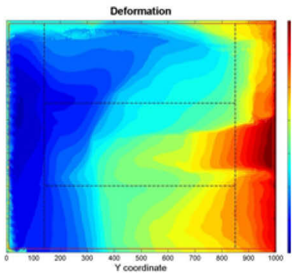
Row 3 + Row 4
0.7

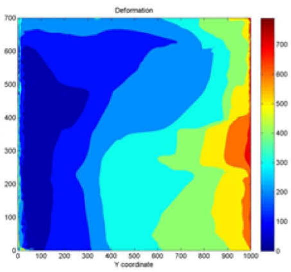
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 27

Department of Automotive Engineering

- vehicle: 54_SUV_4_with_ACE
- vehicle width: 1920mm
- group: G1
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
200	559	1.3	322	0.5	534	1.7	457	1.7	1393	5.2

BDA software

M area + L area
240,470,555

Homogeneity value

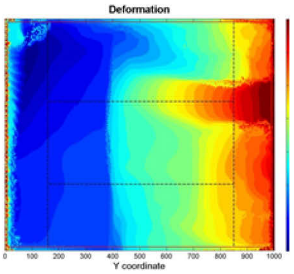
Row 3 + Row 4
1.7

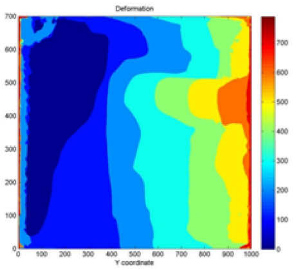
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 28

Department of Automotive Engineering

- vehicle: 50_SUV_3
- vehicle width: 1880mm
- group: G1
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
196	596	0	493	0.2	560	1.9	411	1.9	1082	4.1

BDA software

M area + L area
232,011,092

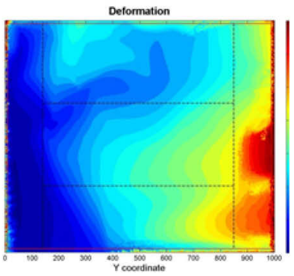
Homogeneity value

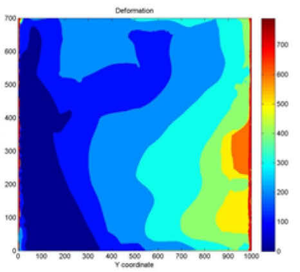
Row 3 + Row 4
1.2

DDY

Department of Automotive Engineering

- vehicle: 49_MPV_1
- vehicle width: 1920mm
- group: G1
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
175	502	1.9	285	1.7	425	1.9	422	1.9	1112	7.4

BDA software

M area + L area
291,113,869

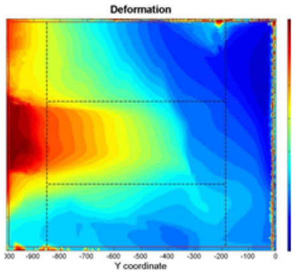
Homogeneity value

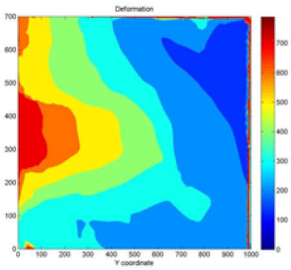
Row 3 + Row 4
0.7

DDY

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

- vehicle: 47_Large_car_4
- vehicle width: 1830mm
- group: G1
- barrier depth: 700mm
- driver position: RHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
195	564	0.3	381	0.3	551	2	344	1.9	1145	4.5

BDA software

M area + L area
148,682,153

Homogeneity value

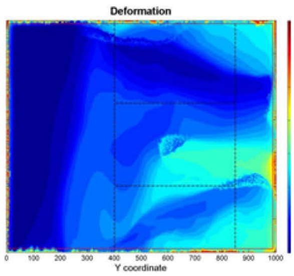
Row 3 + Row 4
0.8

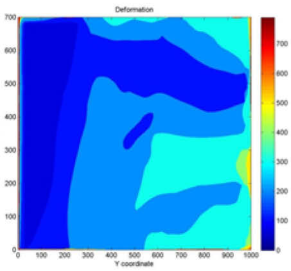
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 31

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

- vehicle: 46_Supermini_3
- vehicle width: 1397mm
- group: G1
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
92	295	2	215	2	215	2	253	1.4	1732	7.4

BDA software

M area + L area
152,047,152

Homogeneity value

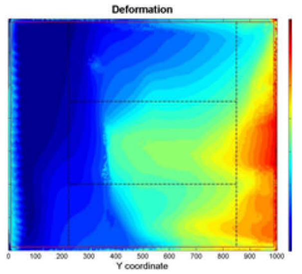
Row 3 + Row 4
0.7

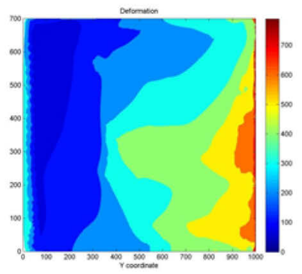
DDY

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 32

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

- vehicle: 34_SFC_homolo
- vehicle width: 1751mm
- group: G1
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
152	477	2	260	1.6	439	1.9	416	1.8	1295	7.2

BDA software

M area + L area
206,548,218

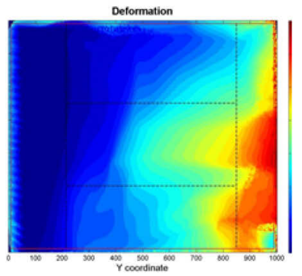
Homogeneity value

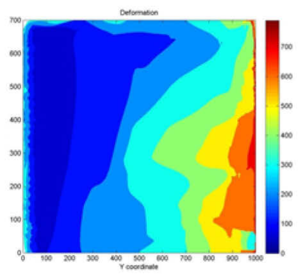
Row 3 + Row 4
1.0

DDY

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

- vehicle: 33_Medium_car
- vehicle width: 1770mm
- group: G1
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
138	549	2	268	1.5	448	2	381	1.6	1424	7.1

BDA software

M area + L area
139,433,536

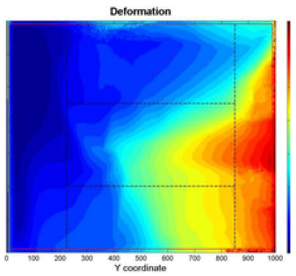
Homogeneity value

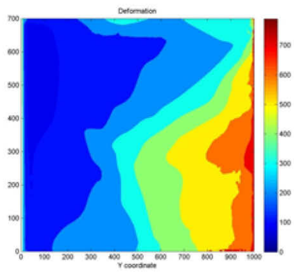
Row 3 + Row 4
1.0

DDY

Department of Automotive Engineering

- vehicle: 29_SFC_3_homolo
- vehicle width: 1752mm
- group: G1
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
155	542	2	230	0.6	523	1.8	428	1.6	1461	6.1

BDA software

M area + L area
154,667,587

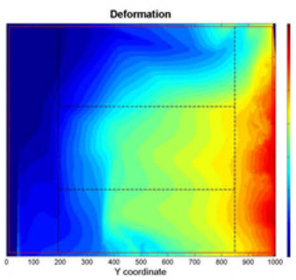
Homogeneity value

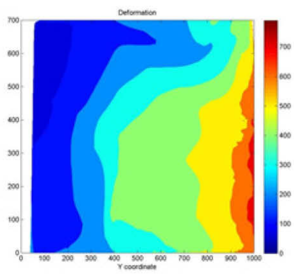
Row 3 + Row 4
1.2

DDY

Department of Automotive Engineering

- vehicle: 15_Large_car_3_DAG
- vehicle width: 1815mm
- group: G1
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
169	467	0.7	357	1.5	448	2	401	2	873	6.2

BDA software

M area + L area
299,503,392

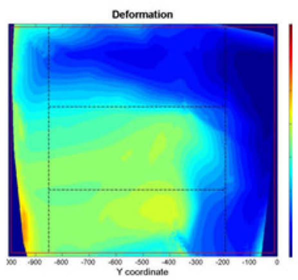
Homogeneity value

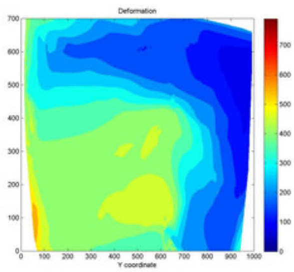
Row 3 + Row 4
0.6

DDY

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

- vehicle: 12_Large_car_3_DAD
- vehicle width: 1815mm
- group: G1
- barrier depth: 700mm
- driver position: RHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
143	399	2	255	2	365	2	396	2	1022	8

BDA software

M area + L area
302,384,904

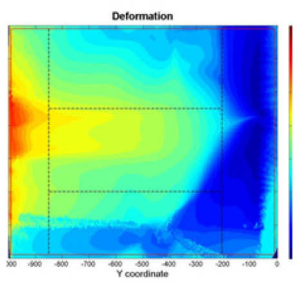
Homogeneity value

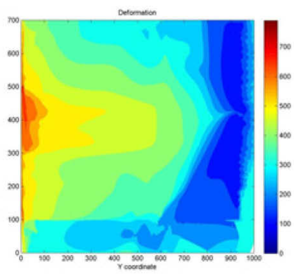
Row 3 + Row 4
0.3

DDY

FIMCAR frontal impact and compatibility assessment research — Department of Automotive Engineering — TU berlin

- vehicle: 10_Large_car_2_DAD
- vehicle width: 1788mm
- group: G1
- barrier depth: 700mm
- driver position: RHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
181	450	0.2	386	1.6	436	2	335	2	843	5.8

BDA software

M area + L area
259,185,762

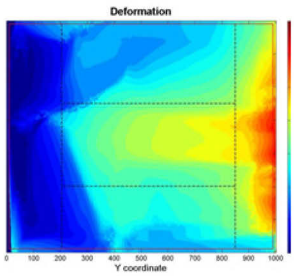
Homogeneity value

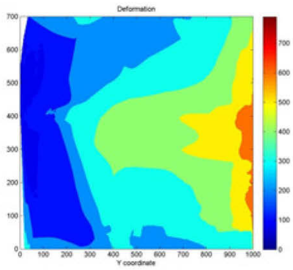
Row 3 + Row 4
0.4

DDY

Department of Automotive Engineering

- vehicle: 08_Large_car_2_DAG
- vehicle width: 1788mm
- group: G1
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
170	452	1.2	328	1.6	437	2	307	1.9	1097	6.7

BDA software

M area + L area
274,825,181

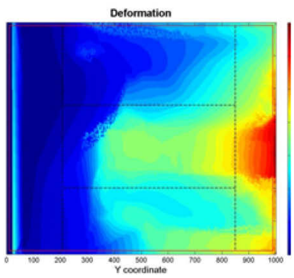
Homogeneity value

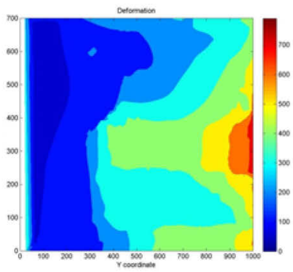
Row 3 + Row 4
0.7

DDY

Department of Automotive Engineering

- vehicle: 06_SFC_2_stiff
- vehicle width: 1783mm
- group: G1
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
142	460	2	253	1.5	447	2	354	1.4	1750	6.8

BDA software

M area + L area
189,625,949

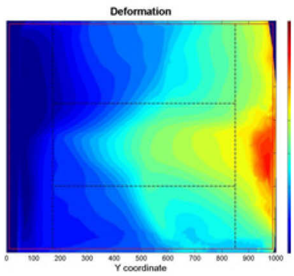
Homogeneity value

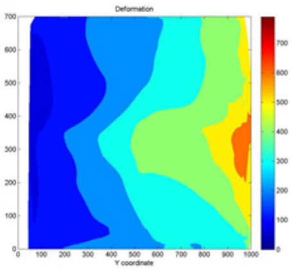
Row 3 + Row 4
1.2

DDY

Department of Automotive Engineering

- vehicle: 04_Large_car_1
- vehicle width: 1853mm
- group: G1
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
145	426	1.8	292	1.8	414	2	304	1.8	1227	7.5

BDA software

M area + L area
214,125,085

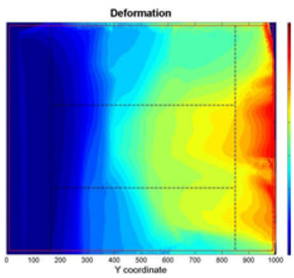
Homogeneity value

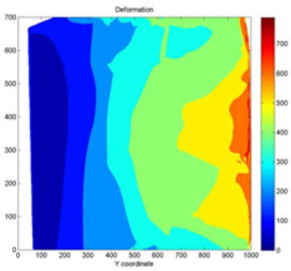
Row 3 + Row 4
1.5

DDY

Department of Automotive Engineering

- vehicle: 02_LCV
- vehicle width: 1870mm
- group: G1
- barrier depth: 700mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
164	465	0.2	388	1.4	455	2	403	2	994	5.6

BDA software

M area + L area
243,894,954

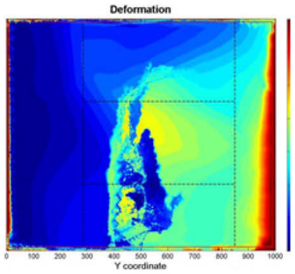
Homogeneity value

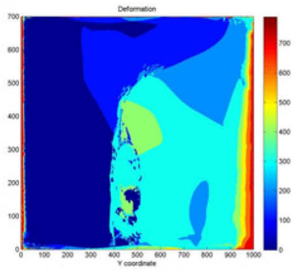
Row 3 + Row 4
1.5

DDY

Department of Automotive Engineering

- vehicle: FIMCAR_Supermini_2_RR_Sc_TUB
- vehicle width: 1627mm
- group: G1
- barrier depth: 790mm
- driver position: LHD





volume [l]	max def [mm]	U area score	U area def [mm]	M area score	M area def [mm]	L area score	L area def [mm]	H (M area) score	H (M area) TV	PPS
146	461	0.8	354	1.6	439	1.8	443	0	4016	4.1

BDA software

M area + L area
41,828,238

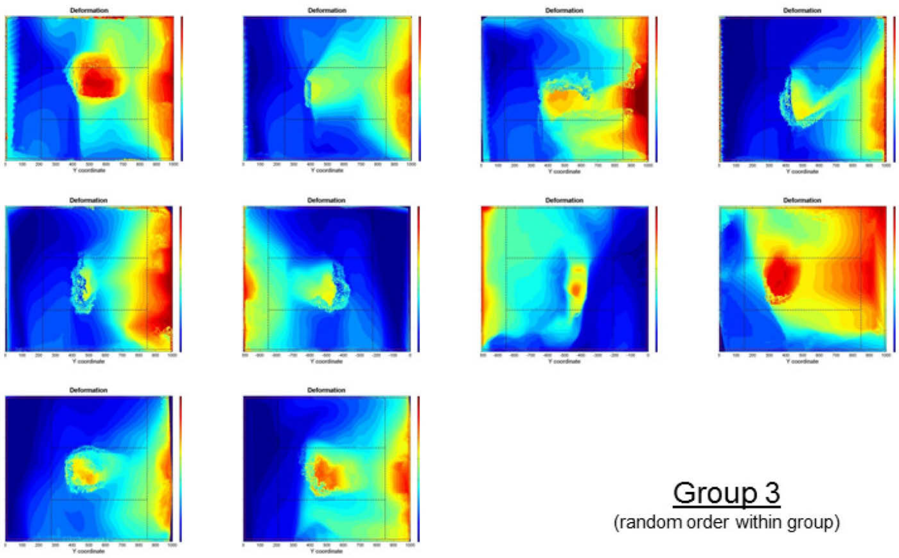
Homogeneity value

Row 3 + Row 4
0.6

DDY

Department of Automotive Engineering

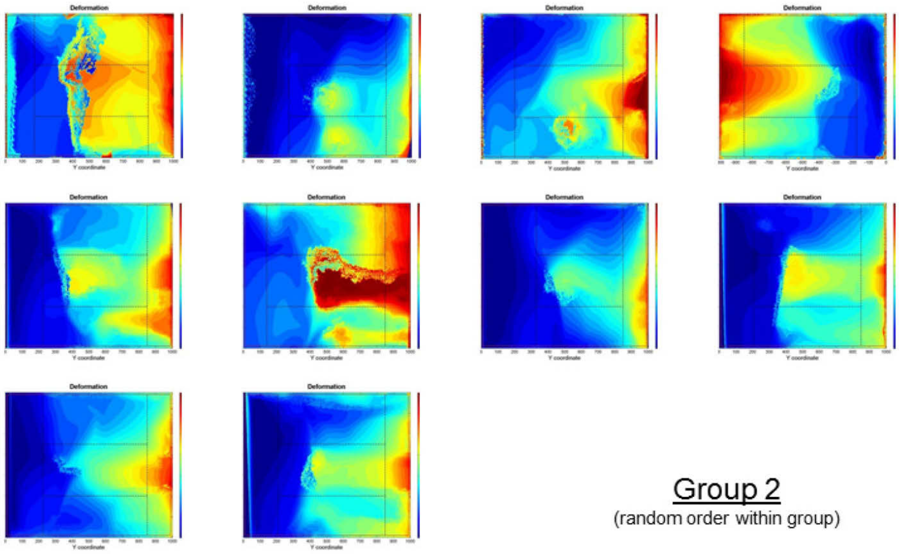
Subjective Classification w.r.t D2.1



Group 3
(random order within group)

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering

Subjective Classification w.r.t D2.1

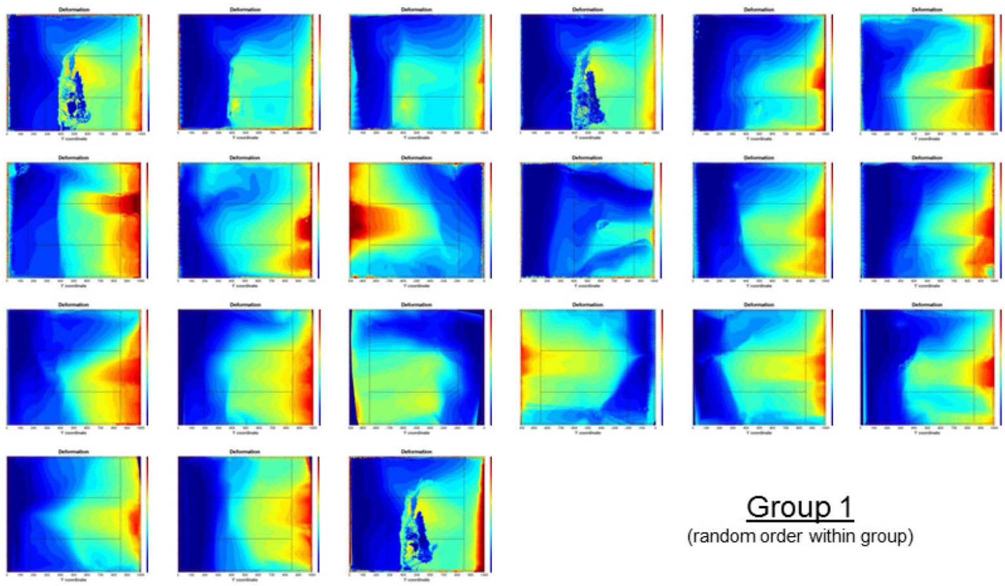


Group 2
(random order within group)

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 45

FIMCAR
frontal impact and compatibility assessment research
Department of Automotive Engineering

Subjective Classification w.r.t D2.1



Group 1
(random order within group)

Mathias Stein FIMCAR – WP 2 – Vehicle PDB Profiles 46

Department of Automotive Engineering

PDB metric results

- **Summary of BDA assessment:**

group	vehicle	volume [l]	max def [mm]	U area		M area		L area		H (M area)		PPS
				score	def [mm]	score	def [mm]	score	def [mm]	score	TV	
	FIMCAR_SFC_1	200	646	0	545	0	638	2	304	1.2	1966	3.2
	FIMCAR_Supermini_1_UTAC	146	415	1.3	321	2	402	2	246	1.3	1826	6.6
	56_SUV_4_without_ACE	185	579	1.3	320	0.8	504	1.8	431	0	3390	4
	52_Supermini_6	116	451	2	169	1.6	437	2	341	0	3819	5.6
G3	37_Small_SUV	157	570	1	339	1	489	1.8	430	0.1	3131	4
	19_Supermini_5_DAD	110	433	2	170	1.8	419	2	265	0	3626	5.8
	17_SUV_7	137	537	1.6	303	0.9	500	2	358	0.7	2444	5.2
	11_SUV_6	252	629	0	509	0	624	1.8	431	0	1459	1.8
	09_Supermini_5_DAG	117	502	2	184	1.2	474	2	300	0	3433	5.2
	05_SFC_2_weak	138	558	2	252	0.5	534	2	336	0.1	3160	4.6
	FIMCAR_SFC_1	228	582	0	548	0.1	568	1.5	495	0	3792	1.6
	FIMCAR_City_Car_1_UTAC	104	425	2	153	2	390	1.9	417	0.8	2373	6.7
	53_Family_car	189	589	1.6	302	0.7	518	1.4	513	1.7	1364	5.4
	48_SUV_5	212	591	0	477	0	577	2	367	0	1438	2
	35_SFC_3_repeat	154	488	1.1	333	1.7	431	1.8	435	1	2207	5.5
G2	30_SUV_4	231	694	0	511	0	692	1.4	496	0	3599	1.4
	28_Supermini_4	99	344	2	218	2	339	2	258	1	2135	7
	21_SFC_2_TRL	133	446	1.1	336	1.6	439	2	303	1.2	1963	5.8
	18_SFC_3	137	468	2	280	1.4	457	2	304	1.4	1742	6.7
	07_SFC_2_serial	141	424	2	276	1.8	414	2	353	0.9	2237	6.8

Department of Automotive Engineering

PDB metric results

- **Summary of BDA assessment:**

group	vehicle	volume [l]	max def [mm]	U area		M area		L area		H (M area)		PPS
				score	def [mm]	score	def [mm]	score	def [mm]	score	TV	
	FIMCAR_Supermini_2_RRSc_IDIADA	156	479	0.4	376	3.5	465	1.9	428	0	3805	3.5
	FIMCAR_Supermini_2_BASt_1	131	411	2	259	2	326	2	407	1.8	1245	7.8
	FIMCAR_Supermini_2_BASt_1	116	451	2	169	1.6	437	2	341	0	3819	5.6
	FIMCAR_Supermini_2_FIAT	125	482	1.1	335	1.8	422	2	401	0	3989	4.8
	55_SFC_3	129	413	2	196	2	398	2	347	1.9	1168	7.8
	54_SUV_4_with_ACE	200	559	1.3	322	0.5	534	1.7	457	1.7	1393	5.2
	50_SUV_3	196	596	0	493	0.2	560	1.9	411	1.9	1082	4.1
	49_MPV_1	175	502	1.9	285	1.7	425	1.9	422	1.9	1112	7.4
	47_Large_car_4	195	564	0.3	381	0.3	551	2	344	1.9	1145	4.5
	46_Supermini_3	92	295	2	215	2	215	2	253	1.4	1732	7.4
G1	34_SFC_homolo	152	477	2	260	1.6	439	1.9	416	1.8	1295	7.2
	33_Medium_car	138	549	2	268	1.5	448	2	381	1.6	1424	7.1
	29_SFC_3_homolo	155	542	2	230	0.6	523	1.8	428	1.6	1461	6.1
	15_Large_car_3_DAG	169	467	0.7	357	1.5	448	2	401	2	873	6.2
	12_Large_car_3_DAD	143	399	2	255	2	365	2	396	2	1022	8
	10_Large_car_2_DAD	181	450	0.2	386	1.6	436	2	335	2	843	5.8
	08_Large_car_2_DAG	170	452	1.2	328	1.6	437	2	307	1.9	1097	6.7
	06_SFC_2_stiff	142	460	2	253	1.5	447	2	354	1.4	1750	6.8
	04_Large_car_1	145	426	1.8	292	1.8	414	2	304	1.8	1227	7.5
	02_LCV	164	465	0.2	388	1.4	455	2	403	2	994	5.6
	FIMCAR_Supermini_2_RR_Sc_TUB	146	461	0.8	354	1.6	439	1.8	443	0	4016	4.1

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

PDB metric results

- **Summary of Homogeneity value (TV upgraded) assessment:**

group	vehicle	M area + L area
G3	FIMCAR_SFC_1	47,915,147
	FIMCAR_Supermini_1_UTAC	100,495,224
	56_SUV_4_without_ACE	71,464,524
	52_Supermini_6	62,144,259
	37_Small_SUV	71,464,524
	19_Supermini_5_DAD	85,738,397
	17_SUV_7	74,689,634
	11_SUV_6	129,748,335
	09_Supermini_5_DAG	47,775,587
	05_SFC_2_weak	108,672,228
G2	FIMCAR_SUV_1_IDIADA	59,929,260
	FIMCAR_City_Car_1_UTAC	81,782,461
	53_Family_car	82,156,892
	48_SUV_5	189,619,514
	35_SFC_3_repeat	127,369,304
	30_SUV_4	57,173,388
	28_Supermini_4	131,503,576
	21_SFC_2_TRL	164,611,553
	18_SFC_3	143,076,073
	07_SFC_2_serial	148,335,514

group	vehicle	M area + L area
G1	FIMCAR_Supermini_2_RRSc_IDIADA	38,180,200
	FIMCAR_Supermini_2_BASt_1	209,418,168
	FIMCAR_Supermini_2_BASt_1	284,247,959
	FIMCAR_Supermini_2_FIAT	122,006,265
	55_SFC_3	190,144,805
	54_SUV_4_with_ACE	240,470,555
	50_SUV_3	232,011,092
	49_MPV_1	291,113,869
	47_Large_car_4	148,682,153
	46_Supermini_3	152,047,152
	34_SFC_homolo	206,548,218
	33_Medium_car	139,433,536
	29_SFC_3_homolo	154,667,587
	15_Large_car_3_DAG	299,503,392
	12_Large_car_3_DAD	302,384,904
	10_Large_car_2_DAD	259,185,762
	08_Large_car_2_DAG	274,825,181
	06_SFC_2_stiff	189,625,949
	04_Large_car_1	214,125,085
	02_LCV	243,894,954
	FIMCAR_Supermini_2_RR_Sc_TUB	41,828,238

FIMCAR frontal impact and compatibility assessment research
Department of Automotive Engineering
TU berlin

PDB metric results

- **Summary of DDY assessment:**

group	vehicle	Row 3 + Row 4
G3	FIMCAR_SFC_1	7.1
	FIMCAR_Supermini_1_UTAC	1.4
	56_SUV_4_without_ACE	17.3
	52_Supermini_6	10.0
	37_Small_SUV	8.6
	19_Supermini_5_DAD	3.0
	17_SUV_7	6.6
	11_SUV_6	3.9
	09_Supermini_5_DAG	5.3
	05_SFC_2_weak	6.3
G2	FIMCAR_SUV_1_IDIADA	0.8
	FIMCAR_City_Car_1_UTAC	1.4
	53_Family_car	5.4
	48_SUV_5	1.5
	35_SFC_3_repeat	2.0
	30_SUV_4	15.7
	28_Supermini_4	2.6
	21_SFC_2_TRL	1.7
	18_SFC_3	1.1
	07_SFC_2_serial	1.7

group	vehicle	Row 3 + Row 4
G1	FIMCAR_Supermini_2_RRSc_IDIADA	0.6
	FIMCAR_Supermini_2_BASt_1	0.6
	FIMCAR_Supermini_2_BASt_1	1.0
	FIMCAR_Supermini_2_FIAT	0.6
	55_SFC_3	0.7
	54_SUV_4_with_ACE	1.7
	50_SUV_3	1.2
	49_MPV_1	0.7
	47_Large_car_4	0.8
	46_Supermini_3	0.7
	34_SFC_homolo	1.0
	33_Medium_car	1.0
	29_SFC_3_homolo	1.2
	15_Large_car_3_DAG	0.6
	12_Large_car_3_DAD	0.3
	10_Large_car_2_DAD	0.4
	08_Large_car_2_DAG	0.7
	06_SFC_2_stiff	1.2
	04_Large_car_1	1.5
	02_LCV	1.5
	FIMCAR_Supermini_2_RR_Sc_TUB	0.6