Crash Simulation in Pedestrian Protection

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Introduction

Within the European Union 8.500 pedestrians and cyclists are killed in traffic accidents per year; 290.000 are injured. This represents about 20 % of all people killed resp. injured in traffic accidents per year. In order to protect the weakest participant in traffic the European Union and European car manufacturers take efforts to improve vehicle's pedestrian friendliness. The European Union will enact legislative measures concerning pedestrian protection in the year 2005, basing on the test procedures developed by EEVC and ACEA. Thus pedestrian protection is becoming a topic of increasing importance.
Besides the integration of simulation into the process of developing a car's front end using a component model, simulation offers additional possibilities to examine a car's crash performance concerning pedestrian protection. For example simulation using a full dummy model allows to understand the kinematics of the human body when impacted by a car. Concerning the subsystem test according to EEVC and ACEA highly simplified models enable general examination in an early state of development when concrete boundaries are not given yet. The aim is to determine the influence various parameters have on the results for the subsystem tests in order to provide a tool in discussion with other departments and to work out guidelines for further car development.

Kinematics of the pedestrian accident

In order to improve the crash performance of a car's front end concerning pedestrian protection the first important step is to analyse the kinematics the human body expires when impacted by a car. Thus the parameters that influence on one hand the pedestrian's kinematics and on the other hand the car's crash behaviour can be investigated. This examination allows to localise critical impact zones that need consideration regarding pedestrian safety. Information about the kinematics of the human body in case of an impact on the car's front end can be obtained by evaluation of accident data, by reconstruction of accidents, furthermore by cadaver and dummy tests and in addition by simulation using a full dummy model. To perform simulation of a full dummy impact a rigid body dummy is integrated into the finite element model of the vehicle. The examples show the impact of a 6 year old child and of a 50 percentile male on a sport car and on a van. (see *Figure 1*)

The animation illustrates that the kinematics of the pedestrian are depending on one hand of the pedestrian's size and weight and on the other hand on the car's font structure.

In the first contact of the 6 year old child to the car many body parts are involved; upper leg, pelvis and torso are impacted by the bumper area. In case of the van an even larger area is impacted due to the bigger bumper system of this vehicle. In the next step the child's head hits the forward section of the bonnet top.

The first contact of the 50 percentile male is the impact of the leg by the vehicle's bumper system, initiating a rotation of the whole body. Depending on the car's front structure the pelvis hits the bonnet leading edge; in case of this example of a relatively flat sport car pelvis and car do not get into contact whereas in case of this example of a van the upper leg and pelvis hit the bonnet leading edge. Finally the head impacts the rearward section of the bonnet top (example of this sport car) or the windscreen area (example of this van).

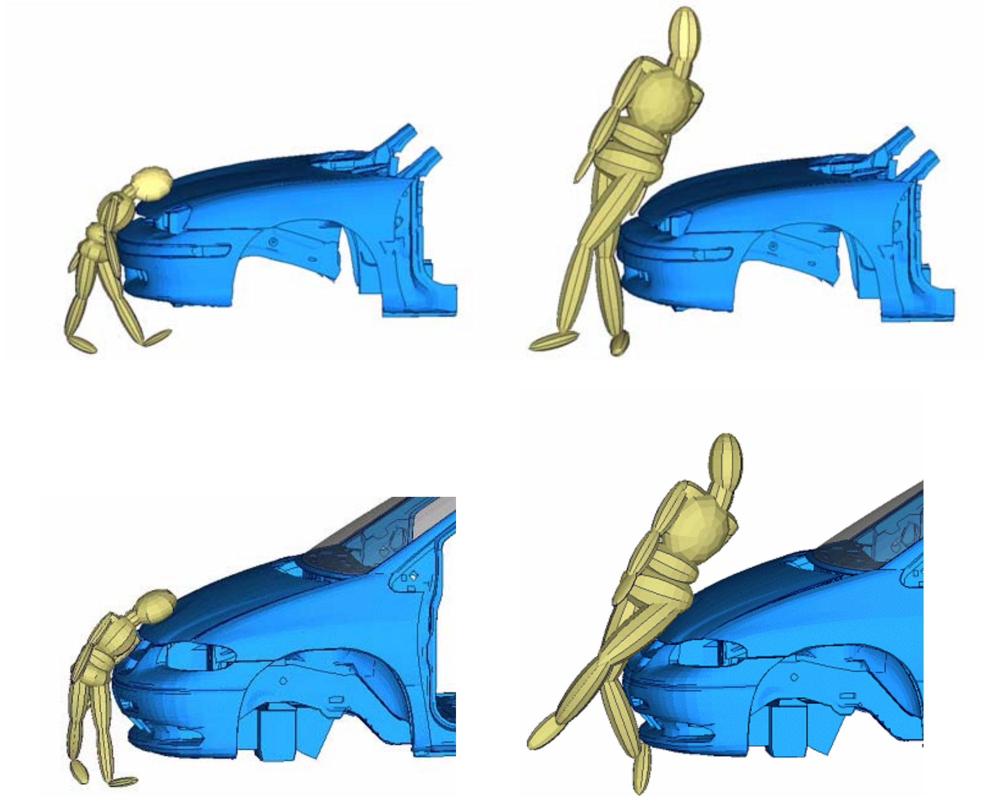

Figure 1 Impact of a 6 year old child and a 50 percentile male on a sport car and on a van

Thus concerning adults the collision of the pedestrian with the vehicle can be divided into three impact phases:

- Bumper hits the leg, rotation of the body is initiated
- Pelvis hits the bonnet leading edge (depending on the vehicle)
- Head hits the bonnet top resp. the windscreen

Legislative Situation

This division into three phases of impact constitutes the base for the subsystem tests using a specific impactor each developed by EEVC (European Enhanced Vehicle Safety Committee) Working Group 10 and 17. ACEA (Association des Constructeurs Européens d' Automobiles) took over the idea of subsystem tests but conducted some alterations concerning the impactors, test conditions and prescribed limits. Based on its Commitment, ACEA elaborated a European Directive to be released in 2005. It consists of

- Lower legform to bumper test
- Alternative upper legform to bumper test (e.g. for SUVs)
- Upper legform to bonnet leading edge tests (monitored only)
- Child / small adult head to bonnet top test
- Adult head to windscreen test (monitored only)

Examination using a parameter model

Concerning for example the lower legform to bumper test a highly simplified model enables general examination of various parameters and their influence on the prescribed subsystem tests. This kind of investigation can be applied for first studies, in an early state of development when no concrete boundaries are given yet. So simulation using a parameter model provides a tool in discussion with other departments and for the elaboration of guidelines for future car development.

The parameter model consists of two half cylindrical bodies representing the upper part of the front fascia (bumper's outer skin and foam corpus) and the spoiler. These bodies are defined as rigid and guided in x direction. Their translations in x are influenced by a spring-damper-system each.
This simplified configuration of the model allows very easy and quick alterations with a minimum of calculation time. So the influence of various parameters on the results for deceleration of tibia, knee bending angle and shear displacement can easily be determined by simple alteration of the position of these two bodies or by changing the spring characteristics.

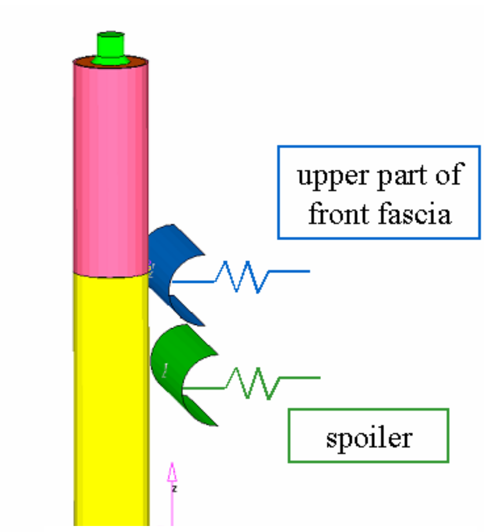

Figure 2 Assembly of the parameter model

Influence of position parameters

Among the parameters that have been determined are the vertical and the horizontal position of the spoiler as well as the vertical adjustment of both the front fascia's upper part and the spoiler.

Figure 3 presents the influence of the horizontal spoiler position. A high potential for the improvement of the bending angle can be observed. In this example moving the spoiler forward about 20 mm a reduction of the bending angle about 17 % can be obtained with an increase in deceleration about 5 %. This adjustment corresponds to a design where the spoiler is nearly at the same vertical position as the upper part of the front fascia. The bending angle can be improved due to the better support of the lower part of the impactor by the spoiler. Moving the spoiler further forward offers additional benefit for the bending angle but is not realistic due to design, ramp angle, etc.

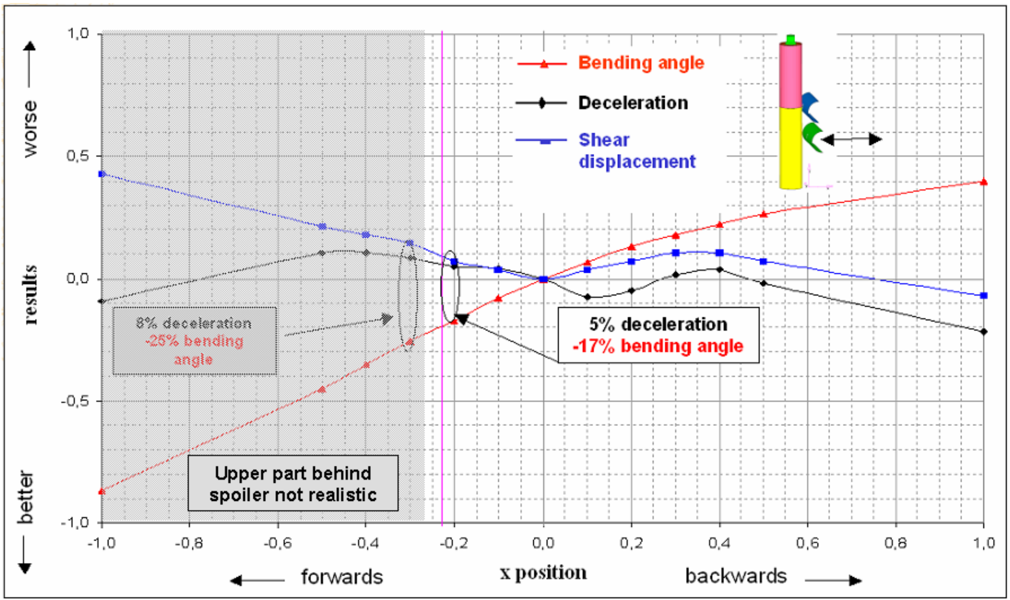

Figure 3 Influence of the spoiler's horizontal position

In *Figure 4* the influence of the spoiler's vertical position is displayed. An alteration of the spoiler's vertical position doesn't have much influence on the deceleration, but moving the spoiler down the bending angle can be decreased. Again, the improvement of the bending angle is consequence of the better support of the lower part of the impactor provided by the spoiler. In this example moving the spoiler down about 20 mm the bending angle can be diminished about 5 %. Moving the spoiler further down allows further decrease of the bending angle. However this measure is limited by reasons like ground clearance and ramp angle.

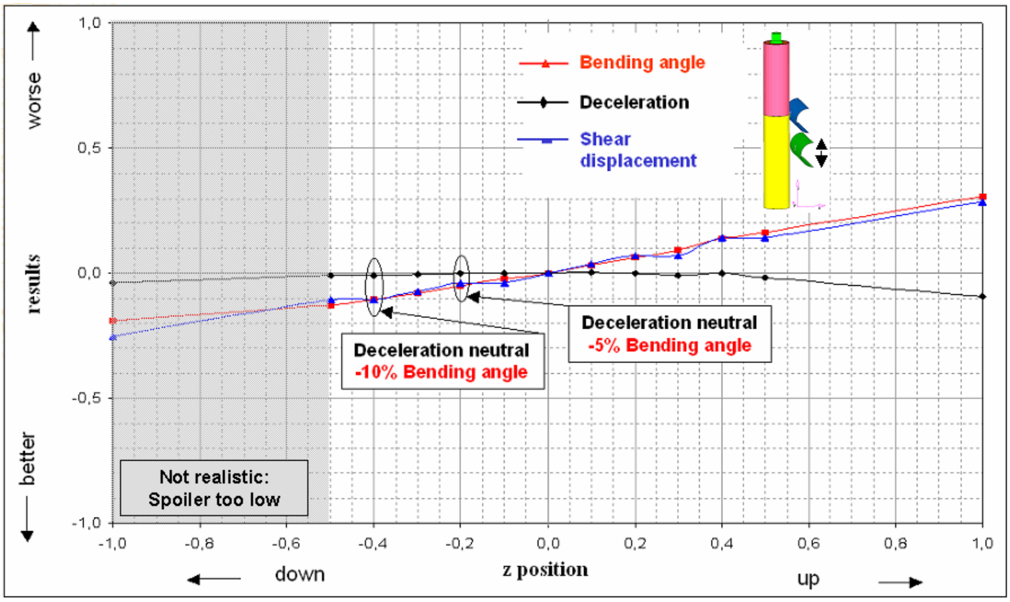

Figure 4 Influence of the spoiler's vertical position

Figure 5 reflects the influence of the vertical position of both, the front fascia's upper part and the spoiler. In this case the improvement of the bending angle is higher than by only moving the spoiler down. In this example, moving both parts down about 20 mm the bending angle can be reduced by 10 %. In addition the deceleration can be decreased, in this case by 4 %. Again, adjusting both parts even lower offers additional benefit, but the position is restricted by compatibility, ground clearance etc. Beyond, in this case the shear displacement is increasing importantly.

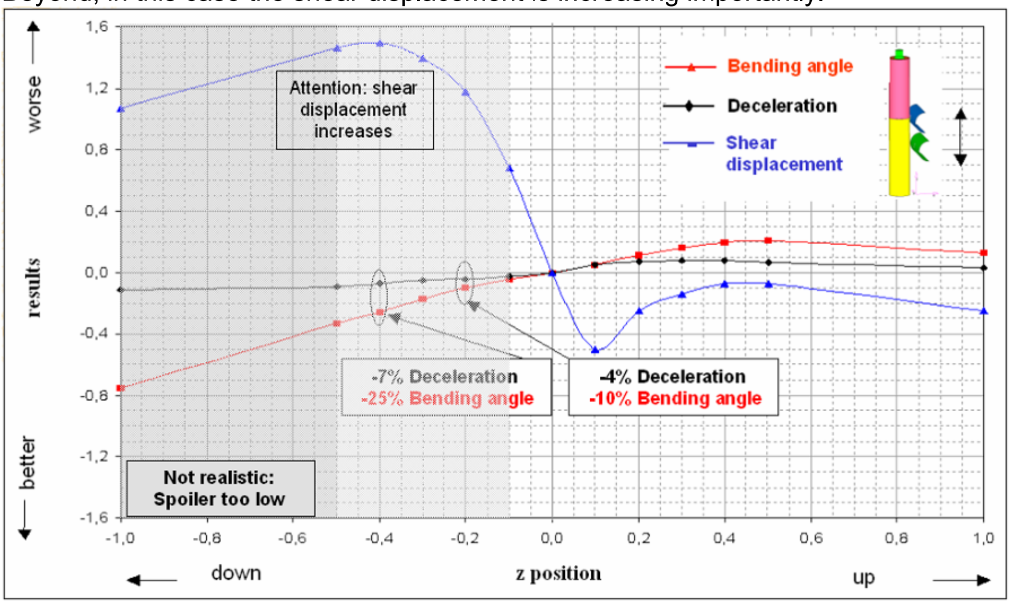

Figure 5 Influence of spoiler's and upper part's vertical position

Influence of stiffness parameters

Besides the position of the front fascia's upper part and of the spoiler the stiffness of these two parts has an important influence on the results for deceleration, bending angle and shear displacement.

Figure 6 displays the influence of the upper part of the front fascia, including bumper's outer skin and the foam corpus located between the outer skin and the bumper cross member. Reducing the stiffness of the upper part, bending angle as well as deceleration can be decreased importantly. For example constituting the upper part weaker by factor 0.2 reduces the bending angle about 42 % with an improvement in deceleration of about 10 %. A weaker construction of the upper part leads to a weaker impact resulting in lower deceleration. Beyond, the weaker construction allows a deeper penetration of the impactor's knee area into the vehicle and thus the bending angle can be reduced. An even weaker constitution of the fascia's upper part leads to additional improvement for both bending angle and deceleration. However this causes deep penetration into the vehicle what is restricted due to design / construction space needed for example for other loadcases and different applications.

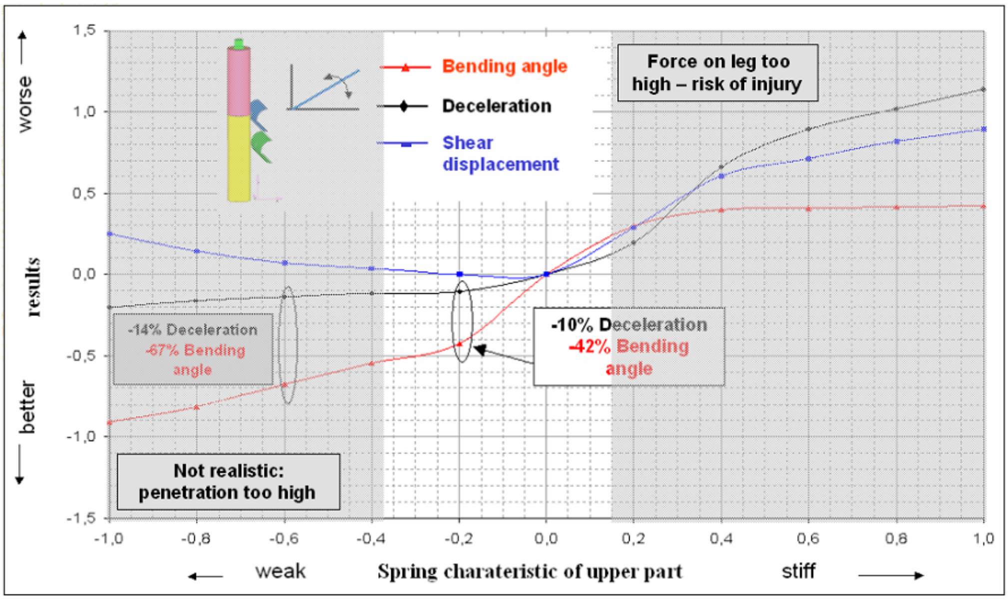

Figure 6 Influence of the upper part's stiffness

Figure 7 represents the influence of the spoiler's stiffness. A stiffer constitution of the spoiler results in an improved support of the lower part of the spoiler and thus the bending angle is diminished. On the other hand a stiffer spoiler leads to higher deceleration. In this example for a spoiler stiffer by factor 0.2 an improvement of the bending angle of about 17 % can be obtained, but deceleration is increasing about 9 %. So depending on the concrete structure of the vehicle these influences have to be weighed up.

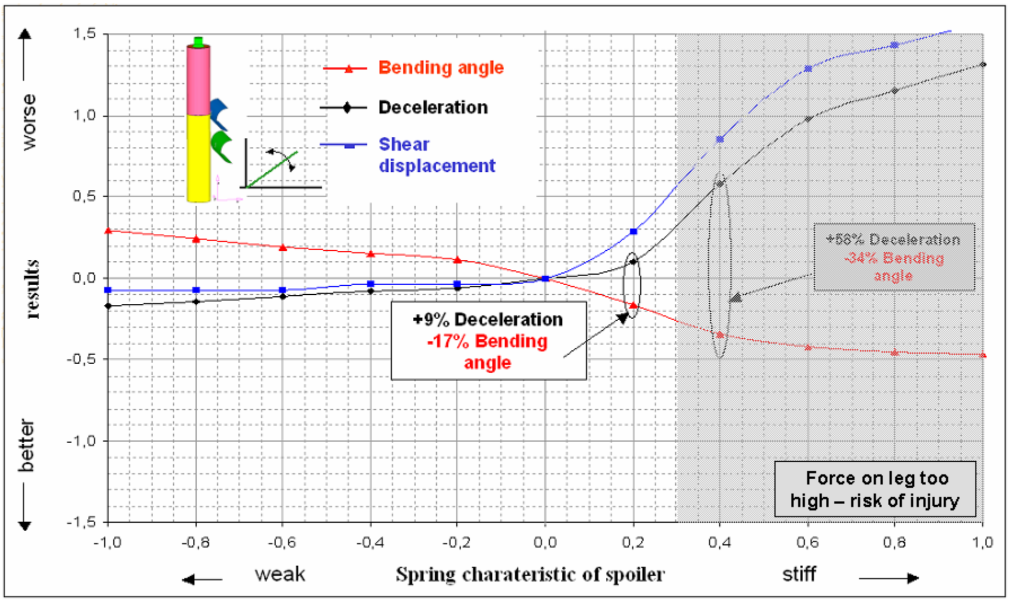

Figure 7 Influence of the spoiler's stiffness

Summary of parameters' influence

After presenting some of the multitude of parameters, the results are summarised and the parameters with the highest potential of improvement are pointed out for this example of a parameter model.

- A weaker composition of front facing's upper part offers the highest potential to improve deceleration and bending angle
- Repositioning the spoiler in line with front facia's upper part improves the bending angle
- A lower position of the spoiler decreases the bending angle with little changes in deceleration
- A lower position of both the upper part and the spoiler improves bending angle as well as deceleration
- A stiffer composition of the spoiler improves the bending angle but deceleration increases

Combination of parameters

After determining the influence of various single parameters in another step the combination of parameters is examined. Among the multitude of catenations the combination of the spoiler's horizontal and vertical position are presented in *Figure 8*. The influence of the spoiler's horizontal position (circle) and its vertical position (diamond) on the bending angle are displayed as well as the curve (triangle) resulting from simple addition of both curves. The last curve (rectangle) represents the results obtained by altering both parameters on the model. A good correlation between the curve determined by addition and the curve resulting form calculation using the parameter model can be observed. So the improvement by the influence of single parameters can be superposed, however the catenation is restricted to reasonable limits.

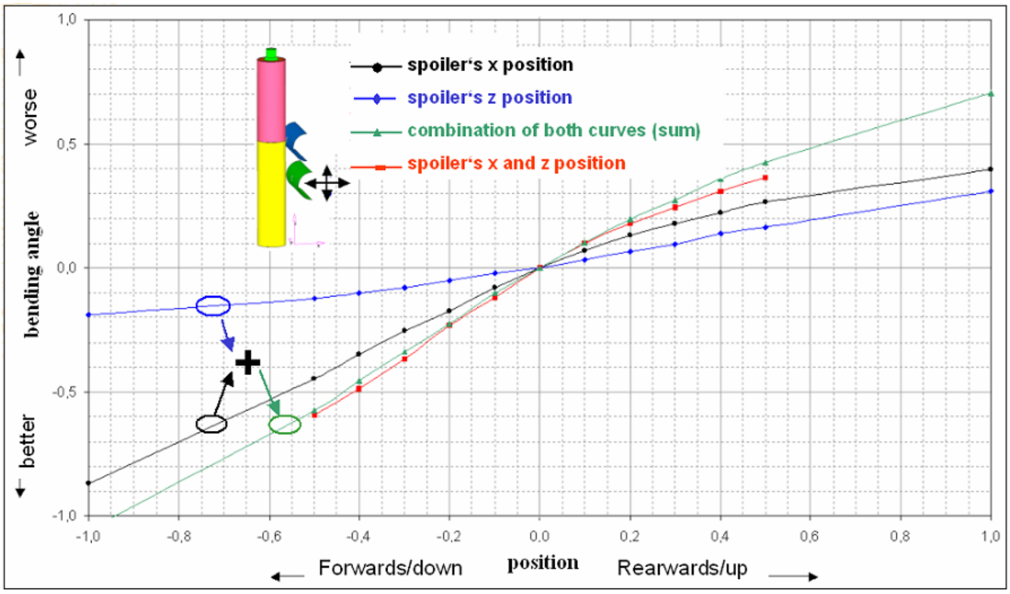

Figure 8 Combination of two parameters

Summary and Conclusions

Simulation using a full dummy model enables to analyse the kinematics of the human body when impacted by a car's front end. So the parameters influencing the pedestrian's kinematics as well as the car's crash behaviour can be investigated and critical impact zones can be localized.
Concerning the subsystem tests according to EEVC resp. ACEA a highly simplified model allows general determination of the influence different parameters have on the results for the prescribed test criteria (deceleration of tibia, knee bending angle and knee shear displacement) for the lower legform to bumper test. A parameter model offers the advantage of very easy and quick alteration of the model and a minimum of calculation time. So the influence of various parameters can be investigated in a fast and convenient way. Examination using a parameter model can be applied for first studies, in an early state of development when no concrete boundaries are given yet. Of course this examination enables to work out tendencies only, concrete values depend on the baseline conditions applied to the parameter model. Nonetheless, a parameter model provides an useful tool in discussion with other departments and allows to develop guidelines for future car design and construction.

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