Safe Small Electric Vehicles through Advanced Simulation Methodologies

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EXECUTIVE SUMMARY

This deliverable focuses on an improvement of the car front in order to increase pedestrian protection. Two versions of the car model were used to simulate a pedestrian accident in order to compare the car behaviour, the body kinematic and finally to assess comparatively the different injury risks posed. The proposed improvement is limited to the change of the front transversal beam. Therefore only lower leg injury risk was reduced. However, due to the slight changes of the body kinematic, increased head injury risk was computed. This illustrates the complexity of pedestrian protection optimization.

Even if the pedestrian protection was not significantly improved in this section, the subtask is a perfect demonstrator of the tool chain developed in framework of SafeEV.

APPROVAL STATUS

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REVISION TABLE

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Glossary

AE-MDB  Advanced European Mobile Deformable Barrier
AHBM  Active Human Body Model
AMuS  Auto Motor und Sport
ECE  Economic Commission for Europe
DAB  Driver Air Bag
FEM  Finite Element Method
FHWA  Federal Highway Administration
FIMCAR  Frontal Impact and Compatibility Assessment Research
FWDB  Full Width Deformable Barrier
GCM  Generic Car Model
HBM  Human Body Model
IIHS  Insurance Institute for Highway Safety
IKA  Institut für Kraftfahrzeuge RWTH Aachen University
IMVITER  IMplementation of VIrtual TEsting in safety Regulations
KAB  Knee Air Bag
KB  Knee Bolster
LL  Load Limiter
LS-DYNA  Finite element method solver provided by Livermore Software Technology Corporation
MIC  Multiple Impact Crashes
MPDB  Mobile progressive deformable barrier
NCAC  National Crash Analysis Center
NCAP  New Car Assessment Programme
NHTSA  National Highway Traffic Safety Administration
ODB  Offset Deformable Barrier
PDB  Progressive deformable barrier
PreTE  seat belt PreTEnsioner
REVM  Reference Electric Vehicle Model
RT  Real Testing
SAB  Side Air Bag
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<td>US</td>
<td>United States of America</td>
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<td>VRU</td>
<td>Vulnerable Road User</td>
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1 Introduction

The purpose of WP5.2 is to demonstrate a use case for an advanced safety solution for dedicated SEVs. Therefore one solution elaborated within WP4 has been selected for further demonstration. In March 2015, at the physical Safe-EV meeting in Turin, Italy the project partners agreed on the use of an enhancement of the REVM2’s cross beam as best solution for pedestrian safety elaborated in WP4. In the present step of the project the developed tool chain is applied to this improved pedestrian solution by simulating comparatively a pedestrian impact with two car models: The model developed in WP3 and the one finalized in WP5.

Within WP5.2 the advanced simulation methods for pedestrian safety in SEVs developed in WP3 has been applied jointly at DAIMLER and UNISTRA.

Within WP4.1 the front structure of the REVM2 FEM model was redesigned in a way to achieve a more pedestrian friendly front bumper. Within the alternative task in WP5.1 the changed front structure of REVM2 has been finalized and transferred to task T5.2.

The present report exposes the comparative pedestrian accident solution based on the virtual tool chain and using alternatively REVM2 model developed within WP3 and the improved car model REVM2) integrating an advanced transversal beam, hereafter called the WP5 solution.
2 Simulation of basic and improved pedestrian protection solution

2.1) Impact conditions and pedestrian kinematic

This section presents the initial condition of the pedestrian impact (figure 1) as well as the comparative kinematic results obtained for the basic solution (WP3) and the improved solution (WP5). Figure 2 shows the WP3 car vs. pedestrian model. It is mentioned that WP5 car model is similar in shape as only the transversal beam was changed. In figure 3 the comparative WP3 vs. VP5 body kinematics is shown. So far no significant differences can be observed.

Figure 1. Initial conditions of the pedestrian impact.
Figure 2. Body kinematic for WP3 car impact: Pictures are taken at 20 ms interval

Figure 3. Comparative pedestrian kinematic obtained for the two accident simulations with car from WP3 and from WP5.
2.2) Human body versus car models interaction

In this section focus is on the comparative interaction between the human body model and the two cars models. Figure 4 shows the interactions between the car bumper and the lower legs. It appears that for WP5 solution this interaction force is slightly lower. Figure 5 shows the comparative transversal beam deformation. It appears clearly that WP5 beam deforms more than WP3 one. Furthermore, Figure 6 to figure 9 show the comparisons between the car and body models respectively at upper leg, pelvis, shoulder and finally head level. Figure 10 presents a more detailed interaction between the head and the car structure for WP3 and WP5 car models. It can be observed that for lower leg interaction forces are slightly lower for WP5 simulation. On the other hand the car vs. head interaction force is slightly higher for WP5 car which will probably lead to different head injury prediction in the following section.

![Graph](image)

Figure 4. Comparative WP3 vs WP5 lower leg versus car interaction force. Peak values correspond respectively to the left respectively right leg impact.
Figure 5. Transversal beam deformation at different time steps (step 10 ms) for WP5 solution in red and WP3 solution in blue (same scale is applied).

Figure 6. Comparative WP3 and WP5 upper leg contact force.
**Figure 7.** Comparative WP3 and WP5 pelvis contact forces versus time

**Figure 8.** Comparative WP3 and WP5 shoulder contact forces versus time
Figure 9. Comparative WP3 and WP5 head contact forces versus time
2.3) Comparative injury risk assessment

For the previous human body versus car interactions injury risk has been assessed for both WP3 and WP5 car models. Figure 11 shows an application of SUFEHM and related IRA tool. It appears that the head injury risk have been slightly increased from WP3 to WP5, due to a slight different body kinematic. Figure 12 reports the plastic strains computed at thorax and lower leg level for WP3 and WP 5 car solutions. It appears that the transversal beam effectively improves pedestrian protection at lower leg level.
Figure 11. SUFEHM injury risk assessment for WP3 (top) and WP5 (bottom)

Ribs Plastic Strain: Fracture Detected @ 57ms (Total number of fractured ribs = 9; On impact side = 8)
Figure 12. Plastic strain in ribcage and lower leg (femur and tibia) for WP3 (top) and WP5 (bottom)
3 Conclusion

In this deliverable two car models developed respectively in WP3 and in WP5 and which correspond to a basic car model and an improved car model have been used for the simulation of a pedestrian accident. The human body model and injury criteria defined within WP3 have been used for this purpose and results show that increased protection has effectively been provided for the lower leg. However, due to the slight change of the body kinematic, head injury risk was slightly increased. As a conclusion it is obvious that the optimisation of the car protection against pedestrian impact is not finalized so far. This step is just feasibility study of how the tool chain can integrate stepwise improvements of car design.

As a whole this step of the project constitutes a demonstrator of the tool chain developed within Safe-EV
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