Heavy Truck Occupant Restraint System - New approved Concepts and Development Methods

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Abstract

The efficiency of current frontal restraint systems in heavy trucks is not comparable to systems in passenger cars. There are no rating tests and legal requirements for the functionality of such systems. Therefore it is comprehensible that even non severe truck crashes in the field lead to non fatal but severe injuries with high rehabilitation costs. Another reason for the low efficiency of the current systems is the non-availability of an adequate development method.

During the development phase of a restraint system it is not possible to observe significant loads applied to the lower extremities by using the conventional test methods. However, the lower extremities gain more and more importance with respect to real world crash data. For that reason a new and approved test method will be introduced and published for the first time. It takes the intrusion of the cabin and interior displacement into account resulting in a good correlation between full scale tests and sled tests.

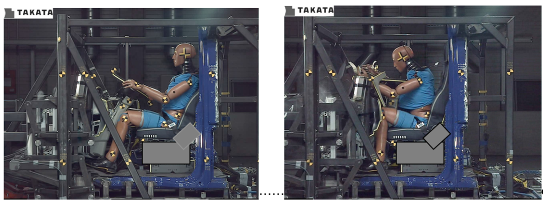

Figure 1: Takata-Petri Berlin Intrusion Device

The new method allows the verification of advanced and additional restraint system components such as optimized knee impact zones, knee airbags and activated steering column kinematics. A restraint system as described above provides optimized occupant kinematics with the effect of reduced loads.
The developed methodology is based on the so called "Trailer Back Barrier" test configuration. However, to date this configuration is not yet being used as a standard evaluation in the industry. This study is concentrating on cab over trucks due to the higher injury risk for the lower extremities compared to bonnet trucks.

Introduction

Occupant safety for passenger cars is on a very high level. Almost every new car generation has new features e. g. adaptive airbag modules to address the new customer rating requirements. The occupant size will be detected and the restraint system performance will be adjusted to the different driver or passenger weight. Up to 8 airbags within a passenger car is state of the art today.

For heavy trucks even driver airbags are only an optional feature presently.
Investigations of heavy truck accidents show that the lower extremities are heavily injured in almost every crash. Driver's pain and high rehabilitation costs occur, even at accidents with low relative velocity.

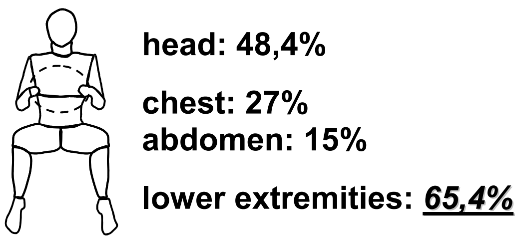

Figure 2: heavy truck occupant injuries based on 78 accidents [1]

Takata-Petri is aware of this issue and developed a test device especially to investigate heavy truck crashes in order to improve the restraint system for these special cars. In the end of this project, Takata-Petri was able to get an occupant safety level which is comparable to present passenger cars. The test device, called "intrusion device" is now a standard /patented/ development tool which shows the heavy truck crash behaviour in a way which was not able to show with usual test equipment. This test device and the results of the improvement of the heavy truck restraint system will be represented in this paper.

Heavy Truck Intrusion Device

Due to non existing regulations, the OEMs set their own crash scenarios based on internal accident data. Two kinds of impacts are used in heavy truck developments.

- Flat Wall Impact
- Trailer Back Barrier Impact (deformable barrier)

The crash velocity depends on the OEM philosophy.

During the trailer back barrier impact test, which simulates the impact at the end of a traffic jam, high cabin intrusion due to the height of the barrier /trailer/ occurs.

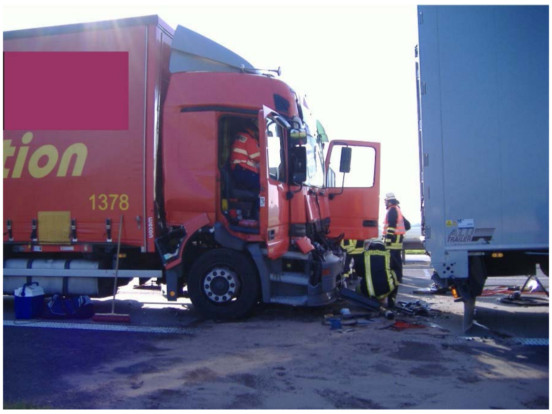

Figure 3: Trailer back barrier impact [2]

With standard test equipment it is not possible to reproduce the injuries e. g. high femur forces. Standard test sleds, which are used in passenger car developments, are usually stiff. This must be changed for heavy trucks. The cabin intrusion has to be taken into account.

Test Rig

The instrument panel is attached to a pendulum device, which allows displacement of the instrument panel. The kinematics of the pendulum can be adjusted to every trajectory of the real car instrument panel. This trajectory is taken from full scale crashes or numerical simulation. Due to two different deceleration devices the crash pulse of the instrument panel and the car body can be adjusted separately.

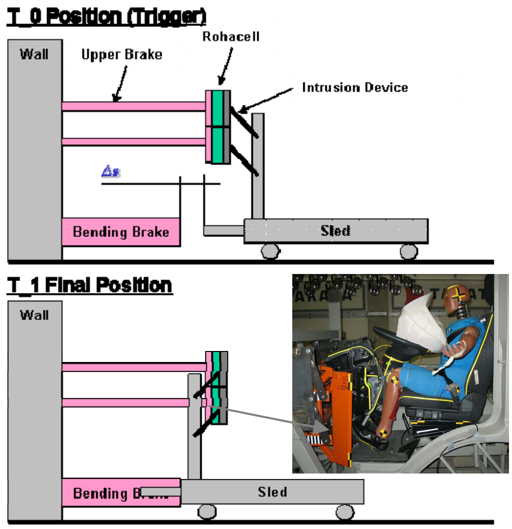

Figure 4: Function of Takata-Petri Intrusion Device

Heavy Truck Restraint System Optimization (HeRO)

Takata-Petri did an extensive pre-development project called HeRO, where the following restraint system components were considered by using the intrusion device.

- driver airbag
- knee airbag (KAB)
- energy absorbing knee bolster
- active steering column (ASC)
- belt pre-tensioner
- belt load limiter

By using these restraint system components a step by step improvement can be seen up to the already mentioned level of modern passenger cars.

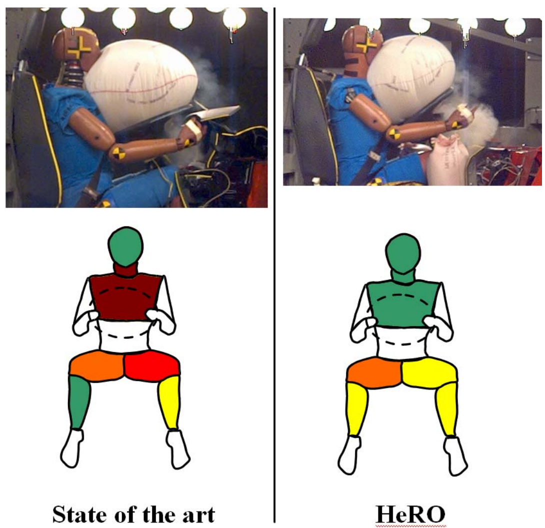

Figure 5: Comparison of restraint system performance between "state of the art" and "HeRO" based on Euro-NCAP assessment

Knee Impact Zone

The instrument panel intrusion device enables us to optimize the knee impact zone by using sled tests because for the first time it was possible to observe similar load characteristics of lower extremities in sled tests and full scale tests.
The first attempt was to design the knee impact zone with energy absorbing deformable structures. The effect could be clearly observed in the sled test results:

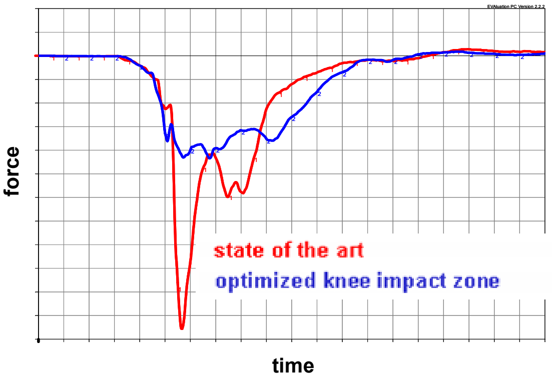

Figure 6: Femur loads with and without deformable structures

Even if the femur force could be reduced significantly, there is still an unfavourable occupant kinematics. And even worse: due to less pelvis restraint a more severe chest – steering wheel contact occurs.

Knee Airbag (KAB)

To improve the occupant kinematics the knee airbag is a well known feature. An early force application to the knees is expected. At the same time the load characteristics is biomechanically more sufficient.

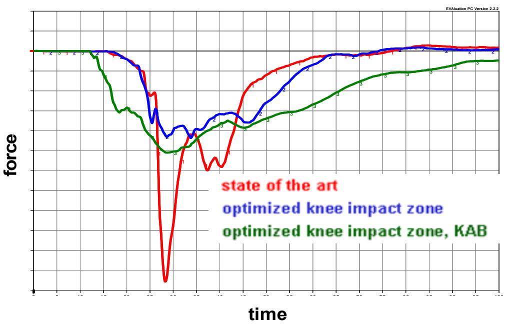

Figure 7: Impact of knee airbag on femur loads

Figure 8: Impact of knee air bag on dummy kinematics

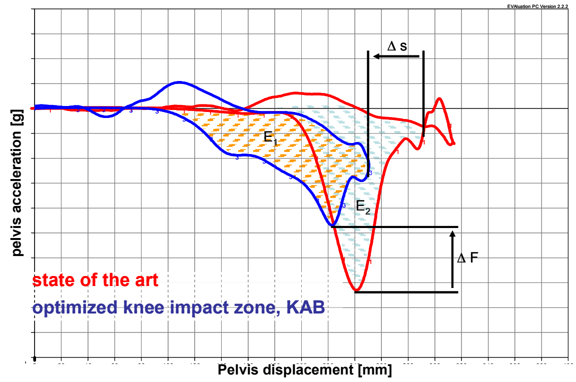

Figure 9: different way of energy absorption shown by pelvis acceleration vs. pelvis displacement

Because of the protruding steering column in the knee impact area, two single knee airbags, one for each knee have to be installed (dual knee airbag).

Figure 10: Application of two knee airbags for the driver (dual knee airbag)

Steering column

Even though the occupant kinematics have been improved by the use of a knee airbag system, there is still an unfavourable upward movement of the steering column. The upward movement of the steering column leads to a severe contact of the lower steering wheel rim to the thorax, which results in a high chest deflection. To avoid this impact on the thorax, the steering wheel should remain in the original position or should even been pulled downward (“active steering column”, ASC).

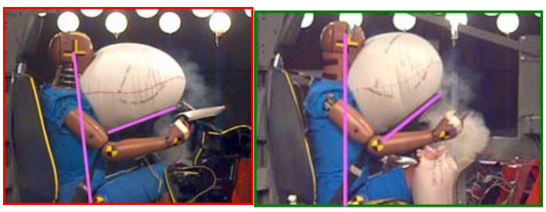

Figure 11: Steering wheel position without and with ASC

With the help of the active steering column, the lining up of the steering wheel is particularly advantageous for the chest deflection value (see figure 12).

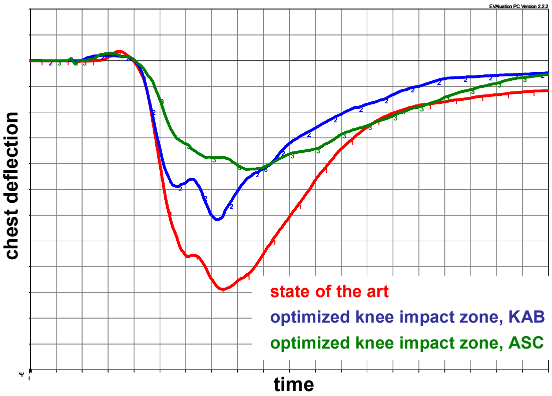

Figure 12: Impact of KAB and ASC on chest deflection

Restraint System Optimization

After conducting the sled tests, a CAE-model was validated and is ready to be used for further optimization steps for several restraint system components. By adjusting the vent hole diameter and the belt system (pre-tensioner, load limiter), a further improvement especially for the chest deflection under the "trailer back barrier"-load condition is possible.

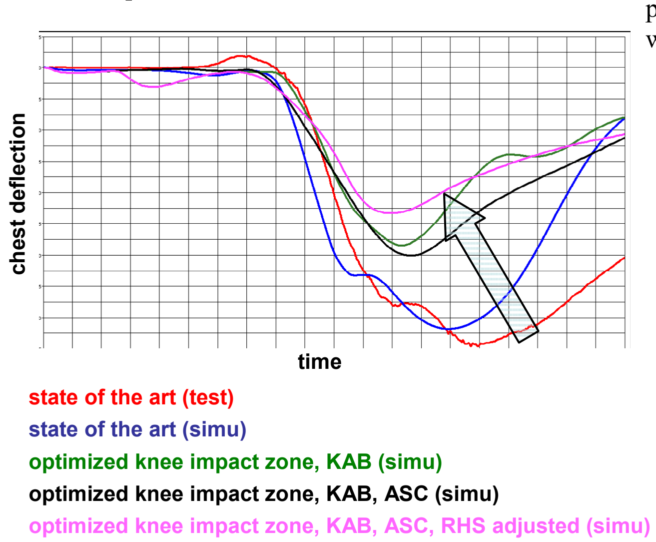

Figure 13: Chest deflection

After optimizing the restraint system, the kinematics of the dummy and the way the driver airbag is working come much closer to the behaviour of a passenger car restraint system (see figure 14).

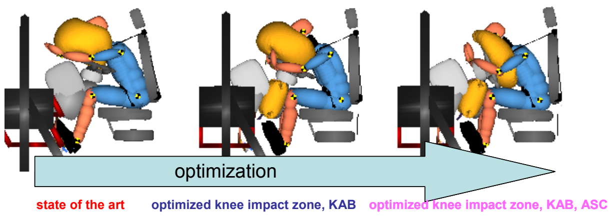

Figure 14: Improvement of dummy kinematics

Conclusion

The intrusion device was introduced as a new sled test method. With the help of this method it was possible to investigate new concepts for restraint systems for heavy trucks, because even the behaviour of the knee impact now correlates sufficiently to the full scale test. As new components for the Heavy Truck Restraint System a Dual Knee Airbag and the Active Steering Column were introduced. Together with the known components of a restraint system, these new components contribute to an optimized system, which shows a comparable performance to a passenger car system regarding kinematics and working principles.

References

[1] R. Zinser, Ch. Hafner, Der LKW-Unfall aus unfallmedizinischer Sicht; VKU April 2006

[2] http://www.feuerwehr-ahrweiler.de , 15.02.2011