COMPARISON OF 10 TO 100 KM/H RIGID BARRIER IMPACTS

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ABSTRACT

Different methods and theories were developed to describe the accident severity. For accident reconstruction the EES (Energy Equivalent Speed)-method [1] is an important tool.

$$E_{def} = \frac{1}{2} \cdot m \cdot (EES)^2 \qquad (1.)$$

This means that the plastic deformation energy of the damaged car is expressed as a kinetic energy of the car with the virtual velocity value EES.

For an authentic EES-estimation various crash-tests with different conditions are necessary, because the energy absorption depends on various parameters. Documented car deformations for EES values up to approximately 60 km/h are available from crash tests. For higher impact velocities only very little data is published.

To gain a better understanding of the crush behavior at higher impact speeds, a series of full scale rigid barrier impacts were performed at impact speeds in the range of 10 to 100 km/h

INTRODUCTION

For accident reconstruction and for accident research the engineers need tools for a realistic assumption of the accident circumstances. But in most of the cases there are not enough data for a reliable statement of the crash, especially the crash severity and the relationship between the crash severity and the occupant load is a difficult and controversial problem. One of the methods with the best results is the EES (Energy Equivalent Speed)-method, which was introduced and published by Burg and Zeidler [1] in 1980.

To get an appropriate estimation of the deformation energy under different crash velocities six vehicles were accelerated towards a concrete block with a mass of about 24.000 kg, using two fixed pretensioned ropes for leading the crash car and a towing rope for the acceleration. Few meters in front of the barrier the vehicle and the ropes were released by a special element and the car crashed without external influence against the barrier (Figure 1.).

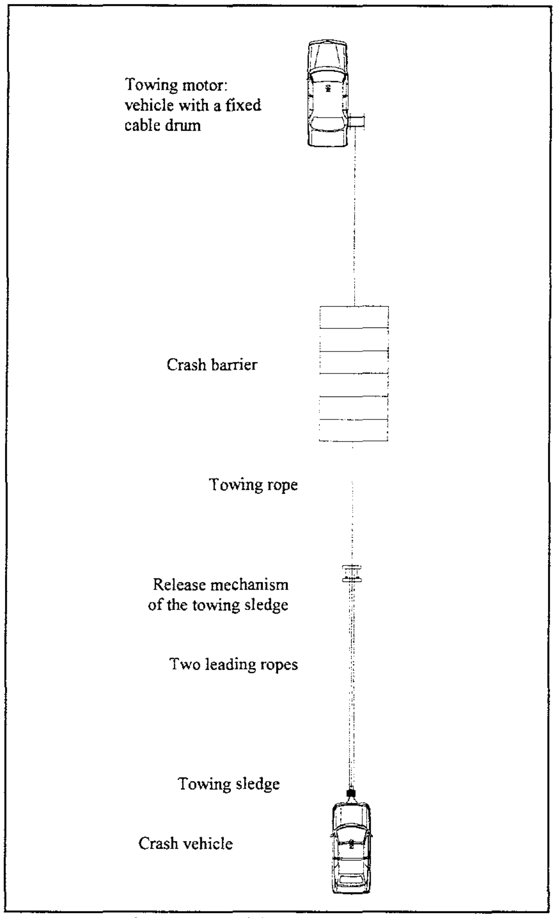


Figure 1. Crash Facility.

The longitudinal and lateral accelerations of the cars during the impact were measured by means of an accident data recorder (UDS™ Unfalldatenspeicher from VDO-Kienzle®) fitted in the trunk of the vehicle. The crashes also were documented with a high speed video camera using a frame rate of 1000 pictures per second. After the impact the vehicle deformations were documented with detailed photos and measurements.

On the one side frontal impacts were performed with identical cars (Ford Escort) at six different impact velocities (13, 21, 38, 52, 83 and 95 km/h). On the other side different cars were crashed at speeds around 90 km/h to see the influence of the car type. These results are not presented in this paper.

CASE 1: 100%, 13 km/h

A Ford Escort was crashed with 100% overlap against a rigid barrier. The impact velocity was 13km/h, the mean deceleration during the time of 60ms was about 8g with a peak value of 20g. During this test two volunteers were sitting in the car, restraint by three point seatbelts and both were without any complaint after the crash.

The remaining deformation was less than 5 cm. Only the bumper showed deformation and the hood buckled very slight (Figure 2.). The impact had an evident elastic part but the occupant load can be tolerated.

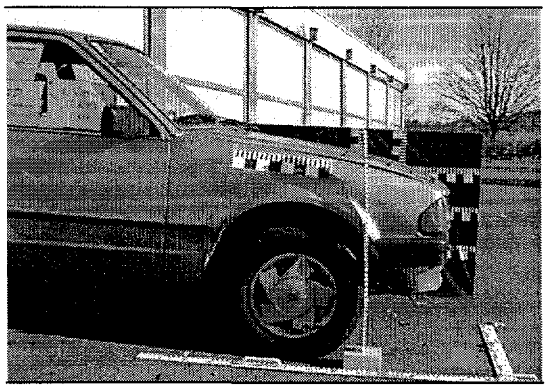


Figure 2. Vehicle after 13km/h frontal crash.

CASE 2: 100%, 21 km/h

The Ford Escort impacted the rigid barrier with a velocity of 21km/h and with a small impact angle of less than 5°. The mean deceleration was 6g during 100ms, the maximum value was about 14g.

The remaining deformation was about 10 cm on the left and 5 cm on the right side. The deformations could be clearly seen at the bumper, hood and the fender. The left headlight was splintered. Also the distance between the front and rear axis was reduced in opposite to the first crash (Figure 3.).

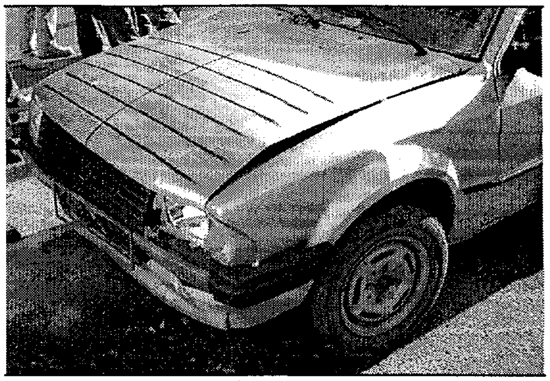


Figure 3. Vehicle after 21km/h frontal crash.

CASE 3: 100%, 38 km/h

The impacts velocity was 38 km/h and lead to a mean deceleration of 14g during 90ms, the maximum value was about 32g.

The remaining deformation was measured with 20 cm on both sides. Beside the buckling of hood and fenders (Figure 4.), also the distance between the front and rear axis was reduced more than 10 cm. However there were no remarkable intrusions of the passenger compartment.

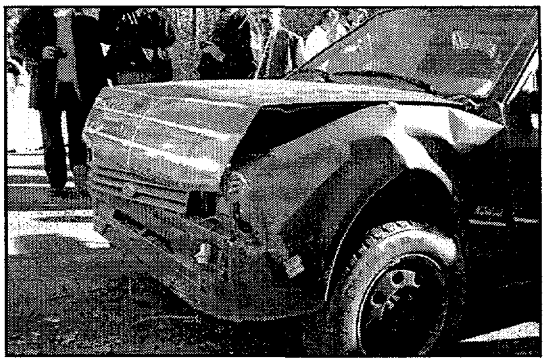


Figure 4. Vehicle after 38km/h frontal crash.

CASE 4: 100%, 52 km/h

The Ford Escort impacts the rigid barrier with a velocity of 52 km/h, the mean deceleration is 15g during 100ms, the maximum value is about 31g.

The static deformation was about 40 cm on both sides. The bumper deformed and the hood buckled, also the fenders showed already strong deformations. The front axis moved back to the A-pillar and so the distance between the front and rear axis was reduced about 20 cm (Figure 5.).

Figure 5. Vehicle after 52km/h frontal crash.

Also a typical deformation on the car roof in the area of the B-pillar could be seen, which is brought through the A-pillar to the cars top.

CASE 5: 100%, 83 km/h

The Ford Escort hit the rigid barrier with a velocity of 83 km/h, the mean deceleration was 20g during 110ms, the maximum value was 42g.

For the remaining deformation 60 cm were measured on both sides. The hood as well as the fenders buckled extremely and showed great deformations. The front axis moved back to the area of the A-pillar and so the wheel-base was reduced about 40 cm. Also the doors showed deformations and there were remarkable great intrusions into the passenger compartment. Finally the base plate was wrinkled (Figure 6.).

Figure 6. Vehicle after 83km/h frontal crash.

CASE 6: 100%, 95 km/h

For the last case the vehicle hit the rigid barrier with a velocity of 95 km/h, the mean deceleration was more than 20g during 110ms, the maximum value was at a level of 49g.

The remaining deformation was 70 cm on both sides. The front of the vehicle had deformed extremely. also the hoot had great plastic deformations. The front axis moved back behind the A-pillar and so the distance between the front and rear axis was reduced more than 40 cm. Also the doors have deformations and there are great intrusions into the passenger compartment (Figure 7.) and the base plate was wrinkled.

Figure 7. Vehicle after 95km/h frontal crash.

SIMULATION

For an estimation of the occupant risk computer simulations were executed using the MADYMO (MAthematical DYnamic MOdel; multibody and FEM computer package) tool of PC-CRASH (program for the simulation of motor vehicle accidents).

The intrusions into the passenger compartment are not calculated but at impact speeds higher than 50 km/h intrusions occur and the accident and injury statistics show that often these injuries are a great problem. Especially for impacts with an overlap less than 50% not the acceleration load is the problem. The vehicle front structure can not deform in a designed manner and therefore other structure parts are loaded. Therefore the vehicle deformation increases but the acceleration load for the occupants decreases.

The dummy was placed on the front-seat passenger side and the model was loaded with the measured crash tests pulses (Figure 8. and 9.).

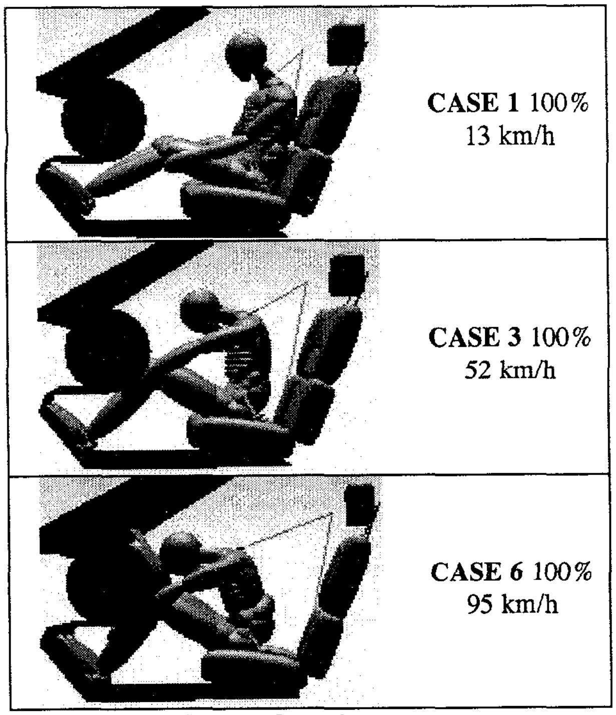


Figure 8. Simulation of maximum occupant movement without intrusions.

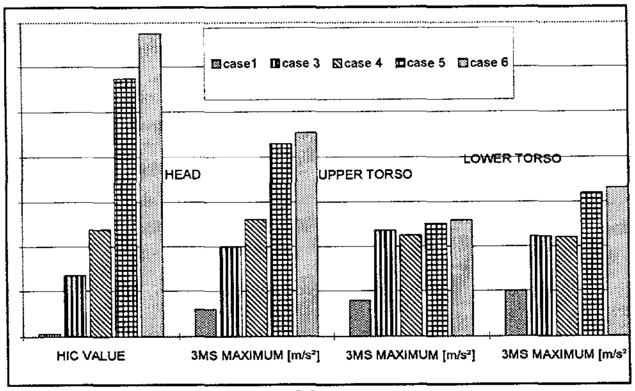


Figure 9. Comparison of injury parameters.

CONCLUSION

As a result of the standard crash tests there are no intrusions into the safety cell at impact speeds up to 50 km/h. Because of the 100% overlap all frontal parts of the car are loaded and therefore the crash energy is dissipated in a planned way. At speed range higher than 50 km/h the frontal structure of the vehicle is overloaded and therefore also the base-plate and parts of the interior are exposed to large deformation.

The risk for the passenger safety up to the 50 km/h impact are the acceleration forces and this loads are requirements for the restraint system. Crashes with higher impact speed result in intrusions and only new structure and compatibility concepts are able to minor this problem.

The crash test also showed a good correlation between impact speed and distance of the vehicle axes from 20 up to 80 km/h (Figure 11.).

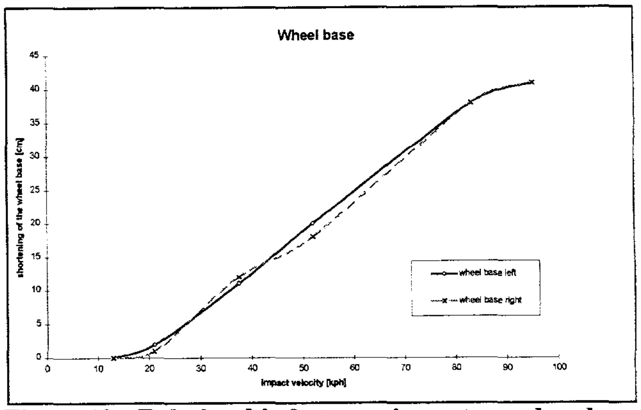


Figure 10. Relationship between impact speed and wheel base.

Table 1 Main data of crash tests

#	v [km/h]	a_{mean} [m/s²]	a_{max} [m/s²]	Δv	wheel base (l+r)/2 [cm]
1	13	78	190	15	240.0
2	21	57	137	23	238.5
3	38	144	325	42	228.5
4	52	147	310	55	221.0
5	83	198	420	84	202.0
6	95	205	490	96	199.0

REFERENCES

[1] Burg H.; Zeidler F.: EES - Ein Hilfmittel zur Unfallrekonstruktion und dessen Auswirkung auf die Unfallforschung - Der Verkehrsunfall 4/1980, Verlag Information Ambs GmbH, Germany.

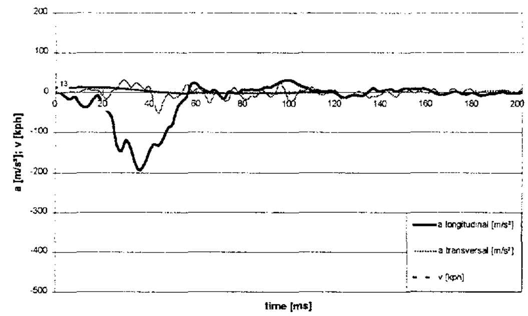
[2] Burg H., Rau H. ; Handbuch der Verkehrsunfall-rekonstruktion; Verlag Information Ambs GmbH; 1981

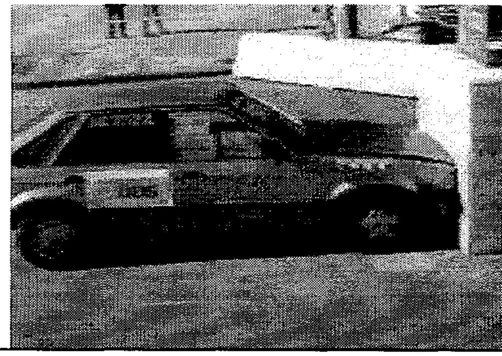
[3] Zeidler F.; Die Bedeutung der Energy Equivalent Speed (EES) für die Unfallrekonstruktion und die Verletzungsmechanik; Mercedes-Benz

[4] Zeidler F.; Die Bedeutung der Formänderungsenergie für die Unfallforschung und das EES-Unfall-rekonstruktionsverfahren; Verkehrsunfall und Fahrzeugtechnik, Heft 4, 19984

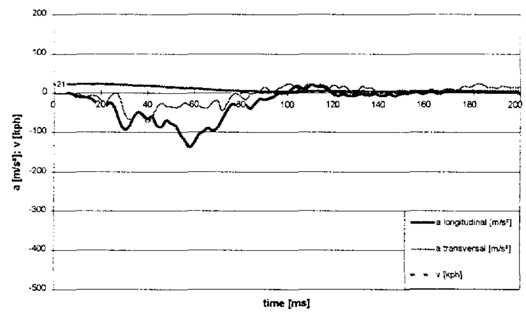
APPENDIX

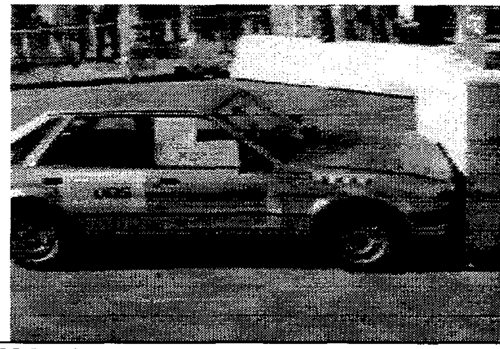
CASE 1: 100%, 13 km/h



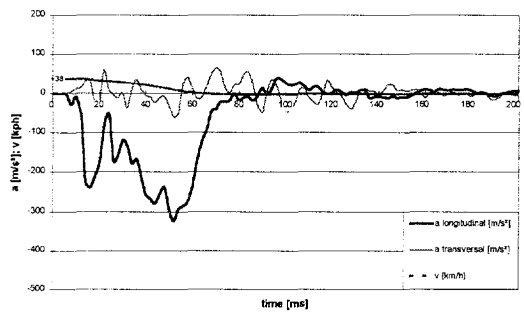


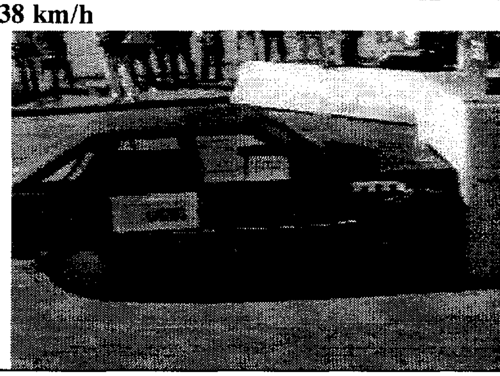
CASE 2: 100%, 21 km/h



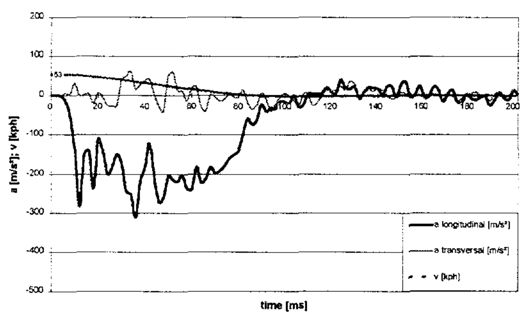


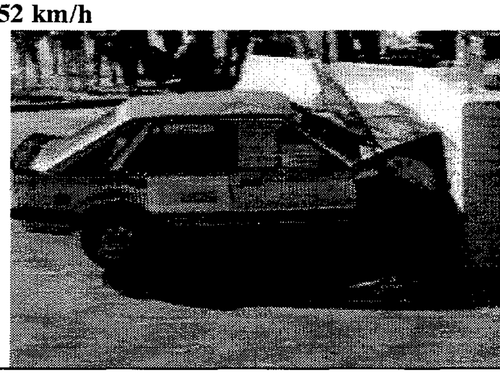
CASE 3: 100%, 38 km/h



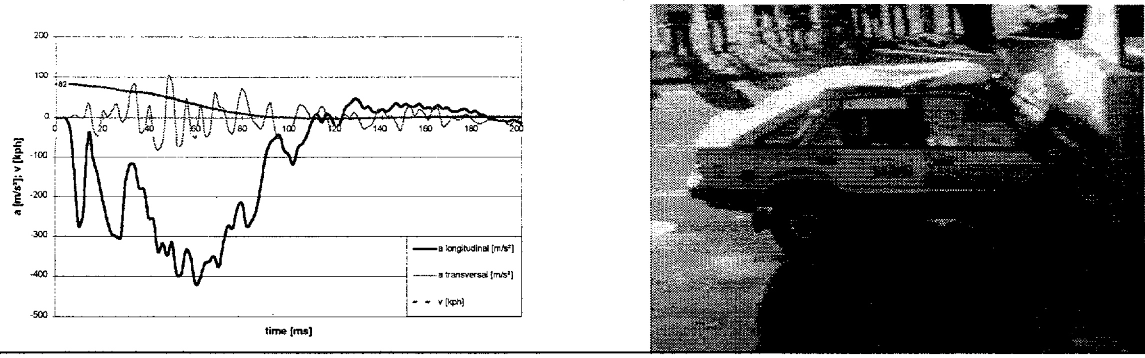


CASE 4: 100%, 52 km/h





CASE 5: 100%, 83 km/h



CASE 6: 100%, 95 km/h

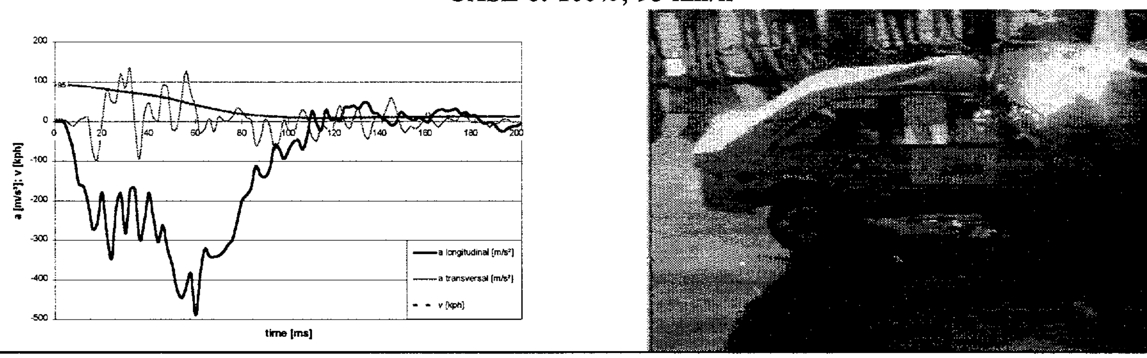
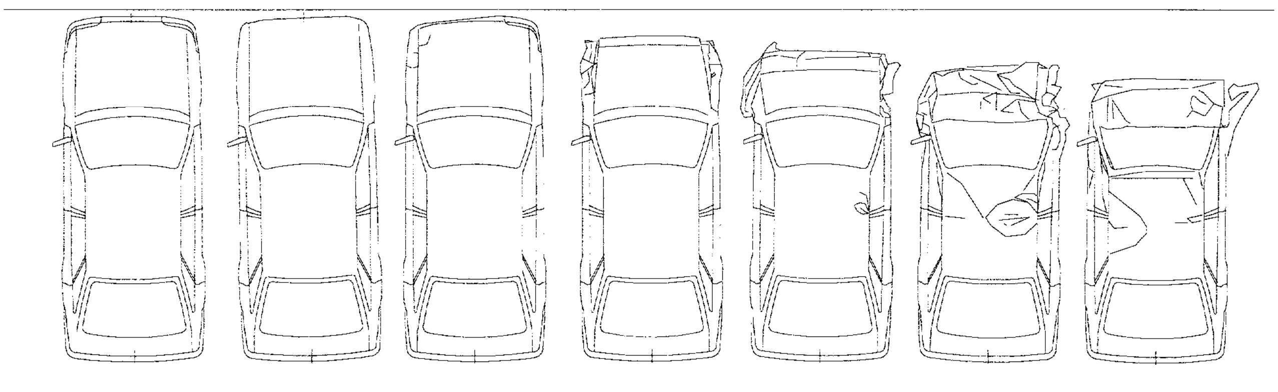


Figure 11. Car acceleration and crash conditions

Original state	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Impact speed	13 km/h	21 km/h	38 km/h	52 km/h	83 km/h	95 km/h



max. Deformation [cm]						
0	<5	10	20	40	60	70

Figure 12. Remaining car deformations