

INVESTIGATION ON THE INFLUENCE OF LATERAL SIDE IMPACT AGAINST CURBSTONES ON SIDE AIRBAG SENSING

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ABSTRACT

With a short deformation zone within the lateral zone of a vehicle great demands are made to the control units and sensors of the side airbag systems according to the reaction time until activation. For further development of those systems and keeping the possibility of erroneous activation low these airbag systems are tested in several impacts that cause airbag activations and in so-called misuse tests. One requirement for non-activation is thereby to hit a curbstone with a vehicle. Since there is only little load for the occupants to expect an activation of the sidebag is not necessary. Executing sled crash tests the Institut für Kraftfahrwesen Aachen (ika) simulates realistically those impact situations. Beside different variations of the boundary test conditions further information referring the sensors positions and signal curves for tuning of the airbag electronics are to determine.

INTRODUCTION

The side impact still presents one of the accident configurations with highest injury potential of the road traffic. Thereby crashes at the sideward door range of the vehicle body are very risky since the resulting injuries are caused by passengers striking on the interior door trim, the pillars, the window edge, the window glass itself or by intruding objects.

For this reason the improvement of the body structure as well as the use of active and passive restraint systems to secure passengers from intruding objects is of general interest. Side-impact beams in the doors and connecting elements between door and sill as well as improved locks and hinges are used to improve the force distribution between doors and pillars and to limit intrusions. Injuries caused by passengers relative movement to the vehicle and the contact with intruding objects, side windows and pillars are alleviated by using several airbag systems. Therefore airbags deploy between the passenger and interior trim and thus the impact decreases by the created larger contact area and the longer deceleration distance. Activating the airbag in time is a great demand to the electronics as well as to the activation algorithm.

With the short available deformation zone and the small distance of the passenger to the sideward interior door trim the airbag systems has to be activated within a time of 10 ms at a side impact with 50 km/h. After that the airbag has to be filled in approx. the same time to achieve its effective protecting effect between the occupants and the door. For the sensing with few exceptions acceleration signals are used as activation criteria. Additional satellite sensors normally collect crash information in the impact zone. Different from the side impact detection based on the increase of the interior pressure within the B-pillar at its deformation (Opel) or travel sensors within the door (Volvo) activation-critical acceleration signals can occur also in so-called misuse-configurations during normal driving. In contrast to cyclists-vehicle collisions and stone impacts, which are to recognize because of their short signal duration, curbstone impacts at a higher velocity can result in the activation of the side bag systems. Caused by the impact at the wheel rims and the following force transfer over the chassis into the body high accelerations are measured by the airbag sensors. Since the occurring passenger loads of such a curbstone impact are very low the airbag activation actually increases the injury risk not to speak of the costs for the replacement of activated modules. Furthermore the impact point is situated far below the vehicle centre of gravity which applies into a rotation of the vehicle around its longitudinal axis so that unlike an side impact no opposite motion between door and occupant will appear.

SIMULATION OF LATERAL CURBSTONE IMPACTS

By executing sled crash tests the lateral curbstone impact of a vehicle can be simulated realistically including the preceding skidding process under different boundary conditions. Contrasting driving tests the test execution on a test bench allows a suitable reproducibility of the test results. The investigation aims are determination the occurring accelerations at individual body positions as well as the caused vehicle damages.

Test Facilities

In order to execute curbstone impact tests a component sled is modified in such a way that a test vehicle can be placed onto two platforms transverse to the driving direction. During the test the sled with the car has been accelerated. In the test only the sled is braked at the crash impact block by using deforma-

tion elements so that the test vehicle is skidding side wards unobstructed on the platforms. To simulate a curbstone a 10 cm high metal section is fixed on the sled surface at which the vehicle bumps in its skidding movement with an explicit velocity (Figure 1.).

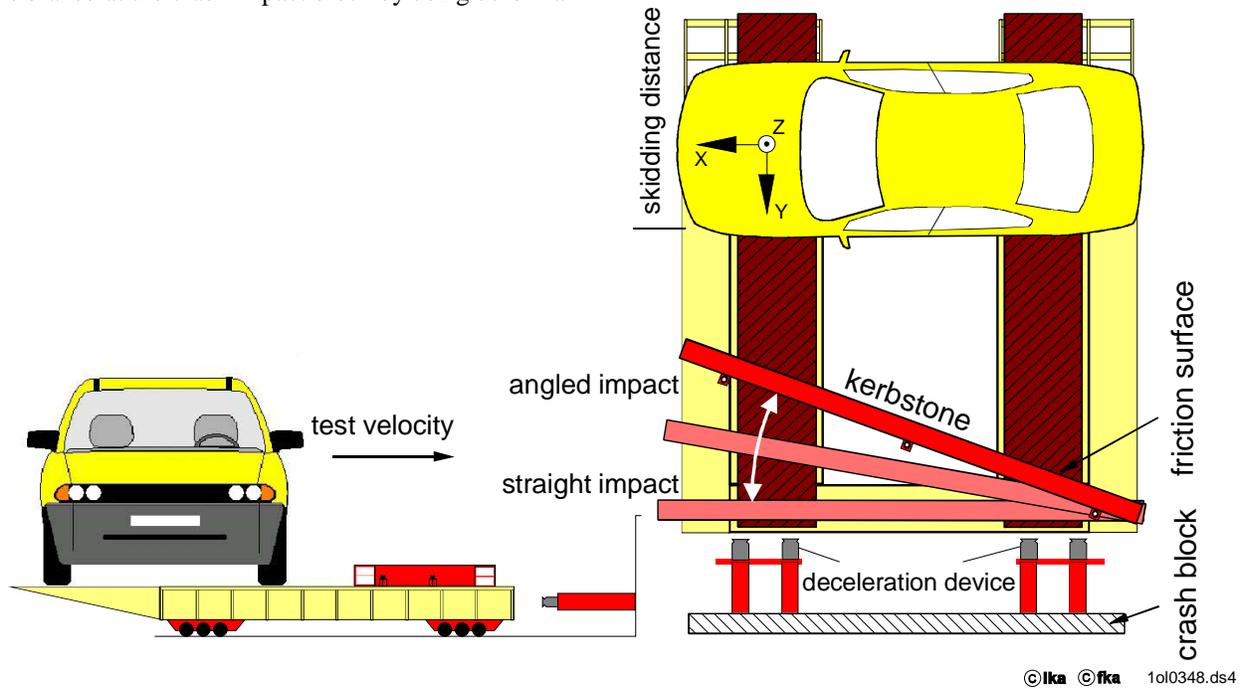


Figure 1. schematic test set-up of the curbstone impact.

Right before the test the vehicle is placed at the rear end of the sled transverse to the driving direction, for which the front or backward left rim flange is located in a definite distance to the sled front.



Figure 2. test set-up of a curbstone impact.

Figure 2. shows the sled with the curbstone and a test vehicle during a rectangular impact.

At the impact block the deceleration device of the sled is installed in form of a deformable buckling tubes. These tubes decelerate the sled in approx. 10 cm. During the tests a rebound motion of the sled after the impact against the deformation elements was prevented by a rebound brake.

Because of the inertia of mass the test vehicle starts skidding on the sled surface after the sled impact. The friction coefficient of the lining causes a sideward

pretension of the chassis during the skidding process. Both wheels have to hit the curbstone at the same time to achieve a maximum deceleration of the vehicle. Caused by the impact a rotational motion of the vehicle around its longitudinal axis is introduced. Figure 3. shows a curbstone impact at 11 kph. Specific moments, measured from the beginning of the sled deceleration are emphasised in the corresponding pictures (Figure 3.).



Figure 3. sequence of a rectangular curbstone impact.

The accelerations and relative motions towards the sled occurring during the crash are recorded by multi-axel accelerometers and laser light barriers with a sampling rate of 10 kHz.

For later motion analyses several high-speed video cameras record the impact as well as the chassis movement with 1000 frames per second for which specific impact moment of each rim is emphasised by photo flashes.

Changeable boundary test conditions

By different boundary test conditions the vehicle reaction and the sensor signals can be influenced. The impact velocity against the curbstone can be changed directly by the initial sled velocity and the skidding distance. An angled installed curbstone as well as the vehicle alignment caused a possible time delay between the impact of the front- and rear wheel. The suspension pretension is realised by different friction coefficients of the used platforms. The profile and

height of the curbstone are further influence parameter for the test. Below the boundary conditions referring to the test bench are explained shortly.

Impact angle: With an angled installed curbstone the force application into the first crashing wheel can be increased at an oblique impact. After the impact the vehicle performs a rotational motion around the

vertical axis and reaches the curbstone with the second wheel providing that there is enough residual velocity (Figure 4.). For this test configuration the curbstone can be fixed at the sled in an angle up to

70° towards the initial direction. To prevent the vehicle from sliding down the sled because of using low friction lining a motion diagonal towards the crash direction can be restricted by a guiding unit without affecting the overturning and rotational movement.



Figure 4. test set-up of the angled curbstone impact.

Profile of the curbstone: The profile of the curbstone presents a further boundary test condition. Using a flat profile with or without a chamfer at the front edge a sliding over is possible for which only



Figure 5. test set-up with flat curbstone.

Friction lining: The friction coefficient of the surface structure can be adapted to a slippery roadway by greased steel plates or with a friction lining as used at drum test benches, which reproduce

the tyre or the lower rim edge meets the low curbstone as Figure 5. shows. The achieved vehicle accelerations can be decreased or dampened that way. The suspension damages at the vehicle are reduced as well.

an asphalt street. Herewith the suspension can be more or less pretensioned on a free skidding distance of up to one meter before the crash. Both, the skidding distance as well as the friction coefficient

influence the impact velocity. Together with axle-load distribution and the type of wheel suspension they cause a possible vehicle rotation around its vertical axis during the skidding phase.

AIRBAG SENSING AT THE CURBSTONE IMPACT

In order to determine the influence of different boundary conditions on acceleration signals at different body points a basic test series with lower-class cars was executed. The spread of the resulting sensor signals present the occurring problematic by considering these misuse deceleration pattern within the activation algorithm of the side airbag control units. For a passenger protection in time the decision for an airbag activation has to be made within the first 10 ms of the deceleration pattern. For this reason a safe differentiation between a relevant deceleration curve and a misuse-case is necessary within that time in order to prevent from erroneous activation.

Airbag sensing

The sensing of airbag activation normally takes place by the acceleration behaviour determined at the body. By exceeding a response threshold the recorded accelerations are processed further by the activation algorithm in consideration of the signal characteristic and maximum value, evaluated and transferred into an activation threshold. If this activation threshold is exceeded by the integrated sensor signals the triggering of the airbag results. Thereby a more rapid increase and a high maximum value of the sensor signals cause an earlier airbag activation. The problem is to subdivide the possibly occurring accident configurations only by sensor signals into fire – and no-fire-configurations. This is the more difficult the more the sensor signals show similarities in these both groups and the more the signals differ within the individual classes in the considered time. For curbstone impacts a significant influence on the measured signal characteristics of the body by the boundary test conditions is possible.

Deceleration pattern of the curbstone impact:

For the curbstone impact three definite phases, which are separable by the sensor signals are to recognize in the deceleration pattern of the vehicle center of gravity. During the skidding phase even a vehicle deceleration of over 1 G is possible depending on the friction lining and the initial velocity (Figure 6.).

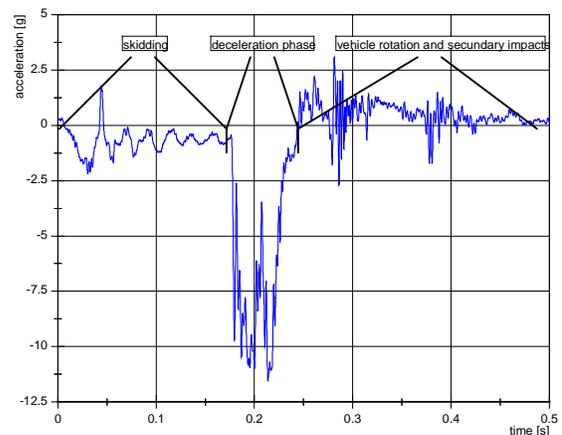


Figure 6. typical deceleration pattern of a curbstone impact.

The deceleration within that phase is overlapped by a vibration, which is caused by a steady change between static- and sliding friction within the sideward skidding tyre contact area. This is more distinct with a lower velocity and a higher friction coefficient. Simultaneously the vehicle is rolling

towards the curbstone and thus those impact averted wheels are discharged. A preload of the suspension rubber elements also take place.

During the second phase the rubber elements of the suspension are knocking against their stop at the impact so that the pushing vehicle is decelerated through suspension- and rim deformations. Moreover deformed wishbones and rear axles as well as knocked out ball joints at the front axis are the usual damages.

Within the third phase the vehicle rolls further around its longitudinal axis and with higher velocities (>7 km/h) it completely takes off the sled surface. Secondly impact effects occur with the sled or the curbstone. Additional vehicle damages can result. From a impact velocity of 15 km/h a rollover cannot be excluded anymore.

Influence of boundary test conditions on the sensor signals

Velocity pattern of a curbstone impact: By braking the sled at then deceleration device the velocity difference between sled and vehicle increases more or less rapidly up to the initial velocity in dependence on the friction coefficient of the skid-surface in order to decrease during the skidding time down to the impact velocity. During the skidding phase the vehicle slows down on its way of approx. 0,6 m on low friction surfaces about 2 kph ($v_{Sled,2}-v_{impact}$), on rough friction surfaces in dependence on further boundary conditions about 6 to 9 kph ($v_{Sled,1}-v_{impact}$) (Figure 7.).

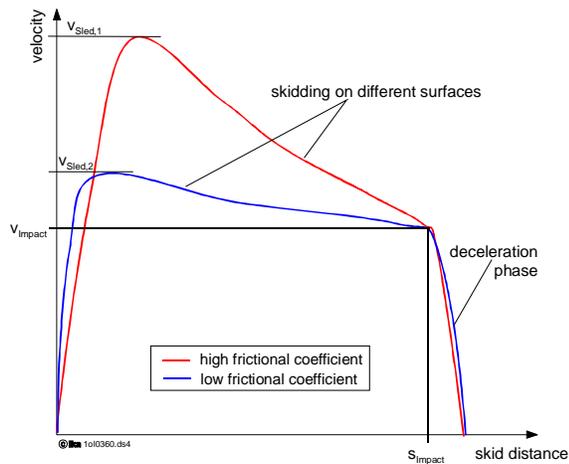


Figure 7. velocity pattern of the curbstone impact.

The velocity reduction is therefore influenced by the tyres (the profile, the tyre width and inflation pressure), the axle-load distribution as well as by the type of wheel suspension. The initial velocity is executed in preliminary tests in order to determine the achieved impact velocity at the curbstone.

Influence of the impact velocity: The impact velocity has a significant influence on the sensor signal pattern. Hereby only the deceleration phase at the curbstone impact is considered in following diagrams. Because of the higher transferred kinetic energy higher decelerations in the vehicles center of gravity result with increased impact velocities and a nearly constantly available deformation way within a decreased deceleration time. The maximum acceleration values occurring with a higher impact velocity reach and overturn thereby the maximum values of vehicle-vehicle-impacts occurrences within the activation-relevant time range (grey zone). In dependence on the individual impact configuration in a sideward angled impact below 10 G are reached [KÖN00]. The determined sensor signals at a curbstone impact multiple exceed this limit at increased impact velocities. Considering only the signal of one single sensor for the airbag activation a erroneous activation is possible (Figure 8.).

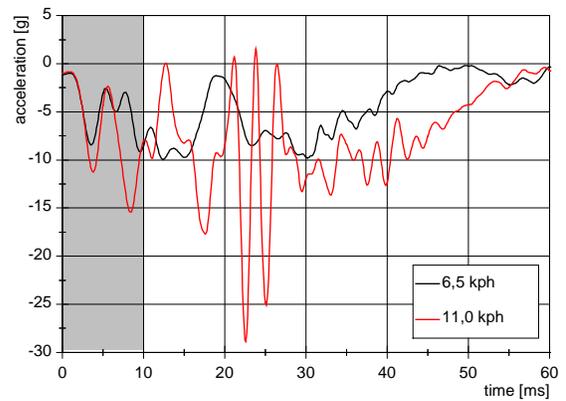


Figure 8. acceleration pattern of different impact velocities.

Influence of different friction coefficients: Even the friction coefficient of the sled surface affects the transferred signals. By using low friction surfaces only little force is transmitted onto the suspension expressed in the low pretension of the rubber elements and the joints. The additionally available deformation distance, compared to the highly pre-tensioned suspension by using rough friction structures, damps the curbstone impact and reduces the initial deceleration level. The initial peak of the

red-marked signal curve, which is also caused by the stiff suspension of this car, clarifies the hard impact. For this boundary condition also acceleration pattern of activation-relevant side impacts can exceed (Figure). In the back-range of the signal both characteristics are similar. The impact velocity is in both cases at approx. 6 km/h.

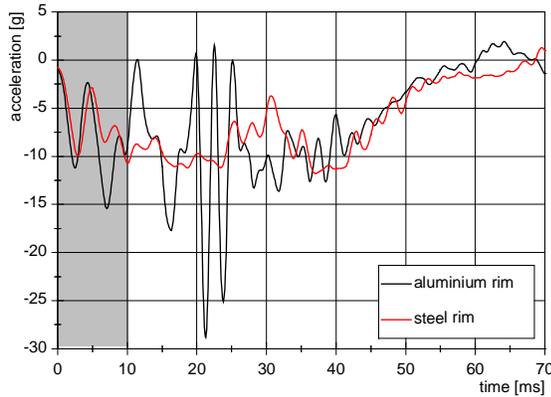


Figure 9. acceleration pattern caused by different friction coefficients.

Very interesting in this context is the possible differentiation of the two signal characteristics by comparing the varying initial acceleration values caused by the skidding.

Influence of the rim material: The rim material also shows a significant effect on the measured acceleration signals at the curbstone impact. While a steel rim can be strongly modified through an impact aluminium rims show only less deformations, which can be seen in a higher and more vibrating sensor signal in the pushing-phase of the vehicle. In this case the deceleration phase is generally shorter (Figure 10.).

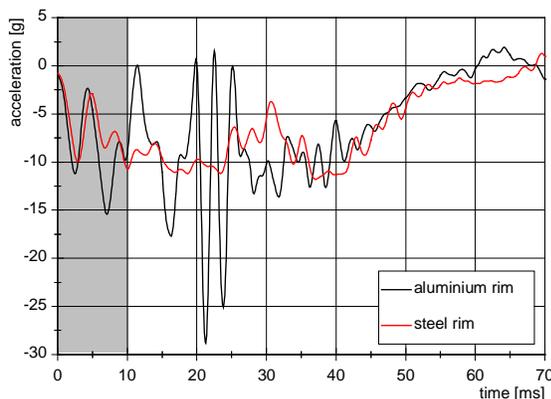


Figure 10. acceleration pattern caused by different rim material.

A differentiation of the two signal curves is not possible until 5 ms, when the vehicle is decelerated by the deformation of the suspension after all mountings are knocked against their stops. In this case the sensor signals also increase to activation-critical values.

The shorter deformation duration is represented in the varying deformation of both rims.



Figure 11. deformations of the aluminium rim.



Figure 12. deformations of the steel rim.

While the aluminium rim shows only small notches at the impact positions without recognizable rim defect (Figure 11.) the steel rim shows strong deformations at the impact-sided rim-flanges as well as a bending within the rim bowl between the screwing and the rim base (Figure 12.).

Influence of the sensor positions: A great amount of the activation time presents the signal running time to the individual sensors. Therefore the occurring differences between sensors at different body positions are compared as follows. Caused by the damping of the rubber elements of the wheel

suspension and the body a time delay of approx. 2 ms result between the hard initial aluminium rim/curbstone impact, (marked with the blue line, 11 kph) and the signal detection by the sensor at the centre tunnel (green) or the instrument panel (black). The signal reaching the instrument panel is damped more and shows lower amplitudes than the signal of the center tunnel. Unlike other side impacts the B-pillar (red-marked), not involved into the impact achieves the signal an additional mille-second later.

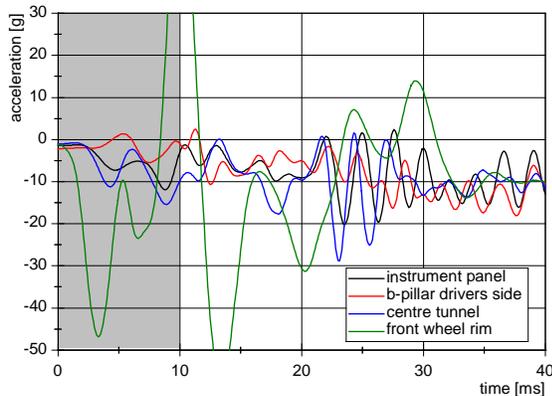


Figure 13. acceleration pattern of different sensor positions.

The roll over motion of the vehicle around the longitudinal axis caused by the impact underneath the center of gravity create a positive acceleration in the first phase of the crash (Figure 13.).

From the time delays between the individual signals and the typical signal pattern of the different measuring points results possibility to differ a curbstone impact even with identical sensor signals with a combination of two or more sensor signals of a side impact with intrusion in the door zone. With an impact in the door range the accelerations increase first there and are transferred into the other directions afterwards. With a curbstone impact the excitation occurs first at the wheel suspension and thus results in an other transfer function to the residual body components.

Additionally also local characteristics and the damping of corresponding body components have to be considered beside all impact configurations for choosing the optimum sensor positions.

In near future tests are planned which combines an airbag activation relevant impact after a misuse condition. By using the experiences of the preceding test series the signal intensity of the misuse-condition can be increased until the airbag activates in the early misuse impact phase.

In a pilot test a skidding above a flat curbstone takes place before a pole was hit with the lateral vehicle surface. This test was conducted to check if an impact speed of 29 kph against the pole is realizable in spite of the preceding curbstone contact.

Figure shows the car an the measured acceleration pattern initial impact

5. CONCLUSION

Considering the great number of occurring accident configurations a corresponding tuning of the restraint systems to the individual type of accident is of great interest for the development of these systems. The decisive factor hereby is the reliable differentiation between activation-relevant and –non-relevant impacts based on determined sensor signals. Within that context the curbstone impact presents such a misuse-configuration for the tuning of side-airbag systems.

The spread of acceleration signals at the possible sensor positions for side-airbag systems is determined by simulating curbstone impacts with varying boundary conditions. Beside the impact velocity the body accelerations are also influenced by the pretension of the suspension, which is affected by the preliminary skidding of the test vehicle and the rim material. The sometimes very hard impacts cause sensor signals, which are comparable with activation-relevant side- and pole collisions. In order to prevent erroneous airbag activation the corresponding deceleration pattern have to be considered in the activation algorithms referring also those occurring during the skidding phase.

A differentiation between impacts at the body (side crashes) and those at the suspension (curbstone impacts) under consideration of varying signal running times and the resulting signals at different body positions seems to be a useful attempt in order to prevent erroneous airbag activations.

Bibliography

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