IMPACT OF DRIVER ASSISTANCE SYSTEMS ON SAFETY AND REPAIR

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ABSTRACT

Driver assistance systems, such as autonomous pre-crash braking systems can reduce the impact velocity (particularly the impact energy) or can even avoid the crash completely. Thus, by reducing the impact speed in order to decrease the number of serious accidents, the subsequent repair costs of the crashed vehicle can also be lowered. However, the testing and assessment of new cars still involves using tests which do not take into account the significant additional potential of integrated safety measures.

In order to investigate the differences during crashes as a consequence of altered kinetic energy at the vehicle front, KTI teamed up with DEKRA and BMW to carry out joint crash tests with the latest BMW 5 series vehicles. The vehicles involved braked automatically from 64 km/h initial test velocity down to different impact speeds.

The paper will describe and discuss some relevant details and results of the crash tests regarding passenger safety and repair costs.

INTRODUCTION

In the last decade, automatic braking and pre-crash occupant positioning systems are offered by an increasing number of automobile manufacturers firstly in their high class vehicles. And now the new systems find their way into all vehicle classes.

The main effects of pre-crash braking are the reduction of velocity and kinetic energy before the car hits the impact barrier. This reduces the biomechanical occupant load and the extent of damage on the car. In addition, the pre-crash-system activated reversible belt pretensioner limits the forward displacement of the driver and passenger dummy during the pre-crash-braking phase to a small extent until the impact starts. Thereby, the occupant safety can additionally be improved.

First results of a test using a pre-crash braked BMW 5 are given in [1]. This paper includes results of two additional tests using the same car model.

TEST VEHICLES

In all tests conducted the vehicle used was a BMW 5 series (type F10/F11) with inline six-cylinder diesel engine and rear wheel drive. The non-braked car for the typical Euro NCAP frontal impact was equipped with standard features.

The autonomous braked cars was, in addition to other serial and prototype safety systems, fitted with the currently available active speed control system including Stop&Go function and an additional head-on collision warning with braking function. It is a radar-based speed and distance regulation system. The system can also monitor the traffic environment in front of the vehicle if the conventional speed control system is not activated. When a critical head-on situation is detected, the driver is warned in two stages. If the risk of a head-on collision situation is very high, an intense visual-acoustic warning is additionally activated that initiates an automatic partial braking with a deceleration of 3 m/s². This means the speed is already being reduced during the driver's reaction time. If the driver reacts, he already encounters a pre-filled brake and swiftly reaches full deceleration – with the aid of the brake assistant – when depressing the brake pedal. This equipment, which is currently found on production models, was taken as a basis for the development of a prototype front safety system, which finally fulfils the requirements for tests in the laboratory crash-test hall. This means that it was first assured that the radar sensor can also reliably detect the target object (in this case the barrier). It is essential that this detection is assured despite the difficult conditions prevailing in the test hall. The vehicle was still equipped with electromotive reversible belt retractors for both driver and front passenger. A pre-crash deactivation of the fuel pump was envisioned as well.

CRASH TESTS

The tests were run by the new intelligent drive system at the DEKRA crash test facility. This required several modifications to be made to the test facility as well as to the vehicle.

The test set up followed the Euro NCAP frontal impact configuration. This is an offset crash test with 40% overlap against a deformable barrier and Hybrid III 50th percentile male dummies on the driver's and passenger's seats. The collision speed is given at 64 km/h. This speed was chosen as the initial speed for the autonomous braking. The cars brake then with different braking scenarios. As consequence of this, the impact speeds was reduced to 51 and 38 km/h.

For comparison, a similar car was crashed without the activation of an active safety system (impact speed 64 km/h). The test set-up is shown in Figure 1.

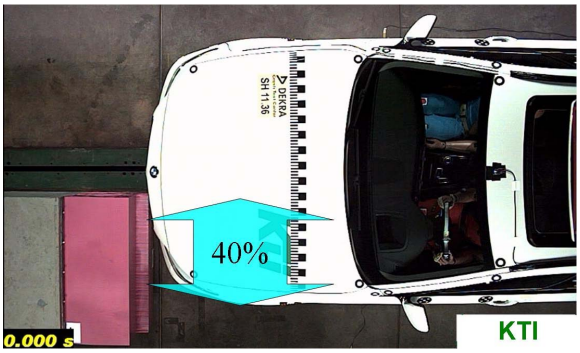

Figure 1. Impact position with 40% overlap.

Approaching the barrier the sensor detected the obstacle and the full braking power was automatically triggered 0.9 seconds before the impact. The collision speed was reduced to 51 and 38 km/h. The collision energy was, thus, reduced from 343kJ to 215kJ respectively 112kJ. The reductions of kinetic energy in the pre-crash phase for each test vehicle are shown in Table 1.

Table1.
Mass, impact velocity and kinetic energy of the test vehicles at start and end of the pre-crash phase

Test	Mass of vehicle	Impact velocity	Kinetic energy
1	2,164 kg	64 km/h	343 kJ
2	2,164 kg	51 km/h	215 kJ
3	2,072 kg	38 km/h	112 kJ

OCCUPANT SAFETY

Basically, reductions in speed and the kinetic energy of the vehicle during the impact with the block must also be reflected in correspondingly reduced load values on the dummy occupants. The tested vehicle (BMW 5 series) has already demonstrated very good results, achieving a top score (5 stars) in a conventional EuroNCAP crash test at 64km/h impact speed [2].

Figure 2 illustrates the results for the head injury criterion (HIC36) for the driver and front passenger dummies in the tests. These injury numbers are greatly reduced when compared to the EuroNCAP test at 64 km/h impact velocity. The reduction in the case of impact at 51 km/h for the driver dummy and the front passenger dummy is 42% and 36%, respectively. For the impact velocity of 38 km/h, there was a reduction of the HIC36 numbers of 76% and 78% for the driver and passenger, respectively.

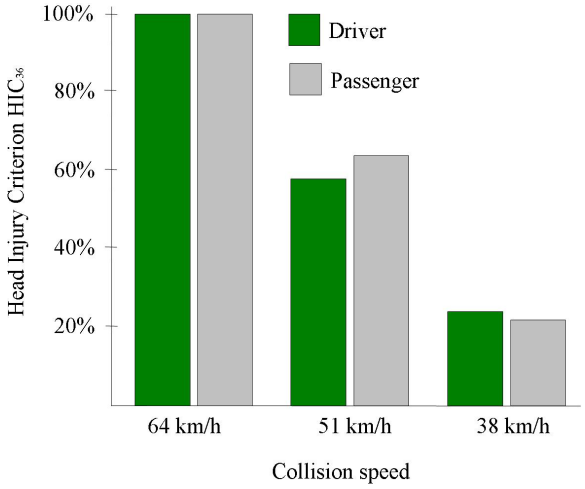

Figure 2. Relative values of the HIC.

It is worthy of note that the reduction of the maximum resultant head deceleration is less significant over a duration of 3 ms (a3ms) as shown in Figure 3. Apparently, at the low load value given here, which is well below the associated biomechanical maximums, the HIC36 values better reflect the reduced load of the head than the a3ms values.

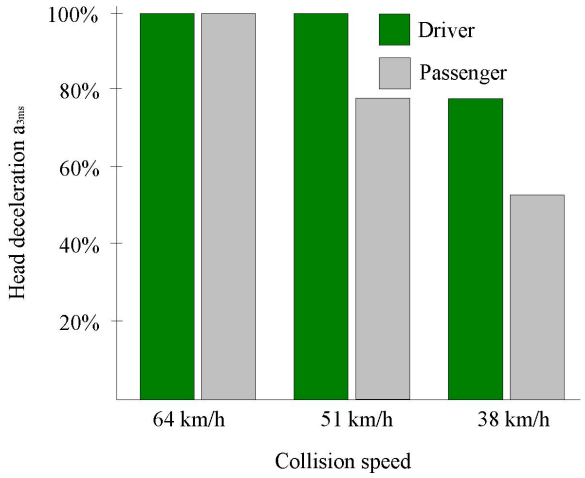

Figure 3. Relative values of the resultant head deceleration.

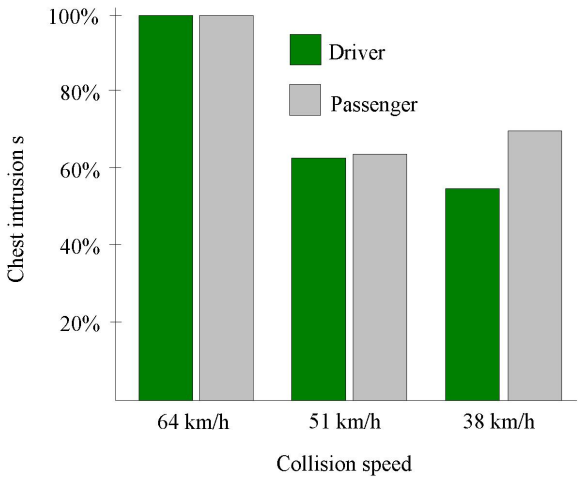

Figure 4. Relative values of the chest intrusion.

A considerable reduction of the dummy chest load in the tests involving pre-crash braking very clearly show the data recorded for chest intrusion (see Figure 4). The values of the resultant chest deceleration a3ms also fail to adequately reflect the reduction of this low load level (see Figure 5).

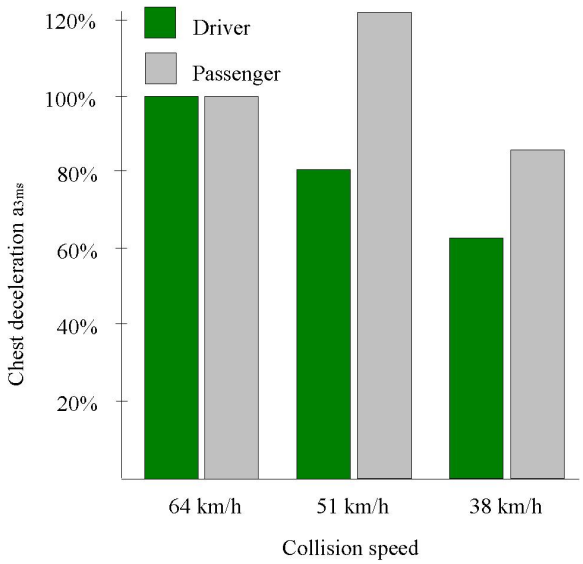

Figure 5. Relative values of the chest deceleration.

VEHICLE DEFORMATIONS

Figure 6 shows a comparison of the front deformation of three test vehicles. In particular, the area around the left front wheel shows a significantly lower deformation of the vehicle, which was involved in a crash test with pre-crash braking at a resulting impact speed of 38 km/h.

Figure 6. Comparison of the deformation of the front of the test vehicles (top down: 64, 51 and 38 km/h impact speed).

The results showed the effectiveness of a pre-crash braking system. The vehicle damage could clearly be reduced due to the reduction of impact speed. The damages on all cars were analyzed. It turned out that the car at 64 km/h impact suffered damage, among other things, on the front bulkhead, A-pillar, windscreen, right side member and left front door.

At 50 km/h impact speed, there are less significant intrusion. The frontleg is deformed and it's necessary to be replace completely this part (up to the passenger compartment). The drive shaft channel damaged but the engine block and gearbox not damaged.

At an impact velocity of 38 km/h, the car has less significant intrusion. The frontleg is damaged and in addition to the deformation of the wheel arches and other load-bearing part in the front structure. No deformation have been detected of the passenger compartment nor the drive shaft channel. A repair of the front light (right side) and the ACC radar sensor (without damage) can carried out.

REPAIR COSTS

The software "Audatex AudaPad" was used to calculate the damages on all three crashed vehicles. AudaPad is a special software used for calculating repair costs on vehicles. The comparison of these results with the ones of a similar crash test with deactivated systems and a collision speed of 64 km/h showed significant differences. The repair costs were reduced by more than 29% respectively 37% in the 38 km/h test depending on the configuration (Figure 7).

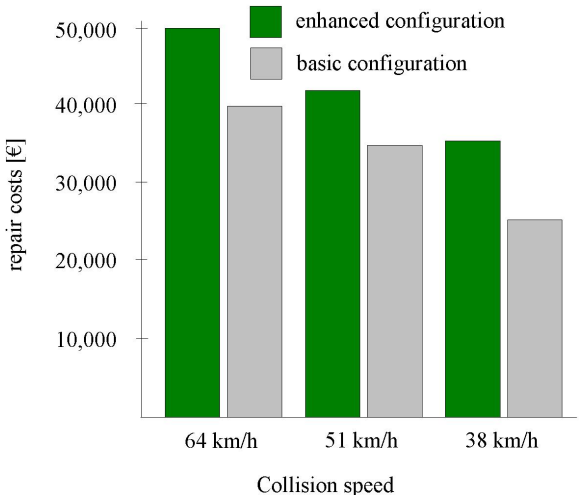

Figure 7. Repair savements depend on vehicle configuration and impact speed.

At all tested cars, the airbag and belt tensioner is triggered. This needs a replacement of the dashboard (passenger air bag deployment) and other expensive parts. Therefore at all crashed cars the repair costs are relatively high. Significantly lower repair costs can be expected when the collision speed is below the threshold triggering the restraint systems.

Bottom line is reflected a serious influence of the configuration. Depend on the vehicle configuration, the additional repair costs in consequence of optional equipment can reach almost one third of the total repair cost. In the crash test with 38 km/h for example, the repair costs at the car with enhanced configuration is circa 10,000 € higher compared to the vehicle in basis configuration. The analysis of calculated repair costs show furthermore the influence of the vehicle electronics of modern cars: electronic systems increases spare part costs up to Euro 8000.

MASTER PROCESS

In the KTI's body shop, a master process and documentation was carried out on the car at 38 km/h impact (Figure 8).

Figure 8. Deformations resulting from the 38 km/h impact.

The OEM’s introduction of new materials and production techniques in cars makes it increasingly important that the repair of such vehicles is carried out with the appropriate techniques and quality. Studies conducted at the KTI have shown that the professional repaired vehicles perform in a similar way to that of an original undamaged vehicle [3]. Non-professional repairs in contrast can have a negative influence on the deformation behaviour of a vehicle involved in a crash [4]. Therefore, OEM information was used during the repair.

Because of aluminium`s electrical flow characteristics, welding is not permitted anywhere on the front structure of the BMW F10; front end components are partially attached with rivets and a high-strength glue. Therefore, it is a requirement that

appropriate technical equipment and parts are used, such as rivet insertion and extraction tool, factory-specified structural adhesive and siliconcoated rivets.

Initially, for proper diagnosis an electronic measurement of the car body was carried out. After additional check with a tear test-spray-set, we found that the right aluminium front shock tower section was not damaged. After removal of exterior attachment parts (such as bumper, headlights, fender, bonnet), the car was fixed on a bench. The repair started with a raw reshaping of the car chassis on a universal straightening bench. During straightening, we measured the dimensions at reference points. The vehicle was then raised on a lift. Windscreen and dashboard were removed (access and front-seat passenger airbag had been deployed). The engine and front suspension were also removed in order to properly access the damaged components. The front end of the car was fully disassembled while mounted on the repair bench to ensure manufacturer`s tolerance would be met (Figure 9).

Figure 9. Car on the repair bench with disassembled front.

To prepare the new parts, were marked the cutting lines and then cut them at those points. We then made a rough cut of the brace (between firewall and strut tower), side member and inner fender apron near the installation area. Welded connections were opened and wheel arch with engine support was removed. In order to replace the parts correctly, we used alignment brackets to mount to the firewall. To preparation of new parts, were severance cut marked and cut. By repairing this vehicle on a bench, we were able to restore it to factory specifications. New components were attached with welding, adhesive and rivets. Thereby, to avoid contact corrosion, we grinded the new wheel arch part in the area of the bonding surfaces. The vehicle had to remain on the bench for 12 hours (at a temperature of 20°) after the structural adhesive was applied to allow it to set properly. The car was then taped and protected so that it could be primed. A factory-recommended seam sealer was then applied to all new joined seams and painted, see Figure 10. Then, the engine and front suspension were installed as a single unit; all systems were installed and checked prior to painting. Finally the errors were deleted in the error memory.

Figure 10. New components were attached with welding and adhesive.

It was clear that electronic components require a extensive diagnostic and system calibration. However that's absolutely essential because the quality of calibration affects the system functionality. The outcome of this are high investments for equipment and training for body shops.

In this context, for accident research arises the question how far the benefit of driver assistance systems in the real world accident occurrence could be reduced as a consequence of non-professional repairs.

CONCLUSIONS

Results of the crash tests described above show that pre-crash braking makes it possible to substantially reduce the severity of a crash in terms of impact velocity, impact energy, and the resulting occupant injuries plus repair costs.

In the crash test with braked cars, the injury numbers are greatly reduced when compared to the EuroNCAP test at 64 km/h impact velocity. The reduction in the case of impact at 51 km/h for the dummies is up to 42%. For the impact velocity of 38 km/h, there was a reduction of the HIC36 numbers up to 78%.

The comparison of the results regarding repair costs also showed significant differences. Compared to the car with deactivated systems and a collision speed of 64 km/h, the repair costs were reduced by more than 29% respectively 37% in the 38 km/h test depending on the configuration. Regarding repair costs, it turned out that airbag firing and vehicle configuration are key factors.

A extensive diagnostic and system calibration is a precondition for the correct functionality of driver assistance systems.

Further tests regarding repair costs at low speed impacts, will be conducted at the KTI in the future.

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