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MAIN ASPECTS IN CAR SAFETY

INGO KALLINA, DIETER SCHEUNERT, FALK ZEIDLER
Daimler-Benz AG, Germany

INTRODUCTION

In Germany, some 19,000 traffic fatalities were registered in 1970. Since then this number has decreased by over half to 8,758 in 1996 (In comparison to the fatalities caused by crashes about 13,000 people commit suicide in Germany every year). This positive development did occur although the traffic density in the meantime has increased many times. The traffic safety potential has clearly increased due to a number of measures in car occupant protection, but also in rescue service, medical treatment, and traffic management.

The emergency rescue service in Germany has grown extensively and is now very high in capacity and efficiency. Emergency rescue headquarters, ambulances, rescue helicopter stations and call boxes were established all over the country. 94% of the emergency patients were treated within 10 minutes after the alarm was sounded (Froböse, 1984). In spite of all efforts the social costs of traffic accidents in 1995, for example were about 16 billion US$ (BASt, 1997). If these costs were distributed over the German car fleet of 40 million cars, it would result in an amount of 400 US$, which could theoretically be spent for additional safety measures to avoid crashes.

That could be done by optimizing the so called active safety (= all measures which avoid crashes). Obviously, crashes will still occur. Therefore, passive safety (= all measures to reduce the injury consequences after a crash) must help to reduce the injury consequences.

Historical development of passive safety

Looking at safety history, the era began in 1939, when the then general director of the Daimler-Benz factory in Sindelfingen initiated safety engineering as a new requirement in the development of passenger cars. The fundamental principles of passive safety, such as an extremely rigid passenger cell, crumple zones in the front and the rear, protection against side impacts, safety door locks, multi-piece steering column, seatbelts and easier repair of front and rear ends were worked on at the theoretical level until 1959 (Figure 1). Later on, Daimler-Benz came to the conclusion that the way to improve the crash safety of passenger cars was to carry out realistic testing (Figure 2). This understanding was also the reason why some years later, in 1969, an accident research group was established to systematically investigate road crashes involving injuries in Mercedes-Benz passenger cars. Each year, approximately 100 in-depth investigations are carried out, so the data base today comprises approximately 3,000 cases.

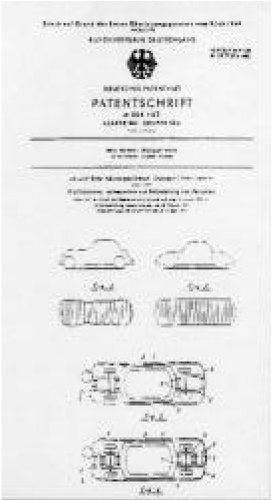

Figure 1 Patent of the crumple zone

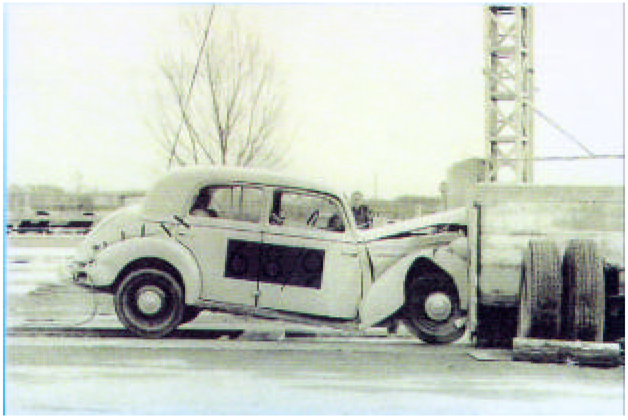

Figure 2 Crash against a rigid barrier with 100% overlap at 50km/h

Two activities are important for the analysis of a crash:

1. the documentation of the collision type and the impact severity including the main car damages and the reconstruction of the crash.
2. the description of the personal injuries and the investigation of their possible causes.

Accident research, which is fully involved in the car development process from the very beginning, has four functions:

1. To influence in-process design improvement measures on the basis of case history data,
2. to create accident mode / frequency statistics, then establish representative test procedures for the development of new vehicles on the basis of these statistics;
3. to focus future protection measures by establishing relative injury frequencies; and
4. Internal performance requirements are updated and used beyond the legally required tests.

New or extended test procedures are derived as well as additional protection criteria, based on biomechanical research. Fig. 3 shows how crash research works.

Figure 3 Accident Investigation

This "road crash data" are the only unbiased indicator of safety, which leads to enhanced safety features of our automobiles, step-by-step, model-by-model, in terms of structural design, interior layout, restraint system technology, and protection for pedestrians and cyclists.

Safety Features

After the introduction of the occupant safety cell with crumple zones, and a compartment interior in which probable causes of injury had been reduced, the further efforts to enhance protection concentrated on the restraint systems. For example, Volvo introduced the three point belt system, which became standard in our car lines in 1973. The high efficiency of the belt system, assuming the belt was used, can be derived from crash findings. In a publication by Daimler-Benz accident research group (Zeidler, 1986), an overall efficiency concerning belted and unbelted fatalities was found to be 0,38 (The value 1 meaning 100% efficiency). This value is especially high only in frontal collisions (0,62), or rollover crashes (0,65).

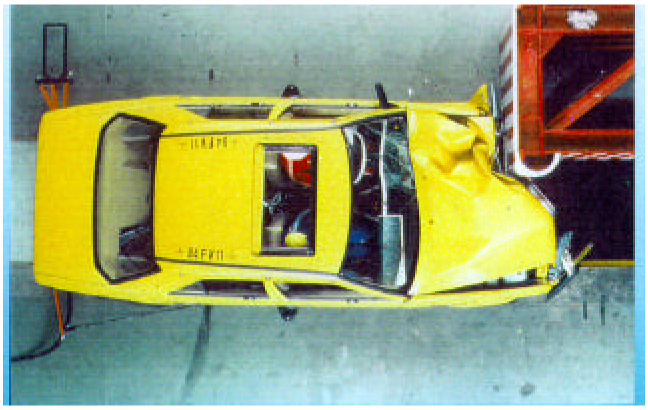

Figure 4 Crash against a rigid barrier with 40% overlap at 55 km/h

Figure 5 Crash into a derformable barrier with 50% overlap at 60 km/h

An additionally bigger step in passive safety, also derived from experience of crash findings, was the offset design, which involves a car-to-car collision, or a car-to-obstacle collision, with only a partial overlap of the car width. The design concept was tested in a crash against a rigid barrier with a 40% overlap of the front end at a speed of 55 kph (Figure 4). The choice of a rigid barrier was governed by the need for reproducibility and the lack of a deformable element, at that time to simulate the force/deflection characteristics of a representative car’s front-end structure. Keeping this possible deficiency in mind, some additional car-to-car crash tests were carried out. These experiences and the findings from real world crashes showed us the right way: The type of deformation which would be reproducible would be a car-to-car test procedure. However, to have a standardized, reproducible, and efficient test procedure, this method had to be rejected. As an alternative, a deformable barrier (Fig. 5) representing a car’s front-end structure seemed to be an appropriate substitute. We published these findings, and at the same time a special task force of Europe automotive company came to a very similar result. Now, we have reached a status that this “frontal offset collision into a deformable barrier“ test will be a regulation in Europe, effective in October 1998.

What is the next important step in passive safety? Again it is necessary to have a closer look at real world crashes to find out the most frequent injury type or collision type. Looking at fatalities, it is apparent that side collisions are very dominant. Testing a car to a ECE-R95 or an FMVSS214 procedure does not cover the many German fatalities occurring in side impacts against trees. This fact shows very clearly the new main points in safety and a shift from frontal collisions to side collisions. Therefore, we need special safety measures for the cars, but also for the roads. For example, guardrails between the road and the trees offer a higher level of protection for car occupants.

Harmonization

The need for global harmonization increases significantly because of a proliferation of crash test procedures and different dummy types worldwide. Financially, no manufacturer is able to carry out all tests with perfect results, but instead performs only some tests. From our understanding of a human being’s anatomy, it makes sense to choose only one dummy type for the different crash tests, especially the one which is most biofidelic. The next step must be in the effort to harmonize an impact configuration involving the most frequent and life-threatening crashes. This procedure would create legal harmonized safety requirements for all countries.

Safety Information

Figures 6 & 7 Consumer information due to crash tests

The interest of consumers to get information about safety has increased more and more. Auto magazines and organizations have carried out special crash tests with great enthusiasm (Fig. 6, 7). Some manufacturers were surprised with the bad performance of their cars in these tests. They were forced to optimize their products, so that the consumer believes the product is now safer. The lack of completing all special crash tests has “opened the door“ to the misnomer that one crash test may be definitive. However, one test in a special configuration does not conclude anything about the overall passive safety. For example, a German car magazine concluded a C-class crash to be “As safe as in Abraham’s bosom”, but the Euro-NCAP crash test result of the same car resulted in only two out of four stars. This is a mixed message. Is the consumer now better informed, or more confused? As long as the consumers are not experts in crash tests and dummy value interpretations’, they are not able to distinguish between the different tests and the different performance criteria. Even the experts have different opinions concerning e.g. the right overlap degree of the car width in frontal crash tests, or the test speed. What is the goal of a particular organization who is carrying out the test? Are they interested in avoiding fatalities in real world collisions? Or are they interested in sensationalism with the aim of selling their magazines, or raising insurance premiums?

The number of various consumer crash tests has grown enormously. If a manufacturer sells his cars worldwide, and is conducting all consumer and legal crash tests with different engine types, the number of crash tests can easily reach more than 100 for each car line. Is a car safer after passing all these tests? From our point of view, the best way to optimize the passive safety of a vehicle is to learn instead how accidents happen on roads. The direct implementation of countermeasures can allow us to quickly react to a change in the injury pattern. Again, accident research is the only unbiased information from the field.

Some consumer tests like the Euro-NCAP (European New Car Assessment Program) are more representative of real world crashes, because they include different tests like a frontal impact and a side collision. However, the main problem the way Euro-NCAP is designed is in the biomechanic interpretation of the dummy readings. For example, a dummy value is assigned for a certain body region to one of five possible groups for this body region, which are further classified into colors from red to green. This classification stands for the risk in suffering an injury at a defined life-threatening level. The “green“-values (= no risk) are partially at a very low level, e.g. the leg of a running person is loaded at a higher level compared to what the “green“-value represents under Euro-NCAP conditions. That means, driving frontal into a deformable barrier at 64 kph should be less risky than running. Another example, if a dummy would fall on its knees from the normal standing height, the dummy reading of the thigh is at a higher level than the Euro-NCAP level assigned to the green range.

Both examples show, that it is necessary to improve the Euro-NCAP procedure and to create a better rating system, orientated to real world crashes, by meeting the wish of the consumer - creating a “shopping list for

A good alternative is a German initiated project called QUPASI (Quantification of Passive Safety). The test program in this project is a combination of the US-NCAP and the Euro-NCAP, but the dummy readings are weighted with the help of risk functions for body regions and the frequency distribution of the collision types derived on the basis of real world crashes.

Enhanced Restraint Systems

Seat belts with new features - In a frontal collision, the high-performance belt tensioners are automatically triggered by means of a pyrotechnic charge. Within a split second, they pull the belts tight, ensuring the occupants participate in the deceleration process from the earliest possible point in time onwards (Fig. 8). A further invention is the belt force limiter. It ensures - once the belt has been tightened - that the belt yields in a controlled manner as soon as a specified load level is exceeded. This prevents excessive loads from acting on an occupant's chest.

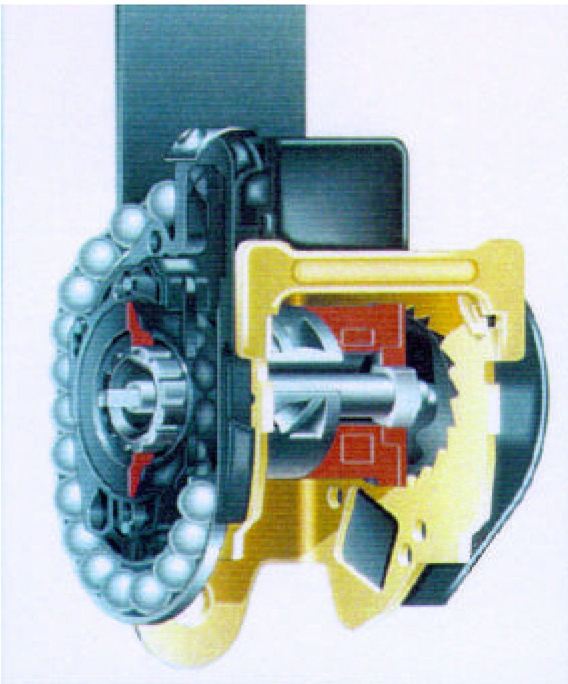

Figure 8 Belt tensioning device

Airbags for driver and passenger - The driver and front passenger are protected by large-volume fullsize airbags. They are triggered by a central electronic sensor unit. The latter processes the deceleration data in a frontal collision and immediately triggers both airbags, provided a specified impact severity threshold is reached or exceeded (Fig. 9). The airbags complement the seat belts. They reduce the dangerous forward and backward whiplash of the head, and cushion the occupant's upper body, thus significantly reducing the risk of sustaining severe head and chest injuries.

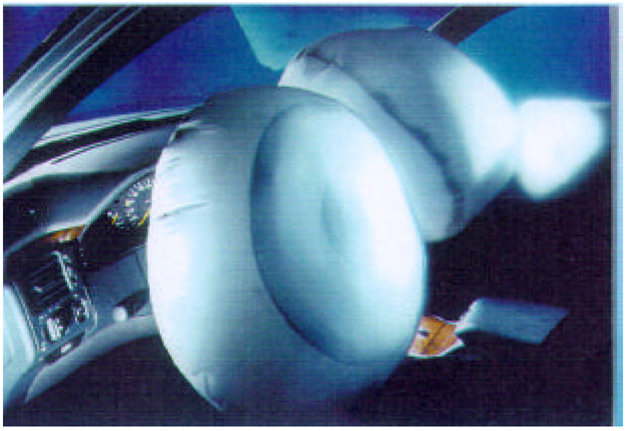

Figure 9 Frontbags for driver and passenger

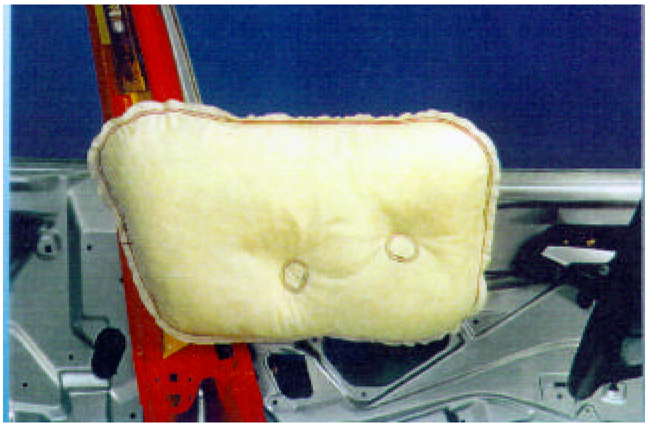

Figure 10   Side bag of the E-Class

Sidebags - The main function of a sidebag is to reduce the injury severity in the occupant's chest area. For example, our recent car lines are equipped with sidebags in the front doors. They are integrated into the door trim above the armrest. When they are triggered, the fabric lining of the door is torn open along a pre-defined line and the sidebag is inflated to form a protective cushion between the occupant and the door. It thus prevents direct contact of the occupants's body with the inner door trim. This reduces the load acting on the occupant's chest as well as lateral whiplash of the head, and thus the danger of severe head injuries (Fig. 10).

Compatibility

Public discussions involving car-to-car collision, especially a large car against a small car, have become more and more important. Crash statistics show very clearly that the risk to suffer severe injuries in smaller cars is significantly higher than in larger cars. Therefore, for compatibility reasons, experts have for many years recommended higher crash speeds for small cars and lower speeds for large cars; a demand which of course is not in accordance with the safety standards. Based on the laws of physics, crash data, etc., experts agree that the stiffness of the front end of a small car should be increased while the stiffness of the front end of a large car should be decreased. As a consequence, crash tests into a deformable barrier (like Euro-NCAP) should be conducted with a mass-dependent speed to avoid heavier cars being tested more severely in terms of EES (Energy Equivalent Speed) than for small cars (Fig. 11). Unfortunately, this reasonable demand cannot be understood and appreciated because of political and technical reasons.

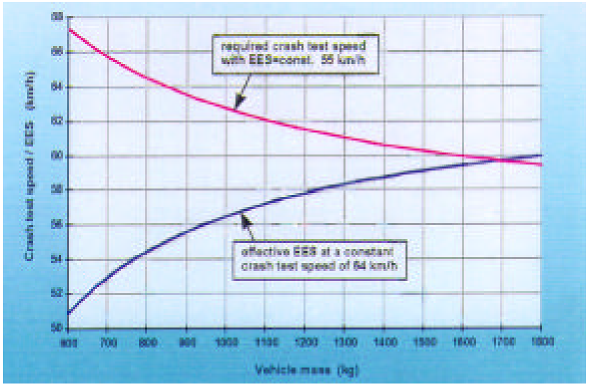

Figure 11 Euro NCAP Test, EES = f(m)

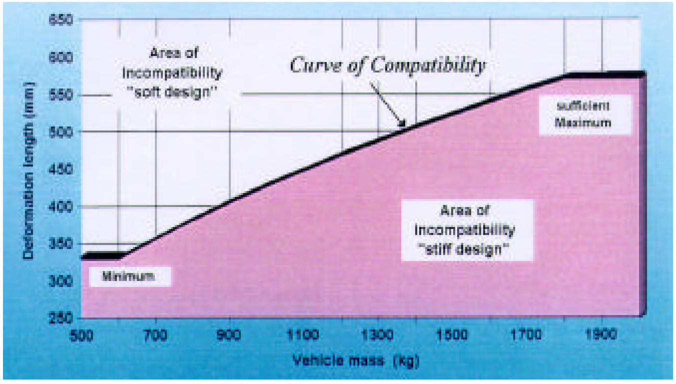

Figure 12 Required dynamic deformation length
(Flat barrier impact at 50 km/h)

The determination of the stiffness, expressed as the resistance to deformation in a certain test, e.g. a flat barrier impact at 50 km/h, leads to a relationship between minimum and maximum deformation lengths. The minimum length is determined by the objective of ensuring success in the above mentioned test with valid biomechanical load values, which is only possible by using the highest quality standards for restraint systems. An effective deformation length of more than 570 mm is not feasible due to the conflict of interest with other vehicle design requirements. Figure 12 shows an ideal compatibility curve. Here, it is especially clear that every deviation from the ideal curve, both in the “soft design” or in the “stiff design” directions, will result in “incompatibility“.

The new A-class demonstrates this theoretical compatibility idea in a convincing way. In a head-on collision involving two cars of different mass, a suitable distribution of the deformation load between the two vehicles must be achieved so there is no risk of intrusion, particularly to the occupants of the smaller car. Compatibility means that in a collision involving two vehicles, they should both activate one another’s crumple zone and be capable of transmitting the deformation load uniformly to both bodies. As an example (Fig. 13, crash A-class against E-class), in the E-class the front end structure of the Mercedes model is designed so that the absorbed energy for the other vehicle in a crash is reduced. In the A-class, however, the design principle is just the opposite.

In general, the following consequences should be considered for compatibility aspects:

- The stiffness distribution and the deformation forces are variable across the front end of the vehicle.
- Over-/ underriding has to be avoided; while impact angle and vehicle front have to be considered.
- For minis (city cars), the passenger cell must be rigid.

Outlook

All these discussions clearly prove the high level of passive safety of newly designed cars. Where do we go? A new development is shown in Figure 14. A window bag system protects the occupants’ heads during side collisions on a struck side (front and rear). The system inflates from the roof side rail where it is mounted.

Figure 13 A-Class versus E-Class

Figure 14 Windowbag

It becomes evident that safety measures tend to become increasingly costly with increasingly smaller benefits. For example, if we carry out more frontal crash tests with higher speeds like Euro-NCAP is planning to do, with dummy criteria which are on a level of “every day“ loads, then we will go the wrong way and start to spend money in inefficient ways.

1. The physical limits are reached at a certain point, so you need longer front end designs, which are in conflict with the environmental, or ecological concerns.

2. By optimizing a car for severe crashes only, low speed crashes could be more dangerous to the occupants than before because of aggressive structures or restraint systems.

3. As many fatalities occur in side impacts against other cars or trees, the focus must be changed on this issue.

The medium-term goal to be pursued will be to use the swift development of electronics to avoid crashes. We are on a very good path, if we look at systems like autonomous cruise control, brake assist, and electronic stability program (Fig. 15). A further step in the right direction are systems to navigate a car and provide a warning, when a critical situation occurs. Nevertheless, crashes will still happen. In this case it is very important to call the police immediately and/or the emergency rescue service with, for example, the help of Tele-Aid. With all these mentioned systems we should be able to further decrease casualties in road traffic (fig. 16).

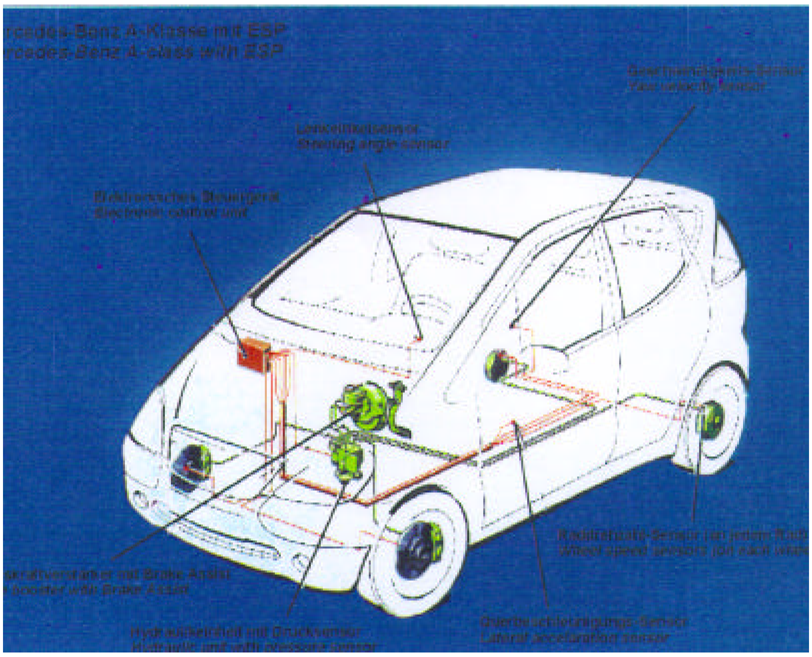

Figure 15 Electronic stability system

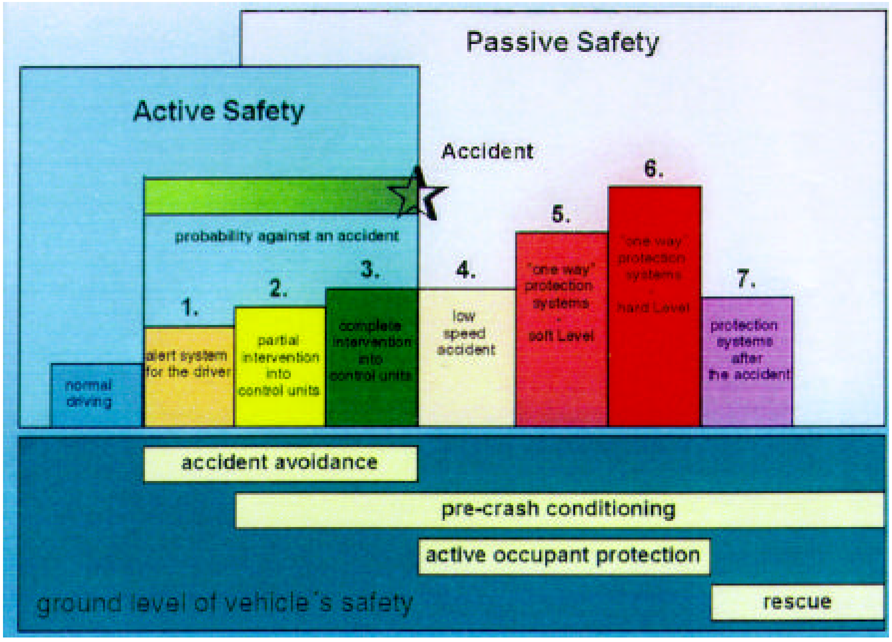

Figure 16 Phases of occupant protection

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