THE EFFECT OF AIRBAGS ON INJURIES AND ACCIDENT COSTS

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ABSTRACT

The global accident figures in Germany have been steadily declining for years now. This positive trend has been intensified by the extra protective effect afforded by front airbags. This additional protection of front airbags has been proven based on analyses of real accidents.

The GDV airbag database has been expanded to 335 airbag cases and currently provides information about accidents involving front and side airbags as well as "problem cases". Since the number of vehicles already equipped with side airbags is still very small in Germany, there are currently still no universally applicable findings about the behavior of side airbags.

Earlier studies carried out by the GDV clearly confirmed the protective action of the front airbag as a restraint system in addition to the three-point seat belt – primarily for the driver. The present paper focuses in particular with "airbag problems", i.e. "injuries caused by the airbag", "airbag activation while the vehicle is stopped", "airbag activation while driving" and "no airbag activation despite high accident severity". The last problem cases involved traffic fatalities. Moreover, the topic of "airbag and the cost of repair work" will also be discussed. The problem cases that are described in this paper demonstrate that the airbag itself, its components, its activation behavior, its activation threshold and the activation safety must still be optimized.

Raising the activation threshold to approx. 25-30 km/h, i.e. coordinating the activation threshold to the belted passengers, would not only reduce the danger of injury caused by the airbag itself, but would also lead to a reduction of the costs for repair work. Even today, expanses amounting to 90 million DM arise in Germany per year due to the premature activation of front airbags. When 50 % of all vehicles are equipped with airbags, this figure will rise to approximately 200 million DM. Since passenger presence detection systems only exist in very few car models, additional expenses of 70 million DM will arise per year, since in approximately 40 % of all cases involving activation of the passenger airbag, the passenger seat is not even occupied.

INTRODUCTION

In the past few decades, the accident situation in Germany has been characterized by a steady decline in the number of traffic deaths despite a rise in traffic volume [1]. Due to improvements in automobile safety and progress in the field of accident medicine and driver education, the number of deaths among car passengers has been declining continually since 1970 (Figure 1). In 1997, there were 8,516 fatalities in Germany, two thirds of whom (5,283 persons) were car passengers.

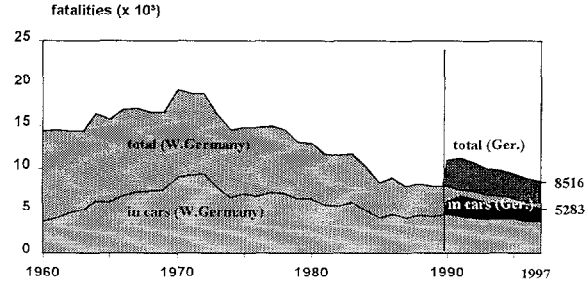


Figure 1. Number of traffic fatalities in Germany.

The reduction in the number of traffic deaths is not due to a reduction in the total number of accidents but predominantly to the avoidance of fatal injuries. The introduction of airbags will allow this positive trend to continue in the future as well – provided that the rate of seat belt use does not decline. There is hardly another safety system that has caught on as quickly as the airbag both in the consciousness of the drivers and in the design of the automobile. In the meantime, 94 % of all vehicle models destined for the German automobile market have been equipped with a driver airbag as standard equipment and as many as 75 % with a passenger airbag (with an additional 4 % added as optional equipment) [4]. The side airbag is already being installed in 11 % of all new vehicle models as standard equipment (with an additional 3 % added as optional equipment). According to estimates made by the GDV, 25 % of all automobiles registered in Germany are currently equipped with a

driver airbag, 15 % also feature a passenger airbag. The figures are rising quickly due to the fact that more than three million new vehicles are registered annually [8]. The official statistics may already be reflecting the positive impact that the airbag has had on the number of casualties in Germany (Figure 2).

Combined with the use of seat belts, the airbag has led to a new, very high level of passive safety in automobiles. A comparison of different GDV accident statistics revealed that one can assume an approx. 80 % to 90 % reduction in the risk of injury in the event of serious head-on collisions involving airbags and seat belts, compared to passengers not protected by either airbags or seat belts. Compared to the passengers secured by seat belts only, the use of an airbag and three-point belts has achieved a greater than 40 % reduction in the number of serious to fatal injuries [3].

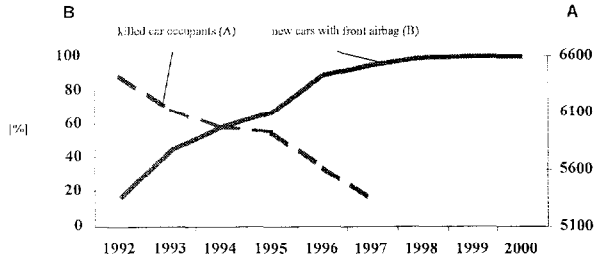


Figure 2. Killed car occupants (A) and frequency of newly registered cars equipped with front airbags (B) in Germany.

DESCRIPTION OF THE CURRENT AIRBAG DATABASE

The accident database described in [3] (249 accidents involving vehicles equipped with front airbags) has in the meantime been expanded and supplemented by including what have been termed "problem cases" as well as accidents involving cars equipped with side airbags. A database covering a total of 335 cases involving airbags is currently available at GDV for accident research.

The present publication will focus on these "problem cases", too, and on the consequences that airbags may have on the costs of car repair and the claim expenditure on the part of car insurers. The topic of side airbags will also be discussed.

Initial experience using side airbags

Compared to front airbags, side airbags have only been available in vehicles for a relatively short time so that the number of automobiles equipped with side airbags in Germany is at present rather low. In spite of intensive research work and efforts devoted to this development, the accident research department at GDV currently has only very few cases involving activated side airbags.

One relevant case is described in Appendix 10. The vehicle was occupied by front-seat passengers who were secured by seat belts when the vehicle side-swiped a tree close to the right front wheel. This side-on collision triggered a total of three side airbags (the thorax side bag in the right front door, the "ITS" (inflatable tubular structure) at the front right and the thorax side bag in the right rear door). The driver, who was secured by his seat belt, remained uninjured. The front-seat passenger, also secured by a seat belt, suffered contusions and sprained his right arm.

This case involved unnecessary activation of the airbags since there was no passenger sitting at the right rear of the car and in addition even if the airbag had not been activated, it would have posed no greater risk of injury to the passenger sitting at the right front [6]. Hence, passengers involved in an accident of the type described have a relatively low risk of injury – even without the additional protection afforded by a side airbag. It cannot be stated at present to what extent this case is universally applicable since there are too few cases available that involve activated side airbags. The GDV accident research department will continue to keep a close eye on side-on collisions involving vehicles equipped with airbags and accumulate the case material, but more time is necessary.

"Problem cases" in the airbag database

In addition to continuously expanding the database on airbag accidents, the studies conducted by GDV over the past two years have concentrated both, on the injury reducing effect of airbags and on possible "problem cases". These are understood as being the problem areas listed in Table 1, i.e. "injuries caused by the airbag",

Table 1.
Number of "problem cases" in the GDV airbag database; cases with and without an accident

	Number
Injuries caused by the airbag	61
Airbag activation while the vehicle is stopped	7
Airbag activation while driving (without involving a collision)	7
No airbag activation despite high accident severity	5

Table 2.
Injuries caused by the airbag (cases with and without an accident)

	Type and severity of injury		DD 0/1 No.	DD 2 No.	DD 3 No.	DD 4 No.	DD n.a. No.	SUM
Head	Facial contusion	AIS 1	3	3	19	7	1	
	Facial burns	AIS 1		2	1		1	
	Hearing impairment	AIS 1			1		1	
	Eye cloudiness / glaucoma	AIS 1		1			1	41
Cervical spine	Neck fracture	AIS 6			1			1
Arm	Forearm contusion	AIS 1	4	4		1	2	
	Forearm burns	AIS 1		3	3		1	
	Deep muscle injury and subluxation of thumb	AIS 2		1	2			
	Chip fracture of wrist	AIS 2					1	22
Leg	Gash in thigh	AIS 1					1	
	Thigh contusion	AIS 1		1				2
	SUM		7	15	27	8	9	66

"airbag activation while the vehicle is stopped", "airbag activation while driving" (without involving a collision) and "no airbag activation despite high accident severity".

Injuries caused by the airbag - A total of 66 front-seat passengers were injured in the 61 cases listed in Table 1 (airbag activation with and without an accident). Depending on the degree of damage ("DD"; refer to the definition given in Appendix 1), the injuries the airbag caused to the individual parts of the body are compiled in Table 2; the AIS values [9] have been provided as well. In most cases, the injuries were minor AIS 1 injuries, although moderate injuries (AIS 2) to the arms (refer to the example in Appendix 4) and even a fatal neck fracture (AIS 6) caused by the airbag (refer to Appendix 2) were also found.

The case described in Appendix 2 is a typical "out of position" situation: the relatively small, female front-seat passenger (157 cm, 67 kg), whose seat was moved far to the front, was subjected to extremely high loads due to the activation of the full-size airbag [10]. The consequence was a massive dislocation trauma to the head and neck region with a broad dislocation between the first and second cervical vertebrae (AIS 6) due to hyperextension of the cervical spinal column. Intensive medical care kept the patient alive for almost 14 days after the accident before she ultimately succumbed to her injuries. Other fatal injuries due to the airbag in Germany, however, are not known to the GDV accident research department.

Most minor injuries (AIS 1) occurred in the head region. Approximately two thirds of all front-seat passengers suffered facial injuries when the head was contacted by the airbag. The most frequent injuries in such cases included contusions and abrasions. Two drivers reported permanent hearing impairment and one driver suffered a cataract. Four passengers sustained injuries to the face. Seven drivers suffered burns to the forearm and hand caused by the hot gases escaping from the outlet opening of the airbag at the rear of the bag.

In addition to the minor injuries and the one fatal injury described above, the airbag database also contains four moderate injuries (AIS 2) to the hand. Appendix 4 depicts a corresponding case. In an extremely minor rear-end collision, the front-seat passenger, who was secured by a seat belt, propped himself up against the instrument panel in a reflex action. He suffered deep lacerations on both hands between the thumb and index finger including injury to the muscles and a subluxation of the saddle joint of the thumb caused by the airbag cover. These injuries were evaluated as being AIS 2.

As long as the airbag has provided protection and spared the passengers serious injury in the event of a severe collision, then such accompanying injuries can still be tolerated, provided they are in the range of AIS 1 or AIS 2 injuries. However, if these injuries are caused by the airbag activation at low speeds corresponding to a deformation pattern of EES $\leq$ 30 km/h, then the injured person will consider such injuries as inadequate. In this speed range, the safety belt reliably protects the

Table 3.
Airbag activation while the vehicle is stopped

Vehicle	Model	Circumstances	Cause	Injuries
No. 1	1995	driver airbag activated when starting engine	unknown	minor complaints of cervical spine
No. 2	1994	driver airbag activated when driver was getting out of car and had removed ignition key	unknown	contusions of arm, thorax
No. 3	1994	driver airbag activated when driver was getting out of car and had removed ignition key	unknown	bitten tongue
No. 4	1985	driver airbag activated when driving in reverse gear	unknown	contusions
No. 5	--	driver airbag activated when engine was jump-started	severed cable under the ignition lock owing to attempted theft	no injuries
No. 6	--	driver airbag activated when driver was getting out of car	unknown	no injuries
No. 7	1994	driver airbag activated when driver was getting out of car and had removed ignition key	unknown	wrist contusion

passenger from serious injury and it is therefore unnecessary to actuate the airbag, thus causing contusions, abrasion or even burns and lacerations which would not have occurred if the airbag had not been activated.

Airbag activation while the vehicle is stopped - Among the "problem cases", there are seven cases in which the driver airbag activated while the vehicle was not moving (without any external application of force due to an accident). Table 3 contains both the circumstances as well as the known causes of airbag activation including the injuries sustained by the drivers.

These incidents did not cause any major injuries to the drivers; injuries exceeding AIS 1 did not occur. Contusions on the arm and wrist were both documented because the airbag hit the upper extremities as the driver was getting out of the car. There were also thoracic contusions and a bitten tongue. One driver suffered minor cervical whiplash complaints because the driver airbag inflated while the driver was starting the engine.

In four of the seven cases, the airbag inflated while the drivers were getting out of the car. In many cases, the ignition key had already been removed from the ignition lock by this time (refer to the case described in Appendix 7).

The reasons for activation of the driver airbag were able to be reliably explained in one case only: cables that had been severed during an attempted theft caused a short circuit which led to the activation of the driver airbag. In all other cases, the reasons remained a matter of speculation.

Airbag activation while driving - As already illustrated in Table 1, the GDV airbag database contains seven cases in which the airbag was activated while the vehicle was moving (without any involvement in an accident). The exact circumstances, the reasons that have become known and the injuries that the passengers suffered can be seen in Table 4. As in the case of airbag activation while the vehicle was not moving, the passengers in the cases mentioned here went uninjured or sustained only minor injuries (AIS 1). The injuries were limited to abrasions, contusions and burns on the arms as well as facial abrasions.

Impact to the floor pan of the vehicle was the principal cause of airbag activation while the vehicle was moving in a total of four cases. This impact to the floor pan originated from driving over a traffic island, from making contact with the exit ramp of a multi-story parking garage (refer to Appendix 3) and from making contact with a tipped-over barrier post (refer to Appendix 8). The damage done to the underside of the vehicle infer that the force as well as the associated deceleration was either transmitted to the frame directly (tow-hook) or were transferred via the sump pan and gearbox transmission to the longitudinal beam, thus causing the airbag to actuate. Even in the one case involving activation of the side airbag on the driver side while overtaking another vehicle, the technical

Table 4.
Airbag activation while driving (without involving a collision)

Vehicle	Model	Circumstances	Cause	Injuries
No. 1	1997	(driver) side airbag activated while passing another car	contact with the underside of vehicle	minor injuries to arm
No. 2	1996	driver and passenger airbags are activated when car drives over a traffic island	strong impact on left front wheel, chassis and transmission	burns and abrasions on forearm and hands
No. 3	1995	driver and passenger airbags are activated when car runs over tipped-over barrier post	contact with the underside of vehicle	unknown
No. 4	1995	driver and passenger airbags are activated when car runs over exit ramp in parking garage	contact with the underside of vehicle	both driver and passenger have abrasions
No. 5	1995	driver airbag is activated at 25 km/h	impact from beneath due to bump in road	abrasions to the face
No. 6	1994	driver airbag is activated when car starts to move	moisture in the control mechanism	none
No. 7	1986	driver airbag is activated when parking the car (without collision)	short circuit between sliding contacts due to two loosened screws	contusions on arms

inspection of the vehicle by the automobile manufacturer revealed signs of impact on the floor pan of the vehicle.

In another case, moisture in the control mechanism was the cause of airbag activation while driving. The driver airbag was activated while the vehicle was moving without a collision or any other type of external force being applied. According to the car manufacturer, moisture was found in the control mechanism, although it was still intact. This moisture caused an interference voltage which ultimately could have caused the airbag to actuate. The car manufacturer had not been able to determine any other causes.

Finally, the GDV accident research department became aware of a case involving a technical defect in the form of a short circuit between the sliding contacts. The driver airbag activated while the car was being parked in a parking space (with no collision involvement). It was found during the subsequent repair work that two screws of an anchor plate had loosened, thus causing a short circuit between the contacts.

No airbag activation despite high accident severity - Collisions with a relatively high accident severity (DD $\geq$ 3; refer to the definition in Appendix 1) involving a vehicle equipped with airbags which fails to inflate are comparatively rare, although a total of five cases were found in the GDV airbag database in which at least one airbag failed to activate.

Table 5 contains these five cases. The injuries to the front-seat passengers were very serious in several cases and even fatal in one case. Both the severity of injuries and the degree of damage make it clear that in these cases the airbag could have actually provided the greatest protection [3].

Case B is illustrated in Figure 3. Looking at such an accident, it becomes clear that the driver airbag should have activated under all circumstances. The reason the airbag failed to activate was due to a connector that had been forced open so that the airbag could not have activated. A similar case involving an improperly closed connector where there was no connection to the driver airbag module (see Appendix 9) has already been published in the German automobile press [11]. The driver was killed in this case as well.

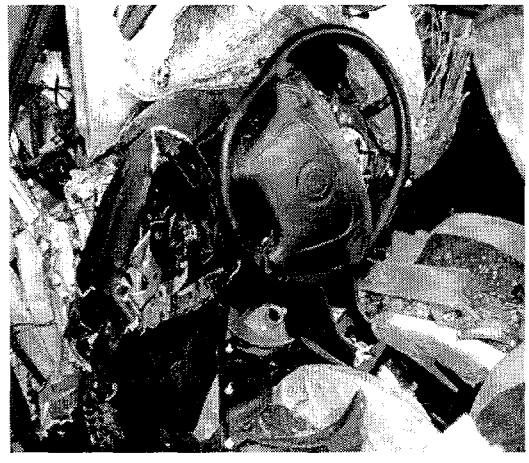
In case D contained in Table 5 (refer to Appendix 6), the front-seat passenger was seriously injured because the passenger airbag failed to activate. That the activation threshold had been reached in this case is confirmed by the fact that the driver airbag did in fact activate. The reasons submitted by the car manufacturer was that it was not possible to activate the passenger airbag, since the cables of the passenger airbag circuit had been severed as a result of the accident. The same automobile manufacturer is known to be involved in another case with a similar accident severity in which the reason for the non-activation of the passenger airbag was stated as being "inadequate energy input into the passenger airbag circuit".

It is not always vehicle defects, however, that cause the airbag to fail to activate. GDV knows one case (case E in Table 5) in which the steering wheel had been interchanged improperly. This thus caused damage to the spiral spring which in turn was the reason the airbag failed to activate.

In summary it has to be pointed out that failure cases are extremely rare, but these cases occur.

Table 5.
No airbag activation despite high accident severity

Vehicle	Model	Circumstances	Cause	Injuries	DD
A	1992	collision with guard rail, no airbag activation	unkown	slight injury of the cervical spine, pulled muscles in forearms	3
B	1995	head-on collision with a tree; driver airbag activated, passenger airbag did not	connector to the driver airbag had been forced open	driver killed (sole passenger))	4
C	1993	head-on collision with a tree; driver airbag activated, passenger airbag did not	probably inadequate energy input into the passenger airbag circuit	driver (sole passenger) sternal fracture, scratches on the arms, contusions of the legs	3-4
D	1997	head-on collision with a tree; driver airbag activated, passenger airbag did not	the cables of the passenger airbag circuit had been severed as a result of the accident	driver slightly injured, front-seat passenger suffered serious brain concussion, lacerations and contusions to the face and body	4
E	---	passenger airbag activated, driver airbag did not	damage to the spiral spring due to improper exchange of the steering wheel	unknown	3



Opel Astra: Collision with a tree

Injuries to the belted driver: Critical craniocerebral trauma **AIS 6**
Critical thoracic and abdominal injuries **AIS 6**

Figure 3. Severe frontal collision with fatal injuries to the belted driver (sole passenger); passenger airbag activated, driver airbag not activated.

AIRBAG AND REPAIR COSTS

Unnecessary activation of the passenger airbag

It was found in [3] that (in real accidents) the current non-intelligent generation of airbags was activated entirely unnecessarily on the passenger side in 42 % of all cases. In 34 accidents out of a total of 82 in which the passenger airbag was activated, there were not even a passenger sitting in the car. It is therefore indispensable that all vehicles equipped with a passenger airbag be provided with a passenger presence detection system as well.

A computer-assisted assessment of damage calculations of two comparable types of vehicle with and without a passenger presence detection produced the following situation with respect to the activation frequency of the airbag and the costs of repair: as vehicle "1" was not equipped with a passenger presence detection, all passenger airbags were activated together with the driver airbag. In vehicle "2", the passenger presence detection prevented the passenger airbag from activating when the passenger seat was vacant in 96 % of all cases in which the driver airbag was activated (Figure 4). This shows that a higher firing level and a passenger presence detection would essentially contribute to less unnecessary deployment of airbags on the passenger side, without reducing the protection effect. If passenger presence detections had been provided in all vehicles equipped with an airbag, annual repair costs amounting to approx. 70 million DM could have been avoided in Germany.

Low activation threshold

The analysis of real accidents [3] shows that approximately 50 % of the airbags are activated in the EES range of 15 km/h. This experience from real accidents has been verified in low speed crash tests as well. At the Allianz Center for Technology, standardized low speed crashes were conducted at 15 km/h and with 40 % offset against a rigid barrier to determine the repair costs for head-on, side-on and rear-end collisions. During these tests, the airbags were activated in a number of vehicles even at these low collision speeds. In these cases, in addition to the extent of damage to the car body, the repair costs tend to be driven up by an additional 8-31 % if only the driver airbag needs to be replaced and by 47-56 % for vehicles equipped with two airbags (Figure 5).

In real traffic accidents that occurred at a low collision speed, the costs of repairs for the airbag-induced damage was twice to three times as high as the actual repairs caused by the accident itself (see Figure 5). In the first of the cases depicted here, the impact of the front tires against the curb was enough to trigger the driver airbag. The result drove the costs of repairs up by 240 % due to the fact that the airbag had been activated (replacement of an aluminium rim and two tires = 1,153 DM in addition to the driver airbag = 2,763 DM). In a second case, the fender had to be replaced after a very minor frontal collision. The seat belts had to be replaced since the seat belt pretensioner had been actuated, something that can be readily accepted. In addition to this, however, the activation of the driver and passenger

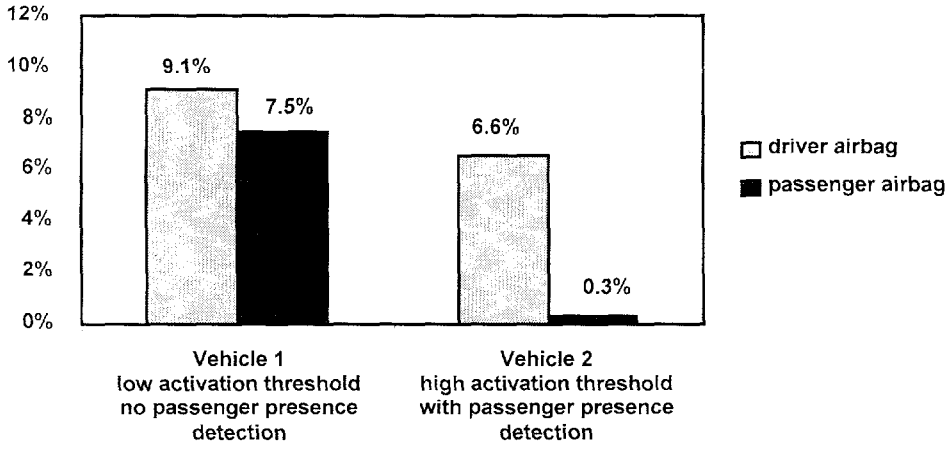


Figure 4. Frequency of driver and passenger airbag activation in two comparable vehicles with and without passenger presence detection.

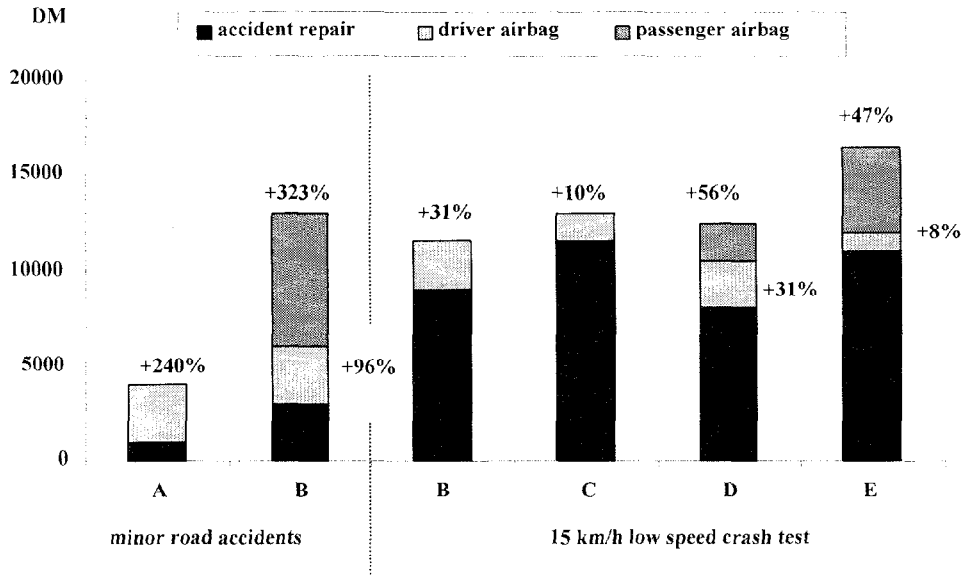


Figure 5. Increase in repair costs caused by driver and passenger airbag activation.

airbags had not only demolished the dashboard and the windscreen, the sunroof had also been damaged due to the pressure wave. In addition to the repair work of the car body (3,000 DM) the total costs rose to 10,000 DM owing to the damage caused by the airbags.

A conservative estimate (assuming that 25 % of all vehicles are equipped with a driver airbag and 15 % with a passenger airbag) indicates that even today the costs of repairs has increased approximately 90 million DM per year owing to the unnecessary early activation of airbags. As more and more automobiles are equipped with airbags, it is quite possible that a figure amounting to about 200 million DM will be reached quickly within the next few years.

In addition to an activation threshold which is often much too low, airbag activation – especially on the passenger side – not infrequently causes needless damage to the passenger compartment so that the windscreen and the entire length of the dashboard, for example, must be replaced. A comparison of the costs of repair work with and without airbag activation for one and the same type of vehicle showed [5, 7] that the vehicle was a write-off in 36 % of all accidents. Hence, the additional costs were irrelevant. In approximately one fourth of all cases, however, the damage caused by the needless activation of the airbag during the accident and the resultant higher costs of repair reached or exceeded the amount of a total write-off.

Engineers are faced with the real challenge of avoiding such unnecessary and costly damage by intelligent solutions to accident repair work.

Added costs due to the airbag

In yet another cost analysis, an attempt was made to estimate the proportion of additional airbag repair costs in full comprehensive vehicle insurance for the entire German insurance market.

The study was based on a random sample taken from a total of six design series being on the German market for less than two years. All vehicles in these design series were equipped with airbags as standard equipment from the very beginning of production.

The average additional costs per airbag repair (costs of labor and spare parts) were calculated for these vehicles. The added cost expenditure which car insurers had to pay in settlement for airbag repairs within the framework of full comprehensive vehicle insurance was calculated on the basis of the number of airbag modules exchanged in the respective design series.

Based on the total amount of costs paid in settlement and the number of insured vehicles in the respective design series, the costs of repairs for airbag damage amounted to approximately 2.5 % for the chosen random sample. If this value is extrapolated for the total market, the result is a sum amounting to approximately 200 million DM per year. Against the background of an increase in the number of vehicles being equipped with airbags and with more side airbags now being installed in cars in addition to the front airbags, an increase in the costs of airbag-induced repair work must be expected in the future.

SUMMARY AND CRITICAL DISCUSSION OF KEY POINTS

The number of deaths due to traffic accidents has continued to decline in the past few decades in Germany. The most recent official statistics concerning road fatalities may well show this positive initial impact of the added protection the airbag offers to car passengers.

The GDV airbag database has been expanded continuously and now provides accident research with 335 cases involving airbags (accidents involving front and side airbags as well as "problem cases"). Unfortunately, the number of vehicles equipped with side airbags is still so low in Germany that no statistically reliable data, but only case reports, can be presented. The case material, however, will be continuously supplemented in the future.

The study confirmed former results on the injury reducing effect of airbags, but showed some "problem cases", especially "injuries caused by the airbag", "airbag activation while the vehicle is stopped", "airbag activation while driving" (without involving a collision) and "no airbag activation despite high accident severity". These problem cases as reported have to be excluded in the future as far as possible.

"Injuries caused by the airbag" are normally limited to AIS 1 injuries, although moderate injuries (AIS 2) and one fatal injury (AIS 6) have also been registered. If the airbag fulfills its protective function in the event of a serious collision and has protected the passengers from severe injury, then AIS 1 or AIS 2 have to be tolerated. However, if the activation of the airbag causes these injuries, in particular at low speeds up to an EES of 30 km/h, then those injuries are totally unnecessary. Seat belts still reliably protect passengers from serious injury at this speed range. It is therefore unnecessary to activate the airbag in this situation, thus giving rise to contusions, abrasion or even burns and lacerations which would not have occurred had the airbag not been activated.

Airbag-induced injuries could be avoided not only by raising the activation threshold of the airbags, but also by using "smart" systems capable of detecting the seating position of the passenger including his/her height and weight.

But even minor injuries (AIS 1) should not be endured uncritically. The incidence and severity of burns (refer to Appendix 5), for instance, could be diminished by modifying the airbag fabric, the outlet openings and airbag cover and by optimizing the hybrid gas generators. Additional innovative solutions need to be found in this respect.

The seven cases of "airbag activation while the vehicle is stopped" prove that activation of the airbag is possible even without the effect of external forces and even after the ignition key has been removed from the ignition lock. In the cases so far known, the passengers suffered only minor injuries or none at all, but there is a risk which should not be underestimated. The fact that the airbag is capable of causing fatal injuries when a person is seated very close to the airbag is proved by the case described in Appendix 2. Hence, cases of airbag activation while the vehicle is stopped must be precluded using all technical means available.

The GDV airbag database currently contains seven cases in which the airbag was activated while the vehicle was moving. The severity of the injuries sustained by the passengers was at most AIS 1 – similar to airbag activation while the vehicle is stopped. In four of the seven cases, impact to the floor pan of the vehicle was the cause of the activation. The problem is that the airbag electronics system apparently interpreted the impact as if an accident had in fact occurred. New intelligent ("smart") systems featuring improved interpretation of acceleration signals should therefore be developed.

A misinterpretation of the acceleration signals was evidently not involved in any of the five cases in which the airbag failed to activate in spite of high accident severity. On the contrary, these cases involved defects in the airbag circuit (poor connectors, severed cables, damaged spiral springs, etc.). Since the consequences of the accidents were in some cases very severe or even fatal injuries, the entire airbag system including all relevant components should be installed in the vehicle with the utmost care.

Today, the passenger airbag is activated in many cases (42 % in the GDV accident database), although the passenger seat is vacant. Extrapolations for Germany have revealed that this causes added expenditure of approximately 70 million DM in repair costs per year. As more and more vehicles are equipped with airbags, this expenditure will continue to rise unless passenger presence detection systems are provided in all cars.

The activation threshold of current airbags is much too low. Even at low speeds (EES about 15 km/h) there was airbag activation in 50 % of the cases. The results from low speed crash tests have verified this fact.

Besides unnecessary risk of injury, which is not always low, added repair costs are to be expected with about 200 million DM by the year 2000, when more than 50 % of all vehicles will be equipped with airbags. The activation threshold of future airbag systems should therefore correspond to a wall impact speed of approx. 25 km/h to 30 km/h and the activation characteristics should be geared to passengers wearing seat belts. Marketing considerations should in no way prevent or even impede the optimum design and construction of

protection systems.

Earlier studies [3, 7] clearly confirmed the protective effect of the front airbag as an additional safety system which supplements the three-point seat belt: The maximum injury severity MAIS to belted drivers in frontal impacts with and without airbag deployment as a function of the degree of damage (DD) is shown in Appendix 11. In a comparison with the accident material of the Vehicle Safety 90 [2] it becomes clear that with the same car damage the drivers are far more rarely severely injured or killed when the airbag deploys. This becomes especially clear in the 3 to 4 range of degrees of damage, i.e. a relatively high accident severity. In the airbag material, only in the case of high car deformation (DD 4) did serious MAIS 3-4 injuries occur, and there were no fatal injuries at all with this accident severity. Only in so-called disaster cases with extreme intrusion into the passenger cell (DD 5) was a fatally injured driver observed in the airbag material.

The airbag therefore was - and still is - a major step towards greater safety. It is thus all the more important to take the few problem cases seriously and eliminate risks which could discredit the airbag from the outset.

ACKNOWLEDGEMENTS

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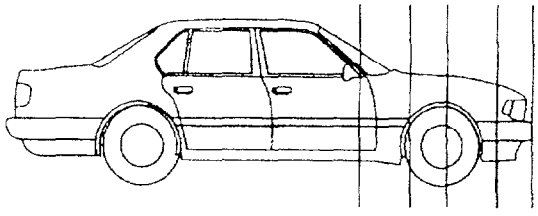
Appendix 1

Examples of Degree of Damage Classification

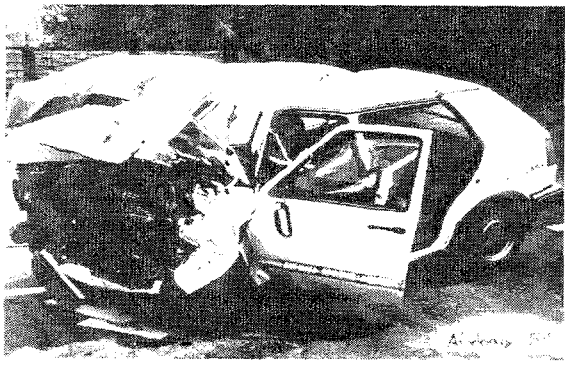


5 4 3 2 1

Degree of damage 1 = light
(corresponds to minor scratches, dents, etc.)

Degree of damage 2 = moderate

Degree of damage 3 = severe



Degree of damage 4 = extreme

Degree of damage 5 = total

Appendix 2

„Airbag Material"
Case No.: 273

Airbag vehicle: Mercedes E 220 (124); Taxi
driver and passenger airbags activated

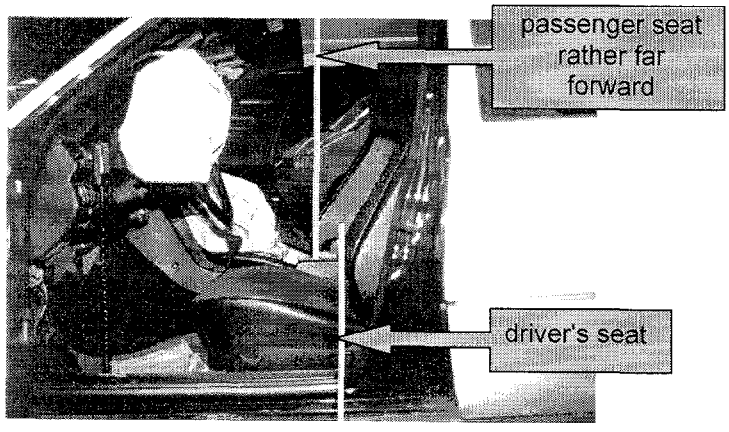
EES = 30 km/h

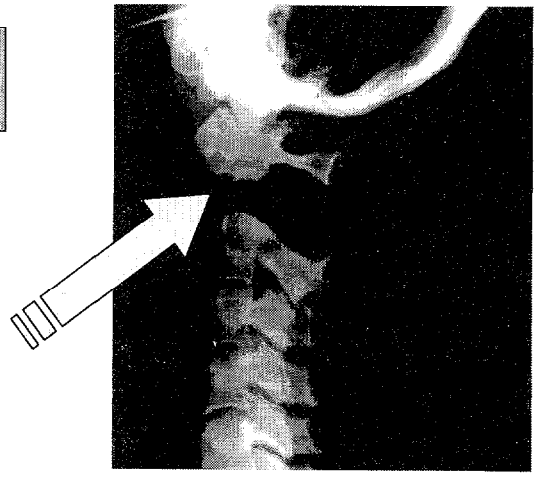
Injuries to the not belted driver:

- contusion to the left knee **AIS 1**

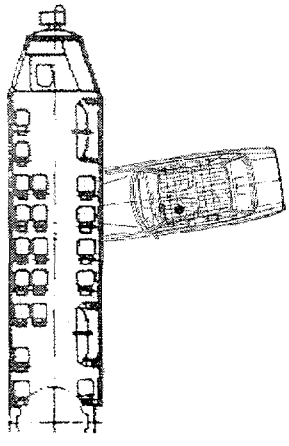
Injuries to the female, belted passenger:

- hyperextension trauma with fracture of the cervical spine between the 1st and 2nd cervical vertebrae **AIS 6**





Accident opponent: streetcar



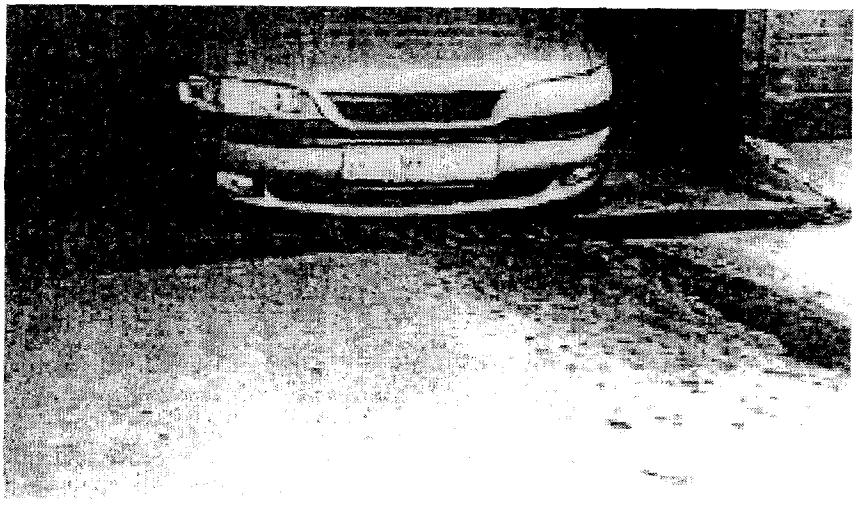
„Airbag Material"
Case No.: 14

Airbag vehicle: Mazda 323
driver and passenger airbags activated

injuries to the belted driver:
- facial contusions **AIS 1**

injuries to the female, belted passenger:
- facial contusions **AIS 1**

Accident opponent: exit ramp of a parking garage

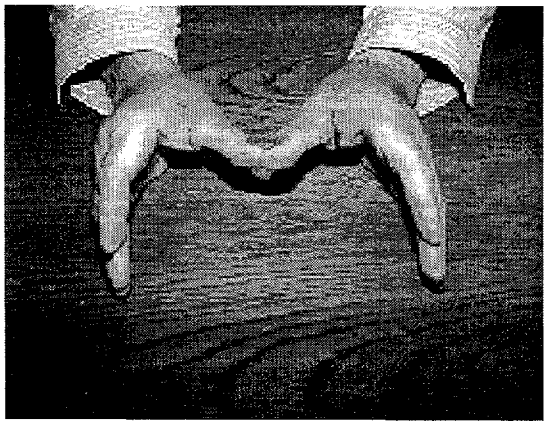


Appendix 4

„Airbag Material"
Case No.: 15

Airbag vehicle: Vw Golf III
driver and passenger airbags activated

EES = 10 km/h



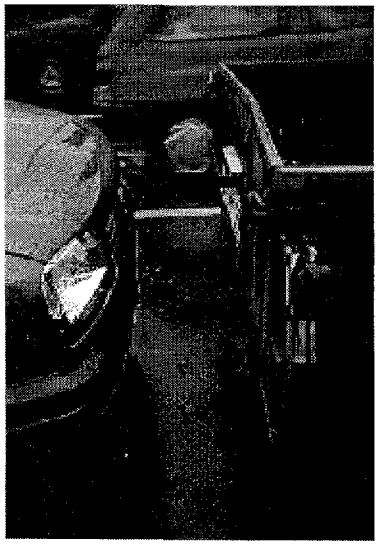
Injuries to the female, belted driver:

- no injuries

Injuries to the belted passenger:

Deep lacerations between the thumb and index finger of both hands with injury to the muscle tissue and subluxation of the saddle joint of the thumb **AIS 2**

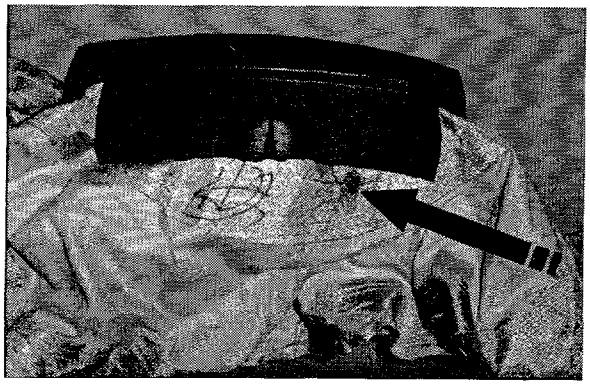
Accident opponent: frontal collision with a trailer



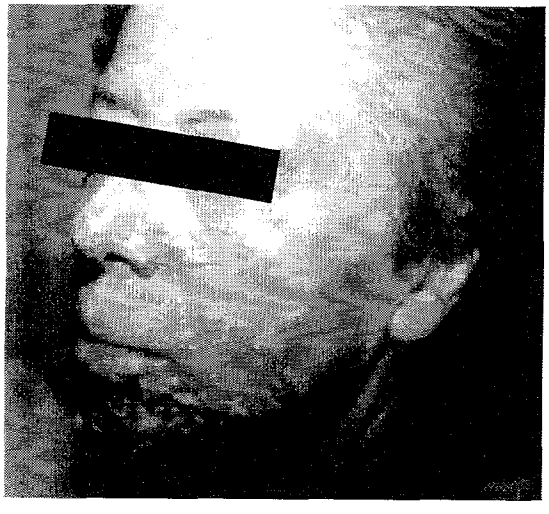
Appendix 5

„Airbag Material"
Case No.: 21

Airbag vehicle: MB 200 E
driver and passenger airbags activated



the damaged site in the driver airbag



Injuries to the female, belted driver:

- 2nd degree chemical burns to the face **AIS 1**
- contusions on the thorax **AIS 1**
- contusions on the left arm **AIS 1**

Accident opponent: collision with a post

Appendix 6

„Airbag Material“
Case No.: 8

Airbag vehicle: VW Golf
driver airbag activated, passenger airbag not activated

Injuries to the female, belted driver:

minor injuries
(without further details) **AIS 1**

Injuries to the belted passenger:

- facial lacerations **AIS 1**
- cerebral concussion **AIS 2**

Accident opponent: collision with a tree

Appendix 7

„Airbag Material"
Case No.: 6

Airbag vehicle: AUDI 80
driver airbag activated, no passenger airbag installed

injuries to the driver:

- contusions on the right arm **AIS 1**
- contusions on the right thorax **AIS 1**

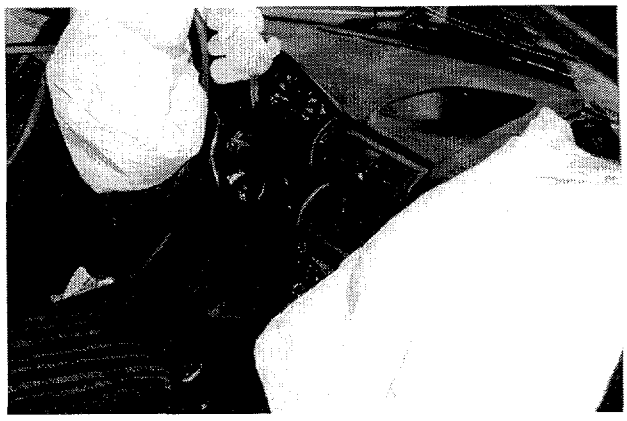
Accident opponent: no collision

The driver airbag activated when the driver was getting out of the car (ignition key had already been removed from the lock)

Appendix 8

„Airbag Material“
Case No.: 13

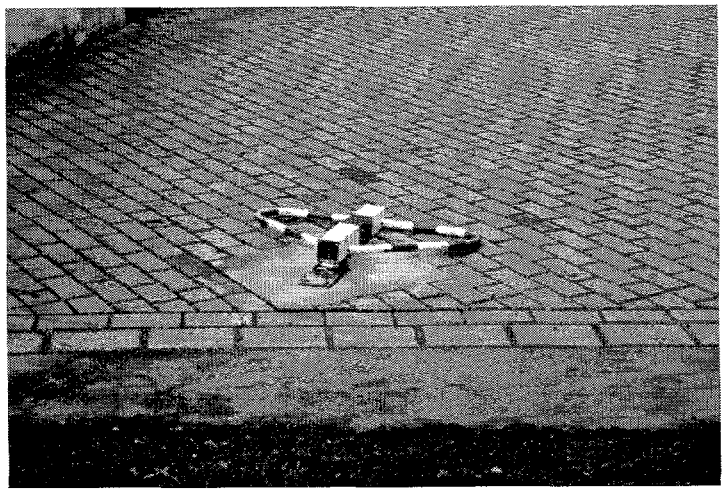
Airbag vehicle: Opel Astra
driver and passenger airbags activated



Injuries to the passengers:

No injuries

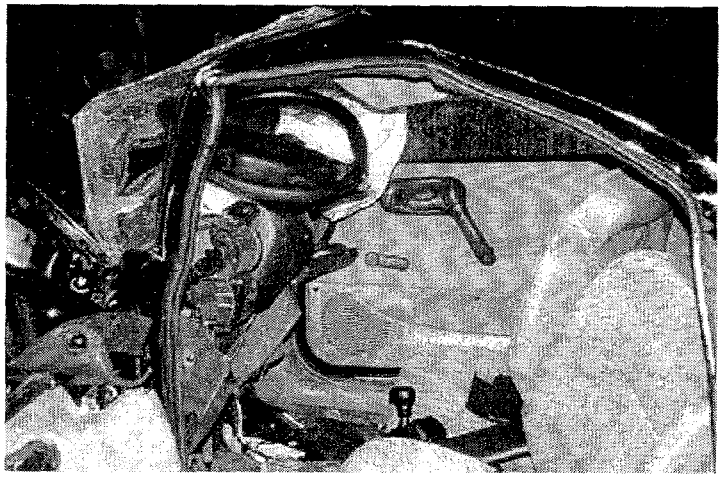
Accident opponent: floor contact with a barrier post

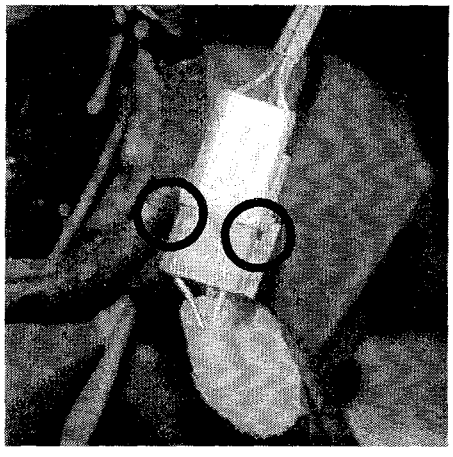


Appendix 9

„Airbag Material"
No Case No.

Airbag vehicle: Opel Corsa
passenger airbag activated, driver airbag not activated





Injuries to the female, not belted driver:

- fatal injuries (not further specified)

Injuries to the female, not belted passenger:

- serious injuries (not further specified)

Injuries to the not belted back-seat passenger:

- serious injuries (not further specified)

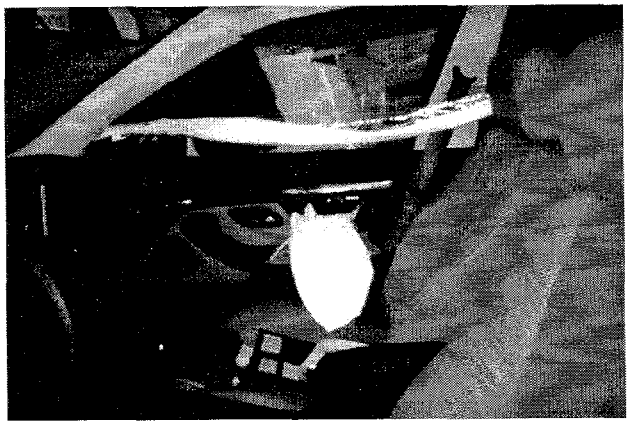
Accident opponent: Renault Megane

Source: „ ams" Nov. 1997 [11]

Appendix 10

„Airbag Material“
Case No.: 41

Airbag vehicle: BMW 540i
ITS and thorax airbags activated



Injuries to the belted driver:

No injuries

Injuries to the female, belted passenger

- contusions on the right arm **AIS 1**

Accident opponent: collision with a tree

Airbag Material - Distribution of the Driver's MAIS as a Function of the Degree of Damage

Driver Airbag Deployed, Frontal Impact, Driver Belted								
Degree of Damage	MAIS							Total
	0	1	2	3	4	5	6	
DD 1 - light								
DD 2 - moderate	35%	53%	12%					100% = 34
DD 3 - severe	13%	67%	20%					100% = 64
DD 4 - extreme	8%	24%	44%	12%	12%			100% = 25
DD 5 - total			50%				50%	100% =2

VS 90 - Distribution of the Driver's MAIS as a Function of the Degree of Damage [2]

VS 90 Frontal Impact, Driver Belted								
Degree of Damage	MAIS							Total
	0	1	2	3	4	5	6	
DD 1 - light	52%	47%	1%					100% = 394
DD 2 - moderate	34%	63%	3%	0.2%				100% = 2,178
DD 3 - severe	12%	68%	16%	3%	0.7%	0.1%	0.3%	100% = 1,402
DD 4 - extreme	1%	28%	33%	20%	9%	3%	6%	100% = 391
DD 5 - total		4%	13%	9%	20%	7%	47%	100% = 54