DESIGN METHODS FOR ADJUSTING THE SIDE AIRBAG SENSOR AND THE CAR BODY

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ABSTRACT

Now that side airbags are used to protect chest and head of the occupants, reliable detection of side impacts is of great importance. Compared to frontal collisions of the same impact speed, side collisions take only the third of time. Thus detection of a side impact at 50 km/h has to be done in less than 5 ms after the first contact. This challenging task cannot be achieved with a single crash sensor in the middle of the car, as used for the ignition of frontal airbags, but requires specialized sensors for the side impact detection.

At present two different principles of sensors are ready for production: devices that measure deformations and devices that use accelerations. Volkswagen utilizes acceleration-based sensors because they are less sensitive in regard to the impact points. However, placing this type of sensors is an extremely critical task. The pros and cons of some typical mounting locations like doors, sills or cross members are discussed in this paper. Also discussed are methods for optimizing the car in order to shorten the sensing time. They include the analysis of the transmissibility of shocks by experimental methods and the numerical calculation by FEM.

The airbag controlling computer processes the accelerations measured by the sensor and decides whether the airbag should be employed. The evaluation algorithm has to be designed for a specific car body. Not only the behavior of the car body in case of violent side collisions has to be taken into account, but unintended firing in case of light traffic accidents or abnormal driving conditions also has to be prevented.

By employing acceleration based side impact sensors a secure ignition of side airbags is possible. However, an adjustment by modifying merely the software of the controller does not lead to acceptable results. A good performance of the side impact protection system requires an adjustment of all components involved, i.e. the car body, the hardware of the sensor / controller and the software algorithm.

INTRODUCTION

After having greatly improved the safety for passengers in frontal collisions, due in no small part to the wide use of airbags, one of the current major development areas is improving passenger safety in side collisions. Here again airbags look like a very promising means to reduce the risk of injury.

An airbag's effectiveness depends to a great extent upon the timing of its ignition. The earlier the ignition of the airbag after the collision, the greater the advantages of the airbag's restraint. Compared to frontal collisions, side collisions require a much faster airbag reaction time. In a typical frontal collision at 50 km/h against a wall the first contact between the driver and airbag is 50 ms after the start of the crash. The inflation of the airbag requires approximately 25 ms. This means that the gas generator must be ignited approximately 10 ms to 30 ms after the crash has begun.

In the case of a side collision at 50 km/h, as defined in the EEVC statutes, the door typically already reaches the passengers after 20 ms. Due to the smaller volume of the side airbag, in comparison to a front airbag, the inflation time takes 10 ms. In order that the side airbag can still come between the door and the passenger, the gas generator must be ignited after only 5 ms after the crash begins, figure 1.

Despite the very short time allowed for the detection of the impact, unintended firing in the case of light traffic accidents or abnormal driving conditions must be avoided. The use of a common crash sensor placed in the middle of the car, as used for front airbags, is not sufficient. The development of a faster and more reliable side collision sensor is therefore of prime importance.

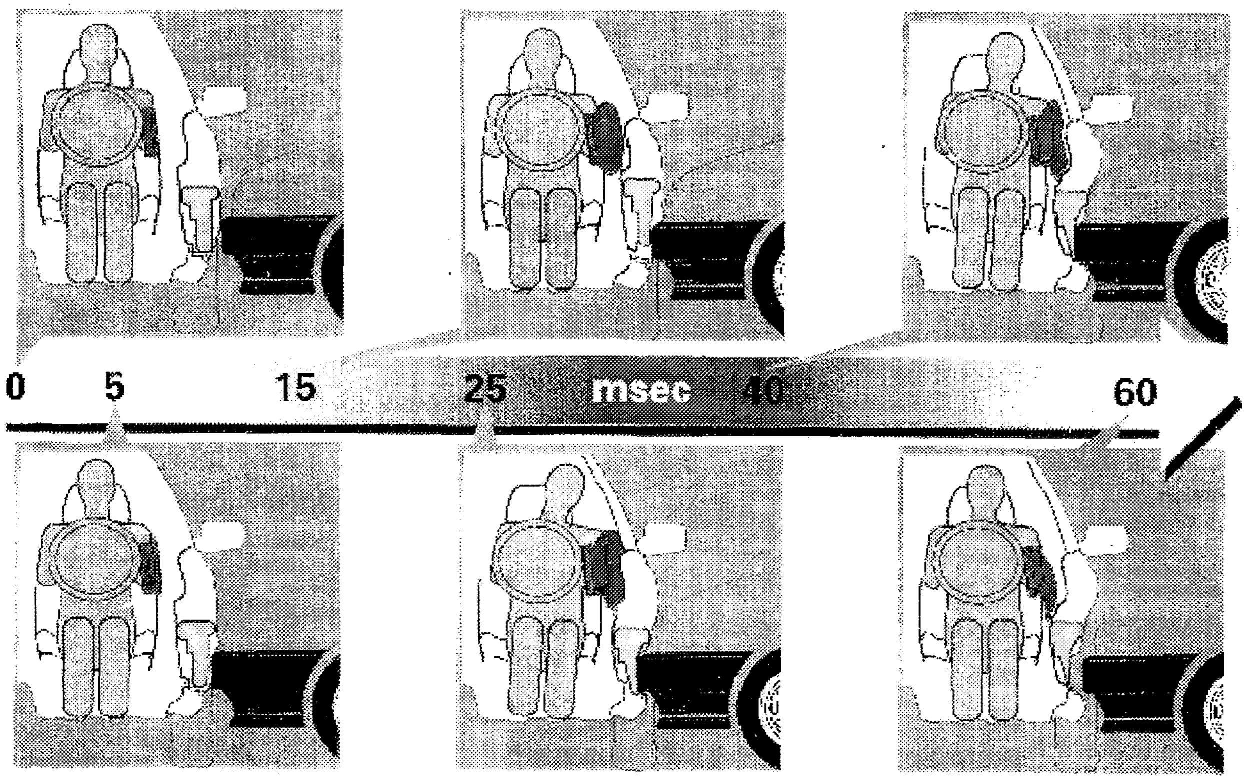

Figure 1. Typical Timing Diagram of a Side Airbag.

PRINCIPLES OF SENSORS

In recognizing a side collision different physical effects can be used. The current side airbag sensors are either deformation or acceleration oriented. Both methods have their advantages and disadvantages. Improvement of the protection offered through airbags is expected in the future through the development of pre-crash sensors, which are to send a crash signal before the actual contact.

Deformation Oriented Systems

A statistical analysis of side collisions has shown those most severe injuries with an injury degree of AIS$\geq$ 3 are chest injuries [1]. This same analysis also categorizes passenger injuries by the type of collision. In the majority of cases the door of the crashed car was hit. A Thorax airbag that is ignited when the door is hugely deformed can in many cases protect the passengers from severe injuries.

The crash is recognized by a simple switch that closes when the car body is deformed beyond a certain degree [2]. This system allows for a very fast recognition of severe accidents. However, due to the crash contacts digital character it is ineffective in the case of moderate accidents, in which a side airbag could already provide protection.

An alternative procedure is based on measuring the difference in volume of the hit door in a side collision [3,4]. In comparison to the switch this system has the advantage that it not only takes into account the absolute degree of the deformation, but also the speed of the deformation in determining the degree of the accident. Due to the analog character of the system moderate accidents can also be recognized.

All of the deformation-based methods have the disadvantage that they heavily depend on the location of the collision. This system can not recognize a severe accident with a collision location in front of or behind the door.

Acceleration Oriented Systems

Just as for frontal crash sensors, these systems are based on measuring the acceleration of the vehicle. The mounting location is of critical importance for a quick employment of the airbag. A mounting location in the middle of the car, as is usually the case for frontal crash recognition, is not sufficient for recognizing a side collision due to the great distance to the collision zone.

This can be improved by using additional acceleration measurement locations near the sill. In comparison to deformation oriented sensors, acceleration oriented sensors can also recognize a collision in the area of the trunk or motor. In addition light traffic accidents and severe deformations, which do not pose a danger to the passengers, can be better recognized.

Pre-Crash Sensors

Pre-crash sensors are still in the development stage [5,6]. Such sensors constantly observe the immediate area surrounding the vehicle and send a signal to the airbag control unit prior to a collision. For this purpose sensors based on infrared, laser or radar are being examined.

The largest problem with all of these methods is guaranteeing a sufficiently high enough reliability for actual accidents. It is not sufficient to simply recognize a possible collision, but also the type of the collision partner has to be detected early enough. For example, the ignition of an airbag when a cat jumps onto the vehicle is unacceptable. In addition such things as fog or radar rays may not influence the crash sensor.

POSITIONING OF ACCELERATION SENSORS

Due to the advantages described above Volkswagen makes use of the acceleration-based system for its side airbags. Various locations can be used for the positioning of the sensors:

On the Tunnel

This location is often used for the detection of frontal collisions. A side collision, however, results in a relatively late signal, and weak amplitude. Therefore, this position is not advisable for the recognition of a side crash. However, the acceleration measured from this position can be used as an additional criterion in judging how severe the collision is (safing function).

In the Door

In this position an early strong signal is sent. However, this area experiences great deformations in a side crash. This can result in the acceleration sensor being turned in the course of the crash, so that a directional placing of the measured accelerations is no longer possible. In addition a sensor placed in the deformation zone has a high risk of being destroyed. Therefore, this position also does not appear to be advantageous.

On a Seat Cross Member

The ideal position for an acceleration sensor is as close as possible to the place of the collision, without being within the deformation zone. In Volkswagen vehicles there is a massive seat cross member underneath the front seats, figure 2. This secures the survival space of the passengers, and at the same time serves as a mounting location for the acceleration sensor.

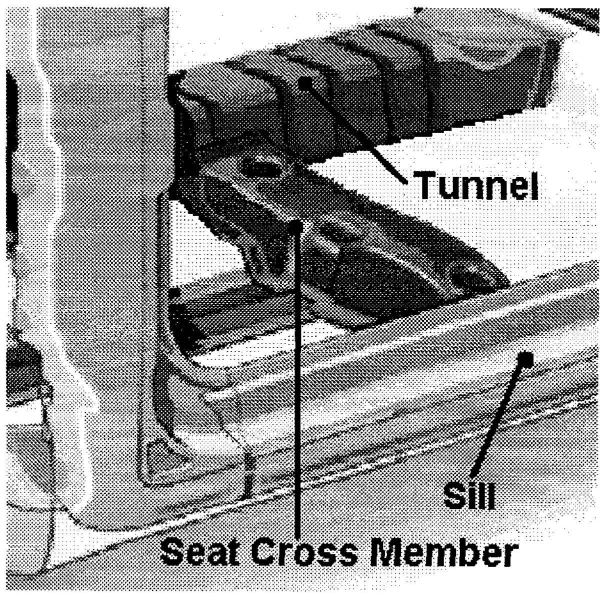

Figure 2. Seat Cross Member.

In the case of a side collision in the area of the trunk or hood the absolute time for the detection of the crash is longer than for a collision with the door. However, the time available for inflating the airbag is also significantly greater due to the lower level of deformation and the slower progress in the front seat area [1]. Therefore, even in these cases the side airbag can reach its full protective effect.

OPTIMIZATION OF THE CAR BODY

For frontal crash controllers, usually the adjustment to the car body is done by modifying the software. The more precise timing requirements of side airbags can only be fulfilled by taking into account the impulse transfer in the construction phase of the car body.

General Construction Principles

A hard and stiff structure is best for the impulse transfer. Therefore, VW has chosen to make the cross section of the seat cross member in the area between the collision zone and the sensor as large as possible, and the connection to the sill inflexible.

Close attention should be paid to the construction of beads in the floor pan. Beads should never cut the direction of the impulse in the impulse transfer area, since otherwise the impulse waves will be weakened or redirected. However, these requirements can contradict the requirements of the frontal crash. In such a case the locating of the sensor and the construction of the beads should be so aligned that longitudinal beads do not cross between the sill and the sensor.

During the critical phase of the crash for the passengers, the crash opponents' acceleration is only reduced minimally. At a collision speed of 50 km/h the crash opponent enters a vehicle hit in a side collision at a rate of 15 mm/ms. An air gap of 15 mm between the body parts carrying the impulse thereby causes a delay of the transfer of the signal by 1 ms! Therefore, a collision should, if possible, not take place on metal membranes such as side parts or outer door metal, but instead on parts supported by members. A car production with small range of tolerance, i.e. with narrow gap measurements between the door and sill, contributes to a fast airbag ignition.

FEM Simulation Calculations

With the help of numerical FEM simulations it is possible to determine how the vehicle will react in a side collision at a very early stage in the vehicle's development, figure 3. Calculating the acceleration impulses at various mounting locations can make a rough positioning of the acceleration sensors. The simulation calculations also supply information on the path of the signal transfer for a particular mounting location.

However, the signal transfer is influenced by many factors that are difficult to simulate numerically, such as the reaction of welding points. Therefore, the FEM calculations can only be used to compare evaluations. Today, an exact calculation of the ignition time isn't possible through computer simulations only.

Experimental Sensitivity Analysis

The sensitivity analysis is a good experimental method for optimization in detail. The body in white is hit with an instrumented hammer, picture 4. The acceleration is measured at the relevant points on the body in white and is compared with the acceleration of the

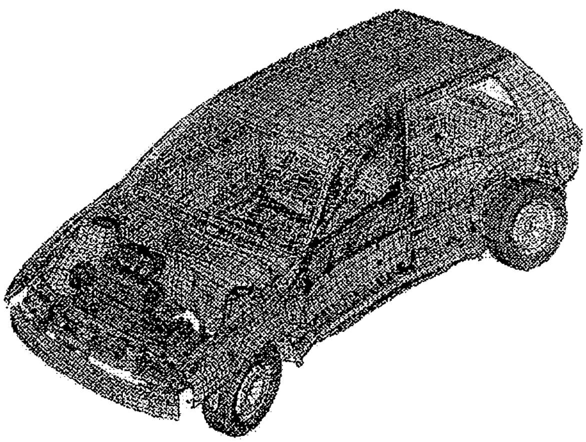

Figure 3. FEM Side Impact Simulation.

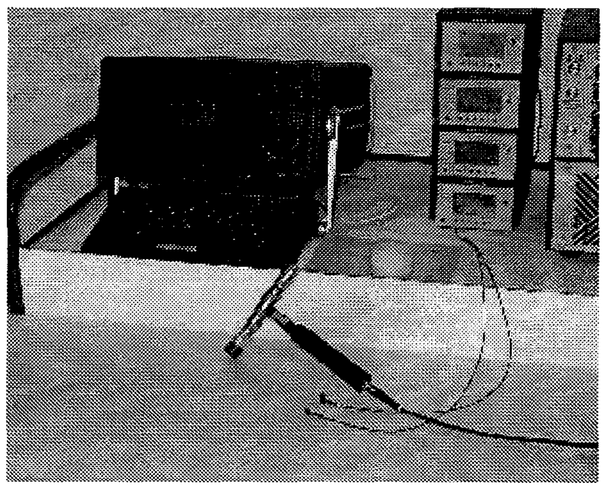

Figure 4. Instrumented Hammer.

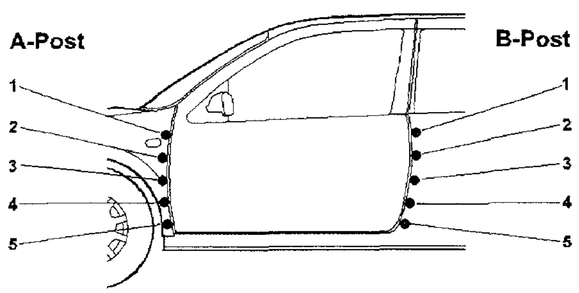

Figure 5. Sensitivity Analysis: Points under Test.

hammer. Through this procedure the most suitable location for mounting the crash sensor can be determined.

The vehicle body itself can also be improved with the help of this method. Transfer functions for various points on the A and B columns are determined, figures 5 and 6. For this particular type of vehicle the height for the best signal transfer is at point 4. In order to transfer the acceleration impulses as quickly as possible from the columns to the sensor the door beam should be at this height.

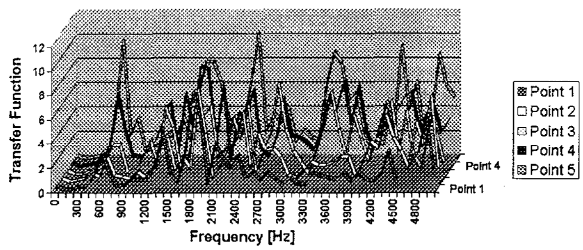

Figure 6. Sensitivity of the A-Post.

INFLUENCE OF THE CONTROLLER

The 5 ms available to ignite the airbag is so minimal that the amount of time needed by the controlling computer to process the measurements can not be ignored. Already the initiator of the processing chain, the A/D-converter, causes a delay lying in the range of a tenth of a ms.

Also the transferal of information between the satellite sensors on the seat cross member and the sensors mounted on the main body require a similar amount of time. A faster communicationsprotocol would result in greater sensitivity to electro-magnetic rays. An increase in speed is difficult to achieve since an unintended firing can in no case be accepted.

A field for optimization is not only offered by the controller's hardware. The evaluation algorithm itself exercises great influence over the speed of the ignition. Problems occur in differentiating between light and violent accidents. A criterion based solely on the level of acceleration that ignites the airbag after a certain value has been exceeded results in a fast ignition, but also ignites in the case of light accidents.

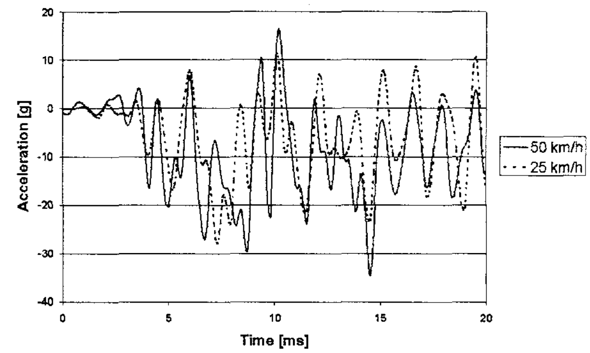

Figure 7. 50 km/h and 25 km/h Crash Tests.

In figure 7 the time history of acceleration of a 50 km/h European side crash is compared with a 25 km/h crash test. It is easy to see that the maximums in acceleration for both tests are at the same level. There is only a minor influence of the crash speed, since the contact force between both parties of the accident during the first phase of the collision is determined primarily by the stiffness of the bodies in white.

As a result the peak value of the vehicle acceleration is also only slightly dependent on the speed of the collision. A greater speed is mostly noticeable in the duration of the deceleration, not in its value. Therefore, a processing of the maximum value is only suitable as a "safing function", i.e. as a secondary criteria to avoid unintended firing.

In order to avoid an unintended ignition with some certainty an evaluation algorithm must use the course of the acceleration over a long time period. This of course negatively influences the ignition time. Therefore, an algorithm that classifies the level of the accident over as short a period of time as possible offers considerable advantages in speed.

CONCLUSION

The prompt ignition of a side airbag poses a challenging task for all involved components. A lot of development time must be placed in making the components for the vehicle body, sensors, controlling hardware and last, but not least the controlling software. By employing a well-tuned acceleration oriented sensor system passengers can also be given the full protection potential of an airbag in a side collision.

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