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Simulation stand for the development of the eCall device

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ABSTRACT

Article describes research stand that recreates voltage signal that corresponds with acceleration signal in real collision and transmits it to the input of collision detection module in mass produced airbag controller. This research stand was prepared in the scope of research and development project „Research on methodology of eCall automatic notification system of road accident". This research stand makes possible to recreate signals with differential amplitude and gradient registered during collision of real vehicles, in which airbags were running or not. There were also conducted studies on road accident detection algorithm, which was implemented in mass produced controllers for airbags of Volkswagen's group cars. Appropriate software enabled possibility to restore default state of airbag from the beginning of simulation. This paper presents results of project's studies.

KEYWORDS: eCall, safety, car accidents, emergency system, 112

1. Introduction

Correct detection of collision, which will require intervention of emergency service, is very important from the viewpoint of properly working eCall system. With about 366 thousands of road collision (about 40 thousand accidents) in 2011, which were placed only in Poland, would give us huge number of notifications, which would be sent to Public Rescue Answering Point. Assuming that only every fourth collision will require intervention, emergency service will be notified approximately every 6 minutes of all day and night, during all year.

Since 2014, in eCall system autonomously device will be used, which will be installed on every new vehicle. It will be composed of accident detection module and transmission module, corresponding for connection with Public Rescue Answering Point. Device will sent short report called MSD (Minimal Set of Data) and establish voice connection between vehicle and duty operator in Point.

Due to safety, vehicle manufacturer did not allowed to use accident data from car systems by eCall on-board devices. Substantiation of a decision was possibility to disturb of theirs work. Producers of eCall devices will be forced to develop independent accident detection modules. This part will be responsible for detecting of accidents and releasing alarm (calling emergency service as a result) in needed cases. Problems related to road accident detection and defining value of acceleration, on which alarm should be released are the most difficult thing in this research [3].

Time of car collision is very short, about 150-200 ms, while temporary accelerations peak, for crash speed – 50 km/h, reach 30 g (where g stands for gravity) (fig. 1).

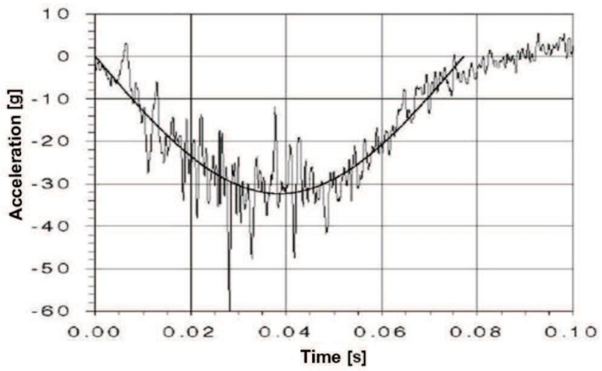


Fig. 1. Temporary acceleration value chart for Hyundai Excel for speed 48 km/h [2]

Half-sinusoid is most common type of acceleration model in road accident

$$P = \Delta V \cdot \frac{\pi}{2} \cdot T$$

Figure 2 presents approximation of acceleration value for two exemplary cars – Ford E150 i Hyundai Excel.

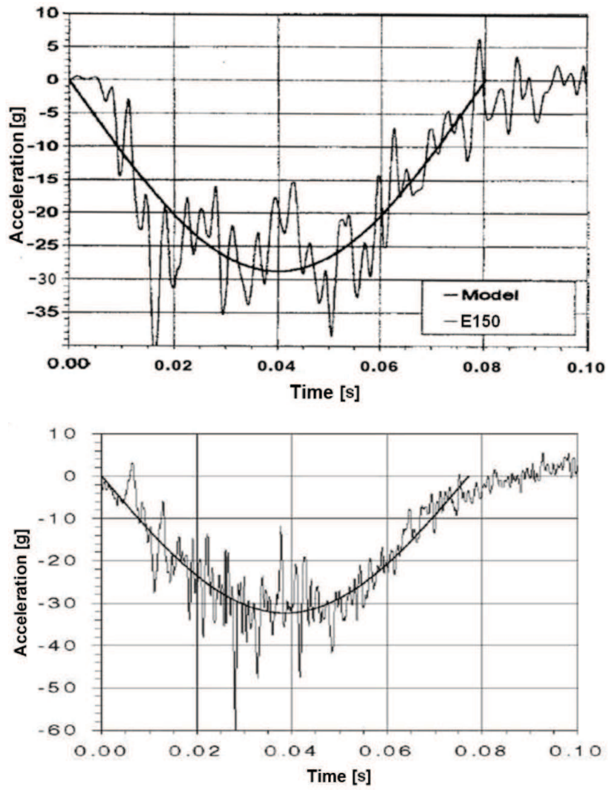


Fig. 2. Real waveform and approximating value curve of car acceleration for Ford E150 i Hyundai Excel [2]

In accordance with data, published by Wolf and Bratton [1] average crash speed in USA is equal to 35,42 km/h, while average crash speed of accident according to official date in Great Britain is equal to 35-42 km/h [5]. Modern cars, are being equipped in more advanced passive and active safety systems. One of them is airbag system, turned on during accidents. At present, having 4, even 6 airbags is standard, for middle class cars while in segment C cars 8-10 airbags are installed in serial production. Airbags are deployed in condition which are analyzed with high speed by airbag controllers. Some car models are using a single controller that is common for all airbags, but some car manufacturers implement additional controllers in every car door, eg. Citroen brand. In such situation every controller works individually, running side airbags. Decision process of airbag run is split into two steps, i.e. at first „Wakeup" command is executed, and then airbag is released or not[4]. „Wakeup" command („Enable") is activated when car acceleration fits in range -1 g to -2 g.

2. Testing airbags controllers

The project developed two research stands. The stand of the test airbag controllers developed in scope of the R & D project "Development of a methodology to evaluate a system of automatic notification of road accidents eCall" is used to reproduce the voltage signal on the course of characteristic of accelertion during collision of the vehicle. Such a signal with a suitable scaling can be sent on the input of collision detection module serial produced airbags controllers, replacing the signal from the accelerometers of controller. Display of consecutive voltage signals recorded during the actual collision, which occurred or not occurred launching airbags, permit the determination of the mode of action implemented in the controller algorithm.

In case of accident detection algorithm value of the vehicle speed change ΔV in the time interval At is evaluated and the limit is determined by the scale of AIS [3]. Developed under the project research stand is equipped with a DACs card to generate a voltage signal sent to the input of collision detection module standard produced airbag controllers. Appropriate software runs under MS Windows can restore the driver to pre-bag launch pads, and also the controller can be programmed. An analysis of the possible use of mass-produced airbags controllers shows that producers provide the single usage of them. When repairing the vehicle in which there was a run airbag, controller should be replaced with a new one. However the one of the few controllers was selected, for which it is possible to program the controller to restore the conditions before the accident. 6Q0909601 driver manufactured by Volkswagen is part of the research stand for inducting the acceleration (Fig. 3)

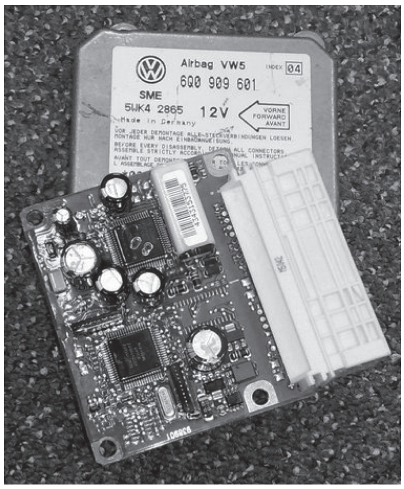


Fig. 3. 6Q0909601 airbag controller manufactured by Volkswagen

Photos of the research stands are shown in Figure 4 and Figure 5. The simulator is controlled from the PC using the software eCallControl. The data are reproduced with the Secure Digital card. The simulator supply voltage is equal to 12V. The data are reproduced with a frequency of 15 kHz, with a maximum number of 42 000 samples. It is possible to obtain the output voltage in the range 0-5V.

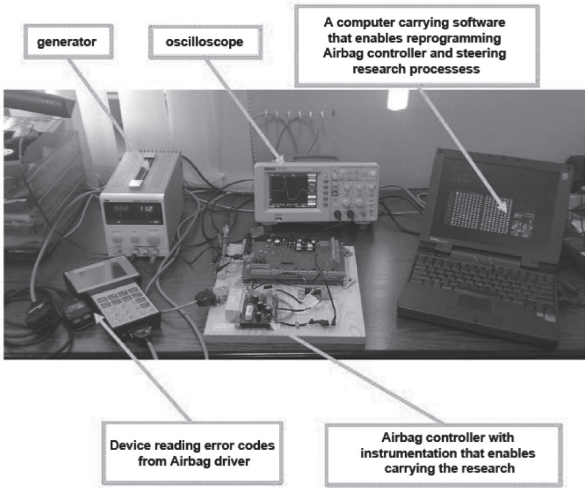


Fig. 4. General view on the research stand to dispaly characteristic of acceleration

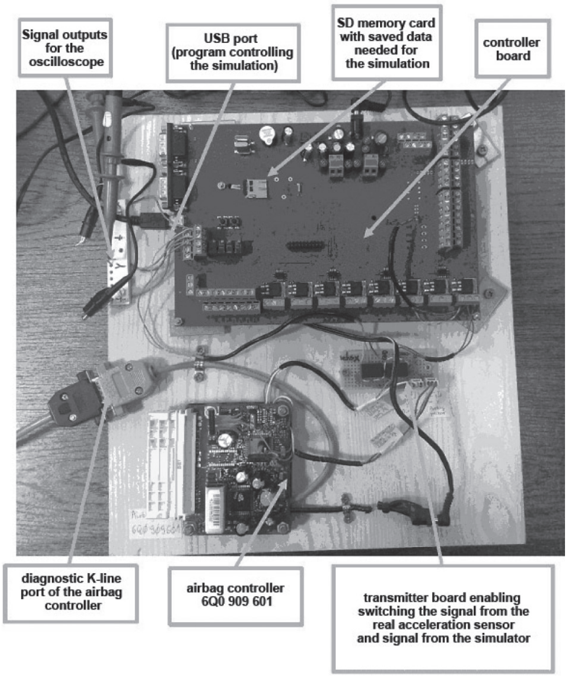
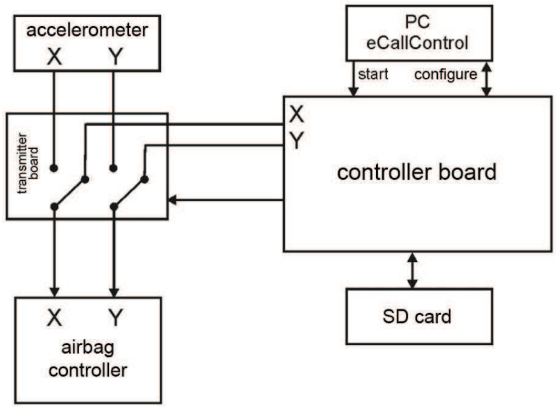


Fig. 5. Elements of the stand to display characteristic of acceleration

The signal voltage sent to the analog processor input and the airbag accelerometer signal are switched by the relay.

The element of stand is a computer with instaled software as eCallControl, eCallConvert and software to erase the fault memory of airbag controller.

On the stand there was used a device allowing to make a connection to the airbag controller with diagnostic line K-line. With its help it is possible to read the fault memory in order to check if the controller registered the occurrence of the accident and ran airbags and belt tensioners.To observe a waveform generated by the simulator it was used a digital oscilloscope. The components of the simulation stand are powered with 12 V. Schematic is shown in figure 6.



Rys. 6. Block diagram of the simulation stand

eCallControl program runs on a PC give possibility to send control commands and configuration commands. These commands are sent to the control board which is responsible for conducting the simulation process, putting the required values of analog outputs.

To build research stands for the eCall device in a high acceleration conditions components from industrial automation was used, such as rails and steel slider. General view of the stand is shown in Figure 7. Bars were mounted parallel to each other in a vertical plane, on a wooden base. The slider is placed with the equipment on these bars, in such way as to minimize friction between the slider and the bars and allow the quasi-free fall.

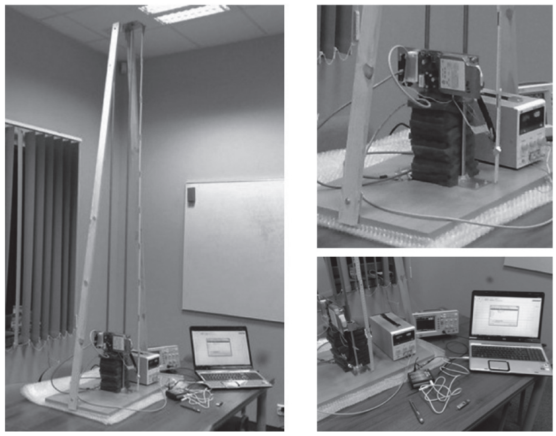


Fig. 7. General view on the eCall stand

The whole structure has been reinforced on both sides with using of wooden slats. Rods are marked with height indicators, for which calculated the expected slider speed in the moment of collision with deformable barrier. Accelerometer ADXL 150 and a driver airbag 6Q0909601, installed in serial vehicles of the Volkswagen group (for example, VW Golf, VW Polo, Seat Leon), were placed on the slider.

Due to the lack of legislative guidelines for the collision detection algorithm of the eCall device, the project assumes that the device should call the help of a collision where the airbags would be activated. This situation is not unequivocal with the arrival of emergency services to the place of collision, because after sending the MSD message, connection between vehicle and Public Service Answering Point (CPR) is compiled, so that in many cases, participants of the events can estimate the scale of the incident by themeselves and send this information to CPR, where the final decision on the possible involvement of emergency services and the scale of the aid is taken.

The developed stand has enabled a series of measurements, which results in aquisitions of data about the conditions in which mass-produced controler activates the airbags. For this purpose, based on the analysis of literature a method of measurement transformation has been developed and a series of experiments has been carried out, each time returning controller to the position before the experiment. These data were then used in the development of electronic collision detection module of eCall device and collision detection algorithm that was implemented in this device. The next stage of work was a preliminary verification of operation of the module, which was conducted by comparing its effects to the effects of serially produced 6Q0909601 airbag controller by Volkswagen.

3. Development of the eCall device simulator

eCall device simulator was built using a prototype device developed by the task 2, consisted of two cooperating elements, representing a total on-board eCall device:

- collision detection module,
- teletransmission module cooperating with GPS receiver to determine the geographical position of the vehicle.

Collision detection module is shown in Figure 8.

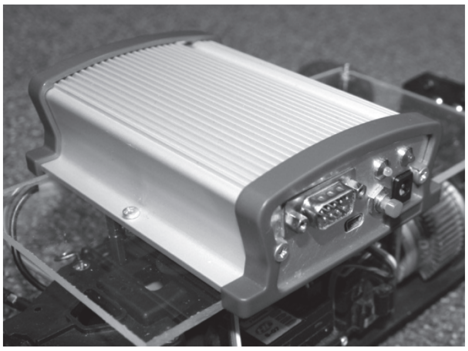


Fig. 8. Collision detection module of eCall device

The module built is based on an accelerometer ADXL 150, data processing module with a possibility of recording data in built-in memory module, I / O module and power module. In the collision detection module a data processing algorithm for measurement and collision detection algorithm were implemented. The signal from the accelerometer in the form of voltage signal required processing to digital form via the integrated 14-bit analog-digital converter. The sensor was calibrated by determining the process output value corresponding to fixed values of acceleration, which the sensor was subjected. Measurement data from the sensor was subjected to digital filtering to get rid of unwanted interference. For this purpose Kalman filter was used. The results of this process is shown in Figure 5. On the basis of data the value ΔV as the integral of acceleration (using rectangles) for the duration of the collision was calculated. For the beginning of a potential collision define the moment when the acceleration value was greater than 1.5 g. Calculation ΔV ended when the overload due to gravity decreased to 0.1 g. Detailed description of how to calculate this value are shown below.

The duration of a collision, in most cases does not exceed 150 ms. Based on data from the sensor (or sensors) of accelerate the controller decides to run or not run the air bag. This process must be done very quickly, using a relatively small number of samples of the acceleration, and it takes account of the structural characteristics of the vehicle. Weight, stiffness of the vehicle and the position of sensor / sensors are some elements that are taken into account when developing algorithms for triggering the airbag. In most cases, the driver should run airbag in 15 ms to 50 ms after the start of a collision. Therefore, in the analysis of the signal from the accelerometer, pace of accelerate change in the first phase of the collision is included.

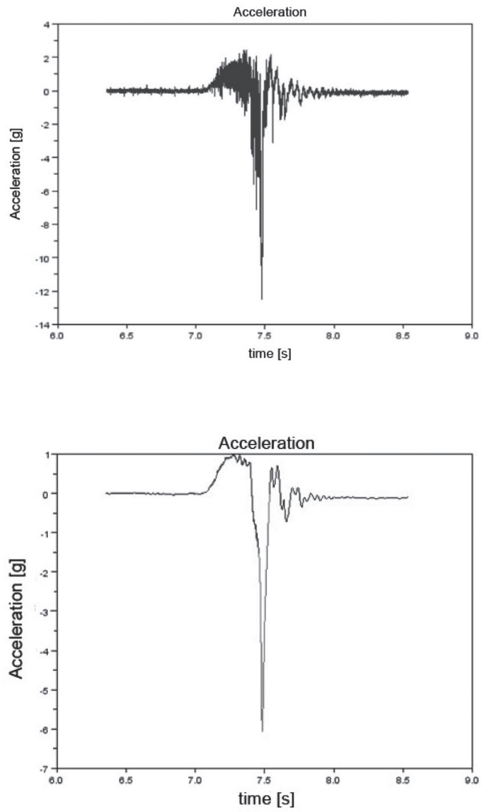


Fig. 9. The results of filtering the signal from the accelerometer by using the Kalman filter

In order to develop an algorithm implemented in a collision detection module two test stands were used. The mass-produced controller instructions by Volkswagen and recorded acceleration measurements during the actual collision of vehicles were taken into account . The result of research is the detection algorithm, which starts the analysis of collisions when the value of deceleration exceeds 1.5 g. Then the following parameters are calcuated:

- the time in which the deceleration value changed from 1.5 g to 2 g,
- the time in which the deceleration value changed from 1.5 g to 3 g,
- a change of speed (ΔV) during 15 ms after the achievement of value for the deceleration of 1.5 g,
- a change in speed (ΔV) calculated for 50 ms after the deceleration value of 1.5 g is reached,
- maximum acceleration obtained during the period to 50 ms after the achievement of the deceleration of 1.5 g, and time after which this acceleration is obtained (starting from when the deceleration of 1.5 g is reached).

Based on these values, a decision whether to launch an air bag or not is taken. Example of acceleration characterisic during the real collision is shown in Figure 10. The green (upper) line was drawn on the basis of data recived from the calculations of the value ΔV - by 50 ms from the reaching value for deceleation of 1.5 g.

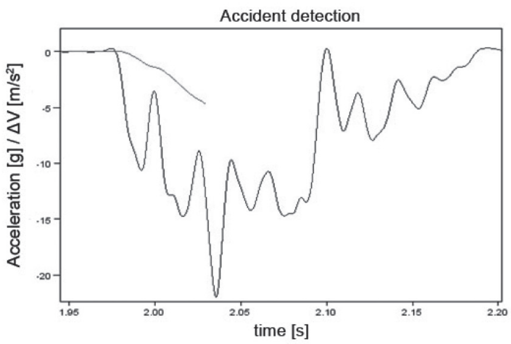


Fig. 10. Example characteristic of acceleration during the real collision

4. Results

During the study the signals of varying amplitude and gradient were used. They were voltage signals recorded during the actual collision of vehicles in which there was or was not an action of run airbags. Therefore, the studies of efficiency of the detection collision algorithm implemented in a production controller was taken.

On the basis of recorded data a chart presented in Figure 11 was prepared. Round markers on the graph are showing the points for which the airbag was run, and square marks are showing the points for which the airbag was not run. Each point is represented by two values – the parameter ΔV and time t. These points belong to two series. In the case of series A there was running of airbag, and in the case of series B airbag was not running. The data analysis shows that collision detection algorithm in addition to the parameter ΔV value also takes into account the duration of the collision, because even at the value of ΔV = 3.45 m/s recorded at the time 0.08 s airbag is triggered, and for the duration of an event equal to 0,14s, ΔV value equal to 3.4 m/s is not enough to run airbag.

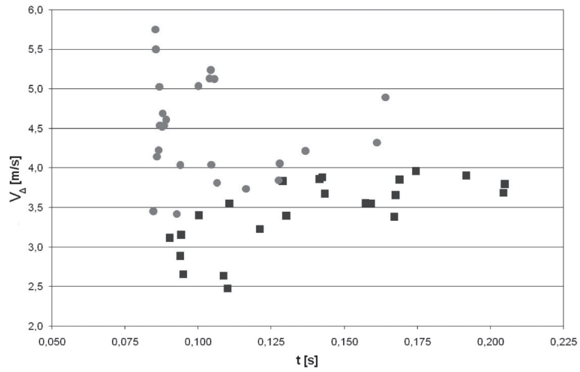


Fig. 11. Chart prepared on the basis of simulations using the airbag controller

5. Conclusion

Implementation a series of vehicle collisions to investigate the collision detection algorithm is very expensive, so an alternative solution was used and it consist of replacing the signal from the airbag accelerometer controller with the signal displayed on the basis of data recorded during the real collision. Such a signal with a properly scaling was transmitted to the collision detection module input serial produced airbags controller. Displaying consecutive voltage signals recorded during the real collision, which occurred or not occurred witch launching airbags, allowed to determine the mode of action for implemented in the controller algorithm. In this way a graph showing functioning of the algorithm, which takes into account the ΔV value, was obtained. This value depends on the duration of the action, and for a shorter time of the action, the less value of ΔV is required to run airbag. Based on this researches the possibility to propose a collision detection algorithm for the eCall device will be able.

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