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VERIFICATION OF THE CONDITIONS FOR WHIPLASH-TYPE INJURIES WITH THE SDC METHOD USING THE SRS-AIRBAG SYSTEM ACTIVATION PARAMETERS

Summary. A problem of car insurance frauds usually refers to reporting non-existent car crash circumstances to acquire the funds required for a car repair. However, the problem is not limited only to this kind of costs. Recently, numerous damage claims connected with spine trauma caused by rear-end collisions have been reported. These are the so-called whiplash injuries caused by a rear impact. Such damage is difficult to verify and hence a necessity to use more effective claim verification methods. An analysis of a collision in the SDC convention makes it possible to determine whether its circumstances were consistent with the reports of drivers involved in it. The aim of the analysis presented in this article has been to determine a possibility of using SRS-AIRBAG activation parameters to determine, with the SDC method, whether the circumstances of a collision reported were consistent with those responsible for a whiplash injury. The article provides an analysis of a series of rear-end collisions of vehicles moving in a column. The results have proven that the SDC procedure can be applied to verify the probability of a whiplash injury. With the above, this study is both academic and practical, and the results can provide benefits to vehicle collision researchers, experts, and students.

1. INTRODUCTION

The phenomenon of insurance crime is familiar to every insurance company in both Poland and worldwide. Insurance companies strive to prevent it. They cooperate by exchanging data and improve tools for fraudulent claim detection. The problem has been addressed and discussed in other works [1 - 4]. Unfortunately, insurance offences are part of the informal market, and as such, they are hardly directly measurable. A wide range of extortion methods make it difficult to classify the offences, and many cases have remained undetected [5]. The paper provides the characteristics of the extortion methods, e.g., simulating the whiplash symptoms claimed to have been suffered in a traffic accident, in a deliberate car collision and causing damage and injuries, simulating traffic collisions and reporting false circumstances the damage or injury is claimed to have been sustained in. The manuscript authors' practical experience shows that the problems of insurance frauds are not completely solved yet, and they call for improving the methods of counteracting the problems today and in the future. The same has also been confirmed by the experience of insurance companies in other EU countries and worldwide. The fraudulent claims apply not only to the vehicle repair costs but also to the medical treatment of the injuries suffered. Even at low collision velocity, the rear vehicle

collisions can lead to whiplash injuries due to rapid longitudinal forces acting from the rear of the vehicle. The passive vehicle safety elements do not secure from such injuries completely.

Such spinal column injury is referred to as “whiplash”, or otherwise as WAD (Whiplash-Associated Disorders) or a neck injury [6].

With that in mind, insurance frauds can be considered a socioeconomic problem which needs addressing. One of the insurance antifraud methods is to verify the claims applying the SDC analysis. It involves a static analysis of damage (S), dynamic impact (D), and characteristic damage that occurs on the contact surfaces (C). The SDC method involves applying the verification procedures that are divided into three groups and is briefly covered in this paper. The method has been also discussed, e.g., in another paper [7].

2. CHARACTERISTICS OF THE SDC METHOD

The core of the static analysis (S) is a geometric comparison of the object damage. The damage comparison can be made with the use of the vehicles involved in the damage reported. It does not always happen that the damaged vehicles are available for inspection. In such cases, to verify the damage inflicted, alternative methods are applied with the use of damaged vehicles and vehicle vector outlines. With the photos, a transparent superposition can be made; it involves placing the scaled photos of damaged cars on each other, one of which is less transparent than the other. Thanks to it, one can analyze the photo visible under it and the damage of the other vehicle and compare the damage with the damage of the first one, an example of which is presented in Fig. 1a. Scaling in that example was made with the gauges placed to the vehicles visible in the photos, and the damage zone has been additionally marked with a frame. While the vehicle vector outlines represent an accurate shape of the vehicle bodies in the same scale in the projection from the top, side projections, the rear, and front projections. They can be marked with the vehicle damage zones, which is seen in Fig. 1b. In the sample vehicle outlines, the damage zones have been marked with different colours.

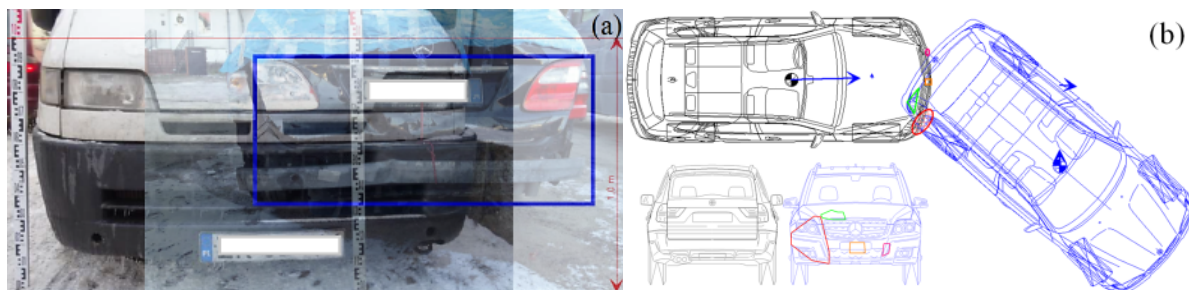


Fig. 1. Static comparison of vehicle damage from the superposition and outlines of vehicles

A dynamic analysis of a vehicle impact (D) includes the application of simulation programs for a reconstruction of road accidents to establish that, despite a geometric consistence of the damage zones and contact marks on the vehicle bodies, the collision circumstances were different from those reported. However, acquiring the input data for numerical calculations to ensure a correct simulation result is a problem. A wrong simulation result assumed as correct provides negative legal consequences for the party to the court proceedings as in the proceedings those incorrect results considered by court will lead to incorrect court decisions. It is associated with the impact modelling uncertainty and the vehicle post-impact movement when models of the same physical phenomenon yield different outcomes [8]. The choice of a simulation program always depends on the requirements. Impacts can be simulated in the Finite Element Method (FEM) convention. Programs applying the finite element method are used by research institutes and vehicle manufacturers for designing vehicles. They are not used, however, in the practice of traffic damage liquidation although they make it possible to perform calculations with the FEM programs. They require a lot of material and geometric data with a limited availability of numerical models of vehicles and a long calculation time. Therefore,

in practice, expert use especially Virtual Crash, V-SIM [9,10], with a simpler impact and contact models. In the simulation programs which model an impact in a simpler manner, the simulation accuracy depends on the selection of the collision detection, an impact model, and the input data quality. The problems connected with the choice of collision detection and impact models are discussed, e.g., in another study [11], which presents different simulation results of a vehicle collision and post-collision movement from the V-SIM collision detection models.

A V-SIM program vehicle model facilitates simulating impacts of vehicles with terrain obstacles. The vehicle movement model uses two reference systems: a global inertial system of coordinates with a description of the temporary simulated object position and a distribution of the environment elements. Its axes are marked x, y, z , whereas a non-inertial system of coordinates is related to the simulated object and its axes are marked x', y', z' . The position of the vehicle mass center is determined with radius vector r_c . Fig. 2a shows a vehicle model used in the program with a reference system.

The movement of a four-wheel vehicle in the V-SIM program is described in a 3D space as a movement of a solid – with ten degrees of freedom. The vehicle model also considers the suspension rigidity of progressive characteristics and different values of the shock absorber damping as well as stabilizer stiffness. The steering system of the vehicle is modelled according to Ackerman's rules. A force-related impact model was also created with forces continuously developing throughout the contact of the simulation objects until separated. The vehicle body, however, is a solid with the averaged rigidity which can be changed. Fig. 2b is a preview of the rigidity zone projected onto the vehicle vector outline. The vehicle movement in different road conditions and modelling of the vehicle collisions are discussed, e.g., in other studies [12 - 16].

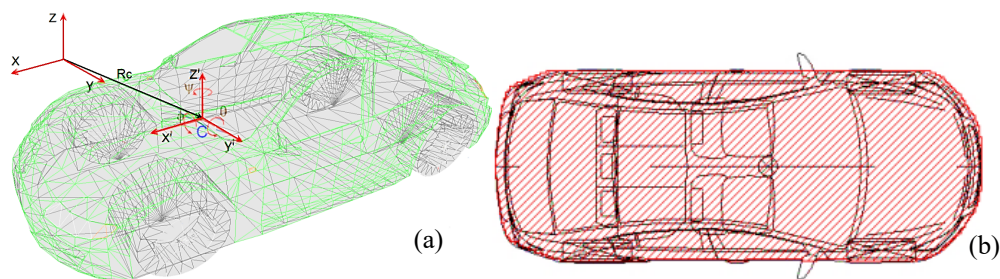


Fig. 2. Model of a vehicle with a reference system (a) and rigid area preview (b)

However, an analysis of characteristic damage covers a verification of the vehicle body surface marks within the contact area, e.g., marks of the paint transferred from one vehicle to the other at the contact place, pieces of tree trunk bark or concrete post stuck into the car body, or damage in a form of a specific shape imprinted from a vehicle element at a place of contact. A sample of fencing pillar brick layering visible on the vehicle bumper lining is given in Fig. 3.

Another study [17], e.g., provides an analysis of how marks, especially dents, bents, scratches, and paint marks occur.



Fig. 3. Vehicle bumper paint layering due to an impact into a fencing pillar

Yet, in practice, the method of static analysis and characteristic damage faces difficulties owing to a deliberate collision of vehicles under the circumstances different than reported. The complex verification with the SDC method provides a solution. It compares the damage but also requires a dynamic analysis of the vehicle impact.

3. CONDITIONS FOR A WHIPLASH INJURY

Another paper [18] analyzes different types of bumper beams for collisions with different obstacles. Based on the study results, the authors selected the bumper beam with the best properties for collisions with low collision velocities. Rear impacts, however, despite a relatively low collision velocity, can cause cervical spine injuries due to a rapid rear impact and due to passive safety features not providing a total protection. Euro NCAP performs whiplash injury tests to promote solutions for designing headrests and seats which would ensure a better protection to the people during impact [19].

The whiplash injury is caused by forced head bending forward and backward against the thoracic spine. This injury results in persistent pain, and it can lead to a permanent physical injury. Such injuries affect the spine bones and the so-called intervertebral spaces. It has been observed that chronic pain can also occur without forced head bending toward the headrest. The injury can then be caused by forced parallel head movement backwards, which also affects the spine.

The significance of the impact biomechanics for assessing the cervical vertebrae and clinical symptoms are discussed, e.g., in other studies [20, 21], whereas another article [22] presents a study of the relationship between the recovery of a road accident victim with a whiplash injury and the insurance claim.

According to yet another study [23], the conditions for a whiplash injury to occur are as follows:

- a relative velocity of the impacting and the impacted vehicles is higher than 11 km/h,
- the average acceleration of the impacted vehicle exceeds 3 g, and
- the maximum acceleration of the upper body is higher than 6 g.

Fig. 4 shows a whiplash injury occurrence mechanism.

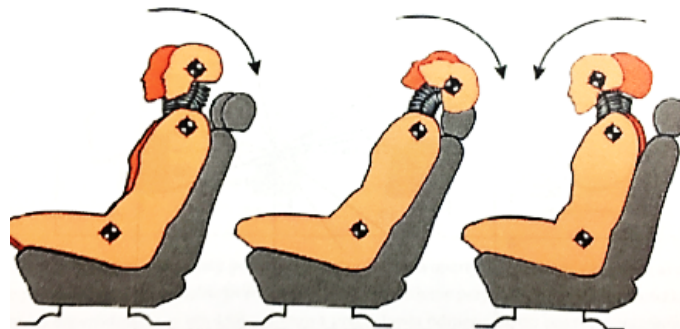


Fig. 4. Whiplash injury occurrence mechanism [23]

4. SRS-AIRBAG SYSTEM ACTIVATION PARAMETERS

Applying the SRS-AIRBAG system in vehicles is to lower the risk of the injuries of the driver and passengers during impact. In the European system, the SRS (*Supplemental Restraint System*) is associated with the safety belt system [24, 25]. The gas airbag activation involves an acceleration sensor and a digital microprocessor system. It is supposed to initiate the activation of the load in a generator when the delay threshold value is exceeded during a crash. Fig. 5 shows the SRS-AIRBAG system used in cars for passenger and driver safety.

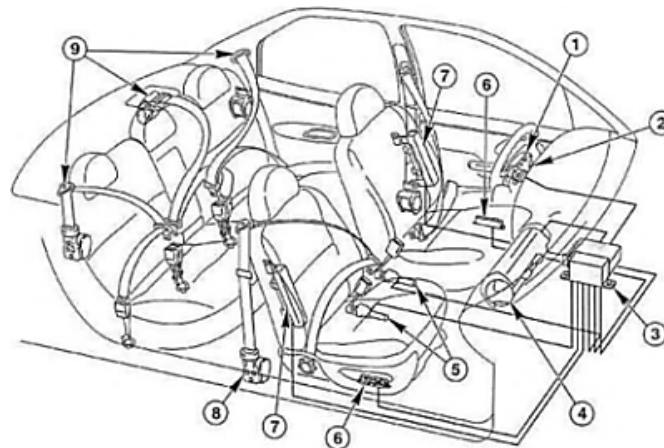


Fig. 5. SRS-AIRBAG system diagram: 1 – driver’s airbag, 2 – control diode AIRBAG, 3 – airbag controller, 4 – passenger’s airbag, 5 – pyrotechnic safety belt tensioners, 6 – side airbag sensors, 7 – side airbags, 8 – seat belt retractor, and 9 – three-point safety belts [24]

A typical airbag consists of three elements: gas generator, elastic folded “bag”, an airbag, and a cover. Gas generator is equipped with an igniter with solid fuel which disintegrates after ignition producing a gas with prevailing content of nitrogen. Fig. 6 shows a diagram of internal structure of the airbag gas generator.

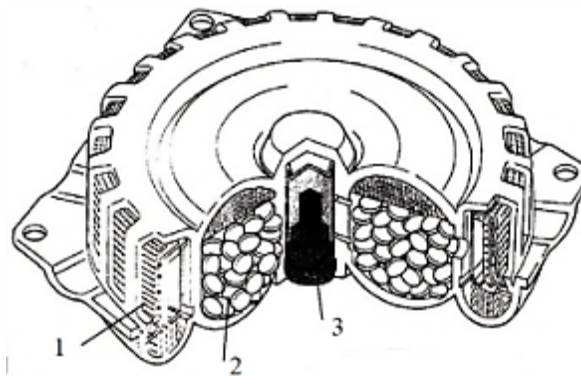


Fig. 6. Airbag gas generator diagram: 1 metal filter, 2 solid fuel in the form of granulate, and 3 igniter [25].

The airbag system is activated for the following [24, 25]:

- the velocity of 25-30 km/h in a collision with a barrier,
- deceleration measured for the body floor 8-15 g, and
- the force impulse vector angle not larger than $\pm 30^\circ$.

5. CASE STUDY

The article presents an analysis of a series of rear-end collisions of vehicles moving in a column with the SDC collision verification method. With the data reported in the vehicle damage and Chevrolet Cruze driver’s whiplash injury claim, the car was going behind an Opel Corsa, whereas the Chevrolet was followed by a Mercedes CLK. The Opel and Chevrolet cars stopped at the intersection and the Mercedes driver did not manage to stop and crashed into the rear of the Chevrolet. The impact displaced the Chevrolet which crashed into the rear of the Opel. From the perspective of the analysis made by the authors, the Chevrolet Cruze is therefore the target vehicle.

Table 1 provides the technical vehicle parameters assumed for the numerical analysis and parameters of the movement environment in simulations performed with the V-SIM program 4.0.20 version.

Table 1
Parameter values

Parameter	Chevrolet Cruze	Mercedes CLK	Opel Corsa
curb weight	1 425 kg	1 450 kg	1 025 kg
driver's weight	75 kg	75 kg	75 kg
length/width/height	4.603 m / 1.797 m 1.477 m	4.652 m / 1.740 m 1.413 m	3.999 m / 1.713 m 1.488 m
tire size	205/60 R16	195/65 R15	185/70 R14
ABS	Yes	Yes	Yes
dry asphalt, flat	Adhesive friction coefficient $\mu_1=0.8$ And slip friction coefficient $\mu_2=0.755$	Adhesive friction coefficient $\mu_1=0.8$ And slip friction coefficient $\mu_2=0.75$	Adhesive friction coefficient $\mu_1=0.8$ And slip friction coefficient $\mu_2=0.75$

In this study, three vehicles were tested using the SDC method following the procedure of static analysis (S) with a comparison of real objects, which is seen in Fig. 7a,b,c,d.

The real vehicles' breakdown confirms the overlap of the damage zones of the front of the Mercedes with the Chevrolet rear and the front of the Chevrolet with the Opel rear.



Fig. 7. Comparison of real vehicles: Chevrolet – Mercedes (a-b) and Chevrolet – Opel (c-d)

Fig. 8 demonstrates a breakdown of the vector outlines for the Mercedes, Chevrolet, and Chevrolet Opel as a side projection.

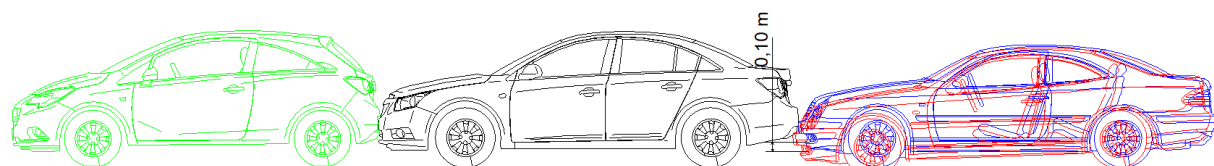


Fig. 8. Comparison of the vector outlines for the vehicles

The verification of the characteristic damage (C) provided the grounds for identifying the damage to both corners of the Chevrolet rear bumper facing sheet from the Mercedes cover of the engine chamber and fenders with visible paint deposits, Fig. 9a,b. However, in the lower left part of the front bumper of Chevrolet, there was found a mark of the paint scuff pointing to the impact of the end of the exhaust pipe in Opel, which is seen in Fig. 10a,b.

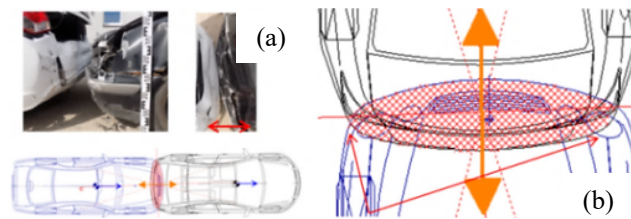


Fig. 9. Characteristic damage to Mercedes and Chevrolet vehicles



Fig. 10. Characteristic damage to Chevrolet and Opel vehicles

The procedures confirmed the contact of both vehicles; however, the conditions necessary for a whiplash injury to occur are still to be verified.

Upon the impact in the Mercedes car, the driver's airbag got activated, while the crash of the Chevrolet into the Opel did not activate the airbag in the Chevrolet. The dynamic analysis (D) thus uses that information assuming the impact velocity of the Mercedes as 25 km/h, which is the value which already allows for the activation of the airbag according to the parameters provided in Section 4 of the article. The damage to the vehicles has also been considered as well as the initial velocity of the Mercedes reported as 70 km/h, when the driver started braking. For that reason, the simulation of that road collision includes the stage of the Mercedes braking before the crash, the Mercedes crashing into the Chevrolet rear, its displacement to the front, and the Chevrolet crashing into the Opel rear, until the cars stopped. The results of the simulation of the series of the rear-end impact are shown in Fig. 11.

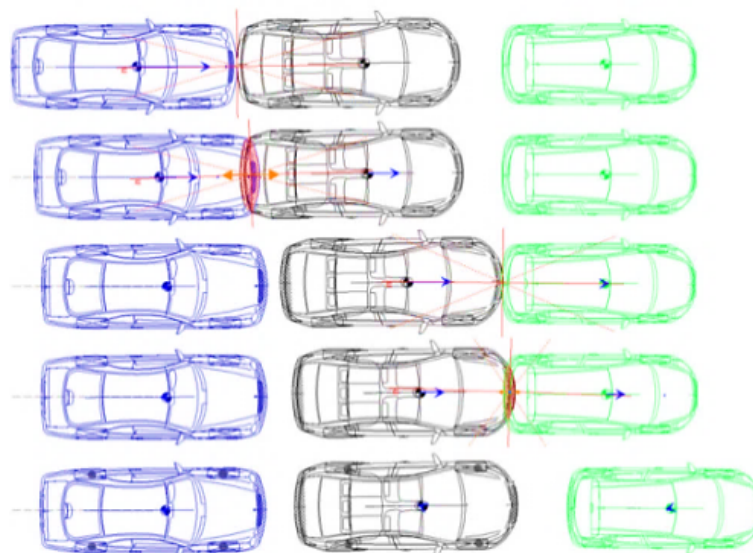


Fig. 11. Simulation of a rear-end collision of three vehicles (Mercedes – blue, Chevrolet – black, Opel – green)
With the basic data from the simulation of the collision, also the time series have been developed for linear velocity V and acceleration in axis x' $A_{x'}$ of the vehicles, as provided below: the Mercedes in Fig. 12a,b; the Chevrolet in Fig. 13a,b; the Opel in Fig. 14a,b

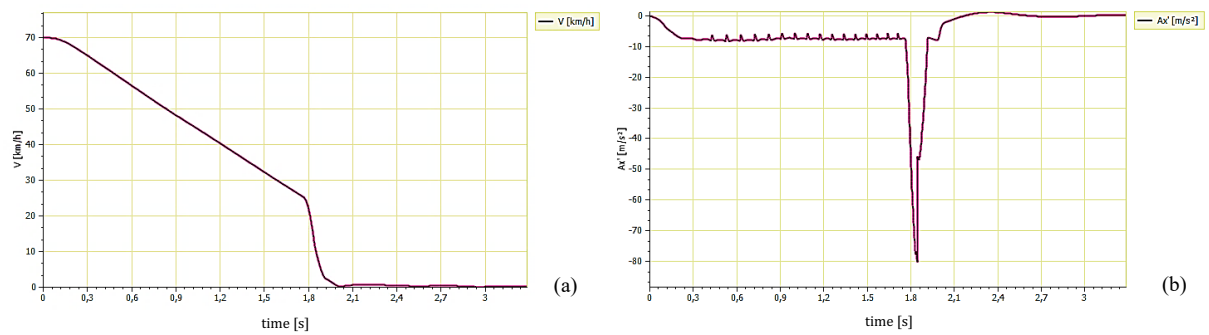


Fig. 12. Mercedes – time series for velocity (a) and time series for acceleration (b)

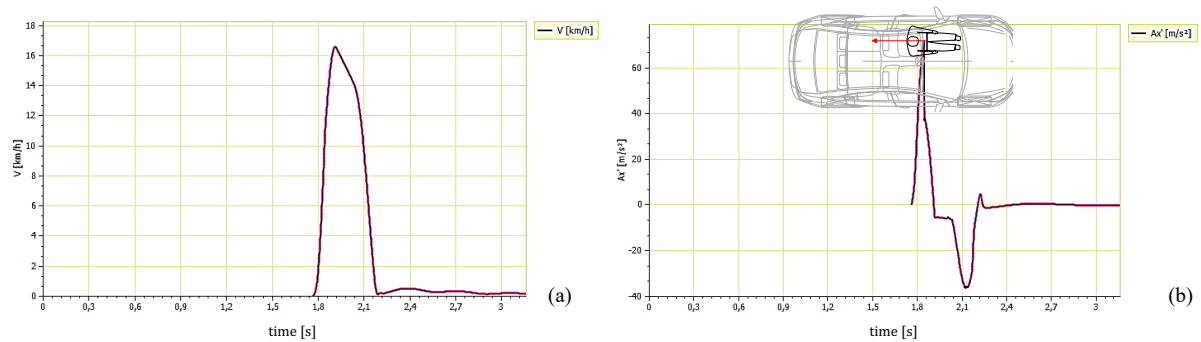


Fig. 13. Chevrolet – time series for velocity (a) and time series for acceleration (b)

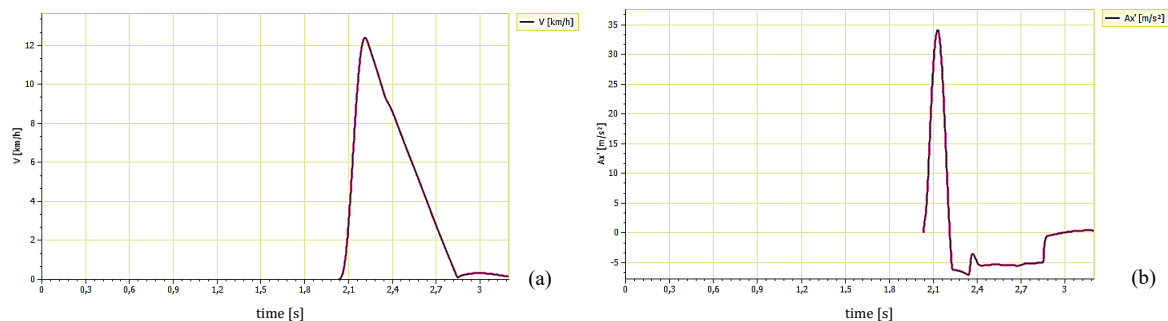


Fig. 14. Opel – time series for velocity (a) and time series for acceleration (b)

The numerical calculations have demonstrated that the impact of the braking Mercedes car with the velocity of $V=25$ km/h into the rear of the standing Chevrolet (the target vehicle) occurred at time $t=1.76$ s of the simulation, whereas the maximum deceleration of the Mercedes – at $t=1.84$ s of the simulation and it reached the value of $A_x=-8.03$ g, which confirmed that the conditions for the SRS-AIRBAG activation in the Mercedes car, provided in Section 4 of the article. The impact of the Mercedes into the rear of the Chevrolet made it accelerate, and at $t=1.84$ s of the simulation it reached $A_x=7.05$ g. The Chevrolet acceleration is then higher than the average acceleration of the vehicle crashed into and exceeds 3 g, creating the conditions for the whiplash injuries given in Section 3. The Chevrolet, due to the rear impact, reached the velocity the maximum value of which was $V=16.5$ km/h at $t=1.92$ s of the simulation, whereas the maximum deceleration of the vehicle during the crash into the Opel was $A_x=-3.67$ g at $t=2.12$ s of the simulation and the conditions for the Chevrolet driver airbag activation were not exceeded.

6. CONCLUSIONS AND DISCUSSION

The research shows that using SRS-AIRBAG activation parameters allows for estimating the minimum velocity of the vehicles involved in a collision and for verifying the possibility for whiplash injury to affect passengers of a car as a result of a rear impact.

The case study analysis results thus demonstrate a possibility of the practical use of the airbag system activation parameters to analyze the impact with the SDC method and to verify the body injury claim by referring the dynamic analysis results to the boundary criteria for which the conditions for the whiplash injuries occur.

The research has also shown that, while verifying the damage, in the convention represented in the article, one cannot disregard the condition and the quality of the elements of the airbag system and steering elements, while making a comparison with the threshold values of the airbag activation. Especially, it refers to the vehicles after the earlier incorrect post-accident repairs as the airbags might not get activated for the threshold values assumed by the manufacturer.

A computer tool has been developed for the SDC verification method to support experts in decision making when they verify collisions compliant with that convention. This program is also available in the English version and it runs under Microsoft Excel, and it can be used via the UTP website: http://wim2.utp.edu.pl/dok/wyklady/analiza_sdc.xlsm

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