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EFFECT OF CONTACT PARAMETERS ON THE PATTERN OF VEHICLE COLLISIONS WITH A ROUND PILLAR

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Abstract: *This article presents the effect of contact parameters on the pattern of a passenger car crash with a round pillar. First the default parameters and then the parameters identified from a crash test were applied to the simulation. Finally, the obtained results were studied. The differences observed between the results of these two simulations are considerable, which show the sensitivity of the obtained results to the input data. Usually expert witnesses do not have other data at their disposal, except for the default data offered by the program, which can lead to inadequate accident pattern evaluation, and an approximate incident reconstruction. This shows the difficulty of accident reconstruction.*

Keywords: Contact parameters, Crash simulation, Collision.

1. Introduction

For research purposes, collisions are simulated with the Finite Element Method. This allows for precise computations of crashes for various scenarios, vehicles and barriers (Dias de Meira et. al., 2016, Qi et al., 2006, Zhang, et al., 2015) whereas expert witnesses apply simpler IT tools offering computations in the MBS (Multi Body System) convention (http://www.cyborgidea.com.pl, http://www.pc-crash.com, http://www.vcrashusa.com). These programs use simplified models: linear relationships between the body crush and the force, as well as constant mass parameters during the crash (McHenry, 1997 and Rose et al., 2006). These programs are applied to the analysis of accidents, braking process and accident visualisation (Aleksandrowicz, 2016, Bułka et al., 2006 and Wolak, 2011). Certified property valuers usually assume default parameters offered by the program, without matching them to the studied incident, which is due to a lack of additional data. This article presents the problems faced in practice, of a change in the results of the simulation depending on the input data. The crashes investigated with computer programs are coupled with modelling of the contact between the vehicle, barrier and the road surface. Various contact models are applied, depending on the purpose, from linear to non-linear with memory (Kostek, 2012). It is also known that the systems with contact are sensitive to initial conditions, which are a result of non-linearity (Kostek, 2014). The model with the parameters identified from the crash test is studied in this article.

2. Collision simulations

The applied program (V-SIM) uses a few co-ordinate systems. The first one is a global system of co-ordinates *x, y, z*, which describes a positions of the barriers and displacement of vehicles. The second one is vehicle-related: *x', y', z'* (Fig. 1a). Axis *x'* is parallel to the ground and it passes through the mass centre of the vehicle *C* and is directed to the front; axis *z'* is directed vertically upwards and it passes through the mass centre of the vehicle *C* (Fig. 1a). Simulations were started from modelling a pillar (barrier) made from a material with the coefficient of friction equal to 1 and the coefficient of stiffness of 100 MN/m^2 –both for the phase of compression and restitution. The object of this study is a passenger car – a Renault Twingo I. The vehicle's initial velocity was 50 km/h. However its mass equaled 981 kg and it did not change during the accident, which is typical for the MBS convention. The wheelbase was 2.247 m, while the tire contact with the road was described using the TM-Easy model. Mass and geometrical parameters as well as the model of the tire contact with the road were taken from V-SIM, and

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the input data describing contact between the car and the pillar were identified from a crash test. The coefficients of stiffness of the car body were 378 kN/m^3 for the phase of compression, and 300 kN/m^3 for the phase of restitution; whereas the value of the coefficient of restitution was 0.08, and the grip index was 0.5. There was also introduced blocking of the left front wheel for $t \geq 32$ ms. The program does not introduce that action automatically, even though the area of deformation covers the wheel. The vehicle was positioned in a way as to receive the overlap 40 % (0.65 m). The time being $t = 0$ ms was assumed for the moment of the contact initiation between the vehicle and the pillar (Fig. 1b). Firstly, for the default parameters (body stiffness during compression and restitution 414 kN/m^3, the coefficient of restitution 0.19, the grip index 0.9 the changes of linear velocity, angular velocity and the position for time being t = 100 ms and t = 1000 ms were (Figs. 1c and 1e). At the next stage of the study, results were obtained for experimentally identified data (Figs. 1d and 1f). It was found that at the beginning the differences were not clear. However, with time, for t = 100 ms there were observed various values of linear and angular velocities, the differences being 2.4 km/h and 0.18 rad/s. There were also noted different directions of linear velocity vectors. Larger differences were observed for t = 1000 ms. The difference of linear velocity was 7.2 km/h, which is a result of wheel blocking and a lower value of the coefficient of restitution. The vehicle positions for that time were also different. Nevertheless, both vehicles stopped rotating for this time. The results obtained for experimentally identified data seem to be more reliable, which should be considered by software producers and certified property values in order to enhance the precision of accident reconstruction (https://www.youtube.com/watch?v = d3tcoG8ynqI, V-SIM4.0 – User manual, 2016).

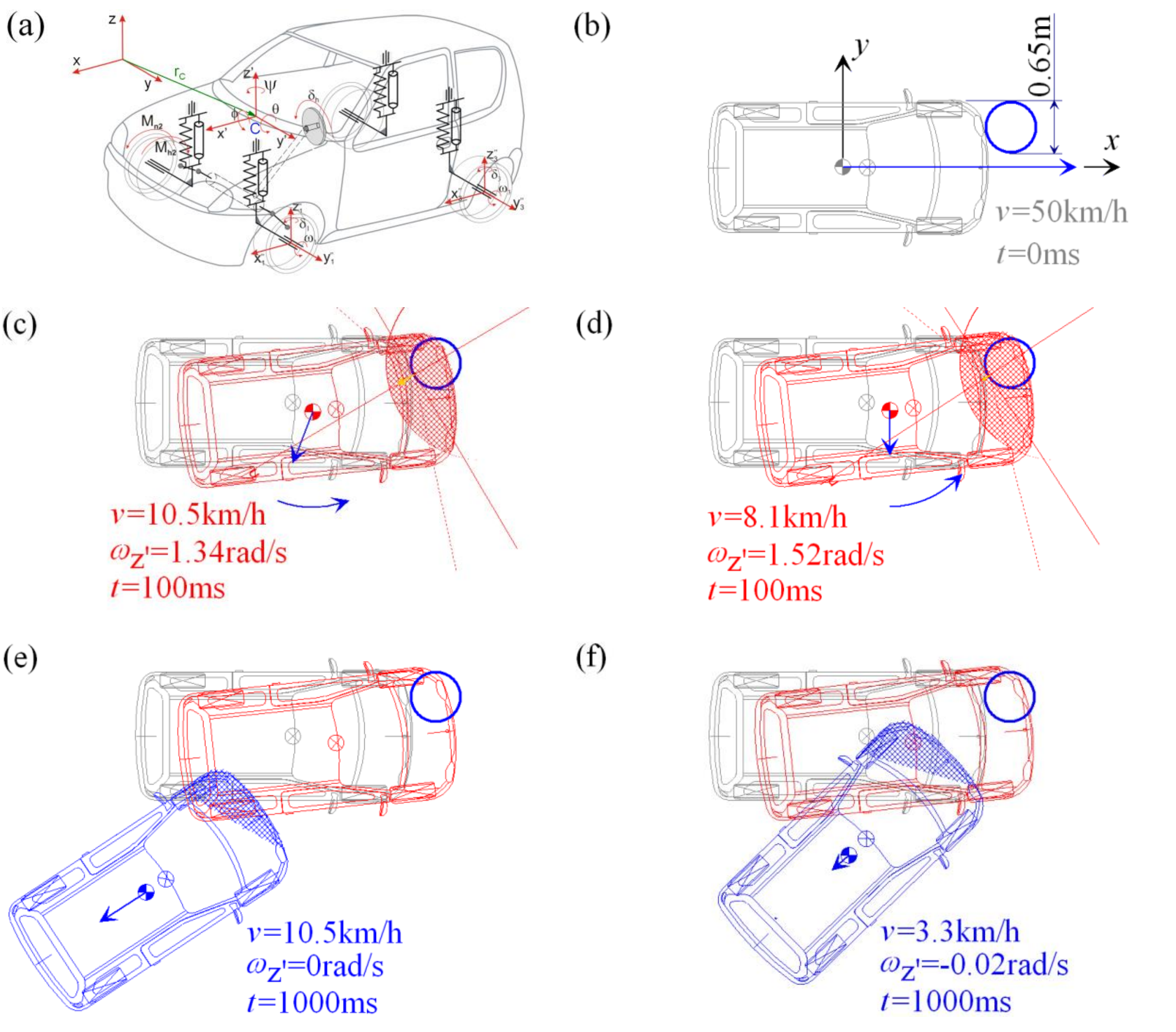

Fig. 1: Vehicle model with co-ordinate systems (a) and a comparison of the simulation results obtained for default program parameters (b, c, e) and the identified ones (b, d, f).

Next, the time histories of forces, moment, linear and angular displacement were presented. The analyses lead to a few conclusions. Large forces and moments act on the vehicle's users over a very short period of time. It was found that the period is about 84 ms, it determines the effects of the crash, especially the users' injuries, the probability of their survival, as well as financial losses (Aleksandrowicz, 2014). Clear differences between acting forces and moments occurred from t = 84 ms to t = 160 ms, at the phase of restitution (Figs. 2a and 2b). It was also observed that the differences between the vehicle positions were increasing with the lapse of time after the phase of restitution (Figs. 2c and 2d). Initially for t = 100 ms, the vehicle displacements for the default parameters were greater than for identified data Δx = 0.043 m and Δy = 0.012 m, whereas the difference between the angles of rotation ψ was $\Delta\psi$ = 0.2 °. Then, for the time being t = 300 ms, the differences were Δx = 0.16 m, Δy = 0.016 m and $\Delta\psi$= 1.7 °. This time corresponds to the end of contact between the vehicle and pillar for the default parameters; whereas for identified parameters the vehicle was in contact. Next, for the time t = 600 ms, the differences increased further and they were Δx = 0.516 m, Δy = 0.045 m and $\Delta\psi$ = 4.9 °, respectively. After that, differences Δx, Δy were observed for t = 1000 ms, and were considerable and they were still increasing; whereas the difference in the angles of rotation became stabilised $\Delta\psi$ = 10.2 °. Finally, positions x, y *and* ψ were presented for t = 1738 ms. It was the time in which the vehicle, from the identified data, stopped v = 0 km/h (x = 1.942 m, y = 2.533 m, ψ = 43.5 °); whereas for the default data it was still moving backwards with the velocity of v = 10.1 km/h (x = 5.053 m, y = 3.931 m, ψ = 33.4 °). To illustrate these two cases, a film was presented (https://www.youtube.com/watch?v=d3tcoG8ynqI). It clearly shows the different scenarios of the incidents and a different post-impact movement and sensitivity to the adopted parameters.

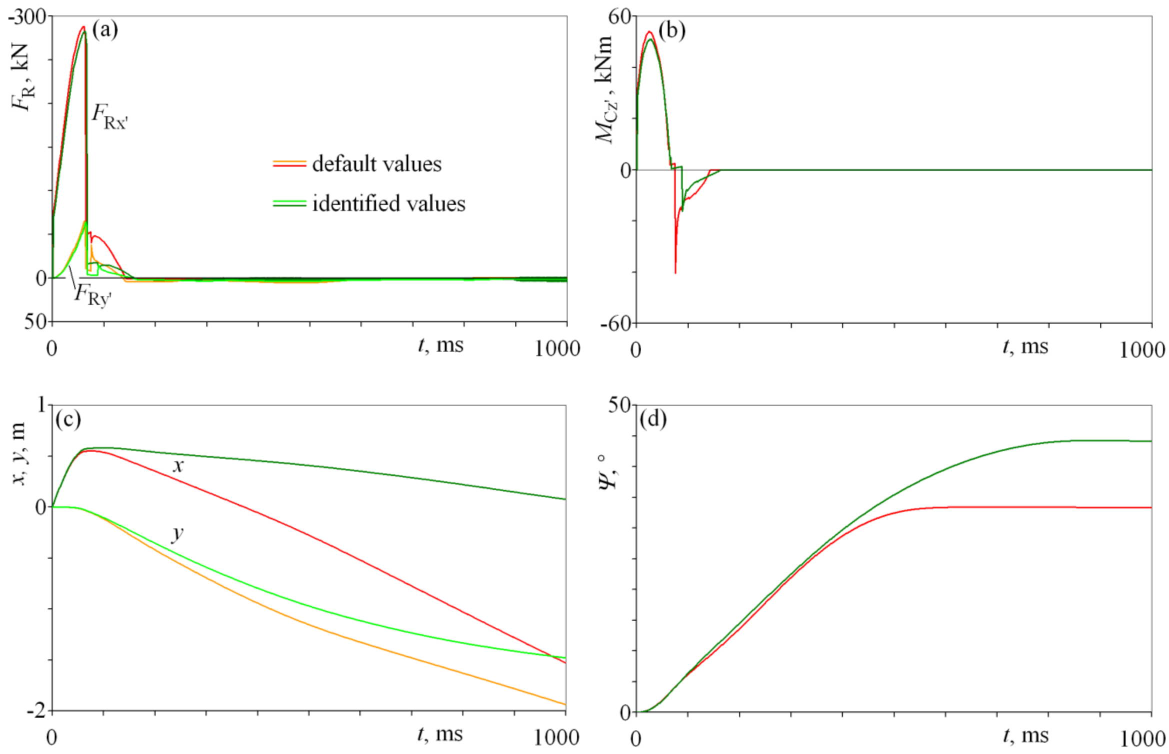

Fig. 2: Time histories of: projection on axis x', y' of resultant force F_R acting on the vehicle (a), a component of resultant moment acting on vehicle $M_{Cz'}$ (b) displacement of vehicle (b) and angle of rotation ψ (d) obtained for default values (red and orange) and identified values (brightly green and dark green).

3. Conclusions

The presented results of simulations show large differences after introducing changes to the input data. There was found a clear change in the post-accident position of the vehicle. The simulation of the crash for the default parameters leads to a smaller rotation of the vehicle around axis z' and unnatural movement backwards. It should be noted that for the time being at t = 1738 ms for identified parameters, the vehicle stops; whereas for default parameters it goes back with velocity v = 10.1 km/h. It confirms the sensitivity of the results of simulations to input data, which leads to a practical conclusion: the application of default parameters offered by IT tools can lead to incorrect results. To make good accident reconstruction, the expert should not only be highly qualified but also perform many calculations to receive the best solution or a group of solutions, which would be closest to a/the real accident. He or she should also use the possibility of changes in input parameters in the program based on the data received from crash tests and literature, and not to accept the default data offered by the program uncritically. Simulation programs, on the other hand, should use experimentally verified data to enhance the reliability of any results. The deformation models should be non-linear. To recapitulate, the sensitivity of simulation results to the input data makes the accident reconstruction very difficult, and it should be noted that computation errors can affect the responsibility of the parties to the court proceedings.

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