

NUMERICAL IMPLEMENTATION OF CAR IMPACT INTO THE MODIFIED ROAD BARRIER

Andrzej Kiczko, Tadeusz Niezgoda, Jacek Nowak, Paweł Dziewulski

*Military University of Technology
Department of Mechanics and Applied Computer Science
Kaliskiego Street 2, 00-908 Warszawa, Poland
tel.: + 48 22 6839461, fax: +48 22 6839355
e-mail: akiczko@wat.edu.pl, tniezgoda@wat.edu.pl
jnowak@wat.edu.pl, pdziewulski@wat.edu.pl*

Abstract

In previous works the research team submitted [1-5] a series of numerical analysis of the car – road barrier dynamical system, directed to the elaboration of the numerical model methodology of an impact problem with the use of the chosen CAE programs. In this article there are presented the results of works on numerical implementation of crash tests of a car with the modified road barrier. The results are presented on the example of the Suzuki Swift car impact into the road barrier, which is equipped with the additional protective panel. The panel consists of the foamed aluminium plate whose fastening to the belt of the W-beam guardrail and a shield presented itself a thin-walled open profile made from the polyester-glass laminate. The whole construction was connected with the W-beam guardrail by riveting. The Geo Metro (Suzuki Swift) car, commonly available model from National Crash Analysis Centre (NCAC), was used for numerical analysis of the car-barrier system. Numerical analysis was carried out with the use of LS-Dyna system. The comparison of the time courses of acceleration, acting on the vehicle centre of gravity and the ways of the barrier and car deformation, achieved by the experimental and simulation ways, took place. The good qualitative and quantitative conformities in accelerations were achieved.

Keywords: road transport, car – road barrier system, crash test, numerical simulations

1. Introduction

Principal components of currently used protective road barriers are: a post, a separator and a guide bar. First two mentioned elements are made of typical steel sections, such as the I-bar and the channel bar. These kinds of selections are characterized by good resistance properties, however their energy-absorbing abilities and the possibility of gentler losing of the vehicle's impact energy are unsatisfactory.

Up to now authors' works have been carried out within the range of experimental and numerical research of energy-absorption of separate elements of the road barrier's belt. In this article the research subject is a modified SP-04 road barrier. In order to increase the energy-absorption of the road barrier's belt modifications were used in a form of an additional composite-foam panel.

2. Full-scale crash test

Experimental research (crash-tests) of the fragment of the protective road barrier construction with the application of additional protective panels, were carried out in the Experimental Research Laboratory of the Industrial Motorization Institute (PIMOT) in Warsaw.

For the crash tests a protective barrier was selected, made of the B type guide bar and bridge posts IPE140. The guide bar's belt was placed 24 cm lower than the standard height to eliminate the possibility of the car driving under the guide bar. To the central part of the barrier there was assembled a panel, comprising a casing made of polyester-glass laminate, filled with polyurethane foam. The

panel was connected with the guide bar with the use of riveting. The examined construction and the vehicle used in the experiment are depicted in Fig. 1. The spacing of posts was conditioned by the research stand's specifics. The distance between the middle posts amounted to 2 m, whereas the distance between side posts amounted to 1m. Road barrier's posts were welded with two steel plates. The plates were supported by a retaining wall and fastened to the ground.

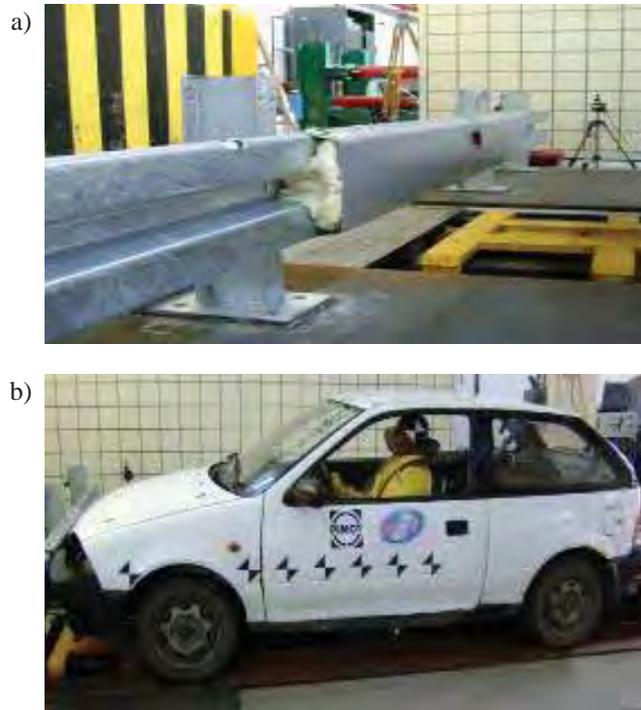


Fig. 1. a) Examined road barrier construction on the examination stand, b) Suzuki Swift car used in the crash test

A crash test course of the system car-road barrier was registered with the use of two cameras designed for fast shooting. The selected shots from the crash test are presented in Fig. 2. During the test a registration of acceleration was carried out by the acceleration sensors placed in the car (among others on the centre of gravity and over the rear axle of a car).

3. Description of the computational model

The evaluated road restraint system is made of construction steel S 235. The W-shaped guardrail is made of approximated 3 mm thick metal sheet. The additional protective panel comprised a casing made of composite material (a fabric with a straight interlace 0/90, 450 g/m² - glass E, resin VE-11 M) 1.2 mm thick, filled with polyurethane foam (Ekoprodur).

The non-linear explicit finite element code, LS-Dyna, was used to simulate the crash-test. To the numerical analysis generally available model of the Goe Metro car (Suzuki Swift) was used from the National Crash Analysis Centre (NCAC). The general view of the car's model is presented in Fig. 3.

The car's model was made of 820 elements of SOLID type (with which things such as an engine's block, brake disks, a radiator were simulated) and of 26120 elements of SHELL type.

To the description of the material of most parts a model of an elastic-plastic material with a consolidation, taking into account a deformation's speed, MAT-PIECEWISE-LINEAR-PLASTICITY was used. Less significant elements of the model were described as an elastic material. Moreover, in the numerical analysis undeformable elements were used, described with the MAT_RIGID material type model. Car's suspension elements took into account the elasticity and damping and were simulated with the use of following materials: MAT-SPRING-ELASTIC and MAT-DAMPER-VISCOUS.

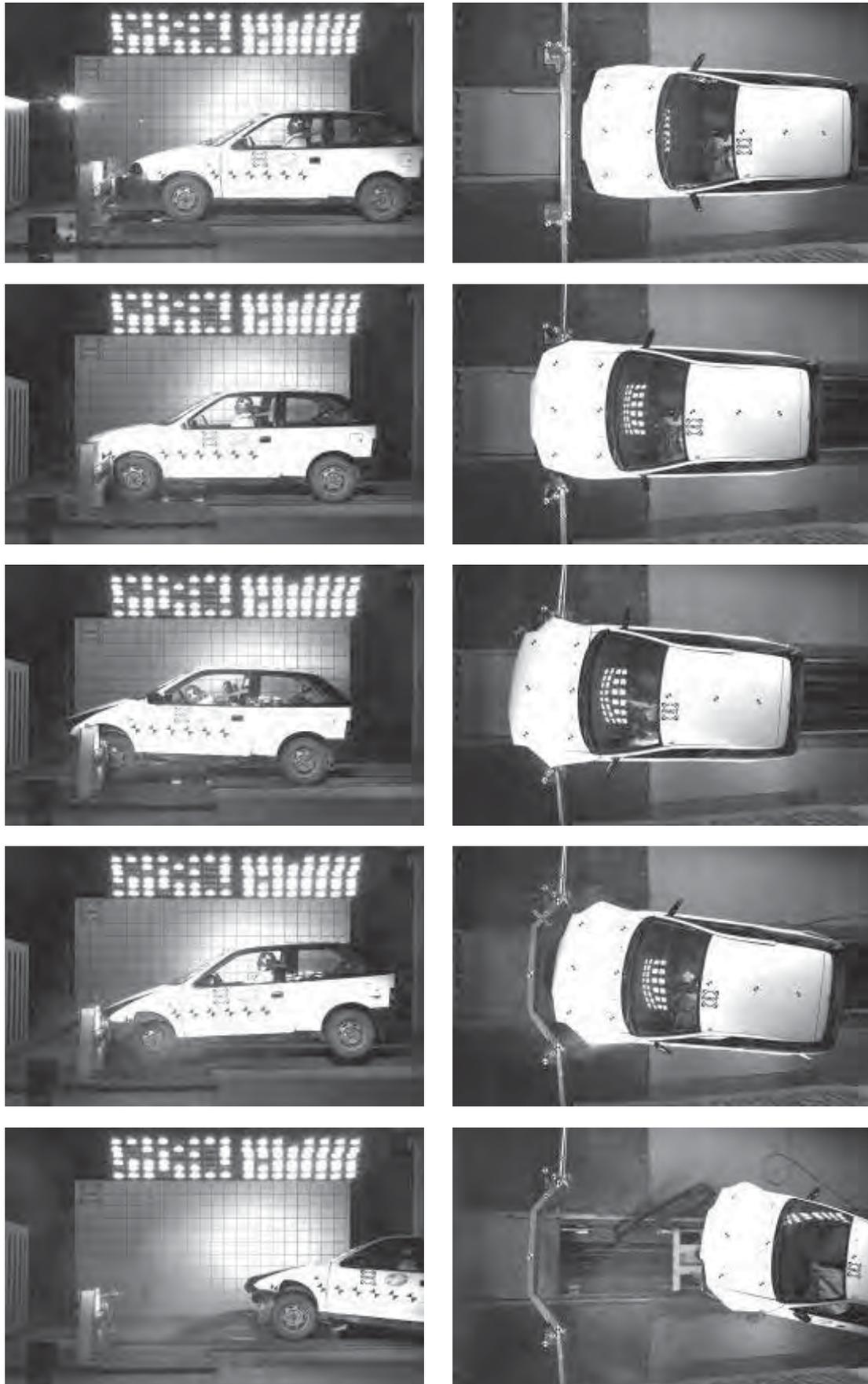


Fig. 2. The crash test course registered with the use of two synchronized cameras designed for fast shooting (FANTOM v12)



Fig. 3. Numerical model of the examined vehicle

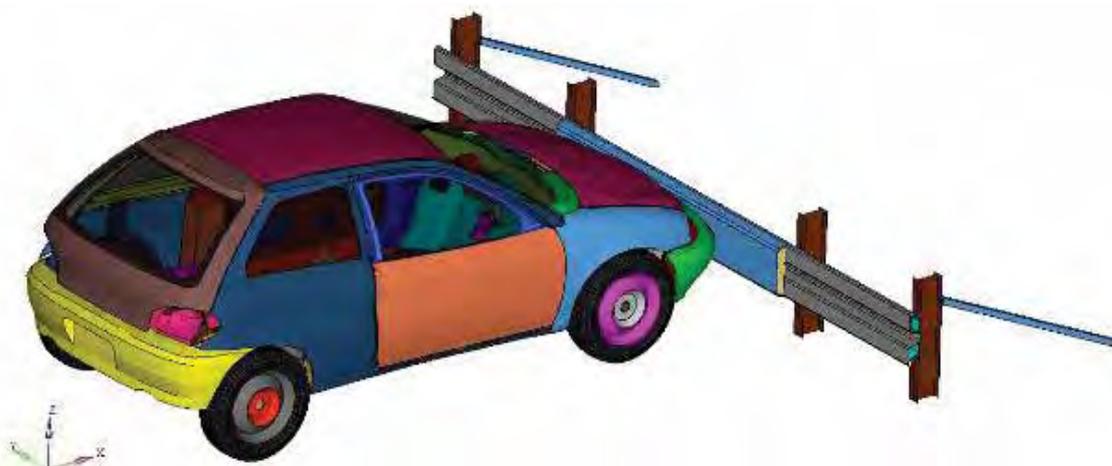


Fig. 4. Numerical model of the stand for crash-test research

In the model the interaction of earth gravity and the friction effect taking place between the ground and the car's wheels and between the examined road barrier and the protective panel were taken into account.

The model of the modified SP-04 barrier fragment contains over 11500 shell type elements. In the model the possibility of the guide bar's material destruction and the destruction of elements connecting posts with the belt were taken into account. The filling of the panel in a form of polyurethane foam was simulated with solid elements. Material characteristic for these elements was acquired basing on the own material research. Initial-boundary conditions for the numerical analysis were identical as in experimental research.

4. Analysis of computational results

In Fig. 5a and 5b a numerical model of the road barrier with an additional protective panel 1B type with a fragment of the car's model (in views from the side and from above) before the impact is presented. In Figs. 5c and 5d the models' deformation for the time $t = 0.25s$, measured from the moment of the front bumper's contact with the barrier, is presented. The speed change in time of the car's centre of gravity is presented in Fig. 6. In the analysed case the car hit the modified SP-04 barrier at an angle of 90° , with the initial speed of 45.5 km/h. After $t = 0.09 s$ the car's speed decreased down to zero, and after that a rebound from the barrier took place, and the car started moving in the opposite direction with the speed of about 10 km/h. The use of susceptible connections (separate elements of the road belt) with the destruction model caused the vehicle's „driving into“ the road belt. However, the road belt's rupture didn't take place. Such an effect is desirable in the road traffic safety aspect.

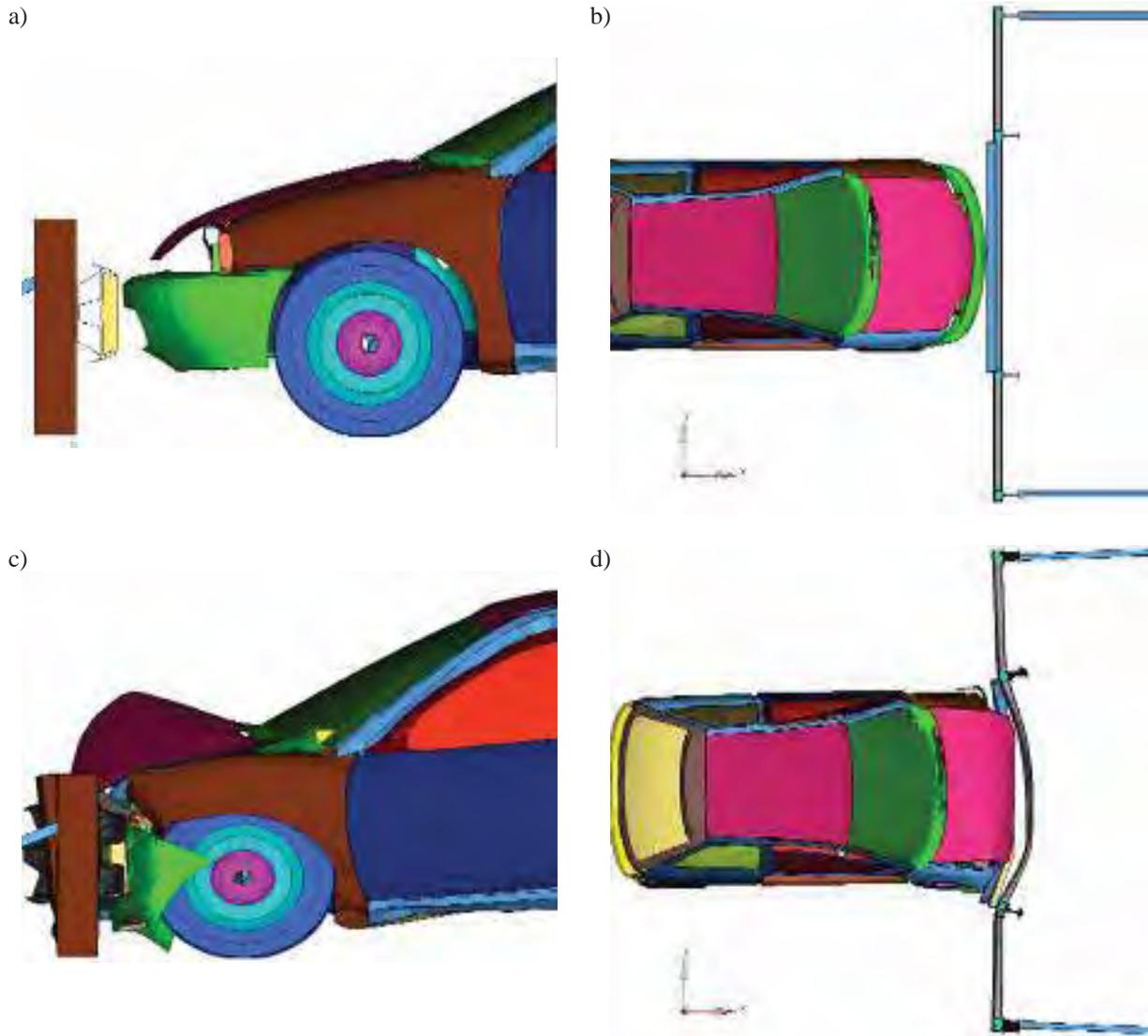


Fig. 5. Numerical model of a dynamical set :a car – a barrier before the impact (a, b) and after (c, d)

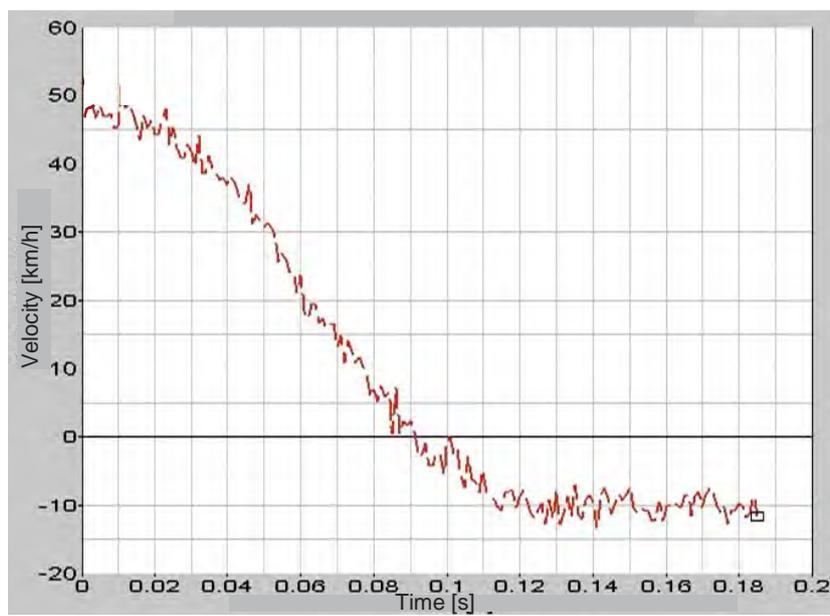


Fig. 6. The car's centre of gravity speed change graph in a set a car – a barrier

In order to verify the correctness of the model a comparison of the way of a car's and a barrier's deformation and the accelerations' course, acquired in numerical examinations and in an actual crash-test carried out in PIMOT, was done. The comparison of deformations is presented in Fig. 7. Successive photos show an actual object and its numerical model at the time instants marked on the acceleration comparison graph (Fig. 8) correspondingly with letters: a, b, c, d. On the mentioned graph of acceleration course, the car's model centre of gravity accelerations were put together (marked as MES) with the acceleration measured during the test on the gearbox tunnel (marked as Eksperyment). The maximum acceleration value obtained in the experimental research is identical as the value obtained in the numerical simulation and amounts to 25.6 g.

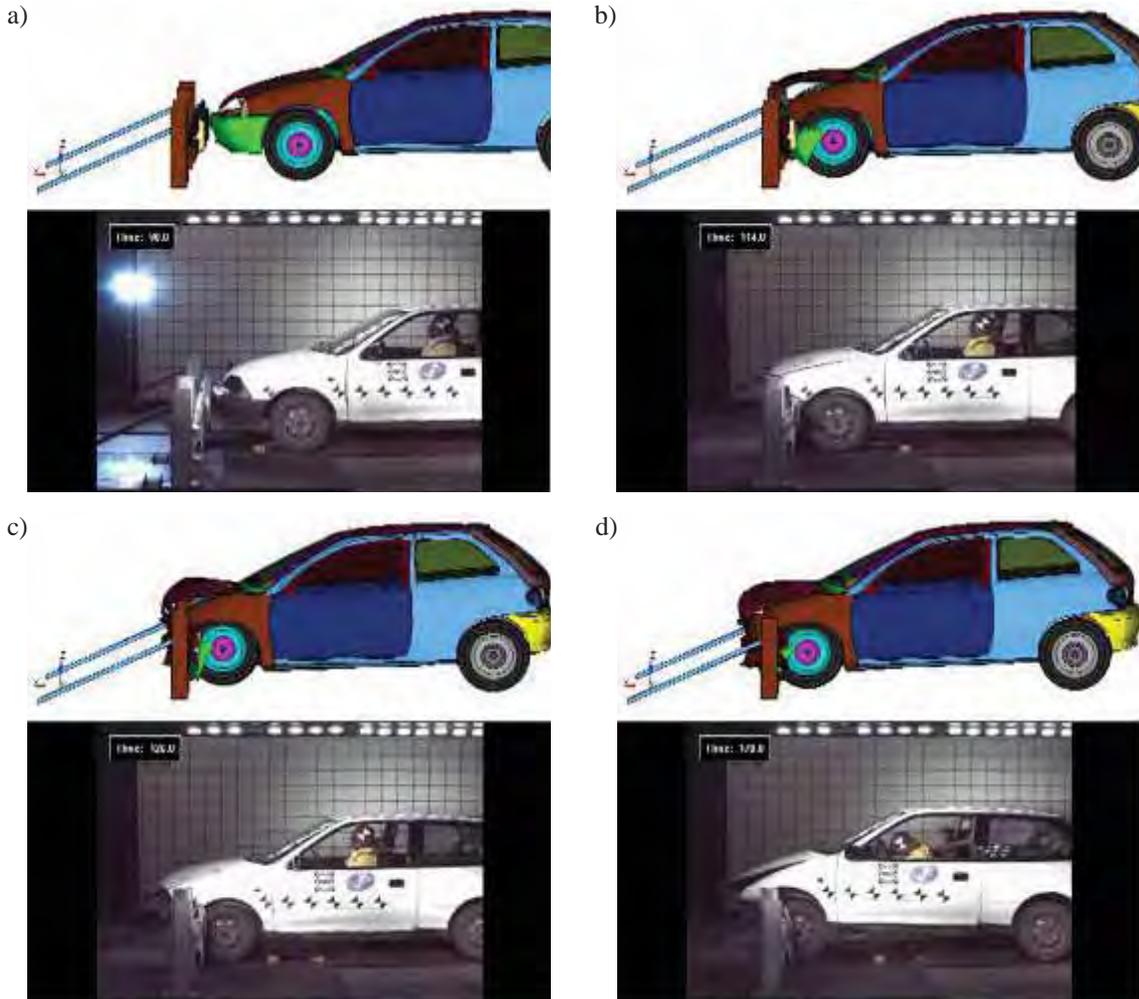


Fig. 7. Comparison of the car's and barrier's deformations

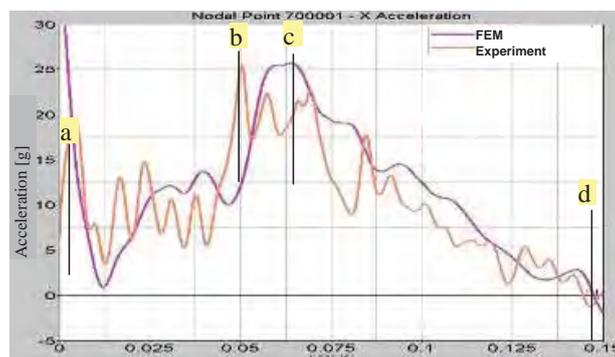


Fig. 8. Acceleration course comparison

A comparison of the deformation way of the road barrier's belt received in the experimental research and the numerical simulation was done. With the use of the hand-held laser scanner EXAscan a three-dimensional scan of the deformed road barrier's belt was produced, after earlier removal of the destroyed protective panel. The received image was put on the image acquired as a result of the numerical simulation, and the comparison effect is presented in Fig. 9. The deformation obtained from the experiment is marked with the red colour, whereas the deformation after FEM analysis is marked with the light-gray. A great similarity of the belt's deformations is visible in the discussed cases.



Fig. 9. Comparison of the road barrier's belt deformation (marked in red colour – experiment, light-gray colour – FEM)

In Tab. 1 absorbed energy values by separate components of road barriers, determined basing on the numerical simulations, are put together,. The comparison was made for the barrier without a protective panel, a barrier with a panel 1B type, discussed in this article, and the panels 1A and 1BL types. In the panel of 1A type the composite casing was replaced with a casing made of a steel sheet 0.5 mm thick. The panel 1BL was filled with foamed aluminium (composite casing). In all cases it was assumed, that the car hits the road barrier perpendicularly with the speed of 45 km/h. The lowest energy-absorbing abilities were indicated by the unmodified barrier (23.7 kJ). From among the barriers with additional energy-absorbing panels the greatest energy-absorption is attributed to the barrier of 1B type (26.8 kJ).

Tab. 1. Energy absorber by separate components of protective barriers

		Barrier	Barrier 1BL	Barrier 1B	Barrier 1A
ENERGY [kJ]	Posts	5.1	4.0	4.3	3.8
	Separator	0.4	0.6	0.1	0.2
	Belt	18.2	16.1	16.7	15.9
	Panel	-	3.7	5.8	6.0
	Sum	23.7	24.4	26.8	25.8

5. Conclusions

This paper presents the results of computational simulations of modified road safety barrier behaviour under vehicle crash conditions. For the analysis a basic burden variant was adopted – impact with a vehicle with the speed of 45.5 km/h at an angle of 90° without the braking process before the impact. Simulations were performed with the explicit finite element code LS-DYNA, running on a multiprocessor computational platform.

The comparison of the computer simulation and a large scale experiment showed a good correlation of computational and experimental results (acceleration, deformation) for the both considered crash tests. From this arises that basing on the numerical calculations the amount of

absorbed energy by separate elements of the construction as well as the correctness of the numerical models can be concluded.

The use of computational simulations leads to a significant reduction of development and testing costs of the new safety barrier designs.

References

- [1] Niezgoda, T., Barnat, W., *Computational and Experimental Study of Energy Absorption Metter by Composite Structures*, Computational Methods in Engineering And Science Epmesc X, Tsinghua University Press & Springer, Sanya, China 2006.
- [2] Niezgoda, T., Barnat, W., *Analiza pasa bariery drogowej wzmocnionej elementami kompozytowymi w zastosowaniu do poprawy energochłonności elementów infrastruktury*, Górnictwo Odkrywkowe, Nr 5-6, 2006.
- [3] Niezgoda, T., Barnat, W., Dziewulski, P., *Numeryczna analiza podatności elementów infrastruktury drogowej*, I Kongres Mechaniki Polskiej, Warszawa 2007.
- [4] Niezgoda, T., Kiczko, A., Barnat, W., Dziewulski, P., *Validation of Numerical Models of Road Barriers Elements With The Use of Experimental Methods*, Symposium on Advances in Experimental Mechanics, Danubia-Adria, Romania 2007.
- [5] Niezgoda, T., Barnat, W., Dziewulski, P., *Numeryczna analiza podatności elementów infrastruktury drogowej na przykładzie barier SP-01, SP-04 i SP-09*, Journal of KONES, Vol. 14, No. 3.