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MODELLING AND NUMERICAL ANALYSIS OF EXPLOSION UNDERNEATH THE VEHICLE

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Abstract

The article presents a method for numerical modelling of interaction of a shock wave on a simplified model of a light armoured vehicle. Detonation of the explosive material occurs centrally underneath the vehicle. The mass of an explosive charge was from 0.5 to 10 kg off TNT. Acceleration, displacement and kinetic energy of the floor plate/panel were verified during the tests.

The model and numerical calculations were carried out using the following programs: CATIA, HyperMesh, LS-PrePost, LS-Dyna. CONWEP approach was applied to describe interaction of a pressure wave on the structure. For each case, the explosive charge was located at the same place under 700 mm from the top surface of the range stand. The results of the calculations present the effects of detonation under the vehicle without a protective system and with the protective system. The proposed protection system is made of low-density materials such as aluminum foam and cork. Thanks to such an approach, the effectiveness of the protective system will be checked to reduce the adverse physical quantities that threaten the health of the soldiers. Thanks to very simple solutions, it is possible to increase passive safety of passers and use of low-density materials will slightly increase the vehicle's mass leaving manoeuvrability at a similar level.

Keywords: *shock wave, LightArmoredVehicle (LAV), CONWEP, protective structure, IED*

1. Introduction

Asymmetrical military actions cause that light armoured vehicles are exposed to the effects of most of fire means, which are at the enemy's disposal, including anti-tank mines and improvised explosive devices. Owing to these reasons, the contemporary requirements to be met by a vehicle on the battlefield determine the design of the bodies of armoured combat vehicles in terms of providing high passive safety [1, 2].

Detonation of explosive charges occurs mostly by a direct wheel overrun or underneath the vehicle. IED and AT charges are mainly buried in the ground, therefore, their detonation causes that the vehicle subsystems which are the most exposed to damage are the elements of the chassis.

A constant development of numerical methods as well as an increase in performance of modern PCs allows modelling of many physical phenomena. The above-mentioned development in connection with a more and more concern for passive protection of structures causes that more and more sophisticated construction solutions are sought with the use of numerical calculations.

The aim of the present article is to develop a methodology for numerical modelling of a shock wave interaction on the structure of LAV vehicle. The effects of a shock wave interaction will be verified using a vehicle both without and with a protection system.

2. Research object

The vehicle, which is the most frequently utilized in armed conflicts and stabilization missions, is a light armoured wheeled vehicle. A great number of such vehicle and their frequent utilization in patrols causes that they are the most frequently attacked vehicles. Owing to the above reasons, it was decided to use a light armoured vehicle for tests on the effects of a shock wave interaction.

Due to licensed sale and a high price for a real object, the work was limited only to numerical calculations wherein a simplified model of a light armoured vehicle was applied (Fig. 1). The simplifications included:

- substituting the suspension system with closed profiles beams,
- neglecting the sprung and damping elements,
- substituting the equipment and drive train systems with substitute masses. A substitutive mass was distributed in a manner providing an equal pressure on the individual vehicle axes. Mass of the whole vehicle was 7 tonnes,
- the vehicle body was made of S355 structural steel and ARMSTAL 500armoured steel,
- the vehicle casing was executed in a closed system.

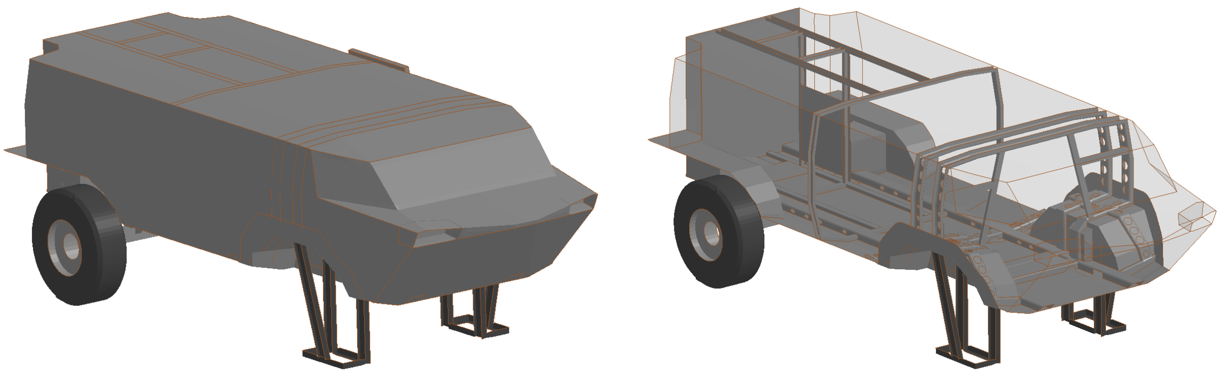


Fig. 1. Supporting structure with simplified suspension system

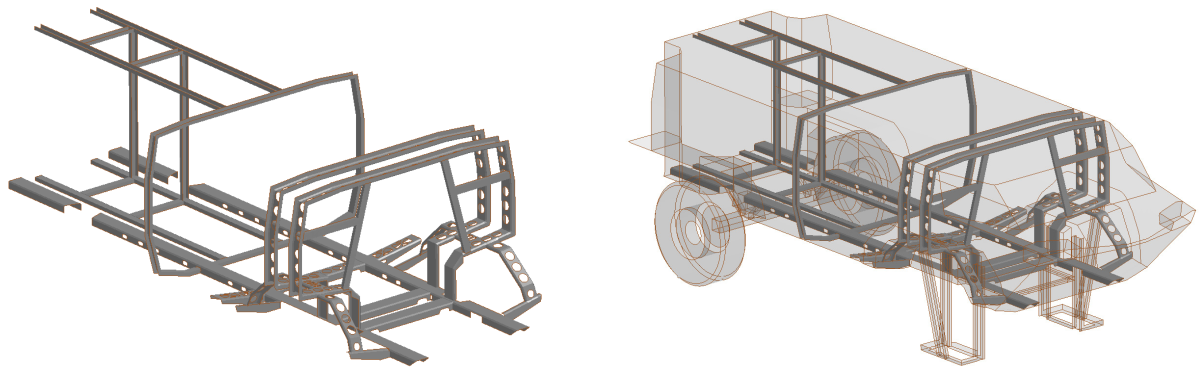


Fig. 2. Inside frames system increasing the stiffness of supporting structure

3. Model of simplified LAV vehicle

A model of a simplified military vehicle was prepared using the following software: CATIA V5, HyperMesh, LS_PrePost. LS_DYNA software was used for numerical calculations. Detonation and loading with a shock wave was realized with the use of built-in CONWEP option [3].

Surface elements of ELFORM16 − „Full integrate point” type, used for the vehicle body, were applied for model discretization. The remaining parts of the vehicle were divided into finite elements using solid type elements with one point of integration ELFORM1.

Loading with explosion was realized with the use of built-in Conwep function [4]. The input parameters include equivalent TNT mass, type of blast, detonation location, and surface identification for which pressure is applied (Fig. 4). ConWep approach allows generation of the equivalent pressure value:

$$P(t) = P_{ref} \times cos^2\theta + P_{in} \times (1 + cos^2\theta - 2cos\theta),$$

where:

θ – is the incidence angle of the wave,
P_{ref} – overpressure value of the reflected pressure wave,
P_{in} – overpressure value of the incident pressure wave.

To make it possible, it is required to declare the surface on which the shock wave will interact. This surface is declared by a segment with normal directed in the charge direction. The declared segment is presented in Fig. 4.

Welded joints were substituted with a contact joint called TIDE depriving a possibility of a shift and rotation of the selected nodes in respect to a selected surface. Options of AUTOMATIC_SINGLE_SURFACE contact were ascribed to the remaining elements. All the above-mentioned contact options use a procedure based on a “penalty function” method.

The applied material constans and the remaining options are presented in Tab. 1-3. The units applied: mm, s, t, N, MPa, mJ.

a) b)

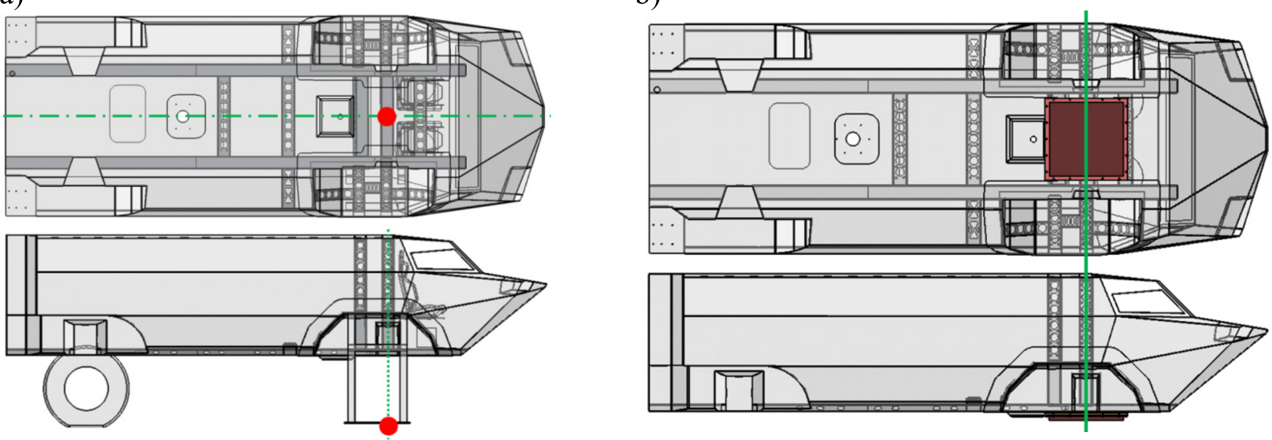
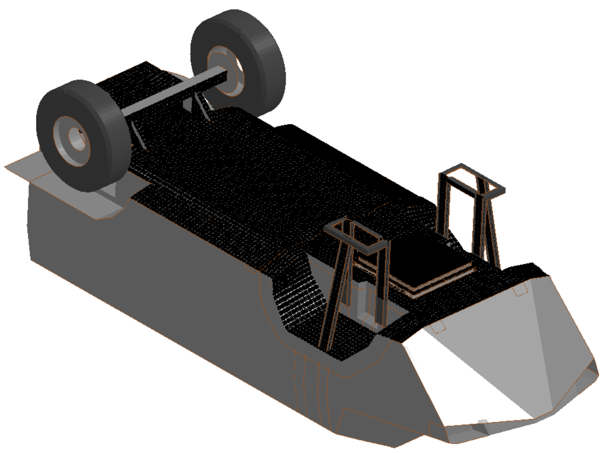


Fig. 1. a) Position of explosive material in respect to the vehicle, b) localization of protection system on the body of the LAV supporting structure



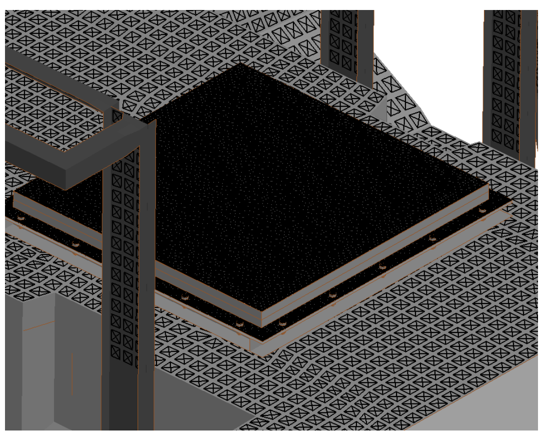


Fig. 2. Point of LAV structure loading and protection system

In order to improve the passive safety of the vehicle crew, there was proposed a protection system. The manner of mounting it to floor plate is presented in Fig. 5. The protective system was built from an additional 8 mm armoured metal sheet to which a 50 mm panel was fixed. The panel was made of an alloy of a foamed aluminium CYMAT_36.

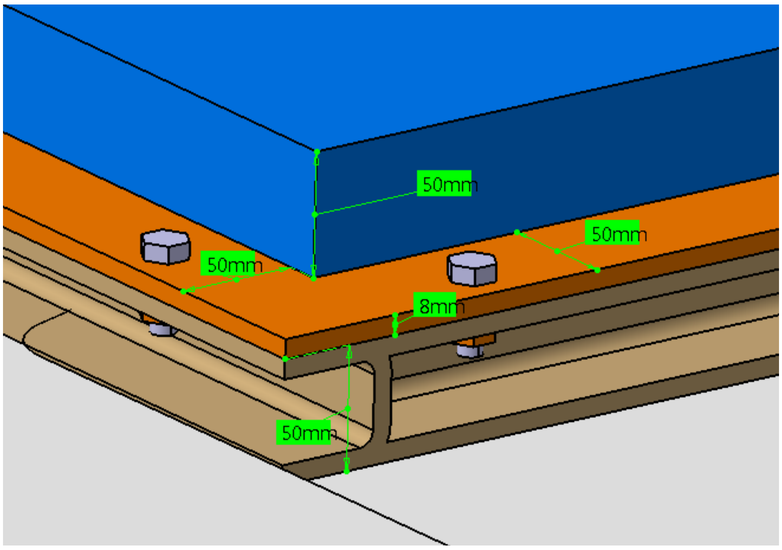


Fig. 5. Protective system mounted to the LAV supporting structure

Tab. 1. Material constants for steelS355

Parameter	Steel
Mass density, RO	7.8e-9
Young's modulus, E	2.1e5
Yield stress, SIGY	355
Plastic strain to failure, FAIL	0.6
First effective plastic strain value EPS1	0.0
Second effective plastic strain value	0.6
Corresponding yield stress value to EPS1	355
Corresponding yield stress value to EPS2	550

Tab. 2. Material constants for steelARMSTAL 500

Parameter	Steel
Mass density, RO	7.8e-9
Young's modulus, E	2.1e5
Yield stress, SIGY	1350
Plastic strain to failure, FAIL	0.5
First effective plastic strain value EPS1	0.0
Second effective plastic strain value	0.6
Corresponding yield stress value to EPS1	1350
Corresponding yield stress value to EPS2	1500

MAT_24 (MAT_PIECEWISE_LINEAR_PLASTICITY).It is the elastic-plastic material with the declaration of any strain curve σ-ε and any depending on the strain rate.

Tab. 3. Material constants for CYMAT_036

Parameter	Steel
Mass density, RO	3.6e-10
Young's modulus, E	7e4
Poisson's ratio for compacted honeycomb material	0.33
Yield stress for fully compacted honeycomb	125
Relative volume at which the honeycomb is fully com	0.13
Elastic modulus	193
Shear modulus	41

Parameters of settings of LOAD_BLAST_ENHANCED option

- Unit conversion flag -EQ7 – metric ton, millimetre, second, MPa,
- Type of blast source – BLAST – EQ1- hemispherical surface burst ¨C charge is located on or very near the ground surface, initial shock wave is reflected and reinforced by the ground,
- Equivalent mass of TNT – m=0.01.

4. Results of calculations

The effects of explosive material detonation underneath the vehicle were verified as a part of numerical investigations. Mass of explosive material was being increased while observing the displacement, acceleration and kinetic energy of the floor plate. The results of the calculations are presented in Fig. 7-13.

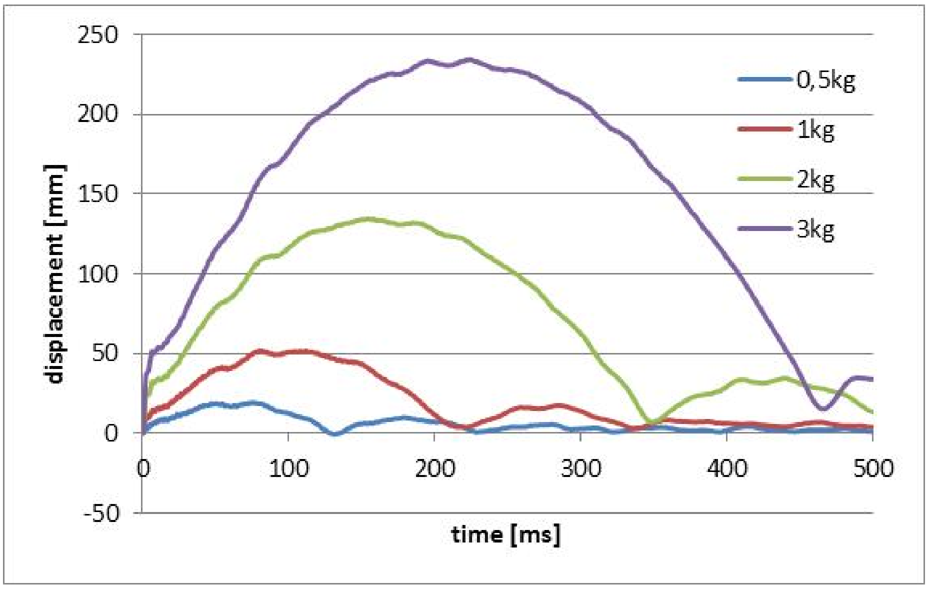


Fig. 3. Displacement of the floor plate for a vehicle without the protection system

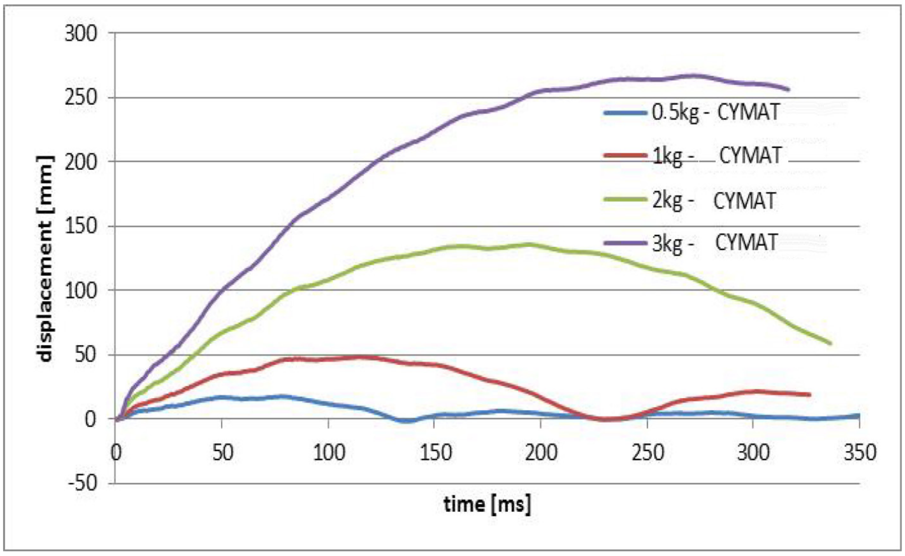


Fig. 4. Displacement of the floor plate for a vehicle with the protection system mounted

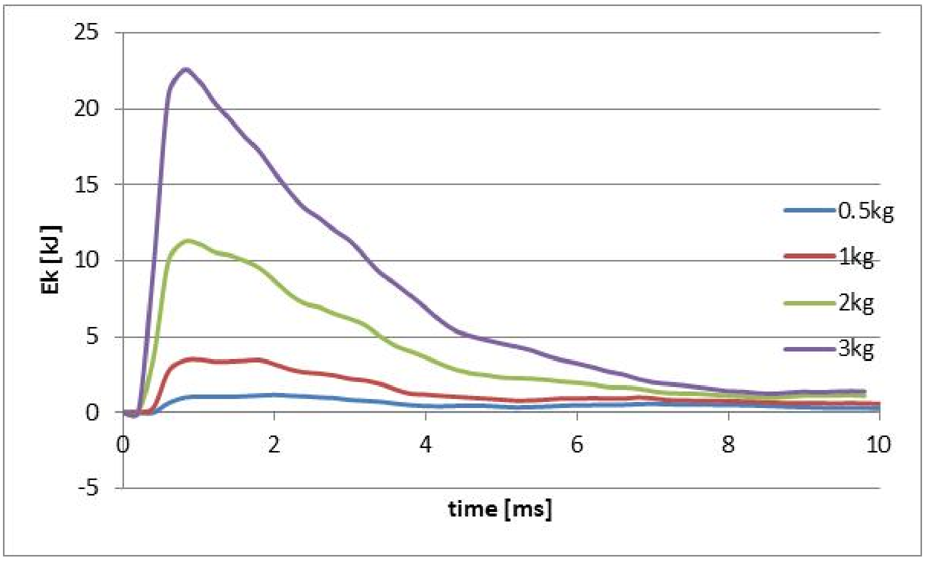


Fig. 5. Kinetic energy of the floor plate for a vehicle without the protection system

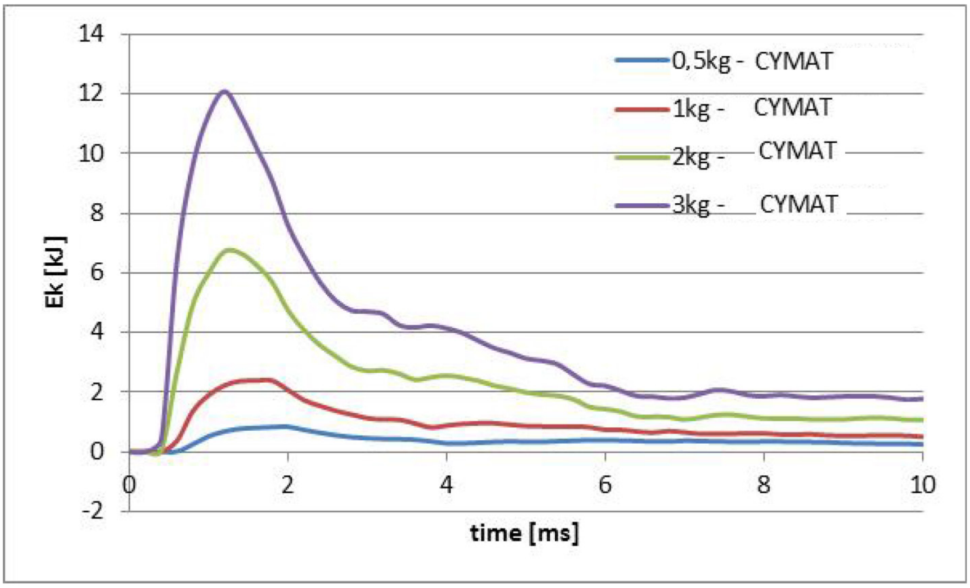


Fig. 6. Kinetic energy of the floor plate for a vehicle with the protection system mounted

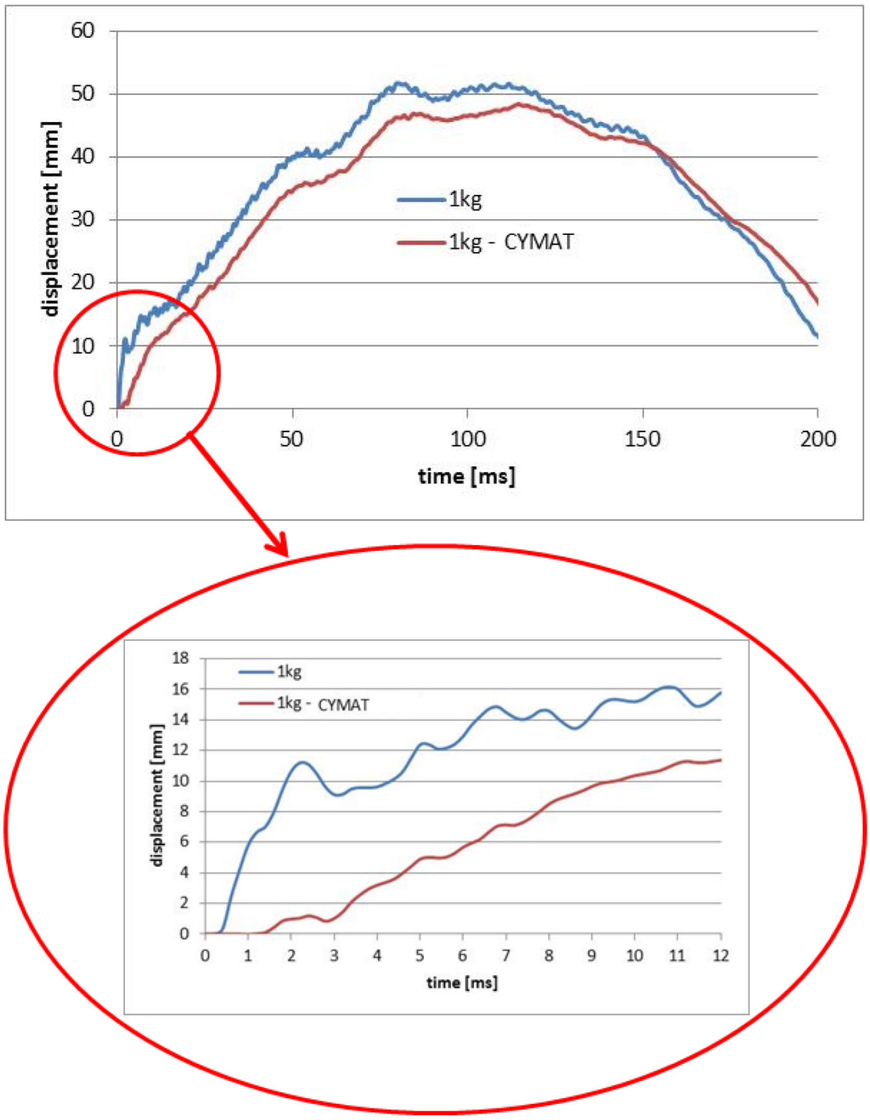


Fig. 7. Acceleration of the floor plate for two cases: with and without the protection system

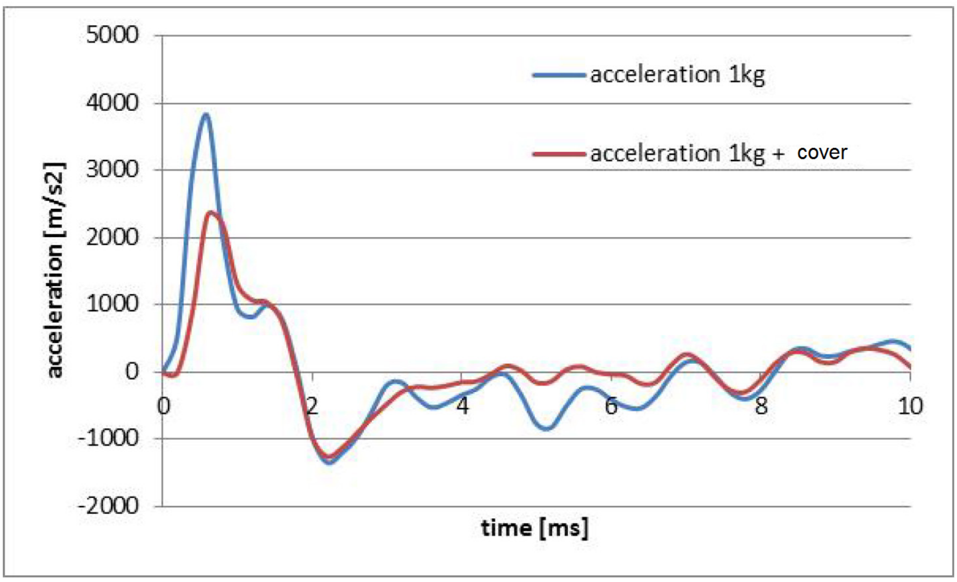


Fig. 8. Acceleration of the floor plate

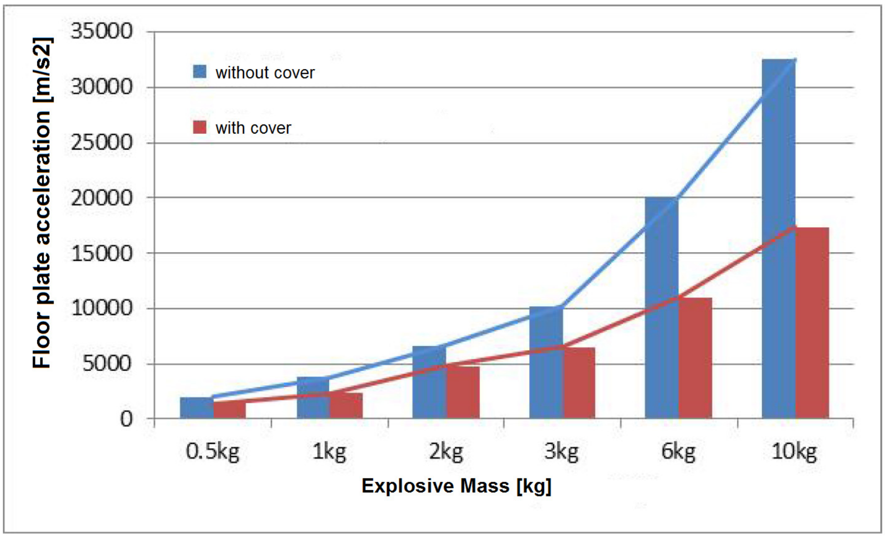


Fig. 9. Comparison of maximum values of acceleration of the floor plate for two cases: with and without the protection system

5. Summary

A methodology for numerical modelling of a shock wave interaction on the vehicle body was developed within the frameworks of the present work. Numerical calculations were carried out for a structure with and without a protection panel. Owing to the calculations, it was possible to verify the effectiveness of the protective panel. The results of calculations allowed formulating the following conclusions:

1. Application of a simple protection system considerably reduces accelerations of the floor plate. Reduction of this value may considerably improve the passive safety of a crew member.
2. The applied protection system reduces a value of an acceleration impulse (Fig. 12), which translates into reduction of an impulse of the force transmitted on the crewmember's lower limbs
3. Positive application of energy absorbing elements is emphasised during interaction of explosive charger over 2 kg of TNT, which is proved by a considerable reduction of acceleration of the floor plate underneath the protection system.

References

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