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# INFLUENCE OF INTERNAL SPACE FRAME IN BODY SHELL ON CHANGE OF ITS RESPONSE AS A RESULT OF IMPULSE FORCING

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***Abstract***

*In order to increase the stiffness anybody chassis in Wheeled Armoured Vehicle on impact of the shock wave, the space frame part in body shell was conducted. The aim of this action is to reduce deformation and damage as a result of the detonation of the mine or an Improvised Explosive Device (IED) under the vehicle. To verify the conducted modernization, numerical calculations of the system response to a blast wave effect were carried out. The mass of the detonated explosive was increased from 6 to 20 kg of TNT. An explosive material was detonated centrally under the vehicle front part according to NATO requirements [1, 2]. The results of the calculations allowed for a deformation assessment of the floor plate and its displacement before and after modernization. A model and numerical calculations were performed using the following software: CATIA, HyperMesh, LS-PrePost, LS-Dyna. CONWEP approach was used to describe an influence of a pressure wave on the structure.*

***Keywords:*** *blast wave, Light Armoured Vehicle (LAV), CONWEP, chassis, space frame, body shell*

## 1. Introduction

The ongoing military conflicts and stability missions over the world show that Wheeled Armoured Vehicles are more and more utilized. Such a vehicle type is characterized by a high mobility and effectiveness in the battlefield. The aforementioned features were achieved due to low mass and a high coefficient of mass to the engine power. Low mass of a vehicle was achieved through applying of space frame in body shell. Such a solution enables adjusting and fitting the vehicle to the battlefield conditions.

Presently, in the armament market, all major companies offering wheeled military vehicles tend to introduce and improve new solutions. For this purpose, to verify new structural solution, preliminary field tests on the simplified body of a wheeled military vehicle were carried out. The tests verified a structure response to an effect of a blast wave originated as a resulted of an explosive material detonation under the vehicle according to NATO requirements [1, 2]. The results of the experimental tests indicated weak points in the supporting structure.

Numerical calculations will be conducted on a modified model of the vehicle with the use of modern calculation methods. The aim of the analyses and calculations is removing weak structural points before further experimental tests.

## 2. Experimental tests

During the experimental tests carried out on the military test field of Tadeusz Kosciuszko 1st Warsaw Armoured Brigade in Wesola, the tests on resistance of Wheeled Armoured Vehicle structure to explosive material detonations under the floor plate (Fig. 1) were conducted. The tested supporting structure was erected as space frame in body shell (combination of anybody and a space frame structure) (Fig. 4). To load the vehicle inside, an additional mass was deployed in the manner ensuring equal pressure on the front and rear axis of the vehicle. The total mass of the vehicle was 8 tonnes.

An explosive material was detonated in the central front part of the vehicle. Mass of the explosive material was from 0.5 to 2 kg of Sentex.

As a result of the conducted experimental tests, an effect of the blast wave caused permanent deformations and damage to the supporting structure. The observed huge deformations of the floor plate were considered to be unacceptable.

Due to the above reason, it was decided to modify the supporting structure through increasing its stiffness.

The most vulnerable joints were the welded joints made with a continuous fillet and a square groove weld (Fig. 2 and 3).


*Fig. 1. Model of a light armoured vehicle structure with a space frame in body shell structure*

a) b)

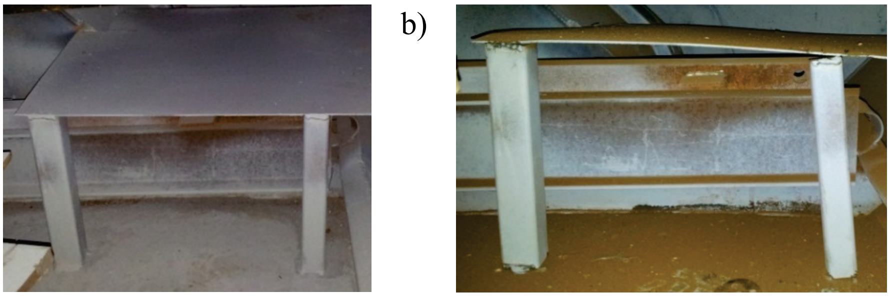

*Fig. 2. a) driver's footstool before experimental tests*
*b) visible deformations of the driver's footstool after experimental tests*

a) b)

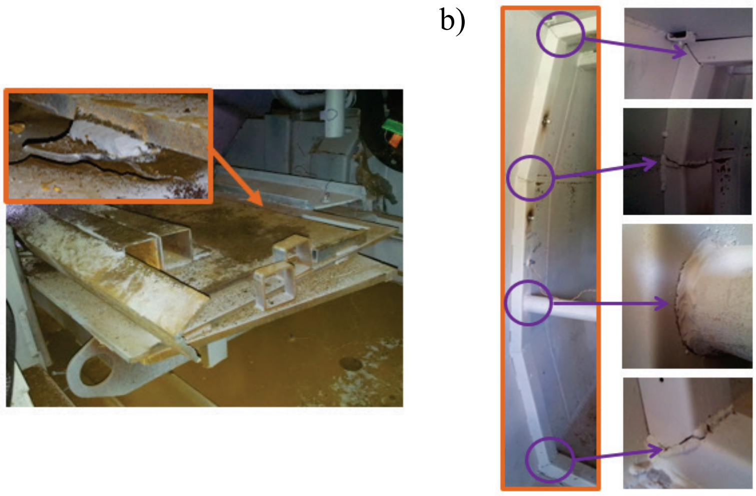

*Fig. 3. Damage inside the vehicle resulting from experimental tests*

## 3. Simplified model of the LAV

In order to eliminate weak structural points (Fig. 2 and 3) and reduce deformations of the floor plate, it was decided to increase the supporting structure stiffness through application of a dense ribbing of the space frame in body shell (Fig. 5). Numerical calculations were conducted on the original and the modified system with the use of LS-Dyna software.

Detonation and loading with a blast wave was realized through using the in-built CONWEP option [3, 4]. This method is based on numerous experimental tests and describes a relation of pressure value of a blast wave incident on the surface to a distance of a charge from this surface. The influence of these factors on the pressure value in the subsequent time intervals is described by relation [5-7]

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

where:

$\theta$ – inclination angle of a pressure wave coming from detonation of an explosive material on the obstacle,

$P_{ref}$ – pressure of an incident wave determined based on the maximum value of the incident wave pressure $P_{ro}$.

$$P_{ref} = P_{ro}\left(1 - \frac{t}{t_0}\right)\theta^{-at/t_0}, \tag{2}$$

$P_{in}$ – incident wave pressure determined based on the maximum value of the wave overpressure $P_{so}$

$$P_{in} = P_{so}\left(1 - \frac{t}{t_0}\right)\theta^{-bt/t_0}, \tag{3}$$

$t_0$ – duration of the overpressure phase,

a, b – decay constants.

For discretization of the model, ELFORM16 -„Ful integrate point" surface elements applied for the vehicle sheathing were used. The rest of the vehicle parts were divided into finite elements with the use of ELFORM1 solid type elements with one point of integration.

Welded joints were replaced with TIDE contact joint blocking the possibility of shift and rotation of the selected nodes in respect to the selected surface. The rest of elements were ascribed with AUTOMATIC_SINGLE_SURFACE contact option. All the aforementioned contact options use a procedure based on the "penalty function" method.

The used material constants are presented in Tab. 1.

The used unit: mm, ms, kg, GPa.

a) b)

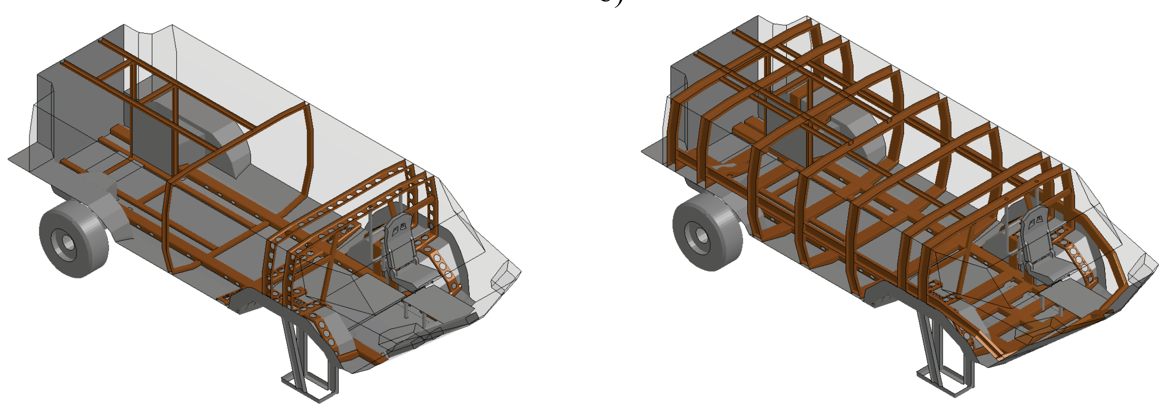

*Fig. 4. View of the supporting structure with a modified suspension system a) supporting structure before modification, b) supporting structure after modification*

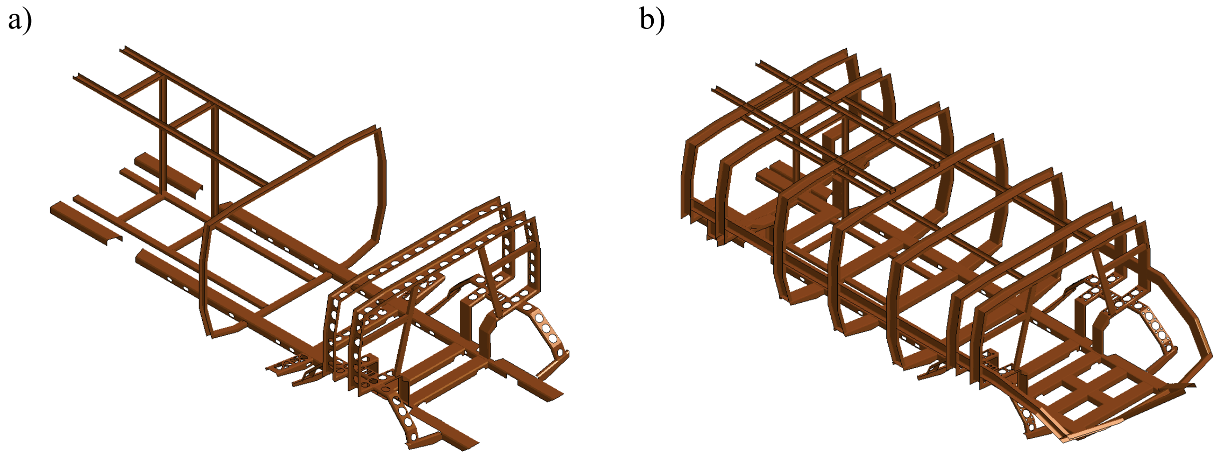


*Fig. 5. System of the internal space frame improving the supporting structure stiffness a) before modification, b) after modification*

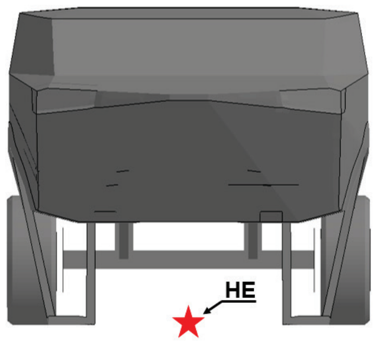


*Fig. 6. Location of the explosive material in respect to the vehicle*

– 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. 1. Material constants for ARMSTAL 500*

| Parameter | Steel |
|---|---|
| Mass density, RO | 7.8e-6 |
| Young’s modulus, E | 210 |
| Yield stress, SIGY | 1.35 |
| Plastic strain to failure, FAIL | 0.8 |
| First effective plastic strain value EPS1 | 0.0 |
| Second effective plastic strain value EPS1 | 0.8 |
| Corresponding yield stress value to ES1 | 1.35 |
| Corresponding yield stress value to ES2 | 1.5 |

Parameters of LOAD_BLAST_ENHANCED option settings:

– Unit conversion flag – EQ.6: kilogram, millimetre, millisecond, GPa
– 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

## 4. Results of calculations

Numerical tests on the effect of a blast wave on the supporting structure verified the results of the explosive material detonation under the vehicle. The mass of the detonated material was increased while observing the displacement and deformations of the floor plate. The results of the conducted numerical calculations are graphically presented in Figs. 7 – 13.

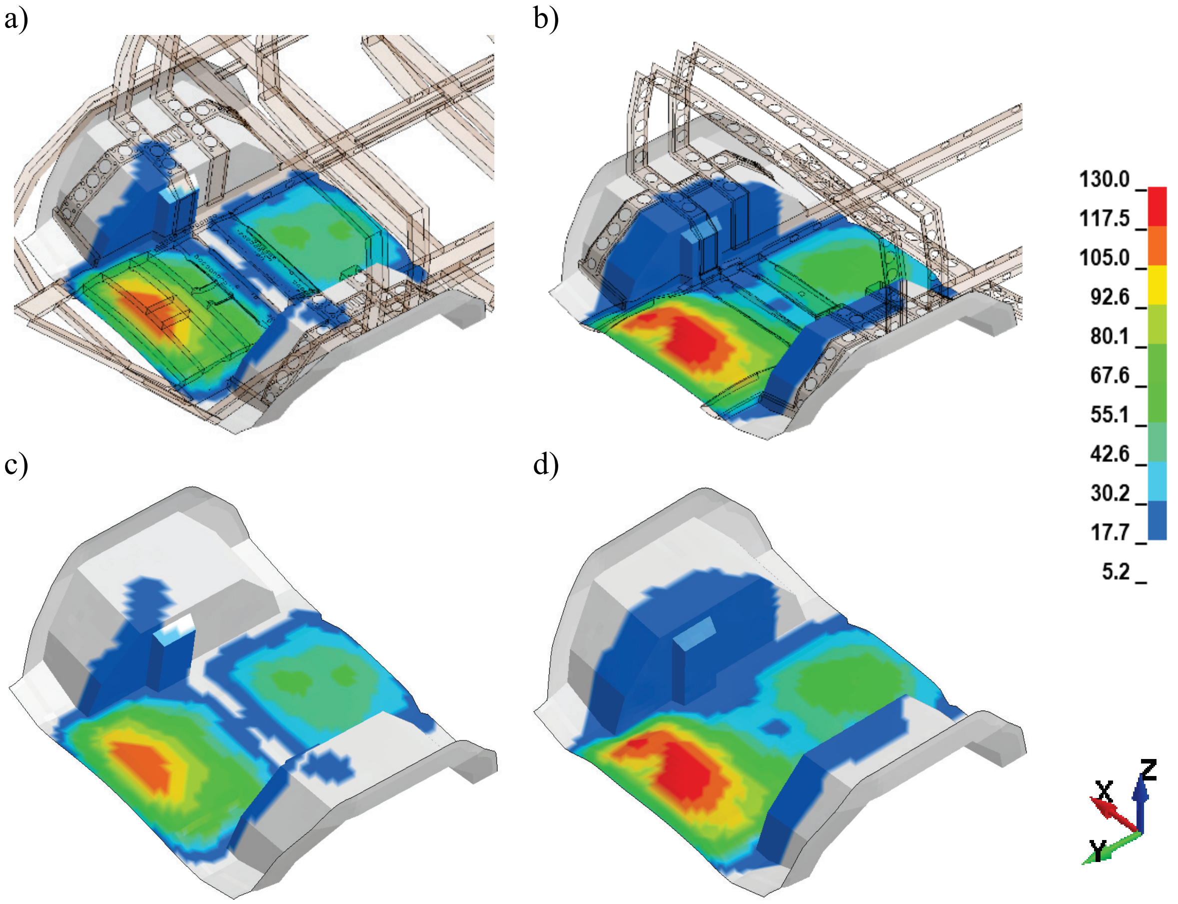


*Fig. 7. Vertical displacement on "z" [mm] of the system for a selected moment of time t = 4 ms. Charge mass 20 kg of TNT a), c) system after modification b), d) reference system (before modification)*

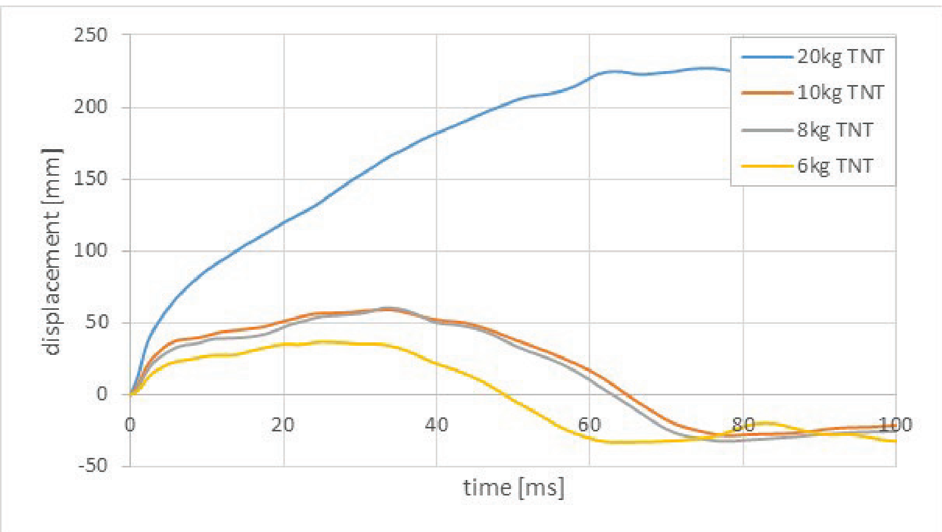


*Fig. 8. Displacement of the floor plate centre of gravity for the reference system (before modification)*

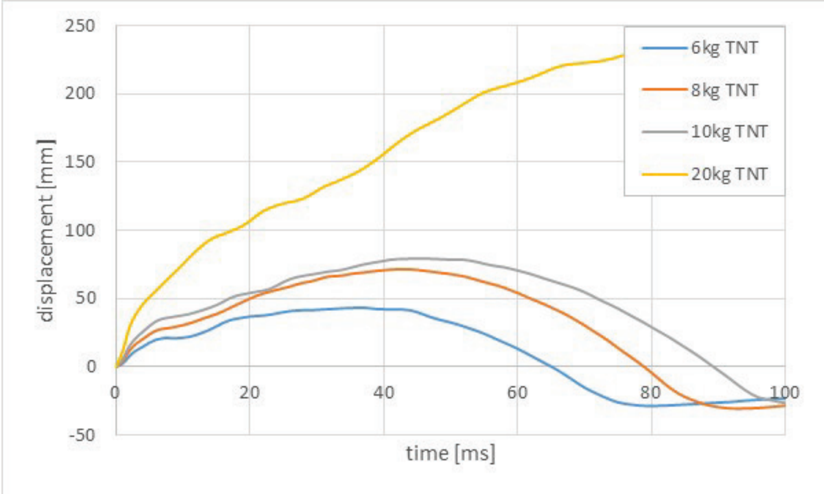


*Fig. 9. Displacement of the floor plate centre of gravity for the modified system*

## 5. Summary

Numerical calculations were carried out for two variants differing with the system of internal ribbing. As a result of modification, a number of ribs were increased improving the structure stiffness (Fig. 5). The mass of the vehicle after modification increased by 1489 kg. Numerical calculations were conducted for two models for the same initial conditions. The results of numerical calculations allowed for formulation of the most important conclusions:

1. Improvement of the structure stiffness allowed reducing the floor plate deformations (Fig. 7).
2. Improvement of the supporting structure stiffness causes an improvement of the impulse transmitted onto the entire vehicle, which results in a greater vertical displacement of the floor plate (Fig. 8, 9).
3. Improvement of a passive safety to injuries of the lower limbs through smaller deformations of the floor plate caused improvement of the impulse transmitted onto the entire system. Such an effect may cause other injuries dangerous to health of the soldier in the vehicle.
4. The improved stiffness of the structure requires additional systems protecting the soldier from possible injuries occurred due to an increase in a value of the transmitted force and acceleration onto the entire system.

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