MODDELING OF IMPACT STRENGH ON COMBAT VEHICLES

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Abstract

In the field of threads to tracked combat vehicle on these days battle field growing importance of wide range of mines. It concern both anti- tank mines – anti-bottom, anti-track, anti-side – as well as specially prepared explosives. In the paper were presented chosen fragment of carried out experimental tests of tank exposed to impact, caused by anti-bottom mine explosion, as well as results of that effect. Methodology how to build models of tested objects were presented. Models of objects that characteristics are similar to typical combat vehicles were tested and test results were linked to publish date and authors test results, then models were loaded. As a load was applied worked out and experimentally verified model of after blast wave propagation, generated by anti-bottom mine explosion, as result of after blast wave propagated in limited space. Conclusions contain information about abilities of presented test methodology. Obtained results of model testing confirm necessity and the possibility of shaping impact strength of armoured vehicles structures. Proper selection of shapes, geometric dimensions and general parameters of structural system may be one of the means to provide proper protection.

***Keywords**: tank, infantry fighting vehicle, carrying structure, anti-bottom mine, model testing*

1. Introduction

Past and present day armed conflicts and local military actions, despite dissenting voices, just verify the fact that tracked armoured vehicles (infantry fighting vehicles and tanks) are and will be the main combat means of ground forces. The main combat features, i.e. fire power, armour, high mobility and autonomy of combat actions decide on their usefulness.

During combat actions (both defensive and offensive), those vehicles are exposed to almost all types of enemy weapons including artillery shells, anti-tank mines, rocket systems and weapons of mass destruction. Vehicle areas, exposed to enemy weapons are presented in fig. 1.1.

Since the dangers lurk everywhere, the armoured bodies of tracked vehicles are shaped in a way providing high survival rate at the battlefield and mechanical strength, considering assumed weight and external dimensions:

- high supporting structure resistance to dynamic loads resulting from movement in any terrain – including overcoming natural and artificial obstacles,
- required resistance to enemy missiles and anti-tank systems,
- effective protection of supporting structure, crew and internal equipment systems against mines,
- geometry and shapes increasing protection of the vehicle interior and providing ergonomic and safe workplace.

Dynamic loads resulting from movement on uneven terrain are excellently minimised by spring and dampening components of the vehicle suspension, smoothening properties of track bands, mechanisms for compensating tension and spring-dampening components used for mounting the equipment sets to the body (monocoque body).

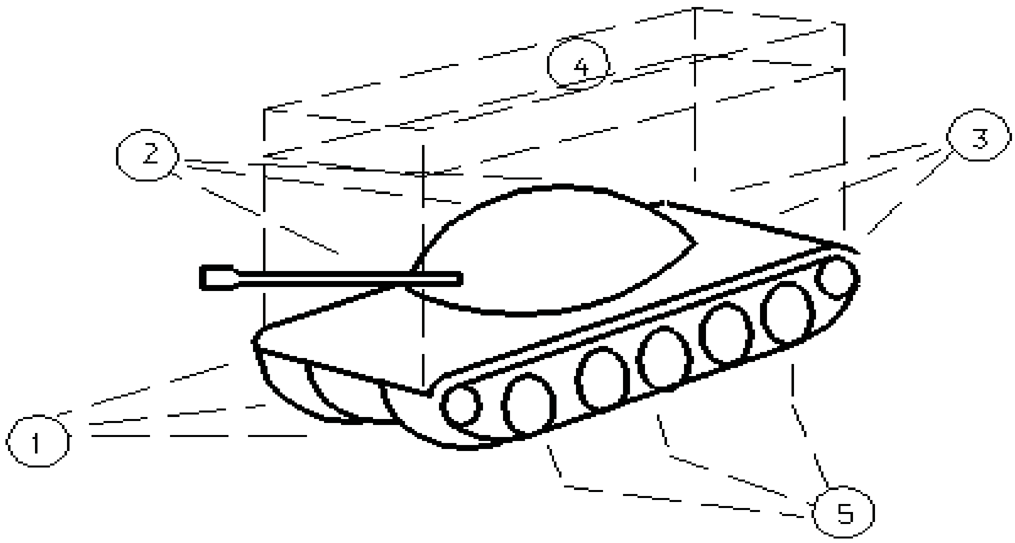


Fig. 1.1 Tank areas exposed to enemy fire: 1 – vehicle's front, 2 – vehicle's sides and track mechanism, 3 – vehicle's rear, 4 – upper part of the body and the turret, 5 – vehicle's bottom

Providing required resistance to enemy weapons depends on protection quality, consisting of passive and active protection. Passive (principal) protection is an armour, multi-layer consisting of steel plates, light alloy, plastic and ceramic elements. Some areas and nodes – at present day technology and material advancement – may be shaped, configured and connected in the required way. Besides specific plates' layers thickness, protective properties are increased by a proper angle. Active protection is a cartridge component with hollow charge, placed at the most exposed area to missile hit or missiles detection and destruction systems before it reaches the main armour.

Body and turret geometry, i.e. its dimensions (height), shape, inclination, etc. are of a great importance for decreasing the probability of detection and destruction or damaging the vehicle armour. Armour piercing does not mean destroying the vehicle interior but it usually causes ammunition explosion or fuel ignition. It is substantiated to distribute the ammunition and operation fluids in special partitions with a single wall, so called weak element (directed outside the crew compartment). This protection is complemented by fast-acting fire and mass destruction weapon protection systems.

Problem arises while creating efficient crew and internal equipment protection against anti-tank mines. Research centres all around the world and armoured equipment manufacturers restrict access to the information about used technologies, methods and means of increasing protection quality, also in relation to so called non-contact mines.

Main striking medium of non-contact mine is a pressure at the face of post-explosion shock wave. Shock wave hitting the obstacle (bottom of the armoured vehicle in this case) causes deformation that disturbs technological bases, eliminating the vehicle from further operation. Mines of this type are also called "humane" since their main striking medium - post-explosion shock wave - does not directly affect the crew of the armoured vehicle.

Photos from experimental tests of non-contact mine impact on an armoured vehicle, detonated under its bottom at the typical, unhardened surface are presented in fig. 1.2. The damage caused by this type of mine to the internal equipment of tested object is presented in fig. 1.3.

Presented effects of mines show that research of those effects and development of body structure considering the resistance increase to such strains, and as an effect, increase of survival rate at the battlefield must be constantly continued.

Especially research using computer technology, providing possibility of testing various versions at relatively low cost is important. This type of research requires co-operation of interdisciplinary research teams.

Fig. 1.2. Explosion of non-contact ground mine under the object (photo P.R.)

a) b)

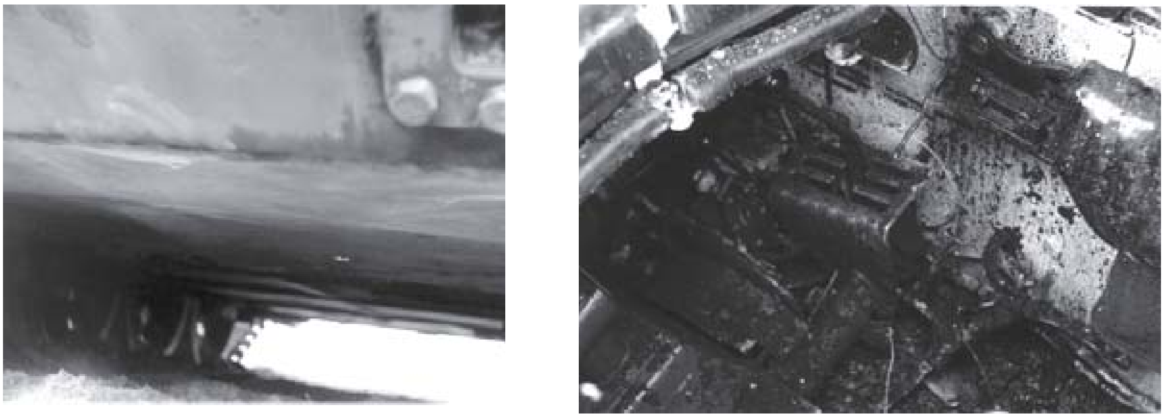


Fig. 1.3. Result of non-contact ground mines impact on armoured vehicle a) vehicle's bottom deformation, b) damage of internal equipment (photo P.R.)

2. Model testing

Model testing of armoured vehicles resistance to impact strain have been performed based on the assumption that the source of the structure strain is a non-contact anti-tank ground mine explosion. Main test purpose:

- assessment of armoured vehicle supporting structure strained with ground mine explosion strength,
- assessment of influence of selected parameters and structural components on armoured vehicle supporting structures' strength,
- indication of weak nodes of the supporting structure and possible directions of increasing internal equipment and crew protection level,
- improvement of numerical tests methodology for structures being the subject to the impact strains.

2.1. General problem formulation

The problem has been formulated in a following way: Shock wave generated at any point of space propagates in the gaseous medium (air) and influence the encountered object. It is assumed that the resulting structure strain does not cause permanent (plastic) strain, and the deformation may be pondered within the frameworks of small relocation theory.

2.2. Load model

Shock wave is an irregular (not constant) change of state parameters (density, temperature, pressure) and speed propagating with supersonic speed in the material medium. During strain model preparation it was assumed that the shock wave formed during explosion propagates in all directions and impacts only the body's bottom. Due to small distance from the vehicle's bottom to the ground it is a subject to repeated reflection from specified surfaces. Moreover:

- pressure acting on tested object may be determined, regardless of the object's reaction to the action;
- tank's bottom surface consists of a series of connected flat components of a different size,
- for analysis of shock wave reflection from tank's bottom, local theory of slanting shock wave reflection from rigid partition has been used.

For accepted assumptions, mathematical strain model, describing multiple impacts of post-explosion shock waves at the body structure has been developed and introduced into WAT-KM computational system. Detailed strain model description is included in items [1, 2, 3]. Sample space-time characteristics of a pressure at the shock wave face for small and large distance from the explosion epicentre are presented in fig. 2.1.

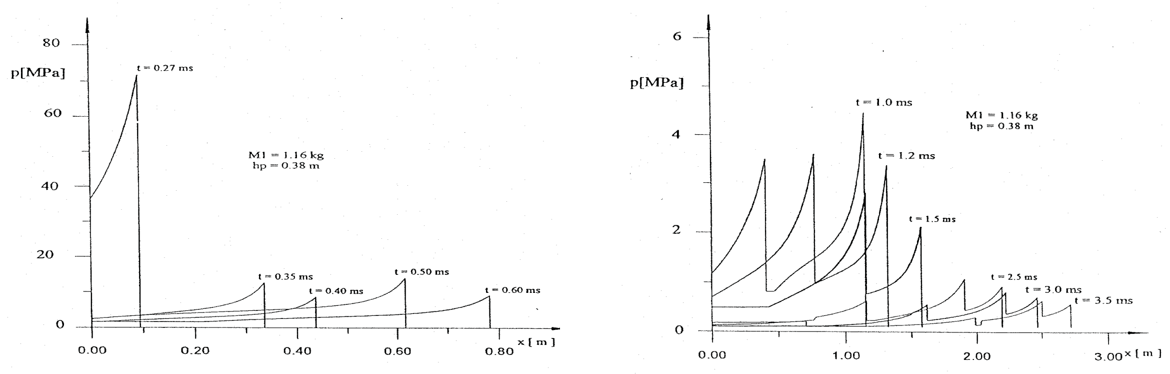


Fig. 2.1. Sample space-time characteristics of a pressure at the shock wave face for m_{MW}=1.16 kg TNT (for small and large distance from the explosion epicentre)

2.3. Test object's models

Tests have been performed at hypothetical objects, which external dimensions, geometry and general structural configuration resembled armoured fighting vehicle and modernised tank. Accepted assumptions that simplify the structure and characteristics of used material do not identify models with any real object. Shapes of objects accepted for tests are presented in fig.2.2.

Test objects' structure digitisation has been performed basing on finite factors method using relocation expression in modified WAT-KM system. Main assumption accepted during the building of computational vehicle models was to copy their main units and their interaction. The following partial models can be distinguished in prepared objects' models.

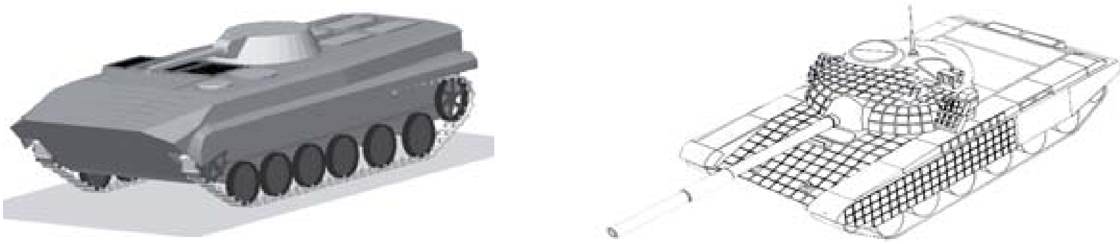


Fig. 2.2. Test objects' shapes

– body bottom,
– monocoque body (body with turret),
– vehicle's suspension (torsion shaft with rockers and fluid springs),
– power transmission system and internal equipment components,
– drive system (direction wheels, sprockets and sections of upper and slanting track branches).

Considering assumed test purpose, special attention has been paid to the body bottom of tested vehicles. It has been prepared with coating and bar components, copying its complex geometry, stiffening reinforcements (fins, brackets, frames) and non-deformability of edges relative to body structure. Vehicle body with a turret has been treated as a rigid solid with specific mass, moment of inertia and precisely specified centre of inertia. Discrete models of each unit have been prepared using deformable and rigid finite components and massless springs (dampening or springy-dampening). Characteristics of used components have been selected to copy the most significant object's dynamic features (mass distribution, rigidity, moment of inertia). The following assumptions have been made:

- vibrations are analysed in space, i.e. body (rigid solid) has six degrees of freedom (three translation and three rotational degrees),
- small vibrations round the stable equilibrium position are anticipated,
- pressure change inside the armoured vehicle is omitted,
- springs have linear characteristics,
- dampening forces are proportional to the speed (viscous dampening model).

For accepted assumptions (small relocation at the resilient range), all structure components' characteristics are linear. Discrete model equation of motion is a matrix differential equation of the second grade with constant coefficients.

$$Mq + Cq + Kq = f(t) \tag{2.1}$$

where: **M –** discrete model inertia matrix,
C – dampening matrix,
K – rigidity matrix,
q – vector (single column matrix) of general relocation of model nodes, and
f – vector of external forces reduced to the model nodes, with data generated by strain model.

Test objects' models – supporting structure of armoured vehicles with division to components - are presented in fig.2.3a, b.

For developed objects' models at the first stage, problem of characteristic values has been solved. Obtained results show that the basic parameters, dynamically characterising test object (free vibrations frequencies and related vibration shape), correspond to the range and form specified in the literature for this type of vehicles, proving the construction correctness. Data accepted for verification are listed in table 2.1. Sample forms of basic free vibrations of infantry fighting vehicle are presented in fig.2.4.

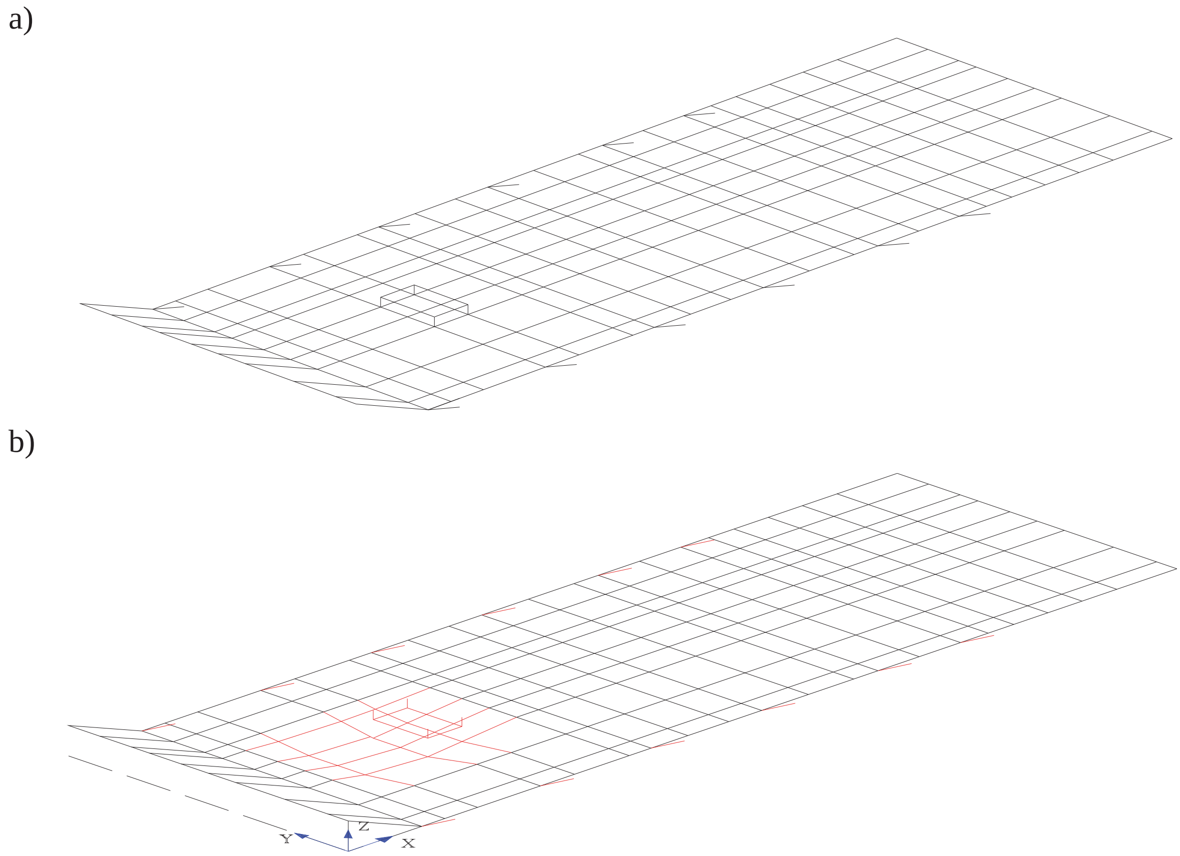
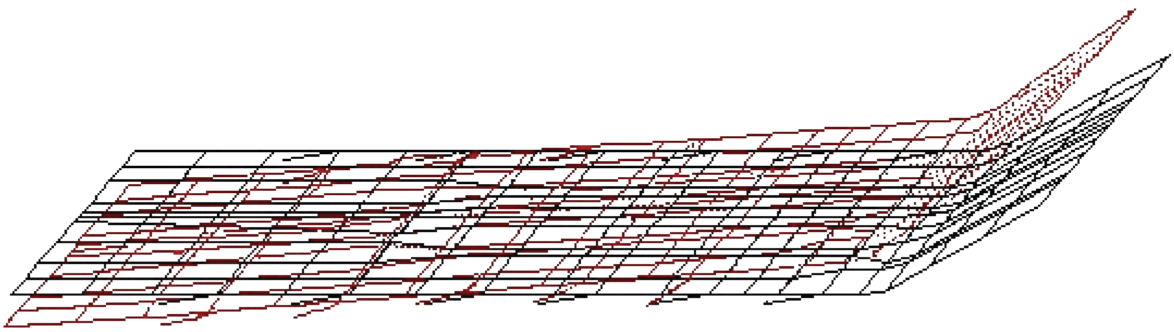


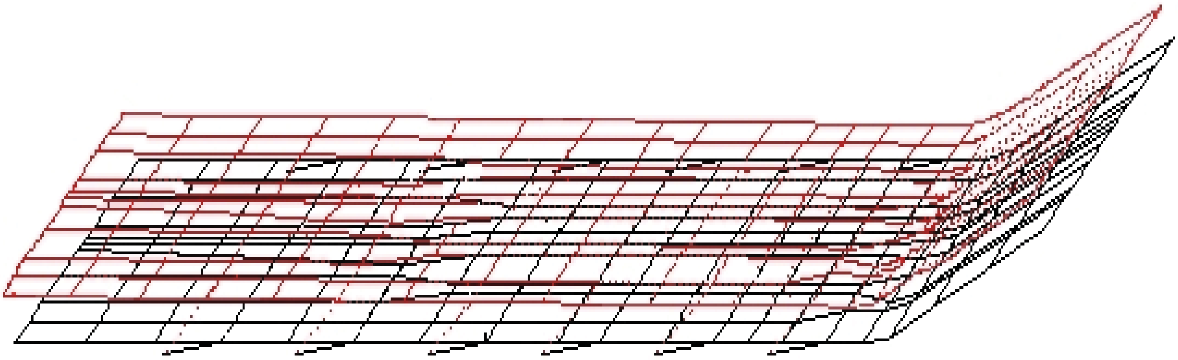
Fig. 2.3. Vehicles' models with division into components: a) infantry fighting vehicle, b) modernised tank

Table 2.1.Main frequencies of free vibrations for tested models

Vibration frequency body of a tanks	**Infantry fighting vehicle**	**Modernised tank**	**Literature data**
horizontal	0.63 Hz	0.87 Hz	0.6 -1.0 Hz
verticals	1.20 Hz	1.56 Hz	1.2 - 2.0 Hz
seat of driver	_	2.51 Hz	2.3 - 2.6 Hz



I shape



II shape

Fig. 2.4. First (I) and second (II) free vibrations form for infantry fighting vehicle model

2.4. Model testing results

2.4.1. Infantry fighting vehicle

Based on the developed strain model, are listed in table 2.1, calculated pressure values at the face of shock wave, hitting the armoured fighting vehicle a several centimetres from the explosion source.

Table 2.2. Sample pressure values at the front of a shock wave

Item	Mine symbol	Explosive weight [TNT] [kg]	Clearance [m]	Pressure [MPa]
1.	PMD-6M	0.2	0.37	~ 8.0
2.	Test charge	0.75	0.37	~ 48.0
3.	MON- 100	1.73	0.37	~ 84.0

During calculations, time courses of relocation of the following nodes have been recorded:

– node over the explosion epicentre at the first wheel level (node no. 73);
– node over the explosion epicentre at the sixth wheel level (node no. 193);
– node of the vehicle's centre of inertia (node no. 1).

Maximum values of analysed nodes relocation, for selected explosives, are presented in table 2.3.

Table 2.3. List of maximum relocation of selected nodes

Node no	Node relocation [cm]					
	m_{MW}=1,73 kg TNT		m_{MW}=0,75 kg TNT		m_{MW}=0,20 kg TNT	
	A	B	A	B	A	B
1	-0.32	1.03	-0.20	0.51	-0.05	0.29
73	9.68	2.53	6.00	1.46	1.61	0.48
193	2.16	18.16	1.27	11.29	0.32	2.89

A – explosive at the first wheel level; B – explosive at the sixth wheel level;

Sample course of relocation for one of the analysed points of vehicle's supporting structure is presented in fig. 2.5. Time course of reduced stresses, determined based on Huber hypothesis, for one of a structure coating components located over the explosion epicentre is presented in fig. 2.6.

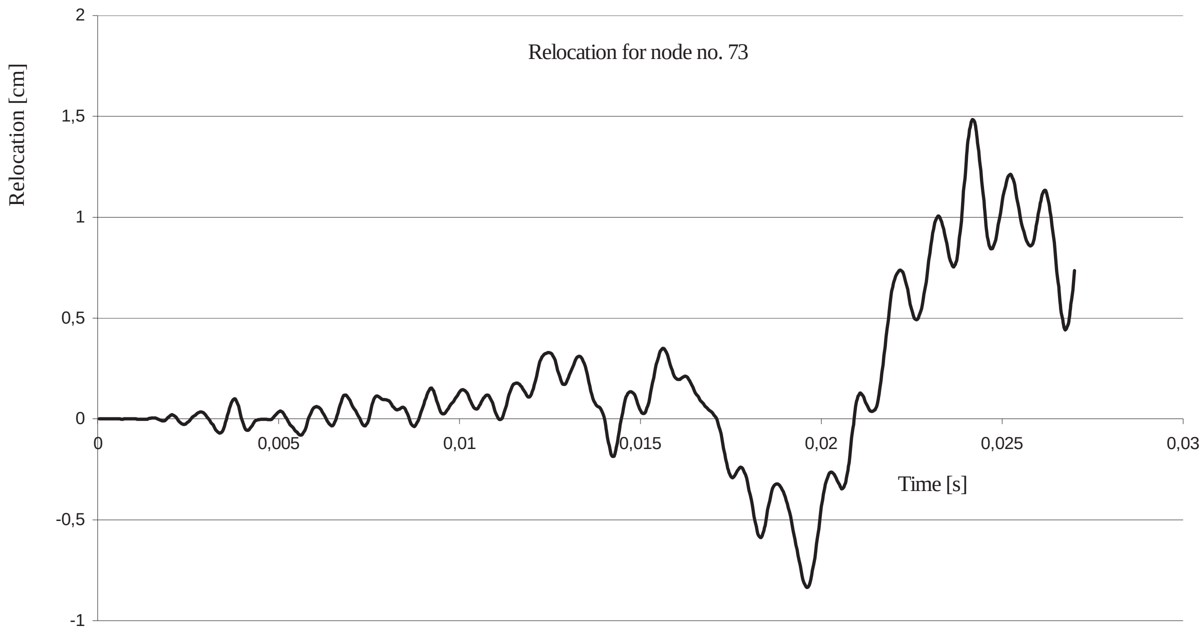


Fig. 2.5. Time course of relocation for one of the structure nodes

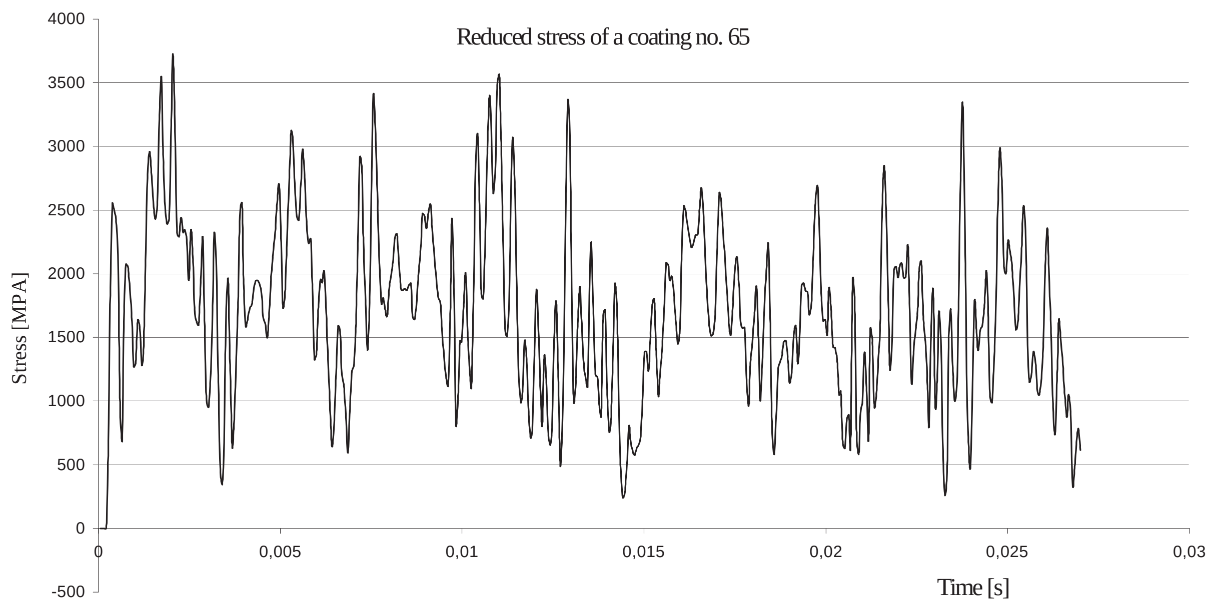


Fig. 2.6. Time course of reduced stresses for one of a structure coating components

2.4.2. Modernised tank

Modernised tank model has been exposed to a shock wave pressure generated by the explosion of ground mine of accepted parameters (explosive weight, clearance). Maximum values of substitute stresses, calculated based on Huber hypothesis for strain versions specified in the table are presented in table 2.4.

Table 2.4. List of maximum stresses reduced at the examined structure areas

Analysed area	**Maximum value of stresses reduced in the tested area [MPa]**				
	m_{MW} = 1.16 kg TNT			*m_{MW} = 2.32 kg TNT*	*m_{MW} = 4 kg TNT*
	Explosive location at the area				
	A	B	C	A	A
at the first wheel level (A)	510	X	X	982	1344
at the area of the mechanic-driver seat (B)	X	420	X	X	X
under the drive compartment (C)	X	X	491	X	X

For the strain version with explosive weight of m_{MW} = 1.16 kg TNT, located under the node in the area of mechanic-driver seat, course of bottom plate straining is presented in the fig.2.7.

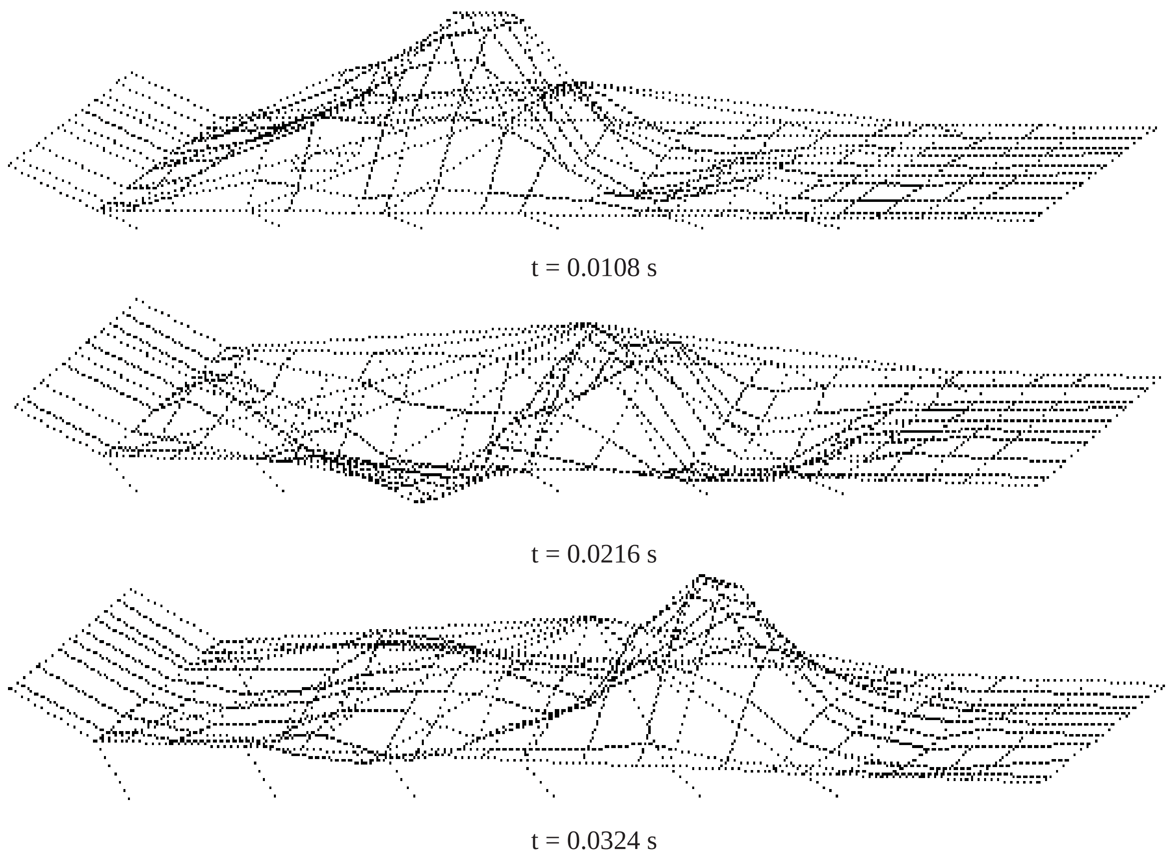


Fig. 2.7. Propagation of plate straining wave in time – strain version B

3. Conclusions

Body construction analysis of basic tanks used by some of the countries showed that the bottom plates are inclined relative to side platelet at a specific angle, with clearances ranging from 35 cm to 60 cm - fig. 2.8.

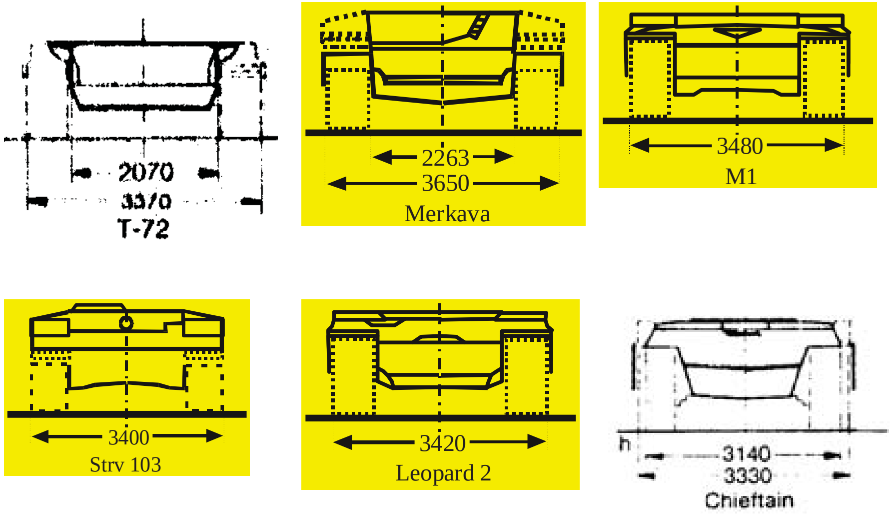


Fig. 2.8. Modern tanks' body section profiles

Authors of the analysis realise that the shape and configuration of armoured plates does not provide effective protection for the crew and internal equipment, but may increase the survival rate. It would be a good protection solution to place the crew and advanced systems inside the cabin made of materials with high mechanical and thermal strength, insulated from the ammunition and fuel.

Obtained results of model testing confirm necessity and the possibility of shaping impact strength of armoured vehicles structures. Proper selection of shapes, geometric dimensions and general parameters of structural system may be one of the means to provide proper protection.

Developed model testing methodology provides:

- determination of pressure distribution along tested structure surface, being the basis for structure strain calculation,
- assessment of armoured fighting vehicle's body and other constructions impact strength,
- specification of impact effects at the design or modernisation stage of vehicle's supporting structures and other technical objects,
- defining types of armoured vehicle body damages and approximate assessment of the repair possibilities,
- design and modernisation of armoured vehicle's supporting structure with increased impact strength.

References

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