EXPERIMENTAL STUDY ON BLAST EFFECTS UPON SMALL SCALLE STRUCTURES

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***Abstract**: This paper includes a small-scale experimental and numerical study on the blast wave effects upon different configurations for vehicles floor. A number of metal plate structures are studied for identifying the optimal geometric configuration which can mitigate the effects of the explosion by shock wave deflection. The results validate the small-scale test procedure and indicate that the V-shaped plate attenuates up to 32% the momentum transferred to the structure.*

***Keywords**: scaled structure, blast effect, geometric shape, attenuation.*

1. Introduction

Previous generation of military vehicles for both transporting troops and fighting had a simple design with floor heights not exceeding 500 mm and were made of military steel grade, a solution that doesn't have the ability to support mines and IEDs action.

Currently, most of the solutions applied to military vehicles use greater floor heights and double floor, obtaining in this way a larger distance between the crew space and the ground, and an exterior floor in V or partially V shape. Also, as an alternative to the V shape, the potential of curved shape plates have been studied [1].

The measure that has been taken - to utilize the doubled floor- allows decoupling movement of the exterior floor from the interior one. As long as they are not going in contact to each other or the parts between them (transmission

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parts) are not propelled into the inside floor, the accelerations undergone by inside floor are diminished.

The other two measures, heightening the entire vehicle and changing the exterior shape have reduced the impulse applied to the vehicle by increasing specific Z number - the heightening of vehicle - and the reduction of floor reflected pressure and of the gases action time on the floor- the changing of floor shape. Tests showed that a structure in V can reduce by 50% the pulse comparatively to a flat plate for the same Z [2].

The great disadvantage of these two measures is that heightening the entire vehicle will affect the ability of not being spotted on the field and also the mobility, especially on rough ground. This makes the protection measures against land mines to increase vulnerability to other threats (amour piercing projectiles, missiles or rocket propelled projectiles).

A comprehensive test of a vehicle, as provided by NATO standards, is a costly operation that involves expensive equipment and material resources which imposed the introduction of intermediary stages in practice: simple tests, small-scale tests and numerical simulations.

An intermediate stage of testing is also the subject of this paper, namely the development and implementation of a test procedure for experimental research at a scale of 1: 6, regarding the blast wave effects of an explosive charge in accordance with STANAG 4569 Level 3B, on new configurations for military vehicles floor, performing missions in theaters of operation [3].

The blast wave effects on a military vehicle are highlighted by the study of the interaction of a shock wave and a structure of plate type, representing its floor.

2.Experimental part

2.1 Test set-up

The research was conducted in the Army Experiences Range from Jegălia. Test program aims the estimation of the effectiveness of a mitigate shock waves system for four geometric configurations of OL50 steel grade plates: standard plate, standard plate with quadrilateral pyramids attached in the center, V-shaped plate with 120° peak angle and semi-elliptical shape plate.

The final dimensions resulted from scaling process [1] are shown in the following table.

Table 1.

The results of the scaling process

Parameter		Real model	Scaled model
Linear dimensions of the structure for the floor plate	Lenght	6000 mm	1000 mm
	Width	1200 mm	200 mm
	Thickness	12 mm	2 mm
The distance between the ground and the plate (ground clearance)		850 mm	141,6 mm
Total mass		10985 kg	50852,4 g
Explosive charge		8 kg TNT	30 g C4

Testing configurations for floor are presented in Figure 1.

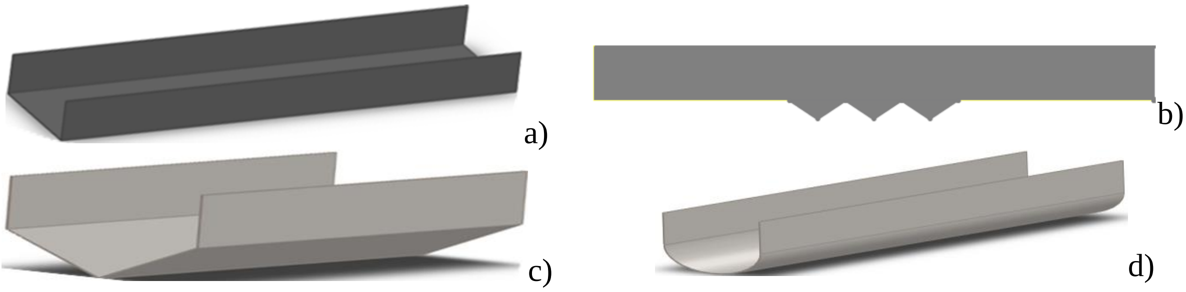

Figure 1. *Standard plate (a), standard plate with quadrilateral pyramids attached in the center (b), V-shaped plate with 120° peak angle (c), semi-elliptical shape plate (d)*

The instrumentation tests was performed with a high speed video camera and an acquisition and measuring system for signals recorded by accelerometers and pressure transducers.

In Figure 2 is presented the fully equipped test set-up. The explosion phenomenon surprised with the high speed video camera is illustrated in Figure 3.

Figure 2. *Experimental set-up*

Figure 3. *Capture from explosion testing*

1.2 Experimental observations

After test performances, there is studied how the plate shape affects the impulse transferred to the vehicle by the shock wave and gaseous products deflection. In Figure 4 is showed the pattern response of plates tested at blast wave.

a) b) c) d)

***Figure 4**. Blast wave effects upon: standard plate (a), standard plate with quadrilateral pyramids attached in the center (b), V-shaped plate(c), semi-elliptical shape plate (d)*

3. Numerical Simulation

Numerical simulation of experimental tests consisted in defining geometries, meshing surfaces, assigning constitutive models of material to discretized elements and imposing initial and boundary conditions. The simulation was performed with finite element method using AUTODYN solver (Ansys Workbench 11.0) for a test duration of 40 ms (Figure 5).

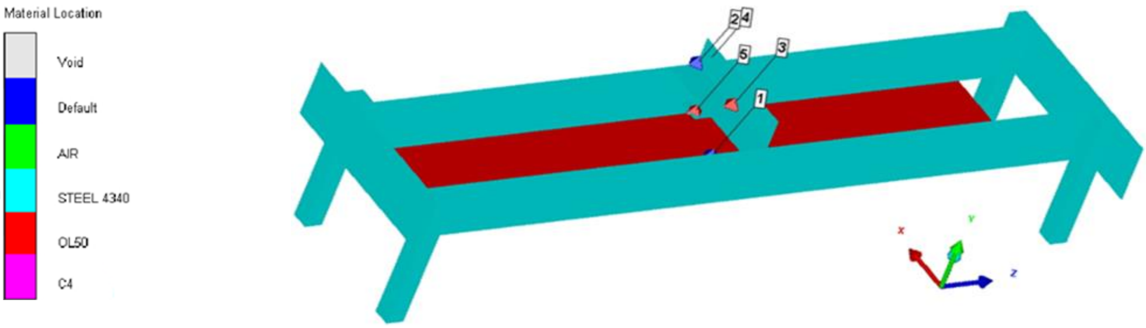

***Figure 5**. Test set-up and position of transducers for set tests no.1*

Propagation and interaction of shock wave with the four studied geometries of the metal plate is shown in Figure 6.

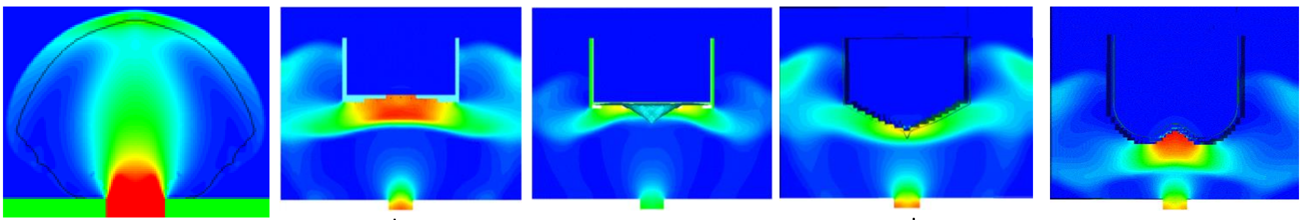

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***Figure 6.** Shock wave evolution: formation and propagation of incident wave (a), formation of reflected wave at the interaction with the plate at t = 0.07 ms in the 3D model for: standard plate (b), standard plate with quadrilateral pyramids attached in the center (c), V-shaped plate with 120° peak angle (d), semi-elliptical shape plate (e)*

4. Results and discutions

After performing experimental tests and numerical simulations with AUTODYN solver, there was conducted a comparative analysis of the results obtained by the two methods to evaluate the proposed solutions for testing, shown in Table 2.

Table 2.

Analysis of tested solutions

		Experimental Test		Numerical Simulation		Jump height (m)	**Attenuation (%)**
Test set	Test no.	Speed (m/s)	Impulse (kg·m/s)	Speed (m/s)	Impulse (kg·m/s)		
Set1 (Standard plate)	1	1,712	78,886	1,736	79,7	0,149	**1**
	2	1,695	78,097				
	3	1,729	79,675				
Set 2 (p. with pyramids)	1	1,703	78,708	1,727	79,5	0,147	**0,99**
Set 3 (V-shape plate)	1	1,153	53,663	1,169	54,24	0,067	**0,68**
	2	1,154	53,717				
	3	1,191	55,8101				
Set 4 (s.-e. shape plate)	1	1,507	70,829	1,528	71,58	0,115	**0,898**

The correspondence between results has confirmed the validity of the testing procedure at small scale (1: 6) and has validated the experimental activity and the development of appropriate numerical models.

The tests for a new geometries indicates that a V-shaped plate has a better behavior than the other three solutions (standard solution, standard plate with quadrilateral pyramid attached to the center and the semi-elliptical shape plate), resulting in a 32% attenuation of the pulse transferred to the structure.

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References

[1] P. KUMAR, J. LEBLANC, D. S. STARGEL, A. SHUKLA, *Effect of plate curvature on blast response of aluminum panels*, International Journal of Impact Engineering No. 46, pp. 74-85, 2012.

[2] S. CHUNG KIM YUEN, G.S. LANGDON, G.N. NURICK, E.G. PICKERING, V.H. BALDEN, *Response of V-shape plates to localized blast load: Experiments and numerical simulation*, International Journal of Impact Engineering No. 46, pp. 97-109, 2012.

[3] STANAG 4965 *"Protection Levels for occupants of Logistic and Light Armored Vehicles*".

[4] F. BUCUR, *Contributions to improve protection factor of military vehicles armor* - PhD thesis, Bucharest, 2015.