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NUMERICAL EXPLICIT ANALYSIS OF ABSORBING MATERIALS USED IN MULTILAYER MINE PROTECTION

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Abstract: *An interaction of the blast pressure wave after detonation of a blast mine under the multilayer mine protection mounted on a military vehicle is described in this project. The main focus was applied to absorbing capability of the multilayer sandwich. Results from numerical simulations were compared with experimental tests. The test procedure is provided according to STANAG 4569/AEP-55 standard with threat level 3B. The main armor material, aluminum, enables high local plastic deformation and high global deflection of the plate. The aluminum foam layer increase an absorption capacity of the armor assembly against a surface attacks. The material crushable foam was used for the aluminum foam layer modeling. Soil, air and explosive were modeled using Euler type FEM grids. Not only deflection, but also stress and strain values were evaluated over all multilayer plates. The residual deflection presents good correlation between the simulation and test. The main goal of this project was to develop a multilayer armor that is able to protect a typical military vehicle against the 8 kg TNT blast mine. It was achieved by a combination of an aluminum base armor, aluminum foam, a glass fiber laminate and ballistic steel sheet.*

Keywords: ANSYS, Explicit Analysis, Mine protection, Blast load, LS-Dyna.

1. Introduction

The present time is bringing wide range of terrorist attack forms. One of them, mine explosion under a military vehicle, was a subject of investigation in this project. The numerical simulations described in this paper investigate an interaction of the blast pressure wave after detonation surrogate charge under the multilayer mine protection mounted on that vehicle. Especially the absorbing capability of the protection was investigated. An influence of the aluminum foams was gratefully noticed. The results from numerical simulations were compared with results from experimental tests. One of objectives of this work was to validate material parameters and numerical simulation setup that is able to describe mentioned mine test. In future this procedure will be applied in the next step of analysis, design of a military vehicle protection.

2. Problem Description

This test represents an attack of the blast mine to the sandwich armor plate (Rolc, 2007 and 2008). The sandwich is mounted on the vehicle from a bottom side. The mine is placed in the soil ground. The test is provided according AEP-55 standard with threat level 3B. Whole experimental equipment (stand) was modeled with regards to correct loading and boundary conditions application.

The related standard AEP-55 level 3B prescribes for an armor testing a blast effect of a surrogate charge placed under the center of tested armor. The reference mass of explosive was to be adjusted to 8 kg of TNT. The mine was placed in sand ground 100 mm under surface of the soil (dimension was measured from the top of the mine casing). Dimension between ground and bottom area of the armor (ground clearance) was prescribed about 450 mm.

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The experimental equipment (stand) in Fig. 1 represents a mass of the protected vehicle. The analyzed assembly consists of four plates: ballistic aluminum, aluminum foam, glass fiber composite and ballistic steel.

Fig. 1: Experimental equipment – stand and testing plate.

The geometry of the stand and testing armor were modeled in complete 3D space with two planes of symmetry (only one quarter of the system has been modeled). The FE model in Fig. 2 was created according related 3D CAD drawing. Analyzed armor was modeled as a sandwich plate.

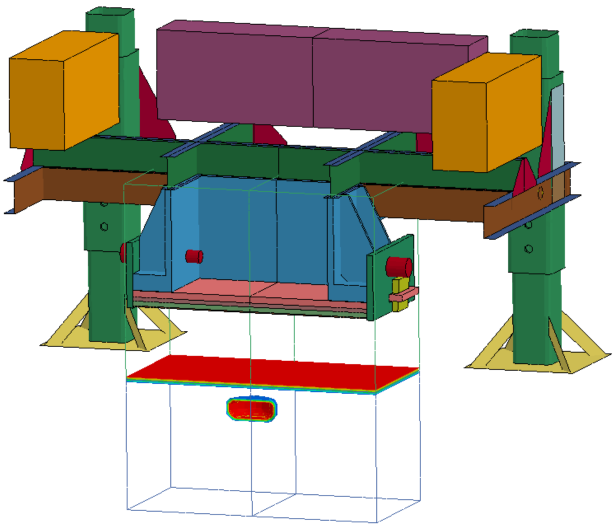

Fig. 2: Numerical model of the equipment.

All of the components in the experimental device were modeled using Lagrange type FEM grids. Also all of the stand components were modeled using material equation Johnson-Cook. Johnson and Cook (Buchar, 2003) express the flow in material model as

$$\sigma_y = (A + B\varepsilon_p{}^n)(1 + C \ln\dot{\varepsilon}^*)(1\text{-}T^{*m}) \quad (1)$$

where **A, B**, **C**, **n** and **m** is input constants, $\boldsymbol{\varepsilon_p}$ is effective plastic strain,

$\mathbf{T}^*$ is homologous temperature = $(T - T_{room})/(T_{melt} - T_{room})$.

The material crushable foam from LS-DYNA database was used for the Aluminum foam layer modeling. This material is dedicated to modeling crushable foam with optional damping and tension cut-off. Unloading is fully elastic. Tension is treated as elastic-perfectly-plastic at the tension cut-off value. The volumetric strain is defined in terms of the relative volume, **V**, as:

$$\gamma = 1 - V \quad (2)$$

The relative volume is defined as the ratio of the current to the initial volume.

Soil, air and explosive in this numerical analysis were modeled using Euler type FEM grids.

3. Mine Protection Results

The initial models supposed a plastic deformation of the armor sandwich with high deflection but without any significant rupture of plates. However this assumption had to be revoked. The front cover plate in simulations was damaged in whole thickness in many armor simulation variants, see Fig. 3. Moreover the main aluminum armor presented some partial crack too. The failure model and elements eroding were added to the material properties.

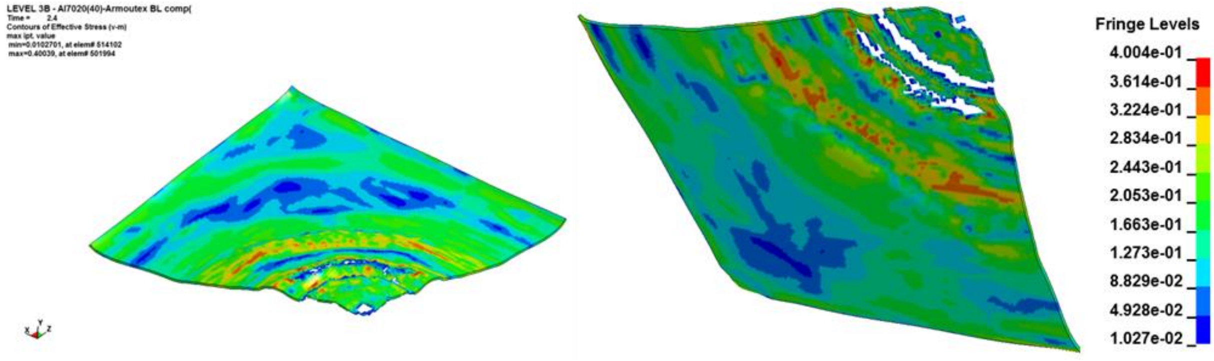

Fig. 3: Effective Stress on the front aluminum cover plate.

The main result from a simulation, residual armor deflection, was decreased in a few simulation steps about 35% to 78 mm in the plate center.

Apart from that also stress and strain values were evaluated over all multilayer plates. The main armor material, aluminum, enables high local plastic deformation and high global deflection of the plate as well.

The aluminum foam layer increase an absorption capacity of the armor assembly against a surface attacks.

Some local areas on the base armor exceed a limit strain 8%. It can cause a failure on the base armor around the stand fixing edge. This was confirmed in a real test.

4. Verification of the Numerical Simulation in Real Tests

The real tests of the armor assembly were performed in two parts. The first test was done after some first simulation in order to agree a numerical model and all his parameters. The second test round was done after a few steps of numerical simulations due to verify the final optimized multilayer armor configuration.

The first comparison between the real test and numerical simulation presented next difference in the residual deflection – Tab. 1.

Tab. 1: Measurement versus simulation comparison.

	Measurement	FE simulation	Difference [%]
Residual deflection			
Armor type I	80.0	90.0	+13%

The material properties used in material models were correlated according to the test results. The optimized multilayer armor variant was checked in a real test with next result.

Next table presents a typical result from a comparison between the final simulation and real test.

Tab. 2: Measurement versus improved simulation comparison.

	Measurement	FE simulation	Difference [%]
Residual deflection			
Armor type II	76.1	78.0	+2%

The residual deflection presents good correlation between the simulation and test, as show Fig. 4 and Tab. 2.

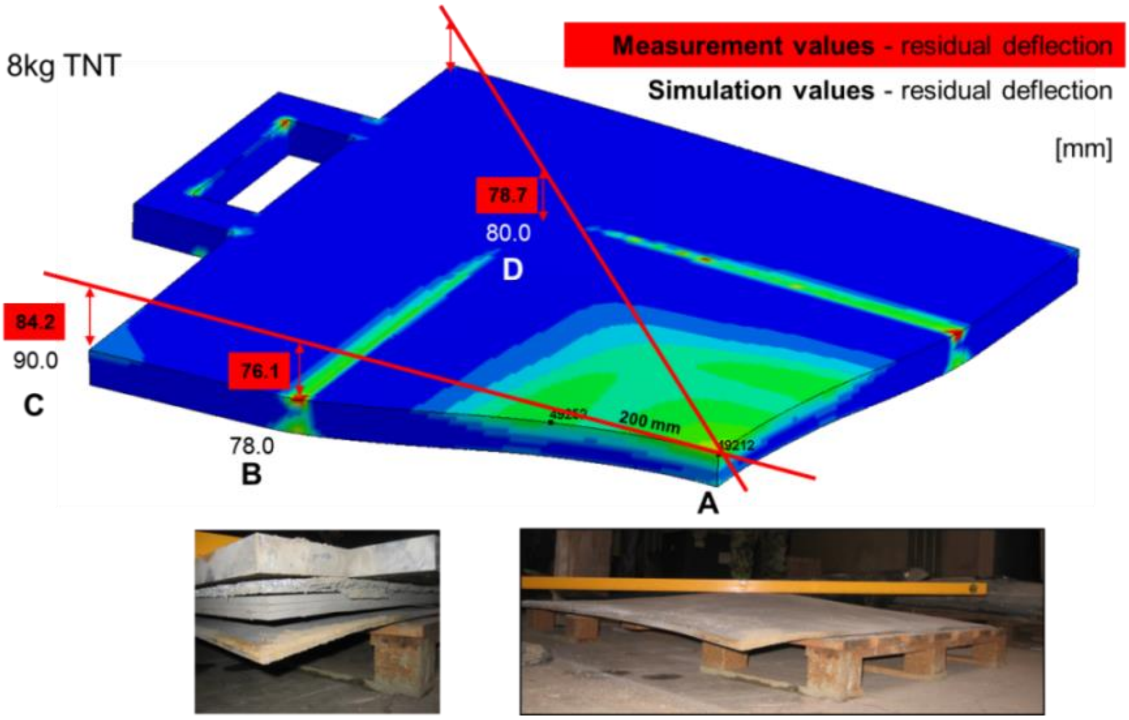

Fig. 4: Verification test of the numerical model.

5. Conclusion

One of the goals of this project was to develop a multilayer armor that is able to protect a typical military vehicle against the 8 kg TNT blast mine. It was achieved by a combination of the aluminum base armor, aluminum foam, a glass fiber laminate and ballistic steel sheet. The dynamic and residual displacements of the armor assembly were decreased during an optimization process applied in sets of numerical simulations.

The benefit from the absorbing material – aluminum foam – was confirmed during numerical simulations and real tests as well. Those studies allow a detailed investigation of a behavior of the absorbing materials that will be implemented in next steps of the project.

The result absorbing multilayer armor is planned to be used in next industry application, mine protection of the military vehicle.

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