acta mechanica et automatica, vol.6 no.1 (2012)

NUMERICAL AND EXPERIMENTAL COMPARISON OF COMBINED MULTILAYER PROTECTIVE PANELS

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Abstract: The paper presents numerical and experimental analysis of combined multilayer protective panels. The developed structures are prospective solutions for enhancing protection of military vehicles and crucial elements of pipelines especially in places like river crossings.

Key words: FEM, Blast Wave, Fluid Structure Interaction, Elastomer, Protective Panel

1. INTRODUCTION

Asymmetric actions used by terrorist formations are directed against the most important elements of infrastructure and human lives. Crews of combat vehicles and industrial installations of oil and gas are mainly subjected to such actions. Counteraction to terrorist attacks is increasing of impact resistance of the construction to short-time loads coming from explosions (Trzciński et al., 2005; Krzewiński and Rekrucki, 2005). The paper describes one of the possible methods of increasing the impact resistance through application of hyperelastic elastomer material as an energy absorbing layer. Layers of this type are widely applied in contemporary mechanics. They are mainly used to disperse energy generated as a result of interaction of pressure, caused, for example, by explosion, on the construction (Thornton and Jeryan, 1988; Babul, 1980; Włodarczyk, 1994). In the considered case, a layer of elastomer was placed on the steel base plate (protected) creating a simple construction. The construction was subjected to dynamic load in the form of pressure wave coming from detonation of explosive material.

The further part of the paper presents various numerical analyses of the developed construction accompanied by experimental verification of the carried out calculations.

In order to perform numerical analyses, implementation of a finite elements method included in MSC.Dytran software was applied.

The results from the conducted analyses will be applied to further validating and optimizing examinations aimed at absorbing or dispersion of maximum significant value of energy interacting on the energy absorbing panel utilized in constructing of armoured vehicles and protective elements of stationary constructions of strategic importance.

2. DESCRIPTION OF EXAMINED OBJECTS

A square steel plate (500 x 500 mm) made of ST3 steel of 2 mm thickness with elastomer layer of 9 mm thickness was subjected to numerical investigations with experimental verification.

The model was loaded with a pressure impulse wave coming from detonation of a 100 g TNT explosive charge in the shape of cylinder is presented in Fig. 1. The obtained numerical results were compared with own experimental data.

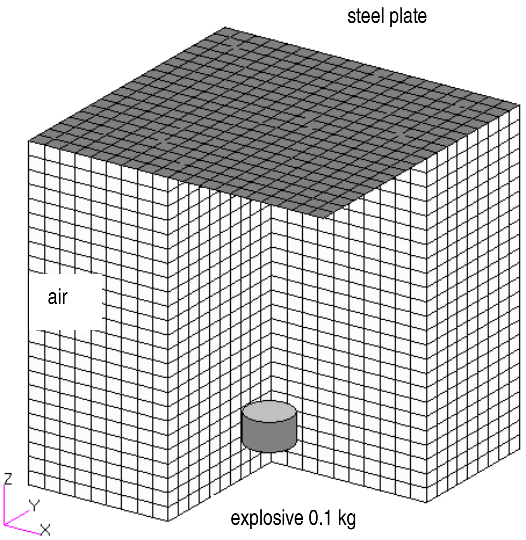

Fig. 1. General view of numerical model

The metal plates were covered with PNMU elastomer. Elastomer has linear build of macroparticules. It is built of elastic and stiff segments, consisting of flexible and stiff mers. This polymer is self-extinguishing, it shows low water absorption and high hydrolytic resistance. Thanks to these properties, elements made of such polymers can work a long time in water environment. They exhibit also high wear resistance. So far, the industrial applications of such polymers include a wide range of parts, especially those working in raw materials processing, e.g. in mining.

The PNMUs remain in the high-elastic state, which means that the energy of thermal vibrations is higher than the energy barrier to rotations about the bonds and, as a result of that, even under a small loading they exhibit considerable elastic deformation, which can be easily and quickly reversed under the influence of the loading.

The elastomer is characterized by density at the range of 1.23 kg/dm³, linear thermal expansion coefficient 2.4 10^{-4} 1/Co, hardness 70 oShA, resiliency equal to 47% and abrasive wear at the range of approximately 30 mm³ (determined with Schopper-Schlobach method). Usage temperature PNMU should not exceed 160°C.

3. RESULTS OF NUMERICAL ANALYSIS

The previous works (Krzewiński and Rekrucki, 2005; Babul, 1980; Barnat, 2010; Dytran Theory Manual, LS-DYNA Theoretical Manual) presented the results of investigations concerning, among others: the influence of Euler elements mesh parameters, values of initial energies of explosive material and selection of coupling between Euler and Lagrange domains on the results of analyses considered in constructions. Based on the obtained experiences, the models used in present considerations were built.

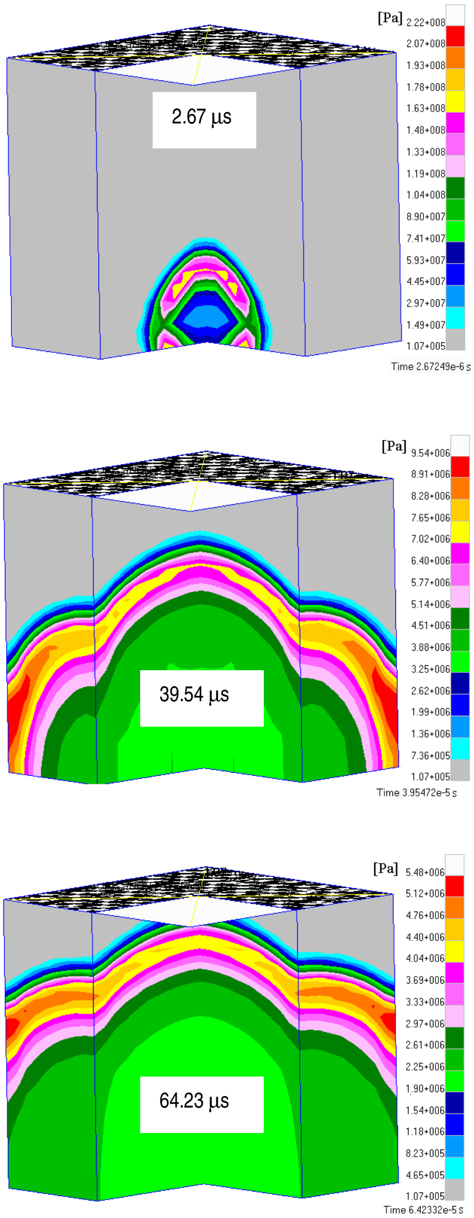

Fig. 2. View of pressure wave for three time moments

The objects were subjected to a pressure wave coming from detonation of 0.1 kg explosive charge in the shape of cylinder made of TNT. Dispersion of a pressure impulse coming from detonation of this charge in Euler area is presented in Fig. 2.

To estimate the results, the estimation of displacement of the plate central node located in the planes of symmetry and reaction coming from the ground was applied.

Fig. 3 presentS the final form of steel plates deformation obtained through numerical calculation with the use of explicit implementation of the finite element method.

At the initial time of approximately 39.54 µs the wave reached the objects without any displacements. The pressure impulse duration time is relatively short as compared to the time of displacement increasing, which is significantly longer and equals to approximately 750 µs. In the case of a model of a single examined plate, the level of displacements stabilizes around the value of 32 mm. A similar course of displacements of the central point was observed for a model of the plate with elastomer layer, however, in this case, the amplitude of vibrations was significantly greater. The final displacement of the central node was equal to 27 mm.

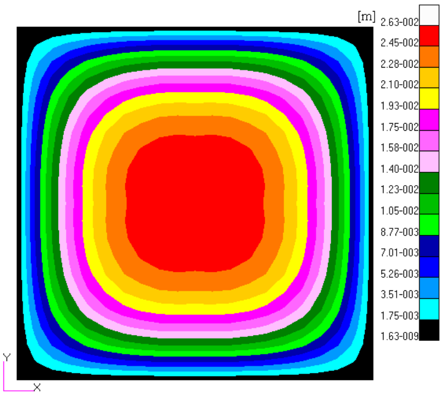

Fig. 3. The final form of deformation of plate with elastomer layer (pressure values in MPa)

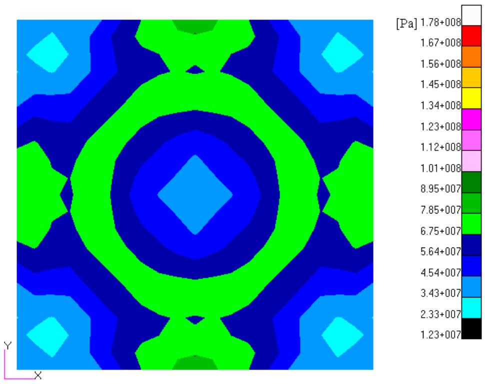

Fig. 4. Strain maps for steel plate with elastomer layer

In the case of application of the elastomer layer, the final form of deformation of the plate is flat. Such character of deformation takes place owing to the elastomer layer increasing stiffness of the system, thus causing distribution of load on the greater surface of the considered system.

The applied layer influences also maximum acceleration which amounted to 700 000 m/s². Along with decaying of external forces, in the further part of the analysis, the decreasing values of acceleration oscillation of the base layer occur. The values of strains, presented in Fig. 4, equal 178MPa.

4. EQUIPMENT APPLIED IN INVESTIGATIONS

Experimental investigations of energy absorption were carried out in the Military University of Technology on the authorial testing stand for measurement of force interacting on the examined panel. The testing stand was designed and constructed in the Department of Mechanics and Applied Computer Science Military University of Technology. The stand allows measurement of forces induced by dynamic processes such as even interaction of a pressure wave coming from detonation of explosive material. Photo 5 presents the testing stand with the system for measuring the forces used in the tests.

In the system of signals processing, there is applied a tensometric amplifier MS 1001, produced by INFEL company from Świdnik, for intensification of signals coming from tensors. The recording of signals was conducted with the use of a measurement card – model NI-USB 6251, produced by National Instruments company, including a fast analogous-digital converter (sampling 1.25 MHz on each of the channels), a portable computer TOSHIBA Satellite and a software for maintenance of a measurement card.

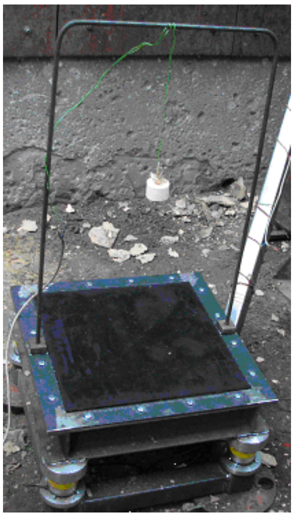

Fig. 5. Force measurement system utilized in tests

5. RESULTS OF EXPERIMENTAL INVESTIGATIONS

After carrying out the tests on the testing stand, the obtained electric signals were subjected to calibration in order to prepare the graphs of changes of force in the function of time. Due to difficulties in measuring during experimental research, it was limited to reading force interacted on the frame and the value of final deformation of the deformation of the system centre.

Fig. 6 presents photos of the plate with an additional elastomer layer.

The measured permanent displacement of the central node of the steel plate was equal to 32 mm. Application of a protective layer reduced the value of this displacement by 30% (displacement amounted to 22 mm). Additionally, based on the recorded courses, there were determined the maximum values of forces (Fig. 7 and 8) interacting on the measuring system for individual objects

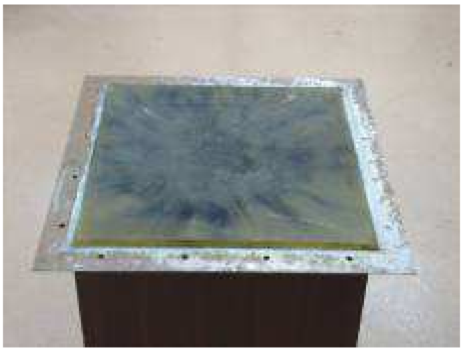

Fig. 6. 2 mm thick plate with elastomer layer
(deformation obtained from the experiment)

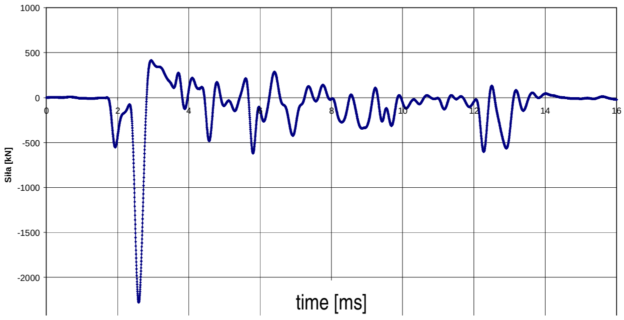

Fig. 7. The course of changes of loading the panel made of steel plate

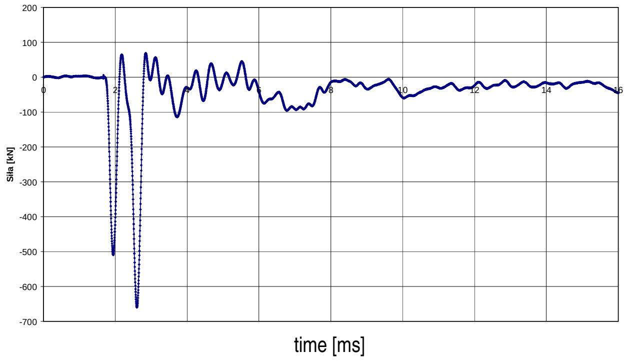

Fig. 8. The course of changes of loading the panel made of steel plate with elastomer layer

6. CONCLUSIONS

Constructions, which can be subjected to damages resulted from different kind of fast-changing constraints such as impacts, or influence of a pressure wave coming from detonation of explosive materials, should have the structure enabling absorption of possibly the greatest part of constraint energy which influences on it. The energy absorbing elements are mainly built in the form of sandwich layers which core is a specially selected material. One of the interesting types of materials, which can be used here, is elastomer. These materials, capable of absorbing energy of a blast wave coming from detonation, enable significant increasing of a protection level. Application of these materials causes reducing of vibrations frequency of the system loaded with a pressure impulse.

The maximum displacements of the protected plate were obtained for model 1. The minimum displacement of the central node was observed for model 2, in which an elastomer layer was applied. The experimental studies verifies also that elastomer layers absorb and disperse well the energy of impact protecting the object against the effects of influence of a pressure wave coming from detonation of explosive materials.

The authors presented the fragment of investigations carried out at the Department of Mechanics and Applied Computer Science, Military University of Technology.

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