NUMERICAL ANALYSIS OF A SHELL WITH A MAIN SHAPED CHARGE WARHEAD STROKE INTO A BAR ARMOUR WITH SQUARE SECTION

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Abstract

Recent operations of Polish troops within the framework of peacemaking missions' uncovered weak points of the equipment used there. It turned out that one of the most significant threats is a shell equipped with a main shaped charge warhead used by partisan detachments. These can break even 900mm of shell-proof steel so it is very difficult to protect anything from the shells. One of the ways of protection from high explosive anti-tank (HEAT) warheads is using bar armours.

This paper focuses on analysis of a shell with PG-7G main shaped charge warhead stroke into a bar armor with a square section. This work presents a short description of the analyzed object. Moreover, there is a principle of operation of a shell with the specification of the most trouble elements from the point of view of high velocity partial stream creation. In addition, the paper indicates steps of a numerical model construction together with geometry simplifications and initial-marginal conditions. On the basis of the results the researchers evaluated the extent of destruction of shell key elements. Furthermore, the work indicates drawings with deformed parts and presents stresses maps of these elements. The summary states to what extent PG-7G shell stroke into the armor made of bars with a square section influences reduction of operation efficacy of this type of firearm.

Calculations were conducted in LS-Dyna system, which is used for oscillation analyses with a finite elements method. In order to solve the motion equation the researchers used an ordinary integration method used for i.e. analyses of highly non-linear oscillation phenomena.

Keywords *mechanics, finite elements method, bar armor, RPG*

1. Introduction

Recent operations of Polish troops within the framework of peacemaking missions in Iraq and Afghanistan allowed characterizing the most significant threats of our enemies. It turned out that the most dangerous are two firearms which effectively use weak points of the equipment used there. The first of them is all sorts of mines and improvised explosive devises (IED). Their basic stroke factor is a pressure wave created as a result of detonation of explosives. In the case of improvised explosive devises the factors that increase the destructive force are all sorts of shrapnel's (nails, bullets, screws, etc.) placed in or on the shell. The second most dangerous firearm is a shell with a main shaped charge warhead. Because of a low cost of their production and the fact of being easily broken (up to 900mm of shell-proof steel RHA [5]) these shells are very often used in all sorts of wars. The shells are produced in post Soviet countries, China or Middle East countries. Over 40 countries use them in armed conflicts. The shells with main shaped charge warheads are extremely popular among terrorist troops and partisan detachments. Although their destination is to break the armours, they are also used to break the rows of non-armoured objects with strategic meaning i.e. buildings, reinforced positions of troops' stationing and even low flying aircrafts.

Because of high efficacy of shells with a main shaped charge warhead, protection from this type of firearm is a serious problem. The only one way of protection is a bar armor with square section. The aim of these armours is a significant decrease of shell efficacy by destroying its key elements. This paper shows the analysis of a shell with main shaped charge warhead stroke into a bar armour with square section. On he basis of the final results the researchers will evaluate this type of armour efficacy.

2. Shell construction and principle of its operation

Unquestionable advantages of P9-7G shells are small dimensions (length about 900 mm, diameter up to 85 mm) and small weight (about 2 kg). Thus, it is easy to transport them and they are excellent as a weapon to take for patrol.

P9-7G shell consists of three basic elements: a warhead, rocket engine and stabilizer (Fig. 1). The warhead consists of a frame, ballistic cap, conical liner, explosive material, shutters, conductive cone, insulator and detonator.

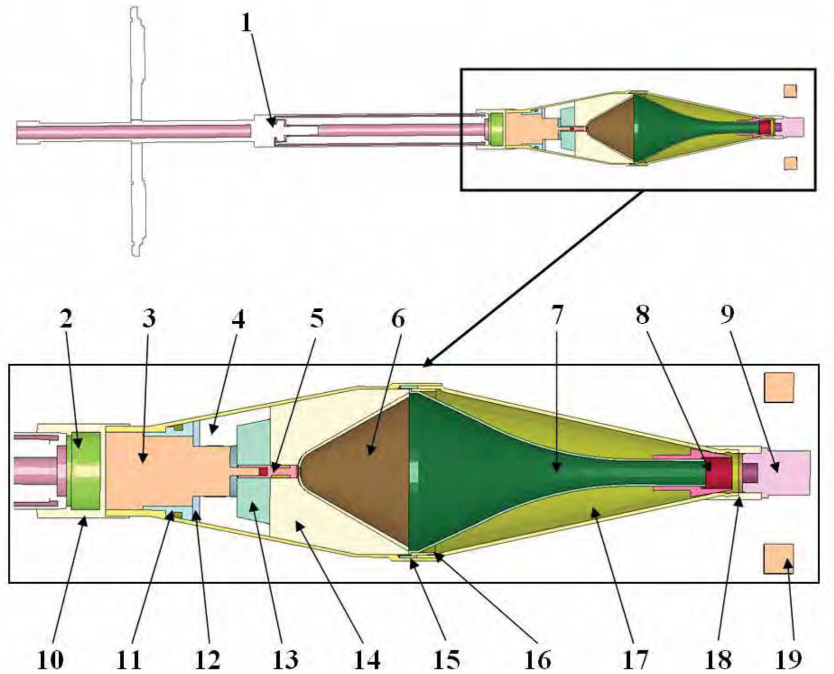

Fig. 1. PG-7G warhead section: 1 – racket engine, 2 – racket engine nozzles, 3 – bottom side of detonator, 4 – explosive material – bottom part, 5 – conductor, 6 – conical liner, 7 – conductive cone, 8 – insulator, 9 – warhead part of detonator, 10 – warhead frame, 11 – determining element, 12 – disc, 13 – shutter, 14 – explosive material – upper part, 15 – insulator, 16 – insulating ring, 17 – ballistic cap, 18 – upper detonator part fixing element, 19 – angle bars

At the time of a shot, P9-7G shell is shot from a manual grenade launcher, accelerated with the use of a racket engine (maximum speed achieved by the shell is about 300 m/s) and finally hits the target. At the time of hitting the target, the detonator generates an electrical impulse which stimulates the explosive material by a blasting cap, the electrical impulse is transferred through two circuits: internal and external. The external circuit consists of a ballistic cap and warhead frame, whereas an internal circuit consists of conductive cone and conical liner. The result of detonation of the explosive material is creation of a high velocity partial stream. In order to direct properly and focus energy, explosive material must be appropriately formed. The optimum form means 60° angle recess in its fore part. In order to increase the efficacy of such a shell it is possible to place conical liners made of varied materials (i.e. copper) in the recess.

The created high velocity partial stream constitutes about 20% of the conical liner mass and moves with the speed of several kilometres per second along the shell symmetry axis. The rest of material conical liner makes so called accumulation and moves relatively slow. The high explosive partial stream takes the form of a thin metal thread - several millimetres of thickness in the widest place. It is a factor responsible for the destructions. At the time of the stroke into the armour it makes a hole up to 9 insert calibres depth.

An important factor directly related to shell efficacy is precision of its production. If we want a high explosive partial stream to be created, explosive material and the conical liner must be precisely made. In order to achieve a maximum destructive force, inaccuracy should not exceed 0.05 mm, whereas radius deviation of the conical liner 0.03 mm. If we do not follow these requirements, the result of shell operation will be less significant. In an extreme situation with significant inaccuracies the shell destructive force will be comparable with a detonation of explosive material with the mass equal the mass of the shell in the warhead.

The aforementioned shell production accuracy condition is also used by bar armours. Their principle of operation is based on such a stroke into a ballistic cap that it is possible to deform or even destroy shaped conical liner and explosive material. In the case of a serious deformation of these elements detonation of explosive material does dot cause creation of the high velocity partial stream.

An important feature of bar armours is the width of the bars and their span. If we want the armor of this type to be effective, at the moment of stroke with the shell the detonator must be placed between the bars. Any type of stroke into the detonator before conical liner and explosive material destruction will cause generation of the factor responsible for destruction.

3. Numerical model construction

In order to conduct numerical analysis of PG-7G shell stroke into armour with a square section it was necessary to elaborate on a numerical model imitating shell operation. While elaborating on the numerical model the researchers tried to limit to minimum the number of used elements and at the same time not to lose the physical conservation of the model. This operation was aimed at reducing the time of solving the whole issue, which allows analysis of many options of calculations within short period of time. Limitation of the number of elements was possible thanks to using simplifications of geometry (Fig. 2), which do not influence conservation of a system as a whole.

The model contains 5 main simplifications:

1. Thickenings and slots in the pipe between the nozzles and the vanes were removed.
2. Stabilizer was replaced with a roller with the same mass.
3. Slots fixing vanes were removed.
4. Nozzles were removed.
5. The part of the detonator that sticks out was replaced with one roller.

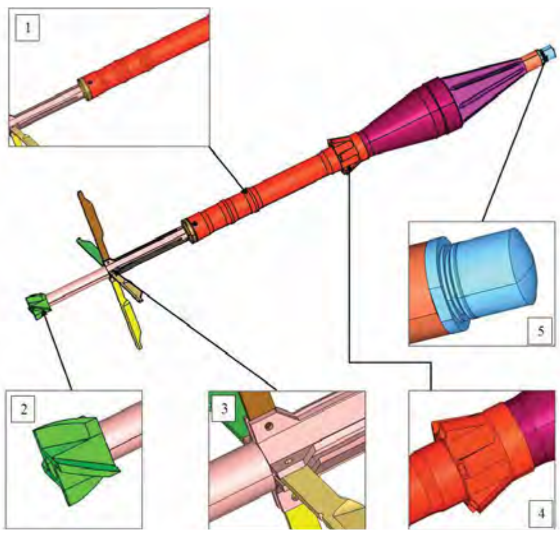

Fig. 2. Simplifications of shell geometry

In addition, all the parts placed behind the nozzles were treated as one part with material features allowing reflecting real mass-inertial parameters of the replaced parts.

The final numerical model consists of 19 elements (Fig. 1), which were made of 106484 finite elements. The number of elements, material and masses ascribed to precise elements were presented in Tab. 1.

Tab. 1. Basic data of shell integral elements

Part no.	No of elements	Material	Mass [g]
1	34424	PA 7	802
2	2704	PA 7	61
3	12148	PA 7	136
4	5280	TNT	76
5	232	PA 7	1.2
6	1416	Cu	116
7	2696	PA 7	44
8	544	PA 7	12
9	864	St3S	81
10	5520	PA 7	153
11	1632	PA 7	27
12	768	PA 7	12
13	5264	composite	16
14	16272	TNT	307
15	240	PA 7	6.9
16	336	PA 7	9.9
17	3008	PA 2	105
18	336	PA 7	12
19 – steel bars	12800	St3S	1539

Material features ascribed to individual parts correspond to materials used in reality. In order to describe materials conservation the researchers used two models: Piecewise_Linear_Plastic and Simplified_Johnson_Cook. Because of the use of stresses diagram in deformation function the first model was used to all parts with the exception of those made of copper. Simplified model of Johnson-Cook's model was used to describe the copper.

A shell numerical model takes into account all elements inside the warhead and contact phenomenon with friction between them. Contact procedure was realized through the Automatic_ single_surface model mainly used in 'crash' type analyses because of high speeds of elements motion and significant deformation. Moreover, the researchers defined Contact_automatic_surface_ to_surface_tiebrak contacts between the warhead frame and the ballistic cap. Thanks to that it was possible to imitate a thread joint between these elements by introducing possibilities of conditional division of these elements.

Numerical analysis was conducted in LS-Dyna system. During the simulation the researchers conducted perpendicular stroke of the shell into two bars with a square section (dimensions 4x4x500). The assumption was that the shell moving with the speed of 300m/s (Fig. 3) hits in the middle of bars length and precisely between them. It means that the detonator does not contact the armor. Because the bars are part of lattice structure, the ends of them were deprived of freedom (Fig. 3).

4. Results

Figure 4 presents the process of PG-7G shell stroke moving with the speed of 300 m/s fired from a recoilless rocket propelled grenade into a bar armor with square section. The initial stadium

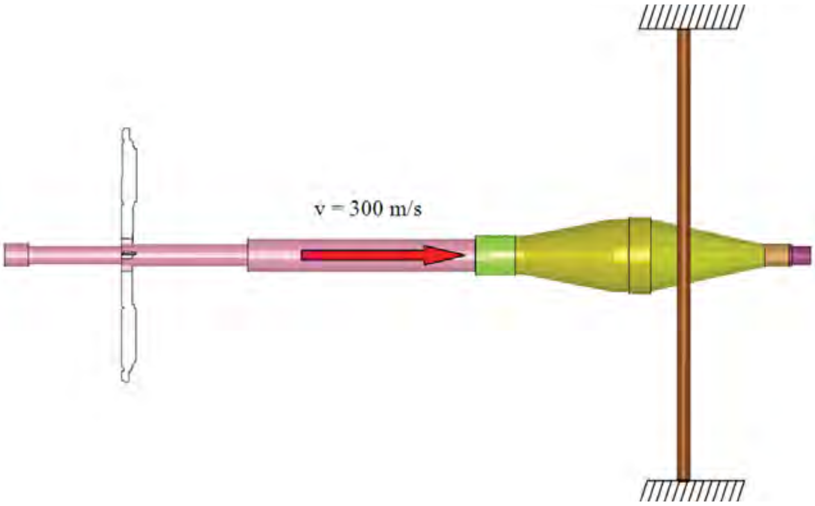

Fig. 3. Initial state of the considered system

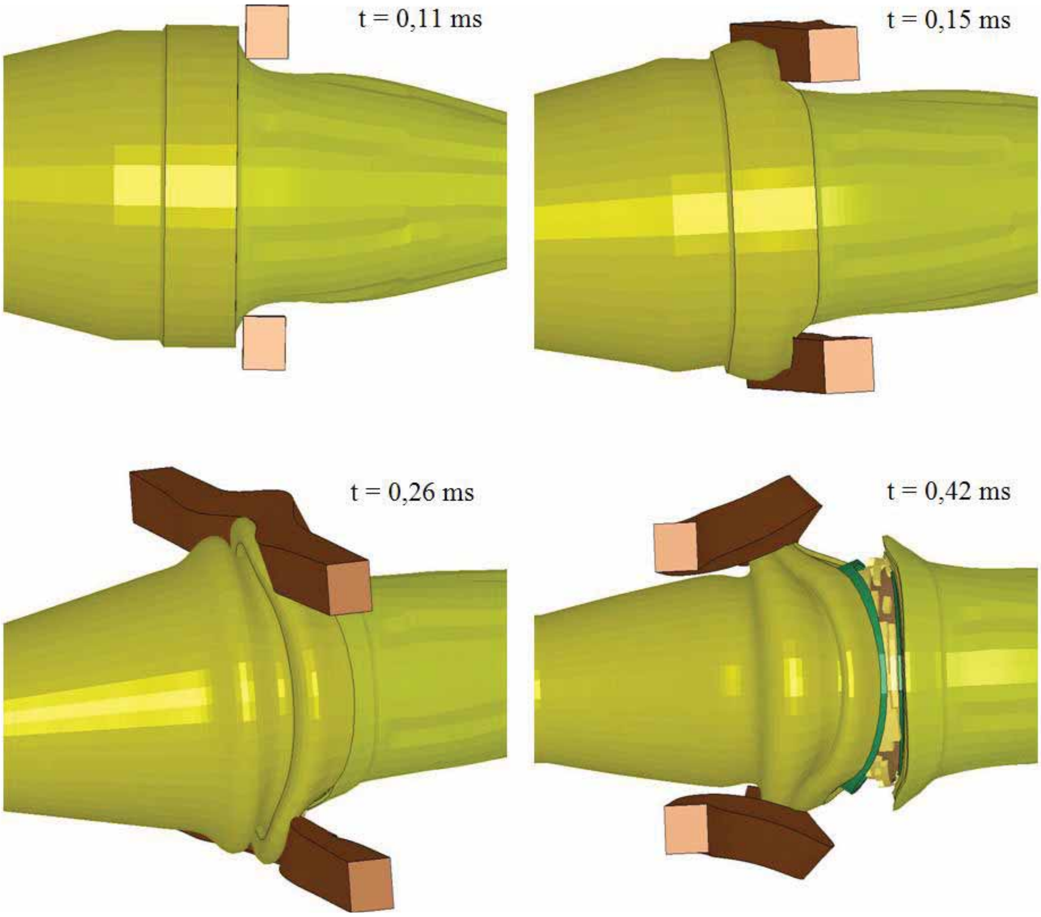

Fig. 4. Shell deformation process at the time of stroke into an armor

shows the decay of a ballistic cap made of aluminum. The next step proves that a warhead frame is crushed and folded. At the moment of the shell passing through the armour, the frame is folded and its folds crush inside elements. What accompanies the shell casing decay is the breakdown of the thread joint between the ballistic cap and the warhead frame. This phenomenon is caused by ballistic cap crush and strong system braking at the time of stroke into the bar armour.

Figure 5 presents explosive material and detonator deformation process. These are the key elements from the point of view of the creation process of high velocity partial stream. Despite of partial destruction of ballistic cap, both elements remain untouched in the initial stadium. Only at the

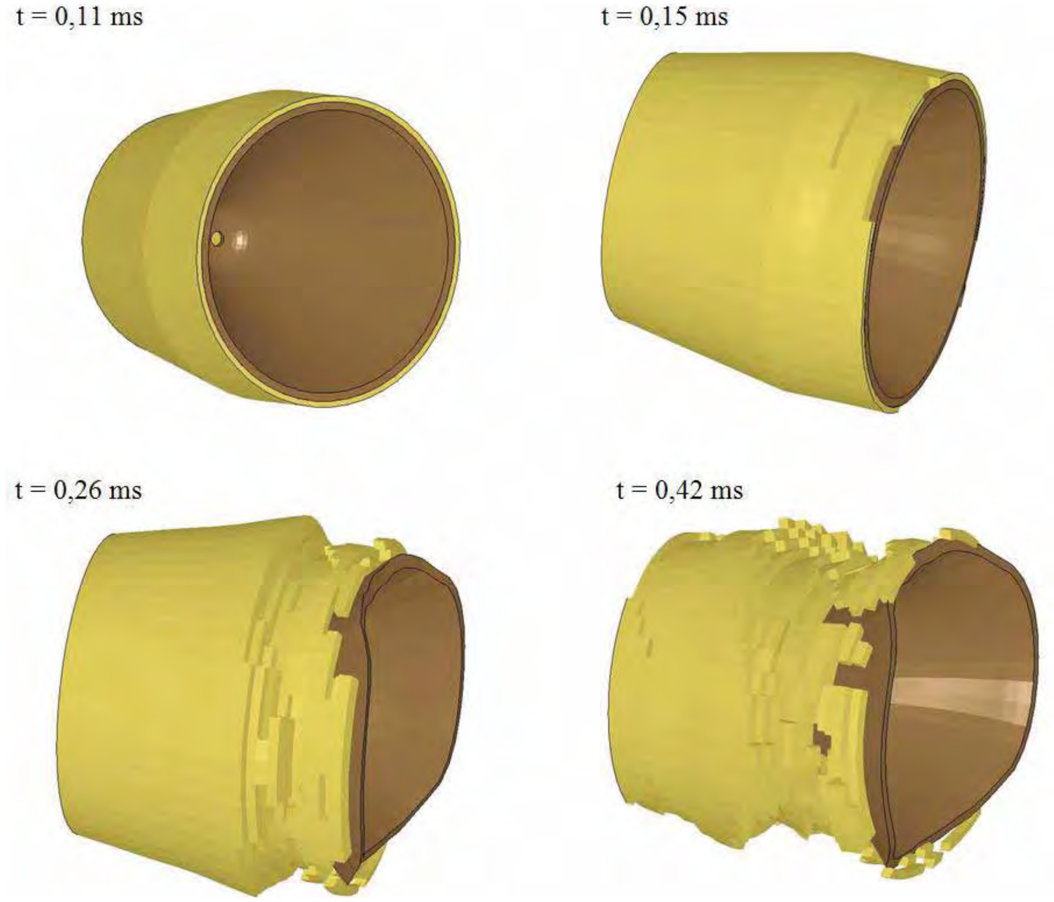

Fig. 5. Conical liner and explosive material deformation process

moment of the beginning of warhead frame crush we can observe inessential and then significant destruction of explosive material and conical liner deformation. The explosive material decay is mainly caused by projectile folds penetration inside the warhead frame. The destruction is so significant that the explosive material decreases its mass over 55%.

5. Conclusions

A crucial factor that determines creation of a high velocity partial stream is shell production accuracy and its condition at the moment of explosive material inside detonation.

To conclude, the conducted analyses prove that at the moment of shell with main shaped charge warhead stroke into the considered bar armor there is a total conical liner deformation and significant destruction in the area of explosive material. It guarantees that the high velocity partial stream is not created.

References

[1] Jach, K., i in., *Modelowanie własności dynamicznych ciał metodą punktów swobodnych*, PWN, Warszawa 2001.

[2] Military Parade, Russia, Moscow 2001.

[3] Niezgoda, T., Panowicz, R., Barnat, W., i in., *System obrony aktywnej do ochrony pojazdów przed pociskami z głowicami kumulacyjnymi,* XXIII Międzynarodowa Konferencja N-T Ochrona ludności przed skutkami nadzwyczajnych zagrożeń, Ekomilitaris, Zakopane 2009.

[4] www.ruag.com.

[5] Wiśniewski, A., *Pancerze budowa, projektowanie i badanie*, WNT, Warszawa 2001.