Numerical study on the influence of the initiation point position on the fragmentation effect of a high-explosive rocket warhead

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Abstract:

Introduction/purpose: Rockets with high-explosive (HE) warheads are the most numerous type used for multiple launch rocket systems (MLRS). They are used for a wide range of combat tasks. Besides other design characteristics, the effect on the target depends on the position where detonation is initiated in their explosive charge. The study analyses the fragmentation effects of steel balls from the 128 mm M77 HE warhead with the standard point-detonating (PD) fuze and with a differently positioned detonating assembly.

Methods: The study uses a simple numerical model for the assessment of the fragmentation effect, which requires modest resources. A numerical model of the fragmentation effect was used with Gurney's model of explosive propulsion and Taylor's and Shapiro's method for the direction of the fragment velocity vector. The penetration ability of projected steel balls through hard homogenous steel was analysed using the Project Thor analytical model of kinetic energy projectile penetration.

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Results: The results indicate that a change in the position of the initiation point can improve the fragmentation effect of steel balls. The most significant improvement is increased fragment dispersion, causing much larger fragment impact zones. A modest increase in the fragment velocity is observed as well, mainly because the direction of the fragment velocity vector is changed. Also, the penetration ability of both types of steel balls at distances up to 50 m is sufficient for the anti-personnel role, while larger steel balls have anti-material capabilities as well.

Conclusion: Changing the fuze on high-explosive warheads in order to change the position of the initiation point can be used to improve the fragmentation effect.

Key words: warhead, detonation, fragmentation, explosive propulsion.

Introduction

Rockets with high-explosive (HE) warheads are the most often used for weapon systems that are used for combat support, such as multiple launch rocket systems (MLRS) on land or air platforms. Their effectiveness is based on a detonation of their explosive charge, where fragmentation and blast effects are produced in accordance with specific design features of a warhead. Such designs are considered to have characteristics that provide nearly universal purposes. Thus, rockets with HE warheads can be used in different combat situations and against different targets, usually with appropriate fuze settings.

The fragmentation effect has been of interest in military research and development activities, since it has proven to be very effective against soft targets, like manpower and combat systems without or with light armour protection, especially when concentrated in bases, on landing zones, etc. Such targets require a small amount of kinetic energy or a large number of small perforations (Carlucci & Jacobson, 2018, p.429). There are many numerical models developed for reliable predictions of explosive propulsion and fragmentation effects (Zukas & Walters, 1998; Orlenko, 2004; Gold, 2017). It depends on design features of an explosive ordnance, whether during the fragmentation process, explosive propulsion or fragment flight. Preformed fragments are used in many modern designs, due to a complex nature of naturally fragmented parts of a warhead, where a wide range of fragment dimensions is expected. The main advantage of preformed fragments is a reliable prediction of fragmentation effects, since shape and dimensions can be considered constant during the effect.

Most HE projectiles have a point-detonating (PD) fuze, so that a detonation wave is traveling towards the base of a projectile. Such design is often used mainly because that the position of a fuze offers the earliest possible and reliable interaction with a target. Additionally, that position is easily accessible for preparation, removal or replacement of a fuze. However, it is possible to use fuzes that are point-initiated and have the detonating assembly positioned elsewhere in the projectile, providing different detonation processes.

Numerical modelling of the fragmentation effect

A simple numerical model will be used to calculate the parameters that are necessary to access the fragmentation effect of the 128 mm HE M77 warhead, used on rockets for domestic multiple launch rocket systems (MLRS), such as Oganj and Morava. The same numerical model will be used to analyse the fragmentation effects of modified designs of the warhead with different positions of the buster: at the base and in the central part of the warhead. The model is not resource demanding and is applicable for engineering purposes, especially in the preliminary analysis of the HE explosive ordnance design.

Design characteristics of the 128 mm M77 HE warhead

The rockets with the 128 mm M77 HE warhead are primarily used against manpower and materiel in open and in field fortifications. They are used for intense and quick fire missions against important targets, such as command posts, telecommunication centres, military bases, depots, airfields, ports, etc.

The main parts of the warhead without a fuze are presented in Figure 1. The warhead is primarily used with the point-detonating fuze UTU M77 that is threaded to the fuze well after the closing plug (1) is removed. The UTU M77 is an impact fuze that can be pre-set for super-quick or delay action. The rocket motor is, during the production, permanently attached to the base parts of the warhead.

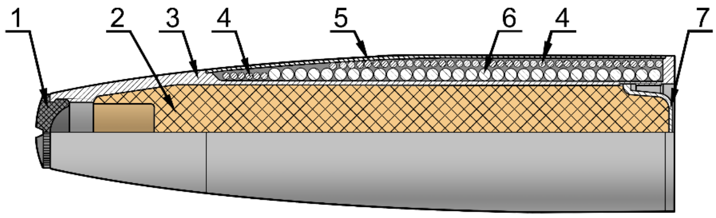

Figure 1 – Main parts of the 128 mm M77 HE warhead:
(1) fuze well closing plug, (2) explosive charge, (3) warhead body, (4) smaller steel balls, (5) liner, (6) larger steel balls and (7) warhead base

The hollow steel warhead case (3) is filled with explosive charge (2) made of 4.050 kg of explosive composition (45 % RDX, 40 % TNT and 15 % aluminium powder). Upon detonation of the explosive charge, the main fragmentation effect is provided by the matrix of steel balls (4) and (6), arranged between the warhead case (3) and the liner (5). Two types of steel balls are used: 930 larger (diameter 10.32 mm, 30 rows with 31 balls each) and 2562 smaller steel balls (diameter 6.35 mm), which are arranged in two layers (6 rows with 47 balls each, and 40 rows with 57 balls each). It should be mentioned that additional fragments are expected to be formed from other metal parts of the warhead (case, liner, base and fuze) and the rocket motor, which will be naturally fragmented.

Numerical model of the warhead fragmentation effect

The Gurney model of explosive propulsion was chosen due to its simplicity. This model has some limitations, but in many similar research studies (Carlucci & Jacobson, 2018; Catovic & Kljuno, 2021) the results have shown an acceptable correlation with experimental results. The following assumptions and approximations have been included in the model:

- detonation process is stationary and in accordance with the model of ideal detonation, so a detonation wave has a spherical shape and all detonation parameters are constant;
- position of a fragments is equal to the position of its centre of mass;
- points of initiation are considered to be on the central longitudinal axis of the warhead; and
- gravitational force is neglected.

Meanwhile, significantly more complex numerical models have been developed, based on the finite element method and hydrocodes (Tanapornraweekit & Kulsirikasem, 2012; Ugrčić & Ivanišević, 2015), which require more resources.

Considering that the warhead is a cylindrical explosive propulsion system with axial symmetry, the velocity of a fragment $v_{f,e}$ caused by the explosive propulsion can be calculated using the following equation (Gurney, 1943):

$$v_{\mathrm{f,e}} = \frac{v_G}{\sqrt{\frac{m_f}{m_e} + \frac{1}{2}}} \quad (1)$$

where m_f is the mass of metal fragments, m_e is the mass of the explosive charge and v_G is the Gurney velocity in m/s, which is a function of the Gurney energy E_G:

$$v_G = \sqrt{2E_G} \tag{2}$$

The Gurney velocity and energy are expressing the propelling ability of an explosive charge and have constant values for an explosive composition. It can be determined experimentally or using an appropriate numerical model. The Koch's model (Koch, 2002) was used in this research:

$$v_G = \frac{D}{0.308} \tag{3}$$

where D is the detonation velocity in m/s.

Since D = 7495 m/s (Kaye & Herman, 1980, p.328) for a very similar explosive composition (a charge diameter of 51.8 mm and an initial density of 1.81 kg/dm^3) as the warhead explosive charge, so v_G = 2433 m/s for all further calculations. Equation 1 and the data for the 128 mm M77 HE warhead (m_e = 4.050 kg and m_f = 15.480 kg) yield the velocity of fragments of $v_{f,e}$ = 1170 m/s.

The initial velocity of a fragment depends on the movement of a projectile in the moment of explosion as well. Thus, the initial fragment velocity is a sum of the velocity vectors:

$$\overrightarrow{v_{f,0}} = \overrightarrow{v_{f,e}} + \overrightarrow{v_p} + \overrightarrow{v_\omega} \tag{4}$$

where v_p is the projectile flight velocity and v_ω is the tangential velocity as a consequence of projectile rotation. Accordingly, the intensity and direction of the initial fragment velocity during a flight are significantly different from those involving static explosive ordnance. It must be noted that static conditions are very usual in most of experimental warhead effectiveness methods, i.e., "arena" tests. The rocket rotates very slowly after leaving the launcher tube (380 rotations per minute), so the tangential velocity v_ω is approximately 2.4 m/s and was neglected in this study.

The Gurney model assumes that fragments move in the direction perpendicular to the layer of fragments. However, the fragment velocity vector is deflected in the direction of the detonation velocity vector by an angle Θ, that can be predicted using Taylor's method and Shapiro's formula (Lloyd, 1998, p.374):

$$\Theta = \tan^{-1}\left(\frac{v_{f,0}}{2 \cdot D}\cos\left(\frac{\pi}{2} + \alpha - \beta\right)\right) \tag{5}$$

where α is the angle between the detonation wave front and the free surface of fragments and β is the angle between the warhead axis and the line perpendicular to the free surface of fragments (Figure 2).

For known coordinates of characteristic points, all angles can be calculated using trigonometric functions, for example:

$$\alpha = \tan^{-1}\left(\frac{y_i - y_I}{x_i - x_I}\right) \tag{6}$$

where x_i and x_I are the axial coordinates and y_i and y_I are the radial coordinates of the i^{th} steel ball and the initiation point I, respectively.

During the flight, air drag constantly decreases the velocity of a fragment. Since steel balls in the warhead are symmetrical and have known dimensions, the velocity at the distance x can be written as (Carlucci & Jacobson, 2018, pp.202-210):

$$v_{f,x} = v_{f,0} \cdot e^{-\frac{\rho_a \cdot A_f \cdot C_d \cdot x}{2 \cdot m_f}} \tag{7}$$

where ρ_a is the density of air, A_f is the surface area of the fragment silhouette in a plane that is perpendicular to the velocity vector $v_{f,x}$, m_f is the mass of the fragment and C_D is the drag coefficient. The following values were adopted for further calculations: ρ_a = 1.225·10^{-3} kg/dm^3 and C_D = 0.95. In order to simplify the model, the constant value C_D was adopted. This can be acceptable because its value does not change significantly for short flight distances of spherical fragments at supersonic velocities (Mach number M between 2 and 4) (Moxnes et al, 2017).

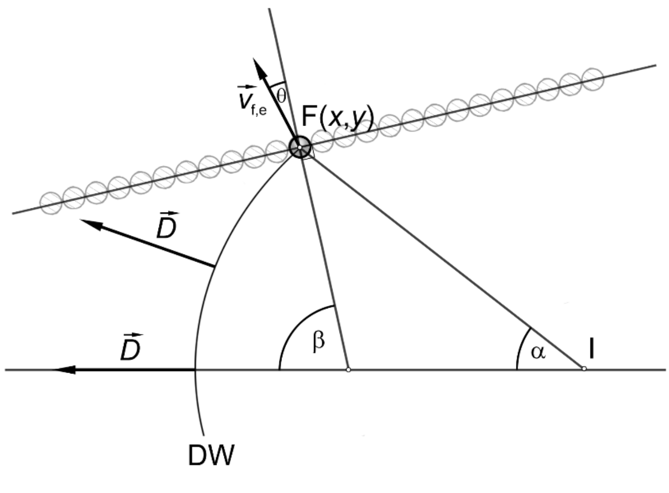

Figure 2 – Direction of the fragment velocity vector:
DW: detonation wave; F: position of a fragment; I: initiation point

Penetration ability of the fragment depends on target and fragment characteristics at impact conditions (mass and dimensions, velocity and angle). It can be evaluated using the numerical model developed in the Project Thor (Zook, 1977), which was used in similar studies (Wang et al, 2014; Rotariu & Trana, 2016). Evaluation can be done using the empirical equation for the residual fragment velocity $v_{f,res}$ (Zook, 1977, p.9):

$$v_{f,res} = v_{f,x} - 10^{C_1}\left(h_t \cdot A_f\right)^{C_2} m_f^{C_3} (\sec\varphi)^{C_4} v_{f,x}^{C_5} \quad (8)$$

where h_t is the thickness of the target, φ is the angle of incidence at impact, while C_1, C_2, C_3, C_4 and C_5 are the empirical coefficients. The empirical coefficients are derived for parameters in the imperial units (dimensions in inches, mass in grains and velocity in feet per second). The following values for hard homogenous steel were used for further calculations: C_1 = 6.475, C_2 = 0.889, C_3 = -0.945, C_4 = .1.262 and C_5 = 0.019. The maximum penetration $h_{t,max}$ is when the fragment impact is perpendicular to the target surface (φ = 0) and $v_{f,res}$ = 0 criterion is met.

Results and discussion

Numerical modelling of the fragmentation effect for the 128 mm M77 HE warhead

The axial coordinates x_i and the radial coordinates y_i of all steel balls were measured from the central point in the mouth of the fuze well, and are listed in Tables 1 and 2.

Table 1 – Positions of larger steel balls

Number of a fragment, *i*	Coordinates of a fragment		Number of a fragment, *i*	Coordinates of a fragment	
	x_i (mm)	y_i (mm)		x_i (mm)	y_i (mm)
1	190.0	51.5	16	354.3	51.5
2	201.0	51.5	17	365.2	51.5
3	211.9	51.5	18	376.2	51.5
4	222.9	51.5	19	387.1	51.5
5	233.8	51.5	20	398.1	51.5
6	244.8	51.5	21	409.0	51.5
7	255.7	51.5	22	420.0	51.5
8	266.7	51.5	23	430.9	51.5
9	277.6	51.5	24	441.9	51.5
10	288.6	51.5	25	452.8	51.5

Number of a fragment, *i*	Coordinates of a fragment		Number of a fragment, *i*	Coordinates of a fragment	
	x_i (mm)	y_i (mm)		x_i (mm)	y_i (mm)
11	299.5	51.5	26	463.8	51.5
12	310.5	51.5	27	474.7	51.5
13	321.4	51.5	28	485.7	51.5
14	332.4	51.5	29	496.6	51.5
15	343.3	51.5	30	507.6	51.5

Table 2 – Positions of smaller steel balls

Number of a fragment, *i*	Coordinates of a fragment		Number of a fragment, *i*	Coordinates of a fragment	
	x_i (mm)	y_i (mm)		x_i (mm)	y_i (mm)
1	151.5	48.1	24	354.2	58.3
2	158.4	48.1	25	361.1	58.3
3	165.2	48.1	26	368.1	58.3
4	172.1	48.1	27	375.0	58.3
5	178.9	48.1	28	382.0	58.3
6	185.8	48.1	29	388.9	58.3
7	236.0	58.3	30	395.9	58.3
8	243.0	58.3	31	402.8	58.3
9	249.9	58.3	32	409.8	58.3
10	256.9	58.3	33	416.7	58.3
11	263.8	58.3	34	423.7	58.3
12	270.8	58.3	35	430.6	58.3
13	277.7	58.3	36	437.6	58.3
14	284.7	58.3	37	444.5	58.3
15	291.6	58.3	38	451.5	58.3
16	298.6	58.3	39	458.4	58.3
17	305.5	58.3	40	465.4	58.3
18	312.5	58.3	41	472.3	58.3
19	319.4	58.3	42	479.3	58.3
20	326.4	58.3	43	486.2	58.3
21	333.3	58.3	44	493.2	58.3
22	340.3	58.3	45	500.1	58.3
23	347.2	58.3	46	507.1	58.3

Since all steel balls are embedded in the matrix that is parallel to the longitudinal axis of the warhead, then $\beta = \pi/2$ and Equation 5 can be written as:

$$\Theta = \tan^{-1}\left(\frac{v_{f,0}}{2 \cdot D}\cos\alpha\right) \quad (9)$$

The fuze well in the 128 mm M77 HE warhead is 43.2 mm deep, so it is considered that the initiation point is positioned at the same axial distance on the longitudinal axis ($y_I = 0$). According to that and the data in Tables 1 and 2, projection angles of steel balls Θ_i were calculated using Equation 9 for the static warhead. Negative values indicate that a fragment is projected “backwards”, i.e., towards the base of the warhead.

After that, projection angles of steel balls were calculated for flight conditions according to Equation 4, where the value for the rocket velocity after the end of rocket motor propulsion v_p = 647 m/s was adopted.

The average fragment velocity and the maximum penetration of steel balls $h_{t,max}$ at distances between 5 and 50 m from the point of warhead explosion for both conditions were calculated using Equation 8 and $v_{f,res}$ = 0 criterion.

The results are listed in Table 3.

Table 3 – Results of the fragmentation effect for the 128 mm M77 HE warhead

Parameter	Fragment type	Conditions	
		static	flight
Angle of fragment projection (°)	smaller steel balls	-4.1 – -4.4	25.7 – 25.5
	larger steel balls	-4.2 – -4.5	25.8 – 25.5
Average fragment velocity at distances 5–50 m, $v_{f,x}$ (m/s)	smaller steel balls	1072 – 487	1186 – 539
	larger steel balls	1109 – 683	1226 –755
Maximal penetration at distances 5–50 m, $h_{t,max}$ (mm)	smaller steel balls	4.3 – 1.8	4.8 – 2.0
	larger steel balls	7.9 – 4.6	8.8 – 5.1
Surface area of the fragment impact zone at distances 5–50 m (m^2)		16.3 – 217.3	16.3 – 214.8
Areal density of fragments at distances 5–50 m (fragment/m^2)		214.1 – 16.1	214.4 – 12.9

Numerical modelling of the fragmentation effect for the modified 128 mm HE warhead with a base detonating assembly

The direction of a detonation wave in an explosive charge directly depends on a position where the detonation is initiated. Change in the position can significantly affect the fragmentation effect of a warhead.

A possible modification of the 128 mm M77 HE warhead is to position the detonating assembly in the base of the explosive charge while the space in the fuze well for the detonation booster is filled with explosive. Such a warhead can have a fuze that has two separate assemblies, like modern electric point-initiated base-detonating (PIBD) fuzes. The main parts of such a modified warhead without a fuze are presented in Figure 3.

The coordinates of the initiation point are: x_I = 464 mm and y_I = 0 mm. Since no other design changes were made, the parameters of the fragmentation effect were calculated using the coordinates x_i and y_i of all steel balls in Tables 1 and 2, and the results are listed in Table 4.

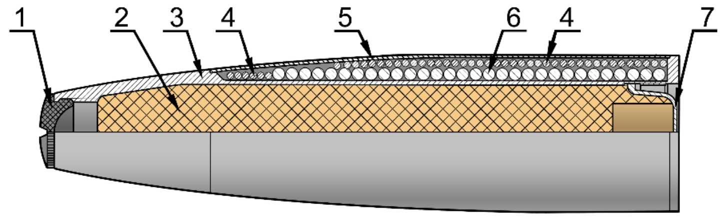

Figure 3 – Main parts of the 128 mm HE warhead with a base detonating assembly: (1) fuze well closing plug, (2) explosive charge, (3) warhead body, (4) smaller steel balls, (5) liner, (6) larger steel balls and (7) warhead base

Table 4 – Results of the fragmentation effect for the 128 mm HE warhead with a base detonating fuze assembly

Parameter	Fragment type	Conditions	
		static	flight
Angle of fragment projection (°)	smaller steel balls	4.4 – -2.7	32.3 – 26.7
	larger steel balls	4.4 – -2.9	32.3 – 26.9
Average fragment velocity at distances 5–50 m, $v_{f,x}$ (m/s)	smaller steel balls	1072 – 487	1251 – 569
	larger steel balls	1109 – 683	1294 – 797
Maximal penetration at distances 5–50 m, $h_{t,max}$ (mm)	smaller steel balls	4.3 – 1.8	5.1 – 2.1
	larger steel balls	7.9 – 4.6	9.4 – 5.5
Surface area of the fragment impact zone at distances 5–50 m (m^2)		35.1 – 2095.6	35.3 – 2111.9
Areal density of fragments at distances 5–50 m (fragment/m^2)		99.5 – 1.7	99.0 – 1.7

Numerical modelling of the fragmentation effect for the modified 128 mm HE warhead with a central detonating assembly

Another possible modification of the 128 mm M77 HE warhead is to position the detonating assembly in the central part of the explosive charge. As with the previous warhead, the fuze with two separate assemblies can be used, so that the coordinates of the initiation point are: x_I = 350 mm and y_I = 0 mm. The main parts of such a modified warhead without a fuze are presented in Figure 4.

The results of the numerical modelling are listed in Table 5.

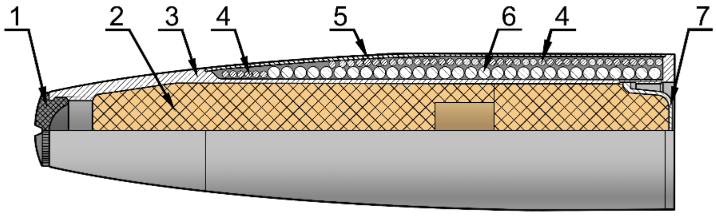

Figure 4 – Main parts of the 128 mm HE warhead with a central detonating assembly: (1) fuze well closing plug, (2) explosive charge, (3) warhead body, (4) smaller steel balls, (5) liner, (6) larger steel balls and (7) warhead base

Table 5 – Results of the fragmentation effect for the 128 mm HE warhead with a central detonating fuze assembly

Parameter	Fragment type	Conditions	
		static	flight
Angle of fragment projection (°)	smaller steel balls	4.4 – -4.2	32.2 – 25.6
	larger steel balls	4.3 – -4.3	32.2 – 25.7
Average fragment velocity at distances 5–50 m, $v_{f,x}$ (m/s)	smaller steel balls	1072 – 487	1225 – 557
	larger steel balls	1109 – 683	1267 – 780
Maximal penetration at distances 5–50 m, $h_{t,max}$ (mm)	smaller steel balls	4.3 – 1.8	4.9 – 2.1
	larger steel balls	7.9 – 4.6	9.2 – 5.3
Surface area of the fragment impact zone at distances 5–50 m (m^2)		39.0 – 2480.8	39.0 – 2481.5
Areal density of fragments at distances 5–50 m (fragment/m^2)		89.7 – 1.4	89.6 – 1.4

Analysis of the results

The results in Tables 3, 4 and 5 show that, for all warheads in static conditions, fragment sprays are directed nearly perpendicular to the warhead longitudinal axis. Fragment sprays from warheads detonated during flight are directed approximately 25-32 °towards the frontal part and have greater velocities. Also, a warhead flight velocity has the most significant influence on the direction of the fragment velocity vector. Thus, the effect of fragments on the target is significantly better than in static conditions. That fact must be taken into consideration when experimental data on the fragmentation effect are analysed.

The fragment sprays for all considered warheads are graphically represented in Figure 5.

The results of the numerical modelling also show that change in the position of the initiation point can improve the fragmentation effect of steel balls. A fragment spray from a warhead with a PD fuze is very narrow because all the fragments have nearly parallel trajectories, resulting in a small impact zone with an extremely large areal density of fragments. Practically, steel balls will achieve 100 % hit probability in such an impact zone, but 0 % outside of that zone.

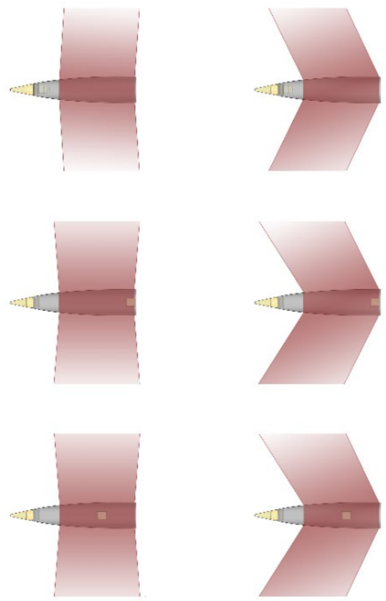

Figure 5 – Graphical representation of fragment spray directions in static (left) and flight conditions (right) for the 128 mm HE warhead with the point-detonating fuze (top), the base (middle) and the central detonating assembly (bottom)

If an explosive charge is detonated from the base or centrally, steel balls will be projected with a slightly higher velocity and in significantly wider sprays due to divergent trajectories of fragments. Both effects will increase the efficiency of a fragmentation warhead. Fragment impact zones are many times larger than those from a warhead with a PD fuze. For both types, at distances up to 50 m, the areal density of fragments is larger than 1 fragment per m^2 (1.7 and 1.4 fragments per m^2, respectively), which is a threshold for the lethal zone in many methods and standards.

Both types of steel balls show penetration abilities at distances up to 50 m which are much better than needed for the anti-personnel role. Penetration abilities of larger steel balls are significantly better compared to smaller ones. According to the results, it can be expected that larger steel balls are effective in the anti-materiel role as well, even against lightly armoured targets.

Conclusion

Changing the position of the initiation point can be used to improve the fragmentation effect of high-explosive warheads. That can be done using an appropriate fuze system which has the most appropriate position of a detonating assembly for required capabilities. Such designs can achieve a better fragment dispersion, so that fragment impact zones are larger, and a slightly larger fragment velocity.

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Estudio numérico sobre la influencia de la posición del punto de iniciación en el efecto de fragmentación de una ojiva de cohete de alto poder explosivo

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Resumen:

Introducción/objetivo: Los cohetes con ojivas de alto poder explosivo (HE) son el tipo más numeroso que se utiliza en los sistemas de lanzamiento múltiple de cohetes (MLRS). Se emplean para una amplia gama de tareas de combate. Además de otras características de diseño, el efecto sobre el objetivo depende de la posición en la que se inicia la detonación en su carga explosiva. El estudio analiza los efectos de fragmentación de las bolas de acero de la ojiva HE M77 de 128 mm con la espoleta de detonación puntual (PD) estándar y con un conjunto detonador ubicado en una posición diferente.

Métodos: El estudio utiliza un modelo numérico simple para la evaluación del efecto de fragmentación, que requiere recursos modestos. Se utilizó un modelo numérico del efecto de fragmentación con el modelo de Gurney de propulsión explosiva y el método de Taylor y Shapiro para la dirección del vector de velocidad de los fragmentos. La capacidad de penetración de las bolas de acero proyectadas a través de acero duro homogéneo se analizó utilizando el modelo analítico de penetración de proyectiles de energía cinética del Proyecto Thor.

Resultados: Los resultados indican que un cambio en la posición del punto de inicio puede mejorar el efecto de fragmentación de las bolas de acero. La mejora más significativa es el aumento de la dispersión de los fragmentos, lo que provoca zonas de impacto de fragmentos mucho más grandes. También se observa un aumento modesto en la velocidad de los fragmentos, principalmente porque se cambia la dirección del vector de velocidad de los fragmentos. Además, la capacidad de penetración de ambos tipos de bolas de acero a distancias de hasta 50 m es suficiente para el papel antipersonal, mientras que las bolas de acero más grandes también tienen capacidades antimateriales.

Conclusión: Cambiar la espoleta de las ojivas de alto poder explosivo para cambiar la posición del punto de iniciación puede servir para mejorar el efecto de fragmentación.

Palabras claves: ojiva, detonación, fragmentación, propulsión explosiva.

Исследование влияния положения точки инициирования на осколочное действие головной части реактивного снаряда с использованием численной модели

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ВИД СТАТЬИ: оригинальная научная статья

Резюме:

Введение/цель: Реактивные снаряды с осколочно-фугасной головной частью являются наиболее распространенным типом боеприпасов для реактивных систем залпового огня. Они используются для выполнения широкого спектра боевых задач. Действие на цель, помимо других конструктивных особенностей, зависит от положения, в котором инициируется детонация разрывного заряда. В исследовании анализируется осколочное действие стальных шариков в 128-мм осколочно-фугасних головных частей М77 со стандартным контактным взрывателем и с другим расположением детонирующего узла.

Методы: В данном исследовании используется простая численная модель для определения осколочного действия, не требующая больших ресурсов. Численная модель содержит модель метательной способности Герни и метод Тейлора-Шапиро для определения направления вектора скорости осколка. Пробивная способность стальных шариков сквозь твердую гомогенную сталь анализировалась с помощью аналитической модели кинетического пробития осколков, разработанной в рамках «Проекта Тор».

Результаты: Результаты показывают, что изменение положения точки инициирования может улучшить осколочное действие стальных шариков. Наиболее значительным улучшением является увеличение рассеивания осколков, что приводит к увеличению зон поражения. Также наблюдается незначительное увеличение скорости движения осколков, главным образом из-за изменения направления вектора скорости движения осколков. Помимо того, пробивная способность обоих типов стальных шариков на расстоянии до 50 м достаточна для борьбы с пехотой, в то время как более крупные стальные шарики также обладают антиматериальными свойствами.

Вывод: Изменение взрывателя на осколочно-фугасных головных частях реактивного снаряда с целью изменения положения точки инициирования может быть использовано для улучшения осколочного действия.

Ключевые слова: головная часть реактивного снаряда, детонация, осколочное действие, метательная способность взрыва.

Истраживање утицаја положаја места иницирања на парчадно дејство разорне бојне главе ракете помоћу нумеричког модела

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ОБЛАСТ: хемијске технологије, машинство
КАТЕГОРИЈА (ТИП) ЧЛАНКА: оригинални научни рад

Сажетак:

Увод/циљ: Ракете са разорном бојном главом најзаступљенија су врста убојних средстава за вишецевне лансере ракета. Намењене су за извршење највећег дела борбених задатака. Њихово дејство на циљу зависи, поред одређених карактеристика конструкције, и од положаја иницирања процеса детонације у експлозивном пуњењу. Анализирано је парчадно дејство челичних куглица лаборисаних у тренутно-фугасне бојне главе 128 mm M77 са стандардним горњим упаљачем и са упаљачима чији се осигурани детонатор налази у другим положајима.

Методе: У истраживању је коришћен једноставан нумерички модел за одређивање парчадног дејства, који захтева скромне ресурсе. Нумерички модел садржи Гурнијев модел експлозивне пропулзије и Тејлор-Шапирову методу за одређивање смера вектора брзине парчади. Способност продирања челичних куглица кроз тврди хомогени челик анализирана је помоћу аналитичког модела продирања кинетичких пројектила, који је развијен у оквиру „Пројекта Тор”.

Резултати: Указано је да промена положаја тачке иницирања експлозивног пуњења може да побољша парчадно дејство челичних куглица. Најзначајније побољшање уочено је у повећању дисперзије парчади, чиме се остварују много веће зоне парчадног дејства. Такође, запажено је и мало повећање брзине парчади, што је, пре свега, последица промене смера вектора брзине парчади. Поред тога, пробојност обе врсте челичних куглица на даљинама до 50 m омогућава противпешадијску намену, док веће челичне куглице имају и способност дејства против материјалних средстава.

Закључак: Промена упаљача на разорним бојним главама, ради промене положаја места иницирања експлозивног пуњења, може се користити за побољшање парчадног дејства.

Кључне речи: бојна глава, детонација, парчадно дејство, експлозивна пропулзија.

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