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Experimental Determination of the Powder Quantity in the Ignition Cartridge for the Reusable Training-Practice Mortar Round for Firing on Short Distances

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***Abstract* - The article presents an experimental investigation for the powder quantity in the ignition cartridge for the reusable training-practice mortar round for firing on short distances, which is part of a training simulator for mortar crews. A formula for approximately calculating of the required amount of quantity of the gun powder in the ignition cartridge for many times used training-practice mine for shooting at a distance of 100 meters is presented in the article. The experimental investigation and the statistical hypothesis checking confirm that the formula can be used for practically determination of the required amount of charge in the ignition cartridge.**

Keywords - mortar, training-practice mortar round

I. INTRODUCTION

A tendency aimed towards the modernization of the Bulgarian Armed forces has been seen during the recent decades. The modernization of the armed forces however requires not only new equipment but also the implementation of modern means and methods for training military personnel and in military education institutions.

Part of these tools are the practical simulators. The most common disadvantage found in most practical simulators is the fact that they cannot simulate the full range of the crew's combat functions. In most cases they lack: the practical implementation of activities related to the preparation of ammunition at the fire position (installation of the fuze; setting the fuze function impact or delayed detonation etc.) and activities related to the loading and unloading of the mortar whether a misfire occurs. In addition, training equipment and simulators do not give an accurate notion for the psychological impact that affects the personnel during the use of real ammunition at the firing position and the additional stress accumulated during the firing.

One type of artillery system that is currently in service in the majority of armies are mortars.

In order for a high quality and effective practical, mortar training to be achieved, the development and implementation of a practical simulator is required. The created simulator must not only lower financial expenses but also guarantee a high level of immersion in real combat activities conducted on the firing position during live firing.

Based on the analysis conducted on developed practical simulators for the training of mortar crews in different countries the following basic requirements for the designed simulator can be identified:

- the construction of the simulator must include the basic components that are required for live-firing: mortar, training-practice mortar round, fuze and ignition cartridge;

- to enable the simulator to most accurately mimic the activities performed by the mortar crew during real combat operations;

- the training-practice mine must resemble, as much as possible, its combat counterpart in terms of appearance, weight and dimensions. The abovementioned criteria are

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required in order for the round to provide better practical training and to create a true picture of the round's operation;

- the construction of the training-practice mortar round must have simple technological design that incorporates already manufactured elements from its combat counterpart;

- the training-imitational fuze must be able to mark the area where the round has made impact with the ground. The fuze must be unable to cause fire, but at the same time, must still be capable of clearly indicating the area where the round has made impact;

- the training-practice fuze must fiction reliably and have a simple design and reliable action;

- the construction of the training-practice fuze must incorporate a safety mechanism that does not allow detonation before the round is fired;

- the ignition cartridge must resemble the ignition cartridge used in the live round as much as possible in terms of appearance and dimensions;

- the maximum firing distance must be 100 m, allowing the system to be used on firing ranges and training grounds;

- the minimum firing distance must be 20 m, ensuring the safety of the mortar team.

In accordance with the above listed requirements a simulator designed for the training of mortar teams was developed. As one of the elements of the simulator is a reusable training-practice mortar round for short distance engagements.

Analytical calculations were carried out about the required initial velocity of the round and the amount of powder in the ignition cartridge in order for a maximum engagement distance of 100 m.

The next step is an experimental study of the fidelity of analytical models and the correct determination of the amount of powder in the ignition charge.

The analytically determined initial velocity of the round required for it to reach 100 m is 35 m/s.

For an approximate determination of the required amount of smokeless nitroglycerin, ballistic, strip gunpowder, brand NBL-11 (НБЛ – 11) in the ignition cartridge, formula 1 is used [2],[4]:

$$\omega = \sqrt[b]{\frac{V_0}{a}} \qquad (1)$$

where:

ω – mass of the smokeless powder in the ignition cartridge[g];

V_0 – the desired initial velocity for the training-practice mortar round required for maximum distance firing 100 m (the desired initial velocity has a value of 35 m/s) [m/s];

a – coefficient determined by the caliber and mass of the round (for the 82 mm training-practice mortar round the value of this coefficient is 20,601892) [2];

b – degree indicator (for the 82 mm training-practice mortar round the value of this coefficient is 0,60068571) [2].

$$\omega = \sqrt[b]{\frac{V_0}{a}} = \sqrt[0{,}6006]{\frac{35}{20{,}602}} = 2{,}4166$$

The required amount of gunpowder brand NBL-11 (НБЛ–11) calculated via (1) is calculated to be approximately 2,4 g.

Using the calculated amount of gunpowder the ignition cartridge are filled with 2,4 g of gunpowder brand NBL-11 (НБЛ – 11).

II. Experimental study

2.1. Objective: experimentally determine the required amount of propelling charge required for the 82 mm reusable training-practice mortar in order for the round to reach 100 m.

2.2. Tasks:

- the amount of propelling charge required for reaching a distance of 100 m for the 82mm reusable training-practice mortar round for short distance engagements;

- determining the hit deviation ellipse for the 82 mm reusable training-practice mortar round at a distance of 100 m.

The experimental research was conducted on the artillery and small arms training site "Markovo".

Conditions under which the research was conducted:

- ambient temperature $19^{o} \pm 2^{o}$C; with a relative humidity of 65 ±5%;

- ignition charges were armed with 2,4 g smokeless nitroglycerin, ballistic, strip gunpowder, brand NBL-11 (НБЛ – 11);

- the temperature conditioning of the ignition charges is conducted inside the premises inside the premise of the armory in the cadet's battery at a constant temperature for the period of 24 hours before firing;

- the trial is conducted by firing from a single 82 mm mortar;

- firing is conducted at an elevation angle of 45^0 for maximum firing distance.

2.3. Procedure for conducting the experimental study

A. Preparation of the weapon system and ammunition

Sequence of activities:

- the bore of the mortar is cleaned from lubricant, carbon and other contaminants before it is fired;

- the mortar is deployed in the firing position;

- the training practice mortar rounds are armed with the ignition cartridges and the charges for the imitational fuze;

- a mortar warm up shot is fired.

B. Carrying out the experimental shooting

The experimental shooting is carried out in the following sequence:

- 10 shots are fired sequentially with training practice mortar rounds;

- after each shot the area where the round has hit is determined and the distance between the hit and the muzzle of the mortar is measured.

2.4. Material supply.

The following material was used to carry out the experimental shootings:

- ignition charges armed with 2,4 g smokeless nitroglycerin, ballistic, strip gunpowder, brand NBL-11 (НБЛ – 11) – 10 (ten) pc.

- charges for the imitation fuze – 10 (ten) pc.

- training-practice mortar rounds – 10 (ten) pc.

- 82 mm mortar;

- tape measure – 25 m.

III. RESULTS FROM THE EXPERIMENTAL STUDY

The results gathered from the experimental study from firing the training-practice mortar rounds, armed with smokeless nitroglycerin, ballistic, strip gunpowder, brand NBL-11 (НБЛ – 11) in the ignition charge, fired from an elevation angle of 45^{o} are presented in table 1.

TABLE 1 RESULTS FROM THE EXPERIMENTAL STUDY GATHERED FROM FIRING THE TRAINING-PRACTICE MORTAR ROUND ARMED WITH SMOKELESS NITROGLYCERIN, BALLISTIC, STRIP GUNPOWDER, BRAND NBL-11 (НБЛ – 11) IN THE IGNITION CHARGE, FIRED FROM AN ELEVATION ANGLE OF 45^{O}

№ fired shot	***Elevation angle***	***Expected hit distance***	***Actual hit distance***	***Error***
	[deg]	[m]	[m]	[%]
1	45°	100	86	-24%
2	45°	100	90	-10%
3	45°	100	97	-3%
4	45°	100	106	+6%
5	45°	100	111	+11%
6	45°	100	115	+15%
7	45°	100	89	-11%
8	45°	100	92	-8%
9	45°	100	103	+3%
10	45°	100	105	+5%
Average hit and error values			99,4	9,6%

The average firing distance is 99,4 m, with an average error from the experimental study results from firing the training practice mortar-round armed with smokeless nitroglycerin, ballistic, strip gunpowder, brand NBL-11 (НБЛ – 11) in the ignition charge, fired from an elevation angle of 45^{o} is 9,6% .

The big axis of the deviation ellipse is 29 m.

IV. STATISTICS HYPOTHESIS CHECKING

The statistics hypothesis can be checked by comparing of the dispersions of the experimental and analytical results [5] [6] [7]. The zero hypothesis is that the dispersion of data, received from the analytical model is commensurable with the dispersion of the experimental data [8].

Formula (2) can be used to check the statistics hypothesis [1]:

$$\chi_0^2 = \frac{ss}{\sigma_0^2} \qquad (2)$$

where:

$SS = \sum_{i=1}^{n}\left(y_{Ei} - \bar{y}_E\right)^2$ - corrected sum of the squares of the experimental investigation data;

$\sigma_0^2 = \frac{1}{n-1}.\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2$ - dispersion of the analytical model data;

$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ - average analytical model data;

$\bar{y}_E = \frac{1}{n}\sum_{i=1}^{n} y_{Ei}$ - average experimental investigation data;

n - data number.

The zero hypothesis is rejected in cases, when $\chi_0^2 > \chi_{\alpha/2;n-1}^2$ or $\chi_0^2 < \chi_{1-\alpha/2;n-1}^2$ [1]. The values of $\chi_{\alpha/2;n-1}^2$ and $\chi_{1-\alpha/2;n-1}^2$ are tabu1lar [1].

The received results are presented in table 2.

TABLE 2 RESULTS OF ZERO HYPOTHESIS CHECKING

№	*α*	χ_0^2	$\chi^2_{(0,025;9)}$	$\chi^2_{(0,975;9)}$
1	0,05	12,24168	23,3366	4,40778

V. Conclusions

The results presented in table 2 show that the zero hypothesis can be accepted as true and the analytical model can be used for practical calculation of the quantity of powder placed in the ignition cartridge for the reusable training-practice mortar round for firing on short distances.

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