

EVALUATION OF HIT'S GROUPING DEVIATION DUE TO TRIBOLOGICAL PROCESSES IN BULLET-RUBBER CHOPPER WHEEL INTERACTION

АНАЛИЗ НА ОТКЛОНЕНИЕТО НА ГРУПИРАНОСТТА ВСЛЕДСТВИЕ НА ТРИБОЛОГИЧНИТЕ ПРОЦЕСИ ПРИ ПРЕМИНАВАНЕ НА КУРШУМ ПРЕЗ ГУМЕН ОБТЮРАТОР

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Abstract: *The use of special weapons in counter-terrorist operations with fitted suppressors and the necessity of reliable target damage even while using individual ballistic armor protection details initiate the need of evaluation of hits grouping deviation. In the report is evaluated hit's grouping deviation due to tribological processes in bullet-rubber chopper wheel interaction with scrutinizes of the experimental fire shooting data.*

Keywords: SILENCER; HITS GROUPING DEVIATION; TRIBOLOGICAL PROCESSES.

1. Introduction

Fight against terrorist organizations requires a change in the traditional perceptions of military action and tactical use of firearms. Due to the complexity of anti-terrorist operations it is necessary to use special equipment for the firearms.

Parts of this special equipment are the silencers. Silencer reduces the sound of the firearms when they fired, by lowering the temperature and velocity of the effluent gases. In addition the use of special equipment for individual ballistic protection requires weapons with high efficiency. High efficiency is achieved by increased precision and shots grouping.

Things to consider in counter-terrorist operations are special equipment and special ammunition usage. Both of them lead to changes in weapon's ballistic characteristics. Last ones are base for achieving maximum efficiency and reliable target damage while using individual ballistic armor protection in combat operation scenario.

The report's subject is the PBS-1 which is a chamber type silencer with rubber chopper wheel. The research of the information in available literature ensures that the rubber chopper wheel serves to initiate the automatic action of the weapon and does not affect the noise suppression. Records can be found, in many information sources that the rubber chopper wheel changes the hit's grouping, but there is no experimental data of conducted researches. Available literature analysis shows that there is no data of evaluated deviation dependencies of hit's grouping due to tribological processes in bullet-rubber chopper wheel interaction.

Therefore the experimental shootings data have been used to determine the dependency between the hit's grouping deviation and the tribological processes. As a milestone in achieving maximum efficiency is the determination of target area limits in semi-automatic fire mode using fitted chamber type suppressor with rubber chopper wheel.

Based on the paragraphs above in the report several researches have been conducted and as a result is evaluated hit's grouping deviation due to tribological processes in bullet-rubber chopper wheel interaction.

2. Evaluation of hit's grouping deviation dependencies

2.1. Purpose: Evaluation of deviation dependencies of hit's grouping due to tribological processes amendment in bullet-rubber chopper wheel interaction while reducing the power of contact tension.

2.2. Tasks:

- to determine the mathematical expectation and the standard deviation from the experimental shooting's data in case of new rubber chopper wheel;
- to determine the mathematical expectation and the standard deviation from the experimental shootings data in case of different diameter of rubber chopper wheel's opening;
- to determine the dimensions of shots grouping using the rule of the three σ on the vertical and the horizontal planes in which the 100% of the bullet hits the target in case of different diameter of rubber chopper wheel's opening and without opening.

3. Results of discussion

In order to achieve the purpose of this report the deviation of hits from the control point are obtained from experimental shootings during single fire with fitted silencer PBS-1 on AK-47 assault-rifle in case of different openings diameter and without opening in the rubber chopper wheel.

3.1. Determination of the mathematical expectation and the standard deviation

For evaluation of deviation dependencies of hit's grouping due to tribological processes amendment in data analyses represented are made several study cases. These cases differs from one another by diameter of the opening in rubber chopper wheel and some of them are made before shooting, others have been normally created by bullet passing through the rubber chopper wheel.

The rubber chopper wheel's opening diameters are:

- $d_n = 0$ mm – new rubber chopper wheel;
- conic opening after 20 shots were fired with input diameter – $d_{co} = 4$ mm and output – $d = 1$ mm;
- conic opening after 100 shots were fired with input diameter – $d_{co} = 6$ mm and output – $d = 2$ mm;
- conic opening after 180 shots were fired with input diameter – $d_{co} = 8$ mm and output – $d = 4$ mm;
- $d_{cy} = 7$ mm – cylindrical opening handmade before shooting;
- $d_{cy} = 8$ mm – cylindrical opening handmade before shooting;
- $d_{cy} = 9$ mm – cylindrical opening handmade before shooting.

Table 1 and table 2 represents the deviation of hits from the control point in horizontal and vertical planes in case of different openings diameter and without opening in the rubber chopper wheel.

Table 1: Deviation of hits from the control point horizontally

Number of hits	Deviations of hits from the control point horizontally, in centimetres						
	The rubber chopper wheel's opening diameter, [mm]						
	dn = 0	dco = 4	dco = 6	dco = 7	dco = 8	dco = 9	dco = 8
1	0	-8,3	-16,4	-25,6	-0,8	-3,6	-27,3
2	-7	-8,4	-18,2	-26,4	-1,2	-5,3	-28,4
3	-7,7	-9,5	-19,8	-27,8	-1,9	-6,3	-31,2
4	-10	-10,2	-20	-28,8	-3,6	-6,5	-32,5
5	-10,2	-11	-20,5	-28,9	-3,7	-6,6	-35,8
6	-12,5	-12	-22,8	-30,3	-4	-6,7	-35,8
7	-12,7	-14	-23,5	-30,7	-6,2	-6,9	-36
8	-13,2	-16	-23,5	-31	-11	-7,1	-36,6
9	-14,4	-17,3	-23,7	-31,6	1,6	-7,3	-36,7
10	-15,2	-18	-24,1	-32,8	2,6	-9,4	-37
11	-15,6	-18,2	-25	-33,1	5,3	-9,5	-39,5
12	-16,3	-19,6	-26	-33,8	5,4	-9,7	-40,2
13	-17,4	-20,7	-26,3	-34,4	6	-9,8	-40,4
14	-18,9	-21,1	-26,4	-35,2	6,6	-10,2	-40,6
15	-19,3	-22,1	-27,8	-35,4	8,2	-10,9	-40,7
16	-19,4	-24	-28,8	-36,6	8,4	-11	-41,2
17	-20	-24,2	-29,5	-37,4	9,3	-11,9	-41,5
18	-22,6	-25,3	-31,8	-38,1	10	-13,8	-43,2
19	-25,5	-26,3	-32	-38,8	12,8	-15,1	-46,4
20	-28,5	-31	-38	-39,4	14,3	-15,6	48,5

Table 2: Deviations of hits from the control point vertically

Number of hits	Deviations of hits from the control point vertically, in centimetres						
	The rubber chopper wheel's opening diameter, [mm]						
	dn = 0	dco = 4	dco = 6	dco = 7	dco = 8	dco = 9	dco = 8
1	6,8	5,6	-2	-1	9,6	-1,1	-4
2	11,8	17,9	-2,2	-2,8	11,6	-2	17,5
3	12,8	24	-2,4	-3,4	12,1	1,1	18,8
4	13	26,2	-2,6	-4,6	12,2	1,4	19,2
5	13,5	26,8	-3,2	-5,2	12,8	1,5	20,8
6	14,2	27,4	-3,4	-6,4	14,6	2,6	24,3
7	15	28	-3,7	-7,8	14,7	3	24,4
8	15,3	29,2	-3,9	-9,4	14,8	3,4	26,2
9	15,5	29,7	-4,2	-10,5	15,2	4,3	26,4
10	15,8	30	-4,5	-11,4	15,3	5,1	26,8
11	16,1	30,6	-5	-12,3	15,6	5,9	28,2
12	17	30,9	-5,2	-12,6	16,1	6,2	29
13	17,2	31,5	-5,9	-12,8	16,6	6,3	29,3
14	17,6	31,9	-6,4	-14,1	16,8	6,6	30,6
15	18	32	-6,8	-15,2	17,2	7,4	31,4
16	18,8	32,2	-7,5	-16,8	19,1	7,5	33,8
17	22	32,4	-7,6	-18,5	20,8	7,8	34,4
18	22,9	32,6	-8,3	-23	21,6	8,8	34,5
19	25,4	33	-8,5	-23,6	21,8	12,1	35,6
20	27,8	34,4	-9,2	-30,6	22,8	12,2	39

To determine the satisfying minimum required number of shots, that provide confidence interval of 99.9%, the following equation is used:

$$(1) n = \frac{S^2 u_{\frac{\alpha}{2}}^2}{\varepsilon^2} = \frac{5,862^2 \cdot 3,37^2}{4,623^2} = 18,26$$

In this equation, the quantities are defined as:

- $u_{\frac{\alpha}{2}}$ – is a quantile of the normal distribution that provide confidence level of 99.9%
- S – standard deviation;
- ε – accuracy of the estimation of mathematical expectation.

Standard deviation can be calculated using the formulas:

$$(2) S = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \chi)^2};$$

Accuracy of the estimation of mathematical expectation is determined by following mathematical apparatus:

$$(3) \varepsilon = t_{\frac{\alpha}{2}} \frac{S}{\sqrt{n}},$$

- $t_{\frac{\alpha}{2}}$ a quantile of the Student's normal distribution.

The minimum required number of shots are 19 during the investigation twenty shots in series were fired which satisfy the requirement.

Using mathematical software Math Lab it is define the mathematical expectation - (χ) and the standard deviation - (σ) of the deviation of hits from the control point in horizontal and vertical planes which are presented in table 3.

Table 3: Mathematical expectation and standard deviation of hit's deviation from the control point in horizontal and vertical planes in case of different openings diameter and without opening.

The rubber chopper wheel's opening diameter, [mm]	value of χ in centimetres		value of σ in centimetres	
	horizontal plane	vertical plane	horizontal plane	vertical plane
dn = 0 mm	-15,32	16,825	6,647	4,851
dco = 4 mm	-17,86	28,315	6,594	6,545
dco = 6 mm	-25,205	-5,125	5,205	2,276
dco = 7 mm	32,805	-12,1	4,128	7,682
dco = 8 mm	2,905	16,065	6,796	3,648
dco = 9 mm	-9,16	5,005	3,249	3,855
dco = 8 mm	-33,125	26,31	19,808	9,295

3.2. Determination of the dimensions of shots grouping

From the analysis made, using the values of mathematical expectation - (χ) and the standard deviation - (σ) and the rule of the three σ – are determined the dimensions of ellipse of dispersion of hits in the vertical and the horizontal planes in which the contains 100% of hits. The values of normal distributed random variable's ellipse of dispersion based on the rule of the three σ are presented in table 4.

Table 3: The dimensions of dispersion ellipse of normal distributed random variable

The rubber chopper wheel's opening diameter, [mm]	$\bar{x} - 3\sigma$		$\bar{x} + 3\sigma$	
	horizontal plane	vertical plane	horizontal plane	vertical plane
dn = 0 mm	-35,262	2,27	4,622	31,38
dco = 4 mm	-37,644	8,68	1,924	47,95
dco = 6 mm	-40,822	-11,954	-9,587	1,704
dco = 7 mm	-45,189	-35,167	-20,421	10,946
dco = 8 mm	-17,485	5,121	23,295	27,008
dco = 9 mm	-18,909	-6,562	0,589	16,572
dco = 8 mm	-92,551	-1,575	26,301	54,195

On Fig. 1 to Fig. 7 graphically represents mathematical expectation and ellipse of dispersion in the vertical and the horizontal planes for different opening diameters in the rubber chopper wheel.

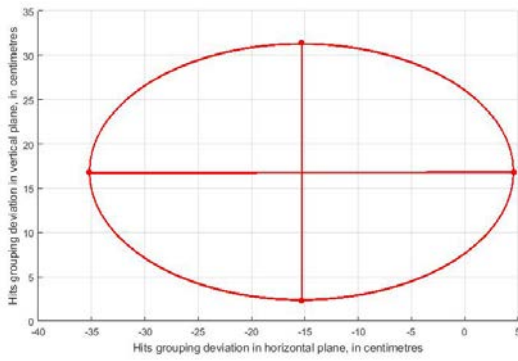


Fig. 1 Graph of mathematical expectation and ellipse of dispersion in the vertical and the horizontal planes in case of the new rubber chopper wheel – $d_n = 0$ mm.

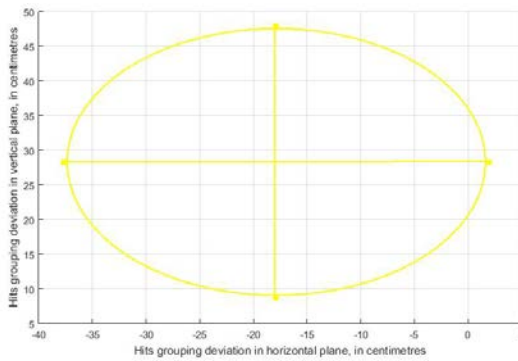


Fig. 2 Graph of mathematical expectation and ellipse of dispersion in the vertical and the horizontal planes in case of the rubber chopper wheel's diameter opening – $d_{co} = 4$ mm.

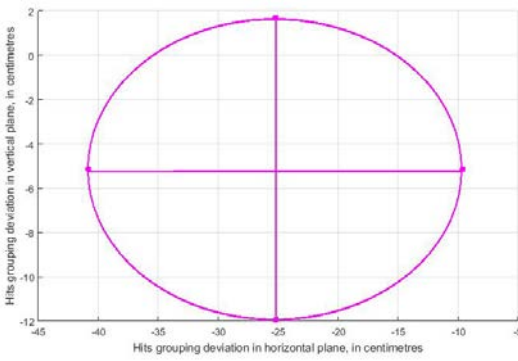


Fig. 3 Graph of mathematical expectation and ellipse of dispersion in the vertical and the horizontal planes in case of the rubber chopper wheel's diameter opening – $d_{co} = 6$ mm.

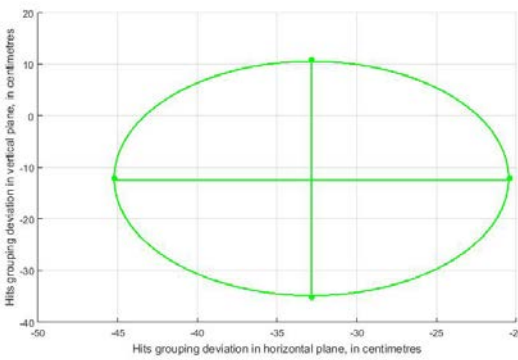


Fig. 4 Graph of mathematical expectation and ellipse of dispersion in the vertical and the horizontal planes in case of the rubber chopper wheel's diameter opening – $d_{cy} = 7$ mm.

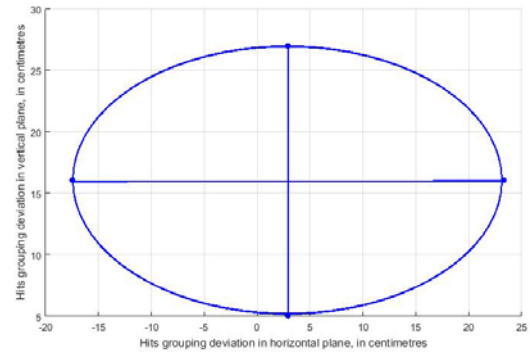


Fig. 5 Graph of mathematical expectation and ellipse of dispersion in the vertical and the horizontal planes in case of the rubber chopper wheel's diameter opening – $d_{cy} = 8$ mm.

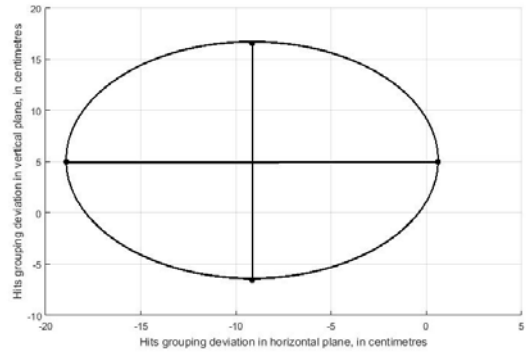


Fig. 6 Graph of mathematical expectation and ellipse of dispersion in the vertical and the horizontal planes in case of the rubber chopper wheel's diameter opening – $d_{cy} = 9$ mm.

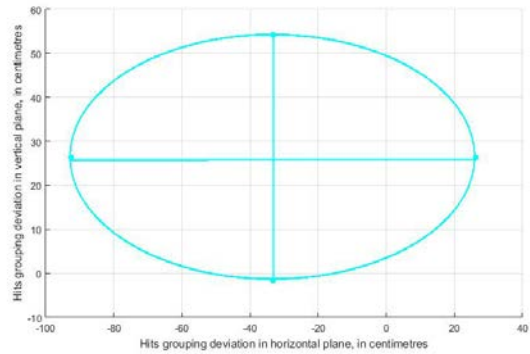


Fig. 7 Graph of mathematical expectation and ellipse of dispersion in the vertical and the horizontal planes in case of the rubber chopper wheel's diameter opening – $d_{co} = 8$ mm.

Fig. 8 graphically presents comparison of hit's grouping deviation for different opening diameter in the rubber chopper wheel. Mathematical expectation and ellipse of dispersion in vertical and the horizontal planes for different occasion are compared.

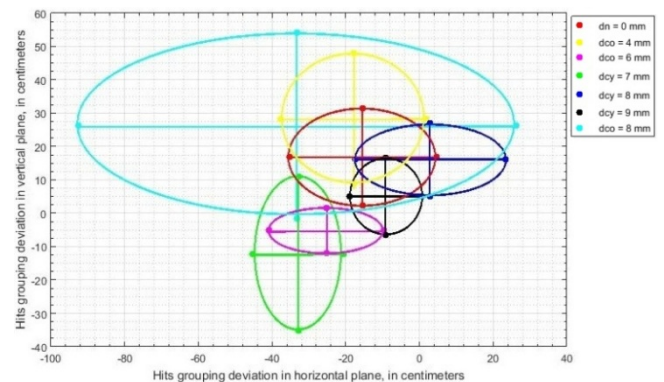


Fig. 8 Summarized graph of hits grouping deviation.

4. Conclusions

1. From the conducted research it can be concluded that the deviation of hits grouping with a fitted chamber type suppressor with a rubber chopper wheel has tribological process dependencies. It can be concluded that the amendment of the tribological characteristics lead to alteration in the deviation of the shots grouping in the vertical and the horizontal planes.

2. The research shows a phenomenon of a handmade opening in rubber chopper wheel before shooting. Based on the PBS-1 service manual information the diameter of normal grouping of hits is 15 centimeters. From Figure 6 presented above, it can be summarize that the hits grouping tends to be normal when contact between the bullet and the rubber chopper wheel of the suppressor is missing.

3. Based on the data analysis it can be concluded that dispersion of hits in range and deflection is at least eight times smaller when shooting with cylindrical handmade opening with diameter – $d_{cy} = 8$ mm than conic opening with same input diameter.

4. The evaluated hit's grouping deviation due to tribological processes in bullet-rubber chopper wheel interaction present that after 180 shots with conic opening $d_{co} = 8$ mm in rubber chopper wheel the diameter of grouping has the greatest size. That determines the wear of the rubber chopper wheel has a significant impact on the hits grouping.

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