DETERMINATION OF CHANGE OF THE POINT OF THE FIRE SHOTS AT SHOOTING WITH FITTED CHAMBER TYPE SUPPRESSOR

Assoc. Prof. Ing. Ganev V. PhD., M.Sc. Ing. Dimitrova Ya.
Faculty of "Artillery, air defense and CIS" –National Military University "Vasil Levski", Veliko Tarnovo, the Bulgarian Republic

vvganev@abv.bg

Abstract: *Part of the global trends related with the development of armaments are currently focused on creating new samples of small arms and device which have increased combat effectiveness.*

Two of the factors that have a significant impact on combat effectiveness are grouping and accuracy in shooting. Installation of the silencer on small arms leads to a change of these factors, especially when must be shoot at long distances.

The report scrutinizes an experimental investigation on the mathematical ratio of hit point on the target at shooting with small arms with fitted silencer of the chamber type with rubber chopper wheel.

Keywords: SMALL ARMS, SUPRESOR, MIDPOINT OF THE HITS.

1. Introduction

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 initiates the need for combatant to consider for the changes of the weapons ballistic characteristics. The ballistic characteristics of the weapon are changed by the use special ammunition.

Suppressor fitting on the small arms causes a deviation from midpoint of hits and necessitates the determination of the dependencies between the horizontal and vertical deviations and the number of shots fired.

In the Republic of Bulgaria, main type of small arm is the automatic rifle AK-47. The suppressor designed for AK-47 is PBS-1, a chamber type suppressor with a rubber chopper wheel.

The science investigation presented in this report is a sequence of researches that include: examine the deviation of hits midpoint, the grouping, and the dimensions of target area limits.

2. Experimental investigation

2.1. Purpose: experimentally determine the dependence under which changes in the hit points are relative to the control point in a semi-automatic fire mode with small arms fitted with a chamber type suppressor with a rubber chopper wheel.

2.2. Tasks:

- to determine the mathematical expectation and the standard deviation of the impact points;

- to determine the dependence under which changes in the hit points are relative to the control point;

In order to achieve the purpose of this report, data obtained from the experimental investigation will be used, described in [1]. The automatic rifle fitted with the suppressor is installed in the "Samozhenkov" stand in order to exclude any errors that might unintentionally be done by the shooter. The distance to the target is 100 meters, the target dimensions are 1000x1000 mm, the rounds used are the 7.62x39 mm "MD" specially designed for shooting with the PBS-1. Shots are fired in 10 series of 20 shots each at a temperature of 21°C under normal atmospheric pressure and windless. Deviations of the hits from the control point in the horizontal and vertical plane are to be determined.

Deviations of the hits from the control point are shown horizontally in Table 1 and vertically in Table 2.

Table1: *Deviations of hits from control point horizontally*

Deviation of hits from control point horizontally in millimetres	Series №									
	1	2	3	4	5	6	7	8	9	10
1	0	-83	-189	-197	-95	-164	22	-12	-70	-273
2	-70	-84	-208	-206	-172	-182	22	-15	-83	-284
3	-77	-95	-218	-250	-206	-198	64	-35	-100	-312
4	-100	-102	-220	-258	-209	-200	75	-38	-113	-325
5	-102	-110	-237	-265	-224	-205	-10	-40	-126	-358
6	-125	-120	-249	-266	-225	-228	-12	-85	-128	-358
7	-127	-140	-250	-266	-227	-235	-14	-100	-137	-360
8	-132	-160	-260	-268	-235	-235	-20	-103	-138	-366
9	-144	-173	-266	-272	-236	-237	-28	-114	-139	-367
10	-152	-180	-268	-278	-274	-241	-28	-120	-140	-370
11	-156	-182	-272	-289	-277	-250	-34	-123	-154	-395
12	-163	-196	-278	-295	-276	-260	-40	-130	-157	-402
13	-174	-207	-273	-298	-278	-263	-54	-150	-161	-404
14	-189	-211	-258	-306	-286	-264	-60	-180	-174	-406
15	-193	-221	-293	-312	-291	-278	-74	-186	-175	-407
16	-194	-240	-297	-318	-296	-288	-96	-207	-180	-412
17	-200	-242	-304	-339	-294	-295	-99	-215	-181	-415
18	-226	-253	-295	-349	-323	-318	-100	-228	-195	-432
19	-255	-263	-325	-356	-334	-320	-140	-236	-225	-464
20	-285	-310	-343	-414	-358	-380	-197	-236	-230	-485

Table 2: *Deviations of hits from control point vertically*

Deviation of hits from control point vertically in millimetres	Series №									
	1	2	3	4	5	6	7	8	9	10
1	135	330	188	83	-84	-52	8	156	58	356
2	68	323	95	15	-60	-45	-70	-31	64	293
3	180	319	101	110	-85	-34	-72	129	38	390
4	150	344	65	43	36	-26	8	119	55	290
5	220	297	128	10	63	-42	-5	78	33	-40
6	118	315	144	34	-52	-20	-17	178	18	268
7	130	274	140	32	120	-37	44	165	-47	264
8	229	268	151	107	19	-68	8	135	28	314
9	142	309	38	-6	74	-22	-21	135	-56	188
10	278	323	146	-8	42	-37	85	198	-147	282
11	155	280	145	28	32	-85	4	186	58	338
12	155	300	87	9	105	-75	37	62	47	306
13	130	262	100	126	68	-64	-6	-17	36	262
14	171	325	210	100	186	-50	122	20	-62	344
15	188	179	135	121	65	-22	42	96	-23	243
16	170	306	170	125	96	-59	-2	28	46	208
17	158	320	177	91	113	-92	-6	18	-9	345
18	161	292	218	72	133	-83	6	-77	8	175
19	254	240	160	125	92	-32	5	-14	45	244
20	171	56	55	102	70	-76	48	-45	36	192

The results are recorded in the following matrix:

$$m = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$$

The quantities are defined as:

n = 10 –number of series;

m = 20 –number of shots per series.

To define the mathematical expectation and the standard deviation of the hits by using mathematical software Matlab, following equations would be used:

- for the mathematical expectation

$$\chi = \frac{1}{n}\sum_{i=1}^{n} x_i,$$

- for the standart deviation

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

In these equations, the quantities are defined as:

n- number of series on the basis of which the arithmetic mean value is determined;

x $_i$–value of ith *(i=1..n)* examined deviation.

In order to determine the minimum required number of shots that provide confidence interval of 99.9%, the following equation is used:

$$n = \frac{S^2 u_{\frac{\alpha}{2}}^2}{\varepsilon^2} = \frac{5{,}713^2 . 3{,}37^2}{4{,}57^2} = 17{,}7$$

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

ε – accuracy of the estimation of mathematical expectation calculated by the formulas $\varepsilon = t_{\frac{\alpha}{2}} \frac{S}{\sqrt{n}}$,

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

Twenty shots in series were fired during the investigation, satisfying the requirement of the minimum required number of shots - 18.

In table 3 the mathematical expectation and the standard deviation of the hits in horizontal and vertical plane are presented.

Table3: *Mathematical expectation and standard deviation of series hits*

	Series №									
	1	2	3	4	5	6	7	8	9	10
χ horizontally in milimetres	-153,2	-178,6	-265,2	-290,1	-255,8	-252,1	-41,2	-127,7	-150,3	-379,8
χ vertically in millimetres	168,2	283,1	132,7	66,0	51,7	-51,1	10,9	76,0	11,3	263,1
σ horizontally in milimetres	64,8	64,3	37,9	49,1	58,8	50,7	63,8	73,5	41,0	52,9
σ vertically in millimetres	47,1	63,8	48,2	47,1	71,8	22,4	43,8	83,4	52,6	90,6

Using the mathematical expectation, Matlab's Curve Fitting application has proposed the following dependencies for changing the hit point:

- in the horizontal direction:

- Linear Fitting:

$$y = a(\sin(x - \pi)) + b((x - 10)^2) + c$$

$$a = -10{,}86$$
$$b = -0{,}05873$$
$$c = -20{,}8$$

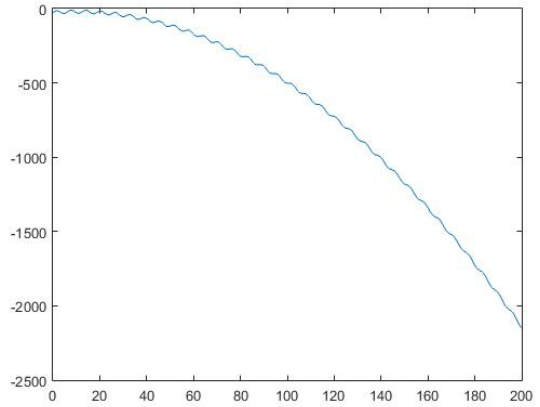

Fig. 1 *Graph of deviation of the hit point from the control point calculated using Linear Fitting.*

- Polynomial:

$$y = p_1 x^8 + p_2 x^7 + p_3 x^6 + p_4 x^5 + p_5 x^4 + p_6 x^3 + p_7 x^2 + p_8 x + p_9$$

$$p_1 = -0{,}0659$$
$$p_2 = -2{,}474$$
$$p_3 = -53{,}4$$
$$p_4 = -457{,}2$$
$$p_5 = -3148$$
$$p_6 = -9525$$
$$p_7 = -2{,}246e^4$$
$$p_8 = -2{,}029e^4$$
$$p_9 = -9503$$

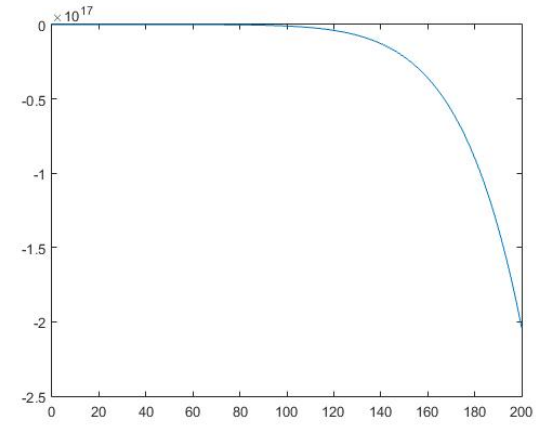

Fig. 2 *Graph of deviation of the hit point from the control point calculated using Polynomial.*

- Rational:

$$y = \frac{p_1 x^4 + p_2 x^3 + p_3 x^2 + p_4 x + p_5}{x + q_1}$$

$$p_1 = -1{,}051$$
$$p_2 = 19{,}08$$
$$p_3 = -106{,}7$$
$$p_4 = 176{,}1$$

$$p_5 = \quad -138{,}5$$
$$q_1 = \quad 2{,}328$$

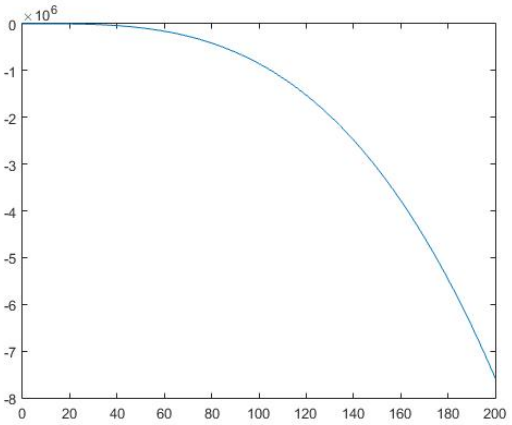

Fig. 3 *Graph of deviation of the hit point from the control point calculated using Rational.*

- in the vertical direction:

- Linear Fitting:

$$y = a(\sin(x-\pi)) + b((x-10)^2) + c$$

$$a = \quad -1{,}11$$
$$b = \quad 0{,}1683$$
$$c = \quad 5{,}163$$

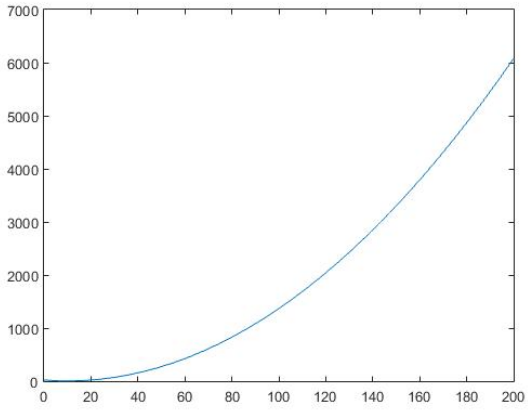

Fig.4 *Graph of deviation of the hit point from the control point calculated using Linear Fitting.*

- Polynomial:

$$y = p_1 x^8 + p_2 x^7 + p_3 x^6 + p_4 x^5 + p_5 x^4 + p_6 x^3 + p_7 x^2 + p_8 x + p_9$$

$$p_1 = \quad 0{,}0004949$$
$$p_2 = \quad -0{,}01196$$
$$p_3 = \quad 0{,}02677$$
$$p_4 = \quad 1{,}804$$
$$p_5 = \quad -23{,}75$$
$$p_6 = \quad 133{,}8$$
$$p_7 = \quad -383{,}1$$
$$p_8 = \quad 524{,}4$$
$$p_9 = \quad -236{,}4$$

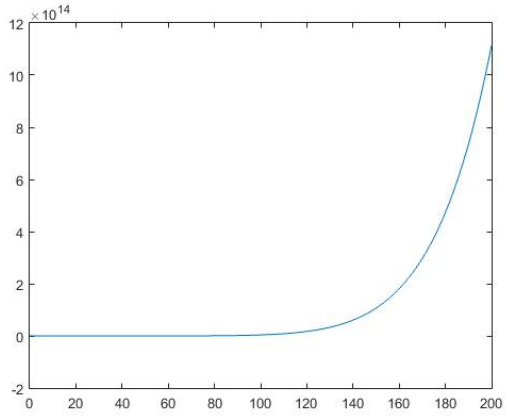

Fig. 5 *Graph of deviation of the hit point from the control point calculated using Polynomial.*

- Rational:

$$y = \frac{p_1 x^5 + p_2 x^4 + p_3 x^3 + p_4 x^2 + p_5 x + p_6}{x + q_1}$$

$$p_1 = \quad 1590$$
$$p_2 = \quad -4{,}497e^4$$
$$p_3 = \quad 4{,}771e^5$$
$$p_4 = \quad -2{,}29e^6$$
$$p_5 = \quad 4{,}559e^6$$
$$p_6 = \quad -2{,}035e^6$$
$$q_1 = \quad 3{,}983e^4$$

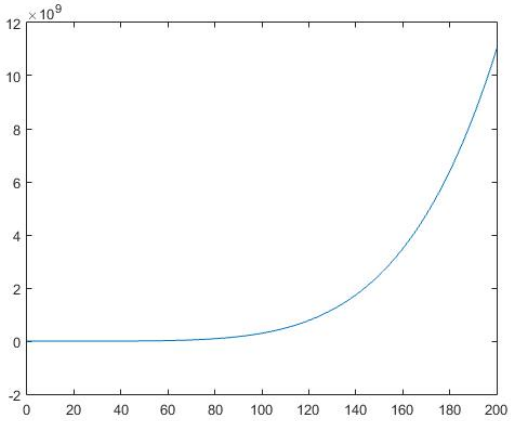

Fig. 6 *Graph of deviation of the hit point from the control point calculated using Rational.*

3. Conclusions

The deviation of the hit point can be described with dependencies of the Linear Fitting, Polynomial and Rational types. If it is necessary to calculate the alteration of the hit point in the horizontal and vertical directions, it is advisable to use Polynomial equations, due to the most exact match with the experimental data.

The alteration of the hit point in horizontal direction - to the left and in vertical direction - in the upward direction

Graphs analysis shows that the value of the deviation in both directions increases steadily up to 200 shots permissible for the rubber chopper wheel, and then the deviation value become much higher.

Due to the specific characteristics of these alterations of the hit point in continuous shooting with a chamber type suppressor with a rubber chopper wheel requires additional training of the shooters.

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