

## COMPARATIVE ANALYSIS OF THE ACCURACY OF BOMB RELEASE AND THE PROBABILITY CHARACTERISTICS OF THE ERROR OF BOMBING OF DIFFERENT METHODS SOLVING THE PROBLEM OF AIMING

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**Keywords:** *Aviation, Air bomb, Accuracy of bomb release, Probable deflection*

### **Abstract**

*An approximate method for estimating the accuracy of bomb release of new methods solving the problem of targeting compared to existing ones is proposed. A comparative analysis of the Root mean square deviation, the expected value and the second starting point of the bomb release error for new and existing methods of the targeting task was performed.*

### **Introduction**

In certain areas of use of different methods for solving the targeting problem, it is possible to perform a comparative analysis of the accuracy of bomb release of these methods by the probable deviations of the drop points of the bombs.

The probable deviation is calculated according to the formula [3]:

$$1) \quad E = 8H + 0,08V_1(1+\sin\lambda)$$

where:  $H$  is the height of bomb release, km,  
 $V_1$  — speed of bomb release, km/h,  
 $\lambda$  — diving angle.

The following expressions (method 1, existing and method 2, new) are used to perform a comparative analysis of the probabilistic characteristics of the bomb release errors of different methods:

$$\begin{aligned} &\Delta\sigma\Delta x = \sigma\Delta x_1 - \sigma\Delta x_2 \\ 2) \quad &\Delta M[\Delta x] = M[\Delta x_1] - M[\Delta x_2] \\ &\Delta\alpha_2 x = \alpha_2 x_1 - \alpha_2 x_2 \end{aligned}$$

where: -  $\sigma_{\Delta x1}$ ,  $M[\Delta x1]$ ,  $\alpha_{2x1}$  are the standard deviation, the mathematical expectation and the second starting point of the bomb error for method 1.

-  $\sigma_{\Delta x2}$ ,  $M[\Delta x2]$ ,  $\alpha_{2x2}$  are the standard deviation, the mathematical expectation and the second starting point of the bomb error for method 2.

### Results

To calculate the probable deviation  $E$  of Method 2, the following formula is proposed:

$$3) \quad E_2 = P_n E_n + P_{nn} E_{nn},$$

Where: -  $E_n$  и  $E_{nn}$  are probable deviations during bomb release during or exiting diving;

-  $P_n$  и  $P_{nn}$  – probabilities for bomb release during or exiting diving.

Probable deviations are calculated by a formula (1) where  $H$ ,  $V1$  and  $\lambda$  are the average values taken for the respective bomb-dropping areas.

Release probabilities are defined as the ratio of the area to the total area of the bomb-dropping area for a given method.

To determine the percentage increase in the accuracy of bomb release when using method 2 compared to method 1, the following ratio is used:

$$4) \quad E\% = \frac{E_{cm} - E_{ym}}{E_{cm}} 100$$

Based on the resulting areas [4] of possible bomb release conditions for method 2 and method 1, the average values for the bomb release conditions ( $H_0$ ,  $V_{1,0}$ ,  $\lambda_0$ ) of the respective areas are determined (Fig. 1, 2, 3, 4). The same figures also determine the probabilities of during or exiting diving release  $P_n$  and  $P_{ip}$  (Table 1).

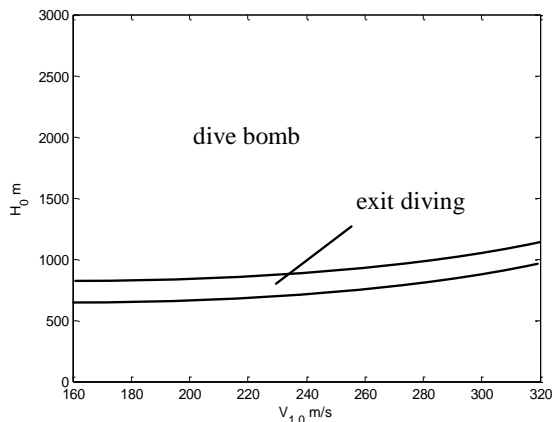


Fig. 1. Dependence of  $H_0$  from  $V_{1,0}$ ,  $\lambda_0 = -30^\circ$

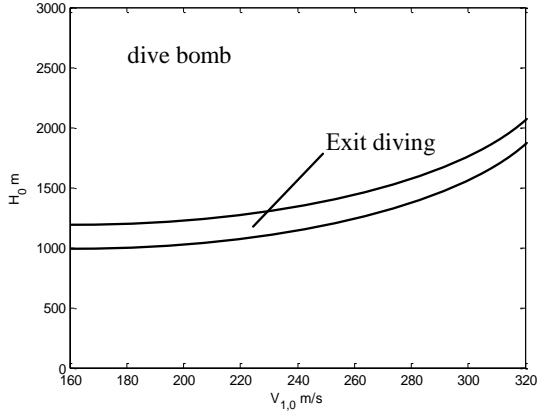


Fig. 2. Dependence of  $H_0$  on  $V_{1,0}$ ,  $\lambda_0 = -50^\circ$

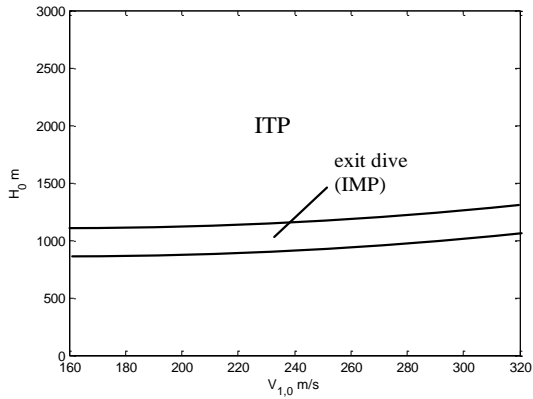


Fig. 3. Dependence of  $H_0$  from  $V_{1,0}$ ,  $\lambda_0 = -30^\circ$

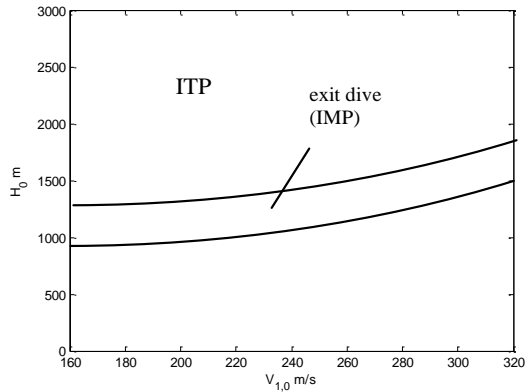


Fig. 4. Dependence of  $H_0$  from  $V_{1,0}$ ,  $\lambda_0 = -50^\circ$

Table 1

	$\lambda_0 = -30^0$				$\lambda_0 = -50^0$			
	<i>Diving</i>		<i>Exit diving</i>		<i>Diving</i>		<i>Exit diving</i>	
	<b>M2</b>	<b>M1</b>	<b>M2</b>	<b>M1</b>	<b>M2</b>	<b>M1</b>	<b>M2</b>	<b>M1</b>
<b>V<sub>1</sub></b>	800	900	850	900	900	900	950	950
<b>H</b>	0,7	1,8	0,5	0,7	1,5	2	1	1,3
<b><math>\lambda</math></b>	$-30^0$	$-30^0$	$-12^0$	$-12^0$	$-50^0$	$-50^0$	$-20^0$	$-20^0$
<b>P<sub>n</sub></b>	0,94	0,94			0,88	0,72		
<b>P<sub>nn</sub></b>			0,06	0,06			0,12	0,28
<b>E<sub>n</sub></b>	33,6	50,4			28,8	32,8		
<b>E<sub>nn</sub></b>			48,4	62,63			58,01	60,40
<b>E<sub>2</sub></b>	34,5				32,34			
<b>E<sub>1</sub></b>	51,13				40,56			
	$E\% = \frac{E_1 - E_2}{E_1} 100 = 32. \%$				$E\% = \frac{E_1 - E_2}{E_1} 100 = 20, \%$			

It can be seen from Table 1 that the accuracy of the bomb release of method 2 at  $\lambda_0 = -30^0$  is with 32% greater than that of method 1, and at  $\lambda_0 = -50^0$  — by 20%.

Table 1 shows that the circular probable deviation of Method 2 for solving the targeting task is closer to the required  $E = 30$  m [4]. The resulting percentage increases of accuracy calculated by the proposed formula (1) and by the root mean square deviations (2) are close in value (for  $\lambda_0 = -30^0$ ,  $\sigma_{\Delta x}\% = 28.63\%$ ; for  $\lambda_0 = -50^0$ ,  $\sigma_{\Delta x}\% = 19.55\%$ ).

As a result of the mathematical modeling of the aiming process, the probabilistic characteristics of the bomb release error are determined. ( $\sigma_{\Delta x}$ ,  $M[\Delta x]$ ) from diving.

The differences  $\Delta\sigma_{\Delta x}$  are given in Table 2 during bomb release at diving angle of  $\lambda = -30^0$ . The difference  $\Delta\sigma_{\Delta x}$  varies within the limits of 1.9 m and 5.3 m.

Table 2

$\Delta\sigma_{\Delta x}$ m, $\lambda = -30^\circ$					
	$V_1 = 170$ m/s	<b>200</b>	<b>220</b>	<b>240</b>	<b>270</b>
<b>H = 650 m</b>	2.7	3.15	3.4	3.65	3.9
<b>1000</b>	1.9	2.4	3.2	4.30	4.8
<b>1350</b>	2.2	2.2	2.7	3.8	5.3
<b>1700</b>	3.4	2.6	2.6	3.5	5.2
<b>2100</b>	5.7	3.5	2.5	2.8	4.4

The difference  $\Delta M[\Delta x]$  varies within the limits of 2.00 and 14.60 m for observed bomb release conditions (Table 3).

Table 3

$\Delta M[\Delta x]$ m, $\lambda = -30^\circ$					
	$V_1 = 170$ m/s	<b>200</b>	<b>220</b>	<b>240</b>	<b>270</b>
<b>H=650 m</b>	6.18	5.36	4.41	3.32	2.00
<b>1000</b>	6.86	6.56	5.82	4.65	3.04
<b>1350</b>	8.47	7.73	6.66	5.30	3.62
<b>1700</b>	11.02	8.86	6.93	5.27	3.84
<b>2100</b>	14.60	9.95	6.64	4.55	3.70

The difference  $\Delta\alpha_{2x}$  assumes its maximum value in the range of conditions under which the method 1 is used — MRD “moment of release display” ( $\Delta\alpha_{2x} = 684$  m<sup>2</sup>), and its minimum value ( $\Delta\alpha_{2x} = 124$  m<sup>2</sup>) is assumed in the range of conditions, under which the method 1 is used — DPD “drop point display” (Table 4). At heights  $H = 1700$ – $2100$  m,  $\Delta\alpha_{2x}$  assumes minimal effect within the range of speeds, at which method 1 is changed from DPD to MRD. With the increase of height  $H$ , the second initial moment of the error  $\alpha_{2x2}$  decreases in relation to  $\alpha_{2x1}$ .

Table 4

$\Delta\alpha_{2x} \text{ m}^2, \lambda = -30^\circ$					
	$V_1 = 170 \text{ m/s}$	<b>200</b>	<b>220</b>	<b>240</b>	<b>270</b>
<b>H = 650 m</b>	139.99	136.56	133.01	128.88	123.77
<b>1000</b>	154.91	169.24	183.50	197.95	212.65
<b>1350</b>	223.60	219.63	228.03	251.86	292.46
<b>1700</b>	383.56	302.31	265.77	278.66	344.56
<b>2100</b>	683.95	431.35	295.03	266.87	351.15

The difference  $\Delta\sigma_{\Delta x}$  varies within the limits of 1.95 to 4.60 m (Table 5) at  $\lambda = -50^\circ$ .

Table 5

$\Delta\sigma_{\Delta x} \text{ m}, \lambda = -50^\circ$					
	$V_1=170 \text{ m/s}$	<b>200</b>	<b>220</b>	<b>240</b>	<b>270</b>
<b>H = 650 m</b>	2.26	2.21	2.13	2.03	1.95
<b>1000</b>	2.27	2.73	2.99	3.06	2.92
<b>1350</b>	2.28	3.06	3.55	3.79	3.69
<b>1700</b>	2.31	3.18	3.79	4.13	4.21
<b>2100</b>	2.36	3.11	3.71	4.16	4.60

The expected value  $M[\Delta x_2]$  of the bomb release error  $M[\Delta x_1]$  for the considered conditions of bomb release, where the difference  $\Delta M[\Delta x]$  varies within 3.20 and 8.90 (Table 6). With the increase of speed  $V_1$  of bomb release  $\Delta M[\Delta x]$  decreases, and with the increase of the height  $H$  the difference  $\Delta M[\Delta x]$  increases.

Table 6

$\Delta M[\Delta x] \text{ m}, \lambda = -50^\circ$					
	$V_1 = 170 \text{ m/s}$	<b>200</b>	<b>220</b>	<b>240</b>	<b>270</b>
<b>H = 650 m</b>	5.32	4.56	3.93	3.43	3.20
<b>1000</b>	6.45	5.77	5.20	4.73	4.38
<b>1350</b>	7.41	6.78	6.25	5.81	5.47
<b>1700</b>	8.20	7.61	7.08	6.66	6.32
<b>2100</b>	8.90	8.22	7.71	7.27	6.91

The second starting point  $\Delta\alpha_{2x2}$  of the bomb release error is smaller than  $\Delta\alpha_{2x1}$  (Table 7).

Table 7

$\Delta\alpha_{2x} \text{ m}^2, \lambda = -50^\circ$					
	$V_1 = 170 \text{ m/s}$	<b>200</b>	<b>220</b>	<b>240</b>	<b>270</b>
<b>H = 650 m</b>	87.23	77.50	69.68	63.21	57.64
<b>1000</b>	132.06	132.63	131.51	127.93	120.53
<b>1350</b>	176.04	188.29	196.48	198.72	193.33
<b>1700</b>	216.49	237.79	254.46	265.13	267.72
<b>2100</b>	251.69	274.12	296.65	317.58	335.62

For the full range of conditions, the accuracy of method 2 for bomb release is higher than that of existing methods 1. The relative increase of bomb release accuracy of method 2 varies between 34% and 56%.

### Conclusion

A formula for calculating the probable deviation of the bombing error is proposed for newly developed methods for solving the targeting problem. As an example, the probabilistic characteristics of the dive bomb release error were calculated and a comparative analysis was performed for different methods solving the task of bomb release targeting.

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## СРАВНИТЕЛЕН АНАЛИЗ НА ТОЧНОСТТА НА БОМБОПУСКАНЕ И НА ВЕРОЯТНОСТНИТЕ ХАРАКТЕРИСТИКИ НА ГРЕШКАТА НА БОМБОПУСКАНЕ НА РАЗЛИЧНИ МЕТОДИ, РЕШАВАЩИ ЗАДАЧАТА НА ПРИЦЕЛВАНЕ

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### Резюме

Предлага се приблизителен метод за оценяване на точността на бомбопускане при нови методи, решаващи задачата на прицелване спрямо съществуващите такива. Извършен е сравнителен анализ на средно квадратичното отклонение, математическото очакване и втория начален момент на грешката за нов и съществуващ метод на задачата на прицелване.

Резултатите могат да се използват и при проектиране на пентратори за екологични изследвания.