COMBAT USE OF AIRCRAFT WITH UNGUIDED WEAPONS

Milen Atanasov
“Georgi Benkovski“ Bulgarian Air Force Academy, e-mail: maa_69@abv.bg

Abstract: The development and introduction of a common ballistic model in the general algorithm of operation of the aviation combat complex will lead to a reduction in the volume of computational operations, which will increase the speed and accuracy of solving combat tasks. Increasing accuracy, in turn, leads to a reduction in the cost of achieving the objectives set for combat aviation.

Keywords: *aircraft, bombing, shooting.*

1. Introduction

Aviation combat complexes are designed to destroy air, land, water and underwater targets with the help of aviation weapons.

At present, the aviation combat complexes use the appropriate mathematical models and algorithms for combat use for each type of weapon. As a result, the pilot manually selects via switches: the type of target (air or ground); moving or stationary target; the type of weapon; mobile or stationary aviation automatic weapons, etc. By selecting the type of weapon, the appropriate ballistic model is selected to determine the ballistic elements.

The rational use of aviation combat complexes by the pilot in performing the assigned tasks is of great importance in the development of new models of aviation equipment.

The introduction of the latest achievements of science and technology in combat aviation allows the compilation and introduction of a common algorithm for combat use of different groups of weapons, as well as the improvement of avionics decisive for the execution of combat missions.

The use of a common algorithm in aviation combat complexes will allow to shorten the decision-making process of the pilot, as well as to facilitate his work with the arms control bodies of the aircraft. It will also increase the speed of computers that solve combat tasks and expand the areas of initial conditions for combat use of weapons.

2. Mathematical modelling of combat use with unguided weapons

Unguided weapons (UW) are used in a wide range of aircraft speeds and altitudes, angles and distances to the target, the presence of an angle between the velocity vectors of the aircraft and the initial speed of the UW. Different airborne targeting systems use fundamentally different ballistic schemes, requiring specific methods of solving ballistic tasks and forms of presenting the results of decisions.

It is therefore necessary to draw up a common ballistic model for all types of UW, with the type of UW used being introduced on board the aircraft.

Using Newton's second law:

$$(1) \quad \sum \overline{F} = \overline{a} m,$$

and presenting equation (1) in scalar form, the flight time T of the flight and the coordinates η_s, ζ_s, ξ_s of the contact of the weapons with the target in the navigation basis $O\eta\zeta\xi$ are determined.

Using the vector kinematic method, the point of contact of the weapon with the target is determined from where the target distance vector $\overline{D}_0$ at the time of the shot is calculated:

$$(2) \quad \overline{D}_0 = f\left(\dot{\bar{a}}_{v1}, \dot{\omega}_{yD}, \dot{\omega}_{zD}, \ddot{D}, \overline{V}_1, \overline{V}_t, \overline{U}, \dot{D}, \omega_{yD}, \omega_{zD}, H, \eta_s, \zeta_s, \xi_s, \bar{r}_c, T, \psi, \vartheta, \gamma, \beta_s, \alpha, \beta', \varepsilon'\right),$$

where,

$\dot{\bar{a}}_{v1}, \dot{\omega}_{yD}, \dot{\omega}_{zD}$ - the vector of the acceleration of the aircraft and the accelerations of the angular velocities of the vector of the distance to the target;

$\overline{V}_1, \overline{V}_t, \overline{U}$ - the velocity, target and wind vectors;

$\dot{D}$ - the speed of convergence of the aircraft with the target;

ω_{yD}, ω_{zD} - the angular velocities of the distance vector to the target;

H - the height of shooting and bombing;

$\bar{r}$ - the vector determining the deviation of the projectile in the case of a mobile artillery weapon;

β', ε' - the angles determining the direction of the weapon relative to the aircraft.

The angles $\beta_{t1,0}$, $\varepsilon_{t1,0}$ of aiming at the target in the connected coordinate system $Ox_1y_1z_1$ are:

$$\begin{aligned} &\beta_{t1,0} = f\left(D_{0z1}, D_{0x1}\right); \\ &\beta_{t1,0} = f\left(D_{0z1}, D_{0y1}, \beta_{t1,0}\right). \end{aligned} \qquad (3)$$
,

The test is performed for firing with: aviation artillery projectile caliber d = 23 mm, initial velocity V_0 = 700 m / s, ballistic coefficient c = 1.52, mass m = 199 g [17]; with unguided aircraft rocket with characteristics [1, 2, 3]: d = 57 mm, initial velocity V_0 = 56 m / s, mass m = 3.86 kg, mass of the propellant engine m_p = 1.13 kg, operating time on the powder engine t_a = 0.9 s, maximum speed V_{max} = 673 m / s [2, 3]; and bombing with an aircraft bomb FAB 500 M62 [4] with a characteristic time θ = 20.38 s, mass m = 497 kg.

2.1. Results of mathematical modelling of combat use with unguided weapons

The study is performed for air shooting with aviation artillery and UR under the following conditions: angle of convergence λ= -10^0, angle of attack of the aircraft α=1^0, speed V of the aircraft from 240 m/s to 300 m/s, height H of fields from 4000 m to 6500 m, target speed V_t = 220 m/s, with the target angle of the target relative to the distance q=150^0 и 90^0 In case the shooting is performed with unguided rocket (UR), the vector based $\overline{L}_0$ on the weapon has values: L_{x1}=0, L_{y1}=1 m, L_{z1}=2,5 m.

As a result of solving the problem of the contact of the weapons with the target, the angles $\beta_{t1,0}$ and $\varepsilon_{t1,0}$ are determined, determining the position of the target at the time of firing and the distance D_c of firing.

2.1.1. Shooting with a fixed weapon at an air target

Tables 1 - 6 show the calculated angles $\beta_{t1,0}$, $\varepsilon_{t1,0}$ and distances D_c of the firing.

At target target q = 150^0: the angle $\beta_{t1,0}$ changes in the range from -9.920 to -8.720, the angle $\varepsilon_{t1,0}$ is in the range from -1.200 to -1.140, the distance D_c of shooting - from 701.22 m to 719. 37 m.

At the target course q = 90^0: the angle $\beta_{t1,0}$ is in the range from -14.620 to -13.370, the angle $\varepsilon_{t1,0}$ is in the range from -3.230 to -3.050, the distance D_c of the shooting - from 717.85 m to 721.49 m.

Table 1.

λ= -10^0, V_t= 220 m/s, q=150^0				
$\beta_{t1,0}$, degr.	**V=240, m/s**	**260**	**280**	**300**
H=4000, m	-9.92	-9.63	-9.36	-9.11
4500	-9.82	-9.54	-9.27	-9.02
5000	-9.72	-9.45	-9.18	-8.94
5500	-9.64	-9.36	-9.10	-8.86
6000	-9.55	-9.28	-9.03	-8.79
6500	-9.47	-9.21	-8.96	-8.72

Table 2.

λ= -10^0, V_t= 220 m/s, q=150^0				
$\varepsilon_{t1,0}$, degr.	**V=240, m/s**	**260**	**280**	**300**

H=4000, m	-1.18	-1.16	-1.15	-1.14
4500	-1.18	-1.17	-1.16	-1.15
5000	-1.19	-1.17	-1.16	-1.15
5500	-1.19	-1.18	-1.17	-1.16
6000	-1.19	-1.18	-1.17	-1.16
6500	-1.20	-1.18	-1.17	-1.16

Table 3.

λ= -10^0, V_t= 220 m/s, q=150^0				
D_c, m	**V=240, m/s**	**260**	**280**	**300**
H=4000, m	701.22	705.37	709.34	713.18
4500	702.60	706.53	710.87	714.51
5000	704.13	707.86	712.01	716.05
5500	705.32	709.44	713.41	717.27
6000	706.19	710.70	714.49	718.16
6500	707.90	711.66	715.27	719.37

Table 4.

λ= -10^0, V_t= 220 m/s, q=90^0				
$\beta_{t1,0}$, degr.	**V=240, m/s**	**260**	**280**	**300**
H=4000, m	-14.62	-14.31	-14.01	-13.72
4500	-14.54	-14.23	-13.93	-13.64
5000	-14.46	-14.15	-13.86	-13.57
5500	-14.38	-14.08	-13.78	-13.50
6000	-14.31	-14.01	-13.72	-13.44
6500	-14.24	-13.94	-13.65	-13.37

Table 5.

λ= -10^0, V_t= 220 m/s, q=90^0				
$\varepsilon_{t1,0}$, degr.	**V=240, m/s**	**260**	**280**	**300**
H=4000, m	-3.23	-3.18	-3.13	-3.09
4500	-3.22	-3.17	-3.12	-3.08
5000	-3.21	-3.16	-3.12	-3.07
5500	-3.21	-3.16	-3.11	-3.06
6000	-3.20	-3.15	-3.10	-3.06
6500	-3.19	-3.14	-3.10	-3.05

Table 6.

λ= -10^0, V_t= 220 m/s,q=90^0				
D_c, m	**V=240, m/s**	**260**	**280**	**300**
H=4000, m	721.49	720.83	719.61	718.69
4500	721.22	720.44	719.10	718.91
5000	720.73	719.83	719.21	718.05
5500	720.87	719.86	719.14	717.87
6000	720.82	719.71	718.89	717.50
6500	720.61	719.40	718.47	717.85

2.1.2. Shooting with UR at a stationary ground target

The study is performed for shooting with UR on a moving and stationary ground target under the same conditions as for shooting aviation artillery weapons, as the base vector $\bar{L}_0$ has the following values: L_{x1}=0, L_{y1}=1 m, L_{z1}=2,5 m.

The angles $\beta_{t1.0}$, $\varepsilon_{t1.0}$, the distance D_c of firing, the time T_c of flight of the projectile and the speed V_c of meeting the projectile with the target are shown in table 7 - table. 10 and fig. 1.

The shooting conditions that meet the conditions for the allowed distance (D_c = 800 - 1800 m) are for heights H from 400 m to 600 m inclusive with a diving angle λ= -20^0.

The calculations were performed in winglessness due to which the angle $\beta_{t1,0} = 0^0$.

Table 7.

λ =-20, degr UR						
$\varepsilon_{t1,0}$, degr	V=200 m/s	220	240	260	280	300
H=400, m	-2.39	-2.30	-2.23	-2.17	-2.10	-2.05
500	-2.56	-2.47	-2.39	-2.32	-2.26	-2.20
600	-2.74	-2.65	-2.56	-2.48	-2.41	-2.35
700	-2.95	-2.84	-2.75	-2.66	-2.59	-2.51
800	-3.16	-3.05	-2.95	-2.86	-2.77	-2.69
900	-3.40	-3.28	-3.17	-3.07	-2.98	-2.89

Table 8.

λ =-20, degr UR						
D_c, m	V=200 m/s	220	240	260	280	300
H=400, m	1096.46	1100.82	1104.19	1107.20	1110.49	1112.99
500	1360.38	1365.53	1370.54	1374.56	1378.65	1382.38
600	1618.97	1625.62	1631.99	1637.75	1643.00	1647.77
700	1872.24	1880.86	1888.30	1895.46	1902.03	1908.50
800	2119.80	2129.92	2139.21	2147.81	2156.17	2163.57
900	2360.75	2372.55	2383.87	2394.16	2403.84	2413.30

Table 9.

λ =-20, degr UR						
T_c, degr	V=200 m/s	220	240	260	280	300
H=400, m	1.86	1.82	1.79	1.75	1.72	1.68
500	2.32	2.28	2.23	2.19	2.14	2.10
600	2.82	2.76	2.71	2.65	2.60	2.55
700	3.34	3.28	3.22	3.15	3.09	3.03
800	3.90	3.83	3.76	3.69	3.62	3.55
900	4.48	4.40	4.32	4.24	4.17	4.09

Table 10.

λ =-20, degr UR						
V_c, degr	V=200 m/s	220	240	260	280	300
H=400, m	592.96	607.60	622.54	637.66	652.84	668.35
500	540.51	553.88	567.36	581.21	595.18	609.39
600	494.20	506.07	518.11	530.43	543.05	555.98
700	453.72	464.08	474.80	485.73	496.96	508.40
800	418.91	427.89	437.15	446.71	456.52	466.71
900	389.61	397.24	405.10	413.30	421.80	430.55

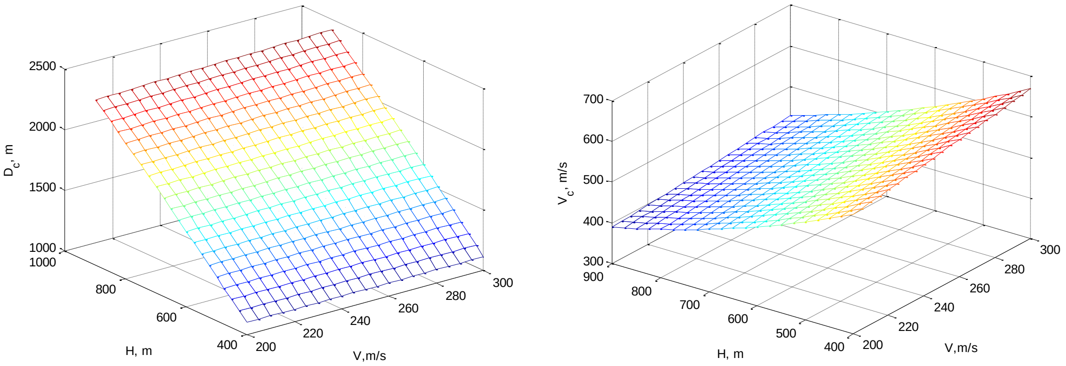

Figure 1. The distance D_c and the speed V_c when shooting with UR on a ground stationary target

2.1.3. Bombing moving target with FAB 500 M62

The study is performed for bombing with an aircraft bomb FAB 500 M62 from horizontal flight and diving on a moving and stationary target with angles λ = -20^0, -40^0, angle of attack of the aircraft α= 1^0, gliding angle β_s = 0, speed V of aircraft from 200 m/s to 300 m/s, bombing height H from 500 m to 1000 m, target speed V target = 60 km/h, target angle ψ_t = 300. The base has values:L_{x1}=L_{y1}=L_{z1}=0 m.

From table. 11 - table 19 it is seen that when bombing from a horizontal flight from heights greater than 600 m and speeds greater than 220 m/s the angle $\varepsilon_{t1,0}$ is greater than the limit value for sighting head C17 VG due to which the bombing will take place in the invisible zone and will use the method "Continuously Computed Release Point" - CCRP. For other conditions, the bombing will take place in the visible area using the method "Continuously Computed Impact Point" - CCIP.

In the case of a dive bomb for the specified conditions, the bombing will take place in the visible area by the CCIP method.

The distance of bombing for horizontal flight is in the range from 1905.65 m to 3997.42 m, and for diving from 690.77 m to 2155.68 m, as the distance for conditions λ = -40^0, V = 200 m/s, H = 500 m (D_c = 690.77 m) borders the safe distance.

Table 11.

λ =0, degr OFAB 500						
$\beta_{ц1,0}$, degr	**V=200 m/s**	**220**	**240**	**260**	**280**	**300**
H=500, m	-2.66	-2.41	-2.20	-2.03	-1.88	-1.77
600	-2.67	-2.41	-2.21	-2.03	-1.89	-1.78
700	-2.67	-2.42	-2.21	-2.04	-1.90	-1.79
800	-2.68	-2.43	-2.22	-2.05	-1.91	-1.80
900	-2.69	-2.43	-2.23	-2.05	-1.91	-1.81
1000	-2.69	-2.44	-2.23	-2.06	-1.92	-1.81

Table 12.

λ =0, degr OFAB 500						
$\varepsilon_{ц1,0}$, degr	**V=200 m/s**	**220**	**240**	**260**	**280**	**300**
H=500, m	-16.20	-14.81	-13.66	-12.68	-11.87	-11.21
600	-17.61	-16.10	-14.85	-13.79	-12.91	-12.20
700	-18.88	-17.28	-15.93	-14.80	-13.86	-13.10
800	-20.05	-18.36	-16.94	-15.74	-14.75	-13.95
900	-21.14	-19.37	-17.88	-16.61	-15.58	-14.74
1000	-22.16	-20.31	-18.76	-17.44	-16.36	-15.48

Table 13.

λ =0, degr OFAB 500						
D_c, m	V=200 m/s	220	240	260	280	300
H=500, m	1905.65	2093.12	2281.03	2468.78	2650.16	2819.51
600	2098.50	2301.87	2505.93	2709.82	2905.97	3088.50
700	2278.87	2496.51	2714.92	2933.30	3142.80	3337.06
800	2449.56	2679.99	2911.48	3143.24	3364.77	3569.35
900	2612.34	2854.67	3098.38	3342.24	3574.70	3788.67
1000	2768.76	3022.09	3276.96	3531.95	3774.41	3997.42

Table 14.

λ =-20, degr OFAB 500						
$\beta_{\text{ц}1,0}$, degr	**V=200 m/s**	**220**	**240**	**260**	**280**	**300**
H=500, m	-2.49	-2.26	-2.07	-1.91	-1.78	-1.67
600	-2.48	-2.25	-2.07	-1.91	-1.78	-1.67
700	-2.47	-2.25	-2.06	-1.91	-1.78	-1.67
800	-2.46	-2.24	-2.06	-1.90	-1.78	-1.67
900	-2.45	-2.23	-2.05	-1.90	-1.78	-1.67
1000	-2.44	-2.23	-2.05	-1.90	-1.78	-1.67

Table 15.

λ =-20, OFAB 500						
$\varepsilon_{\text{ц}1,0}$, degr	**V=200 m/s**	**220**	**240**	**260**	**280**	**300**
H=500, m	-9.67	-8.55	-7.63	-6.88	-6.26	-5.76
600	-10.69	-9.46	-8.46	-7.63	-6.94	-6.38
700	-11.64	-10.32	-9.24	-8.33	-7.60	-6.98
800	-12.53	-11.13	-9.97	-9.01	-8.21	-7.56
900	-13.36	-11.89	-10.66	-9.64	-8.80	-8.11
1000	-14.14	-12.61	-11.32	-10.25	-9.37	-8.64

Table 16.

λ =-20, degr OFAB 500						
D_c, m	V=200 m/s	220	240	260	280	300
H=500, m	1042.56	1081.37	1115.54	1145.44	1171.58	1193.96
600	1211.57	1259.10	1301.30	1338.80	1371.40	1399.60
700	1373.85	1429.51	1479.60	1524.46	1563.53	1597.69
800	1530.28	1594.07	1651.87	1703.75	1749.40	1789.32
900	1681.83	1753.37	1818.74	1877.77	1929.59	1975.13
1000	1829.44	1908.31	1980.85	2046.61	2104.61	2155.68

Table 17.

λ =-40, degr OFAB 500						
$\beta_{\text{ц}1,0}$, degr	**V=200 m/s**	**220**	**240**	**260**	**280**	**300**
H=500, m	-2.42	-2.20	-2.03	-1.87	-1.75	-1.64
600	-2.40	-2.19	-2.02	-1.87	-1.74	-1.63
700	-2.38	-2.18	-2.01	-1.86	-1.73	-1.63
800	-2.36	-2.16	-2.00	-1.85	-1.73	-1.63
900	-2.35	-2.15	-1.99	-1.84	-1.73	-1.62
1000	-2.33	-2.14	-1.98	-1.84	-1.72	-1.62

Table 18.

λ =-40, OFAB 500						
$\varepsilon_{\text{ц}1,0}$, degr	**V=200 m/s**	**220**	**240**	**260**	**280**	**300**
H=500, m	-7.40	-6.60	-5.95	-5.41	-4.98	-4.62
600	-7.99	-7.12	-6.41	-5.82	-5.34	-4.95
700	-8.56	-7.62	-6.85	-6.21	-5.70	-5.27
800	-9.09	-8.09	-7.27	-6.60	-6.04	-5.58
900	-9.60	-8.54	-7.68	-6.96	-6.37	-5.88
1000	-10.09	-8.98	-8.07	-7.32	-6.70	-6.19

Table 19.

λ =-40, degr OFAB 500						
D_c, m	V=200 m/s	220	240	260	280	300
H=500, m	690.77	700.08	707.90	714.55	720.06	724.77
600	820.85	832.73	842.71	851.31	858.51	864.54
700	948.95	963.45	975.83	986.42	995.26	1002.86
800	1075.41	1092.60	1107.40	1119.93	1130.62	1139.76
900	1200.25	1220.20	1237.34	1252.10	1264.72	1275.41
1000	1323.69	1346.40	1366.02	1382.95	1397.34	1409.69

3. Conclusions

1. It can be seen that as the exchange rate q decreases, the angles $\beta_{t1,0}$ and $\varepsilon_{t1,0}$ increase. At $q = 90^0$, the existing sighting heads used in aviation targeting systems cannot work out the calculated angles for $\beta_{t1,0}$ ($B_{t1,0max} = \pm 12^0$ for C17 VG). In order to reduce the angle $\beta_{t1,0}$ in absolute value it is necessary to reduce the angle of the target or to reduce the firing distance. Reducing the firing distance at a large angle leads to an increase in the overload of the pilot when performing the aiming maneuver and difficulties in aiming.

Decreasing q reduces the angle $\beta_{t1,0}$ in absolute terms to a greater extent than by reducing the firing distance.

2. From the research conducted on UR firing at ground target, it can be concluded that in order to increase the range of firing altitude, it is necessary to increase the diving angle.

The angles $\varepsilon_{t1,0}$ when firing with air artillery weapons are smaller than when firing with UR, which is explained by the greater distances η than that of UR.

3. From the research performed on horizontal flight and dive bombings, it can be concluded that increasing the diving angle increases the area of use of the CCIP method.

For the bombing conditions under consideration, the angle $\beta_{t1,0}$ does not exceed the limit values $B_{t1,0max} = \pm 12^0$ for C17 VG.

References

1. Kostov M.I., Aviatsionna vŭnshna balistika, S, VI, 1985 g.

2 https://topwar.ru/165730-neupravljaemaja-aviacionnaja-raketa-s-5u-novyj-variant-starogo-izdelija.html

3. http://www.russianarms.ru/forum/index.php?topic=5769.0

4. https://11750-bg.all.biz/fugasna-aviatsionna-bomba-fab-500m62-g76338