THE MANAGAMENT OF BALLISTIC OPERATIONS USING MATLAB SOFTWARE

Cosmin-Constantin IACOB, Gabriel BORSOS, Gavrilă CALEFARIU

Transylvania University, Braşov, Romania (cosmin.iacob@unitbv.ro)

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Abstract: *The purpose of this paper is based on the analysis of military products performances between the interests of the company and customer's requirements achieved by using MATLAB software method in exterior ballistics calculation.*

I have started with a few notions related to the method in order to understand exactly how it applies continuing with generic drawings and descriptions of product in order to protect the company interests, and finally the proper analysis by numerical modeling through MATLAB.

Keywords: *exterior ballistics, illuminating bombs, trajectory, aerodynamics*

1. INTRODUCTION

Exterior ballistics is a branch of mechanics that studies the laws of motion of a heavy body thrown at an angle to the horizontal plane.

By definition characteristics of illuminating bomb aims to bomb the center of mass motion until initiation system operation.

For the proper functioning of bomb, and increased accuracy, aims to determine all elements bomb trajectory: maximum range, arrow trajectory, total flight time [5].

Bombs are equipped with a stabilization system disposed at the rear of the body; in this case the center of pressure is behind the center of mass.

Behavior bomb while flying along the trajectory is defined by movement around the center of mass bomb [10].

Because the bomb hasn't its own rotational motion, movement around its center of mass is given by movement around its longitudinal axis [8].

2. FORCES AND MOMENTS ACTING ON THE BOMB TRAJECTORY

2.1 The stability of bomb along trajectory. When leaving the launcher bomb is committed outside longitudinal movement, in a swirling motion around an axis passing through the center of gravity C_g (figure 1) and perpendicular to the axis of symmetry of the bomb , the movement characterized by initial angular velocity ω_0 [4].

Longitudinal displacement is determined as a result of the action of the initial velocity V_0 and initial lateral velocity ω_0.

The initial conditions of the movement of rotation of the bomb is determined by the size and direction of the angular displacement φ_0 and the speed of rotation ω_0 [9].

On leaving the launcher, due to inertia, the bomb will tend to rotate around its center of gravity. Appears but the force of air resistance (R), the point of application (C_p) is set to stabilizer behind the center of gravity. The timing of that force relative to the center of gravity gives it a bomb that opposes the rotation speed ω_0.

If when resistance force fails to stop at a certain time (characterized by the angle of rotation φ_{0max}) the rotation bomb, then it will tip over losing stability [1].

In reality however, the parameters change from blowing to blowing and so the bomb trajectory oscillations will differ from the bomb to bomb, which is one of the important causes of spreading blowing. To improve scattering have acted on building the bomb to achieve value for ω_0 and a greater ability to quickly absorb bomb trajectory oscillations.

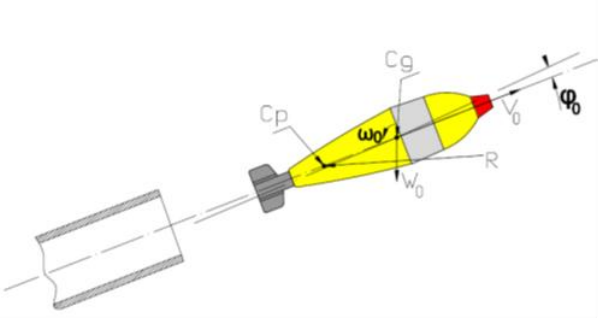

FIG. 1. The initial conditions of the motion trajectory bomb

On bomb the force of gravity acting on the trajectory and force of air resistance. The size and direction of the resultant of the air resistance depends on the velocity of the center of gravity of the bomb, the angle of inclination of the axis of symmetry of the bomb, to the tangent to the trajectory, the speed, and the construction of the pivoting movement of the stabilizer body and the bomb [1].

As a result of the inclination of the axis of symmetry of the bomb to the direction of action of the resultant of the air flow (figure 2) direction of air resistance R does not overlap with the direction of air flow V_{aer}. Therefore decomposition of air resistance force into two components: one noted R_x directed in the direction of center of gravity speed and reverse it, and another noted R_y after normal to the direction of travel of the bomb [1].

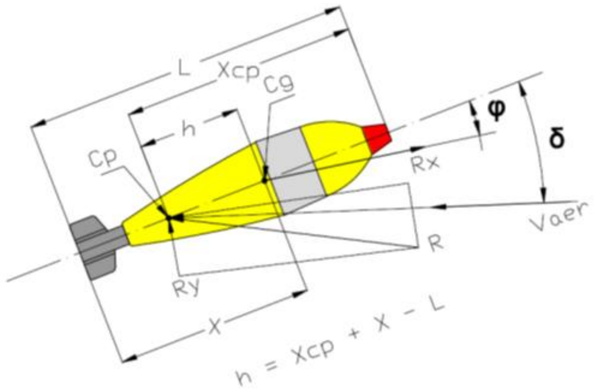

FIG. 2. Air resistance force components

R_x component is called the frontal resistance and R_y component ascending power.

The frontal resistance R_x has the expression:

$$R_x = C_x \cdot v^2 \cdot \rho \cdot S \tag{2.1}$$

when :

C_x – Front aerodynamic resistance
ρ – air density
S – maximum transverse surface action bomb
v – velocity of the center of gravity of the bomb

Front aerodynamic resistance characteristic size depends on the angle of attack δ and can be calculated with a sufficiently good approximation formula:

$$C_x = C_{xc} \cdot \left(1 + k \cdot \delta^2\right) \tag{2.2}$$

when :

C_{xc} – is the characteristic of front air resistance for δ=0;
k – a coefficient based on the construction of the bomb

C_x - aerodynamic characteristic graph of variation depending on the angle of attack δ is shown in figure 3 showing that for angles from 0^0 to 3^0, C_x=ct .

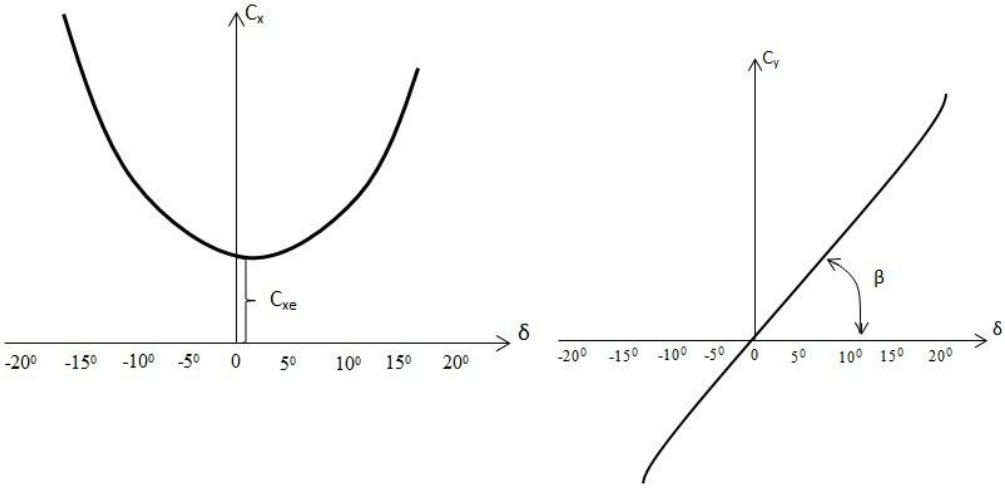

FIG. 3. Graphs C_x and C_y aerodynamics changes depending on the angle *δ*.

For angles $\delta = \pm 10°$, C_x increase by 50%, and $\delta = \pm 15°$ with 110 %.
The component ascending power R_y has the expression:

$$R_y = C_y \cdot v^2 \cdot \rho \cdot S \tag{2.3}$$

when:
C_y is the aerodynamic caracteristic of ascending power .

Variation graph of C_y depending on δ angle is shown in fig. 3 which results in:

a) The value and characteristic sign is the value and sign of the angle δ
b) For δ=0 , C_y=0
c) For $\delta = \pm 15^0$, C_y is proportional with δ : $C_y = C'_y \cdot \delta$ where C'_y is the coefficient of slope of the curve C_y=f(δ).

The force of air resistance R gives a moment which in turn decomposes to stabilizer moment M_s and amortization moment M_a. [3].

Stabilizer moment is composed of front resistance moment (Mx) and ascending force moment (My).

From figure 2 results:

$$M_x = R_x \cdot h \cdot \sin(\delta) \quad (2.4)$$

$$M_y = R_y \cdot h \cdot \cos(\delta) \quad (2.5)$$

when:

h is the distance between the center of gravity and center of pressure.

$$M_s = M_x + M_y \quad (2.6)$$

$$M_s = \left(C_x + \frac{C_y}{\delta} \right) \cdot v^2 \cdot \rho \cdot S \cdot h \cdot \delta \quad (2.7)$$

$$M_s = \left(C_x + C'_y \right) \cdot v^2 \cdot \rho \cdot S \cdot h \cdot \delta \quad (2.8)$$

Noting

Cx+C'y=Cm

Result

$$M_s = C_m \cdot v^2 \cdot \rho \cdot S \cdot h \cdot \delta \quad (2.9)$$

Stabilizing moment is proportional to the angle δ and transverse surface moment ($S \cdot h$). The maximum value of the stabilizing moment occurs when the maximum angle δ value. When overlapping axis tangent to the trajectory bombs, the stabilizer moment is null. In conclusion when motion stabilizer angle δ acts to tilt the axis of symmetry of the bomb to the tangent to the trajectory [2].

M_s stabilizing moment fails to achieve damping of oscillations. Depreciation is actuated through oscillation damping moment (Ma) of the force of air resistance. Moment oscillation damping occurs as a result of the bomb trajectory, being proportional to the angular velocity of the bomb oscillations around its center of gravity and moment of cross-sectional area ($S \cdot h$).

$$M_a = C_a \cdot v \cdot S \cdot h^2 \cdot \frac{d\delta}{dt} \quad (2.10)$$

Maximum damping moment is obtained for δ = 0, when the angular velocity is maximum. When δ=δmax the amortization moment is null because dδ/dt=0. In this way moment M_a tends to decrease the speed of oscillation, making this move a amortized oscillation [3].

In aerodynamic the aerodynamic characteristics above are determined in relation to the factor $\frac{\rho \cdot v^2}{2}$ and the entire lenght of the bomb (L).

3. NUMERICAL MODELING BOMB TRAJECTORY MATLAB PROGRAM

The purpose of studying the movement of the center of mass of bomb consists mainly trajectory calculation and thus determining the change of speed, time, motion and tilt speed along the trajectory [7].

The trajectory calculation is done in the following assumptions [6]:

- Longitudinal axis of the bomb is almost tangent to the trajectory
- Weather conditions are normal ground (standard), and the variation with altitude meteorological parameters normal law-abiding
- Ballistic conditions are normal (standard) for bomb mass, form and its dimensions mass and temperature load flinging.
- The acceleration of the weight is constant in size and direction, being parallel to the plumb line from the origin of the trajectory.

To determine the outer ballistic trajectory, that is the relationship between Fight (x) and Height (y), the system (3.1) must be integrated.

$$m\ \frac{d^2x}{dt^2} = -F_{rao}\ \frac{\frac{dx}{dt}}{\left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2}$$

$$m\ \frac{d^2y}{dt^2} = -\left(G+F_{rao}\right)\ \frac{\frac{dy}{dt}}{\left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2} \tag{3.1}$$

Where:
m – the mass of the projectile;
G – Weight
F_{rao} – It is the pressure force exerted by the air on the head of the ogive.

$$F_{rao} = 0{,}55\rho\, A_o c_d \left[\left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2\right] \tag{3.2}$$

Where:
ρ – air density;
A_0 – the area of the maximum section of the ogive;
C_d – a coefficient comprised between 0 and 0.6 depending on the speed.

The model described above can be more effective if the air resistance is considered to be on the bomb wings and horizontal deviation due to lateral wind (if any).

Although the system is nonlinear, solving it does not pose problems when it comes to numerical computation.

The integration of differential equations was performed using ode23 function of the Matlab software, customized for illuminating bombs.

3.1 Input data. Processed data are intentionally distorted in order to protect the company interests

- Speed leaving the bomb launcher : $V_0=257\ m/s$;
- Shooting angle : $\theta_0=45^0$;
- Bomb caliber : $d = 82 \cdot 10^{-3}\ m$;
- Projectile mass: q=5,2 kg;
- The index : i=0.9;

3.2 Results. After implementing the system in Matlab and initial data entry, running the program and saves the results in table form for entering or angle value for all values or as a shooting board for all illuminating bombs (see figures 4 and 5).

Do you want to realize a new simulation?

Specify the caliber [mm]: 82

Specify the mass [kg]: 5.2

Specify the load 0……6: 5

Specify the lunch speed [m/s]: 257

Specify the burst height [m]: 400

Specify angle to the horizontal [degrees; minutes]: 45

%%%%%%%%%%%%%%%%%%%%%%%%

Drawing board: Cal=82 mass=5.200 Inc=5 V_0=257 Is=400

D m	I 10^{-3}	NF div	dI 10^{-3}	dxm m	yT 10^{-3}	dyNF m	om gr	Vs m/s	ts s	Apb m	Api m	y m	gr	N min	10^{-3}	D m	B m
4511	1000	83				51	47	178	30			1386	45	0	750	4511	4842

Do you want to realize graphics in plan?

End sssssssssssssssssssssssssssssssssssssssssssssssss

FIG. 4. Simulation for maximum range.

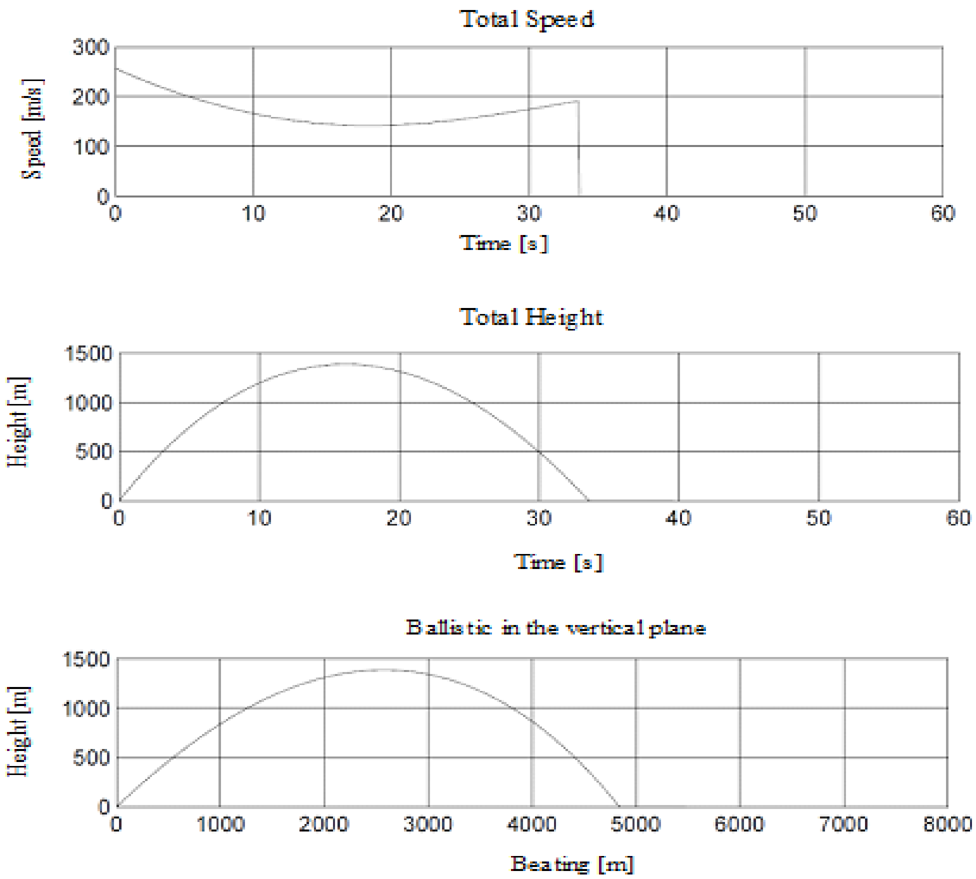

FIG. 4. Trajectory speed variation graph, the graph height versus time and trajectory chart.

The main benefit of the method presented above is the considerable costs decreasing.

Currently, for each bomb load, it is necessary to test hundreds of projectiles for a statistical determination of precision. This is very expensive in terms of time and money.

Our purposed method allows to optimize the batches size and to decrease the resources consumptions.

Transposed in money, this means notable savings (see table 3.1):

Table 3.1 Benefits of the proposed method

Actual method			Proposed method			Saving
1	2	3	4	5	6	(3) –(6)
Pieces tested	Unit Value [€]	Total Value [€]	Pieces tested	Unit Value [€]	Total Value [€]	105000
110	1000	110000	5	1000	5000	

CONCLUSIONS

Following the analysis made using the integration of differential equations performed in Matlab software, a correlation has been achieved, between customer requirements of high standards quality of military products performances and business interests.

In a competitive economy environment on a short market the most important criteria for the company are customers satisfaction and maintaining it as well as the reducing the production costs.

The company wants to improve the criteria listed above in order to be able to achieve its objectives on everything related to service quality, improving customer relationships and possible national and international expansion, in other words to gain a competitive advantage in the market.

In this paper has developed a knowledgebase of ballistics analysis customized for illuminating bombs in a nonflexible manufacturing system that adapts knowledge into product development where the major objectives were to provide decision support to help economic field, according the utilization of best-know knowledge, minimize costs, achieve quality assurance and shorten time to product.

Product development activities must be structured in such a way that any engineering decisions taken are based on proven knowledge and experience.

REFERENCES

[1] I.Antonescu , Bazele Proiectării bombelor de aruncător, Academia Militară, Bucureşti 1976, pag.188-205;

[2] T.V. Chelaru, *Dinamica zborului, îndrumar de laborator*, Ed. Politehnică Press, ISBN 978-606-515-445--2, Bucureşti, 2013;

[3] T.V. Chelaru, *Dinamica zborului, note de curs*, Ed. Politehnică Press, ISBN 978-606-515-059-1, Bucureşti, 2009;

[4] H. Deconinck, E. Dick, "*Computational Fluid Dynamics*", Proceedings of the Fourth International Conference on Computational Fluid Dynamics, ICCFD 4, Ghent, Belgium, 10-14 July 2006;

[5] M.J. Nusca, Army Ballistic Research Lab Aberdeen Proving Ground MD., " *Supersonic/Hyper-sonic Aerodynamics and Heat Transfer for Projectile Using Viscous-Inviscid Interaction*", Defense Technical Information Center, 1990;

[6] L. A. Pars, *A Treatise on Analitical Dynamics*, London 1965*;*

[7] J.M. Sidi, *Spacecraft dynamic & control - a practical engineering approach*,, Cambridge University Press, New York, NY 1003-2473, USA;

[8] M. J. Spearman, *"The Aerodynamics of Some Guided Projectiles"* , N.A.S.A, 1984;

[9] Sir Geoffrey Ingram Taylor, "*Aerodynamics and the mechanics of projectile and explosions*", University Press, California, USA, 1963;

[10] V. Titică, *Balistică interioară şi exterioară* vol I şi II.