Theoretical Evaluation of Drag Coefficient for Different Geometric Configurations of Ballistic Caps for an Experimental 30×165 mm AP-T Projectile

Alexandru SAVASTRE, Cătălin FĂȚILĂ, Irina CÂRCEANU, and Adrian BOLOJAN

***Abstract*—The present study is based on calculation of drag shape index and drag coefficient for three different geometrical configurationsfor a ballistic cap intended to be mounted over a 30 mm AP-T Naval projectile. The calculations are made in PROTech numerical application under the influence of three laws of resistance (Law 1930, Law 1943 and Siacci's Law) for Mach number values which vary from 0.1 to 4, with the main purpose of choosing the best geometrical shape from the proposed forms of ballistic caps.**

***Index Terms*—AP-T, projectile, drag coefficient, shape index, law of resistance.**

I. Introduction

The 30×165 mm AP-T ammunition analyzed in this paper is designed for use by naval CIWS (close-in weapon system) AK-630 or AK-306.

Armor piercing shells are generally roughly forged from a billet of alloy steel, then they are annealed, bored, turned to shape outside and tempered by a suitable hardening process. After such manufacturing operations have been completed, a steel cap is placed over the front or pointed end of the shell, and on the forward end of said cap a so called "ballistic nose is fitted to assist the shell aerodynamically in its travel from a gun to the object to be penetrated." [1]

A primary condition for armor-piercing projectiles is that the kinetic energy should be as high as possible when it is hitting the obstacle. This energy (K_e depends on the mass (m) and velocity (v) of the projectile at the time of impact with the armor as (it) can be seen in (1).[2]

$$K_e = \frac{mv^2}{2} \tag{1}$$

Since the mass of the projectile cannot vary too much due to the fact that it depends on some technical design specifications such as the material, caliber and length (usually 3 to 4 calibers) of the ammunition, it is the velocity of the projectile which can be increased in order to achieve the desired energy [2].

In order for a projectile to maintain a value of the impact velocity on its trajectory close to the initial velocity at the gun muzzle, it has to possess a good aerodynamic shape with a small value of the drag coefficient.

In order to study the influence of the gravity, drag, and, if present, wind over the projectile's trajectory and terminal velocity the science of external ballistics is used.

External ballistics or exterior ballistics is a branch of mechanics that studies the laws of motion of a heavy body, thrown at a certain angle on the horizontal plane. In fact, from an etymological point of view, the word ballistics, derived from the verb "*βαλλω*", which in Greek means to throw, refers to the science that deals with the laws of motion of discarded bodies[3].

The main issues studied by external ballistics are:

- the study of the movement of the center of mass of the projectiles and the calculation of their trajectories taking into account the ballistic and meteorological firing conditions;
- the study of the movement of the projectile around the center of mass during the movement on the trajectory and the establishment of the conditions of the correct movement of the projectile on the trajectory;
- the study and evaluation of the influences of the variation of the ballistic and meteorological conditions on the elements of the trajectory and in general on the movement of the projectiles;
- the study and determination of the scattering of the trajectories when firing a series of projectiles in apparently identical conditions, as a result of small and accidental errors that characterize the firing with each projectile separately, within the respective series;
- the preparation of firing tables, which provide all the necessary data, based on which, depending on the firing conditions, there is offered the possibility to determine the firing elements needed in order to hit a specified target, with projectiles of a certain kind and a certain mass of propellant. [3]

In fluid dynamics, drag (sometimes called air resistance, a type of friction, or fluid resistance, another type of friction or fluid friction) is a vector oriented by the tangent to the trajectory in the opposite direction to the velocity vector of the center of mass of the projectile (in the opposite direction to the movement of the projectile). The effect of the resistance to advance is to decrease the speed of the projectile and, implicitly, to increase the curvature of the trajectory.

In aerodynamics, the drag force (R) is expressed with (2), where ρ, is the mass density of the fluid, v is the projectile center of mass velocity relative to fluid, S is the reference area (usually the cross section of the projectile) and C_D is

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the drag coefficient – a dimensionless coefficient related to the object's geometry and taking into account both skin friction and form drag [4]

$$R = \frac{1}{2}\rho v^2 S C_D \qquad (2) \quad (2)$$

In order to reduce the drag for a given AP projectile, a ballistic cap is usually mounted over the tip of a projectile. As it can be seen in (2), the easiest way to reduce the drag force is to reduce the C_D coefficient.

Three geometrical configurations of ballistics caps are proposed, which are tested with PROTech application in order to find which one provides the lowest drag coefficient for the designed projectile.

II. Drag Coefficient for Projectiles

In fluid dynamics, the drag coefficient is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid environment, such as air or water. It is used in the drag equation in which a lower drag coefficient indicates the object will have less aerodynamic or hydrodynamic drag [4].

The variation of the drag coefficient under the influence of Mach number is essential in ballistics calculations, being the basis of shooting tables [3].

Due to the fact that the variety of artillery projectile shapes is relatively limited, certain standard functions have been adopted to simplify ballistic calculations. Such a function corresponds to a certain type of conventional projectile called a "standard projectile" which is representative in terms of shape and variation of C_D for a certain group of projectiles with similar shapes.

The value for the drag coefficient for a newly designed projectile is given in (3), where *i* is the form index of the given projectile and the C_{Dref} is the standard function

$$C_D = iC_{Dref} \qquad (3)$$

The standard function is obtained using the results of the same experimental drawings. Over time, based on experiences in several countries, with projectiles of different shapes used at a given time, several laws of resistance to progress have been established. The three most used laws of resistance are: Law 1943, Law 1930 and the Siacci Law described as it follows:

- the 1943 law (elaborated in the USSR in 1943) corresponds to the current, elongated, long-barreled projectiles, with an ogival front, with a length of about 2.5 calibers, and a total length of about 5 calibers. The establishment of this law was based on the results of the special shots fired with a large number of projectiles and bullets in the shape of those currently used;
- the 1930 law also corresponds to long-range elongated projectiles, being used more in the case of missiles;
- the Siacci Law (after the name of the Italian ballistician Francesco Siacci) was obtained based on the experiences made in several countries with projectiles of different shapes. It responds appropriately to a relatively wide range of projectile shapes. Therefore, this law is one of the most widely used [3].

III. PROTech Application

Testing and evaluation of products assumes in many cases a high consumption of resources and as a consequence high cost. For this reason, in the first stages of development of a product, engineers are encouraged to make use of different types of design software to create a product's 3D shape or prototype for simulations [6].

The PROTech application is a ballistic software used in the development of new designs of projectiles, able to execute:

- calculation of the tolerances of a parameter using statistical methods;
- calculation of the drag coefficient taking into account the tolerances of the geometric dimensions of the projectile;
- calculation of the elements of the trajectory of a projectile taking into account the values of the coefficient of resistance to advance obtained [5].

Taking into account the capabilities listed above, the PROTech software application contains three main modules, namely: a module for calculating geometric parameter tolerances, a module for evaluating the drag coefficient and an external ballistics module [5].

For this paper, the module for evaluating the drag coefficient was used.

The presented calculation method uses one of the empirically determined laws of resistance, namely: Siacci's law, the 1930 law or the 1942 law. The applicability of these laws is conditioned by the relative elongation of the projectile.

In the case of small caliber projectiles, the drag coefficient has the highest influence on the flight.

The main geometrical dimensions of the projectile used for determining the drag coefficient are shown in Fig. 1.

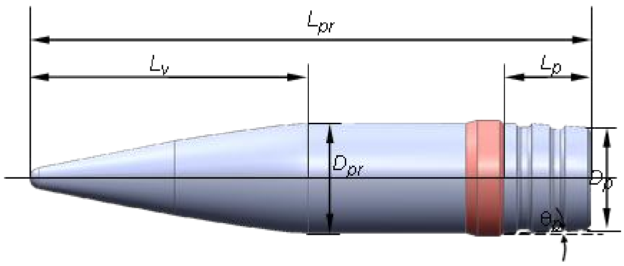

Figure 1. Geometrical dimensions of the projectile used in the application [7]

The calculation method comprises two steps as follows:

- calculation of the form index of the projectile using empirically determined calculation relations;
- multiply the calculated form index by the drag coefficient from the empirically determined laws of resistance used as a reference.

In Fig. 1, there are presented the following parameters:

- L_{pr} – Length of projectile;
- L_v – Length of the ogival component;
- D_{pr} – Projectile caliber;
- L_p – Length of the posterior part of the projectile;
- D_p – Diameter of the posterior part of the projectile;
- θ_p – Inclination of the posterior part of the projectile.

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For the calculation of the projectile's form index, the following auxiliary equations are used as it is shown in (4), (5) and (6), where λ_v is the relative length of the ogival part, γ_{pr} is the form coefficient of the projectile and γ_p is a geometrical coefficient of the posterior part of the projectile:

$$\lambda_v = \frac{L_v}{D_{pr}} \quad (4)$$

$$\gamma_p = D_{pr} - 2 \cdot L_p \cdot \text{tg}(\theta_p) \quad (5)$$

$$\gamma_p = 1 - \frac{\gamma_p^2}{D_{pr}^2} \quad (6)$$

The following step is to calculate the form base index of the projectile using (7).

$$i_T = \frac{12 \cdot \lambda_v}{\sqrt{5} \cdot \left(4 \cdot \lambda_v^2 + 1\right)} \quad (7)$$

Using the calculated base form base index, the projectile's form index is calculated, for different velocity intervals, as (it) follows:

- for 0 m/s ≤ V_0 < 250 m/s:

$$i_{TC} = i_T \cdot \left[1 - \left(0.6 + \frac{\lambda_v}{10}\right) \cdot \gamma_{pr}\right] \quad (8)$$

- for 250 m/s ≤ V_0 < 400 m/s:

$$i_{TC} = i_T \cdot \left[1 - \eta_{pr} \cdot \gamma_{pr}\right] \quad (9)$$

where $\eta_{pr} = 0.6 + 0.167 \cdot \lambda_v - 0.0027 \cdot \lambda_v V_0$

- for V_0 > 400 m/s;

$$i_{TC} = i_T \cdot \left[1 - 0.6 \cdot \left(1 + \frac{\lambda_v}{10}\right) \cdot \gamma_{pr}\right] \quad (10)$$

The value of the C_D drag coefficient is calculated with (11), where C_{Dref} is the reference law drag coefficient [5]

$$C_D = i_{TC} \cdot C_{Dref} \quad (11)$$

IV. Evaluation of Proposed Geometrical Dimensions

In this chapter, there are presented the main characteristics of the geometrical configuration analyzed with PROTech application in order to obtain the suitable dimensions for a ballistic cap. Three models are proposed, each one with different ogival length (53 mm,73 mm, 93 mm). The presented CAD models are designed with SolidWorks CAD Software.

A. Analysis of drag coefficient for a 53 mm ballistic cap

Fig. 2 presents the proposed 53 mm ballistic cap mounted on the projectile.

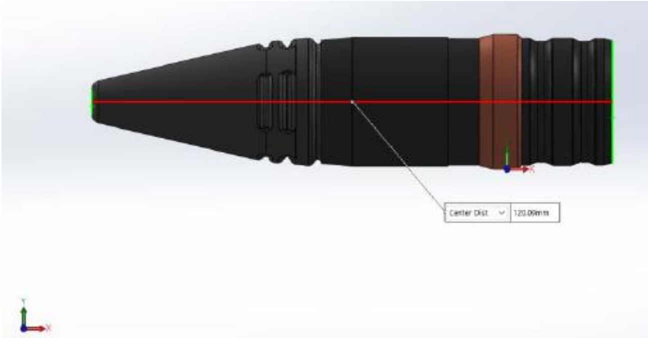

Figure 2. 53 mm ballistic cap mounted on AP-T projectile CAD

In Table I, there are presented the geometrical dimensions of the projectile needed to run the simulation in PROTech application.

Table I. Characteristics of Analyzed Projectile with 53 mm Ballistic Cap

Characteristic	Value
L_{pr}	120.09 mm
L_v	53 mm
D_{pr}	30 mm
L_p	2 mm
D_p	28.32 mm
θ_p	15º
Mach number variations	0.1…4

(8)

B. Analysis of drag coefficient for a 73 mm ballistic cap

Fig. 3 presents the proposed 73 mm ballistic cap mounted on the projectile.

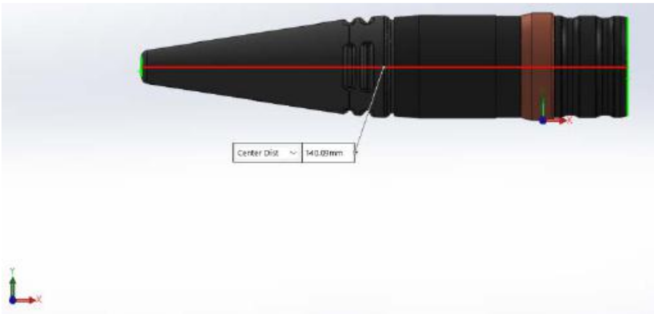

Figure 3. 73 mm ballistic cap mounted on AP-T projectile

In Table II, there are presented the geometrical dimensions of the projectile needed to run the simulation in PROTech application.

Table II. Characteristics of Analyzed Projectile with 73 mm Ballistic Cap

Characteristic	Value
L_{pr}	140.09 mm
L_v	73 mm
D_{pr}	30 mm
L_p	2 mm
D_p	28.32 mm
θ_p	15º
Mach number variations	0.1…4

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C. Analysis of drag coefficient for a 93 mm ballistic cap

Fig. 4 presents the proposed 93 mm ballistic cap mounted on projectile.

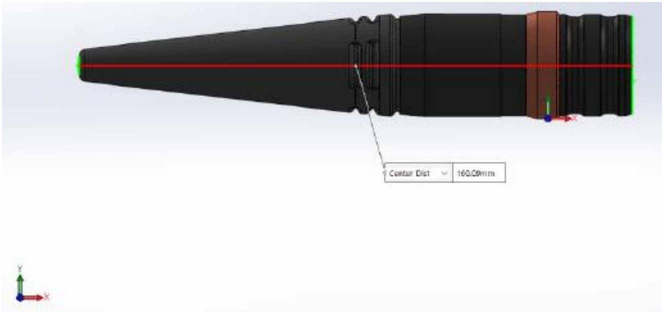

Figure 4. 93 mm ballistic cap mounted on AP-T projectile

In Table III, there are presented the geometrical dimensions of the projectile needed to run the simulation in PROTech application.

TABLE III. CHARACTERISTICS OF ANALYZED PROJECTILE WITH 73 MM BALLISTIC CAP

Characteristic	Value
L_{pr}	160.09 mm
L_v	93 mm
D_{pr}	30 mm
L_p	2 mm
D_p	28.32 mm
θ_p	15º
Mach number variations	0.1…4

V. RESULTS

A. Results of drag coefficient for a 53 mm ballistic cap

In Fig. 5, there is presented the evolution of the drag coefficient C_D over the variation of Mach number on the 1930 ('s) law of resistance for the 53 mm ballistic cap.

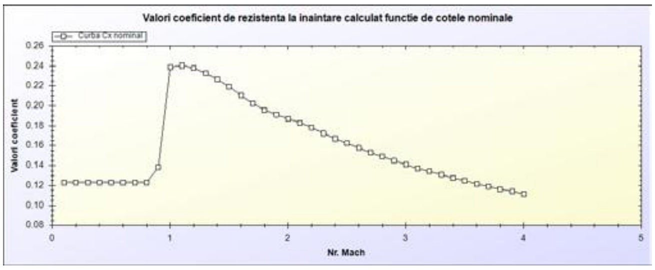

Figure 5. Drag coefficient evolution on variation of Mach number for the 53 mm ballistic cap (1930's Law of resistance)

In Fig. 6 is presented the evolution of drag coefficient C_D over the variation of Mach number on the 1943 ('s) law of resistance for the 53 mm ballistic cap.

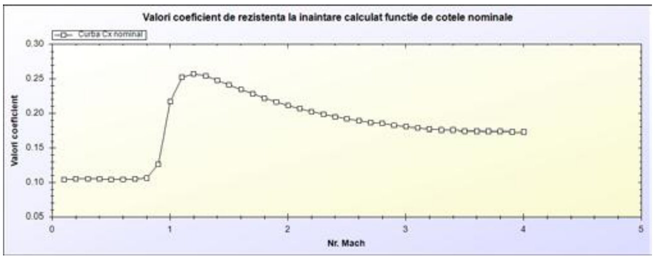

Figure 6. Drag coefficient evolution on variation of Mach number for the 53 mm ballistic cap (1943's Law of resistance)

In Fig. 7 is presented the evolution of drag coefficient C_D over the variation of Mach number on the Siacci's law of resistance for the 53 mm ballistic cap.

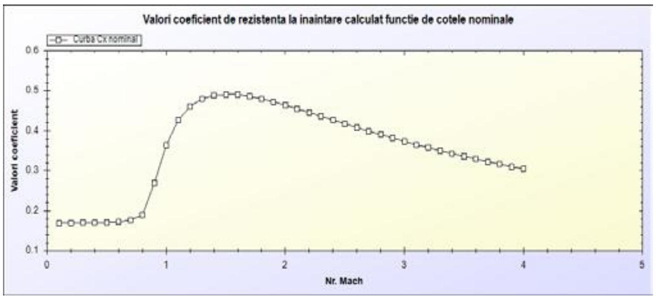

Figure 7. Drag coefficient evolution on variation of Mach number for the 53 mm ballistic cap (Siacci's Law of Resistance)

In Table IV, there are presented the values of the drag coefficient over the variation of Mach number under all three laws of resistance for the 53 mm ballistic cap configuration.

TABLE IV. VALUES OF THE DRAG COEFFICIENT C_D OVER THE VARIATION OF MACH NUMBER UNDER ALL THREE LAWS OF RESISTANCE FOR 53 MM CAP

Mach Number Value	Shape index Value	1930 Law of Resistance	1943 Law of Resistance	Siacci's Law of Resistance
0.1	0.664778378	0.122984	0.10437	0.169519
0.2	0.664778378	0.122984	0.105035	0.169519
0.3	0.664778378	0.122984	0.105035	0.170184
0.4	0.664778378	0.122984	0.105035	0.170184
0.5	0.664778378	0.122984	0.10437	0.170848
0.6	0.664778378	0.122984	0.10437	0.172178
0.7	0.664778378	0.122984	0.105035	0.176831
0.8	0.665345946	0.123089	0.106455	0.189623
0.9	0.666144231	0.138558	0.126568	0.269789
1	0.666946927	0.238767	0.216757	0.364152
1.1	0.667747222	0.240389	0.252408	0.42669
1.2	0.668266854	0.237903	0.257282	0.461104
1.3	0.668267241	0.232557	0.254609	0.479815
1.4	0.668265487	0.226542	0.247927	0.488503
1.5	0.668265244	0.219191	0.241244	0.490507
1.6	0.668266667	0.210504	0.234561	0.490507
1.7	0.668267327	0.202485	0.228547	0.486498
1.8	0.668266212	0.195802	0.221864	0.479815
1.9	0.668265734	0.191124	0.216518	0.472464
2	0.668267857	0.187115	0.211172	0.463777
2.1	0.668266423	0.183105	0.206494	0.455089
2.2	0.668265918	0.178427	0.202485	0.445734
2.3	0.668267442	0.172413	0.198475	0.436378
2.4	0.668268	0.167067	0.195134	0.427022
2.5	0.66826749	0.162389	0.191792	0.417666
2.6	0.668266949	0.157711	0.189119	0.408311
2.7	0.668266376	0.153033	0.186446	0.398955
2.8	0.668264574	0.149023	0.18511	0.390936
2.9	0.668267281	0.145014	0.182437	0.382248
3	0.668265403	0.141004	0.180432	0.373561
3.1	0.668268293	0.136995	0.178427	0.364873
3.2	0.668263682	0.134321	0.177091	0.358191
3.3	0.668265306	0.13098	0.175754	0.350171
3.4	0.668267016	0.127639	0.175754	0.343489
3.5	0.66826738	0.124966	0.174417	0.336138
3.6	0.668263736	0.121624	0.174417	0.329455
3.7	0.668264045	0.118951	0.173749	0.322773
3.8	0.668264368	0.116278	0.173749	0.316758
3.9	0.668269006	0.114274	0.173081	0.310075
4	0.668263473	0.1116	0.173081	0.304729

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B. Results of blunt geometrical configuration simulation

In Fig. 8, there is presented the evolution of the drag coefficient C_D over the variation of Mach number on the 1930 ('s) law of resistance for the 73 mm ballistic cap.

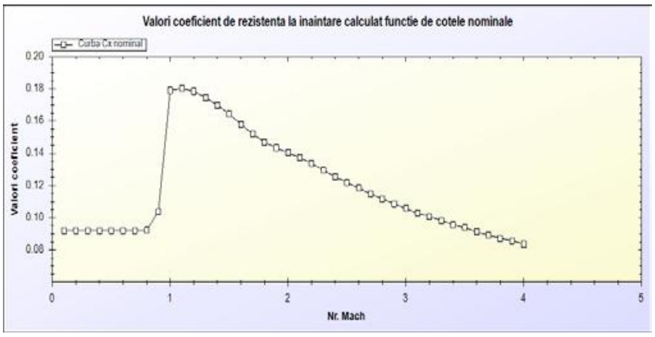

Figure 8. Drag coefficient evolution on variation of Mach number for the 73 mm ballistic cap (1930's Law of resistance)

In Fig. 9, there is presented the evolution of drag coefficient C_D over the variation of Mach number on the 1943 ('s) law of resistance for the 73 mm ballistic cap.

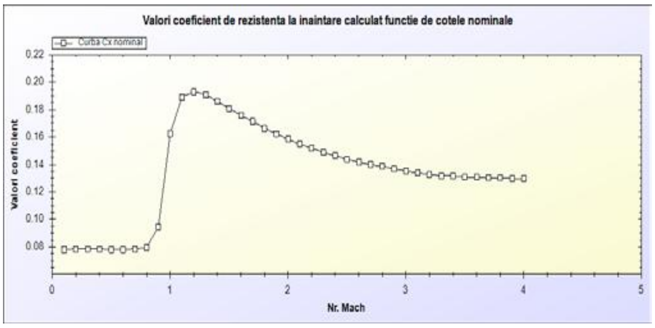

Figure 9. Drag coefficient evolution on variation of Mach number for the 73 mm ballistic cap (1943's Law of resistance)

In Fig. 10, there is presented the evolution of drag coefficient C_D over the variation of Mach number on the Siacci's law of resistance for the 73 mm ballistic cap.

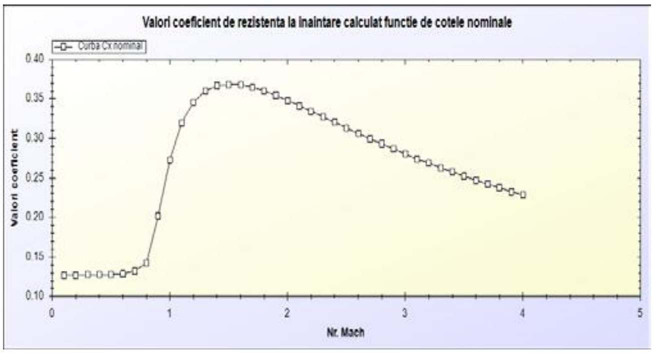

Figure 10. Drag coefficient evolution on variation of Mach number for the 73 mm ballistic cap (Siacci's Law of resistance)

In Table V, there are presented the values of the drag coefficient over the variation of Mach number under all three Laws of resistance for the 73 mm ballistic cap configuration.

TABLE V. VALUES OF THE DRAG COEFFICIENT C_D OVER THE VARIATION OF MACH NUMBER UNDER ALL THREE LAWS OF RESISTANCE FOR 73 MM CAP

Mach Number Value	Shape index Value	1930 Law of Resistance	1943 Law of Resistance	Siacci's Law of Resistance
0.1	0.497714	0.092077	0.078141	0.126917
0.2	0.497714	0.092077	0.078639	0.126917
0.3	0.497714	0.092077	0.078639	0.127415
0.4	0.497714	0.092077	0.078639	0.127415
0.5	0.497714	0.092077	0.078141	0.127913
0.6	0.497714	0.092077	0.078141	0.128908
0.7	0.497714	0.092077	0.078639	0.132392
0.8	0.498297	0.092185	0.079728	0.142015
0.9	0.49913	0.103819	0.094835	0.202147
1	0.499958	0.178985	0.162487	0.272978
1.1	0.500789	0.180284	0.189298	0.320004
1.2	0.501329	0.178473	0.193011	0.345916
1.3	0.501328	0.174462	0.191006	0.359953
1.4	0.501327	0.16995	0.185993	0.36647
1.5	0.501326	0.164435	0.180979	0.367974
1.6	0.501327	0.157918	0.175966	0.367974
1.7	0.501327	0.151902	0.171454	0.364966
1.8	0.501328	0.146889	0.166441	0.359953
1.9	0.501329	0.14338	0.16243	0.354439
2	0.501329	0.140372	0.15842	0.347921
2.1	0.501328	0.137364	0.15491	0.341404
2.2	0.501326	0.133854	0.151902	0.334386
2.3	0.501329	0.129343	0.148894	0.327367
2.4	0.501328	0.125332	0.146388	0.320348
2.5	0.501329	0.121823	0.143881	0.31333
2.6	0.501326	0.118313	0.141876	0.306311
2.7	0.501328	0.114804	0.13987	0.299293
2.8	0.501327	0.111796	0.138868	0.293277
2.9	0.501327	0.108788	0.136862	0.286759
3	0.501327	0.10578	0.135358	0.280242
3.1	0.501327	0.102772	0.133854	0.273725
3.2	0.501328	0.100767	0.132852	0.268712
3.3	0.501327	0.09826	0.131849	0.262696
3.4	0.50133	0.095754	0.131849	0.257682
3.5	0.501326	0.093748	0.130847	0.252168
3.6	0.50133	0.091242	0.130847	0.247155
3.7	0.501326	0.089236	0.130345	0.242141
3.8	0.501328	0.087231	0.130345	0.237629
3.9	0.501327	0.085727	0.129844	0.232616
4	0.501329	0.083722	0.129844	0.228605

C. Results of hollow point geometrical configuration simulation

In Fig. 11, there is presented the evolution of drag coefficient C_D over the variation of Mach number on the 1930 ('s) law of resistance for the 93 mm ballistic cap.

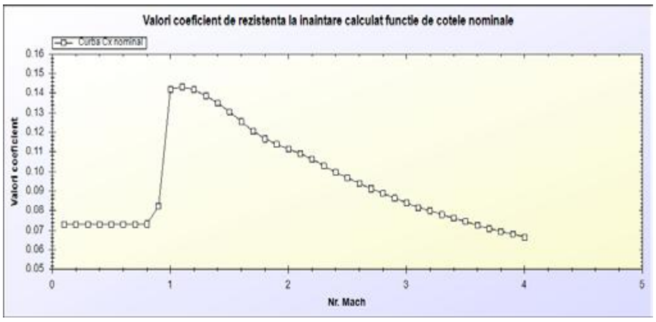

Figure 11. Drag coefficient evolution on variation of Mach number for the 93 mm ballistic cap (1930's Law of resistance)

In Fig. 12, there is presented the evolution of drag coefficient C_D over the variation of Mach number on the 1943 ('s) law of resistance for the 93 mm ballistic cap.

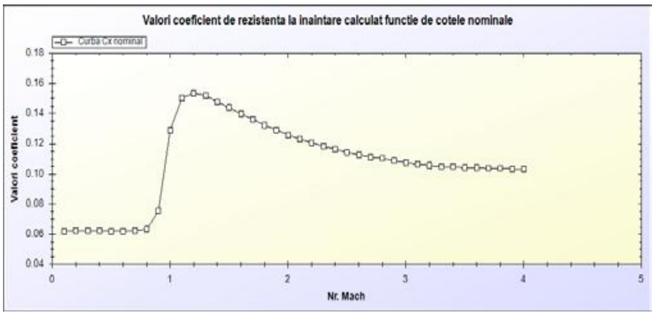

Figure 12. Drag coefficient evolution on variation of Mach number for the 93 mm ballistic cap (1943's Law of resistance)

In Fig. 13, there is presented the evolution of drag coefficient C_D over the variation of Mach number on the Siacci's law of resistance for the 93 mm ballistic cap.

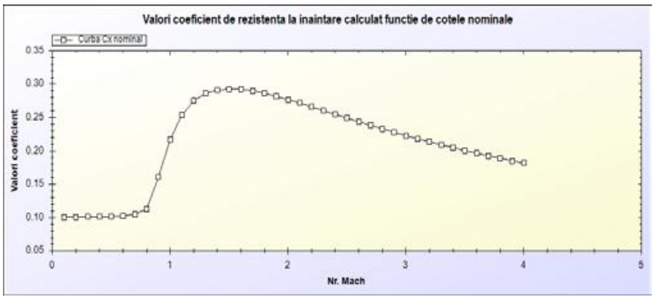

Figure 13. Drag coefficient evolution on variation of Mach number for the 93 mm ballistic cap (Siacci's Law of Resistance)

In Table VI, there are presented the values of the drag coefficient over the variation of Mach number under all three Laws of resistance for the 93 mm ballistic cap configuration.

TABLE VI. VALUES OF THE DRAG COEFFICIENT C_D OVER THE VARIATION OF MACH NUMBER UNDER ALL THREE LAWS OF RESISTANCE

Mach Number Value	Shape index Value	1930 Law of Resistance	1943 Law of Resistance	Siacci's Law of Resistance
0.1	0.394876	0.073052	0.061996	0.100694
0.2	0.394876	0.073052	0.062391	0.100694
0.3	0.394876	0.073052	0.062391	0.101088
0.4	0.394876	0.073052	0.062391	0.101088
0.5	0.394876	0.073052	0.061996	0.101483
0.6	0.394876	0.073052	0.061996	0.102273
0.7	0.394876	0.073052	0.062391	0.105037
0.8	0.39547	0.073162	0.063275	0.112709
0.9	0.396313	0.082433	0.0753	0.160507
1	0.397156	0.142182	0.129076	0.216848
1.1	0.398	0.14328	0.150444	0.254322
1.2	0.398548	0.141883	0.153441	0.274998
1.3	0.398546	0.138694	0.151846	0.286157
1.4	0.398549	0.135108	0.147861	0.291338
1.5	0.398546	0.130723	0.143876	0.292534
1.6	0.398546	0.125542	0.13989	0.292534
1.7	0.398548	0.12076	0.136303	0.290142
1.8	0.398546	0.116774	0.132318	0.286157
1.9	0.398549	0.113985	0.129129	0.281773
2	0.398546	0.111593	0.125941	0.276592
2.1	0.398547	0.109202	0.123151	0.271411
2.2	0.398547	0.106412	0.12076	0.265831
2.3	0.398547	0.102825	0.118369	0.260251
2.4	0.398548	0.099637	0.116376	0.254672
2.5	0.398547	0.096847	0.114383	0.249092
2.6	0.398547	0.094057	0.112789	0.243512
2.7	0.398546	0.091267	0.111195	0.237933
2.8	0.398547	0.088876	0.110398	0.23315
2.9	0.398548	0.086485	0.108803	0.227969
3	0.398545	0.084093	0.107608	0.222788
3.1	0.398546	0.081702	0.106412	0.217607
3.2	0.398547	0.080108	0.105615	0.213621
3.3	0.398546	0.078115	0.104818	0.208839
3.4	0.39855	0.076123	0.104818	0.204853
3.5	0.398545	0.074528	0.104021	0.200469
3.6	0.398549	0.072536	0.104021	0.196484
3.7	0.398545	0.070941	0.103622	0.192498
3.8	0.398546	0.069347	0.103622	0.188911
3.9	0.39855	0.068152	0.103224	0.184926
4	0.398545	0.066557	0.103224	0.181738

VI. CONCLUSION

After analyzing the data obtained from the calculations done with PROTech application, it is pointed out that the geometrical configuration of a ballistic cap has a big influence over the drag coefficient of a projectile. Based on the detailed investigations, the following conclusions can be drawn:

- The evolution of drag coefficient was analyzed for three different dimensions of ballistic cap (53 mm, 73 mm, 93 mm) under three laws of resistance (1930, 1943 and Siacci).
- As it was presented in (11), the form index of a designed projectile has a big influence over the variation of the drag coefficient. A projectile with a lower form index will have to overcome a lower drag during its flight on the trajectory.
- For the studied projectile, a longer ballistic cap will generate a lower shape index with a lower drag coefficient. As it can be seen in Tables IV, V and VI, the lowest shape index and drag coefficient values were recorded for the 93 mm long ballistic cap, but with close results with the values recorded for the 73 mm length cap.
- An analysis with cost/drag influence is compulsory in order to decide if the manufacture of the 93 mm long ballistic cap is worthier than the manufacture of 73 mm long ballistic cap.

REFERENCES

[1] V. S.Makaroff, "Armor piercing projectile, including a method of increasing its piercing power," Patent number US2022137A, 1934, https://patents.google.com/patent/US2022137

[2] "Construction, Operation, Effects and Calculation of Ammunition - Artillery Engineer Course, Part I", Military Academy, Bucharest, 1980 (in Romanian).

[3] F. Moraru, "External Ballistics Manual", Military Publishing House, Bucharest, 1976 (in Romanian).

[4] L.J. Clancy, *Aerodynamics*, Pitman Publishing Limited, London, 1975.

[5] G. Surdu, "Research on the influence of the aerodynamic characteristics of small-caliber projectiles on flight dynamics and firing accuracy", National Institute of Economic Research, Bucharest, 2015 (in Romanian).

[6] G. Surdu and G. Slămnoiu, "Considerations on Efficiency in Experimental Tests Specific for Projectiles of Low Caliber,"*Procedia Economics and Finance*, 2015, vol. 32, pp. 899-905, https://doi.org/10.1016/S2212-5671(15)01541-5

[7] G. Surdu, G. Slămnoiu, A. Sava, and I. Vedinaş, "Comparative evaluation of projectile's drag coefficient using analytical and numerical methods,"*Review of the Air Force Academy*, 2015, vol. 28, no. 1, pp. 101-104.