PROTECH „IN-HOUSE" SOFTWARE AN ALTERNATIVE FOR PROJECTILE'S DRAG COEFFICIENT EVALUATION IN CASE OF SMALL TOLERANCES OF ITS GEOMETRICAL DIMENSIONS

George SURDU*, **Cristian MOLDOVEANU****, **Șomoiag PAMFIL****

*Research Center for Navy, Constanța, Romania
** Military Technical Academy, Romania

DOI: 10.19062/2247-3173.2016.18.1.9

Abstract: *In this paper is described a software product for projectile's drag coefficient evaluation in case of small finite differences of projectile's geometrical dimensions. The software is useful for engineers who work in research and ammunition design when is necessary to evaluate the preliminary projectile drag coefficient and its implications on trajectory. The paper offers an evaluation of projectile's drag coefficient by two different methods: numerical simulation using the flow around the projectile shape and using ProTech design software. The evaluation is made with two different software products, a fluid mecanics one and the "in-house" ProTech software instrument, by comparing the results for drag coefficient obtained using four different projectile shapes.*

Keywords: *drag coefficient, ammunition, aerodynamics, projectile, aerodynamic configuration*

1. INTRODUCTION

The evaluation of the aerodynamic parameters of a projectile's shape assumes to calculate theirs variations taking into account geometrical tolerances of the projectile's geometrical shape.

This variation can be evaluated using some numerical methods specialized on fluid flow evaluation in general and high-speed flow simulation around aerodynamic configurations in particular, which are not in this case a useful instrument. For this reason, was developped an "in-house" software instrument named ProTech that is based on analytic methods. This software instrument has the main purpose to evaluate the projectile's drag coefficient tolerances and the influences of these tolerances on drag coefficient without using a large amount of resources.

This instrument offers to engineers or field test specialist of ammunitions an important standalone software that serves in projectile geometrical modification evaluation, ballistic table evaluation, and projectile's trajectory evaluation using drag coefficient modifications caused by small tollerances of projectile's dimensions.

Some of these instruments can represent a cheap and handy alternative for field-testing but cannot replace the experimental tests. Specialist for preliminary evaluation and implications can use these instruments.

The study has two main objectives: drag coefficient evaluation using the ProTech "in-house" software instrument for four different shapes of projectiles and compare the results with the ones obtained by flow simulation, and the other goal is to make known in a few words the capabilities of the ProTech "in-house" software.

ProTech software is a project financially supported within the project entitled "Horizon 2020 - Doctoral and Postdoctoral Studies: Promoting the National Interest through Excellence, Competitiveness and Responsibility in the Field of Romanian Fundamental and Applied Scientific Research", contract number POSDRU/159/1.5/S/140106. This project is co-financed by European Social Fund through Sectoral Operational Programme for Human Resources Development 2007-2013. Investing in people!

This software has implemented a series of mathematical models developped to execute: statistical evaluation of a ballistic or geometrical parameter, projectile's drag coefficient evaluation taking into account his geometrical tolerances, projectile's trajectory study using projectile's drag coefficient tolerances.

Taking into account, the capabilities briefly presented before the ProTech software instrument contains three main evaluation modules: statistic calculus module named StatTech, drag coefficient module named AeroTech and trajectories evaluation module named BalextTech.

The diagram, for the software modules presentation and theirs icons identification, is presented in Fig. 1.

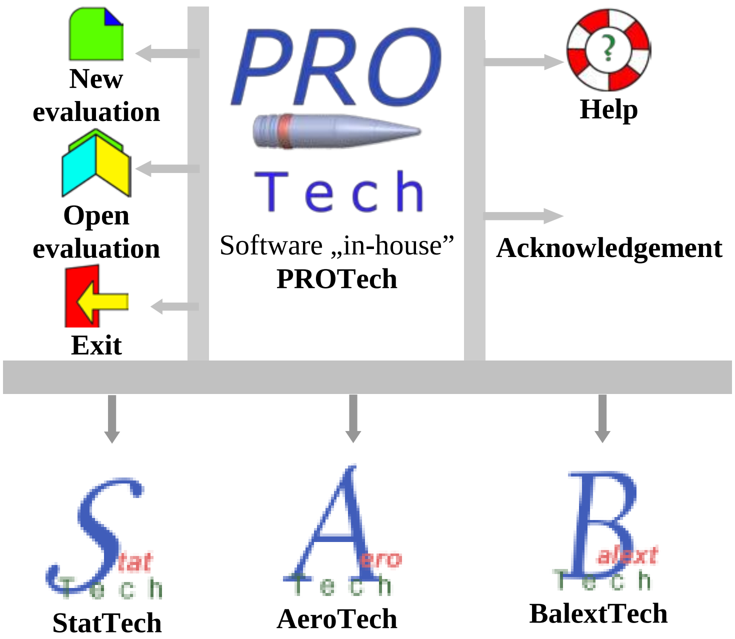

FIG. 1. ProTech sofware diagram

(Source: Authors database presented in [1])

For the presented study, we used the AeroTech module, which represents only the drag coefficient evaluation capability from the ProTech "in-house" software instrument.

Using Protech and a flow simulation software will be compared a few results obtained for four different geometrical configurations of projectiles of 23 mm and 30 mm caliber.

2. NUMERICAL DATA AND 3D MODELS USED FOR DRAG COEFFICIENT EVALUATION

In this study, we used four projectile geometrical configurations. For these configurations, the 3D models of them are presented in Fig. 2, Fig. 3, Fig. 4 and Fig. 5.

FIG. 2. Projectile 23x152B for ZSU canon 3D virtual model, configuration 1-23
(Source: Authors database presented in [1])

FIG. 3. Projectile 23x260 for Rikhter 23-R canon 3D virtual model, configuration 2-23
(Source: Authors database presented in [1])

FIG. 4. Projectile 30x165 for Gsh-30 canon 3D virtual model, configuration 3-30
(Source: Authors database presented in [1])

FIG. 5. Projectile 30x210B for NN-30 canon 3D virtual model, configuration 4-30
(Source: Authors database presented in [1])

All four configurations presented before are use to evaluate the drag coefficient using the flow around projectile and the analytical implemented in ProTech software instrument.

The mathematical model [1, 2, 3] for drag coefficient estimation uses projectile's geometrical dimensions (Fig. 6).

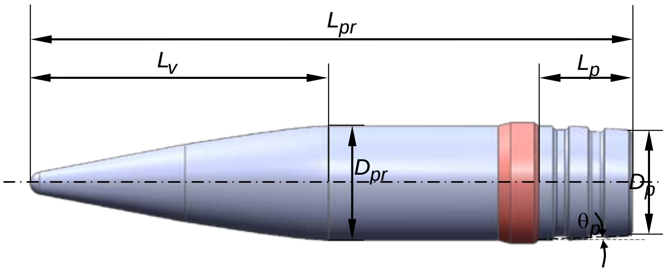

FIG. 6. Projectile's dimensions used (Source: Authors database presented in [1])

These dimensions are: L_{pr}– projectile's total length, L_v- ogive length, L_p- tronconical length, D_{pr} - transversal section diameter, D_p - projectile back – side diameter, θ_p – angle for projectile's tronconical part.

These four configurations of projectiles have the ballistic characteristics presented in Table 1.

Table 1. Projectiles ballistic characteristics

Configuration	Weight [kg]	Initial velocity [m/s]	Total length [mm]
1-23	0.190	970	98.6
2-23	0.175	850	102.35
3-30	0.400	860	139.7
4-30	0.3285	1050	118.6

Source: Authors own database [1]

In Table 1 are presented the ballistic parameters of the four configurations of projectiles and all these data were used for numerical flow 3D simulation and analytical calculation with ProTech software. The numerical evaluations were made for three Mach numbers taking into account their initial velocity.

The numerical results obtained by simulation for every configuration are compared with the results obtained using ProTech's drag coefficient module AeroTech. In addition, the drag coefficient evauaton using ProTech is based on Siacci's law as reference law.

3. NUMERICAL RESULTS

The drag coefficient evaluation with the ProTech software application was made using the geometrical data presented in Table 2. the dimension presented n Table 2 are acording the dimensions presented in Fig. 6.

Table 2. Configurations geometrical parameters

	Configuration			
Parameter	1-23	2-23	3-30	4-30
D_{pr} [mm]	23	23	30	30
L_{pr} [mm]	98.6	102.35	139.7	118.6
L_v [mm]	51.89	40.4	82.8	39.8
L_p [mm]	3.9	6.1	3	5.7
θ_p [deg]	45	45	60	6

Source: Authors own database [1]

The flow simulation was made in the flow simulation scenarios presented in Table 3, Table 4, Table 5 and Table 6 for each configuration separately.

Table 3. Flow design scenarios data for configuration 1-23

Parameter	Flow scenario		
Free stream Mach number value [-]	2.7	2.8	2.9
Free stream density [kg/m^3]	1.22		
Reference surface [m^2]	0.000415476		

Source: Authors own database [1]

Table 4. Flow design scenarios data for configuration 2-23

Parameter	Flow scenario		
Free stream Mach number value [-]	2.5	2.6	2.7
Free stream density [kg/m3]	1.22		
Reference surface [m2]	0.000415476		

Source: Authors own database [1]

Table 5. Flow design scenarios data for configuration 3-30

Parameter	Flow scenario		
Free stream Mach number value [-]	2.5	2.6	2.7
Free stream density [kg/m3]	1.22		
Reference surface [m2]	0.000706858		

Source: Authors own database [1]

Table 6. Flow design scenarios data for configuration 4-30

Parameter	Flow scenario		
Free stream Mach number value [-]	3.0	3.1	3.2
Free stream density [kg/m^3]	1.22		
Reference surface [m^2]	0.000706858		

Source: Authors own database [1]

Drag coefficient was evaluated using the flow field around each of these four configurations presented before. The results for the pressure field and Mach distribution for each configuration are presented in Fig. 7 to Fig. 14.

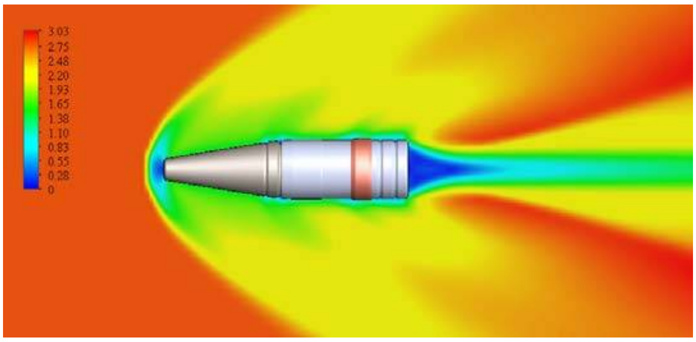

FIG. 7. Mach field for 1-23 configuration at 2.9 Mach free stream velocity

(Source: Authors database presented in [1])

As we can see in Fig. 7 the flow around the projectile's geometrical configurations is with shock waves one. This flow is characteristic for all four configurations and is a symetrical flow around the projectile's main axis. The pressure distribution field is in acordance with the flow as we can observe in Fig. 8. The sresults obtaind for the othe other three configurations will be only exposed without any explanations because the flows around them has the same charatheristics.

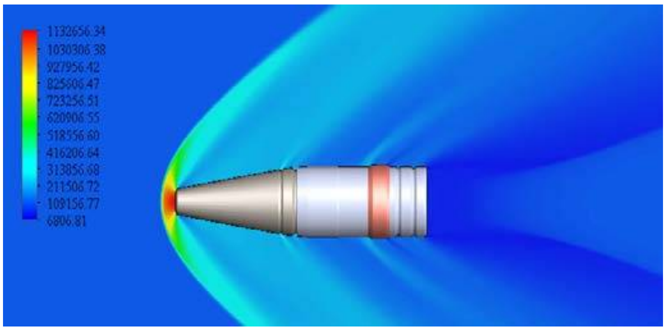

FIG. 8. Pressure field for 1-23 configuration at 2.9 Mach free stream velocity (Source: Authors database presented in [1])

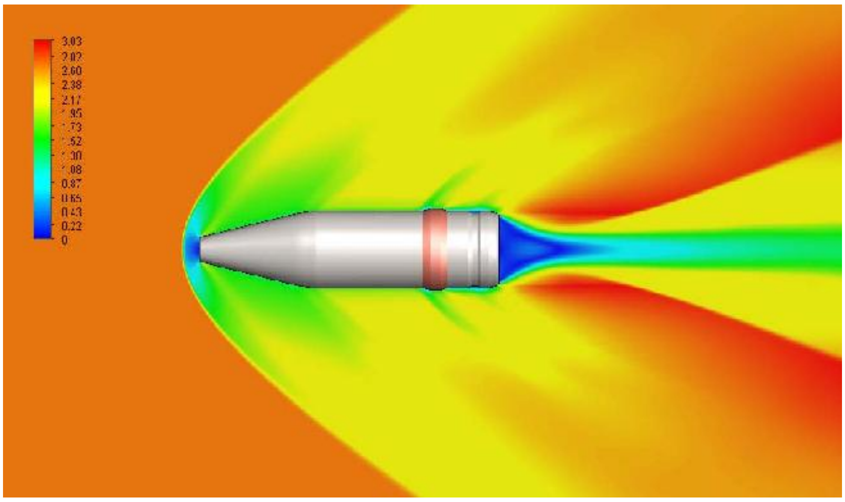

FIG. 9. Mach field for 2-23 configuration at 2.7 Mach free stream velocity (Source: Authors database presented in [1])

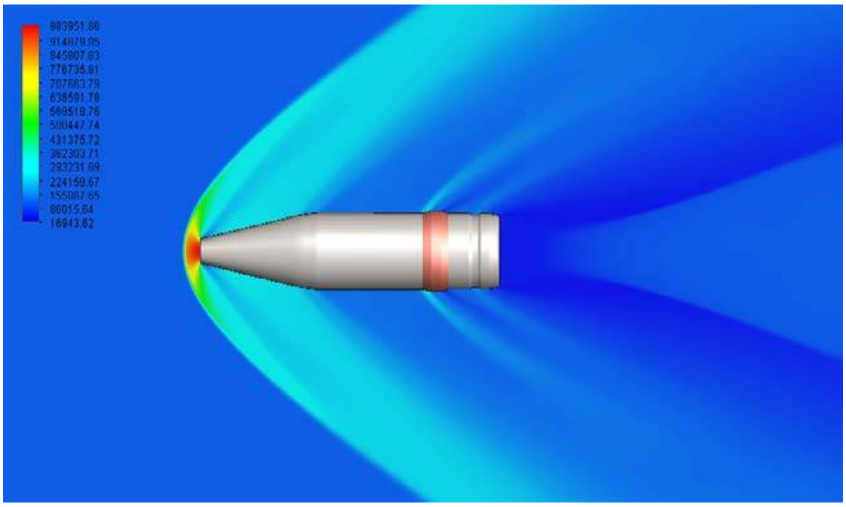

FIG. 10. Pressure field for 2-23 configuration at 2.7 Mach free stream velocity (Source: Authors database presented in [1])

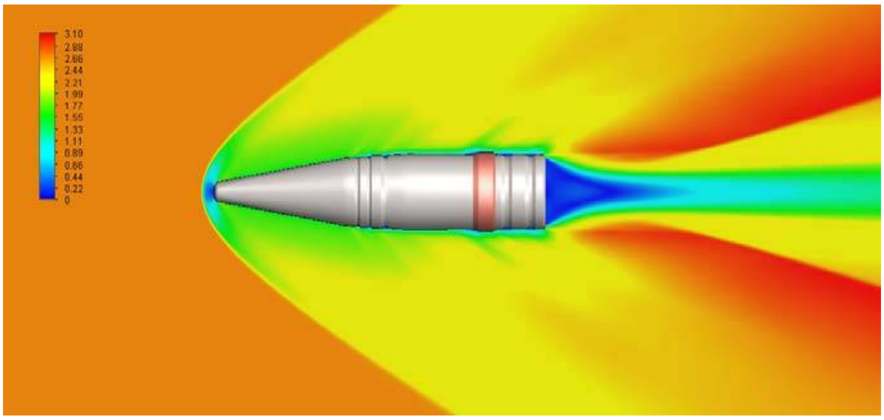

FIG. 11. Mach field for 3-30 configuration at 2.7 Mach free stream velocity (Source: Authors database presented in [1])

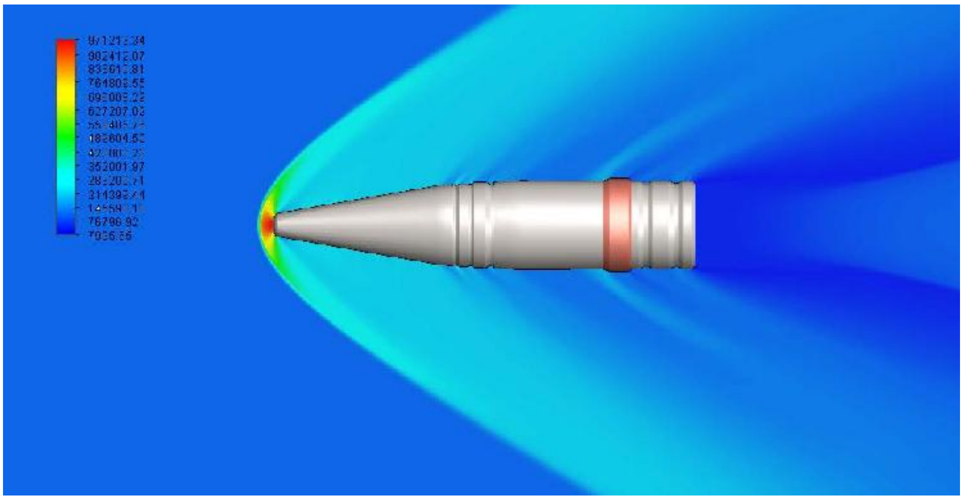

FIG. 12. Pressure field for 3-30 configuration at 2.7 Mach free stream velocity (Source: Authors database presented in [1])

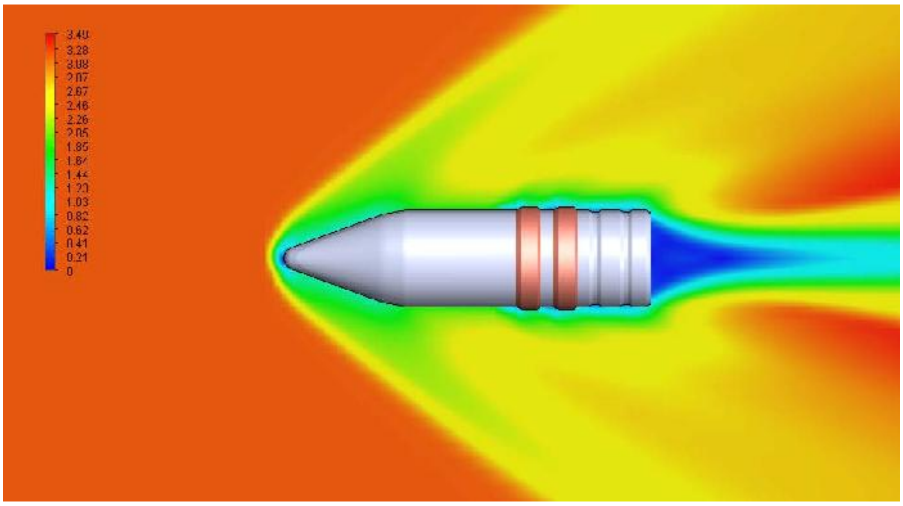

FIG. 13. Mach field for 4-30 configuration at 3.2 Mach free stream velocity (Source: Authors database presented in [1])

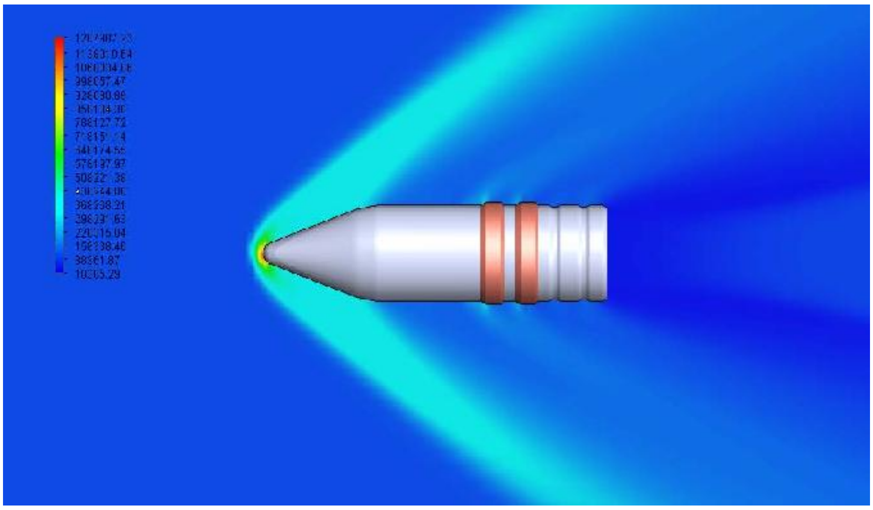

FIG. 14. Pressure field for 4-30 configuration at 3.2 Mach free stream velocity

(Source: Authors database presented in [1])

Drag coefficient for projectiles configurations obtained by simulation and using ProTech's software module AeroTech are compared and exposed in Table 7, Table 8, Table 9 and Table 10.

Relative deviation between the simulation results and ProTech results for drag coefficient value is calculated using the following relation:

$$dev\_rel[\%] = \left| \frac{C_{d\_flow} - C_{d\_ProTech}}{C_{d\_flow}} \right| \cdot 100 \qquad (1)$$

in which: dev_rel represents the relative deviation, C_{d_flow} represents drag coefficient calculated using the flow field, $C_{d\_ProTech}$ represents the drag coefficient value calculated using ProTech software.

Table 7. Drag coefficient comparative results for configuration 1-23

	Mach = 2.7	Mach = 2.8	Mach = 2.9
Drag value ProTech	0.19823	0.194252	0.18993
Drag value flow simulation	0.19940	0.195711	0.18993
Relative deviation	0.583330	0.745732	0.00099

Source: Authors own database [1]

Table 8. Drag coefficient comparative results for configuration 2-23

	Mach = 2.7	Mach = 2.8	Mach = 2.9
Drag value ProTech	0.20134	0.19683	0.19232
Drag value flow simulation	0.19564	0.19182	0.19075
Relative deviation	2.91363	2.61403	0.82532

Source: Authors own database [1]

Table 9. Drag coefficient comparative results for configuration 3-30

	Mach = 2.5	Mach = 2.6	Mach = 2.7
Drag value ProTech	0.16515	0.16145	0.15775
Drag value flow simulation	0.16728	0.15861	0.15695
Relative deviation	1.27067	1.79178	0.50816

Source: Authors own database [1]

Table 10. Drag coefficient comparative results for configuration 4-30

	Mach = 3.0	Mach = 3.1	Mach = 3.2
Drag value ProTech	0.17690	0.17187	0.16851
Drag value flow simulation	0.17121	0.16676	0.16404
Relative deviation	3.32151	3.06356	2.72739

Source: Authors own database [1]

From the results analysis we can see easily that the relative deviation in absolute value is between 0.001 % and 3.33%, which means that the deviations are in the accepted limits of 3% to 10 %. We can consider accepted the results obtained with the ProTech software instrument.

4. CONCLUSIONS

The drag coefficient evaluation was made using two different methods by flow simulation evaluation and using ProTech software instrument.

The results obtained for drag coefficient using ProTech software was in good agreement with the results for it obtained with the flow simulation around the projectile geometrical configuration.

This result can be very useful for the projectile's trajectory evaluation. This can be done using the ProTech's trajectory evaluation module BalextTech.

The software "in-house" ProTech can be used with good results in: research, desing and development for armaments and ammunitions.

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