Determination of extra trajectory parameters of projectile layout motion

A Ishchenko¹, V Burkin¹, V Farapono¹, L Korolkov¹, E Maslov¹,², A Diachkovskiy¹, A Chupashev¹, A Zykova¹

¹ Tomsk State University, 36 Lenina Avenue, Tomsk 634050 Russian Federation
² Tomsk Polytechnic University, 36 Lenina Avenue, Tomsk 634050 Russian Federation

E-mail: maslov_eugene@mail.ru

Abstract. The paper presents a brief description of the experimental track developed and implemented on the base of the RIAMM TSU for external trajectory investigations on determining the main aeroballistic parameters of various shapes projectiles, in the wide velocity range. There is comparison between the experimentally obtained dependence of the fin-stabilized projectile mock-up aerodynamic drag coefficient on the Mach number with the 1958 aerodynamic drag law and aerodynamic tests of the same mock-up.

1. Introduction

One of the main parameters that characterize the body motion in the air is an aerodynamic drag force coefficient (Cx) [1]. An experimental ballistic track for research aimed to identify aeroballistics parameters, including the Cx of different shapes projectile layouts, is developed and implemented in TSU Research Institute of Applied Mathematics and Mechanics.

2. Description of the experimental installation and a technique of conducting experimental researches

A smoothbore ballistic installation is used as an accelerator (Fig. 1, 1). The accelerator has on the muzzle an induction sensor of projectile assembly muzzle velocity [2]. A barrel partly recessed into an evacuated suppressor (Fig. 1, 2).

Figure 1. Schematic disposition of track basic elements.

The suppressor is matched with a windows section (Fig. 1, 3) for video and lighting division projectile assembly process. A master device fragments clipper is installed on the section output. There are two photoelectron velocimeters FEB-7M (Fig. 1, 4, 6) after clipper on the projectile axis at a certain distance from each other. Frames with paper target-marks are mounted on the area between the
velocimeters on the guide fixture (Fig. 1, 5). These target-marks are serving as needed to monitor the projectile attitude on the trajectory. A bullet catcher shield is behind the second FEB-7M (Fig. 1, 7). The total length of the element flight path is 27 m.

![Image of FEB-7M, signal synchronization unit, and ballistic chronometers](image)

**Figure 2.** Appearance of the FEB-7M, a signal synchronization unit and a ballistic chronometers "RUSH-MP".

Developing ballistic track hardware allows: to detect the accelerator chamber pressure by a piezoelectric pressure sensor; to determine the projectile assembly velocity at the exit of the accelerator by the inductive muzzle velocity sensor; to produce a high-speed video of the processes accompanying the projectile motion on the trajectory; to measure the projectile velocity on the two sections of the trajectory by the velocimeters FEB-7M. In the open part of the trajectory, projectile velocity is registered by microwave radar.

Figure 2 shows the appearance of the FEB-7M, a signal synchronization unit and a ballistic chronometers "RUSH-MP".

Used photoelectron velocimeter allows to determine the projectile velocity in the range of 100 ... 2000 m/s at fractional accuracy less than 0.15%.

Figure 3 shows a typical finned projectile layout tested on the ballistic track. The element is made of duralumin with screw weighted steel head.

![Image of finned projectile](image)

**Figure 3.** Appearance of the FEB-7M, a signal synchronization unit and a ballistic chronometers "RUSH-MP".

3. Results of experimental studies
Before the test the layout was placed in the polyethylene master device made for it, which consisting of a pair of beams, steel labels required for the flight time registration by the induction muzzle velocity sensor assembly and a pushed plastic pallet.

Moment of master devices disclosure to clipper was fixed speed video. Fig. 4 shows the projectile layout moves without apparent attack angle, and master device fragments were correctly separated without introducing further movement perturbations.

![Figure 4. Scheme (a) and general view (b) of cone model.](image)

There is a series of 14 tests to determine the aerodynamic drag force coefficient $C_x$ of the similar projectile layout. The same way during the tests temperature and atmospheric pressure was recorded in the ballistic track room.

Determination of the $C_x$ is conducted in accordance with the scheme Figure 5.

Before the performance of the tests series, the distance between the centers of photoelectric velocimetre was measured by a laser ranger. The obtained value was used in the calculations as the distance $L$ between the velocity measuring points $V_1$ and $V_2$.

![Figure 5. Scheme of the ballistic track to calculate the value of $C_x$.](image)

The average value of the coefficient of layout aerodynamic drag forces $C_x$ on the considered distance $L$ is determined by the relation [3]:
$C_{xav} = \frac{2m}{\rho SL} \ln \frac{V_1}{V_2}$,

where $m$ – a mass of the projectile, $S$ – an area of projectiles middle section, $\rho$ – an air density at the test conditions.

A coefficient calculated by this formula corresponds to the number of Mach $M_{av} = V_{av} / a$, where $a$ – a local velocity of sound, $V_{av} = (V_1 + V_2) / 2$.

Figure 6 shows the test results are grouped under the velocities. There are the results of aerodynamic tests [4–7] of the identical finned projectile layout obtained on the TSU model aerodynamic installation and data calculated using the aerodynamic drag law of 1958 year.

![Figure 6. Comparison of test results finned projectile layout with the data of aeroballistic tests and the resistance law of 1958 year.](image)

4. Conclusion

The nature of the obtained dependences generally repeats the resistance law of 1958 year with shape factor of 0.8.

Thus, the developed experimental ballistic track can be used to determine the drag coefficient projectile layouts in order to assess the extent of their target trajectory in the shot.

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