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Comparative Analysis of Trajectory of 7.62 × 51 mm Projectiles Fired at Different Initial Velocities

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Abstract. The subject of the analysis involves the trajectories of 7.62 mm Lapua Scenar GB432 projectiles and "Ball" lead core projectiles manufactured by MESKO S.A. (Poland) fired at different initial velocities from 16-, 20- and 26-inch-long barrels. Calculations in the scope of the external ballistics concerning the characteristics of the trajectories of projectile fired from the analysed weapons were made using the PRODAS 3.5 software by Arrow Tech, using a mathematical model of the solid body movements with six degrees of freedom. During the analyses, the phenomena of the internal and transient ballistics and barrel vibrations were not taken into account. The subject of the study was only the trajectory of a projectile fired with a specific initial velocity corresponding to a barrel of a given length. The impact of wind was assessed by modifying the atmosphere model by adding a side wind blowing at a constant velocity throughout the distance.

The results allowed the analysis of the effect of the barrel length and the associated initial velocity of the projectile on the nature of the projectile trajectory, especially the obtained overheight path and projectile range.

The impact of the side wind on different types of projectiles was also assessed. When shooting precision rifles, it is better to use rounds with heavy projectiles, optimized for long-distance shooting. Lightweight-projectile rounds can be successfully used in the semi-automatic rifles used for support at the lowest levels, where more manoeuvrability (including barrels with a length not exceeding 20 inches) and higher fire rate is required, and, at the same, where shooting at distances exceeding 500 m is not necessary. Lightweight-projectile rounds can also be successfully used for marksmanship training at distances below 500 m, where the differences between the trajectories of different projectiles are the least.

Keywords: mechanics, ammunition, ballistics, small arms, rifle

1. INTRODUCTION

The subject of this analysis are trajectories of 7.62 × 51 mm projectiles fired at initial velocities corresponding to being shot from barrels with a length of 16, 20 and 26 inches. Such barrel lengths apply to the Sako TRG-21/22 and TRG M10 (26 inches) sniper rifles currently used by the Polish Armed Forces and the designed MSBS-7.62N and MWS semi-automatic sniper rifles (20- and 16-inch-long barrels). In addition, the weapons can use ammunition with different projectiles. For long-distance shooting, the Polish Army uses rounds with Lapua Scenar GB432 projectiles, with a weight of 12 grams. In parallel, the Polish Armed Forces also use lead-core projectiles. Their weight is 9.45 grams and are manufactured by MESKO S.A. (Poland). This round is intended first for machine guns, although in certain circumstances it can be used for sniper weapon use, which applies particularly to semi-automatic sniper rifles. This has become a boost to analysing both types of projectiles, fired from barrels of different lengths. A detailed analysis of this issue allowed the determination of the differences between the trajectories and constitutes a starting point for developing long-distance ballistic tables.

Calculations in the scope of external ballistics [1, 2] concerning the characteristics of trajectories of projectile fired from the analysed weapon were made using the PRODAS 3.5 software by Arrow Tech, using a mathematical model of solid body movement with six degrees of freedom. During the analyses, the phenomena of the internal and transient ballistics and barrel vibrations were not taken into account. The subject of the study was only the trajectory of a projectile fired with a specific initial velocity corresponding to a barrel of a given length. The impact of wind was assessed by modifying the atmosphere model by adding a side wind blowing at a constant velocity throughout the distance.

Physical models of projectiles were developed on the basis of catalogue data [3] and actual projectile measurements. Based on the physical models of projectiles, their aerodynamic models could be created [5].

Subsequently, the positions of the centre of gravity (CG) and centre of pressure (CP) allowed the determination of the projectiles and their aerodynamic characteristics, such as the ballistic coefficient and drag coefficient.

It constituted the basis for assessing projectile stabilisation by analysing graphs representing the projectile angle of attack and yaw angle versus time. Thus, the quality of the physical and aerodynamic models of projectiles with known ballistic coefficients [3] and good stabilisation, confirmed by experience resulting from the use of these projectiles by the Armed Forces, were verified.

Simulations were then performed to develop trajectories for the different barrel lengths [4]. The initial velocities of the projectiles corresponding to the tested barrel lengths were assumed on the basis of the ammunition manufacturer's data (velocity of a projectile with a lead core fired from a 26-inch barrel) and measurements during tests on MSBS-7.62N rifles (other velocities).

2. ANALYSIS OF TRAJECTORIES OF LAPUA SCENAR PROJECTILES FIRED AT VARIOUS VELOCITIES

The 7.62 × 51 mm rounds with Lapua Scenar GB432 projectiles are the basic type of ammunition used by Polish Army snipers. The GB432 projectile (Fig. 1) is a 12-gram HPBT (*Hollow-Point Boat Tail*) projectile. Its characteristic feature is a core completely shielded from the bottom side and a hollow-point tip formed from the jacket. The projectile also features a boat tail base improving its ballistic coefficient. The projectile fired from the barrel with a length of 26 inches (0.66 m) reaches a velocity of V_0 = 755 m/s; V_0 = 748 m/s when fired from a barrel with a length of 20 inches (0.508 m) and V_0 = 718 m/s when fired from a barrel with a length of 16 inches (0.406 m).

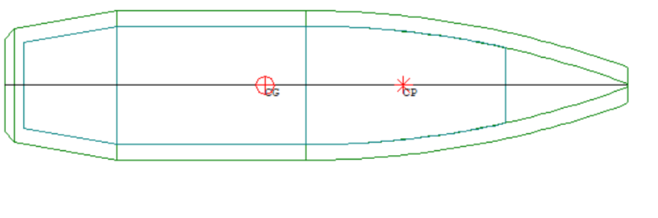

Fig. 1. Physical model of 7.62 mm Lapua Scenar GB432 projectile:
CG – centre of gravity, CP – centre of pressure

The projectile fired at 755 m/s is characterised by a ballistic coefficient of *bc* = 0.508. Figure 2 shows a graph of the angle of attack α_g versus time for a Lapua Scenar GB432 projectile fired with a side wind of 10 m/s. The chart indicates correct stability, thus confirming the model design correctness.

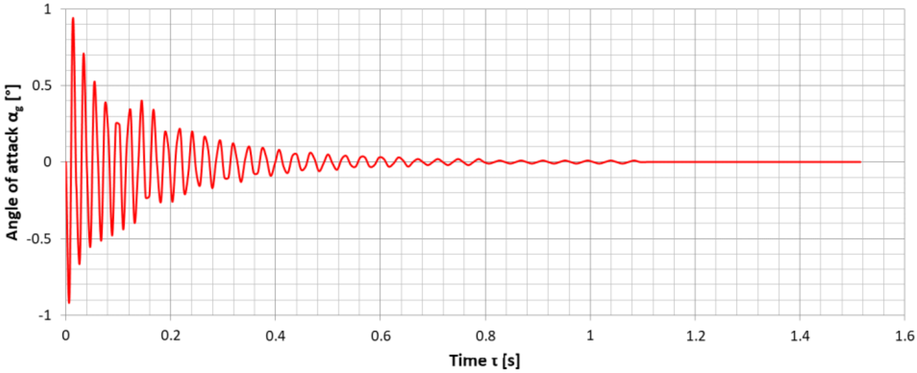

Fig. 2. Angle of attack α_g of a Lapua Scenar GB432 projectile as a function of time, with a 10 m/s side wind

Figure 3 shows the characteristics of the C_x zero yaw drag coefficient versus Mach number (*Ma*).

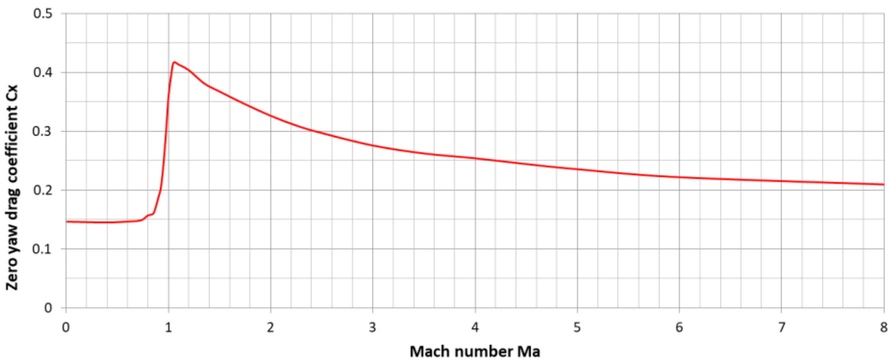

Fig. 3. Zero yaw drag coefficient, C_x, of a Lapua Scenar GB432 projectile versus Mach number

A typical method of sniper rifle zeroing assumes that the aiming point coincides with the average hit point, at a distance of 100 m from the muzzle. A scope sight is usually mounted on a base locating the sights optical axis 75 mm above the barrel axis. All simulations and comparisons were performed in relation to such conditions. Fig. 4 shows trajectories of BG432 projectiles fired from barrels with lengths of 16, 20 and 26 inches.

Trajectories of projectiles fired from barrels of different lengths are similar in nature. Within the initial section, the trajectories overlap, and the apex is located at a distance of 100 m from the muzzle, which results directly from the weapon zeroing conditions.

The differences between the trajectories of projectiles fired from barrels with lengths of 26 and 20 inches were minimal, which resulted from the very small difference in muzzle velocities, i.e., 755 and 748 m/s, respectively. At a distance of 800 m, the hit point for a barrel with a length of 20 inches was 0.17 m below the hit point of the projectile fired from a 26-inch barrel. The trajectory of a projectile fired from a 16-inch barrel clearly deviated from other trajectories and diverged noticeably over a 400 m distance. Over the 800 m distance, the difference between the hit points achieved using a 26-inch and 16-inch barrel was 1 m.

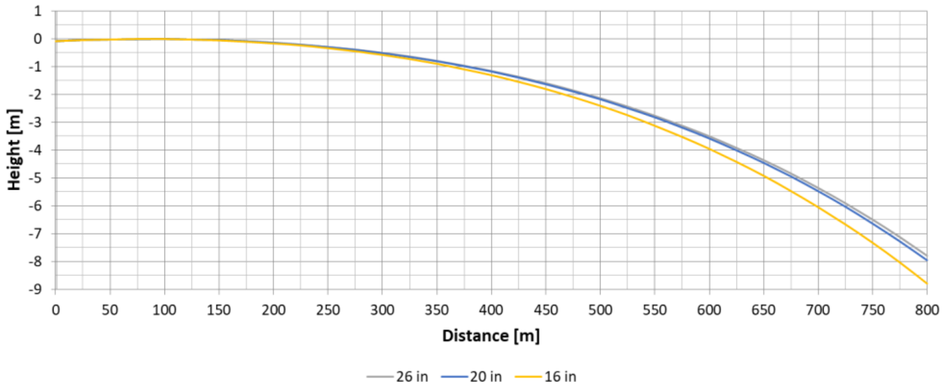

Fig. 4. Trajectories of GB432 Lapua Scenar projectiles fired from barrels with lengths of 16, 20 and 26 inches

Figure 5 shows the projections of trajectories on the horizontal plane under, normal conditions and in the case of a side wind with a velocity of 10 m/s. Under normal conditions, the projectile trajectories overlap along the entire length, and the difference in the hit point positions between the 26-inch barrel and the 16-inch barrel was just 0.01 m at a distance of 800 m.

In the case of a side wind, the trajectory of the projectile fired from the barrel with a length of 16 inches clearly deviated from the other projectiles. In this case, the difference between the position of the hit point of the projectile fired from a 26-inch barrel and the projectile fired from a 20-inch barrel was 0.07 m, at a distance of 800 m from the muzzle. However, the difference between the location of a hit point for a projectile fired from a 26-inch barrel and 16-inch barrel was 0.39 m.

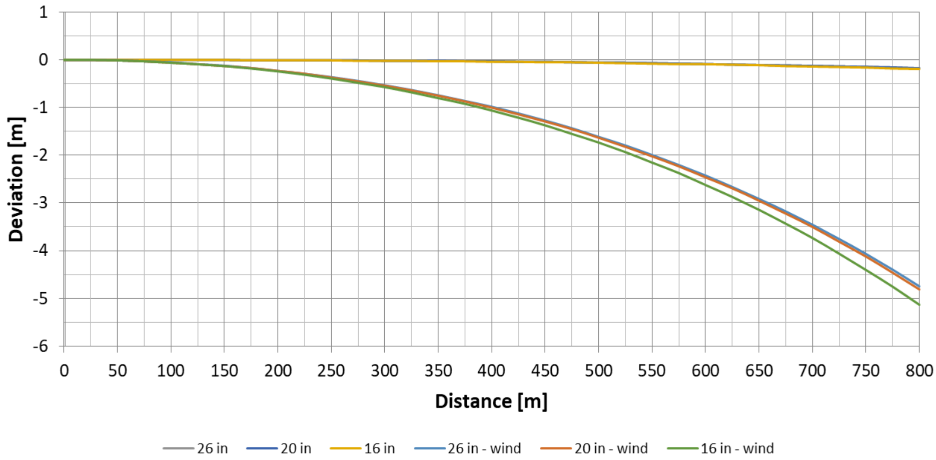

Fig. 5. Projections for the trajectories of a 7.62 mm Lapua Scenar GB432 projectile fired from 16-, 20- and 26-inch barrels on the horizontal plane, under normal conditions, with a side wind velocity of 10 m/s

Figure 6 shows graphs of the projectile velocity changes within the trajectory in relation to the tested barrel lengths. Regardless of the length of the barrel, and thus the initial velocity, the nature of the graph is the same. It is worth noting that, in each case, the projectile retains supersonic velocity up to distance of 800 m.

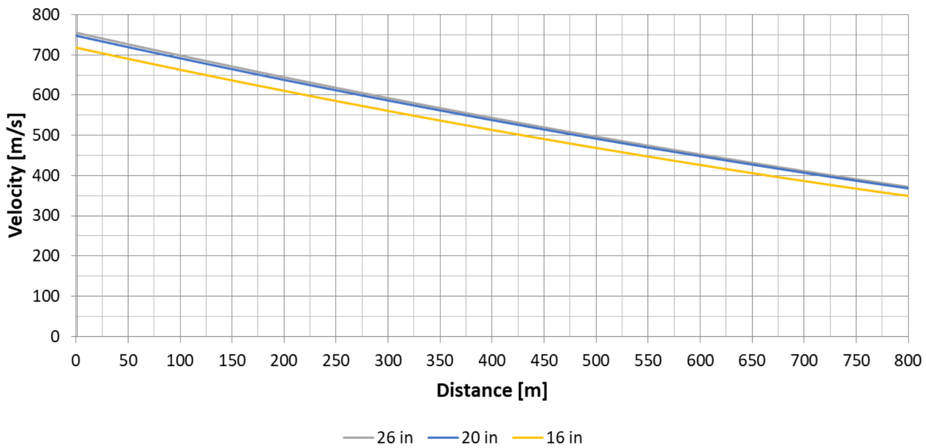

Fig. 6. Velocity of 7.62 mm Lapua Scenar GB432 projectiles fired from 16-, 20- and 26-inch barrels

3. ANALYSIS OF THE TRAJECTORIES OF PROJECTILES WITH LEAD CORES FIRED AT VARIOUS VELOCITIES

A 7.62 × 51 mm round with the "Ball" lead core projectile manufactured by MESKO S.A. is the basic type of rifle ammunition used in the Polish Army. This round is primarily intended for machine guns in the first place, although its use in sniper rifles cannot be excluded. This particularly applies to semi-automatic sniper rifles used at the lowest level of the organisation, where the supply of specialist ammunition may be significantly hindered during the course of military operations. As this ammunition is much cheaper than those with GB432 projectiles, it can also be used for training purposes. A "Ball" projectile manufactured by MESKO S.A. (Fig. 7) is a full metal jacket projectile with a weight of 9.45 grams, a classic design with an open bottom that shows the lead core. This lead-core projectile, similarly to the GB432 projectile, comes with a boat tail base, but it is much shorter. The projectile fired from a barrel with a length of 26 inches (0.66 m) reaches a velocity of V_0 = 870 m/s; V_0 = 815 m/s when fired from a barrel with a length of 20 inches (0.508 m) and V_0 = 773 m/s when fired from a barrel with a length of 16 inches (0.406 m).

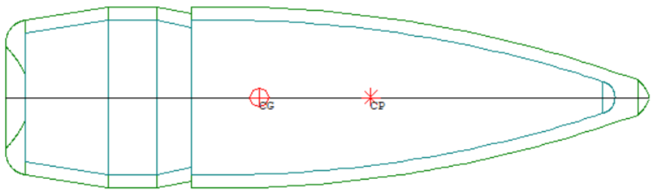

Fig. 7. Physical model of a 7.62 mm "Ball" projectile with a lead core manufactured by MESKO S.A.: CG – centre of gravity, CP – centre of pressure

The projectile fired at 773 m/s is characterised by a ballistic coefficient of *bc* = 0.508. Figure 8 shows a graph of the angle of attack α_g versus time for a projectile fired at the side wind of 10 m/s. The chart indicates correct stability, thus confirming model design correctness.

Figure 9 shows the characteristics of the C_x zero yaw drag coefficient versus Mach number (Ma).

Simulations and calculations for the lead-core projectile were performed in relation to the same conditions as the GB432 projectile. Fig. 10 shows trajectories of lead-core projectiles fired from barrels with lengths of 16, 20 and 26 inches.

The trajectories of projectiles fired from barrels of different lengths are similar in nature. Just like in the case of GB432 projectiles, the trajectories overlap within the initial section, and the apex is located at a distance of 100 m from the muzzle, which results directly from the weapon zeroing conditions.

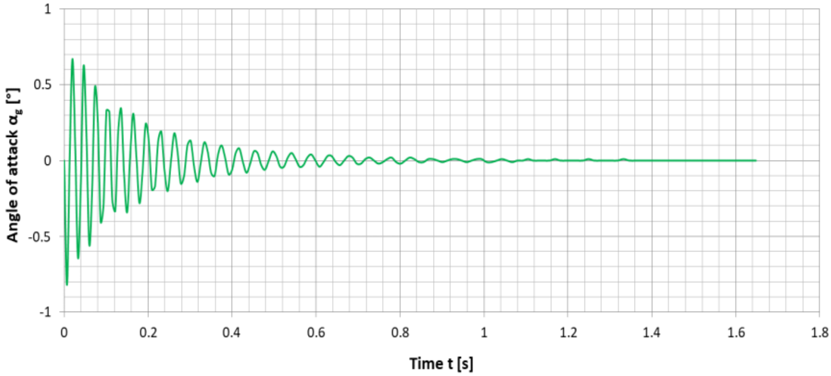

Fig. 8. Angle of attack α_g of a 7.62 mm "Ball" projectile with a lead core manufactured by MESKO S.A., at a side wind with a velocity of 10 m/s

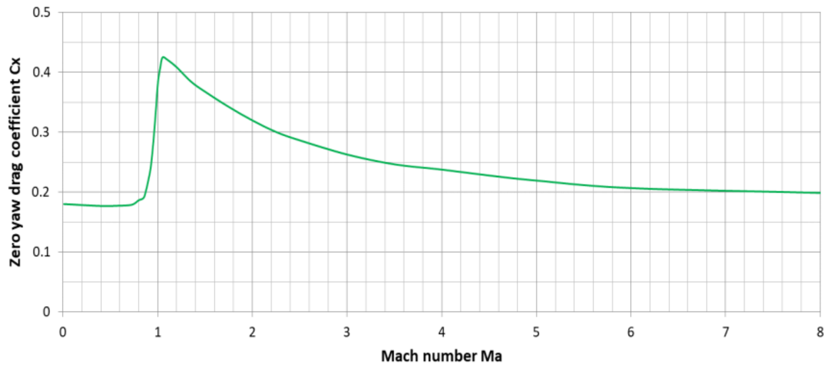

Fig. 9. Zero yaw drag coefficient, Cx, of a 7.62 mm "Ball" projectile with a lead core manufactured by MESKO S.A.

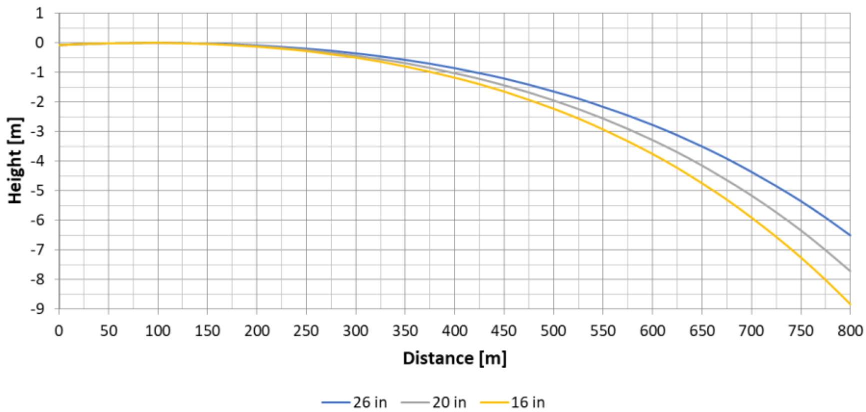

Fig. 10. Trajectories of 7.62 mm "Ball" projectiles with a lead core manufactured by MESKO S.A. fired from 16-, 20- and 26-inch barrels

However, at a distance of 350 m, the trajectories of projectiles fired from the individual barrels differ noticeably, which results in a significant difference in the muzzle velocity values (870, 815 and 773 m/s). At a distance of 800 m, the difference between the 20- and 26-inch barrel hit point is 1.2 m, while the difference between 20- and 16-inch barrel hit points is 1.12 m.

Figure 11 shows the projections of trajectories on the horizontal plane under, normal conditions and in the case of a side wind with a velocity of 10 m/s.

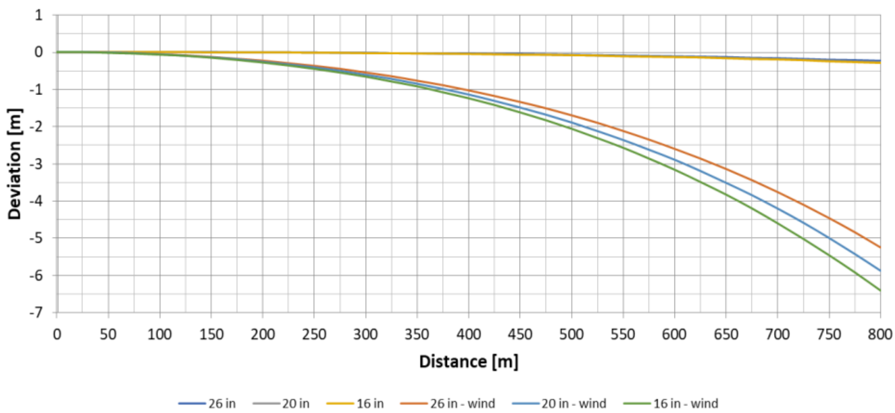

Fig. 11. Projections of trajectories of a 7.62 mm "Ball" projectile with a lead core manufactured by MESKO S.A. fired from 16-, 20- and 26-inch barrels on the horizontal plane, under normal conditions, with a side wind with a velocity of 10 m/s.

Under normal conditions, the projectile trajectories overlap along the entire length, and the difference in the hit point positions between the 26-inch barrel and the 16-inch barrel was just 0.05 m at a distance of 800 m.

As far as the side wind is concerned, the trajectories of projectiles fired from barrels of different lengths are similar in nature. However, at a distance of 350 m, they deviate noticeably, resulting in a difference in the position of the hit point at a distance of 800 m from the muzzle. In the case of a projectile fired from 20- and 26-inch barrels, this difference is 0.62 m, and 1.16 m when a projectile is fired from 16- and 26-inch barrels.

Figure 12 shows graphs of the projectile velocity in relation to the trajectory of the tested barrel lengths. Similarly, to the SCENAR projectiles, regardless of the length of the barrel, and thus the initial velocity, the nature of the graph is the same. For the 800 m distance, only the projectile fired from a 26-inch barrel retained the supersonic velocity (365.48 m/s). For the shorter barrels, the projectile retains a supersonic velocity up to 750 m (20-inch barrel) and 700 m (16-inch barrel).

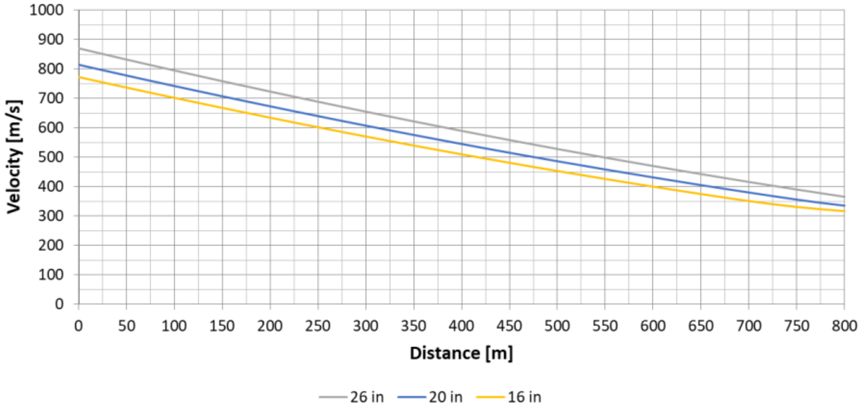

Fig. 12. Velocity of 7.62 mm "Ball" projectiles with a lead core manufactured by MESKO S.A. fired from 16-, 20- and 26-inch barrels

4. COMPARISON OF THE TRAJECTORIES OF PROJECTILES FIRED AT VARIOUS VELOCITIES

The comparison of trajectories of projectile fired from barrels of different lengths is presented in the form of graphs. Figure 13 shows a comparison of trajectories of Lapua Scenar GB 432 projectiles and lead-core projectiles fired from barrels with lengths of 16, 20 and 26 inches.

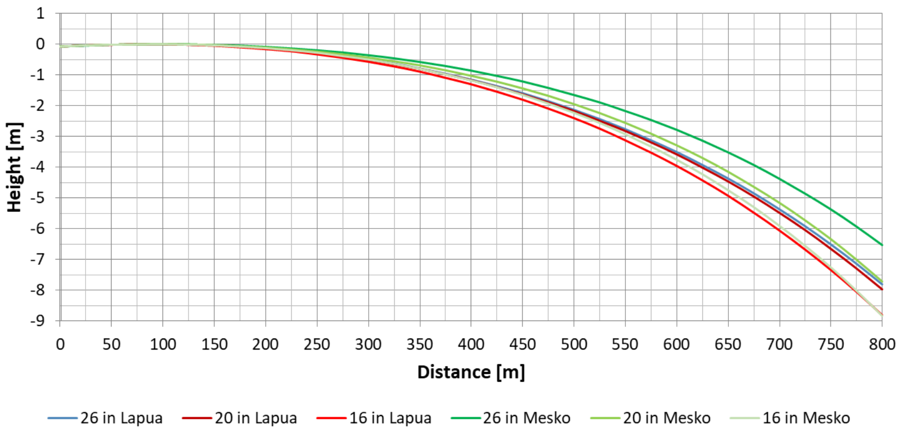

Fig. 13. Trajectories of 7.62 mm lead-core Lapua Scenar GB432 projectiles fired from 16-, 20- and 26-inch barrels

Within the initial section, trajectories of all projectiles overlap, but already at a distance of 300 m differences can be observed.

The trajectory of a lead-core projectile fired from a 26-inch barrel appears to be clearly flatter than other trajectories, with the drop at a distance of 800 m amounting to 6.52 m. Trajectories of GB432 projectiles fired from 20- and 26-inch barrels and trajectories of lead-core projectiles fired from a 20-inch barrel are very similar and, over the entire distance, the differences between individual trajectories are small and do not exceed 0.32 m. This makes it possible to conclude that a 20-inch barrel is the best compromise when using interchangeably rounds with GB432 projectiles and lead-core projectiles.

Trajectories of projectiles fired from 16-inch barrels are also very similar, and the differences do not exceed 0.19 m. Also in this case, interchangeable use of both rounds should not pose any difficulties for a shooter, as it requires only minimal corrections.

Figure 14 shows a comparison of the projections of trajectories in a horizontal plane in standard conditions for GB 432 projectiles and lead-core projectiles fired from 16-, 20- and 26-inch barrels.

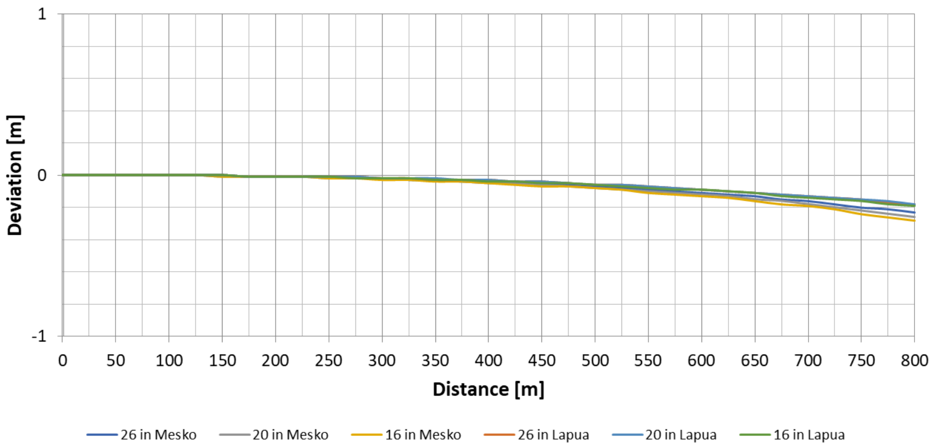

Fig. 14. Projections of trajectories of 7.62 mm Lapua Scenar GB432 projectiles and lead-core projectiles fired from 16-, 20- and 26-inch barrels on a horizontal plane, in standard conditions

Under standard conditions, trajectories of both types of projectile overlap practically along the entire length. The most significant difference in the position of the hit point is obtained for GB432 projectiles fired from 20- and 26-inch barrels and lead-core projectiles fired from 16-inch barrels, although it only amounts to 0.1 m, at a distance of 800 m.

The trajectories of GB432 projectiles fired from 20- and 26-inch barrels and trajectories of lead-core projectiles fired from a 26-inch barrel are very similar and, over the entire length, the differences between individual trajectories are small, not exceeding 0.05 m.

This makes it possible to conclude that interchangeable use of both rounds in standard conditions should not pose any difficulties for a shooter, as it requires only minimal corrections.

Figure 15 shows a comparison of projections of trajectories on a horizontal plane with a side wind of 10 m/s, for Lapua Scenar GB 432 projectiles and lead-core projectiles fired from 16-, 20- and 26-inch barrels.

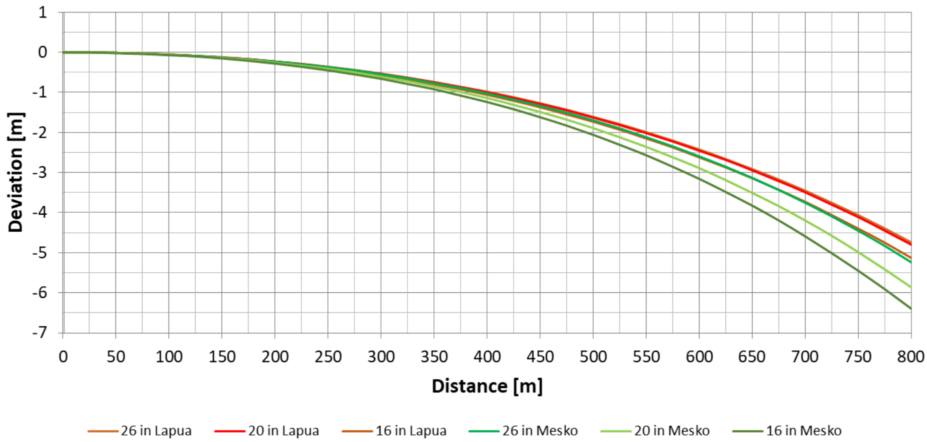

Fig. 15. Projections of trajectories of 7.62 mm Lapua Scenar GB432 projectiles and lead-core projectiles fired from 16-, 20- and 26-inch barrels on a horizontal plane, at side wind of 10 m/s

Within the initial section, projections of trajectories of all projectiles overlap, but at a distance of 300 m differences can be observed. The most significant differences are observed for GB432 projectiles fired from 20- and 26-inch barrels and lead-core projectiles fired from 16-inch barrels, as it amounts to 1.67 m, at a distance of 800 m. The projections of trajectories of GB432 projectiles fired from a 16-inch barrel and lead-core projectiles fired from a 26-inch barrel are very similar, as the differences do not exceed 0.12 m.

Lightweight (9.45 g) lead-core projectiles proved much more sensitive to side wind than heavy (12 g) GB432 projectiles. In real conditions, this may result in significant difficulties in replacing this ammunition type. The greater resistance of GB432 projectiles to side wind gusts also makes it a much better solution for long-range shooting (over 500 m).

5. CONCLUSIONS

The results obtained by way of simulations allow us to conclude that a round with a GB432 projectile is a much better solution for long-distance shooting (above 500 m) than a round with a lead-core projectile.

The GB432 retains supersonic velocity over a larger distance and is also much more resistant to side wind gusts.

On the other hand, the lead projectile cartridge provides a flatter flight path and is suitable for shooting over distances below 500 m, where it retains supersonic velocity even when fired from a 16-inch barrel, and the impact of wind is not yet as strong as at larger distances.

In practice, this means that when shooting precision rifles, it is better to use ammunition with a heavy projectile, optimized for long-distance shooting. Light-projectile cartridges can still be successfully used for self-loading rifles used for support at the lowest level, from which greater manoeuvrability (including barrels with a length of not more than 20 inches) and higher fire intensity is required, and at the same time no distances exceeding 500 m are required.

Ammunition with a light-projectile can also be successfully used for shooter training at distances below 500 m, where differences between the trajectories of various projectiles are the smallest.

Comparing trajectories of projectiles fired from barrels of different lengths, it can also be noted that the use of barrels with a length greater than 20 inches gives relatively few benefits, especially when using ammunition with GB 432 projectiles. A 20-inch barrel ensures supersonic velocity of a GB 432 projectile at a distance of 800 m, and 750 m in the case of a lead-core projectile, not deteriorating the weapon manoeuvrability, so it represents a good compromise, especially for automatic rifles. Simultaneously, it should be emphasized that the results obtained as a result of the simulation require verification during actual shooting exercises and changing the ammunition will probably still require repeating rifle zeroing operations. However, the results here make it possible to assess the range of a permanent correction resulting from the use of ammunition with a projectile demonstrating different parameters.

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Analiza porównawcza torów pocisków 7,62x51 mm wystrzelonych z różnymi prędkościami początkowymi

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Streszczenie. Przedmiotem analizy są tory pocisków 7,62 mm Lapua Scenar GB432 oraz pocisków z rdzeniem ołowianym „Ball" produkcji MESKO S.A. wystrzelone z różnymi prędkościami początkowymi z luf o długościach 26, 20 i 16 cali. Obliczeń z zakresu balistyki zewnętrznej, dotyczących charakterystyki torów pocisków wystrzelonych z analizowanej broni dokonano za pomocą oprogramowania PRODAS 3.5 firmy Arrow Tech korzystając z modelu matematycznego ruchu ciała stałego o sześciu stopniach swobody. W trakcie analiz nie brano pod uwagę zjawisk balistyki wewnętrznej i przejściowej ani drgań lufy. Przedmiotem rozważań był jedynie tor pocisku wystrzelonego z określoną, odpowiadającą lufie o danej długości, prędkością początkową. Wpływ wiatru oceniono modyfikując model atmosfery poprzez dodanie wiatru bocznego wiejącego ze stałą prędkością na całym dystansie.

Uzyskane wyniki pozwoliły dokonać analizy wpływu długości lufy i związanej z nią, prędkości początkowej pocisku na charakter toru pocisku, a zwłaszcza uzyskane na torze przewyższenia oraz donośność pocisków. Oceniono również wpływ wiatru bocznego na różne typy pocisków. Przy strzelaniu z karabinów precyzyjnych lepiej stosować amunicję z pociskami ciężkimi, optymalizowaną do strzelań dalekodystansowych. Naboje z pociskiem lekkim mogą być z powodzeniem stosowane w karabinach samopowtarzalnych stosowanych do wsparcia na najniższym szczeblu, od których wymaga się większej manewrowości (w tym lufy o długości nie większej niż 20 cali) i większej intensywności ognia, a jednocześnie nie wymaga się strzelania na dystanse przekraczające 500 m. Amunicja z pociskiem lekkim może być też z powodzeniem stosowana do szkolenia strzeleckiego na dystansach poniżej 500 m, gdzie różnice między torami różnych pocisków są najmniejsze.
Słowa kluczowe: mechanika, amunicja, balistyka, broń strzelecka, karabin.