Title: Sniper Rifle Cartridge

Authors: Zenon Syroka

To appear in: Technical Sciences

Received 12 July 2021;
Accepted 15 November 2021;
Available online 20 November 2021.

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.
SNIPER RIFLE CARTRIDGE

Zenon Syroka
ORCID: 0000-0003-3318-8495

Faculty of Technical Sciences
University of Warmia and Mazury in Olsztyn

Received 12 July 2021, accepted 15 November 2021, available online 20 November 2021.

Correspondence: Zenon Syroka, Katedra Elektrotechniki, Energetyki, Elektroniki i Automatyki, Wydział Nauk Technicznych, Uniwersytet Warmińsko-Mazurski, ul. Oczapowskiego 11, 10-719 Olsztyn, e-mail: zenon.syroka@uwm.edu.pl, syrokaz@onet.eu.

Abstract

The paper proposes a modification of the 7.62 mm NATO rifle cartridge. The design and the results of a computer simulation were presented. The projectile’s flight behavior under different weather conditions was simulated. A figure diagram and a digital model of the projectile were presented. Ballistic calculations were performed, and an animation showing the projectile’s behavior under various weather conditions was developed. The results were patented.

Keywords: cartridge, sniper rifle, firearm.

Introduction

This study describes a sniper rifle cartridge. The design was patented (SYROKA, SKŁODOWSKA 2020). A cartridge has two definitions in military terminology. In the basic definition, a cartridge is a unit of ammunition for a single shot – a gun cartridge (handgun, shotgun or rifle) or an artillery cartridge. A cartridge consists of:

- a projectile
- propellant (such as gunpowder),

and in fixed ammunition, also:

- primer,
- casing, such as a brass shell, that houses all projectile components.

In the second definition, a cartridge is a propellant charge (such as a gunpowder cartridge) that is located behind the projectile in the firing chamber and leads to the explosion of gas in the barrel.

**The designed cartridge has several advantages.** It contains a lead core and penetrates hard targets at longer ranges. The projectile has an elongated shape, which increases its mass, reduces air resistance, and increases travel velocity, thus enabling the projectile to reach the intended target faster. The use of nitrocellulose powder as propellant slows down and stabilizes the burn rate in all types of weather, and it increases and stabilizes internal pressure which is always consistent with the specification.

Ammunition can be defined as cartridges that are intended for use in firearms. The main aim of sniper rifle ammunition is to neutralize a live enemy target.

**Existing ammunition designs for sniper rifles**

**7.62×51 mm NATO cartridge**

The cartridge was developed by the Institute of Armament Technology at the Faculty of Mechatronics and Aviation of the Military University of Technology in Warsaw and MESKO S.A. Metal Factory (presently MESKO S.A.) in Skarżysko-Kamienna. The cartridge contains a standard projectile with a lead core. Projectile tips are color-coded to indicate their type and designation. For example, projectiles with red tips are intended for live targets, whereas projectiles with black tips are light armor penetrators with a range of up to 500 m. Differently colored projectiles do not differ in size, but they contain different propellants or powders.

**.300 Winchester Magnum**

.300 Winchester Magnum measures 7.62×67 mm, and it was developed by the US Army. It was initially used by hunters, and it is currently deployed in police sniper rifles. Similarly to the
7.62×51 mm NATO cartridge, .300 Win Mag has differently colored tips to identify various projectile types.

**.338 Lapua Magnum**

.338 Lapua Magnum measures 8.6×70 mm or 8.58×70 mm. It has been designed for sniper rifles, but it is also used in hunting rifles. The cartridge was produced by the Finnish ammunition manufacturer Lapua, and it combines the features of 7.62 mm and 12.7 mm NATO cartridges. .338 Lap Mag has a maximum effective range of 1,000 m, and it is not much heavier than NATO cartridges.

**Structural design of a patented cartridge for sniper rifles**

The cartridge is presented in Figure 1, and the projectile is shown in Figure 2. The sniper rifle cartridge was designed as a long-range cartridge for penetrating hard targets. The cartridge (1) contains a lead projectile (2) in a brass jacket. The cartridge has a sharp tip (3), and the tungsten carbide core (4) weighs 1.62 g. Core height is equal to 2/3 of projectile length, and core width is equal to 1/3 of projectile width. The shell (5) was crimped to a length of 69.00 mm, and it contains N140 nitrocellulose powder (68.8%) (6). The shell is connected to a Large Rifle Magnum primer.

Projectile seating depth is 7.60 mm. The core material is protected against excess gas and friction by a solid brass jacket with a bridge. The cartridge has a boat tail base. Shell length is 69.00 mm. Shell volume is typical for projectiles of the type. The shell is filled with N140 nitrocellulose powder (6) with a weight of 4.760 g. A Large Rifle Magnum primer (5) is integrated into the base of the cartridge. This primer is characterized by higher explosive energy which facilitates the ignition of spherical powder propellant. Cartridge length is 81.42 mm.
Fig. 1. Cartridge for a sniper rifle; description in the text

Fig. 2. Projectile in the sniper rifle cartridge; description in the text
Projectile design and model

The trajectory of the designed projectile was calculated with Gordons Reloading Tool software. The program supports the selection of materials, primers and powders. All values are calculated automatically, the results are presented graphically in diagrams, and the optimal values are suggested. Trajectory calculations are presented in a diagram in Figure 3.

![Diagram of projectile trajectory](image)

Fig. 3. Calculations of a projectile’s trajectory parameters

Cartridge model

The cartridge was modeled in Blender 2.8 software. The modeling process was divided into several stages. The projectile and its tip were modeled in the first stage. The carbide core was modeled in the second stage, and the shell and primer were modeled in the third stage.

Model of the projectile and the projectile tip

In the first step, the projectile was modeled with the Circle tool. Cell layers were extruded and transformed to generate a grid object. The projectile tip was modeled separately because projectiles designed for various purposes have differently colored tops. The
Subdivision Surface modifier was added to smooth the edges of the modeled object. A model of a projectile without a tip is presented in Figure 4, and a model of the projectile tip is shown in Figure 5. The entire projectile is presented in Figure 6.

Fig. 4. Model of a projectile without a tip

Fig. 5. Model of the projectile tip
Core model

In the first step, the projectile core was modeled with the Circle tool. The resulting object was rescaled, and a modifier was added to smooth the edges. In the last step, the core was connected to the projectile based on the location and characteristics described in the patent. The core model is presented in Figure 7, and the model of the projectile with the core is shown in Figure 8.

Fig. 6. Model of the entire projectile

Fig. 7. Core model
Shell model

The projectile, the projectile tip and the core were modeled with the Circle tool, whereas the shell was modeled with the Cylinder tool. The object was opened, and several commands were used to model the shell. Wall thickness was modeled with the Solidify modifier. The same method was applied to model the primer and the shell. The front view of the shell model is presented in Figure 9, and the rear view is presented in Figure 10.
The materials for all cartridge components were selected. Nodes were not used. The selection of color was most problematic. Surface color and texture were modeled by the selecting the appropriate values of Specular and Roughness.

**Basic calculations**

**Ballistic resistance of armor against the designed projectile**
Ballistic resistance is the protection offered by armor against projectiles that do not contain explosive materials. The ballistic resistance of armor is influenced by the projectile’s kinetic energy which is calculated with the use of the following equation (SPERSKI 2009):

\[
\frac{(m \cdot v_p^2)}{2} = k \cdot \pi \cdot d \cdot h \cdot h
\]

(1)

where:

\( m \) – projectile’s mass [kg],
\( v_p \) – projectile’s velocity upon impact with target [m/s],
\( d \) – caliber [m],
\( h \) – shield thickness [m],
\( k \) – average shear stress on the lateral surface of a cylindrical shaft with base diameter \( d \) and height \( h \) (FLIS, SPERSKI 2012).

Shield thickness is calculated with the use of the following equation:

\[
h = v_p \sqrt{\left(\frac{m}{K \cdot d}\right)}
\]

(2)

where:

\[
K = 2 \cdot k \cdot \pi
\]

(3)

Coefficient \( K \) is determined experimentally for various types of steel and projectiles. Parameter \( K \) has to be computed, but a method where shield thickness is calculated based on the available data delivers better results. In this approach, the mass \( m_1 \) of a cuboid that comes into contact with the shield is calculated. The volume of shield material that is displaced by the projectile upon impact is equal to the volume of a cylinder with diameter \( d \) and height \( h \) (SPERSKI 2009):

\[
m_1 = \rho \cdot \left(\frac{\pi \cdot d^2}{4}\right) \cdot h
\]

(3)

where:

\( \rho \) – density of a shield made of steel with a density of 7,860 kg/m\(^3\) (FLIS, SPERSKI 2011).

Projectile and shield parameters are presented in Figure 1 (SPERSKI 2009).
The initial velocity $v_0$ of the center of mass of a system composed of a projectile with mass $m$ and a shield with mass $m_1$ is calculated with the use of the following equation:

$$v_0 = \frac{m}{m + m_1} \cdot v_p$$

(4)

where:

$v_p$ – the projectile’s velocity upon impact.

The distance that has to be traveled by the projectile to achieve a terminal velocity of 0 is referred to as the braking distance, and it is equivalent to the thickness of the penetrated shield. A projectile’s braking distance is calculated with the use of the below formula (SPERSKI 2009):

$$s = \frac{(m + m_1)}{2 \pi \cdot d \cdot h \cdot R_{\tau}}$$

(5)

where:

$R_{\tau}$ – the shear strength of the shield material, which is calculated with Huber’s equation:

$$R_{\tau} = 0.577 \cdot R_m$$

(6)

where:

$R_m$ – the material’s tensile strength which, in this case, equals 1,100 MPa.

The projectile’s terminal velocity after shield penetration is calculated with the following equation (SPERSKI 2009):

$$v_k = \sqrt{v_0^2 - \frac{2 \pi d h^2}{m + m_1} \cdot R_{\tau}}$$

(7)

The following formula is applied to calculate shield penetration time (SPERSKI 2009):
\[ t_k = \frac{m + m_1}{\pi d h R_e} \cdot (v_0 - v_k) \] (8)

The above calculations were performed in Matlab.

The results of the calculations performed in Matlab for a projectile that travels in vacuum and does not penetrate the shield are presented in Table 1.

Table 1. Calculations for a projectile that does not penetrate the shield

| Parameter                                | Value     |
|------------------------------------------|-----------|
| Projectile’s mass [kg]                   | 0.019     |
| Muzzle velocity [m/s]                    | 736.2     |
| Caliber [m]                              | 0.00726   |
| Shield thickness [m]                     | 2.8       |
| Shield density [kg/m³]                   | 7,860     |
| Tensile strength [MPa]                   | 1,100     |
| Shear strength                           | 634.7     |
| Nose shape factor [°]                    | 0.33      |
| Acceleration of gravity                  | 9.81      |
| Height of the shooter [m]                | 1.72      |
| Range [m]                                | 2,532.5   |
| Time of flight [s]                       | 3.44      |
| Velocity upon impact [m/s]               | 769.94    |
| Volume of shield material displaced upon impact [m³] | 0.94 |
| Initial velocity of the system’s center of mass [m/s] | 15.19 |
| Distance traveled by projectile after impact [m] | 2.64 |
| Projectile’s velocity after impact [m/s] | 0         |
| Shield penetration time [s]              | 0         |

The results of the calculations performed in Matlab for a projectile that travels in vacuum and penetrates the shield are presented in Table 2.

Table 2. Calculations for a projectile that penetrates the shield

| Parameter                                | Value     |
|------------------------------------------|-----------|
| Projectile’s mass [kg]                   | 0.019     |
| Muzzle velocity [m/s]                    | 736.2     |
| Caliber [m]                              | 0.00726   |
| Shield thickness [m]                     | 2.8       |
| Shield density [kg/m³]                   | 7,860     |
| Tensile strength [MPa]                   | 1,100     |
| Shear strength                           | 634.7     |
| Nose shape factor [°]                    | 0.33      |
| Acceleration of gravity                  | 9.81      |
| Height of the shooter [m]                | 1.72      |
| Range [m]                                | 2,532.5   |
| Time of flight [s]                       | 3.44      |
| Velocity upon impact [m/s]               | 769.94    |
| Volume of shield material displaced upon impact [m³] | 0.94 |
| Initial velocity of the system’s center of mass [m/s] | 15.72 |
Distance traveled by projectile after impact [m] | 2.83  
---|---  
Projectile’s velocity after impact [m/s] | 14.89  
Shield penetration time [s] | 0.0192  

Conclusions:

The results indicate that the projectile will not penetrate the shield if shield thickness exceeds the distance traveled by the projectile upon impact. The range and time of flight can be determined when the projectile penetrates the shield.

**Ballistic coefficient**

The ballistic coefficient (BC) of a projectile is its ability to overcome air resistance, such as wind, during flight. This parameter is largely influenced by a projectile’s geometric dimensions that affect aerodynamic drag. Aerodynamic drag, such as wind force, slows down a moving projectile. The ballistic coefficient is calculated with the use of the following equation:

\[
BC = \frac{SD}{i} \quad (9)
\]

where:

SD – sectional density determined with the GR calculator,

\[i = \frac{2}{n} \cdot \sqrt{n \cdot \frac{4n-1}{n}} \quad (10)\]

where:

\[n – \text{caliber of an ogive-tipped projectile}.\]

The closer the value of BC is to one, the lower the aerodynamic drag and the more stable the projectile’s flight. The designed projectile has a BC of 0.7798.

**Gyroscopic stability**

A fired projectile is subjected to gyroscopic drift which is an interaction between the projectile’s mass and aerodynamic forces. One of such forces is wind which exerts an adverse impact on a projectile’s trajectory. A projectile has to be stabilized to ensure that it precisely...
hits the target. This is accomplished through gyroscopic stabilization. Projectiles for high-precision rifles are affected by gyroscopic precession when:

- a projectile rotates around its axis of symmetry with a certain speed – the higher the projectile’s spin rate, the greater the gyroscopic motion,
- the direction of a projectile’s rotation around its axis of symmetry does not change,
- the forces acting on a projectile can rotate the projectile by as much as 90°,
- a projectile is characterized by complex motion in three-dimensional space, which resembles that of a spinning top.

Gyroscopic stability is determined by the twist rate of the barrel. The twist rate should equal 1, and it should be higher than 1.2 for sporting projectiles and higher than 1.5 for military projectiles to guarantee stability (EJSMONT 2019).

This solution is not free of defects, and it can lead to the horizontal deflection of a projectile. The projectile can be stabilized or the twist rate can be decreased to minimize horizontal deflection. The gyroscopic spin of a projectile can be calculated with a formula developed by Bryan Litz (EJSMONT 2019):

\[
Z = 1.25 \cdot (s_g + 1.2) \cdot t^{1.83}
\]

where:

\( S_g \) – gyroscopic stability factor calculated based on the Miller’s twist rule,
\( t \) – time of flight.

**Influence of wind on a projectile’s trajectory**

The presented examples apply to ideal conditions that are very difficult to achieve. Wind often influences a projectile’s territory. A projectile can be deflected by crosswind that blows from right to left or from left to right, as well as by headwind that blows in the opposite direction of a projectile’s flight path. These influences are very difficult to eliminate. Wind phenomena have been extensively studied, but their effect on a projectile’s path is difficult to model. To compensate for this path deviation, the sighting components have to be adjusted based on the direction and speed of wind. The elevation angle at which the projectile leaves the muzzle has to be calculated. The Minute of Angle (MOA) adjustments to compensate for bullet drop at different wind speeds is given in Table 3. Wind angle was set at 90° and range at 500 m.
Table 3. Projectile’s speed under different weather conditions

| Wind speed [m/s] | Time of flight [s] | Velocity upon impact [m/s] | MOA |
|-----------------|-------------------|-----------------------------|-----|
| 2               | 0.763             | 574                         | 1.3 |
| 3               | 0.763             | 574                         | 1.9 |
| 5               | 0.763             | 574                         | 3.2 |

The time of flight and velocity upon impact with a target situated at a distance of 500 m are identical at different wind speeds, but the MOA ranges from 1.3 to 3.2. The MOA is critical for sighting the scope of a sniper rifle. The calculations were performed with the use of an online calculator, and they account for weather conditions such as temperature and barometric pressure. The parameters of a projectile influenced by a wind angle of 90° are presented in Table 4.

Table 4. Calculations for a projectile influenced by wind

| Parameter                                      | Value          |
|------------------------------------------------|----------------|
| Projectile’s mass [kg]                         | 0.019          |
| Muzzle velocity [m/s]                          | 736.2          |
| Caliber [m]                                    | 0.00726        |
| Shield thickness [m]                           | 2.8            |
| Shield density [kg/m³]                         | 7.860          |
| Tensile strength [MPa]                         | 1.100          |
| Shear strength                                 | 634.7          |
| Nose shape factor [°]                          | 0.33           |
| Acceleration of gravity [m/s²]                 | 9.81           |
| Height of the shooter [m]                      | 1.72           |
| Range [m]                                      | 2532.5         |
| Time of flight [s]                             | 3.44           |
| Velocity upon impact [m/s]                     | 574            |
| Volume of shield material displaced upon impact [m³] | 0.94  |
| Initial velocity of the system’s center of mass [m/s] | 14.21 |
| Distance traveled by projectile after impact [m] | 2.32 |
| Projectile’s velocity after impact [m/s]       | 13.45          |
| Shield penetration time [s]                    | 0.0175         |

Conclusions:

The projectile’s parameters are influenced by the direction of wind. When the direction of wind changes, the projectile’s velocity upon impact also changes, and shield thickness that can be effectively penetrated by the projectile decreases. Therefore, the MOA has to be optimized to guarantee that the projectile precisely hits the target.

Animation of cartridge motion
When a round is fired, the cartridge is separated into two parts: the projectile and the shell. The spent shell is ejected from the chamber, and the projectile is fired from the muzzle (Fig. 12). The projectile travels towards the target and is flattened upon impact (Fig. 13). The projectile’s trajectory was modeled in vacuum and under the influence of light wind with a speed of 2 m/s. The flattening of the projectile upon impact with the target was modeled in the animation. The tungsten carbide core is visible upon impact.

![Fig. 12. Projectile leaving the muzzle](image-url)
Summary

The structure of a cartridge for a sniper rifle was described. The design process and basic calculations were presented. The projectile’s behavior under different weather conditions was simulated. The designed cartridge was patented (SYROKA, SKŁODOWSKA 2020).

References

Amunicja wojsk lądowych: podręcznik. 1985. MON, Warszawa.
BIALCZAK B. 1988. Amunicja strzelecka. Wydawnictwo Politechniki Świętokrzyskiej, Kielce.
BRODACKI J. 1983. Amunicja małokalibrowa. Wydawnictwo Politechniki Warszawskiej, Warszawa.
DINDL F. 2020. Lightweight cartridge case and weapon system. 2020-09-22, US10782107 (B1).

DOBIECH I. 1982. Balistyka doświadczalna. Cz. I. Metody i układy pomiarowe ciśnienia. Wojskowa Akademia Techniczna, Warszawa.

DOBIECH I., MAJEWSKI S., Sienko S., TORECKI S. 1973. Budowa i eksploatacja broni lufowej i amunicji. Cz. 3. Eksplatacja techniczna broni i amunicji. Wojskowa Akademia Techniczna, Warszawa.

EISMONT J.A. 2007. Celność broni strzeleckiej. Praktyczny poradnik. Wydawnictwo Naukowo-Techniczne, Warszawa.

EISMONT J.A. 2018. Amunicja i jej elaboracja. Wydawnictwo Naukowo-Techniczne, Warszawa.

EISMONT J.A. 2019. Balistyka dla snajperów. Wydawnictwo Naukowo-Techniczne, Warszawa.

FLIS L., SPERSKI M. 2011a. Badanie odporności balistycznej pancera ze stali 10GHMBA na ostrzał pociiskiem 12,7 mm. Zeszyty Naukowe Akademii Marynarki Wojennej, LII, 3(186): 27-42.

FLIS L., SPERSKI M. 2011b. Eksperymentalna weryfikacja wybranych modeli obliczeniowych balistyki końcowej. Zeszyty Naukowe Akademii Marynarki Wojennej, 4(187): 35-44.

FLIS, L., SPERSKI M. 2012. Ocena wpływu kształtu wierzchołka pocisku na proces przebijania pancerzy stalowych. Zeszyty Naukowe Akademii Marynarki Wojennej, LIII, 2(189): 29-44.

FURMANEK W., GACEK J., WOŹNIAK R. 2007. Modelowanie i badanie charakterystyk balistycznych pociisków o ograniczonej podatności na rykoszetowanie. Modelowanie Inżynierskie, 34: 23-28.

FURMANEK W., WOŹNIAK R. 2009. Zaprojektowanie, wykonanie oraz przeprowadzenie wstępnych badań modeli nabojów karabinowych 7,62×51 mm z pociskiem zwykłym o zwiększonych przebijalności. Wojskowa Akademia Techniczna, Warszawa.

GACEK J. 1999. Balistyka zewnętrzna, Wojskowa Akademia Techniczna, Warszawa.

GACEK J. 2007. Opracowanie i wdrożenie do produkcji amunicji strzeleckiej o ograniczonym rykoszetowaniu kalibru 9×19 mm, 9×18 mm, 7,62×51 mm i 7,63×54 mm. Sprawozdanie merytoryczne z realizacji projektu badawczego celowego nr 34/BO/B PC 013/WAT/2002. Wojskowa Akademia Techniczna, Warszawa.

GACEK J. 2008. Teoretyczno-doświadczalne badania konstrukcyjne, balistyczne, technologiczne i eksploatacyjne broni oraz amunicji strzeleckiej pod kątem realizacji
przyszłościowego programu pn. "Zaawansowane wyposażenie żołnierza sił zbrojnych RP". Sprawozdanie z realizacji II etapu projektu badawczego PBS 777. Wojskowa Akademia Techniczna, Warszawa.

HE W., GU P., LIANG Q., YANG G., LIN X., HUANG J. 2021 Multi-stage buffer structure and large-caliber sniper rifle. CN112833703 (A).

HOGG I.V. 2001. Amunicja strzelecka, artyleryjska i granaty. Bellona, Warszawa.

JALOSZYŃSKI K. 1999. Technika posługiwania się bronią. Oficerska Szkoła Policji, Legionowo.

KOCZAŃSKI S. 1986. Wybrane zagadnienia z podstaw projektowania broni strzeleckiej. Wydawnictwo Politechniki Warszawskiej, Warszawa.

KOCZAŃSKI S. 1991. Automatyczna broń strzelecka. SIGMA-NOT, Warszawa.

KYZIŁ L. 2007. Przestrzeliwanie materiałów w niemetalicznych stosowanych na konstrukcje okrętowe. Zeszyty Naukowe Akademii Marynarki Wojennej, XLVIII, 2(169): 113-126.

KYZIŁ L., ŚWIĄTEK K. 2009. Modelowanie i weryfikacja doświadczalna przebijalności tarczy pociskami. Zeszyty Naukowe Akademii Marynarki Wojennej, 2(177): 71-90.

LECIEJEWSKI Z., SOBCZAK W., SURMA Z. 1997. Balistyka wewnętrzna. Ćwiczenia labortoryjne. Wojskowa Akademia Techniczna, Warszawa.

LI H. 2020. Toy building block sniper rifle. CN210773670 (U).

ŁUKASZEWSKI T. 2019. Amunicja karabinowa. Wydawnictwo Napoleon V, Oświęcim. Podręcznik strzelca wyborowego. 1972. Szkol. 444/71. Ministerstwo Obrony Narodowej, Warszawa.

RADZISZEWSKI L. 2007. Balistyka końcowa pocisków amunicji małokalibrowej przy strzelaniu do wybranych celów. Wydawnictwo Politechniki Świętokrzyskiej, Kielce.

SANNER M., CALDWELL E., PADGETT CH., WALL CH., HARDING G., PADGETT L. 2021. Lightweight ammunition articles comprising a polymer cartridge case. US2021131245 (U).

SOSZYŃSKI R. 2010. Amunicja strzelecka i działowa. Centrum Szkolenia Wojsk Lądowych, Poznań.

SPERSKI M. 2009. Model obliczeniowy do oszacowania odporności balistycznej pancerzy stalowych. Zeszyty Naukowe Akademii Marynarki Wojennej, 4(179): 51-59.

SYROKA Z., SKŁODOWSKA K. 2020 Nabój do karabinów snajperskich. Patent P.434026, data zgłoszenia 21.05.2020.
ZADKOWSKI J. 2004. Balistyka zewnętrzna, model balistyczny. Wydawnictwo Politechniki Świętokrzyskiej, Kielce.

SZULADZINSKI G. 2010. Formulas for Mechanical and Stuctural Shock and Impact. Taylor & Francis Group, New York.

Szyrkowiec A. 2001. Wszystko o broni myśliwskiej. Bellona, Warszawa.

TAN Y., DONG J., LIU J., TANG B., ZHOU W. 2021. Micro-sound sniper rifle structure and working method thereof. CN112665451 (A).

Torecki S. 1978. Balistyka – wybrane zagadnienia balistiki wewnętrznej. Wojskowa Akademia Techniczna, Warszawa.

Torecki S. 1980. Balistyka wewnętrzna. Wojskowa Akademia Techniczna, Warszawa.

Torecki S. 1982. 1000 słów o broni i balistycy. Wydawnictwo MON, Warszawa.

Torecki S. 1985. Broń i amunicja strzelecka. MON, Warszawa.

Trębiński R. 2003. Amunicja strzelecka o zwiększonej zdolności do penetracji osłon obiektów opancerzonych. Sprawozdanie z realizacji pracy badawczej nr 513/PBW. Wojskowa Akademia Techniczna, Warszawa.

Ważyń M., Idziaszek Z. 2005. Model symulacyjny ruchu pocisku po jego wylocie z przewodu lufy. Eksploatacja i Niezawodność, 3(30): 30-40.

Wisniewski A., Żurowski W. 2002. Amunicja i pancerze. Wydawnictwo Politechniki Radomskiej, Radom.

Wisniewski S., Gacek J. 1987. Balistyka zewnętrzna. Cz. II. Uzbrojenie klasyczne. Wojskowa Akademia Techniczna, Warszawa.

Włodarczyk E. 2006. Balistyka końcowa pocisków amunicji strzeleckiej. Wojskowa Akademia Techniczna, Warszawa.

Włodarczyk E., Jackowski A. 2008. Balistyka końcowa pocisków szybkich. Wojskowa Akademia Techniczna, Warszawa.

Wolsky S.P., Czanderma A.W. 1980. Ballistic materials and penetration mechanics. Elsevier Scientific Publishing Company, New York.

Woźniak R., Ciepliński A. 1994. 7,62 mm karabin wyborowy SWD. Wydawnictwo Bellona, Warszawa.

Zukas J.A. 1990. High velocity impact dynamics. John Wiley & Sons, New York.