Professional paper

627.51(470+571):327(1-622HATO)"20"
623.438.3(470+571: 1-622HATO)"20"

LETHALITY OF CONTEMPORARY RUSSIAN APFSDS ROUNDS AGAINST NATO'S MAIN BATTLE TANKS

Nikola MANEV[1]
Elenior NIKOLOV[2]

Abstract: *Rising tensions in NATO - Russian relations challenge stability in Europe. A hypothetical conventional engagement between the two sides would see massive use of armor and main battle tanks (MBTs). So far, the only proven means to stop a large, armored force is by employing tanks of your own, with armor-piercing fin-stabilized discarding sabot (APFSDS) rounds as the ultimate kinetic energy (KE) tank-killing asset. While current guns and propellants are at the design limit for muzzle velocities, enhancements to this ammunition continue through modifications to the projectile's Length/diameter ratio. Recent development has focused on creating "long-rod" KE projectiles which have increased penetrating power due to their length and mass. Russian technological advances of this ammunition type have been substantial and aimed at out-guning their NATO counterparts. The Svinets 1 (3BM59) and 2 (3BM60) and the Vacuum 1 (3BM69) and 2 (3BM70) projectiles are the latest in this line of development and likely pose a threat to NATO armor. Based on currently available data, evaluating these projectiles against an RHA (rolled homogenous armor) plate at different ranges and angles of impact, simulating different thicknesses of NATO's MBTs armor will allow us to evaluate their lethality and answer which side will have a potential edge over their opponents in conventional warfare.*

Key words: Armor-piercing, penetration, capability, design, trends

Introduction

Rising tensions in NATO-Russian relations challenge stability in Europe. In a hypothetical military engagement between the two sides, as a precursor to conventional fighting, we might be looking at rising tensions and warnings, "hybrid warfare" that combines military power with covert efforts to undermine and discredit the enemy's government and cyber attacks at the opposing forces critical infrastructure. However, when it comes to conventional warfare, tanks are in many ways a fearsome deterrent, a symbol of power and a standard element of national armories. This holds truth for Russia more than any other country as their inventory of tanks encompasses 13 000 functioning MBTs. (GFP, 2021)

[1] *Assistant, Military Academy "General Mihailo Apostolski" - Skopje*
[2] *Full Professor, Military Academy "General Mihailo Apostolski" - Skopje*

Tanks pose a difficult obstacle for armed forces to overcome so that other strategically important objectives can be pursued, and so far, the only proven means to stop a large, armored force is by employing tanks of your own. Sources have made different claims over the tank's increasing vulnerability in the wake of the Russo-Ukrainian and the Nagorno-Karabakh War especially from aerial threats such as UAVs, but these have quickly been disputed or discredited as unfounded. (Bateman, 2020)

The arsenal of most Russian MBTs will include a number of general-purpose, high-explosive fragmentation (HE-frag) rounds for use against infantry, bunkers and light vehicles; then high explosive anti-tank (HEAT) rounds primarily used at shorter ranges (up to 2000 m) and against lighter targets, older MBTs and armored personnel carriers; and finally, Armor-Piercing Fin-Stabilized Discarding Sabot (APFSDS) rounds used against modern MBTs. Additionally, some tanks might be able to fire guided ammunitions carrying a HEAT warhead, at a maximum effective range between 4000 – 5000 m, for missiles fired with the 2A46 tank gun (T-72, T-90), and up to 12000 m, for missiles fired with the 2A82 gun, mounted on the T-14 Armata.

While the introduction of explosive reactive armor (ERA) and spaced armor has rendered most HEAT projectiles useless, since by the time the shaped charge reaches the tank's base armor, it has already lost any penetrating capacity, kinetic energy (KE) rounds such as the APFSDS round remain the ultimate tank killing asset, as they pack the largest blow at the longest distance.

As a result, Russian efforts to out-gun their NATO counterparts have resulted in more than 15 different APFSDS rounds developed for the 125mm gun (model 2A46 and newer 2A82) found in T-64, T-72, T-80, T-84, T-90, and T-14 MBTs. The Svinets 1 (3BM59) and 2 (3BM60) and the Vacuum 1 (3BM69) and 2 (3BM70) projectiles have been designed latest and therefore have the largest potential to pose a threat to NATO armor. That being said, the aim of this paper is to evaluate their lethality against an RHA plate at different ranges, simulating different thicknesses of NATO MBTs armor based on currently available data.

Materials & Methods

Development of the APFSDS Round

Sub-caliber armor-piercing ammunition was created to deal with the large number of tanks deployed on the WW2 battlefields. As armor thickness increased, KE rounds were designed by wrapping a rigid tungsten carbide core in a lighter metal alloy to reach the gun's caliber. Upon impact with the target, the casing deformed, but the core (the penetrator), concentrating all its kinetic energy on a small area, penetrated through the armor.

The smaller the diameter of the penetrator (increased length-to-caliber ratio - L/d) it retains a greater portion of its initial energy at the target. By abandoning the gyroscopic stabilization principles, and introducing aerodynamic fins, the projectile's L/d ratio rose from 5:1 to 30 or 40:1 therefore attaining higher penetration on impact. (Panda, et al., 2017) An additional design improvement was the introduction of a discardable segmented carrier (also known as sabot) of the KE penetrator instead of the early light metal casing. Other major design changes were using tungsten heavy alloy (WHA) instead of tungsten carbide, with WHA being more flexible and not as brittle, allowing the projectile to deform without losing its hardness and moreover improve performance against angled targets. The advantage increased with penetrators made from depleted uranium (DU) with a density of 18.6 g/cm3 (unlike WHA's density of: 14.3-16.3 g/cm3).

This ammunition came to be known as armor-piercing, fin-stabilized, discarding sabot – APFSDS, and from the 1980s until today it has been the primary anti-tank ammunition of the main battle tank (MBT).

Terminal Ballistics of APFSDS Rounds

The basic principle of any KE projectile is to have the highest possible impact velocity, to be long and thin. At extremely high speeds of about 3 km/s, upon impact, penetration is achieved by mutual erosion of the projectile and the target. Assuming that both the projectile and the target behave as non-compressive fluids and that the penetration takes place at a constant velocity, and invoking conservation of momentum, we can write that:

$$(1) \qquad P = L\sqrt{\frac{\rho_p}{\rho_t}}$$

where: P – target penetration depeth; L – KE penetrator (rod) length; p_p – KE penetrator (rod) density; and p_t – target material density.

However, based on equation (1) the amount of penetration is dependent only on the length of the penetrator and the densities of the target and penetrator and is independent of the striking velocity. The initial velocity, which is mostly retained during flight of modern APFSDS projectiles ranges from 1500 to 1800 m/s. Therefore, the effects caused by a projectile which travels at roughly this velocity, can be better represented by the semi-empirical Lanz-Odermatt equation:

$$(2) \qquad P = aL\sqrt{\frac{\rho_p}{\rho_t}}e^{-(2S/\rho_p v^2)}$$

where: a – function of the penetrator L/d ratio; S – measure of target ressistance; and v - impact velocity.

Equation (2) still proves that the penetration primarily depends on the length of the penetrator and the densities of the penetrator and the target, but less so on the increase of the impact velocity. (Andrews, 2003) Consequently, a penetrator will be incapable of penetrating much deeper than its own length, as the sheer stress of impact and perforation will ablate it. As a result, current guns and propellants are at the design limit for muzzle velocities, but to increase penetration, enhancements continue to the L/d ratio.

Contemporary Russian APFSDS Rounds

Russia inherited the ammunition development legacy of the Soviet Union. During the Cold War, they were the first to adopt APFSDS technology by fielding the 115 mm 2A20 smoothbore gun on the T-62 MBT and continued with the larger 125 mm gun (2A46 and its variants), mounted on the T-64, T-72, T-80, T-84 and T-90 MBTs.

The development of the original Svinets ammunition started in 1985 and lasted until at least 1991 and uses a DU penetrator with a length of 546 mm and a diameter of 25 mm. The Svinets penetrator is reportedly able to penetrate an estimated 600-650 mm of RHAe at 2.000 m, at an angle of 90°. (BTTR, 2016) Although there is a factor of secrecy involved in the production of tank ammunition, so far it seems both possible (and probable), that Russia has been mass producing the improved Svinets ammunition (Svinets 1 or Svinets 2) for the best part of the last two decades as serial production is rumored to have started back in 2002 to 2005.

The Svinets 1 (3BM-59) uses a DU penetrator, while the Svinets 2 (3BM-60) is fitted with a WHA penetrator. They utilize an aluminium sabot with three points of contact which is rather unique, as most other APFSDS round sabots use only two points of contacts. This might affect accuracy and barrel wear, but it is not likely that in any way enhances penetration. Still, the projectile length for the Svinets ammunition is an overall improvment over older Vant (3BM-32) - 380 mm, Mango (3BM-42) - 452 mm and Lekalo (3BM-44M) - 570 mm and could mean a major boost in the anti-armor capabilities for Russia's tank force. (Figure 1)

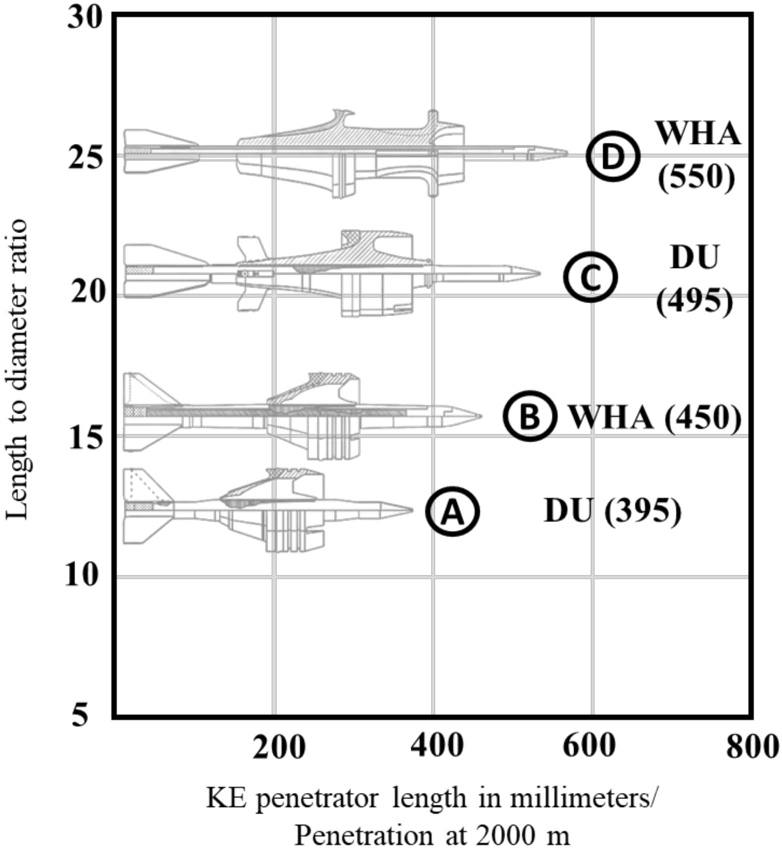

Figure 1. Russian APFSDS Projectiles Development (A – Vant, B – Mango, C – Svinets, D – Lekalo)

The newer Russian 2A82 tank gun, which is now installed on the T-14 Armata MBT (Roblin, 2019) was conceived to modernize the numerous fleets of T-72 and T-80 MBTs, and to equip new modifications of the T-90. The 2A82 can employ new 3BM69 Vacuum 1 and 3BM70 Vacuum 2 APFSDS rounds with extra-long 900 mm penetrators (Pawlikowicz & Surowiec, 2019) fired at a muzzle velocity of 2 km/s, striking with 15-24 MJ of energy to penetrate 900 - 1000 mm of armor at a distance of 2000 m.

Designation	Dimensions	L/d Ratio	Material	Muzzle Velocity	Penetration RHAe at 2000 m	
					0°	60°
3BM48 "Svinets"	546 mm x 21 mm	26:1	Uranium	1700 m/s	650 mm	300 mm
3BM59 "Svinets 1"	740 mm	30:1	DU	1650 m/s	830 mm	410 mm
3BM60 "Svinets 2"	735 mm x 21 mm	35:1	WHA	1660 m/s	740 mm	350 mm
3BM69 "Vacuum 1"	900 mm	/	DU	1700 - 2050 m/s	1000 mm	460 – 490 mm
3BM70 "Vacuum 2"	900 mm	/	WHA	1700 - 2050 m/s	900 mm	410 – 440 mm

Table 1. Penetration of Russian APFSDS Rounds against RHAe at 2000 m (Сергей, 2020; Ezoteriker, 2021)

Layered armor protection & RHA equivalent

Due to the lethality of anti-tank weapons, crew survivability is one of the largest challenges of MBT design.

Rolled homogeneous armor (RHA) was a type of armor, made of hot-rolled steel which fell out of use on MBTs as new KE and chemical energy (CE) weapons (such as the HEAT round) were capable of penetrating even significantly thick RHA. Moreover, weight, mobility, and fuel consumption constraints did not allow engineers to improve protection by simply inserting more, heavy RHA between the crew and the projectile. As a result, RHA has largely been superseded by spaced and composite armor, which incorporates air spaces and materials such as ceramics or plastics in addition to steel.

Protection against KE projectiles is a matter of one or a combination of three things: slow down; turn; or break up the projectile. (Zahn, 2000) With spaced armor, the projectile's penetration capability is reduced by placing a thin sheet of armor a few inches from the base armor. As the round penetrates the spaced armor, it begins to turn and, by the time it hits the base armor, it may be nearly perpendicular to its flight path. Since most KE projectiles are brittle, another advantage of using spaced armor composed of high-hard steel and ceramics (also known as composite armor) is that it causes the penetrator to break up as it crosses the distance between the spaced and the base armor.

A very hopeful alternative to RHA is explosive reactive armor (ERA), which at its basics is a sandwich of two metal plates with explosive material between them. The plates are mounted on the tank body on the path of the penetrator so that, when attacked, the explosive reacts causing the two plates to fly apart. The movement of the plates breaks up the KE penetrator. These characteristics make ERA more efficient than homogenous armor and allow greater protection at a fraction of the weight.

For the testing and calibration of anti-tank guns and ammunition, the term RHAe (Rolled Homogeneous Armor equivalency) is used when giving an estimate of either the penetrative capability of a projectile or the protective capability of a type of layered armor which may or may not be steel. Today, the term is primarily used as a unit of measurement of the protection offered by layering armor on a vehicle in equivalent "millimeters of RHA", referring to the thickness of RHA that would provide the same protection. (US Army, 2000)

Composition of the NATO tank fleet

Out of 30 NATO member states, 8 do not operate MBTs, while the 22 member states that do have MBTs in their land forces operate 12 different models, reflecting diverse armor capabilities among NATO countries. Of the rough total of 13000 plus in-service platforms, the largest portion of 43 % fall under the US-made Abrams, represented with the M1A1 and M1A2 models which NATO wise are used exclusively with the US Army. 20 % are represented by the German - made Leopard family (Leopard 1 and 2 variants), while the third largest portion of MBTs is in the form of Russian export variants of the T-72 (9%). With a significantly smaller representation follow the French – Leclerc (3%), the Italian – Ariete (2%), and the British – Challenger 2 (2%). Finally, some 22 % include the Romanian TR-85 and its variants, some Soviet T-54/55s, as well as US made - M60 and M48 Patton variants. (Figure 2)

Looking at the operational status of MBTs in NATO, as well as some of the member states (such as the UK) defence budget cuts by 2025 there is a significant number of these platforms to be phased out. Nonetheless, based on Figure 2, as well as the defence policy of NATO, almost certainly both the Abrams and the Leopard 2 variants will stay in use for the foreseeable future. (ESD, 2021)

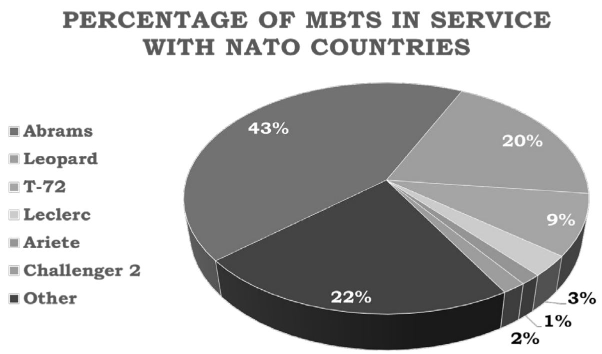

Figure 2 Percentage of MBTs (by manufacturer) in service with NATO countries (GFP, 2021; ESD 2021; Marrone and Sabatino, 2020)

MBT	Armor	RHAe for KE penetrators
Abrams	Modular Chobham composite armor, Spaced armor, and DU Paneling + Reactive armor kit (TUSK)	940-960 mm
Leopard	3rd generation composite armor, with reinforcement to the turret and externally mounted add-on armor modules	920-940 mm
T-72	High hardness steel with ceramic insertions + ERA	400 mm
Leclerc	Welded steel plates with a thickness of 30 - 50 mm + Semi-reactive armor modules and titanium, spaced armor	800 mm
Ariete	Steel and composite blends and spaced armor	490-500 mm
Challenger 2	2nd generation modular Chobham composite armor + Reactive armor kit	920-960 mm

Table 2. Armor thickness of NATO MBTs in RHAe

Results

A simple comparison of the data provided in Tables 1 and 2 allows us to reach a well-founded conclusion, that Russian 3BM69 Vacuum 1 and 3BM70 Vacuum 2 APFSDS rounds with their extra-long 900 mm KE penetrator pose a significant threat to most NATO MBTs as well as their armored forces in general. Seeing as the data provided in Table 2 presents the best frontal armor protection estimate (RHAe) regardless of the MBT model, we can safely say that this finally gives Russia a tank round that could reliably penetrate NATO MBTs at medium range (2000 m).

It is also worth mentioning that neither of the abovementioned MBTs will have the same protection on all points of their frontal arcs. In fact, even with the mighty Abrams M1A2 SEP or the Leopard 2A7+ (latest variant MBTs), some points will be weaker, especially say the upper front turret or the gun mount. With this in mind, even the Svinets 1 (3BM-59) and the Svinets 2 (3BM-60) rounds have a fighting chance of effectively engaging the representative NATO tanks.

However, MBTs irrespective of the type and make have a certain sloping to their armor, especially on the front glacis. Although each of these slope values are different for different MBTs, we can see that a hit on target under a 60-degree angle, significantly reduces penetration (by 45-50%). On that note, it is highly unlikely to achieve a perfect perpendicular frontal hit (at an angle of 90 degrees) which reduces the chances of successfully destroying a target.

Moreover, achieving a first-round hit ultimately comes down to the fire control system and its gun stabilization platform, sighting systems, ballistic computer, target acquisition system etc. as well as the element of surprise, and the opposing tank's active protection and warning measures. But, when it comes down to sending any of these projectiles down-range, they are a more than capable and lethal asset which will attain massive damage against any armored target, including NATO's MBTs.

Discussion

Today, T-72s remain Russia's primary MBT, supplemented by turbine-engine T-80s and some T-90s. All carry variants of the 125 mm 2A46 smoothbore gun, which loads its ammunition using an autoloader. Both the Svinets 1 and 2, as well as the Vacuum 1 and 2 have penetrators exceeding 640 mm, whereas T-72 and T-80s autoloaders could only accommodate a maximum ammunition size of 640 millimeters.

Supposedly the T-90A features an upgraded autoloader design capable of supporting longer parts, but the original production model of the T-90, which largely relied on the old T-72B chassis, might not have been fitted with the improved autoloader. This might result in the newer ammunition being only useful with a limited number of tanks, which would result in a lower production volume and higher per unit costs. The Armata with 10

its new 2A82 gun and autoloader is most likely capable of handling the Svinets 1 and 2 APFSDS rounds and larger ammunition.

The Svinets 1 and 2 rounds have been in development since the late-1990s or early-2000s, and development on the Vacuum 1 and 2 has started a lot sooner than that. While it has been known for quite a while that Russia has been working on the development of more advanced APFSDS ammunition for the T-72, T-80 and T-90 tanks - it is more likely that most of Russia's tanks are still supplied with older ammunition from the mid-1980s, likely taken from Soviet stocks.

Conclusion

MBTs are a major obstacle for armed forces to overcome and so far, the only proven means to stop a large, armored force is by employing tanks of your own. APFSDS rounds have proven themselves as the most formidable tank-killing asset, as they pack the largest blow at the longest distance. Consequently, Russia's efforts to out-gun their NATO counterparts have been aimed at developing more lethal APFSDS ammunition.

An analysis of their terminal ballistics shows that the basic principles of any KE projectile are to have the highest possible impact velocity, to be long and thin. Generally, a penetrator is incapable of penetrating deeper than its own length, as the sheer stress of impact and perforation ablates it. Also, while current guns and propellants are at their design limit for muzzle velocities, recent development has focused on creating "long-rod" penetrators, which have increased penetrating power due to their length and mass. The Svinets 1 (3BM59) and 2 (3BM60) and the Vacuum 1 (3BM69) and 2 (3BM70) projectiles are the latest in this line of development.

Based on currently available data for NATO armor and Russian contemporary ammunition penetration capacity, allowed us to conclude that Russian (3BM69) Vacuum 1 and (3BM70) Vacuum 2 APFSDS rounds with their 900 mm long KE penetrator pose a significant threat to most NATO tanks. Since neither of NATO's MBTs will have the same protection on all points of their frontal arcs and some points like the upper front turret or the sides of the hull will be less armored, even the Svinets 1 (3BM-59) and Svinets 2 (3BM-60) rounds have a fighting chance of effectively engaging the representative NATO tanks.

MBTs irrespective of the type and make also have a certain sloping to their armor, especially on the front glacis. A hit on target under a 60-degree angle reduces penetration by 45-50 % which reduces the chances of successfully destroying a target. Moreover, a first-round fatal hit would ultimately rely on the tank's fire control system, the element of surprise, and the opposing tank's active protection and warning measures.

When it comes down to sending any of these projectiles down-range, they are a more than capable and lethal asset which will attain massive damage against any armored target, including NATO's MBTs. Seeing as the data of armor thickness of NATO's MBTs presents the best frontal armor protection estimate (regardless of the MBT model), we could safely say that this gives Russia a tank round that could reliably penetrate all NATO main battle tanks at the medium range of 2000 m.

REFERENCES:

Andrews, W. S. (2003). Depleted Uranium on the Battlefield, Part 1 – Ballistic Considerations. Canadian Military Journal. pp. 41-46

Bateman, R. (2020). No, Drones Haven't Made Tanks Obsolete. Foreign Policy. Available at: https://foreignpolicy.com/2020/10/15/drones-tanks-obsolete-nagorno-karabakh-azerbaijan-armenia/

BTTR (2016). Russia is mass producing the improved Svinets-1 and Svinets-2 ammunition. Bellow the turret ring. Available at: https://below-the-turret-ring.blogspot.com/2016/10/russia-is-mass-producing-improved.html

ESD (2021). Main Battle Tanks (MBTs) in NATO. European Security & Defence. Available at: https://euro-sd.com/2021/09/articles/exclusive/23961/main-battle-tanks-mbts-in-nato/

Ezoteriker (2021). БОПС - Противотанковые снаряды и их разновидности Подкалиберные снаряды типа свинец. Available at: https://ezoteriker.ru/bops-broneboinye-operennye-podkalibernye-snaryady-protivotankovye-snaryady/

GFP (2021). Tank Strength by Country. Global Firepower. Available at: https://www.global-firepower.com/armor-tanks-total.php

Marrone, A. and Sabatino, E. (2020). Main Battle Tanks, Europe and the Implications for Italy. Istituto Affari Internazionali

Panda, S. S., Gite, L. K., Anandaraj, A., Deodhar, R.S., Joshi, D.K., Rajan, K. M. (2017). Dispersion sensitivity analysis & consistency improvement of APFSDS. Defence Technology. 13 (4), pp 316-322

Pawlikowicz, L. and Surowiec, K. (2019). Modernisation of the armoured component of the Russian federation's ground forces in the years 2015-2018. An outline of the subject. Humanities and Social Sciences. XXIV (26, 4/2019). pp. 105-113

Roblin, S. (2019). Russia Has a 'Bullet' That Could Kill America's Best Tank (But There's a Problem). National Interest. https://nationalinterest.org/blog/buzz/russia-has-bullet-could-kill-americas-best-tank-theres-problem-51122

Сергей, Ч. (2020). Как разбить лоб «Абрамсу» Создатели бронебойных снарядов дошли до предела возможностей. ВПК. Available at: https://vpk-news.ru/articles/56212

US Army (2000). Armor Plate, Steel, Wrought, Homogeneous (for Use in Combat-Vehicles and for Ammunition Testing). Army Research Laboratory, Department of the Army

Zahn, B. R. (2000). The Future Combat System: Minimizing Risk While Maximizing Capability. USAWC Strategy Research Project