Scientific Journal of the Military University of Land Forces
ISSN: 2544-7122 (print), 2545-0719 (online)
2020, Volume 52, Number 2(196), Pages 339-351
DOI: 10.5604/01.3001.0014.2537

Original article

Development trends in armored weaponry

Adam Kunz

Institute of Command,
General Tadeusz Kościuszko Military University of Land Forces, Wrocław, Poland,
e-mail: adam.kunz@awl.edu.pl

INFORMATIONS

Article history:
Submited: 08 October 2018
Accepted: 29 October 2019
Published: 15 June 2020

ABSTRACT

The article presents the current state and the directions of development of contemporary tanks. Trends in the development of armored weaponry as a structure were considered in four areas: firepower, mobility, protection and situational awareness of the crew. Examples of combat vehicles used in various armies of the world and their upgrading and planned construction works were described herein. Combat vehicles used in the German, Israeli, Russian and Polish armies were assumed to be the most representative for the purpose of this study. An attempt has also been made to assess the adopted and planned technical solutions.

KEYWORDS

tank, firepower, mobility, security, situational awareness

Introduction

Tanks made their debut on battlefields during World War I in the Battle of the Somme, which was over 100 years ago. Since then, they have changed the image of warfare, taking part in every significant conflict, and their presence on the battlefield has often determined victory.

Despite the passage of time, resulting in the development of new weapons, tactics and changes in the nature of conflicts, tanks have remained an important part of the armaments of the world's major armies.

The aim of these considerations is to evaluate the adopted and to identify conceptual directions of construction and improvement of contemporary tanks. The article is the result of an analysis of documents comprising numerous articles, monographs and observations made by the author during his service in the Armored Brigade. The involvement of a new-generation Polish tank designed under the patronage of the Defence24 portal is also important in this case.

The significant role of tank subdivisions in the current conflicts contributed to the creation of this article. The war in eastern Ukraine serves as a very good example. It is estimated that the armored forces of the so-called "separatists" consisted of 13 battalions in April 2015.

Considering the organization of tank battalions according to the Russian model, the number of tanks on the separatist side in the discussed period was probably 390-510 [1]. For comparison, the number of tanks in linear units of the Polish Army is about 652. During the fights in eastern Ukraine, tanks were entrusted with tasks which determined the victory of either of the sides in a clas. The most famous example of such arrangement is the battle of "Dobalcewo", where victory was decided by duels of subdivisions of tanks [2].

The wars in Ukraine and Syria are an impulse to accelerate the development of armored armies, especially on the European continent. This thesis has been confirmed by the modernization or acquisition of new combat vehicles over the last two years in such countries as Germany, the Netherlands, France [3], Denmark [4], Great Britain, Turkey, Russia [5] and Poland [6]. In the case of the Polish Army, the modernization of subunits equipped with tanks is considered a priority in planning technical modernization and, according to the Undersecretary of State, Tomasz Szatkowski, after Turkey, Poland may be the largest recipient of new-generation tanks in Europe.

The experience of recent conflicts (Ukraine and Syria) shows that the further development of armored weapons proceed in four critical areas: firepower, manoeuvrability, protection [7, p. 23] and situational awareness. The experience of designers and users of tanks shows that improving the parameters in one area often has a negative impact on the other. The role of engineers is to apply such technological solutions which will provide the best results in all areas under consideration when designing new or upgrading existing tanks.

Moreover, the direction of development of the above mentioned areas of armored weapons is conditioned by such factors as the nature of the conflict, the environment and armament of the potential enemy in armored and armor-piercing weapons.

1. Firepower

Considering the development of armored weapons so far, the most important equipment has always been the main weapon – the gun.

So far, the simplest and most effective way to improve the firepower of a tank, as history shows, is to increase the caliber and length of the gun (L). However, this path of development poses some serious limitations. A larger gun requires more space in the turret which results in an increase in its weight and negatively affects the overall mobility of the tank. Currently, NATO tanks are mostly equipped with 120 mm guns, while countries of the former "eastern" block have tanks equipped with 125 mm guns. In terms of firepower, the structures of these vehicles have reached their peak modernization capabilities. This is mainly due to the impossibility of using larger guns, and the increase in firepower was linked to the development of ammunition and fire control systems. This is best exemplified by the modernization path of the Leopard 2 tank, where its individual versions from A4-A7 have the same gun caliber, limited only to increasing its length from L-44(A4,A5) to L-55 (A6,A7). Another example of avoiding interference in the size of the gun is the modernization of the T-72 tank, where the improvement of firepower was sought in the improvement of the quality of ammunition and the fire control system [7, p. 15].

In order to solve the problem of not increasing the size of the gun and yet obtaining greater firepower, research on electro-thermal-chemical (ETC) guns was opened. These guns use electricity and chemical reactions to propel missiles. The first trial of this type of gun was carried out in 1985 by the American company GT Devices. Germany, Great Britain and Israel also took part in the gun's trials. With a 120 mm gun, the initial testing velocity of the missile was 2300 m/s – 2400 m/s, for comparison, in traditional guns of this caliber, ones that are currently in use, this velocity is 1650 m/s (L44) – 1750 m/s (L55). In 2002 the German Rheinmetall company presented the ETC gun, which gave the bullet 30 percent more kinetic energy (around 15 MJ), compared to a traditional gun of this size. Despite the lapse of 15 years since the presentation of the ETC guns, there are no sources implying their application in combat vehicles. According to prof. R. Ogorkiewicz, a lecturer at the British Academy of the Land Forces, the reason for this situation is the positive experience with larger conventional tank guns. It has been proven that a 140 mm cannon gives the missile kinetic energy from 18 MJ to 23 MJ and presents the advantage of being built with the use of proven technologies. Earlier, weaponry companies worked on the electro-magnetic (EM) guns, but due to their complex design and weight of 25 tons at 90 mm caliber, it was found that they were not suitable for tank mounting. The same problem applies to laser guns, a gun offering sufficient power to be mounted on a tank would reach the size of a football stadium [8, p. 304-5].

It is likely that the negative experiences encountered with EM and ETC guns is the use of conventional 120 mm and larger guns in emerging tank modernizations, planned and new tank designs. There are a few examples of this. The "GEPARD" program assumed that the new Direct Support Vehicle for the Polish Army to replace the T-72M1 and PT-91 tanks would be equipped with a 120 mm gun [7, p. 10]. Germany and France have jointly implemented the "Main Ground Combat System" programme (MGCS), which will develop a design which will replace the Leopard 2 and Leclerc tanks. As part of the MGCS program, Rheinmetall demonstrated the 130 mm gun at Eurosatory 2016 as a weapon for a new generation of tanks [9, p. 10] (Fig. 1). The new Russian T-14 tank which was presented for the first time in 2015 is equipped with a 125 mm gun, and can be easily adapted to the conventional 152 mm gun [5]. According to a report prepared by Defence24 on the new-generation tank program for the Polish Army, there are recommendations for equipping the new platform with a 120 mm gun or larger, or for designing a vehicle to give it a structural reserve for the use of such a large gun in the future, which will allow to effectively combat any new weaponry used by a potential opponent. Furthermore, the gun must be complemented by the latest armor-piercing and programmable ammunition, capable of combating various targets, including unmanned aerial vehicles and helicopters.

According to the author, increasing the caliber of conventional guns in emerging structures is a temporary solution due to the increase in size and weight of the tank, which negatively affects its mobility and protection. Articles devoted to the future of armoured weapons describe the use of the ETC high-energy guns as a secondary solution. However, nowadays, ETC guns appear to be the only path of revolutionary change in the area of firepower.

2. Security

In order to effectively oppose any anti-tank weapons, tanks were equipped with increasingly strong armors and other types of protection were developed. Over the years, the technology and materials used in its construction have changed. Despite the use of more advanced materials, increasing the cut-through strength of the armor resulted in an increase in its weight

Fig. 1. The 130 mm tank gun demonstrator, developed for the tank of the new generation, is often referred to as "Leopard 3"
Source: [10].

and volume. This has negative impact on the mobility of the tank and reduces the space available for other equipment.

Current design works aiming to develop improved tank security are carried out in two main areas, as exemplified by past modernizations and concepts for new vehicles [7, p. 18-9].

The first area called "passive" protection applies to the tank armor. Modern tanks are equipped with multilayer armor. This armour consists of steel plates interlayered with rubber, aluminium, ceramics, glass or depleted uranium. This composition increases its resistance to high-explosive anti-tank warheads and armor-piercing missiles twice, even when the armor is equally thick and is made of steel only. The solution thus decreases the overall weight of the armor. Despite this, due to their armor, modern tanks reach an average weight of 60 tons, which negatively affects their operating costs and mobility on bridges and viaducts. Researchers from such countries as the United States and the United Kingdom were looking for alternatives to steel in the form of plastics. The "S-2" glass fiber used in the production of spacecrafts presented a new opportunity. It was believed that the mass of a composite vehicle would decrease by 33 percent. Unfortunately, the research works were narrowed only the hull, which constitutes 1/3 of the weight of the whole vehicle, which in fact reduced its weight by only 10 percent. Furthermore, the process of manufacturing composite armor itself creates problems and is much more expensive, compared to multilayer armor, so these designs have not been developed. Probably the failure of the research on composite armor stimulated the development of the Explosive Reactive Armor (ERA) which, by means of a system of additional plates filled with explosives, mounted above the proper armor, compensates for the action of explosive anti-tank warheads and, to a lesser extent, armor-piercing missiles [8, p. 306-14]. This solution significantly increases the security the tank without the need to interfere with the proper armor. ERA solutions are frequently applied in the modernization of T-64, T-72, T-80, T-90 tank structures. According to reports of Ukrainian armored troops fighting in the Donbas region, the reactive “NÓŻ” armor used in T-64 BM Bułat effectively protects the turrets during clashes with T-72 tanks [2]. An innovative approach to passive protection, as shown by the example of the Russian T-14 tank, is to make structural changes by using an unmanned turret [5]. This solution allows to reduce losses among crew members, since they are in the hull, which is less vulnerable to impacts than the turret, which is the highest point of the tank and, at the same time, they are isolated from the ammunition compartment. One of the more realistic scenarios for the foreseeable is that army vehicle protection will be increased by using intelligent masking systems, which adjust the masking color to the terrain background. It is to be expected that current tank upgrades and new designs will continue to be equipped with armor as a basis for protecting crew against missiles, and that its weight and dimensions will be similar to those currently in use.

Another form of tank protection is Active Vehicle Protection System (ASOP). Such systems are used for protection, mainly against explosive anti-tank warheads. There are two types of Active Vehicle Protection Systems – “soft kill” and “hard kill”.

Soft kill is based on disturbing the anti-tank missile guidance and observation systems. Detectors detect incoming missiles and trigger the infrared interference devices (German MUSS) or, additionally, produce a smoke screen (Russian SZTORA). According to a report written by Dr. Phillip A. Karber from the Potomak Foundation titled “Lessons Learned from the Russo-Ukrainian War”, quoted on the “DEFENCE24” website, “soft kill” type systems mounted on T-90 tanks provide them with effective protection against PPK KONKURS used by the Ukrainian side [5]. “Soft kill” systems are effective in protecting against some anti-tank guided missiles, but they are ineffective against unguided RPG’s, as shown by the war in Chechnya in 1995 and in Iraq in 2003. As a result of these experiments, tanks were equipped with “hard kill” Active Vehicle Protection Systems, capable of fighting various threats. This shield works by automatically firing a series of anti-missiles targeting an incoming enemy missile in order to neutralize it before it reaches the vehicle’s armor. The Israeli army boasts the greatest achievements in this area. In 2007, 100 systems comprising the “hard kill” active shield TROPHY were mounted on MERAKVA MARK 4 (Fig. 2). In 2011, TROPHY destroyed an anti-tank missile fired in the direction of the tank by a Palestinian fighter [8, p. 316]. It also proved its worth in 2014 in the Gaza Strip, during Operation Protective Edge, where it effectively fought KORNET-type missiles. The U.S. army became interested in the system, as it is to send an armored brigade equipped with M1A2 Abrams SEPV2 tanks with the Israeli TROPHY system to Europe by 2020 [12]. Also noteworthy is the German AMAP – ADS system which, in addition to being able to combat high-explosive anti-tank warheads, has the ability to combat fast-moving armor-piercing missiles. In the report written by the Defence24 portal concerning a new-generation tank for the Polish Army, opinions have emerged that it is desirable to use layered solutions where passive armor, especially in sensitive areas, will be complemented by active protection. The report also points out that the new tank, due to its saturation with digital systems, should be protected against cyber attacks [7, p. 40]. The multi-layer protection solution was applied in the Russian tank T-14 [5].

Fig. 2. MERKAVA IV tank with its multilayer protection, illustrated
Source: [11].

In the future, the main task of protecting the vehicle and its crew will be performed by Active Vehicle Protection Systems, while the importance of armor will decrease. Its task will be to neutralize missiles in the event of Active Vehicle Protection System failure. It is therefore expected that systems protecting the vehicle's electronics and cyber space will be created. In their first phase, today's "hybrid" conflicts rely on cyber-attacks and electronic warfare. As a result of installing these combat measures in the vehicle, the electronics controlling the fire control system, the drive unit, radio stations and systems supporting the situational awareness of the crews may be destroyed. Subdivisions of tanks can be paralysed before the fight, if they enter areas of permanent dislocation or any centralization areas.

3. Mobility

The mobility of a tank is its third important advantage. It is considered in the strategic and operational aspects.

Strategic mobility means the ability to travel long distances by sea, air and land. To protect crews, tanks must still have thick armor, and their weight and dimensions are considerable. Therefore, in order to move the subdivision of tanks over long distances, a large amount of heavy transport equipment is required, which involves significant costs. A good example is the transfer of Canadian and Danish Leopards 2 to Afghanistan, which were individually transferred in 2009 by Russian Antonov An-124 transporter aircrafts [8, p. 320]. What is noteworthy is the aforementioned Polish "GEPARD" program. Its basic assumption was to create a modular caterpillar platform, which could be transferred over long distances. However, this concept was rejected on the grounds that this design could not provide an effective passive shield comparable to modern tanks weighing 50-60 tons [7, p. 10]. It should be therefore assumed that the strategic tank mobility indicator will not improve in the near future due to the armor factor.

Operational mobility refers to the engine power in relation to the tank weight. The higher the engine power and the lower the weight, the more manoeuvrable the vehicle is and the faster it is capable of moving It should be remembered, however, that armor allows the crew to ignore the dangers from small firearms, which affects the tactical mobility of the vehicle, giving it freedom of manoeuvers. In order to maintain adequate protection and mobility, more and more powerful engines are being developed. Modern tanks are powered by diesel engines and 1000-1500 hp gas turbines. The MB 873 and MT 883 is a very popular diesel engine manufactured by the German MTU. These engines are mounted in Leopards 2 and in the export versions of French Leclerc, American M1, British Challenger, Merkava 4, South Korean K-2 and Turkish Altaya. It is surprising that the MT 883 engine was developed in 1979 and a completely new design is not to be expected in the near future. However, considering the objective of the MB 873 engine and its development, it can be concluded that future diesel engines installed in tanks in the coming years will be increasingly smaller, lighter, easily replaceable on the battlefield (Fig. 3), more fuel-efficient, while maintaining their current power. We may also hardly expect any revolutionary solutions in this type of engines in the East, where, starting with the T-34 tank and ending with T-90, the developmental structures of the W-2 engine (created in the 30s) are used, consisting mainly in increasing its power from 600 hp (T-34) to 1200 hp (W-99 in T-90s). It is worth noting that such a standardized approach to diesel engines and their simple construction allowed Russia to make significant savings, especially in times of economic crises.

The second engine type are gas turbines, which were used in the M1, T-80 and Swedish Stridsvagn 103 tanks. Compared to diesel engines, gas turbines are characterized by smaller dimensions, weight, fast start-up at very low temperatures, significant amounts of heat produced and, above all, huge fuel consumption. Such beneficial features as reduced weight (it is 1.5t between a diesel engine and a gas turbine of the same class) and sizes in terms of

Fig. 3. The crew of a Leopard 2A4 and Bergerpanzer tank with 10BKPanc during the replacement of a MB 873 engine in training ground conditions. The power pack replacement time is 30 min
Source: [13].

mobility are offset by the amount of fuel and spare parts needed to take up. The experience of the 1991 and 2003 Persian Gulf conflicts showed that American M1 tanks equipped with AGT-1500 gas turbines burned twice as much fuel as diesel engines. The same problem was reported for the turbines of the Russian T-80U tank and, therefore, some of these tanks received 6TD diesel engines and were given the T-80UD designation. A similar procedure of replacing turbines with diesel engines was applied in the export versions of M1 tank [8, p. 322]. The trouble-free start-up of the structure at extremely low temperatures is undeniably its greatest opportunity for survival. In 2015, the Russian Armed Forces decided to equip their units ordered to operate in extremely low temperatures (–50°C) with T-80BWM tanks (219RWM Unit) with upgraded GTD-1250TF engines. According to available sources, no breakthrough developmental research on gas turbines to the tank is currently being conducted, and probably due to the poor parameters of these engines, it should be taken into account that developmental versions of the current diesel engines will be installed in the new or modernized structures.

This does not change the fact that fuel consumption is still enormous, in Leopard 2, the aforementioned MB 873 engine burns approximately 550 liters of diesel oil per 100 km in combat conditions [14, p. 3].

Hybrid engines give hope for improvement. In 2013, BEA Systems announced that it has the capability to equip CV90 Swedish combat infantry vehicles with hybrid engines. This type of engine combines combustion and electric propulsion. According to the company's representatives, the hybrid drive is characterized by a 10-30 percent lower fuel consumption. Its main task will be to provide additional power at critical moments and to power additional systems during less dynamic driving or parking. The Swedish army estimates the cost of supplying 1 liter of fuel to CV90s used in Afghanistan at $107, and the US army is paying even more [15].

Thus, the fuel consumption criterion may turn out to be the most important parameter in assessing the choice of drive unit for new or modernized structures, which will accelerate the research on hybrids. This work is necessary since the road to the widespread use of a serial hybrid engine with similar performance to that of a diesel engine in a tank is still long, because, on average, its weight is three times greater than that of an infantry combat vehicle (20t), and additional on-board systems, such as fire control systems, are very energy-consuming. In the aforementioned DEFENCE24 report, the choice of power supply for the new tank for the Polish Army is an open question between a modern power pack and a hybrid power supply.

The author envisages the withdrawal of gas turbines. Diesel engines will be used for a long time as the basic drive unit of a tank, even in a hybrid system, e.g. with electric motors.

4. Situational awareness

Situational awareness, which means "See first, Aim first, Hit first" is the fourth area which is often not taken into account in tank design. To a large extent, the survival of a tank on a modern, very chaotic battlefield will depend on the right decision made by the commander. In order to develop an appropriate solution and control the course of the fight, the commander needs up-to-date, reliable and precise information about the combat environment, the enemy and their own troops. Tanks are equipped with different sensors and communication systems to ensure data flow to and from individual crew members in order to maximize situational awareness. Improving crew awareness is achieved by improving their observation capabilities (especially in conditions of reduced visibility) and communication, and by implementing battlefield management systems. A clear though distant example of the importance of this factor is Operation "Barbarossa", where German tanks (PzKpfw II-IV), less armed and armored than Russian tanks (T-34, KW-1), won, among other things, because they had a radio station and better observation devices [16, p.94]. Presently, every developmental version of tanks in use or their new models puts emphasis on the improvement of situational awareness. Again, we can use the example of Leopard 2, the most exported third-generation tank in the world. Each subsequent version of the tank, from 2A4 to 2A7, received expanded equipment in the discussed area. The added items included an independent thermal vision observation devices of the commander, a new GPS navigation system, a camera observing the rear hemisphere, third-generation thermal vision observation instruments and a battlefield management system (BMS) [17]. The Israeli army has recently revealed a new variant of the Merkava IV tank named the "Barak" (Polish: Błyskawica). The development of this version of the tank was influenced by the experience of asymmetrical conflicts, in which Israel was involved. The main goal of this modernization was to increase the situational awareness of the crew. It was the first machine in the world to receive AI-based software in a fire control system. Its activity is based on advisory/supporting functions, and in case of life-threatening situations, the system is capable of making decisions, to a limited extent. The crew received Iron View helmets from Elbit Systems, with the function of virtual and augmented reality to provide See Through Armor vision, i.e. a 360° view around the machine, in all conditions. Special sensors transmit the image of the surroundings to the viewfinders placed on the crew's helmets without limitations, which give classical solutions attributed to optical instruments [18]. A similar system called "BattleView 360" is offered by BAE system. The idea behind this system is to integrate all information into one source. "BattleView 360" collects and identifies data around the vehicle and simultaneously overlays tactical information (position of enemy and own troops) received from the BMS presenting a complete and up-to-date picture of the situation (Fig. 4). A clear picture simplifies the decision-making process for the crew, and serves as a tool for the vehicle commander to control the situation during the task. Furthermore, this system uses the digital 3D map technology, has the ability to obtain information from an unmanned BSP aircraft and cooperate with the Active Vehicle Protection System [20]. Looking at the majority of Russian tanks and comparing them with their Western counterparts, the situation awareness of the crews was lower. However, available information on the T-14 and the modernization of the T-72 vehicle family indicates that the aim is to gain an advantage in this area. T-14 received integrated systems comprising combat management, fire control, diagnostics and communication, as well as means of circular observation [5]. In case of the T-14 tank, it is worth noting that the above mentioned design solution (unmanned turret), which is to protect the crew, requires the use of electronic observation systems, which are currently not able to fully replace the direct optical path (German experience with the PUMA IFV project). When undertaking the modernization of T-72B tanks to the T72B3 version, the primary attention was on the ability to operate at night and in difficult weather conditions. The issue of situational awareness was also widely discussed in the recommendations concerning the new generation tank for the Polish Army. The suggested solutions were similar to the "BattleView 360" system presented by BAE system. It was additionally pointed out that the system should cooperate with other systems, both in the national- and alliance-level.

Situational awareness is the most dynamically developing area of armored weaponry systems. This is probably due to the fact that proven digital technologies are used here and the

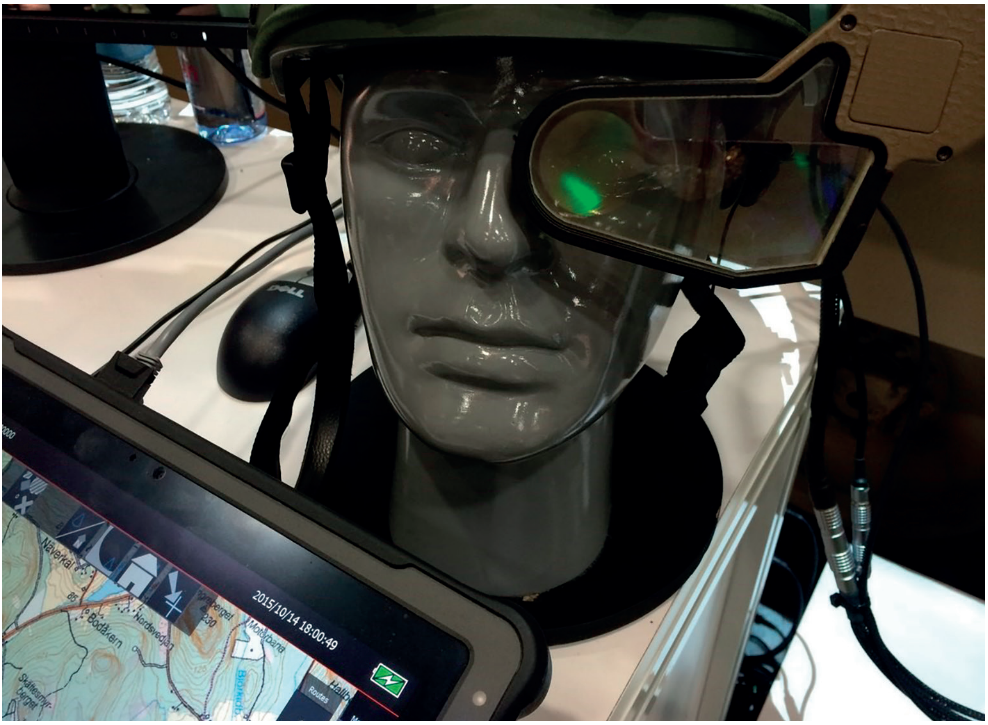

Fig. 4. Monocle and Battleview 360 touch screen
Source: [19].

increase in the combat potential of the equipment takes place without interference in the structures. Another factor stimulating the development of this area is the increasingly chaotic character of the battlefield (asymmetric and hybrid conflicts), which require the use of systems supporting the decision-making process and the performance of tasks by the crews.

Conclusions

After 1989, the main focus was on the thorough modernization of the existing structures. The result of this trend is the lack of further possibilities of modernization of used tanks and breakthrough solutions in terms of firepower, armor or mobility. The ongoing conflict in Ukraine and Syria, which aroused the threat of confrontation with Russia in the Western armies and apparently influenced the increase of interest in having a deterrent armored potential, will probably result in the emergence of breakthrough solutions in this type of army, but time is needed.

The time from the development of a concept for a new tank to reaching its operational readiness can be estimated over a period of two decades (based on the experience of implementing the South Korean K2, which does not feature a revolutionary design). Nowadays, in order to fill this period, armies are modernizing tanks to meet the requirements of the modern battlefield. Therefore, future designs to replace the currently used vehicles will have to adopt solutions which are as revolutionary as possible in the development areas discussed in the article, while maintaining the required modernization capabilities. The author believes that the tanks of the new, 4th generation, which will replace the tanks of the 3rd generation, which have been serving for 40 years, will have the following solutions:

- High-energy guns will be used to improve the firepower. A new type of ammunition will be developed for these guns, whose action will consist in incapacitating the electronics of combat vehicles without piercing the armor and unmanned aerial vehicles.
- The Active Vehicle Protection System, i.e. the “dome” protecting the vehicle against missile strikes, cyber attacks and electronic warfare weapons, will be primarily responsible for the protection of the combat vehicle. As the importance of armor decreases, lighter armor made of composite materials will be used.
- When it comes to mobility, hybrid drive units and quickly replaceable power packs will be deployed to reduce the enormous operating costs. They will be a combination of diesel and electric engines. Moreover, the modernization capability of the vehicle will be maintained, which will enable the electric motor to take over the main role of the driving unit. Due to the use of lighter armor, the strategic mobility parameter of the vehicle will be improved.
- Tanks will receive a series of systems supporting the situational awareness of the crew, integrating all received information into one source, presenting the location of their own troops, the opponent, the received tasks with the simultaneous possibility of unlimited “iron view” circular observation. The display also shows information about the condition of individual vehicle components, consumables and ammunition.

Acknowledgement

No acknowledgement and potential founding was reported by the author.

Conflict of interests

The author declared no conflict of interests.

Author contributions

The author contributed to the interpretation of results and writing of the paper. The author read and approved the final manuscript.

Ethical statement

The research complies with all national and international ethical requirements.

ORCID

Adam Kunz https://orcid.org/0000-0002-9456-5058

References

1. Gawęda M. *Pancerna pięść „separatystów” w Donbasie [ANALIZA]*, [online]. Post.: 21 August 2017. Available at: https://www.defence24.pl/pancerna-piesc-separatystow-w-donbasie-analiza [Accessed: 3 October 2018].
2. Gawęda M. *Pancerna Ukraina. Pojedynki czołgów w Donbasie*, [online]. Post.: 13 March 2016. Available at: https://www.defence24.pl/pancerna-ukraina-pojedynki-czolgow-w-donbasie [Accessed: 10 December 2017].

3. Malicki PK. *Francja: modernizacja Leclerców. Opóźni projekt nowego czołgu?*, [online]. Post.: 18 January 2018. Available at: https://www.defence24.pl/francja-modernizacja-leclercow-opozni-projekt-nowego-czolgu-komentarz [Accessed: 3 October 2018].
4. Malicki PK. *Duńczycy testują Leoparda 2A7*, [online]. Post.: 29 December 2017. Available at: https://www.defence24.pl/dunczycy-testuja-leoparda-2a7 [Accessed: 3 October 2018].
5. Pawłowski J. *Brytyjski wywiad: „Rewolucyjny" czołg T-14 Armata*, [online]. Post.: 08 November 2016. Available at: https://www.defence24.pl/brytyjski-wywiad-rewolucyjny-czolg-t-14-armata [Accessed: 12 September 2018].
6. Palowski J. *Więcej Leopardów do modernizacji. Podpisano aneks [News Defence24.pl]*, [online]. Post.: 13 July 2018. Available at: https://www.defence24.pl/wiecej-leopardow-do-modernizacji--podpisano-aneks-news-defence24pl [Accessed: 3 October 2018].
7. *Raport – Program czołgu nowej generacji Wojska Polskiego*, Warszawa: Defence 24; 2017.
8. Ogorkiewicz R. *Czołgi. 100 lat historii*. Warszawa: RM; 2015.
9. Foss CF. *Design concepts emerge for possible new French-German Main Ground Combat System*, [online]. Post.: 29 May 2018. Available at: https://www.janes.com/article/80463/design-concepts-emerge-for-possible-new-french-german-main-ground-combat-system [Accessed: 1 October 2018].
10. *Eurosatory 2016: Nowa armata dla Leopardów*, [online]. Post.: 14 June 2016. Available at: https://www.defence24.pl/eurosatory-2016-nowa-armata-dla-leopardow [Accessed: 1 October 2018].
11. *Czołg Merkava 4 zaatakował izraelski BWP*, [online]. Post.: 14 October 2013. Available at: https://www.defence24.pl/czolg-merkava-4-zaatakowal-izraelski-bwp [Accessed: 1 October 2018].
12. Pawłowski A. *Niezniszczalny pancerz*. Polska Zbrojna. 2018;7:78-9.
13. Politowski B. *Załoga Bergepanzera w akcji,* [online]. Post.: 20 June 2018. Available at: http://www.polska-zbrojna.pl/home/articleshow/25607?t=Zaloga-Bergepanzera-w-akcji [Accessed: 4 October 2018].
14. Rawicki N. *TDv 2350/033-10, Część 1 Opis, Czołg bojowy Leopard 2*. Dowództwo Wojsk Lądowych; 2006.
15. *CV90 z napędem hybrydowym?*, [online]. Post.: 8 September 2013. Available at: https://www.defence24.pl/cv90-z-napedem-hybrydowym [Accessed: 3 October 2018].
16. Guderian H. *Wspomnienia żołnierza*. Warszawa: Bellona; 2006.
17. Palowski J. *Bitwa pancerna – jak mogłaby wyglądać dzisiaj?*, [online]. Post.: 10 May 2014. Available at: https://www.defence24.pl/bitwa-pancerna-jak-moglaby-wygladac-dzisiaj [Accessed: 3 October 2018].
18. Dąbrowski M. *Izraelski czołg ze sztuczną inteligencją*, [online]. Post.: 26 August 2018. Available at: https://www.defence24.pl/izraelski-czolg-ze-sztuczna-inteligencja [Accessed: 3 October 2018].
19. Judson J. *BAE Debuts 'See Through' Armored Vehicle System in US*, [online]. Post.: 14 October 2015. Available at: https://www.defensenews.com/digital-show-dailies/ausa/2015/10/14/bae-debuts-see-through-armored-vehicle-system-in-us/ [Accessed: 4 October 2018].
20. Dąbrowski M. *System BattleView 360 – zwiększona świadomość sytuacyjna dla załóg wozów bojowych*, [online]. Post.: 27 January 2018. Available at: https://www.defence24.pl/system-battleview-360--zwiekszona-swiadomosc-sytuacyjna-dla-zalog-wozow-bojowych [Accessed: 3 October 2018].

Biographical note

Adam Kunz – a graduate of the General Tadeusz Kościuszko Military Academy of Land Forces in Wrocław, currently an assistant at the General Tadeusz Kosciuszko Military University of Land Forces in Wroclaw.

Tendencje rozwojowe broni pancernej

STRESZCZENIE W artykule zaprezentowano stan obecny i kierunki rozwoju współczesnych czołgów. Tendencje rozwoju broni pancernej jako konstrukcji rozważono w czterech obszarach: siły ognia, mobilności, ochrony i świadomości sytuacyjnej załogi. Opisano przykłady wozów bojowych wykorzystywanych w różnych armiach świata i podejmowanych wobec nich prac modernizacyjnych oraz konstrukcji planowanych. Za najbardziej reprezentatywne uznano wozy bojowe w armiach Niemiec, Izraela, Rosji i Polski. Podjęto również próbę oceny przyjętych i planowanych rozwiązań technicznych.

SŁOWA KLUCZOWE czołg, siła ognia, mobilność, ochrona, świadomość sytuacyjna

How to cite this paper

Kunz A. *Development trends in armored weaponry*. Scientific Journal of the Military University of Land Forces. 2020;52;2(196):339-51.

DOI: http://dx.doi.org/10.5604/01.3001.0014.2537