Analysis on the Development of Active Protection System for Tanks and Armored Vehicles

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Abstract. Tanks and armored vehicles are facing increasingly diverse threats on the battlefield. Active Protection System (APS) can apparently enhance the protection capability of tanks without reducing mobility. The principle of active protection technology is introduced, and particularly the performance of radar detection subsystem and intercepting ammunition subsystem are analyzed. Moreover, the application status of APS is elaborated and the current level and main deficiency are dissected. Furthermore, the probable development trends of APS are listed.

1. Introduction
As the army's leading weapon, the tank and armored vehicle have played a prominent part in warfare since its inception. In recent years, with the increasing sprawl of intelligent anti-armor weapons, tanks and armored vehicles have been under all-round and three-dimensional threats both on the ground and in the air, and the survivability of the crew has been tested as never before. In the face of this situation, many countries have developed tanks and armored vehicles with protection as the most important performance. However, to effectively improve the protection of tanks and armored vehicles, it is futile to simply thicken conventional armors or enhance sandwich-type reactive armors [1], which will be at the cost of decreasing in mobility due to increased weight and affecting their strategic airlift capacity. In this context, the active protection technology emerges next as a hot spot of current studies in the field of tank protection.

2. Principle of Active Protection Technology
The active protection system, as a new type of protection devices for tanks and armored vehicles, is designed to discover incoming hostile targets in advance and confuse, intercept or destroy them to avoid being hit by them [2]. With limited weight gain, the active protection technology enables to not only increase the depth of protection but also expand the protection space by integrating multiple other
protection technologies. Originated in the late 1970s and early 1980s [3], the study of active protection technologies has started to unfold in the world's major military countries in recent years, which helps their technology continuously develop and improve.

According to different protection mechanisms, APS is divided into aggressive type (i.e., the soft-kill system), active type (i.e., the hard-kill system), and a combination of the two [4]. The soft-kill APS uses “interference” and "camouflage" as the main tactical means, including detection alert and decoy jamming, to achieve its own protection. The detection alert mainly detects the threat to the vehicle and issues an alarm signal using laser, infrared or radar detection systems. After receiving the signal, the crew releases plumes of smoke and other means to interfere the incoming target, so as to achieve their own protection. A typical soft-kill system using detection alerts is the Russian "Curtain-I" optoelectronic interference system, which provides protection against semi-active laser-guided missiles and crosshair semi-auto guided missiles by forming an aerosol smoke screen. The decoy jamming system uses infrared decoy and laser decoy to interfere with the guiding system of anti-tank missiles in an attempt to make them deviate from their intended flight trajectory, thereby achieving their own protection.

This paper focuses on the analysis of hard-kill APS. The hard-kill APS detects the incoming target in an active manner and builds a counterattack defense system at medium and close ranges, i.e. an active fire circle is formed around the vehicle to intercept and destroy the incoming target before it hits the vehicle. The hard-kill APS consists primarily of one or more sensors which can detect the threat, one computing and data processing device which enables identification of the threat and initiates countermeasures, and one countermeasure device which can destroy or otherwise disable the threat [5]. Its working process is shown in Fig. 1.

If the detector identifies a munition attacking the vehicle, it tracks the incoming munition and identifies its attack direction and speed and other information which is then sent to the control center. The control center decodes the available information and sends a signal to the transmitter to put it into a ready state. If the incoming target is within the interception range, the control center calculates the appropriate launching moment and sends it to the launch system which will then launch the counter ammunition. If the counter ammunition engages with the incoming target, the counter ammunition explodes and generates the large plume of high-speed fragments to destroy the incoming target. According to the different interception distances, the hard kill system can be divided into close range, medium range and long-range subsystems.
Figure 1. "Hard kill" APS working process.

Based on the features of tanks and armored vehicles and the battlefield environment characteristics, the hard-kill APS shall have the following basic capabilities:

- On the battlefield, the tank and armored vehicle is in dynamic motion, so that the APS shall have the capability of operation on stationary and moving platform.
- The APS shall have the capabilities of all-weather and all-day working, such as in wind, rain, smoke, fog days.
- The protection range of the APS shall be as broad as possible.
- The interception probability of the APS shall be as high as possible.
- The after-effects residue after interception shall be as low as possible.
- The APS shall be highly cost-effective.

3. Status quo of Active Protection System

The technical core of the APS lies in the detector’s capability of accurately detecting incoming munitions, the control system's precise dynamical solving and computing capacity, as well as the counter ammunition’s efficient destruction capability to munitions. At present, more than 20 types of APSs developed for tanks and armored vehicles in the world are available, e.g. Israel's "Trophy" and "Iron Fist", Russia's "Arena" and "Afghanite", the United States "Quick kill" and "Iron Curtain", Germany's "Awiss" and AMAP-ADS, Ukraine's "Zaslon", South Africa's LEDS, etc., which have been applied at different levels or subject to a large number of tests. Several typical APSs are available, as shown in Fig. 2, for their main components and performance comparisons, see Table 1 [2][5][6][7].
(a) "Trophy" APS  
(b) "Afghanite" APS  
(c) "Awiss" APS  
(d) “Zaslon” APS  

Figure 2. Several typical APS.

Table 1. Comparison analysis of foreign typical "hard kill" APS.

| Name of APS | Trophy | Afganite | Quick Kill | Awiss | LEDs |
|-------------|--------|----------|------------|-------|------|
| Development countries | Israel | Russia | United States | Germany | South Africa/Sweden |
| Detection method | Phased radar | Phased array radar + UV detector | Phased array radar + Ka-band radar |          | Millimeter wave radar |
| Detection distance | 50 m | - | 150 m | 75 m | > 200 m |
| Counter form | MEF | High Explosive Squash Head | Vertical launching guided missiles | Grenade | High-explosive bombs |
| Interception distance | 10~30 m | 15~20 m | 10~30 m | 10~30 m | 5~25 m |
| Reaction time | 0.3~0.35 s | - | 0.35~0.4 s | 0.355 s | 0.2 s |
| Horizontal area | 360° | 360° | 360° | 360° | 360° |
| Pitch field | <60° | <50° | <60° | 50° | -15°~45° |
As can be seen from Table 1, the current hard-kill APS mainly uses radars to detect incoming targets, some are the radars and optical composite detectors, a variety of photoelectric, acoustic sensors and other detection means are used, and the range is extended from tens of meters to a few hundred meters. In addition, with the simultaneous action of multiple radars, it can achieve dead-zone free detection at azimuthal 360°, pitch detection in the range of more than 50°. The counterattack interception technology used roughly includes three types: fragmentation/projectile type, explosive type and guided type, of which, fragmentation/projectile type mainly uses sub-caliber counterattack missiles that can explode in mid-air or forms a fragmentation interception wall by direct firing; the explosive type is attributable to the explosion effect; the guided type can refer to the "Quick kill" APS used in the U.S., which enables a non-direct fire guidance for intercepting munitions with interceptor. The latency time of system response is mostly in the millisecond level, and interception distance exceeds over 10 meters.

4. Analysis of Main Technology of APS

4.1. Threats Analysis of APS to Counter
Along with the conflict happened in Nagorno-Karabakh region, the threats faced by tanks and armored vehicles on the battlefield have once again refreshed the perception of scientists. In general, the tanks and armored vehicles on the modern battlefield are facing multi-dimensional threats, as shown in Fig. 3. In terms of spatial dimensions, there are air, ground and underground dimensions, and it is likely that all parts of the tank suffer from assault. In terms of threat types, there are anti-tank barrel weapons, the kinetic energy and shaped charge fired by tank guns, air-to-ground and cruise missiles fired by UAV or armed helicopter, dexterity munitions like terminal sensitive ammunitions, high-powered bombs such as mines and IEDs and other large-caliber guided or unguided artilleries [8], among which anti-tank barrel weapons include anti-tank guided missile (ATGM) and rocket propelled grenade (RPG).

![Figure 3. Threats faced by tanks.](image-url)
No single system can effectively defend against the above threats, and any protection strategy is targeted, including the hard-kill APS. Based on the working principle of hard-kill APS, and by analyzing the frequency of anti-tank weapons employed in local wars in recent years, as Fig. 4, the author believes that the threats that APS needs to respond to are mainly in the ground and semi-air domains, involving several main types, i.e. anti-tank guided missile (ATGM), rocket propelled grenade (RPG), ammunitions fired by tank guns and air-to-ground missiles with certain attack angle, etc. For other threats, however, the effect played by APS is limited.

![Figure 4. Frequency of anti-tank weapons used in war.](image)

4.2. Analysis of Detection Capability Requirements of APS

As the "eye" of the APS, the detection subsystem not only undertakes the detection and perception of incoming targets, but also tracks the targets in real time and provides parameters for the solution and decision of the control system. In actual combat, fighting vehicles with APSs lies in a complex battlefield environment where there are various weather types and changing weather conditions, the enemies who may assault in any direction and at any distance, and many other factors that should be effectively addressed by the detection and perception system.

At present, the most commonly used detection method for APS is radar. However, because the targets radars that can detect are mainly near-ground ones, and its process is very vulnerable to ground clutter interference signals and enemy active interference. In this regard, the further the detection distance, the worse its detection effect, and the system may not be able to react in time since radars have a limited capability to detect kinetic energy and other high-speed targets.

4.3. Analysis of Counterattack Capability Requirements of APS

The counterattack subsystem serves as the "fist" of the APS. With relatively single function, it mainly undertakes the task of destroying incoming targets. However, among the threats that the APS can counter, there is the fact that their shell thickness and mechanism of action vary from each other. For example, the wall thickness of anti-tank guided missile (ATGM) and rocket propelled grenade (RPG) are in the order of 5 mm or 10 mm, and the wall thickness of kinetic energy and shaped charge is even thicker, the counter ammunitions shall have the capabilities to effectively destroy all kinds of threat
targets and control the residual fire stream at the same low level. On the battlefield, no tanks and armored vehicles will be operating independently, either in clusters or in cooperation with other weaponry and is often accompanied by infantry. Therefore, APS shall not damage the equipment or kill infantry outside the mounting platform while intercepting the threat target.

As mentioned earlier, the counter ammunition of hard-kill APSs mainly uses HESH/projectile, explosive, and guided types, combining the effectiveness and cost efficiency of destruction, the author believes that the combined effect of HESH/projectile type is optimal. In recent years, the widely developed multi-explosive formed projectile (MEFP) is widely used in the field of active protection thanks to its strong destructive capability.

5. Development Trends of APS

The Active Protection System has effectively responded to many threats faced by tanks and armored vehicles with its unique protection strategies, expanded the defense space of vehicles and enhanced the defense level. However, in recent years, anti-tank weapon technology and protection technology of tank and armored vehicle have been developing in a catch-up manner. If the APS is to play a more effective effect in the future, the author believes that it will be developed possibly in the following trends:

- Any single APS cannot play an all-around defense effect, active protection shall be evolving toward an integration of hard and soft kill types, in order to counter different types of weapons and different forms of attack.
- The advantages of APS over ordinary armor protection systems is that the possibility of reducing excessive weight, so that their future development towards an integrated type shall feature with small size, light weight and high integration
- APS shall not be dependent entirely on radar. Instead, it should develop toward composite detection means in order to respond to incoming targets at different speeds.
- While using high destructive counter ammunition against targeted munitions, APS shall load counter ammunition that mainly enable oblique downward destruction to mitigate after-effects and avoid accidental injury
- The application of electric armor technology and high-energy laser weapons, etc. will provide more options for the interception modes of APSs.

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