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Recent Developments in Anti-Tank Ammunition

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Abstract. Every advance in anti-tank ammunition has been matched by advances in armour material or vice-versa. This applies both to kinetic energy and chemical energy type of ammunition. Today the kinetic energy ammunition appears to have an upper hand over armour. In this paper, a brief survey of the modern FSAPDS ammunition, its design aspects and its material technology is made. The capabilities of HEAT type of ammunition are also discussed and the likely trends in ammunition technology are indicated. Some futuristic developments in the field of propulsion are briefly mentioned.

1. Introduction

The battle between armour protection and the anti-tank ammunition is a long standing and continuing one with the advantage resting with one or the other from time to time. During World War II, the appearance of the HEAT (High Explosive Anti-Tank) type ammunition gave even the infantry soldier a capability to take on the main battle tank. The development of HESH (High Explosive Squash Head) and the APDS (Armour Piercing Discarding Sabot) type of ammunition further seemed to have struck the death-knell of the tank. The armour designer trying to reduce the effectiveness of the anti-tank ammunition has come up with a number of developments such as face hardened armour, spaced armour, multi-stack armour, composite armour and introduction of non-metallic materials including ceramics and by suitable configuration of the armour such as grills or by ribbing. The most recent advance in the technique of armour protection is known as re-active armour where explosive metal sandwiches are used to blow the anti-tank ammunition particularly the HEAT ammunition. Such an armour is reported to have been used by the Israelis in Lebanon in 1982 and is being manufactured by Israel under the name of Blazer[1].

The developments in the field of anti-tank ammunition have increased the capability of the ammunition to defeat higher and higher thicknesses of more advanced armour. APDS ammunition of World War II has been transformed into a long rod fin stabilised projectile known as FSAPDS (Fin Stabilised Armour Piercing Discarding Sabot). In the context of this struggle of supremacy between armour and anti-tank ammunition, it is proposed in this paper to review the state of art of the current anti-tank ammunition and comment on the possible lines of developments of the anti-tank ammunition of the future. Since the performance of the anti-tank ammunition is directly related to the launcher, some of the major developments that are likely to take place in the field of propulsion will also be touched upon.

2. Mechanisms in Ammunition Design

Basically two types of mechanisms are used for the defeat of armour viz :

(a) Kinetic energy (KE), and (b) Chemical energy (CE). While the kinetic energy mechanism is embodied in the design of the FSAPDS ammunition, the chemical energy mechanism is embodied in the design of both HESH and HEAT. While the FSAPDS and HESH ammunition are fired from a tank against an enemy tank, the HEAT ammunition has been used in a number of systems such as gun ammunition, rocket warheads, missile warheads and as submunition.

The duel between the tank and anti-tank KE ammunition has been a perennial one. Every advance in KE anti-tank ammunition has been matched by advances in armour material and vice-versa. There have been a number of developments in kinetic energy ammunition over the years such as AP (Armour Piercing), APC (Armour Piercing Cap), APBC (Armour Piercing Ballistic Cap), APCBC (Armour Piercing Cap Ballistic Cap), APDS (Armour Piercing Discarding Sabot) and FSAPDS (Fin Stabilised Armour Piercing Discarding Sabot).

What is required of the anti-tank ammunition today, particularly of the kinetic energy type, is to achieve a very high probability of hit with the very first round fired, an extremely small ballistic dispersion, and the capacity to defeat massive thickness of armour sloped at very large angles to the vertical. Purely in terms of penetration it means achieving higher and higher striking energy per unit area. This is achieved by designing the projectile to have high residual mass with a low diameter and high L/D ratio. The projectile is also fired at a higher muzzle velocity (MV) by using the discarding sabot principle with the penetrator of very high density material. The use of low density sabot fulfills the requirement of achieving very high muzzle velocities at acceptable pressure level.

3. FSAPDS Ammunition Design

The FSAPDS ammunition has, therefore, become the most important anti-tank ammunition today. Advanced design of FSAPDS shots have penetrators of diameter between 25-30 mm, length between 400-450 mm and are fabricated out of tungston alloy with a specific gravity between 17-18 and/or depleted uranium alloy with a specific gravity of around 19 and fired from guns of different calibres from 105/125 mm at velocities between 1600-1800 m/s and are capable of defeating MBTs upto a range of the order of 5000 m. The penetration capability of a long rod penetrator depends on the strength relationship of the target and the penetrator as also the velocity history. During penetration, either the penetrator and the target flow together or depending upon the velocity one of them flows. The calculation of the penetration depth is contingent upon the determination of the different flow regimes. Generally one dimensional code assumes a semi infinite target and normal attack[2]. In two or three dimensional analysis, more sophisticated modern finite elements or finite differences techniques are used for taking account of the finiteness of the target and the obliquity of the attack[3].

Till the evolution of FSAPDS kinetic energy ammunition, KE ammunition was fired from a rifled gun for achieving stability. The requirement of increasing energy per unit area on the target, which led to the design of sub-calibre long thin rod sub-projectile, necessitated the design of a smooth bore gun since it was not practicable to get the degree of spin required to achieve stability for such a large L/D ratio projectile with a rifled gun. However, the extension of the slipping driving band concept used in the design of HEAT ammunition has made it possible to fire FSAPDS from the rifled gun and today fin-stabilised ammunition is fired both from rifled and smooth bore guns.

At this stage, it would be interesting to look at the conditions today's anti-tank ammunition are subjected to when fired from a modern tank gun :

Pressure	500 Mpa (approx)
Force on shot	4 M N
Acceleration	5×10^5 m/s^2
Velocity	1500 m/s at muzzle
Energy	30 MJ in 10 millisec
Horsepower	4×10^4 hp (contrast tank 1500 hp)
Heat Transfer	400 MW/m^2 max (contrast re-entry vehicle 1 MW/m^2)

The very high pressure and very high acceleration in the barrel calls for sufficient strength of the sabot material while, on the other hand, the requirement of achieving high muzzle velocity at acceptable pressures requires a low density material. While magnesium alloy material was found suitable for use as a sabot with the APDS type of ammunition of the 50s, the modern FSAPDS ammunition uses high strength aluminium alloys. Important developments in sabot material are likely to be the use of aluminium lithium alloys, titanium alloys and composite fibre materials and it is expected that the mass of the sabot in proportion to the mass of the penetrator is likely to go down in future design[4].

4. Materials for Ammunition

As regards the material for the penetrators, the steel shots used in the AP designs were replaced by tungsten carbide core in the APDS design. Modern FSAPDS shot penetrators use tungsten alloy material with specific gravity of 17-18 and with sufficient mechanical properties. In the quest for higher and higher density materials, it has been reported that depleted uranium alloy has been used as penetrator material. This has naturally led to intense debate among the armament designers. Depleted uranium has an additional advantage particularly when used against steel armour. The effect of DU penetrators against composite ceramic armour is not widely known and it is sometimes felt that taking into consideration the overall cost of manufacture and the environmental effects, conventional alloy materials may be preferable as penetrators for FSAPDS ammunition for the MBTs[5]. As the quest for higher and higher penetration capabilities continues, there will be a consequent emphasis on higher muzzle velocities which will naturally subject the ammunition to increasingly higher pressures and higher accelerations. Further ammunition fired from the gun is subjected not only to compressive and tensile stresses axially but the unsupported sections of the core may experience bending moments due to slide slap of the projectile during its motion in the barrel. The use of longitudinal reinforcements of a matrix could minimize bending and fracture and also improve target penetration capability. Today, therefore, one is looking at metal matrix composites (MMC) as possible penetrator materials and the future FSAPDS may actually be made out of such MMCs[6].

The development of Chobhum type of composite armour has considerably reduced the effectiveness of gun fired HEAT ammunition. Such ammunition when used in the tank guns will mainly be for secondary roles and as a multipurpose ammunition. The main anti-tank ammunition fired from the tank is likely to be FSAPDS in the near future. However, HEAT as a warhead will continue to be used with anti-tank guided missiles. While the penetration capabilities of World War II ammunition was limited to 3 calibres, modern HEAT ammunition can achieve 6-8 calibre penetration. This has been possible mainly due to a better understanding of the mechanisms of jet formation, improved HE composition and filling techniques, introduction of wave shaping techniques and better manufacturing technologies. Codes also exist for the analysis of the performances of HEAT ammunition. As in rod penetration analysis, one dimensional codes are easier and consume less computer time than 2 or 3 D codes. Generally 1-D code assumes perfect axial propagation of detonation wave and collapse of the liner. These codes are generally calibrated against the experimental data to make the code more useful[7]. Improvements in these areas will continue and the work on tandem HEAT warheads is extremely interesting[8].

5. Propulsion Systems

Any consideration of the developments in ammunition will not be complete without considering the developments in the propulsion systems. Starting from 300 Mpa pressures of the World War II guns, today these are being fired at pressures in the region of 500-600 Mpa. The design of guns to meet modern requirements poses many problems such as optimising thermodynamic efficiency, maximising piezometric efficiency, reducing muzzle blast and obscuration and lastly improving accuracy[9]. The accuracy with which the projectile hits the target is dependent on a number of parameters other than those relating to the gun ammunition systems itself such as sighting systems, state of motion of the platform and the target, training of the crew etc. However, ballistic dispersion by itself improves with increasing length of the barrel until barrel vibrations droop and thermal effects dominate. Increasing piezometric efficiency has also to be balanced with the requirements of accuracy.

One of the possible methods of increasing the piezometric efficiency is the use of liquid propellant gun systems[10]. Even with the improvements in materials technologies and the development of fully sealed and welded storage tanks, the adoption of liquid propellants for tank guns may not come about in the near future and even then may be suitable only for an external gun. Another possible development for achieving very high velocities is the technology of electro-magnetic propulsion or rail guns. It is conceivable that tank guns of the future may use rail guns or may have an add on EMP unit to increase velocities[11]. Further developments which could come about in the future is the use of ramjet propulsion for tank fired ammunition. The design of a ramjet assisted FSAPDS will pose serious engineering problems when considered in the context of the stresses it has to withstand during firing.

The designer of anti-tank ammunition of today is concerned whether it is always necessary to attack the tank where it is most heavily protected. Usually the top and the belly of the tank are not very heavily armoured. Defeat of the tank from the bottom is the realm of the anti-tank mine which today uses flat cone charges with sensor fuzes. Such mines can be dispersed from aircraft, helicopters or rocket warheads or even by gun fired shells. As regards the attack on the top, guided missiles delivered from aircraft or helicopters and missiles from ground based systems are being designed to hit the tank from the top. Such missiles generally have a HEAT type of warhead. New systems using self forging fragments (SFF) warheads are being fielded. Such ammunition called 'shoot to kill' ammunition is being developed as a part of cluster weapon systems using SFF warheads, vortex parachutes, sensor fuzes etc[12-15]. A ramjet assisted guided kinetic energy projectile is also under development.

In the above context, it will be interesting to watch the duel between the designers of armour and anti-tank ammunition in the years to come.

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