



L6 Ordnance Munitions and Explosives

BEng

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How Tanks Transformed Warfare

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Abstract

Tanks are an iconic main stay of modern military land systems, and their roots are long established through their use in the First and Second World Wars. The lessons of those wars shaped the way ensuing conflicts were fought, and this is reflected in the design changes of tanks of the era, as well as their modern counterparts. This report questions their place in modern conflict against the enhanced threats of drones, intelligence/detection and man-portable anti-tank systems. Recommendations are made to improve overall doctrine and carefully consider the role of tanks in combined arms approach, as well as introduce systems which leverage new technologies in the AI and detection domain.

Keywords:

Tanks, WW1, WW2, Ukraine, Drones, Doctrine

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List of Equations

- (1) – Angular resolved force for small arms deflection

List of Abbreviations

WW1	First World War
WW2	Second World War
QF	Quick-Firing
HE	High Explosive
APDS	Armour Penetrating Discarding Sabot
HEAT	High Explosive Anti-Tank
HESH	High Explosive Squash Head
IED	Improvised Explosive Device
MBT	Main Battle Tank
MANPATs	Man-Portable Anti-Tank System
APFSDS	Armour Penetrating Fin-Stabilised Discarding Sabot
ERA	Explosive Reactive Armour
APS	Active Protection System
AI	Artificial Intelligence

1 Introduction

Tanks are some of the most iconic vehicles in military history. They were first developed in the First World War (WW1), in order to break through the stalemate of trench warfare. In the ensuing Second World War (WW2), tanks were used to oppressive effect by the Nazi forces of Germany, only later being matched by the tanks of other countries. In modern times, tanks are typically thought of as a main stay of mechanised infantry and fire-support, but this report will investigate whether those foundations are beginning to shake.

2 Determining the Big Four

Any war or battle is, ultimately, an extraordinarily complex system of integrating parts. As such, it is almost impossible to isolate single traits which independently contribute to the success or failure of a war, battle, or even a piece of machinery involved, like a tank. Therefore, it should be noted that while 4 traits have been selected for their particularly notable effect on the outcomes of tanks in the First and Second World Wars, each and every trait or characteristic belonging to what become known as tanks is deeply intertwined. The traits most notable were:

1. Tactics and Doctrine
2. Mechanical Reliability
3. Firepower
4. Protection

3 First World War

3.1 Tactics and Doctrine

Prior conflicts in history saw significant reliance on the concept of manoeuvre warfare, with effective use of highly mobile cavalry shock units to penetrate and flank being pivotal to success in many battles. However, by the time of the second world war, advances in military technology such as machine guns and artillery led rendered mobile units completely ineffective. This led to the prevalence of

positional warfare: static, heavily fortified, defensive positions, i.e. trench warfare [1].

The introduction of tanks to WW1 was resultant of a doctrinal change within the British military, as leadership realised a solution to the attritional style trench warfare was needed [2]. This can be seen in some of the design features of early tanks [3], [4], also seen in Fig.1:

- Moving armoured vehicles to provide mobile cover for infantry crossing no man's land
- Long caterpillar tracks and rhomboid geometry for crossing uneven terrain of no man's land and rolling over the top of trenches
- Machine guns side-mounted to fire down the length of trenches



Figure 1: Mark IV British Tank from WW1 showing the rhomboidal caterpillar tracks, by Alan Wilson from Stilton, Peterborough, Cambs, UK, licensed under the Creative Commons Attribution-Share Alike 2.0 Generic license.

Another doctrinal concept which was relevant to the use of tanks in WW1 was that of Combined Arms. This concept can be mapped onto many historical combat doctrines, as at its core, it simply refers to the heightened effectiveness

of different types of combat units when used in a coordinated manner. Examples of this are ancient and can be seen in almost any era of history, the most prominent being the interplay between infantry, archers and cavalry; a combination which saw through a large part of the last 1000 years. Likewise, tanks were most effective when combined with long ranged artillery support, machine gun cover and infantry support.

As the war progressed, it was noted that tanks were most effective under the element of surprise [3], causing shock, disruption and loss of morale, concepts reminiscent of the past cavalry shock units of manoeuvre warfare.

3.2 Mechanical Reliability

As expected of the introduction of any new concept, early tanks were fraught with mechanical issues. Famously, in the Battle of Cambrai (1917) 179 tanks were lost despite the British taking the Germans completely by surprise. Of those 179 only 65 were taken down by direct hits, with 71 being disabled purely due to mechanical failures and 43 being ditched [5].

Failures often included engine overloading, track failures, overheating and ingress of mud into moving parts [6]. Repairability was mixed, some aspects of tank design required bespoke spares which were scarce [7]. However, some aspects, such as the simple armour plating and sponson guns, had relatively available replacements ready for field repair [3], [6].

3.3 Firepower

Most of the British tanks of WW1 had similar armaments. Almost all tanks had some number of machine guns fitted, typically at least 4, although the 'Male' variants opted for two shortened 6-pounder naval guns either side on rotating turrets called sponsons, see Fig. 2 while the 'Females' had 2 extra machine guns [4]. As mentioned above, these weapons reflected the role the tanks were designed to play in countering the positional tactics of fortified entrenchment. The 6-pounders fired 57 mm diameter Fixed Quick-Firing (QF) and High Explosive (HE) rounds which, when paired with the rotating sponson, allowed for effective assaults on fortified positions and clearing laterally down trenches. The machine

guns mounted in various directions allowed for the clearing of infantry who presented a significant threat to the tanks [4].

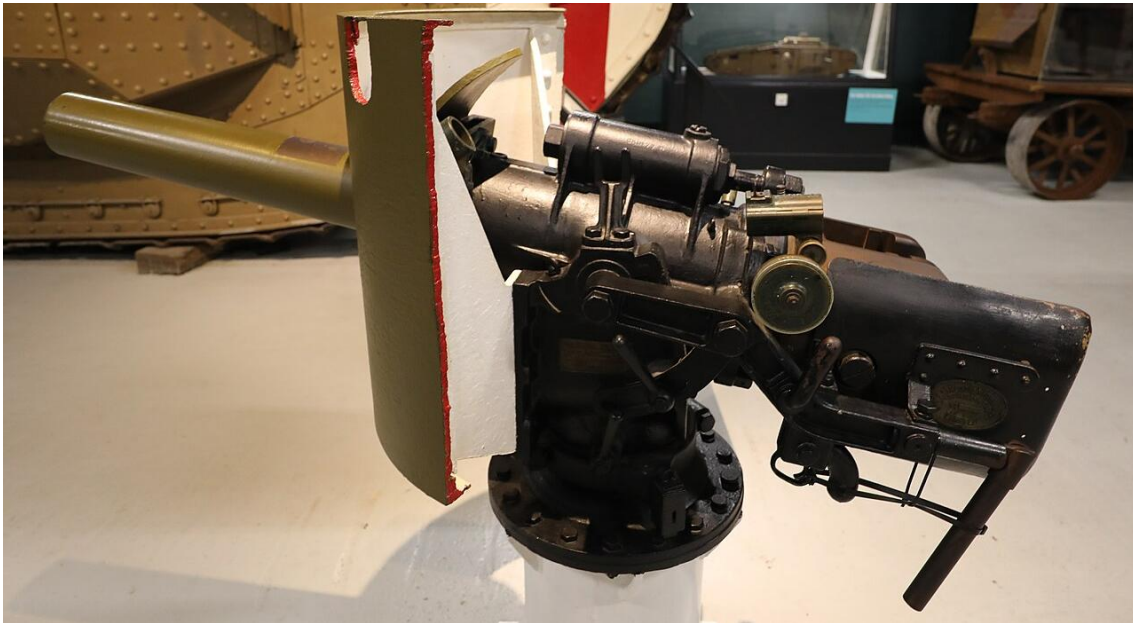


Figure 2: 6-pounder gun on sponson, by Geni, CC-BY-SA 4.0

3.4 Protection

Similarly to their firepower, early tank armour was designed with a specific purpose in mind: to protect against the small arms fire that they would be exposed to while crossing no man's land and encroaching on trenches. This led to relatively thin steel armour being used, in the range of 8-14 mm [4], with one source [3] citing 12 mm for the Mark I. While this armour was effective against small arms, it was ineffective against artillery and explosive weaponry [6].



Figure 3: K-bullet, by PoisonMiller, Public Domain

Countermeasures were quickly adopted with the Germans developing the K-bullet, see Fig. 3, a 7.92 mm bullet fired from a Mauser rifle [8]. This bullet held enough kinetic energy density to penetrate the thin steel of tanks, although firing such a weapon did leave the user exposed.

4 The Second World War (WW2)

4.1 Tactics and Doctrine

By the time of WW2, the Germans had given a great deal of thought to the place of tanks in war doctrine. Their resultant strategy, which achieved radical success in the early stages of the war, is now famously referred to as 'Blitzkrieg', however this was not how the Germans chose to describe it [9]. The German war doctrine of the time was actually somewhat of a resurrection of the much older 'Bewegungskrieg', translating approximately to manoeuvre warfare, a tried and tested doctrine [10], [11]. When used with a combined arms approach, tanks were able to act similarly to cavalry, executing attack, penetrate and flank manoeuvres, see Fig. 4, to devastating effect [12].

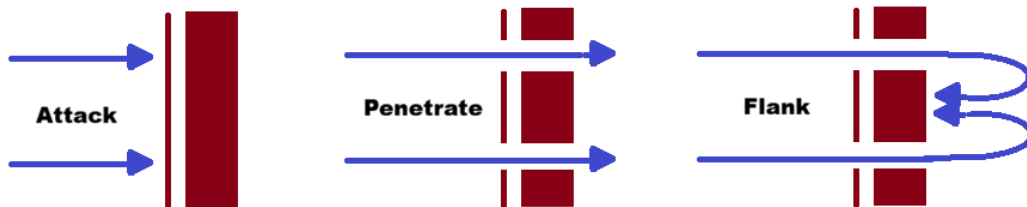


Figure 4: Basic principles of tank battle tactics

4.2 Mechanical Reliability

While German Tiger tanks (called Panzer in German) were infamously effective warfighting machines, they had an equally notorious reputation for breaking down [13], especially in comparison to the Allied Sherman tanks which were designed with standardisation, interoperability and field repair in mind [14], [15]. Coupled with well-trained crew and engineers, this allowed the allied forces to gain

incremental advantages in the later parts of the war, especially as German supply lines stretched longer and longer.

4.3 Firepower

Due to the extensive use of tanks in WW1 and the beginning of WW2, a munitions arms race had begun, where tanks would not only have to attack infantry, but also other armoured units. This led to various armour penetrating munitions making their way into tank armaments [4], [14]. These munitions included the introduction of Armour Penetrating Discarding Sabot (APDS) rounds which were high mass, fine tipped kinetic energy penetrators, designed for optimal kinetic energy density, see Fig. 5.



Figure 5: APDS round, licensed under the Creative Commons Attribution-Share Alike 4.0 International license, by Argonaut9999

The shaped charge concept also began to see use in High Explosive Anti-Tank (HEAT) rounds, which make use of the Munroe effect (wherein a hollow cavity in an explosive charge creates increased penetration) to produce a high velocity jet of metal capable of penetrating deep into armour, see Fig. 6.

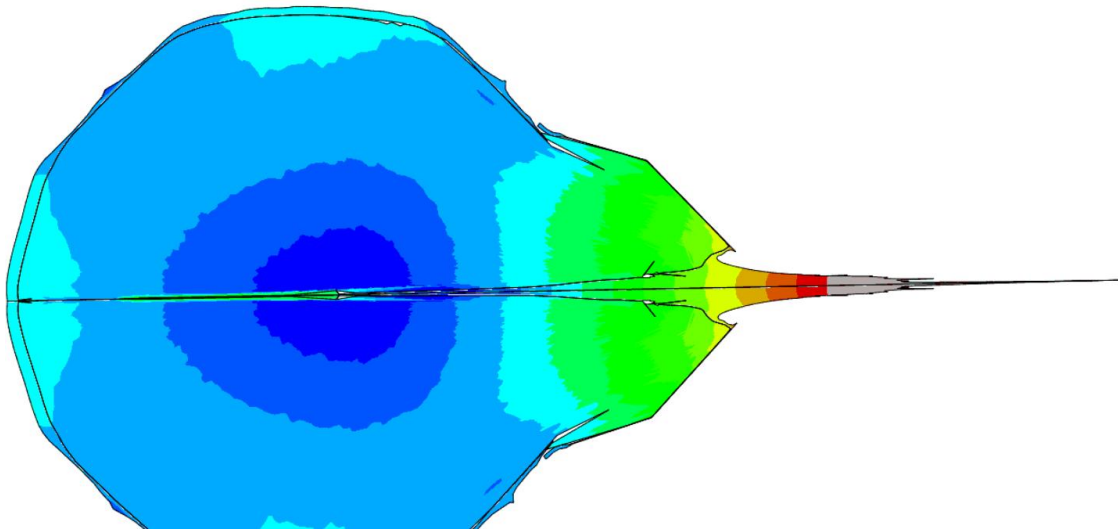


Figure 6: Shaped charge jet simulation using Abaqus CAE, by this report's author

British Tanks were also capable of using High Explosive Squash Head (HESH) rounds which had a delayed fuze on impact, which allowed the explosive fill to squash up against the target before exploding, allowing stress waves within the target material to overlap, referred to as 'impulsive loading', creating fragmentation out of the inside surface of the armour.

4.4 Protection

As engines became more powerful, tanks were able to carry thicker and thicker armour, going from approximately 15 mm to 150 mm on the Tiger II, even as far as 250 on the Jagdtiger [4]. The material properties of this armour also continued to evolve with differing hardening and mass production techniques.

Sloping of armour was also introduced in WW2 to great effect against small arms, and lesser effect against kinetic penetrators and shaped charges. Sloping was effective for two reasons.

First, since small arms travelled from a predictably small arc of fire, they would hit at a predictable angle. Some amount of the impact force could be redirected 90° from the surface of the armour leading to a lower effective amount of kinetic energy imparted onto the armour, see Eq. 1, where θ is the angle between the

trajectory of the projectile and the armour plate. This practically means that an angle of 45° would result in 70% of the original force being imparted.

$$(1) \text{ Force against armour} = F \times \sin \theta$$

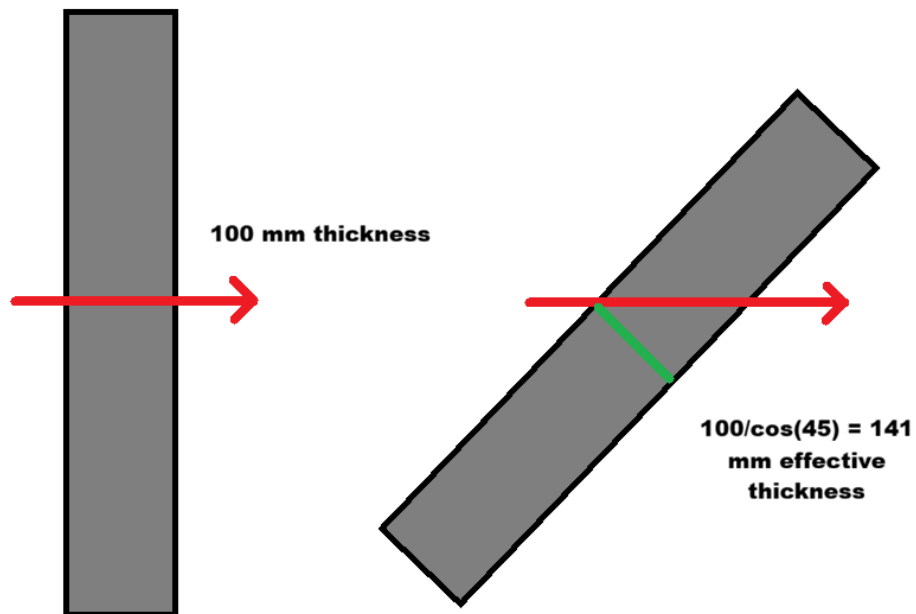


Figure 7: Effect of sloping armour vs normal armour

Secondly, as seen in Fig. 7, sloping the armour creates a greater effective thickness as it forces projectiles in a typical range to move through a longer section of material than if it were striking perpendicularly.

During this time, infantry also began carrying countermeasures for tanks, most notably the Panzerfaust and Panzerschreck launchers which made use of shaped charge technology and could be used by infantry, especially in urban settings, to great effect [16].

5 The Modern Era

5.1 Tactics and Doctrine

The doctrine of warfare has only accelerated alongside advances in technology and thinking. Asymmetric warfare has become increasingly effective against armoured fighting platforms, with mines, improvised explosive devices (IEDs) and compact anti-tank weaponry posing a significant threat to what have now become Main Battle Tanks (MBTs). The increased emphasis on the inclusion of intelligence the air domain into the combined arms doctrine has presented another significant threat to MBTs due to their slow movement and poor concealment [17]. Furthermore, the advent of unmanned and/or autonomous weapon/recon systems such as drones has been devastating to the role of tanks.

Two case studies are most exemplary of this:

1. During the Yom Kippur war, the Egyptian forces used a combination of intelligence, deception, positional fortification, and Man-Portable Anti-Tank Systems (MANPATs) to destructive effect against Israeli armoured forces, far beyond what seemed possible at the time. Although the conflict was ultimately unsuccessful, this particular instance demonstrated how effective preparation and combined arms can easily overcome the strength of MBTs [17], [18].
2. The ongoing 2022 Ukraine War provides myriad examples of tank kills at the hands of MANPATs, mines, IEDs, artillery and drones. The ability of drones to perform reconnaissance over a wide area from above with infrared (IR) sensory systems allows both Ukrainian and Russian forces to accurately acquire the positions of MBTs and other armoured vehicles from extremely long distances away, and when combined with technologies such as HEAT equipped drones, cruise missiles and accurate artillery systems, MBTs are seen as easy targets [17], [19].

So long as such oppressive countermeasures exist without some kind of major doctrinal or technological shift, MBTs may be relegated to the role of mobile medium/long-range fire support [20].

5.2 Mechanical Reliability

MBTs feature immense technological advancements in almost all domains, as will be detailed in the coming sections on firepower and protection, perhaps most notably the addition of the boiling vessel from WW2, which affords British soldiers the superior tactical advantage of brewing tea. But advanced technology comes advanced spares and repairs, requiring increasingly skilled engineers and outfitted facilities. The capacity for field repair is greatly diminished as even the most resourceful engineers are unable to replicate bespoke parts. As such, a broken down MBT typically now requires relocation out of the combat area, and potentially out of country, back to the manufacturer for repair or refit. This places a significant burden on supply chain and not to mention, the forces on the front lines who are without support [4], [19].

5.3 Firepower

Modern MBTs typically tend to carry a limited but effective set of munitions. Armour Penetrating Fin Stabilised Discarding Sabot (APFSDS) rounds feature a long rod penetrator comparable with the APDS rounds of WW2 but with enhanced effect [4]. Most tank armour is incapable of defending against such weaponry for long due to its extremely high kinetic energy density, owed to its fine point and high-density composition [21]. Furthermore, HESH and HEAT weapon systems are deployed for anti-structure and light anti-armour activity.

5.4 Protection

To compete with the ever evolving threat landscape, great advancements have been made in tank protection systems. While armour thickness has increased, hardening and sloping techniques, as well as additional protection systems like slat cages, Explosive Reactive Armour (ERA) and active protection systems (APSS) have proved far more effective relative to their weight [4].

Explosive reactive armour was developed to counter HEAT and kinetic energy penetrators, and consists of tiled explosive sheets underneath a layer of armour which detonate with the intended effect of disrupting integrity of the shaped charge jet or penetrator [21].

Active protection systems offer, as the name suggests, an active form of defence by targeting the projectiles themselves with munitions, intending to initiate them early when they are too far to have full effect.

However, the threat landscape currently appears to be outpacing such systems, as drone warfare, MANPADS and top attack weaponry prove effective against most passive armour protection systems [17], and tandem warheads defeat ERA by triggering the explosives early with a primary shaped charge, followed by a secondary munition behind it.



Figure 8: Ukraine conflict caged tank, by armyinform.com.ua licensed under the Creative Commons Attribution 4.0 International license.

The battlefield is ever evolving. Ukrainian and Russian forces have deployed nets and mesh cages to disrupt drone flight and increase standoff against shaped

charge devices, see Fig. 8, but simple interventions are defeated by simple countermeasures. Only with a fully integrated combined-arms approach can MBTs reach their full potential on the battlefield.

6 Conclusion and the Future

The iconic tanks of WW1, while perhaps not as militarily effective in battle, certainly planted the seed which became the devastating Panzers of the German land army. The ensuing arms race led to the impressive feats of engineering now known as Main Battle Tanks which were dominant post-war period and beyond towards the 2010s. However, modern technology and enhanced warfighting doctrine has finally begun to outpace concept of a modern MBT.

In order to regain their prevalence, the following efforts will likely need to be made:

1. Even tighter integration with the combined arms approach, with emphasis on intelligence, infantry support and air superiority.
2. The introduction of AI (artificial intelligence) or autonomous weapon and protection systems to counteract the effect of drones and other unmanned weapon systems.
3. Enhanced camouflage or intelligence-fooling systems to further counteract unmanned reconnaissance systems.
4. A complete overhaul of tactics and doctrine to better reflect the current battle space.

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