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Present and Futuristic Trends in Weapon System

A.K. Roy*, P.H. Lankennavar, and V.S. Ghadge

Armament Research and Development Establishment, Pune - 411 021, India
**E-mail: akroy.arde@gmail.com*

ABSTRACT

The basic principle of war is based on protection, mobility and firepower. The present scenario of omni-directional and multidisciplinary threats and decreasing response time has made intelligence inevitable for the system to survive and win the war. The intelligence of the system calls for interface of refined logic with systems without compromising any parameters of the gun. However, much of the efforts and funds are directed towards developing the newer technologies to enhance the performance of weapon system in terms of accuracy, consistency, range (stand-off), lethality and transportability. The efforts are also directed towards making smart weapons controlled distantly and cost effective. The future battlefields are going to be dominated by the technological advancements taking place and thus, the technological superiority (i.e. systems with high degree of intelligence) over the adversaries will be the deciding factor to win the war.

Keywords: Differential autofrettaging; Self obturating breech mechanism; MR fluid; Weapon system

1. INTRODUCTION

Presently, nobody is thinking of face to face collision and trend is towards in-direct firing weapon systems. Moreover, preferences are given to smarter weapon systems that are distantly guided and controlled, leading to nil loss to service personnel. The basic principle of war is based on Protection, Mobility and Firepower. The present scenario of omni-directional and multidisciplinary threats and decreasing response time has made intelligence inevitable for the system to survive and win the war. The intelligence of the system calls for interface of refined logic with systems without compromising any parameters of the gun. At the same time, the weapon systems must be highly survivable through:

(a) Best tactical and strategic mobility
(b) Low thermal and RADAR signature
(c) Rapid deploy-ability and movability, and
(d) Ultra-low silhouette.

Much of efforts and funds are directed towards developing the newer technologies to enhance the performance of weapon system in terms of accuracy, consistency, range (stand-off), lethality and transportability and cost effective.

The future battlefields are going to be dominated by the technological advancements taking place and thus, the technological superiority (i.e. system with high degree of intelligence) over the adversaries will be the deciding factor to win the war.

To defeat the target at higher range and of higher magnitude there is a requirement of higher muzzle velocity of improved ammunition. To achieve higher muzzle velocity following technologies can be adopted:

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(i) Conventional gun barrel with higher chamber pressure, higher calibre and higher shot travel length
(ii) Liquid propellant gun
(iii) Electro-Thermal-Chemical (ETC) gun
(iv) Electro-magnetic (EM) gun
(v) Two stage light gas gun
(vi) Auxiliary chamber gun, etc.

The comparative statement for the concurrent combat vehicles is as given in Table 1.

2. GUN BARREL

The gun barrels are subjected to very high propellant gas pressure to achieve higher muzzle velocity and in turn higher range. In order to sustain severe operating conditions, the barrel is to be manufactured using suitable manufacturing process and high strength clean steel.

As the higher calibre of the gun does not prove to be advantageous from all aspects like dimensions, weight of the weapon and weight of ammunition to engage the present and futuristic target of the battlefield, to meet the present and futuristic requirement of the battle field the world is converging on 125 mm calibre of the gun for combat system.

The gun barrel requires various technologies for its development. Some of the vital technologies required are as follows:

(a) Clean steel process for steel e.g. Electro Slag Refined (ESR) plant - for better fatigue life of the steel
(b) Forging technology - for preparation of forging from clean steel (e.g. ESR steel) ingot
(c) Autofrettaging - to reduce the barrel weight and to enhance the life of the barrel. The differential autofrettaging (hydraulic) is more advantageous over other autofrettaging

Table 1. Comparative statement of FRCV

Parameter	PAK	Russia	France	China	UK	USA	India
Name/Type of tank gun	MBT 2000	T- 90	LECLERC	85-IIM MBT	CHALLENGER 2	M1 A1/A2	MBT ARJUN
Crew	3	3	3	3	4	4	4
Wt (Ton)	48	46.5	56.5	41	62.5	68	62
Ground clearance (mm)	NK	492	500	480	500	500	450
Speed (kmph)	NK	65	72	57.25	65	51.6	70
Fording depth (m)	NK	1.80- 5	1	1.4	1.07 - 2	1.2	1.4
Engine HP	12000	840	1500	730	1500	1200	1400
Calibre (mm)	125 SB	125 SB	120 SB	125 SB	120 SB	120 SB	120 RB
Ele/dep (º)	NK	14/ -6	15/ -8	14/ -4.5	20/ -10	20/ -10	20/-9
NBC protection	NK	Yes	Yes	Yes	Yes	Yes	Yes
Projectile velocity (m/s)	NK	NK	1790	1730	1690	NK	1660
Range (m)	NK	NK	NK	2000	NK	NK	2000

processes. Hydraulic Autofrettaging process not only inbuilt compressive stress layer in mono-block barrel but also it has following advantages:

(i) Check soundness of the barrel material
(ii) Reduces weight to strength ratio
(iii) Enhances linear elastic limit of the material
(iv) Increases bore surface hardness due to work hardening during autofrettaging
(v) Increases higher stress bearing capacity without increasing in wall thickness of the barrel, etc.

The schematic layout of hydraulic autofrettaging is shown in Fig. 1.

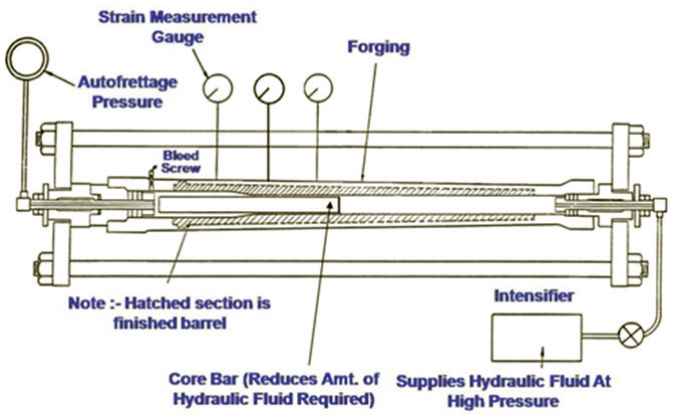

Figure 1. Schematic layout of full length hydraulic autofrettaging.

(d) Shape optimisation technique to reduce the wear resistance of the bore
(e) Thermal management and surface engineering to enhance the wear life of the barrel. A severe thermal environment exists in the large caliber high performance guns due to the burning of high energy propellant and friction due to projectile and barrel interaction during the launch phase. The barrel heating leads to:
  (i) Self ignition of rounds
  (ii) Variation in muzzle velocity due to variation in charge temperature
  (iii) High rate of wear at C of R
  (iv) Loss of material strength

If the crew continues to fire the gun after it has reached to the self ignition temperature of the round, known as cook-off temperature, accidents may occur. On the other hand, chemical action of the hot propellant gases and mechanical action of driving band and the projectile on the bore results in the removal of the metal from the surface. These results in the increase of the bore diameter (wear) which ultimately causes deterioration in the performance of the gun and eventually limits it useful life.

The following methods are used to enhance the wear life of the barrel (by reducing the heat input to the barrel) and reducing the wear.

(a) Chrome plating
(b) Coating of functionally graded material
(c) Coating of tantalum by magneto sputtering method
(d) Laser hardening.

3. BREECH MECHANISM

Breech Mechanism is mainly accommodating mechanically coupled parts with firing circuit. Rate of fire is a critical operational requirement, which depends on the selection of obturation method, type of Breech mechanism and auto loading design.

Steels manufactured with double refinement methods (VIM + VAR) are the obvious choice for breech mechanism application as it provides very high fatigue life. System with sliding wedge breech block, currently adopted in several 155 mm guns having metal to metal obturation. Such type of system is very common in SP guns and also taking root in towed artillery guns due to its advantage over other type of breech mechanisms. Sliding block mechanism in its simplest form has the breech block sliding along key ways to open or close the chamber during firing cycles to facilitate loading/unloading of rounds. Sliding wedge type Breech mechanism, as shown in Fig. 2, initially used mainly for case obturated system, but it has been successfully adapted for breech obturated systems. Such type of mechanism needs almost no space in the breech end for its operation and make the system suitable for both type of gun

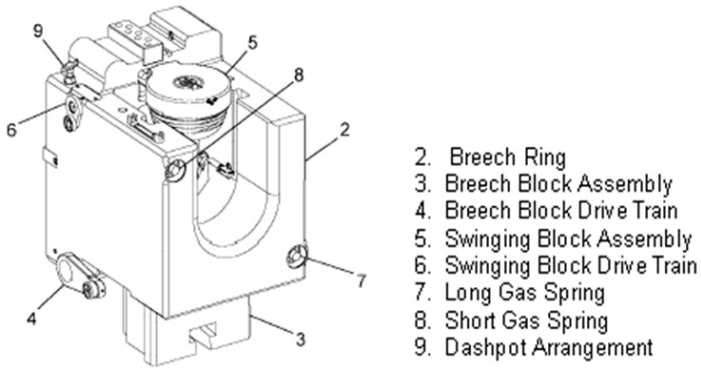

Figure 2. Sliding wedge block mechanism.

(SP and towed). But not suitable for dusty terrain and hence generally not accepted in towed gun systems.

The requirement of self obturating Breech Mechanism due to development of combustible cartridge case has given birth to elastomeric obturation mechanism. The elastomeric obturation system is widely used in artillery gun. To safeguard obturating pad from high propellant gas temperature, metallic support rings are used. The metallic support rings do not give obturation rather it safeguards the elastomeric pad from exposure to hot propellant gases. There are currently two types of breech mechanism in use:

(i) Sliding wedge block mechanism and
(ii) Screw type breech mechanism (shown in Fig. 3).

The elastomeric obturation system has very good active and storage life after development of Acrylo-Nitrile Butadiene Rubber (NBR) which is the prime constituent of elastomeric obturating pad. This pad does not lose its stability up to 10 years of its storage life. The pad gives effective sealing at lower pressure as well as at higher pressure due to higher Poisson's ratio. The elastomeric obturation system, as shown in Fig. 4, was developed by Captain Henry of French Army, in 1872. It works on the principle of radial expansion on application of compressive load, also called De Bange obturating mechanism or radial spring.

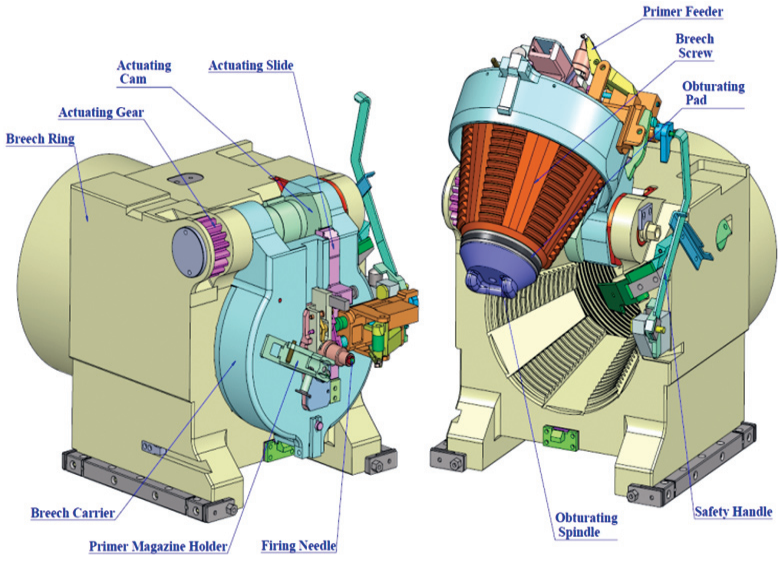

Figure 3. Screw type breech mechanism.

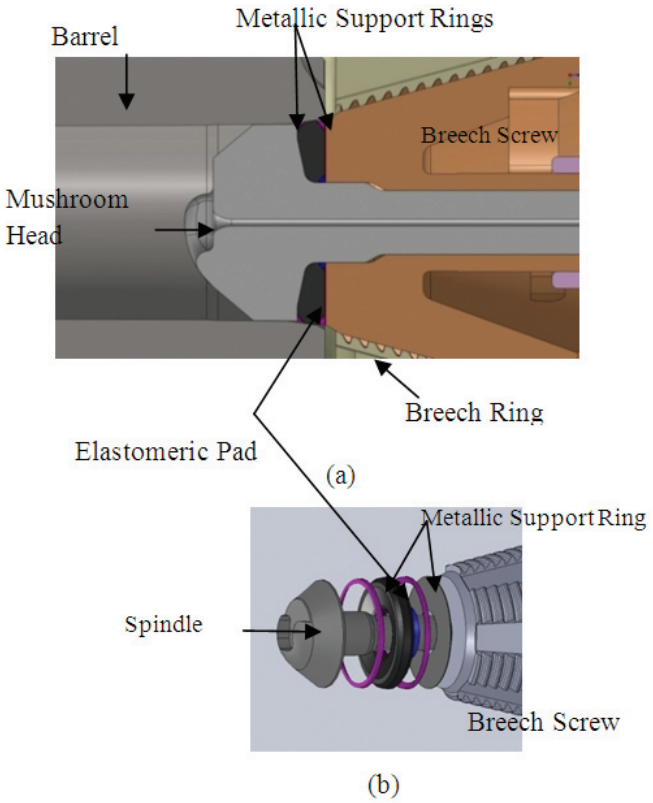

Figure 4. Elastomeric obturation[1].

The post war era has seen decline in the use of the screw breech in new gun systems due to it being slow to operate and more difficult to make semi or fully automatic. But the new screw breech mechanism with H-NBR obturating pad and adaptable automation is used in field gun. The futuristic breech mechanisms will also in-house thermal warning system, breech wash mechanism, primer loading mechanism and laser based firing mechanism, etc. along with obturating and loading mechanism.

3.1 Thermal Warning System

Thermal sensors would be attached to Barrel/ Breech to monitor the temperature of its surface and give warning to the crew when nearing cook-off temperature.

3.2 Breech Wash Mechanism

This mechanism helps to remove the dust/dirt particles from the Breech mechanism to avoid ingress of these in the chamber and thus helps for proper functioning of the same. Also it helps to reduce the Barrel temperature and thus delay cook off temperature and increases the number of rounds to fire to reach cook off temperature.

3.3 Primer Loading Mechanism

There is a need to load the primer after loading of shot and charge mass. The primer loading mechanism holds sufficient number of primer to load after closing of Breech block. This mechanism is very important to decide the rate of fire of the gun, as it contains primary

explosive which is highly sensitive. Thus this type of mechanism needs automation for safety to crew and higher rate of fire.

3.4 Laser Firing Mechanism

For the consistent firing performance of propellant without any misfire, laser firing mechanism becomes imperative for the future weapon system for changing loading density.

4. RECOIL SYSTEM

The recoil system is a necessary accessory of the gun. It is defined as an assembly of components whereby the forces acting on a gun and its related mount during a firing cycle can be controlled and limited to certain parameters by one or more recoil mechanism.

When the gun is fired the gas thrust generated tending to move the gun rearward is very large, and if the gun is mounted rigidly without any recoil system, it would be impossible to build a mounting strong enough to resist the stresses without rupturing or overturning. To reduce the stresses to reasonable values, and to ensure stability of the equipment, the gun must be allowed to recoil relative to the mounting. This is achieved by an elastic link between cradle and Ordnance. This link is called Recoil System.

The recoil system consists of buffer for absorbing and dissipating part of energy of recoil, a recuperator for storing part of the energy to be used subsequently for returning the gun to the firing position; and control plunger for controlling run-out or smoothen the last stages, and ensures that the gun returns quietly to its firing position, and a replenisher to feed the buffer to take care of any leakage. The recoil system affects the accuracy, stability and the rate of fire of the gun. It also reduces the Trunnion pull of the gun according to the length of recoil. Trunnion pull reduces with increase in length of recoil of the gun. Operation cycle of a typical recoil system is as shown in Fig. 5. Presently hydro-pneumatic type of recoil system is in vogue in all gun system for its consistent performance, but change in terrain changes its performance. To make it independent of weather condition/terrain conditions non-Newtonian fluid (Hydraulic) is under exploration for the use.

The cut section of hydro-spring type recoil system being used in combat vehicle having variable orifice e.g. MBT Arjun is as given in Fig. 6.

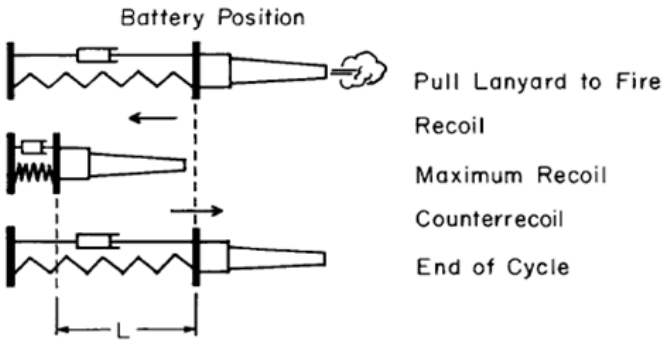

Figure 5. Operation cycle of a typical recoil system.

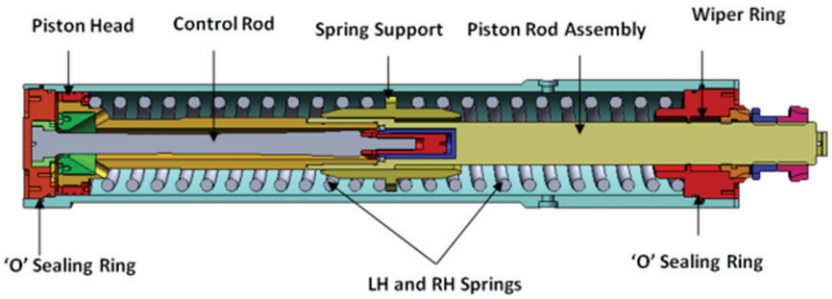

Figure 6. Cut section hydro-spring type recoil system[2].

4.1 Function of the Recoil System in the Gun

The recoil system has following functions to perform in the gun:

- To absorb the recoil energy smoothly in a convenient distance to bring the ordnance to rest
- To return the ordnance to the firing position
- To hold the ordnance in the fully run-out position at all angle of elevation
- Enhance the stability of the gun
- To enhance the accuracy of the gun.

4.2 Recoil System for Futuristic Gun

There are many types of recoil systems but few have got futuristic relevance in the futuristic combat system. For futuristic development for next three decades following types of recoil system will be more relevant and appropriate for the combat system. These are - curvilinear recoil system and adaptive recoil system based on soft recoil mechanism and non-Newtonian fluid (e.g. Electro-rheological (ER) and Magneto-rheological (MR) fluid).

4.2.1 Curvilinear Recoil System

In this system the rearward recoil force is converted into downward thrust which artificially increases the weight of the gun during firing to enhance the stability. This is achieved by specially designed curved recoil path on which recoil mass rides on during firing on recoil and thus artificially increases the weight by accelerating the recoiling parts upward and increasing the stabilizing force downwards. This design has been patented by royal ordnance and presently used on Ultra Light weight Field Howitzer.

4.2.2 Adaptive Recoil System

The adaptive recoil mechanism is a spinoff of soft recoil mechanism and smart fluid. In soft recoil system the conventional fluid restrict it to be used in all terrain even though it reduces the Trunnion pull and enhances the rate of fire. The cycle of operation of soft recoil system is shown in Fig. 7. But use of MR fluid in Soft Recoil Mechanism makes it all weather and all terrain independent along with enhanced rate of fire. Figure 8 shows a plot of resistance offered *vs* stroke length for a typical MR fluid with incre4ase in velocity. The use of MR fluid in the recoil system make the design very simple as the Trunnion pull is not controlled by variable dimension orifice whereas it is controlled by constant dimension orifice and variable viscosity of fluid, which make it more reliable, consistent and easy in

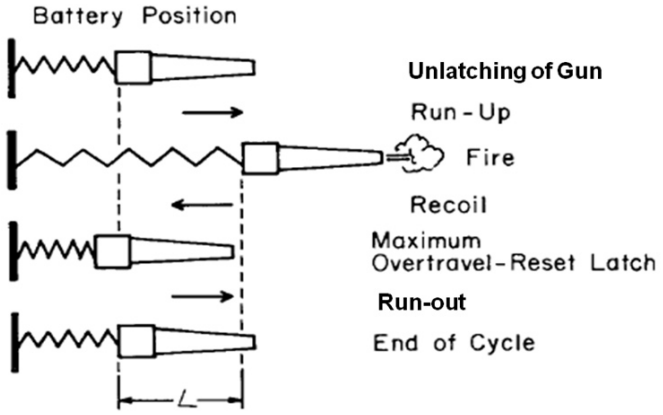

Figure 7. Operation cycle of a soft recoil system[3].

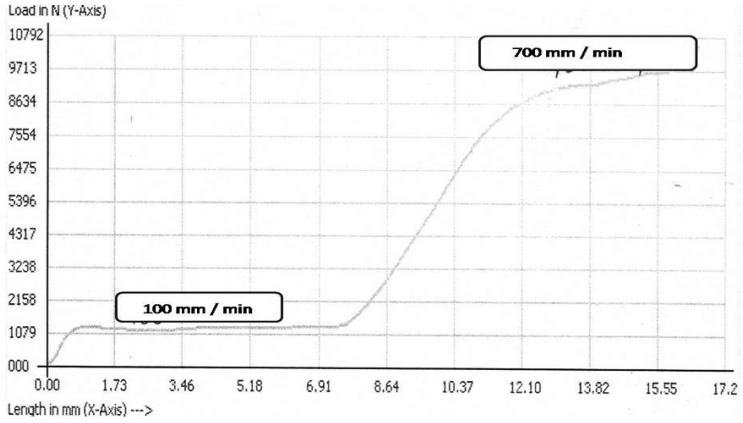

Figure 8. Resistance *vs* stroke length for a typical MR fluid[2].

manufacturing. MR fluid viscosity is based on the magnetic field strength, which makes it terrain independent and thus gun system also become terrain independent in performance.

The adaptive recoil system does not only enhance the stability of the gun but also enhance accuracy and the fire power of the gun. Generally such type of recoil system possesses number of sensors and actuators with refined logic interface with the system to dispose the desired function of recoil system as and when required. Due to presence of logic unit with sensors and actuators call for power source which can be fed from the APU of the towed gun or from the engine power of the SP gun. In this recoil system the viscosity of the fluid plays vital role. The apparent viscosity of fluids can be increased by many folds with response time of 0.01 s to 0.0001s with application of electric field of electro-rheological (ER) fluids and magnetic field of magneto-rheological (MR) and vice-versa. The viscosity of smart fluid depends on temperature and shear rate.

The study of a recoil time and recoil velocity for a typical gun with conventional and soft recoil system are as shown in Figs. 9(a) and 9(b), respectively.

5. MUZZLE BRAKE

The muzzle brake is a mechanical device attached at the muzzle end of the barrel or an integral part of the barrel. The very purpose of the muzzle brake is to absorb some of the recoil impulse by deflecting propellant gases, and thereby reducing the force of recoil of the gun. Muzzle brake by its typical geometrical construction shares around 30 per cent - 45 per cent recoil energy. Thus around 55 per cent - 70 per cent recoil energy remains to be absorbed by the recoil system.

The muzzle brake causes imbalance in moments because of its location at an extreme end of the Barrel. The muzzle brake is either screwed or welded to muzzle end tip. The problem of imbalance of moments aggravates if calibre length of the gun is larger. It has to withstand high pressure gas flow. By diverting the gases to reverse direction the required purpose of reduction of thrust on the gun support system is achieved. Therefore, high strength to mass ratio is a major criterion in selecting material for muzzle brake

Secondly, since it is fitted at the muzzle end tip, the outside diameter of the muzzle brake will approximately be around 2 to 2.5 times larger than the outside diameter of Barrel at muzzle end for its better performance. Types of Muzzle Brakes used in tank and artillery guns are shown in the following Fig. 10 and the study shows the free recoil velocity of a typical gun with various types of muzzle brake is as shown in Fig. 11.

The Barrel section between maximum pressure positions to muzzle end tapers down. But if we make muzzle brake as integral of a Barrel, a large amount of raw material has to be wasted for this configuration. Following considerations are kept in view during designing a muzzle brake.

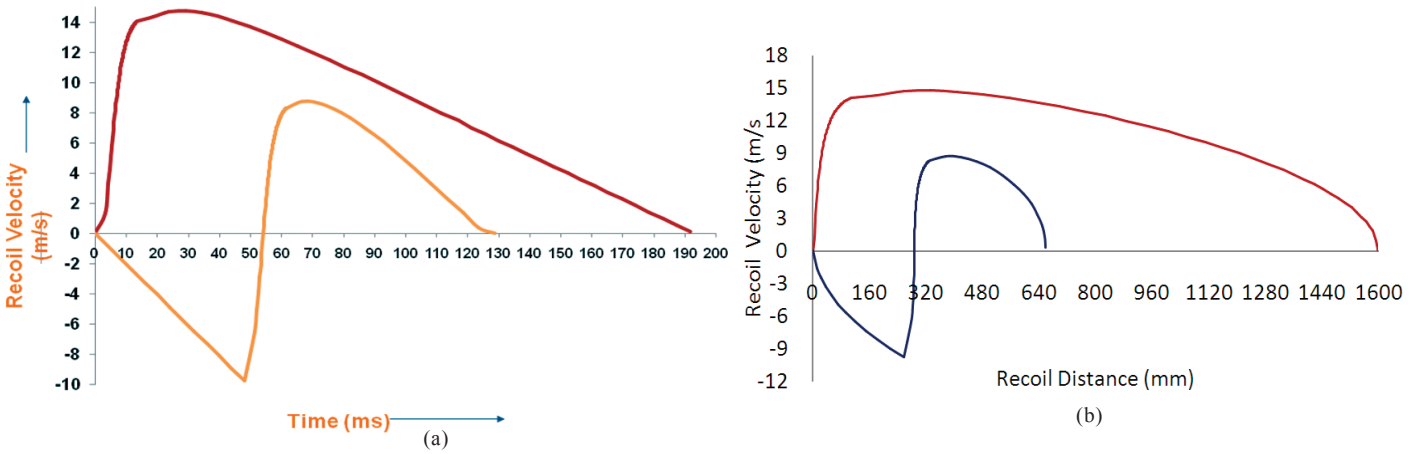

Figure 9. (a) Conventional recoil *vs* soft recoil and (b) Conventional recoil *vs* soft recoil.

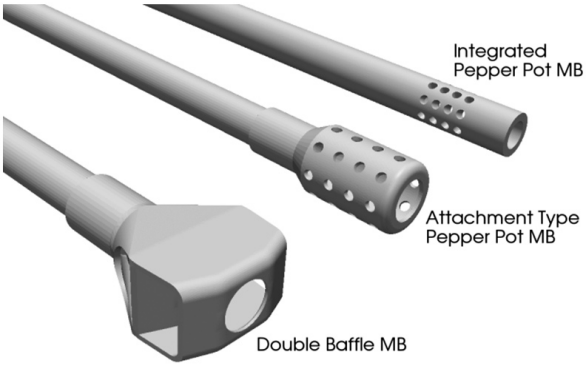

Figure 10. Various type of muzzle brake for futuristic combat system.

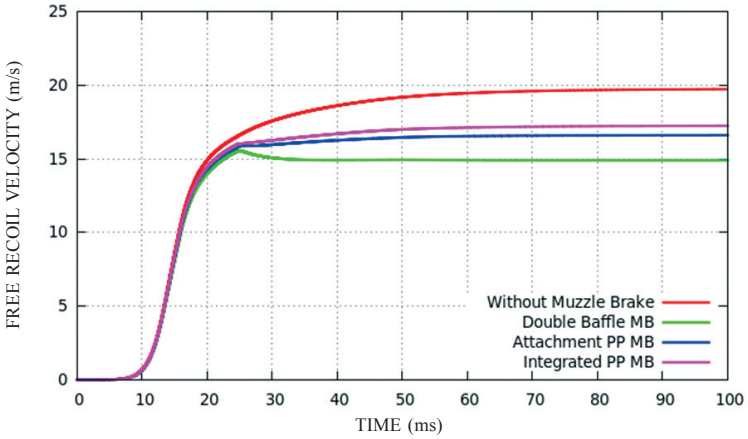

Figure 11. Comparative performance of free recoil velocity for various muzzle brake for a typical gun.

(a) The barrel material and muzzle brake material should be different, so that by choosing a high strength to mass ratio we can reduce imbalance of moments
(b) Screw type attachment is preferable for ease of fitment, dismantling and replacement, if needed
(c) For replacing a damaged muzzle brake (for integral type of MB) whole barrel has to be replaced.

To overcome these problems the choice of separately fitted muzzle brake will be more appropriate, cost effective and logistically acceptable proposal. Titanium/Aluminium alloys are suitable candidate material for muzzle brake due to their high stiffness and low density. These alloys are thermally very stable in high temperature applications. Presently forged steel is used to make muzzle brake. The futuristic muzzle brake will be made up of composite material with metallic insert.

6. CONCLUSIONS

The present trends of conventional weapon system of large calibre will not be sufficient to defeat the futuristic target. The futuristic battlefields are going to be dominated by the technological advancements taking place and thus, the technological superiority (i.e. systems with high degree of intelligence) over the adversaries will be the deciding factor to win the war. To enhance the fire power of the gun for defeating the futuristic targets of the battlefield there is a need of paradigm shift in the development of weapon system, which will be governed by ETC and EM technologies, however the conventional weapon system with higher degree of intelligence will be first and foremost choice for present as well as futuristic combat system.

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CONTRIBUTORS

Mr A.K. Roy has completed BSc Engg. (Mechanical) from MIT, Muzaffarpur and MTech (Thermal and Fluid Engg.) from IIT, Bombay. Presently he is Scientist E and heading Ordnance and Recoil System division of Advanced Towed Artillery Gun System (ATAGS) at Armament Research and Development Establishment, Pune. He has been working for the design and development of armament system of tank and artillery gun. He has worked for the design and development of weapon systems of 120 mm MBT Arjun and 155 mm x 52 cal of ATAGS. He has published/presented more than 25 papers in journal/ symposium/conference.
Contribution in the current study, he helped in literature survey, study and writer of manuscript.

Mr P.H. Lankennavar has completed BE (Mechanical) from Gogte Institute of Technology under Karnataka University, Dharwad, in 1996. Presently working as Scientist in Advanced Towed Artillery Gun System (ATAGS) division at Armament Research and Development Establishment, Pune. Since then he has been working for the design and development of armament stores for tank and artillery guns. Presently he is working for the design and development of weapon system for ATAGS gun.
Contribution in the current study, he helped in literature survey and formatting of manuscript.

Mr V.S. Ghadge is currently Scientist 'G' and Associate Director in Armament Research and Development Establishment, Pune. He was associated with the design and development, performance evaluation trials and integration of armament system of main battle tank MBT Arjun, a project of national importance. He is currently leading a team of scientists for design and development of 155 mm x 52 cal ordnance and recoil-system for ATAGS gun.
Contribution in the current study, he has reviewed the manuscript.