TECHNOLOGICAL ADVANCEMENTS AND INNOVATIONS IN COMBAT ENGINEERING EQUIPMENT

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ABSTRACT

Combat engineering is essential in enabling forces to overcome diverse obstacles. Traditionally, combat engineering tasks have been manpower intensive, time-consuming, logistically demanding and dangerous. Now, modern combat engineering equipment requires less manpower and logistics to operate, features people-centric designs and allows tasks to be completed in a safer and faster way.

This article illustrates the role of technological advancements and innovations in combat engineering equipment, and shares how combat engineering equipment is expected to evolve over time.

Keywords: combat engineering, military bridges, mechanised, mine clearing

INTRODUCTION

Combat engineers play an essential supporting role in any force as they enhance force mobility for friendly troops and hinder the mobility of adversaries. Some activities undertaken by combat engineers include bridging, obstacle clearance, soft ground mobility enhancement as well as mine and improvised explosive device (IED) neutralisation.

Traditionally, combat engineering tasks have been manpower intensive, time-consuming, logistically demanding and dangerous. Now, technological advancements and innovations have contributed to combat engineering in three main areas: (a) automation to enable leaner manning of combat engineering equipment; (b) reduction of time spent on combat engineering tasks; and (c) improvement of man-machine interfaces and ergonomics to make systems safer and easier to use.

This article presents and explores the role of technological advances and innovations in the evolution of combat engineering equipment, with a focus on three areas of combat engineering tasks: fixed bridging, wet bridging, and mine clearing.

FIXED BRIDGING

Military fixed bridges are required to be strong enough to transport heavy military vehicles, light enough to be transported easily and simple enough to be constructed quickly. Bridge engineers use the concepts of bending moments and shear forces to design efficient bridges to achieve the optimal balance between span, strength and weight.

Classification of Bridges

Military bridges are classified by their Military Load Class (MLC) in accordance with NATO's Standardisation Agreement 2021[1]. The MLC is a single number which represents the strength of the bridge and class of vehicle it can transport, and is proportionate to the maximum bending moment and shear force the bridge can withstand without undergoing irreversible yield.

Vehicles are similarly assigned an MLC rating dependent on the maximum bending moment and shear force it exerts on a bridge. This is dependent on the vehicle's weight, length, number of axles and wheel loading. The determination of a vehicle's MLC rating involves tedious calculations of the maximum shear force and bending moment over 44 predefined bridge spans for a total of 88 test cases. DSTA has developed an in-house application to automate these calculations, allowing engineers to estimate a vehicle's MLC quickly.

Innovations on Modern Fixed Bridges

Modern fixed bridges have come a long way since the early days, when crudely bundled brushwood called fascines and one-piece bridges were used to cross tank ditches. Technological advancements in welding and the development of stronger materials have enabled modern bridges to be longer, stronger and deployed quickly. Some of these innovations are as follows.

Launching of Long Bridges

Carrying bridges significantly longer than the launching vehicle hampers the mobility of the vehicle and makes launching unwieldy. To enable the launching vehicle to carry longer bridges, these bridges were innovatively folded in half, and then launched by unfolding them with a scissor-launch mechanism (see Figure 1). However, scissor-launched bridges have a large visual signature during launching – posing challenges for them to be launched in areas with overhead obstacles and making it easier for enemies to spot them.

Further improvements have been made to the designs of assault bridges and a horizontal-launch mechanism has been developed instead. The Leopard 2 Armoured Vehicle Launched Bridge (AVLB), introduced into the Singapore Armed Forces' (SAF) service in 2010, uses the horizontal-launch mechanism (see Figure 1). Another advantage of this design is the absence of hydraulic components in the bridge that improves its reliability and service life.

Automation of Bridge Systems

Early fixed bridges were constructed manually which called for significant manpower and time. The new generation bridges are launched by bridge layer vehicles with fully automatic launching and retrieval modes operated by a crew of two, which can launch a 26m bridge in less than eight minutes. In the Leopard 2 AVLB, this is made possible through the use of an electronically controlled hydraulic system and an array of sensors and actuators on board the bridge layer vehicle. With these sensors and cameras monitoring the launch, the operator is able to launch the bridge without the need to come out of the vehicle and open the hatch, making it safer for the operator.

Figure 1. Scissor-launch mechanism on a M60A1 AVLB (© Quihuis / File:M60A1 Armored Vehicle Landing Bridge.jpg / http://www.news.navy.mil/view_single.asp?id=5015 / Public Domain) (left) and horizontal-launch mechanism on a Leopard 2 Armoured Vehicle Launched Bridge (Ong, 2013) (right)
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WET BRIDGING

Wet bridging (also known as float bridging) is a solution to overcome long wet gaps which fixed bridges are unable to overcome. This is done through the construction of float bridges or forming of ferries. Wet bridges build upon the principles of fixed bridging, but add a degree of complexity with flotation considerations.

Origins of Wet Bridges and Ferries

Wet bridging involves the linking up of pontoons or boats until the wet gap is bridged or a raft of a required size is formed. The traditional types of wet bridge solutions were logistic intensive, and required multiple trucks to transport the pontoons, tugboats, decks, ramps and associated accessories. For example, a 100m assault boat bridge required a team of 60 men, 20 logistic trucks and over 90 minutes for construction.

Innovations on Modern Float Bridges

Compared to assault boat bridges and early amphibious vehicles, modern float bridges are more effective and easier to operate. For example, the M3G, which was introduced into the SAF's service in 2008, requires only six vehicles and 24 men to form a 100m bridge in 25 minutes - as compared to the Heavy Assault Bridge which required 30 trucks, 60 men and 4 hours to construct. This is a significant decrease in the manpower, logistics and construction time required. The technological innovations are as follows.

Propulsion Systems

The earlier amphibious vehicles used a propeller for water propulsion. The latest M3G utilises pump jets instead. Traditional pump jet designs utilise a reversing bucket attached to the end of the nozzle to achieve reverse thrust and braking of the vehicle in water, and plates to manipulate the direction of the jet for steering. The M3G's pump jet is an innovative design where the nozzle can be rotated 360° to provide maximum manoeuvrability of the vehicle in water (see Figure 2).

Control System

The M3G has one pump jet at the fore and aft of the vehicle, allowing the system to achieve a very high level of manoeuvrability which a traditional propeller is unable to achieve. In order to control the full range of complex motions of the dual pump jets, an innovative control system was implemented on the M3G (see Figure 3). This intuitive control allows the coxswain to retain full control over the complex motion of the M3G with minimal task loading.

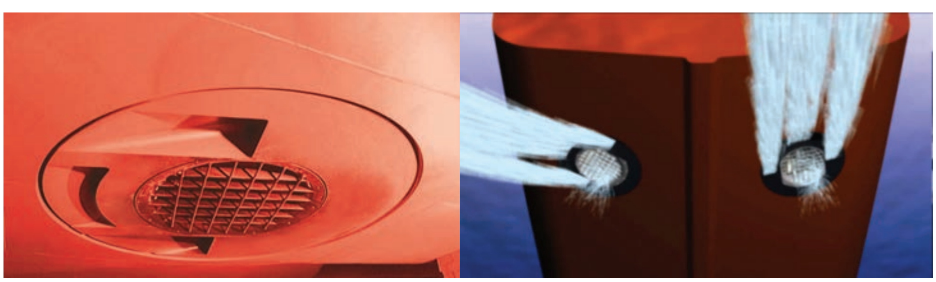

Figure 2. M3G's Schottel Pump Jet up-close (C. Teuert, 2014) (left) Schottel Pump Jet 360° movement (Schottelru, 2011) (right)

Figure 3. Demonstration of the marine controls of the M3G. The level controls the power and primary direction, and the "horns" control the relative rotation of the rig.

Furthermore, multiple vehicles connected together to form a ferry can be networked for operation by a single console, allowing a single operator control over the ferry. This improves the control of the entire ferry and enables lean manning of the system.

Reducing the Logistics Requirement of Float Bridges

Prior to the SAF acquiring the M3G, the design of the original equipment manufacturer (OEM) included three ramps per vehicle. While this was adequate for the construction of a float bridge, it was insufficient for the construction of a two-vehicle ferry in open-couple configuration[2]. A logistics vehicle to transport the three additional ramps is required for this configuration.

The SAF's M3Gs were modified to accommodate an extra ramp each (see Figure 4). Modular panels can also be placed laterally between two ramps to form the third ramp (see Figure 5). This innovation eliminated the need for the logistics vehicle, reducing the logistics footprint and achieving manpower savings.

Figure 4. OEM's M3 bridge with one ramp on the each side versus Singapore's M3G with two ramps on each side. The third ramp on OEM's M3 bridge is stowed in the centre of the vehicle and is not visible.

Figure 5. The modular panels of the M3G as a third ramp. The modular ramps are stored as seen on the right.

MINE CLEARING

Mine clearing is an important component in a combat engineer's tool list. The ability to clear a minefield quickly and safely offers significant strategic and tactical advantage to the force.

Mine Clearing Methods

Manual Methods – Mine Prodders and Metal Detectors

The most rudimentary method of clearing mines involves personnel using mine prodders or metal detectors. These methods relied on human operators to detect buried mines before they could be neutralised, typically using a bomb-disposal operator. Due to the close proximity of operators to potential mines, these manual methods are time-consuming and dangerous.

Mine Rollers and Mine Ploughs

Mechanised methods of mine clearing include using mine rollers to trigger pressure sensitive mines, or mine ploughs to push aside surface and shallow mines. However, mine rollers are ineffective against mines which are not pressure activated, and mine ploughs are only effective against shallow buried mines on relatively soft ground.

Mine Flails

The method which provides the highest assurance of clearing mines is the use of mine flails (see Figure 6). This method employs a flail system to impact the ground physically to neutralise mines. Modern mine flail vehicles have incorporated the latest technology and innovations to allow soldiers to clear a minefield faster, with less manpower and a high safety margin. The SAF has two types of mine flailing systems – the Mine Clearing Vehicle MCV910 and the Trailblazer Counter

Figure 6. Mine flail system on Singapore's Trailblazer (Ong, 2013)
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Mine Vehicle. The former was procured off the shelf with customisation while the latter was developed jointly by DSTA and Singapore Technologies Engineering.

Mechanised methods enable the clearing of mines with remarkably little effort compared to manual methods. The latest innovations in mine clearing vehicles have made the dangerous task of mine clearing safer, faster and possible with less manpower.

Innovations in Modern Mine Flails

The mine flail that the SAF uses currently includes numerous innovations which make it safe to operate and more efficient as compared to off-the-shelf mine flails. Some major innovations are as follows.

Hydro-Mechanical Continuously Variable Transmission

While mine clearing operations are conducted at low speeds of less than 1km/h, normal driving speeds are up to 70km/h. Conventional vehicle transmissions are normally unable to perform well at both low (less than 1km/h) and high (up to 70km/h) speed ranges.

Instead of using two separate transmission systems[3] which would require additional weight and space on the platform, the Trailblazer was equipped with a hydro-mechanical continuously variable transmission which consists of a hydraulic pump for the low speed range and a mechanically geared torque convertor for high speed range within a single housing. This compact and light transmission system enabled the Trailblazer to be capable of both extremely low and high speeds while contributing to weight and space savings.

Lane Marking System

The lane marking system specially designed for the Trailblazer possesses pneumatically fired rods. Compared with other systems that employ pyrotechnic firing, the pneumatic system enables safer and more accurate lane marking. To minimise the workload on the operators, the lane marking system is deployed hydraulically and can be retracted with ease for stowage from the crew cabin.

Fully Automated Control

The fully automated software control of the Trailblazer reduces the operator workload and sustains the operator for longer missions. The software control achieves auto-contouring effect for complete mine clearing. This creates operational flexibility for the operator to clear undulating contours when necessary. Coupled with the pneumatic lane marking system, the Trailblazer is able to clear and mark the lane for follow-on forces automatically with significantly less effort and time compared to past systems. Using digital control also enables mobility to be controlled with a joystick, presenting better ergonomics for the operator over long missions.

FUTURE TRENDS

Combat engineer equipment has benefitted from technological advancements and innovations over the years. This section explores the potential evolution of combat engineer equipment.

Advanced Materials

The advancement of materials technology will play a significant role in the future of combat engineering equipment. One promising area is the use of composites in float and fixed bridges which will bring about lighter, stronger and longer bridges. However, the use of composites is not without disadvantages. Other than cost, the use of composites poses several technical challenges.

The maintenance of composite material structures is more challenging than conventional material structures used in bridges like steel or aluminium alloys. While conventional materials can be repaired by welding, the repair is considerably more complex if a delamination occurs between the fibre and matrix in a fibre composite structure. Furthermore, the delamination may not be visible to the operator who would not be able to sense the need for maintenance even when potentially severe damage has occurred. Hence, more experience and expertise are required to maintain composite structures. Composites are also very sensitive to flaws sustained during the manufacturing process as compared to metals. Any deviation from a tightly controlled process may lead to a compromise in the material properties of the composite. These factors contribute to the high cost of incorporating composites in combat engineering systems.

However, as more advanced composites are developed, the use of composites could be more cost effective. This could result in a trend towards the use of more composites in combat engineering systems.

Autonomous Equipment

Although unmanned technology is relatively mature, it has not been widely implemented in combat engineering equipment. One main factor is cost. As unmanned technologies become more cost effective, there could be more drive-by-wire combat engineering systems to enable the development of remote-controlled and autonomous systems.

Fully autonomous equipment will require sufficient artificial intelligence (AI). As AI technology improves in the future, it is likely that systems for dull, dirty and dangerous tasks such as mine clearing will make the first push to fully autonomous systems.

Improvised Explosive Device Neutralisation

In the future, IEDs will present one of the biggest challenges for combat engineers. Current technology includes radio jammers and ground penetrating radar systems, but these solutions have their shortcomings. Future developments in the area of IED neutralisation would likely include high energy weapons such as high powered microwaves and lasers to disrupt the electronics and detonators in IEDs.

CONCLUSION

There have been great technological advances in combat engineering equipment over the years. These advances, particularly in automation, have been leveraged in the systems used by the SAF. The benefits include a leaner operating force, more ergonomic systems, as well as safer and faster completion of combat engineering tasks. Besides utilising technology, innovations in design have also played a role in reducing the logistic requirements of the systems. While technology continues to advance, it would take time for these advancements to be adopted in combat engineering equipment, due to the difficulties and high cost associated with implementation currently.

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ENDNOTES

[1] The Standardisation Agreement 2021 MILITARY LOAD CLASSIFICATION OF BRIDGES, FERRIES, RAFTS AND VEHICLES is a standard for NATO forces that provides methods for computation of MLC for bridges, ferries, rafts and vehicles (both tracked and wheeled vehicles).

[2] This configuration is ideal as it not only provides a larger deck space for ferrying vehicles, but also increases the metacentric height for additional stability.

[3] The transmission systems comprise a mechanical transmission for high speed travelling and a hydrostatic drive for low speed mine clearing. This is because a mechanical transmission is unable to provide high torques and is inefficient at low speeds, whereas a hydrostatic drive suffers from low efficiency and excessive losses at high speeds.

BIOGRAPHY

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