Focus on Machine Assisted Demining

Mechanical Assistance Systems for Humanitarian Mine & UXO Clearance

What really works?

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Removing the phrase "Mechanical Mine Clearance " from humanitarian demining terminology was an issue that gained approval from most during the Karlsruhe Conference. The amount of money spent within the last few years on systems that are now in the advanced stages of rigor mortis is staggering. Now there seems to be many questions about what is an acceptable standard for the new definition of "Mechanically Assisted Demining". In some perspectives the answer is fairly clear, but in others it is as dark as Turkish coffee.

To begin with, mechanically assisted mine clearance is by no means new. MgM, HALO Trust, Mine-Tech, and many others have used it for quite some time. MgM was the first to actually use it, and title their successful technique the "MAM" system (Mechanical Assisted Mine clearance), which involved mounting hydraulic arms with mulching devices on mine-protected vehicles to remove the brush for manual deminers. Armored scoop loaders, tractors, excavators, and other machines have also been used with various degrees of success, depending on the objective of the clearance.

What works the best?

For general mine clearance, the most successful systems are employed to remove obstructions that deter manual and canine search methods, *without severely disturbing the soil*. These manual/mechanical techniques have provided the highest level of safety for the operators and confidence of clearance for the local population. One has to keep the intent of the clearance in mind: *Make the land safe for daily living and restoration to what it was prior to the hostilities*. Any mechanical assistance system should compliment this effort, not hamper it or simply move the problem elsewhere.

The decision process to help define what "right" would look like for a specific area, and what "wrong" would be, could go along these lines:

How the system is employed?

Is the system effective against the types of munitions used?

Does it provide an acceptable level of protection against the local threat?

Can the mechanical components be cost-effectively replaced in the intended environment?

What will be the means of conducting a Quality Assurance check once it's finished?

One thing should immediately be very clear: ***There is no single system that can effectively work everywhere, period!***

Those who claim that their systems can do this should spend time in three to four different former war zones *with the deminers* and become more familiar with what the conditions are. What may work in one specific region or country would be useless in another.

Every area has its own challenge of vegetation, obstacles, soil conditions, logistics channels, and types of munitions used during the conflict. A flaw of many past systems is that the intent was only focused at breaking up or detonating land mines through sheer force or impact. What was overlooked was the full range of the explosive threat *including* Unexploded Ordnance (UXO) and the intended use of the land, once it's clear.

Large tilling devices and over-sized flail systems have great promise as military breaching devices, where speed of movement through a mined obstacle is the critical task. During high intensity conflicts, mine fields are employed to protect flanks, retreat routes, perimeters, and to channel the opposing force into killing zones. What remains in the ground is not important, moving across the field to engage the enemy is. Research and Development efforts are always on-going for better systems to accomplish this.

Many firms have tried to employ breaching equipment in humanitarian roles and have generally been left with very poor results. The reason is apparent: the equipment was never designed for the humanitarian role. The tool-box methodology has been unilaterally accepted as the most effective approach to dealing with mine and UXO clearance, so think back to the old saying that most of our fathers pounded into us as teenagers: "Use the proper tool for the job."

Balance the wheel to the speed you want to go, instead of re-inventing.

With the "*proper tool"* technique in mind, one first needs to know what the task actually is and what the local conditions are. The most effective method for this is to conduct a hands-on assessment of the area with personnel who are knowledgeable of:

The type of munitions that were employed.

The intended use of the land after being cleared.

Acceptable methods to obtain the required level of clearance.

What equipment is currently available on the open market that can be used to assist in this task.

While the inherent risks involved with conducting clearance operations require us to enforce high standards of safety, many steps involved in the tasks are very similar to what is done on a daily basis in the commercial industry. Some of the most successful systems are adaptations of commercial, off the shelf (aka COTS) equipment that has been adjusted to the needs of the environment.

The most successful systems were designed by those who had the foresight to use a locally available vehicle as the prime mover for the system, therefore ensuring that parts were on hand when mechanical problems occur. If you are familiar with any type of heavy equipment, then you know that the term "maintenance free" does not apply. Mechanical systems will break down; moving parts wear out and there is no way to avoid it.

Parts will wear out faster when they are subjected to the stress and abuse that heavy or even light construction equipment endures on a daily basis. The key to success with these systems is being able to quickly repair what is broken with a minimal amount of down time and cost. Professional construction companies realized this many years ago and plan accordingly. The same must be considered for any mechanical assistance system. In this field, we have the added consideration of what will be lost or damaged when that piece is subjected to a detonation.

Valiant Effort, But,…

More than one company has spent millions of dollars towards mechanical clearance systems, only to watch it gather cobwebs since no one is willing to use them. To better learn from past mistakes, let’s look at what the mistakes were.

Tilling Devices:

These systems originated from reforestation machines designed to grind large tree stumps and/or rock grinding systems designed to make little rocks from big ones. There were some changes made to the tilling drums, some tried double rows of drums, others went for large spike like teeth instead. Most were adapted to armored bulldozers or tank chassis, and some were even openly billed as the "most effective system in the world." However, they are also probably the biggest and most expensive folly for Humanitarian Clearances to date. So, (in sequence) what went wrong?

How the system is employed?

Most were billed to rapidly till or grind the soil to a depth of one meter, and supposedly all threats contained within that meter of soil would be broken apart or detonated. However, due to their bulk and design, they are useless in built up urban settings, on mine fields that are not on a horizontal plain, or where possible erosion may be an issue (future use of the land?).

Is the system effective against the types of munitions used?

Some, but by no means all types. Being effective means that the system can handle the full realm of potential mines or UXO that could be located in the threat area. I do stress

UXO for the simple fact that this is the bulk of what is generally found in post war countries (if you doubt me, then research the reports). **Do not think that UXO are not a threat.** In many countries, UXO is a larger threat then mines. Vietnam and Namibia are two countries that contribute the lion's share of the casualties to UXO, even though they may be classified as mine-related. The KB-1 sub-munition is so common in the Former Yugoslavia that it is illustrated in most of the mine awareness posters.

Tillers can be effective at breaking up or detonating light bodied mines, but have problems with the sturdier design of the bounding fragmentation types. They cannot effectively work against the structural integrity of many hand grenades, some sub-munitions, most mortars, and all artillery or air-dropped fragmentation bombs. The best these systems can hope for is that the UXO would be caught in the teeth and found during post-operation inspection. Mid-range would be that the item detonates in the mechanism and hopefully only causes minimal damage. The worst case would be that the UXO is simply driven deeper then where it what once, possibly out of the range of the detection equipment being used.

Does it provide an acceptable level of protection against the local threat?

Some are adequate against small blast or fragmentation mines, however many of them had the operator directly overlooking the tilling device. From this view point, the blast and over-pressure created from stacks of anti-tank mines can break through the armor plating and kill the operator. Double and triple stacks are actually pretty common, and stacks containing as many as six mines have also been found.

Many people will automatically say, "Do it via remote control." Yes, this is an option, however it's much easier said then done when you are dealing with equipment this size. I've spent a decent amount of time with various robots in my previous career as an EOD soldier. Absence of depth perception, no feel of the terrain (other then the bouncing of a video picture), and lack of peripheral vision is bad enough on small vehicles. Employing this in large vehicles that may have to work in and around houses or steep embankments is another problem in its own. Common Question: Is remote control necessary for this type of equipment? Realistic Answer: Not really (read on).

Can the mechanical components be cost-effectively replaced in the intended environment?

For the most part: No. These machines normally come with a rolling support system plus a full staff of ex-pat mechanics and technicians to service them. The systems designed on battle-tank chassis are the worst. Modern tanks are complex systems that require advanced skills and parts not generally found in many post-war environments, so highly trained (and therefore expensive) personnel must accompany the machine with a full stock of consumable supplies and spares to keep it running.

What will be the means of conducting a Quality Assurance check once it's finished?

Here is another fallacy of these systems. Every system should have internal quality control checks in place, other than beating the ground with a hammer. However once the clearance is finished, the governing authority appoints a competent person or organization to randomly check at least 10% of the land cleared to help ensure safety and a level of confidence. So, if the system is used as it was originally billed, how do we check it?

Mine (metal) detectors are not effective, as the area has never been cleared of metal and the Q/A personnel will likely spend all their time chasing metal fragments that were created by the tiller striking the mine.

The system is supposedly capable of breaking apart a mine. Should this actually happen as intended, then a 9 kg explosive main charge from an anti-tank mine will now be spread far and wide by the tilling drum mixing it into the soil. This rules out explosive sniffing dogs.

Sifting devices following the tiller have been attempted, however there is still the problem of crumbled explosives and UXO components being lost through the sifting screens and remaining in the area as a hazard.

A young child who is maimed by a left over detonator assembly is no better off then if he or she had stepped on a small anti-personnel mine. The level of medical care available in many of these countries will result in amputation either way. Bottom line: The child is still maimed and the land is still not safe.

The procedural approach of one very controversial tilling system in Mozambique was changed to try and make use of it, since it was already in country and being paid for. The depth was reduced to a maximum of 30cm (1/3rd of what the system was designed to do) and the tilled area was then checked by manual methods. The added safety factor of tripwires and vegetation being removed did substantially accelerate the manual clearance, however there are other less expensive systems that can also effectively accomplish this.

Flail Devices:

These systems have achieved greater success then the tilling devices, but many still have fatal flaws that prevent them from being what they were first billed as. So again, by the numbers:

How the system is employed?

The rapidly spinning chains were designed largely for the military to breach minefields, and are respectable enough at that task. Depending on the speed of the flail, direction of travel, and weight of the hammers or knives secured to the end of the chains, flails are also very good at removing vegetation, saplings, and even small diameter trees.

Some systems are able to do limited work on sloped surfaces, but many would be too difficult to maneuver into these areas. Nearly all will remove the bulk of the roots and a good layer of topsoil, so if erosion is a threat then this would be counter-productive. As with tillers, these systems are generally too bulky for most built up urban areas, Technopol's OUS-155 being a limited exception.

Is the system effective against the types of munitions used?

Most surface laid and near surface mines are generally detonated or sometimes moderately torn apart. However, unless it came in direct contact with the flail, some **blast resistant mines *are able to survive these systems.***

Part of the billing was that the rapid, dynamic hammering of the soil would exert enough pressure to activate the mines. Blast resistant mines are designed in a fashion that *extended* pressure must be exerted on the fuze, therefore being able to resist the dynamic over-pressure impulse wave created by explosive breaching systems. As the flails hammering action was so fast, the duration of pressure was not long enough to initiate the fuze.

Another serious problem from designs that rotate against the direction of travel is kick-outs. Light surface mines or UXO have been launched forward or to the sides, instead of being detonated or destroyed. While this might not sound bad at first, when you consider that the item can easily land in an area that had already been cleared, then the problem is obvious.

Light-skinned UXO that are on or close to the surface, such as shoulder fired anti-tank weapons, are also normally torn apart or detonated. Mortars and artillery rounds will remain intact, and generally in place, if they are not detonated by the jarring.

Does it provide an acceptable level of protection against the local threat?

Most flails were designed in a fashion that the cab was well back from the device, so survivability of the operator is greatly improved. The selection of vehicles to use as a prime mover is much wider for flail devices. Being considerably lighter then tillers and generating less torque, major structural reinforcement and center of gravity considerations are not so demanding.

Can the mechanical components be cost-effectively replaced in the intended environment?

This largely depends on the prime mover and design of the flails power system. Many will use common chains as the flailing link, however those designed on battle tank chassis or specialized vehicles again have a logistic problem.

What will be the means of conducting a Quality Assurance check once it's finished?

This depends on how the flail is used. If it is only in cast in a vegetation/trip wire removal role, as Mine-Tech's Ground Clearance Flail is employed, then manual/dog teams conduct a normal search of the area and the routine Q/A methods used by the MAC or NDO can follow. I specify this system for a reason; the flail rotates with the direction of travel, therefore kick-outs are not an issue.

Flails that work against the direction of travel, if employed as the sole method of clearance, must also have the kick-out fan checked (or rechecked, if the target has previously cleared areas on its borders).

If large, blast-resistant mines are a threat, then the operator must be securely fastened in. Should the vehicle remain intact when the wheels or tracks tread on a triple stack, this will help him survive the dynamic ride he'll take when the chassis is launched into a slow orbit.

Without dwelling too much on the ground clearance flail, here is another design feature that one has to appreciate on this system. The stand-off between the front and rears wheels, plus the "weak-link" design of the frame (intentional or not) will help the operator survive if the front wheels strike a large stack of AT mines.

Roller Devices:

Tank-mounted roller systems are not even worth discussing at length. These systems are combat breaching tools that have virtually no place in the Humanitarian Demining role, other then a possible use "proofing" an area that has already been cleared. Many well-seasoned armor soldiers who have done their historical research are the first ones to tell you, "These systems have been around since WW II, and didn't work that well then either."

However, the use of rigid steel wheels on Wolf & Casspir vehicles is an area that deserves discussion. This has been used with various levels of success, depending on whom you speak with.

How the system is employed?

Wide, sturdy steel wheels are mounted on mine-resistant vehicles, which in turn are systematically driven over the field to detonate the mines. One could also call it "mine clearance by Braille." The Wolf and Casspir designs are without a doubt, the pinnacle of what mine protected vehicles should be. Strong, safe, mobile, and easily repairable, they have a reputation that very few, if any, vehicle can match. Thousands of mine strikes with no deaths cannot be wrong. However, the steel wheel technique has not gained the unanimous approval that the prime mover itself has.

Is the system effective against the types of munitions used?

Mines that are laid by doctrine and have not shifted from their original position, plus any tripwire devices will normally detonate when this system passes over. Light UXO that are also laying on the surface may either detonate or be flattened by the pressure, but sub-surface or thick-skinned UXO are normally not effected.

Mines that have shifted or were placed sideways as a trap for prodding deminers (yes, this has happened) are a different story. The force from the wheel is no longer focused on the fuze, and the mine will likely survive. A South African gent who I have a great deal of respect for and gladly call "friend" has driven these vehicles in this role. He speaks very highly of it as a tool. A German fellow working in Mozambique who I equally respect and also consider a friend views the systems differently. Here is why:

Since the ground is never perfectly flat, pressure actuated AP mines such at the PMN can be located in hollows or small depressions. This will prevent uniform distribution of the pressure exerted from the wheel and can potentially partially depress the firing mechanism. What is left is a mine that is now ***hyper-sensitive and even more dangerous to the deminer.***

To be on the safe side, the German gent directed that mine flags be placed at 30 cm from a signal, as opposed to 10 cm, when conducting manual sweeps following the steel wheels.

Does it provide an acceptable level of protection against the local threat?

For mines: without a doubt. Large UXO like aerial bombs: No.

Can the mechanical components be cost-effectively replaced in the intended environment?

When used in the southern African region, or in the Wolfs case, areas that have VW/MAN truck components readily available: Yes.

What will be the means of conducting a Quality Assurance check once it's finished?

This system was intended to be part of the tool box approach to help reduce the threat (not totally eliminate it), so manual/dog searches and accepted Q/A method should follow its use. Because this does not actually till or disturb the soil, the Q/A is easier.

On the flip side of the coin, many have viewed this system as a valid and effective method of proofing a previously cleared area for the Q/A process, or in the level II survey role to help define the boundaries of suspected mine fields.

Getting close, but still needs some work

Mini-Flails

These systems have provided a better service in certain applications but are still a far cry from what they were originally billed as, which was a *mine clearance device.* The less expensive ones have found niches in the Level I survey role of helping define the boundaries of the mine field and as a vegetation cutting tool to assist in Level II actions.

How the system is employed?

A small remote control vehicle is used as the prime mover of a light flail device to remove tall grass and initiate tripwires and small anti-personnel mines. The cutting capability depends largely on the type of tip used on the end of the flail (if any), the speed at which it turns, and the power behind it to maintain the speed.

For obvious reasons, their employment was strictly designed for small AP mines, which contribute to the largest share of mine related accidents. Should an anti-tank mine be encountered (they do show up in the strangest places some times), then the remaining vehicle parts have just added to the other scrap that the deminers must pull out of the field.

Is the system effective against the types of munitions used?

Yes, and No.

Much the same as the rollers, if a AP mine has shifted or was placed sideways, then these systems have little or no effect on it. Light-skinned UXO on the surface may be torn apart or detonated, but these frequently have enough power to destroy the machine in the process.

The speed of the flail is another issue. Mini-flails have problems with blast resistant mines just as their bigger brothers do. However, due to the light weight of these systems, they must maintain the speed in order to effectively cut the vegetation. Try running your gas powered lawn weed eater at low rpms and you'll see why.

The power train has also been part of a design flaw with some systems**.** When the prime mover comes to an incline, the engine must work harder to overcome it and often bogs down. Some manufacturers have designed the flail to run from the internal hydraulics, which draw their power from this motor. What happens is when the motor looses rpms, the hydraulic power decreases and the flail slows down. This was the root of a very embarrassing moment during the demonstration of a well-known mini flail in Zagreb.

Another problem that has occurred with small flails is the tendency to create a forward wake in tall, dense grass. The US engineers I spoke with who were operating the US mini flail in Bosnia complained of finding stake mines that had been laid down by the flail with the trip wire cut and the pin partially withdrawn. While the trip wire hazard was eliminated, the mine itself was now in a more hazardous state to the deminers.

Does it provide an acceptable level of protection against the local threat?

An obvious "Yes," as it is a remote control system.

Can the mechanical components be cost-effectively replaced in the intended environment?

Sometimes, depending on the area it is used in and the amount of technology that is involved in its design. With most robotic systems, the remote control is the most difficult piece to replace in field conditions, and so naturally it is the piece that will undoubtedly fail. It may be a bleed over from EOD robotic requirements, but for some reason many designers seem to feel that the system must be able to operate miles away from the controller. In fact, direct line-of-sight is nearly always kept on the vehicle and it is not going to be required to perform any handling tasks during its operation.

So while high-tech radio control has advantages, it is not necessarily a requirement, and actually neither are cameras. These systems are generally used to cut down overgrown areas that may contain mines. If you've ever watched a video display of a flail at work in this type of environment, then all you normally see is tall grass and brush flying around. Better yet, just watch the operator. He often has his head poked around the side of the monitor watching the vehicle.

Locally available, low-tech controls are preferable for these systems. One very clever designer I met in Croatia utilized Russian Sagger anti-tank missile parts in his controls for this exact reason. Simple cable links between the operator and the machine are a reliable and inexpensive way of controlling the system. While it does limit the distance that the flail can travel, most operations can realistically be done within the range of a cable system.

Additionally, we must keep in mind that the system is designed to initiate the mines, so a recovery plan for the device should be established prior to employing any mechanical system in a suspect mine field. The safest way to recover a small system is to have a strong cable already attached to it that allows the operators to connect to the winch of a truck and pull it from the field without physically entering the area. This does limit the vehicle's ability to turn around, but then most mine clearance operations are done by cutting lanes at 90 degree angles from the datum line.

What will be the means of conducting a Quality Assurance check once it's finished?