

Centre International de
Deminage
Humanitaire - Geneve



Geneva International
Centre for
Humanitarian Demining

Tel: +41 22 906 1662/ 1663 - Fax: +41 22 906 1690; - CP 1300, 7bis avenue de la Paix - CH-1211 Geneve 1, Switzerland

THE MgM ROTAR SYSTEM, A NEW PATH IN HUMANITARIAN DEMINING

EVALUATION AND TEST REPORT

Written by Håvard Bach



INTRODUCTION

MgM (Menschen Gegen Minen) is a German NGO that has been involved in mine clearance since 1996. Its area of operation has been limited to areas north of Luanda in Angola. Despite being a rather small organisation MgM has managed to become one of the best known NGOs in the global demining theatre. This is achieved through professional marketing and inventive thinking on how to increase productivity and reduce costs of operations. MgM uses a concept involving a variety of complimentary machinery to achieve its demining goals while the number of employees has been kept to an absolute minimum.

Initially MgM developed the MaM system which consisted of a small manual mine clearance component supported by a vegetation cutter (mulcher) mounted on a mine proof Wolf(1). The aim was to increase the speed and safety of demining by cutting the vegetation (and possible tripwires) mechanically before areas were cleared manually. MgM's main priority has been to demine and rehabilitate the secondary road network in the northern Bengo province. A mine protected grader was therefore integrated as part of the MaM system approach. The grader would grade a road while the manual mine clearance team would visually inspect the road surface and clear the berms built up by the grader. The system was effective but it could only be applied on roads with a low density of mines. Dogs were therefore introduced to work behind the armoured vegetation cutters and as a means of quality control after grading and manual clearance. According to MgM the system worked so well that they decided to name it the Voodoo system. The principle is similar to what is used by several other organisations. High clearance rates (99,6%) are achieved through a series of complimentary approaches. The main difference between MgM and other organisations is that MgM has developed and built most of its own machinery. Old machines have been bought from scrap yards in Namibia and re-built to satisfy MgMs requirements.

Note (1) Wolf : Mine proof vehicle specially constructed to provide a high level of safety for personnel sitting inside the vehicle if it detonates an anti-tank mine. The V-shaped construction enables most of the blast effect to pass on both sides of the vehicle without causing damage to the armoured body. Its axles are constructed in such way that an AT mine detonation under a wheel will separate the wheel from the axle without inflicting too much damage to the axle itself. The vehicle can therefore normally be repaired in the field after a detonation. Trained personnel will typically take from 2 to 4 hours to

repair the vehicle if spares are available. The windows in the Wolf consist of armoured glass and will withstand direct hits from 7.62 mm rifle bullets.



The new MgM grader. The mine protected cabin is similar to the cabin on the MgM ROTAR



All vital areas have been protected with armoured plates.

The MgM ROTAR was developed as a result of practical problems experienced in the field. Mines and UXO had been found in domestic garbage and many mine suspected areas had been littered with tin cans and other shrapnel. The above mentioned demining approach had not provided a satisfactory result and MgM was looking for a new way of dealing with this problem. The desired solution was to construct a relatively lightly armoured sifting system that could safely remove the topsoil for sifting and subsequent visual inspection of all larger objects outside the hazardous area. The rotating sifter had previously been considered as a possible solution to the mine problem along the electricity pylons in Namibia. The idea was rejected. MgM, however, saw a potential in the use of such a system. After some two years of investigation and preparation the MgM ROTAR was finally developed in Namibia.

MgM sees a potential for an extended use of the ROTAR beyond the clearance of domestic garbage. Previous clearance of electricity pylons in Namibia has deteriorated the mine problem since mines have been deep buried into berms of soil or sand instead of being removed or destroyed. A relatively straight forward clearance task has been turned into a difficult challenge due to the depth of the remaining mines. It seems that sifting of the soil/sand is the best approach and MgM believes that their ROTAR is the most suited machine for the task. A second potential for the machine according to MgM is the clearance of regular mine fields and rice paddies.

DESCRIPTION OF THE MgM ROTAR

The ROTAR consists of an armoured front loader with a rotating sifter bucket mounted to the front end. The front loader is a refurbished and armoured Caterpillar 916. The cabin is mine proof and all vital areas have been protected with armoured plates. Like all other front loaders the Caterpillar 916 is hinged at the middle which makes the machine easy to manoeuvre in restricted areas. Anti-tank mines would probably inflict serious damage to the machine. The ROTAR is therefore only intended to be used in areas where no anti-tank mines are suspected.

The cabin is made from 6 mm ballistic steel plates with bullet/fragmentation proof windows on all fire sides. Because of the armouring and sealing, it has been necessary to install an air condition inside the cabin. The cabin is also fitted with HF, VHF and HF PGS radio communication equipment.



*Armoured plates can be seen on the sides of the machine.
The black antenna socket is for HF communication*

The rotor is a Dutch building rubble sifter (ROTAR) which has been customised according to MgMs own specifications. Extra protection is added on all susceptible parts. The strength of the retaining bars has been increased and the grid size in the sifter is 4,5 x 4,5 cm, which means that most anti-personnel mine types will be restricted from slipping through the GRIDS during rotation and sifting. The rotor is a closable bucket with 10 teeth at the front for easier penetration into hard ground. The upper part of the bucket can be locked and opened hydraulically. After the lower bucket has been pushed into the ground and filled with soil, the upper part of the bucket will close on the lower part. The lower bucket part has a 2 mm sheet plate inside while the upper part of the bucket has a cross-ruled sieve. The rotor can be lifted and lowered in the same way as a normal front loader bucket. In addition, when closed, the rotor can be repeatedly rotated which will improve the sifting ability of the machine.



The 45 x 45 mm sifting grids clearly visible. The inner sheet steel plate is also seen on the picture



The rotor in closed position



The rotor in open position

THE ARMoured TIPER TRUCK

The armoured truck is a refurbished Samil 100 tipper with a foldable catwalk and an armoured cabin with an armoured turret on the top. The truck body can be fitted with removable grid size 20 x 20 cm to add an extra sifting process if the ROTAR is used in areas with large rocks.



The Samil tipper in profile. The armoured turret can be seen on the top of the cabin



The ROTAR emptying the rotor content in the truck body

THE CONTROL CENTRE

The ROTAR is normally supervised during work through a mine proof Wolf equipped with radio and surveillance camera. The surveillance camera is fitted to a high telescopic mast on the top of the vehicle. The camera has limited zooming abilities, which makes it difficult to supervise and direct the work from inside the Wolf. During the tests, the ROTAR was therefore not supervised from the Wolf but rather by a Supervisor who walked freely around the whole test area. During real clearance this would not be possible due to the blast/fragmentation threat from mines/UXO. However, MgM informed the evaluation team that they intended to build a portable test cabin that could be moved easily around. The test cabin would be placed on the ground near the clearance site for better supervision and control of the clearance.

THE TESTS, GENERAL INFORMATION

The test site was located outside Windhoek in Namibia. The area consisted of flattish medium rocky land with little or no vegetation. For the purpose of the test, MgM had prepared plastic dummy mines with similar shape and size as the South African R2M2 AP mine (43 x 62 mm). It was agreed that the use of these plastic mines would be realistic replacement for real mines as the purpose of the clearance tests was to determine the machine's ability to clear mines and not the ability to withstand detonations from mines. An individual test had been prepared to determine the level of damage to the bucket and the machine as a result of mine detonations inside the bucket.



Two dummy mines placed in the test line during the first clearance test

The 50 meter long and 1 meter wide test field after marking and placement of 100 dummy mines (test one)

CLEARANCE TEST ONE - RT2 - (100 mines in a 50 sqm area — surface laid)

Site layout

The first test was undertaken on flattish land with soft sandy soil with a high density of small rocks. The soil had been prepared mechanically by someone else (not MgM) before the test which made the consistence very loose. A 1 x 50 metre straight lane was prepared and marked and 100 AP mines where surface laid inside this lane. The distance between each mine was approximately 50 cm. The mines, which had been numbered from 1 to 100, were laid in a numbered order, meaning that mines with low numbers would be cleared first while mines with high numbers would be cleared last.

Supervision

MgM was allowed to supervise and direct the work by walking freely around in the whole area. When a mine had been found in the truck after sifting, it was placed in a pre-prepared row with space for mines from 1 to 100. The MgM Supervisor was constantly informed about which mines had or had not been found at any stage of the test. This was clearly a weakness of the test since it might have caused the Supervisor to advise the driver to re-check areas more times than he would normally have done if this information was not available. The result could have been less mines found in a shorter time period.

Test results

The machine cleared 99 out of 100 mines in 4 hours and 16 minutes. This gives a clearance rate of 99%.

Comments

The machine had a constant tendency to push the soil to the sides and to the front and create berms containing mines. Some of the mines were pushed more than 25 metres to the front before the rotor finally picked them up. Some mines were pushed several metres out to the side of the original test line, which made it necessary for the ROTAR to sift a much wider area than one metre. After the completion of the test, it was established that the machine had sifted an area 8 to 10 metres wide in order to remove all the berms created to the sides as a result of soil pushing. The ROTAR also had to clear a much longer area than 50 meters in order to remove and sift the front berm successfully. Approximately 280 cbm of soil were removed as a result of the overall clearance.



The rotor bucket being pushed into the soil thereby moving soil further to the front and to the sides



The rotor is lifted and closed. More sand escapes from the rotor



The ROTAR backs out of the field. Sand is constantly falling back on the ground



The ROTAR has backed out of the field and is ready to sift the content inside the bucket. Sand is constantly falling out of the bucket. Much of it back into the test line

When the ROTAR excavated, soil was pushed to both sides of the bucket meaning that mines that have been pushed out of the suspected area could easily be pushed back into the cleared area. The MgM ROTAR tried to deal with this problem by re-clearing the cleared area with the newly created berm. Theoretically mines could then be pushed further into already cleared areas. The only way to be sure that no mines had escaped was to lift all the soil out of the area and sift it. Due to the sandy and loose surface, much of the sand actually ran out of the sifter and back onto the same



spot before the ROTAR had time enough to back the machine and drive out of the test site. It therefore became difficult to know which soil had actually been sifted and

Mines can be seen in the front of the berm almost two meters to the side of the original test line.

On one occasion a mine jammed while the rotor tipped its contents onto the truck body. The MgM crew did not discover this. The ROTAR backed out from the truck and manoeuvred around and finally back into the minefield with the mine loosely resting on one of the bucket teeth. Luckily the mine did not fall out during the manoeuvring of the ROTAR and was finally pushed well into the bucket on the next excavation. The mine could, however, easily have fallen out into areas considered as safe without anybody noticing it. The mine was also not discovered by the Supervisor. Upon inspection a small elevation was discovered in the joint between the inner sheet steel plate and the bucket teeth. The mine had probably jammed in this joint.

CLEARANCE TEST TWO - RT4 - 50 mines laid in a 25 m² area - buried to depths from 0 to 30 cm

Site layout

The second clearance test was carried out on flattish dry ground with low grass and few rocks. The surface was relatively hard due to natural compaction. The test was originally meant to be undertaken on a 5 x 10 meters area with 100 mines. However, due to the length of the first test, it was anticipated that it was too late in the day for the machine to clear 50 m². 50 mines were therefore buried to different depths, from 0 to 30 cm. All the mines were laid in a 5x5 metres square, which was marked with red paint. This time the mines were not laid according to their numbers but in a random way.

Supervision

The supervision was carried out in the same way as for the first test. It was agreed in beforehand that that the Supervisor and the driver should not be informed about the number of mines found or not found at any stage during the test. Unfortunately, spectators gave information about the found number of mines on a number of occasions. Especially towards the end of the test, spectators constantly informed the Supervisor about the number of missing mines. Again this reduced the credibility of the test as it may have prompted the Supervisor to work differently if he did not know about the number of missing mines.

Test results

The test was terminated after 52 minutes because of twilight, which made it too difficult to supervise the work of the ROTOR. By that time the whole area had been cleared but the machine had pushed soil into berms outside the mined area. 48 out of 50 mines had been found which gives a clearance rate of 96%. It is, however, possible that the machine would have found one or both of the two remaining mines if it had been allowed to sift longer.

Comments

During the early stage of the test, it seemed that it would be more successful than the first due to the favourable soil conditions. However, the test revealed that the machine had the same problems pushing the soil and building up berms. Berms of soil were quickly built up on all sides of the test field and mines were pushed far out of the test site. This again resulted in the machine needing to sift a much larger area than the actual test site of 5 x 5 metre.

Assuming that the machine would eventually have managed to remove all the mines, this would probably have taken some time, 20 — 30 minutes is anticipated. Although 25 sqm cleared in approximately 1 hour and 15 minutes is significantly faster than the first test, it remains a fact that the ROTAR system is slow and time consuming if applied as demonstrated during the tests in Namibia.

DEMOLITION TEST ONE - RT3— One J69 bounding fragmentation mine placed in soil inside the rotor

Test layout

The test was carried some hundred meters from the clearance test sites for safety reasons. The rotor bucket was first filled half way with soil. Subsequently a J69 bounding fragmentation mine (copy of the Italian Valmara 69 bounding mine) was placed inside the bucket half way buried in the soil. The mine was prepared for non-electric detonation and the rotor was finally closed. The observation team observed the demolition test from inside the mine proof wolf, which was placed some 50 meters away from the ROTOR.

Results

Inspection of the bucket after the detonation of the mine proved that the rotor bucket and the machine had taken minimal damage. A small bulge could be observed on the inner sheet steel plate on the rotor. Metal fragmentation had also caused several small grooves in the steel side plates inside the rotor. No other damage could be observed on the machine. The rotating and closing functions on the rotor were subsequently tested and showed no sign of being damaged.

Comments

The damage inflicted on the rotor and machinery was minimal and the machine wouldn't have had any problems in continuing to work immediately after the detonation. The test therefore proved that the ROTOR could withstand even larger fragmentation mine detonations. The J69 mines contains 597 g of explosive (Composition B)

During previous tests an R2M2 mine detonation had caused a bulge and a small hole in the sheet steel plate. Other R2M2 mine detonations inside the rotor during the same test did not cause any damage. It is therefore likely that the particular mine that caused the damage was detonated while being in contact with the steel sheet plate while the other mines detonated as a result of pressure caused by the soil or rocks. The J69 used for this test was not placed in contact with the rotor. It is likely that the bucket would have taken more damage if the mine had been placed in direct contact with the bucket. However, even if the bucket had taken more damage, it would probably have been easy and little costly to repair.



Valmara 69 bounding fragmentation mine. The J69 is an exact copy of this mine



*The J69 mine detonating inside the closed bucket
Flames can be seen meters to front of the bucket*

STANDING OPERATING PROCEDURES

MgM has not yet incorporated its ROTOR system into their Standing Operating Procedures and no particular drill has been developed for the use of the ROTAR. Ideally the two clearance tests should have been undertaken in accordance with MgMs own SOP. This would have added credibility to the tests. No safety measures were considered during the two clearance tests, the obvious reason being that only dummy mines were used. The Supervisor was allowed to walk freely around the minefield, which would not have been possible during real clearance. When the remnants after sifting were emptied in the truck body, three people were standing on the catwalk looking into the open sifter to ensure that it emptied properly. This would not have been possible during real clearance. The lack of methodical approach to the use of the machine was obvious. The machine cleared the test site from three sides without any conspicuous pattern.

SUSTAINABILITY

Although it was not the purpose to test the machine's sustainability, it was noted that the machine was stopped three times during the first test due to minor problems with the hydraulic system. A hydraulic leakage was discovered and subsequently inspected by the Caterpillar team from Windhoek. The problem was assessed as minor and the test could continue without the need for repair. Some minor repair would, however, probably be required after the completion of the tests.

Despite some minor hydraulic problems the machine appeared to be well constructed, sustainable and fully functional. No other problems occurred with the machinery, the hydraulic system or the rotor during the tests.

ADDITIONAL OBSERVATIONS

Following are a few observations and recommendations for future use and further development of the ROTAR system:

- The bucket appeared too small, which resulted in a limited intake of soil and easy creation of side and front berms. It is questionable whether a rotating sifter is faster than e.g. a normal mine protected front loader with an external sifter.
- Much of the sand/soil actually fell back onto the ground before the machine could move out of the mine field. Since the only way to be sure of total clearance is to remove all the soil, soil that had already been sifted but had fallen back into the field was sifted again. The machine is therefore less effective in dry areas where the soil is loose or in sandy areas. It might be more effective in clogged soil.
- The problem of safe supervision remains unsolved. During real clearance the Supervisors would not have the freedom to move around as was done during these tests. A more restrictive use of the Supervisor may well have less favourable test results.
- The rotation of the rotator and the sifting of soil created significant visibility problems. Due to the close supervision (1 — 2 metres from the excavation site), this did not cause any problems during these tests. It is, however, envisaged that dust may cause significant problems during real clearance. Under dry conditions wind is probably a precondition for safe clearance.
- Although the rotor has proven to withstand detonations from fragmentation mines such as the Valmara 69, it is not known what damage the detonation of UXO, such as 82 mm mortars would cause. UXO are found in any theatre and must be taken into consideration. It is also likely that some UXO would detonate inside the rotor due to the rough processing during the sifting process.
- Like all wheel driven machines, the ROTAR will experience accessibility and manoeuvrability problems in areas with wet and muddy soil. The clearance e.g. rice paddies is probably not possible during the rainy season, only when the paddies are dry.
- The machine proved to be able to deal with limited vegetation without any problems. In areas with thick vegetation, however, it is likely that the bush will cause problems for successful rotation. Cutting of vegetation by using a vegetation cutter is probably required.
- Although the machine managed to remove a satisfactory number of mines when taken into consideration that it will be used as part of a system approach, the clearance efficiency must be seen in correlation with the time spent for the clearance. 4 hours and 16 minutes for the clearance of 50 sqm is far from satisfactory. In comparison two manual demining pairs (two metal detectors in work) would probably have used the same time to clear the area. However, further experience with the machine coupled with the establishment of suitable SOPs and clearance systems will probably increase the speed of future clearance.
- In areas with very rocky soil it might be difficult for the EOD Specialist to recognise mines between all the rocks. Especially if the machine is working in wet packed soil where mines can not easily be distinguished from normal rocks due to the typical soil layer covering the mines. The removal of rocks for better view beneath can be a dangerous exercise, which will jeopardise the safety for the EOD Specialist.

- The grids in the sifter are given by MgM to measure 45 x 45 mm. This will effectively prevent all known mine types from falling through the grids when sifting. There are a few mines with a height lesser than 45 mm. All of these mines, however, have a diameter larger than 45 mm which will effectively prevent them from falling through the sifter. 45 x 45 mm openings is therefore the most practical grid size.

CONCLUSION

The MgM ROTAR has potential in the clearance of mine/UXO contaminated domestic garbage or berms, such as the berms found around electricity pylons in Namibia. In a typical mine theatre there are many different scenarios and the MgM ROTOR will probably be capable of dealing with some of them. When clearing berms contaminated with mines, sifting is probably a good, if not the best, solution. However, the MgM ROTAR may not be the best sifting option. The bucket has a limited loading capacity and can only take a small amount of soil at a time. In addition, much of this soil will fall back into the suspected mined area. The bucket consequently pushes mass out to the sides or to the front causing a potential for mines to be pushed into mine free land or already cleared areas. The problem of berm creation is the greatest obstacle to the use of the machine and must be addressed before the machine can be used successfully. It is recommended that MgM undertake a series of trials to investigate whether it is possible to eliminate this problem through changes in operating procedures and techniques.

The machine would probably also have a much greater capacity if the bucket itself was larger. The inner plate of sheet steel did not prevent soil from falling when lifting the bucket. This problem can possibly be overcome by increasing the size of the plate so that it covers a larger inner area. This will probably make the sifting process more time consuming. The increase sifting time must be balanced with the decreased excavation time.

If the machine is to achieve satisfactory clearance rates, it is imperative that the work is closely monitored and supervised. The supervisor must be able to stand fairly close to the bucket when it is excavating. Ideally the supervisor must be able to move relatively freely around the machine during operations. This can not be done without the use of a mine protected vehicle. MgM should investigate the use of a small mine protected vehicle for this purpose. A hand portable protection unit on the ground will probably not be the best solution as it limits the supervisor to walk/stand on land that are not suspected as mined. In a real theatre very few areas can be considered as safe. This problem can, however, be overcome by providing safe access using a wolf with steel wheels. A second alternative is to further develop the remote monitoring system through improved video cameras. Several cameras set up on both sides of the field in safe areas might be a possible solution.

The machine did not satisfy the UN requirement (99,6% of all mines) of clearance in any of the two tests. The clearance results were, however, more than satisfactory taken into consideration that the machine is intended to be used as part of a system approach. This achievement must, however, be seen in correlation with time used for the clearance. If the machine had not worked so slowly this might have affected the overall results and left more mines behind.

The machine was able to withstand the fragmentation and blast effect from a J69 (Valmara 69) bounding fragmentation mine containing 597 g of explosive plus approximately 100 gram of plastic explosive, which was used as a primer during the test. The detonation only caused minor damage to the inner steel plate in the rotor. The inner plate can easily be repaired or replaced if damaged although this would not be necessary after this blast test.

Safety is an important issue for MgM. The ROTAR concept provides a high level of safety for the operator. The level of protection on the ROTAR and the truck tipper is very high. It remains to be seen what will happen if the ROTOR detonates an anti-tank mine with the rotor or one of the wheels. Most likely the machine will take substantial damage while the operator will be safe if properly strapped. Since the machine is not intended for use in areas where anti-tank mines cause a treat, the conclusion is that the system provides a high level of safety for people involved. This is if MgM finds a solution to the protection of the supervisor.

The machine is able to clear mines to a satisfactory level with a high level of safety for the

operators. The concept is, however, slow which will make overall demining less cost effective for typical mine clearance of mine fields on flat ground. The machine may still contribute to increased overall cost efficiency if it is used to clear areas where other demining methods have little application, such as domestic garbage, deep buried mines and berms.