[Journal of Conventional Weapons Destruction](https://commons.lib.jmu.edu/cisr-journal)

Volume 12
Issue 2 *The Journal of ERW and Mine Action*

Article 40

March 2008

Mixing It Up: The Rotary Mine Comb

Chris Wanner
U.S. Department of Defense Humanitarian Demining Research and Development Program (HD R&D)

Follow this and additional works at: https://commons.lib.jmu.edu/cisr-journal

Part of the Defense and Security Studies Commons, Emergency and Disaster Management Commons, Other Public Affairs, Public Policy and Public Administration Commons, and the Peace and Conflict Studies Commons

Recommended Citation

Wanner, Chris (2008) "Mixing It Up: The Rotary Mine Comb," *The Journal of ERW and Mine Action* : Vol. 12 : Iss. 2 , Article 40.
Available at: https://commons.lib.jmu.edu/cisr-journal/vol12/iss2/40

This Article is brought to you for free and open access by the Center for International Stabilization and Recovery at JMU Scholarly Commons. It has been accepted for inclusion in Journal of Conventional Weapons Destruction by an authorized editor of JMU Scholarly Commons. For more information, please contact dc_admin@jmu.edu.

The Rotary Mine Comb combing the test minefield.
ALL IMAGES COURTESY OF THE AUTHOR

Mixing It Up: The Rotary Mine Comb

The Rotary Mine Comb has been put to the test on Angola's most dangerous stretch of road. In the province of Cuando Cubango, The HALO Trust has deployed the vehicle-based RMC system with impressive results. This article assesses the system's features and minimal-metal anti-tank mine-clearance capabilities in the field.

by Christopher Wanner [United States Department of Defense Humanitarian Demining Research and Development Program]

If humanitarian demining equipment was judged in beauty contests, the Rotary Mine Comb would no doubt be voted Miss Congeniality. Looking more like an egg beater than a serious piece of equipment, the RMC nonetheless provides a capability unmatched in the demining world. Where else could one find a continuous, full-width, vehicle-based process for nondestructively recovering anti-tank mines from 40 cm of soil? The RMC recently moved off the test range and into the field, providing a solution to the previously intractable problem faced by The HALO Trust of finding and removing low-density, nondetectable, anti-tank mines laid along hundreds of kilometers of Angolan road.

"Early indications are that this will be one of the most significant projects undertaken in the history of HALO's involvement in Angola, particularly because there has not until now been a viable method for clearing large swaths of road containing a threat of minimal-metal anti-tank mines," says Guy Petts, Mechanical Officer for The HALO Trust.[1]

This glowing assessment/prediction of capability was made as the RMC began the task of clearing the 200-km stretch of road linking the southwest Angolan province of Cuando Cubango with the town of Cuito Cuanavale, gateway to the rest of Angola. In the months that have followed, the RMC clearance project has moved steadily outward from Cuito Cuanavale toward its objective, the town of Mavinga, at a rate of about one km per day of operation.

Unique in many respects, the RMC tool engages the ground with twin rotors. Four soil-engaging tines project downward from the rotors and sweep out areas of the soil in front of the host vehicle as it is driven. As each successive pass of the tines shaves off another increment of soil, mines and other solid objects are pushed to the surface and nudged out of the way. With a rotational speed of 16–24 rpm and a progression rate of 100–400 m per hour, the RMC will gently nudge a given object dozens of times in small increments, working it to the surface and off to the edge of the vehicle path. The action clears a mine-free path in front of the vehicle without plowing up unnecessary berms.

The road from Cuito Cuanavale to Mavinga.

Originally conceived and constructed by Pearson Engineering of the United Kingdom, the RMC tool was designed and developed under the specifications and sponsorship of the United States Department of Defense Humanitarian Demining Research and Development Program at the Night Vision and Electronic Sensors Directorate in Virginia. The RMC tool has been further integrated by Night Vision into two very different host vehicles for mine clearing. The first vehicle is a 115-kW farm tractor. The comb attaches via the standard three-point hitch on the rear with no special interface and is powered by the power take-off drive of the tractor. The tractor can be either manually or remotely driven (backwards when combing) in order to clear the vehicle path. The second vehicle configuration is on board a 77-kW tracked crawler tractor. The comb attaches to a special mounting built to interface with the standard front dozer-blade lifting arrangement. The comb is driven from a hydraulic motor built into the comb chassis and is powered by an 80-kW hydraulic system with a separate diesel engine mounted on the rear of the tractor.

Both systems offer full-cab protection for an operator to drive the system manually. The farm tractor can be remotely operated as well. The remote farm tractor vehicle has front and rear driving cameras, and both systems are equipped with a remote monitoring system that provides video images of the comb tines to an independent observer located either remotely or on board the vehicle. This system allows real-time, independent monitoring and visual detection of mines and the workspace, as well as of the AT mine engagements and excavation. The intent in low-density mined areas is to stop combing and manually recover each mine engaged as soon as it has been made visible or otherwise detected by the operator or independent observer. At a typical vehicle combing speed of 250 m per hour, an excavated mine remains in the field of view of the cameras for 20–30 seconds and testing has shown excellent results in detecting AT mines visually. In field operations HALO performs a shallow physical examination of the areas along the edges of the combed path to check for mines that have had a short engagement and may not have been fully excavated or may have been pushed into debris or soil alongside the cleared path.

The limitation in soil conditions appropriate for the RMC is more dependent upon the strength and depth of the buried mine case than any physical limitation of the comb. The RMC itself is capable of combing in remarkably tough soils; however, there is a limit on how far a mine can be moved through cohesive, shear-resistant soil without breaking up. In compacted, rocky roads, shallowly buried mines may show signs of damage from the combing process. On the other hand, in sandy conditions like those found in thousands of kilometers of mine-suspected Angolan roads, the RMC has successfully surfaced mines from up to 40-cm burial depth in tests. The remedy for combing in tough soils is slower rotor speed.

Cuito Cuanavale was once the site of fierce conflict between National Union for the Total Independence of Angola rebels and South African forces against the People's Armed Forces for the Liberation of Angola and Cuban forces. The town sits at the southern end of the only improved road in the region. Clearance of the road means safe passage for the 229,000 inhabitants and renewed economic activity for this isolated corner of Angola. The route south from Cuito is crossed by several defensive mine belts around the town, mine belts around defensive military positions along the route and possible nuisance mines. Dead armor, destroyed civilian vehicles of recent vintage and evidence of mine strikes along the way give testament to the peril of traveling this road today.

On the cleared route, the RMC has uncovered a variety of AT mines from the several combatant forces traversing the areas during the 1987–88 battle for Cuito Cuanavale, including TM57s, some with anti-personnel mine fuzes, some double-stacked, plastic-cased Chinese T72's and South African No. 8 mines.[2] Many of the mines being uncovered are in parts of the route that have previously been treated with mine rollers in attempts to reduce the threat. But the technical challenges of pulling heavy rollers through noncompacted soil, added to the reduced triggering efficiency of rollers in soft conditions, make the roller option for threat reduction problematic. HALO site manager Grant Salisbury explains, "Before the arrival of the RMC, there was no suitable and certainly no quick method for finding nonmetallic mines."[3]

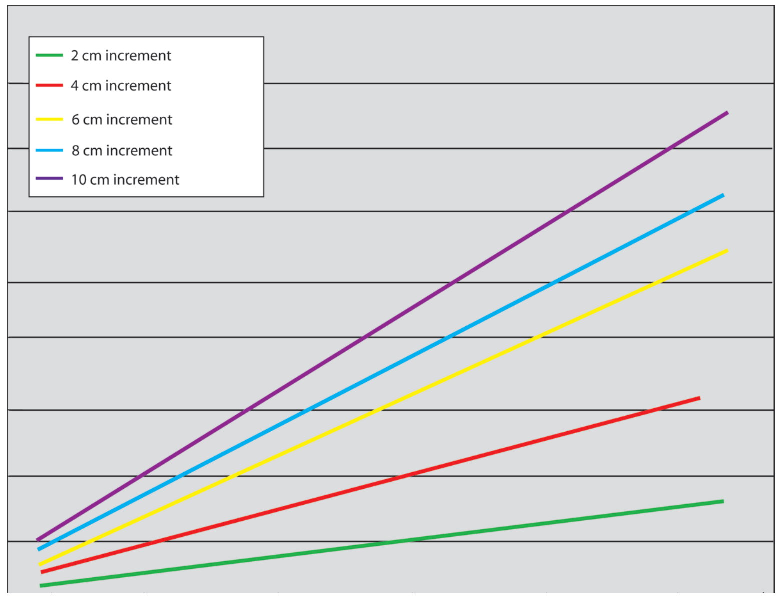

Figure 1: The relationship between line increment, rotational speed and vehicle travel speed.

Complete clearance of the route is expected in 2009, and along with it the economic and social benefits of safe travel between the provincial capital and points north with the southern corner. Already the RMC has proven its worth, as local inhabitants waste no time in putting the cleared road sections to use. Thousands of kilometers of road in Angola like the route from Cuito Cuanavale are mined or suspect, according

Published by JMU Scholarly Commons, 2008

to HALO. Clearly a mammoth task lies ahead just in making the roads of Angola mine safe, but the way forward has become a little clearer thanks to the RMC.

Under the Hood

A key variable in the combing process is the relationship between rotor speed and vehicle speed. The "tine increment" or forward distance between successive passes of the tines must be maintained at or below some maximum value, which is itself dependent on the size of the object to be excavated. In order to achieve reliable, repeatable clearance results, both RMC variants use vehicle speed-control systems with infinitely variable transmissions capable of running at speeds below 100

Agricultural tractor-mounted RMC.

meters per hour. Infinitely variable mechanical transmissions, hydrostatic drives and slow creeper gears make for a harmonious union between RMC tool and vehicle from the standpoint of being able to provide stable, very low-speed vehicle motion while simultaneously serving as a source of high mechanical power to turn the rotors.

Vehicle Variants

Agricultural tractor-based system. The wheeled version of the system is based on the John Deere 7820 agricultural tractor. With vehicle armoring and the 3,000-kg comb installed, the total system weighs approximately 10,400 kg. The automatically controlled, infinitely variable transmission can move the tractor at any digitally set speed as low as 50 meters per hour, with the engine at full rpm and the rear power takeoff shaft putting out 1,000 rpm power to spin the comb. The wheels offer the flexibility to drive point-to-point at speeds up to 40 km/h, ideal for crossing roads and bridges and for moving among several noncontiguous target areas. The drawbar pull required for the RMC vehicle is low because the comb rotation does most of the work in shearing the soil. In mixed-threat areas, the pneumatic tires can be exchanged for solid rubber or special-purpose blast-resistant tires for combing past threats too small to be picked up by the comb. Although this removes only the vehicular threats, the contaminated area is cleared for additional mechanical processes.

The one Achilles' heel in operation with the wheeled machine is stability/directional control in shear-resistant or rocky soil. Cab vibration can be heavy, and side-pulling forces on the comb teeth can influence the vehicle heading unless these forces are kept balanced on both sides of the comb. In tough soil this requires overlapping passes to be made alternately with odd passes in completely uncombed soil and even passes taking out the center with overlaps in previously tilled soil on both sides of the comb. Otherwise the comb will tend to walk from the uncombed soil into the tilled soil if the overlap is made only on one side. In light or sandy soils, this issue is not present; the operator can just dial in the vehicle speed and comb-rotation speed as desired and take off in any direction. Comb depth is controlled by the tractor hitch and is very stable, with only occasional readjustment by the operator required.

In a moment's notice, the wheeled tractor can be switched from manned operation to remote and run via radio control if needed. The remote features a PC tablet-based, hand-held controller. All vehicle functions are at the user's fingertips, and a touch screen displays vehicle data, images from the driving camera and a global-positioning system based local map with user configurable guidelines to aid in steering and tracking ground coverage. Small-scale technical testing of the system demonstrated the ability to blind comb a 2,500-sq-m test plot using 40-cm average overlaps with no gaps in coverage and recovery of all 95 test mines emplaced in the area.

Crawler-dozer based system. The tracked version of the RMC system in use by HALO is built around a Liebherr 712 Crawler Tractor. With the rotary comb replacing the standard dozer blade, and a rear-mounted hydraulic power unit, the system weighs 20,865 kg. Although the hydrostatic drive of this crawler offers most of the required characteristics needed to move the comb, the stability in maintaining a given speed at the very low rates needed is not good on the stock machine. A custom cruise control has been integrated to free up operator tasking and increase focus on steering and monitoring the workspace in the comb.

An auxiliary power pack attached at the ripper points on the rear of the tractor supplies up to 80-kW hydraulic power via a closed-loop transmission and comb-mounted motor. Total system power (vehicle plus comb) is comparable to the farm-tractor system. In contrast to the wheeled system, the directional stability and level of cab vibration are very good in all combing conditions.

Visual Monitoring of the Workspace

Both vehicle systems are equipped with cameras cantilevered in front of each rotor looking at the tine/soil engagement arc where the mines appear as they are brought to the surface. Mines in this zone

Whether operated manually or remotely, independent visual monitoring of the comb workspace is an integral part of field operation.

Construction dozer-mounted RMC.

are continuously bumped toward the outside edge of the vehicle path, and there is generally ample opportunity to see the majority of AT mines engaged and moved. Initial testing with a single camera monitoring both rotors and the systems clearing AT mines buried 20 cm revealed an 82% chance that a mine could be detected visually by independent observers watching the images from these cameras and 98.5% chance that a mine would be cleared from the vehicle path, with a composite expectation that 99.7% of mines would be either seen or cleared. Addition of a second monitoring camera (one to watch each rotor) has significantly improved observer efficiency in spotting mines visually since the initial performance was documented and is believed capable of pushing the composite expectation of either seeing or clearing an AT mine experimentally close to 100%. An added bonus of manned operations is that an operator can generally feel an AT mine engagement before it appears or breaks the ground surface, giving additional reliability to the task of "detecting" the mines.

Operational Control

Both vehicle systems are quite simple to train and run from an operator's standpoint. Vehicle travel speed and comb rotational speed are set and actively controlled electronically. Depth control is simple and not focus-intensive, and other than the problem of operating the wheeled variant in unbalanced load conditions, directional control is easy. A novice operator can be running and controlling the systems manually as effectively as an experienced operator in a couple of hours. The real challenge to successful operation is not in the control but is in mission planning. Selecting the operating parameters and deployment patterns all take significant experience to manage effectively. Soil conditions, mine burial depth, effective clearance width, suspected mine type, target combing depth and tine increment all have a subtle interplay, which affects best vehicle speed, rotor speed, combing depth and combing pattern. ✣

See Endnotes, page 114

Christopher Wanner is the Project Leader of Mechanical Developments for the Humanitarian Demining Research and Development program at the U.S. Army's Night Vision and Electronic Sensors Directorate. He is a registered professional engineer with more than 20 years' experience in countermine and humanitarian-demining equipment development. He has had experience with mine-action programs in Angola, Azerbaijan, Cambodia, Chile, Guantanamo (Cuba), Honduras, Israel and Jordan.

Christopher Wanner
AMSRD-RD-CER-NV-CM-HD
10221 Burbeck Road
Fort Belvoir, VA 22060 / USA
Tel: +1 703 704 1076
E-mail: chris.wanner@us.army.mil
Web site: www.humanitariandemining.org