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Ivan Steker
Croatian Mine Action Centre (CROMAC)

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Testing and Use of Demining Machines in the Republic of Croatia

In the course of achieving the quality employment of machines and their development, CROMAC is conducting the activities of testing, verification and accreditation of demining machines.

by Ivan Steker, *CROMAC Center for Testing, Development and Training*

Introduction

In the frame of their development programs and projects, other countries besides Croatia (the United States, Sweden, Germany) also test demining machines. What distinguishes us from other programs and projects is that we test machines by using available information about the machine and we do so in real mine clearance projects. Achieved results direct further methodology development, which means that we do not need to eliminate this testing model—we need to improve it.

In Croatia, during the execution of demining work, only tested machines can be applied. This procedure has resulted in a high degree of safety and a high percentage of involvement of machines during mine clearance operations. It also led to the current use of 36 machines. The tendency to use machines on 90–95 percent of mine-affected areas is realistic in relation to the achieved results and understandings until now. The achieved results need to be distributed to other countries in the region (southeastern Europe) to speed up the mine clearance process. In other words, make the land available for economic purposes as soon as possible. In the course of applying and testing demining machines, the experience of other countries (especially some institutions) and existing literature have been used.

Use of Demining Machines in Croatia

In the Republic of Croatia, organized mine clearance and humanitarian approach started in 1996 when the state-owned company AKD Mungos was established and the Law on Demining was passed. Before that, forces of the Croatian army and Special Police, together with the United Nations were engaged in mine clearance operations with the aim of collecting information about the mined areas in order to create the database and to conduct mine risk education (MRE).

In 1998, the government of the Republic of Croatia passed a decree and established the CROMAC and based its headquarters in Sisak. That same year, AKD Mungos purchased the RHINO, the first machine for demining with the purpose of mechanically treating huge agricultural areas where minefields were laid. Also in 1998, the Croatian company DOK-ING designed the light machine MV-1 for realistic minefield conditions (different approach in relation to heavy machines, the RHINO and others). This was the beginning of the application of demining machines in Croatia. It quickly became clear that the machines were useful; they speed up the mine clearance process, cut vegetation, destroy mines and create safer and better conditions for deminers.

The following year, in 1999, the Swedish company SCANJACK employed the prototype of a demining machine of the same name in Croatia, with the aim of testing and verifying it. According to the machine technical data and the testing plan, testing was conducted on the agricultural area of the Agricultural Faculty of Osijek. A mined area with low vegetation was selected. After a few days of work, good results were achieved. But the minefield did

not contain all types of mines, so we had to prepare additional testing and analyze the results achieved. During the testing of the SCANJACK, we gathered firsthand experience, and after that, in 2000, new machines were designed for use in Croatia.

The first step was to define the concept of a demining machine. Since different names were used for demining machines (vegetation cutters, machines for preparing the area for mine clearance activities), the following definition was set to avoid ambiguity. Demining machines are machines that mechanically treat the mined area, cut vegetation (by chopping and/or grinding) and destroy mines (by activating and/or crushing) up to a depth of 20 cm. The phrase "demining machines" is a provisional name so that we do not need to continuously repeat the whole definition. We know that only a human deminer can demine, and not the machine.

In addition, the classification of demining machines was formed based on their technical features, their functional capabilities and their relation to mines. A rough classification of demining machines is related to the area of employment. There can be machines for military mine clearance operations and machines for humanitarian mine clearance operations (or their common name—demining machines). Machines for military mine clearance operations (in literature, they often can be found under the name "mine cleaner") are intended for fast mine-breaching operations during combat and they enable combat units a fast passage through a narrow corridor. The following is a brief description of the three different sizes of demining machines and their functions.

- **Light (small) demining machines:** Light demining machines weigh up to five tons and are on tracks or wheels. Their purpose is to treat an area mined with AP mines or mines with up to 0.5 kg of trotyl. For safety reasons, light machines can be operated only by remote control devices. These machines often do not have the driver's cab, and even if they have one, direct driving from the driver's cab is technically impossible. For safety reasons, driving the machine directly from the driver's cab (if it has a driver's cab) is not allowed.
- **Medium-sized demining machines:** Medium-sized demining machines weigh from five to 20 tons and are on tracks or wheels. Operation of medium-sized machines can be directed from the driver's cab or the machine can be operated by a remote control device. The operational experience shows that medium-sized machines weighing five to 10 tons are usually operated by a remote control device, and machines weighing more than 10 tons also have a driver's cab for direct operation. If the armored protection of the machine and driver's cab is certified and invulnerable to the effect of AP and AT mines (total amount of 6.5 kg of trotyl), it is possible to operate the machine directly from the driver's cab. Since these criteria of safety are difficult to achieve, the problem is solved by introducing a remote control device.
- **Heavy (big) demining machines:** These machines weigh more than 20 tons and have powerful engines for movement of the machine and working tools. Heavy machines can move on tracks or on wheels, but in most cases on tracks. The working tool is a single or a double mill or a flail. Heavy machines can be operated directly from the driver's cab and/or by a remote control device. The armored protection of the machine and driver's cab must be able to effectively and safely protect the machine operator from the effect of all types of AP and AT mines, including the ammunition with up to 10 kg of trotyl. The transportation of heavy machines is a complex procedure because a special tow vehicle and a traffic security escort are needed (in addition to the size and weight of machine).

Special machines are classified as demining excavators and support vehicles and are needed because the mine-suspected area in Croatia is intersected by channels, streams and infrastructure objects. Demining excavators have proven to be irreplaceable for mechanical treatment of slopes, channels, dykes and embankments. Considering the operation of the excavator (it was the case with all tested and employed excavators) is directly from the driver's cab, for safety reasons we have regulated the particular methodology for their application. Demining machine-excavators can move only on mine-cleared and safe areas. With the working tool, which is at the end of the crane, it can treat the ground from the side of machine. Moreover, operation on the ground where there are indications of the possible presence of AT mines should be avoided. That means that demining excavators have the purpose of mechanically treating the ground where AP

mines were laid. The length of the crane is usually between 7.5 and 12.5 m. As a working tool, it can use the vegetation cutter and flail.

Support vehicles are armored vehicles from which demining machines are operated by remote control. They may also serve for mechanical detection/verification of the area demined with a demining machine. There is also a possibility of some other technical solutions, which might appear in the future.

Organization of Demining Machine Testing

On mine-contaminated (or mine-suspected) ground, the primary or secondary manual method may be used in demining. The following characterize a primary method:

- Highest degree of risk
- Slow working process
- Expensive action
- Time-consuming activity
- Need for numerous deminers

If a mined area is mechanically treated at a depth of 20 cm, a deminer may use the secondary method. Why is there a need to search a mined area after a mechanical treatment? In the course of a mechanical treatment of a mined area, different working tools that crush and grind the soil are used. When they come across a mine, the following is possible:

- The mine is activated
- The mine is crushed
- The mine remains untouched
- The mine is tossed aside

If there are AP mines in an area, activation by the working tool is desired. The amount of explosives in AP mines is relatively small, so the working tool will suffer little or no damage. From our operational experience, the results are different. There are situations in which AP mines are activated, but there are also situations in which AP mines are completely or partially crushed or the mines are untouched (because of the depth discontinuity during the treatment of the ground, the ground is not ideally flat, and the machine operator usually does not have the ability to predict the uneven spots in front of the machine). Some mines can be tossed aside. If results revealed that each AP mine was completely activated, then we would not need the manual mine clearance after the mechanical treatment of the soil.

If there are AT mines in the ground (heavy and medium-sized machines are used) we hope that a machine breaks or grinds them, so that they will no longer pose a threat. However, AT mine activation is undesirable because the explosion may damage the machine. One detonation will not destroy the machine, but numerous consecutive detonations will surely result in damage and drastically reduce the life and employment of the machine. Likewise, there is a possibility that a mine will remain untouched or will be tossed aside. Therefore, verification search after the mechanical treatment of the ground is necessary.

Operational experience shows that the biggest problem in mine removal is vegetation and mine detection. On the mined area in Croatia, the vegetation has been spreading over the last 10–12 years. Plants that were one to two cm in diameter in 1991 (most of the mines were laid in that time period) are now trees with dense weeds around them. In order to reach the ground, it is necessary to remove all vegetation, except the trees that are 10–12 cm or more in diameter. Removal of existing vegetation is expensive, time-consuming and risky, since uncontrolled activation of mines can occur. Since the ground was not used for a decade, the soil is hard and compressed, due to the precipitation and climate changes. Penetration of the prodder into the hard and compressed soil is both difficult and slow, and the real depth of the searched area is questionable. Therefore, it is necessary to employ demining machines that are able to:

- Remove vegetation
- Crush and grind the soil

- Destroy mines

After a machine removes vegetation, crushes and grinds the soil, and destroys mines, conducting secondary clearance faces the following situation:

- Vegetation is removed
- The soil is crushed and ground (high-quality and safe use of personal tools is enabled)
- Detection of mines (or pieces of crushed or milled mines) is easier
- Degree of deminer risk during the activities is significantly reduced
- Execution of mine clearance of the area is significantly faster
- Mine clearance is significantly cheaper

To achieve such results, it is necessary for an independent institution to test the demining machines and to use the achieved results in the operational phase of demining activities. Demining machines are not produced (like cars) by assembly line production. First, a prototype is designed, and then the prototype is tested, improved and developed. Each construction and demining machine production generation is qualitatively better, and solutions are adjusted to the demands. When constructing demining machines there are a few options:

- Constructing the original machine
- Reconstructing the machine for ground activities
- Reconstructing the forest machine
- Reconstructing the agricultural machine
- Reconstructing the military armored vehicle

When an original machine design has been used in construction, all essential systems are mutually coordinated and compatible with their uses (action, transportation, operation, protection etc.). When using reconstructed machines that originally had a different purpose, they are less effective.

Development of improved demining machines for the mechanical treatment of mined areas is necessary for:

- The user of the machine (demining company)
- CROMAC (to be able to plan and monitor the work of the machine)
- The machine manufacturer/designer (to be able to further develop the machine, to eliminate the defects and to improve the machine)

CROMAC, as an independent institution, has started organizing and implementing testing of demining machines. The following goals have been established to:

- Determine general technical data of the machine and the working tool
- Determine safety of the machine operator
- Check and verify the possibilities of machine employment on the mine-suspected area
- Check and verify the endurance of the machine in relation to activated AP and AT mines
- Check the degree and the size of the second mine clearance method
- Determine the logistic needs of the machine (on-field repairing, repair service, spare parts needed)

To be able to start the testing, the demining company or machine manufacturer must hand over the necessary documentation (request for testing, technical data about the machine and the working tool, the results of the testing during the development of the machine, and certificates for the quality of the built-in materials—especially armored protection of the machine, the driver's cab and the armored glass of the driver's cab). Based on the documentation, the positive evaluation of the machine operator safety and planned use of the machine, a testing program is developed, defining the following:

- Goal of the demining machine testing
- Machine testing on the mined area

- Mine clearance of mechanically treated area
- Testing of the machine and the working tool on AP and AT mines in the controlled environment
- Organization of the execution of the testing

The machine is deployed on the mine-suspected area, and according to the machine assignment, it needs to mechanically treat the foreseen project area. Light machines are tested on an area of 30,000 sq m, medium-sized machines on an area of 50,000 sq m and heavy machines on an area of 100,000 sq m. The size of the project area is determined by the possible and anticipated capacities of machines in mine clearance operations so that researchers can gain an overview of the continuous operation of the machine. Data collection will be based on repetitive testing of the machine, thereby acquiring reliable results. The test field is the real mine clearance project. During the course of operation of the machine, the following data are collected:

- Ability to overcome and remove the vegetation (low, medium and high)
- Ability to crush and chop the soil
- Depth of mechanical treatment of the soil
- Ability to overcome the slopes
- Ability to overcome high-humidity ground
- Impact of the machine and the working tool on an activated mine
- Impact of an activated mine on the machine and the working tool
- Working speed of the machine in different conditions (vegetation, slope, mine situation, climate)
- Achieved results of the machine during one working hour and one working day
- Possible number of hours in which the machine can be used during one working day
- Condition of essential parts of the machine's construction (engine, hydraulics, electronics, transmission, cooling, armor)
- Condition of the working tool
- Organization of machine logistic support
- On-field machine repairing
- Pulling out and self-pulling out of machine from mined area

After the mechanical treatment of the ground, mine clearance activities are conducted with the goal of:

- Clearing mines from mechanically treated ground
- Detecting all remaining mines or their parts
- Verifying the depth of mechanical treatment of the ground
- Measuring the possible effects of deminers' working day activities (working day = five working hours including a 30-minute break)

Testing demining machines with AP and AT mines in a controlled environment is conducted in the following way. The area has the same characteristics as the actual work site (same soil category, hardness, slope, vegetation) New, never-before-used AP and AT mines are laid. The aim of this part of testing is to gather the following indicators:

- Impact of the machine and the working tool on a mine (activated, crushed, thrown aside, untouched).
- Impact of activated mine on the working tool and the machine (size and degree of working tool damage, possibility of damage of essential parts of machine construction, danger to the machine operator in the driver's cab).
- On-field machine repairing (for minor damage, the exchange of the working tool parts needs to be ensured).
- Parts of mines left on the ground when using the different types of mines laid and armed at different depths.

Afterwards, a testing report is written, containing the following information:

- General information on the machine and working tool (description of machine, working tool, technical data)
- Testing program

- Testing procedure
- Perceived strengths and weaknesses
- Conclusion

Results in Testing and Use of Demining Machines

Since 1999, CROMAC has organized the testing of 25 machines, shown in Table 1.

| Year | Light | Medium | Heavy | Excavators | Total |
|--------------|----------|----------|----------|------------|-----------|
| 1999 | | | 1 | | 1 |
| 2000 | 1 | | 3 | 3 | 7 |
| 3001 | 2 | 3 | | 3 | 8 |
| 2002 | 2 | 2 | | 5 | 9 |
| Total | 5 | 5 | 4 | 11 | 25 |

Table 1: Demining machines tested per year.

In the course of developing and testing demining machines, the following criteria have been established:

- Safety of the machine operator
- Clearance of the ground
- Efficiency of the machine
- Maneuverability of a machine
- Logistics
- Reparability

Safety of the Machine Operator

As mentioned earlier, demining machines may be operated directly from the cab, by a remote control or by a remote control with video monitoring. In each of these cases, a machine operator has to be completely safe. If a machine is operated from the cab, it should be designed in a way that the operator inside is protected from all kinds of AP and AT mines (minimum of 6.5 kg of trotyl and mine fragments). There should be a certificate of quality for materials used for the cab armor and bulletproof glass, in order to evaluate safety prior to the testing. The cab must also protect the operator from the noise at the moment the mine is activated. The volume of the sound at the moment of explosion is determined on the basis of sound pressure. Duration of sound pressure differs from mine to mine. For example, for TMA-3 (6.5 kg of cast TNT), sound pressure is 14 ms, while the noise inside the cab must not exceed 150 dB. In order to achieve as much noise reduction as possible, the inside of the cab armor is padded with a noise-absorbing material. If a machine is operated by remote control, the operator must be at least 200 m away, wearing protective equipment or in an armored support vehicle (at 50–70 meters away).

Clearance of the Ground

The concern with ground clearance is the number of mine targets destroyed and the remaining number of mine targets on the ground in relation to the number of mine targets deployed. The working tool must reach and maintain a continuous clearing depth, and often this is not possible (due to technical reasons and ground conditions), depending on the technical capabilities of the working tool, the way of operating the machine, soil configuration, vegetation and the mine situation. Keeping in mind some parameters of the working tool (e.g., flail: type of soil, moving velocity, revolutions of the flail axis, distribution of chains and striker heads), it is possible to develop a mathematical model and graphic representation of ground clearance. In practice, nevertheless, factors of influence are much more numerous, and certain changes occur. Experience has shown that in addition to the mathematical model, practical testing should be performed, because this is the only way to obtain complete and complex results. After mechanical treatment, a search must be performed in order to detect, pick up and remove possible remains of mine targets.

Efficiency of the Machine

The machine's efficiency can vary depending on the conditions on a test area, such as:

- Type and category of soil
- Vegetation (low, medium and high)
- Suspected mine situation (depending on a type and use of the machine)
- Readiness of the machine for testing (logistic support, spare parts, mechanics)
- Skillfulness of a machine operator

Testing of efficiency is performed on actual demining work sites, which means that different machines will be working in different conditions. Nevertheless, after the testing has been performed, the machine is used in demining operations on other work sites and its efficiency is monitored. Results have shown that efficiency achieved during testing is within limits of efficiency achieved during subsequent use of the machine.

Keeping in mind the different factors of influence during testing of demining machines, in order to obtain the best results possible, the following should be taken into consideration:

- A test site should be prepared.
- Machines should be tested on projects which meet the same conditions.
- Prior to the testing on the actual work site, the machine must be tested on a test site.
- The demining machine should be fully prepared for testing.
- A qualified machine operator should operate the machine during the testing (because the machine and its operator achieve results as one unit).

After testing, demining machines are used in demining operations on work sites. Table 2 below gives data on machines used in Croatia in 2001 and 2002.

| Machine type | 2001 | 2002 |
|--|-------------|-------------|
| Heavy | 4 | 4 |
| Medium | 6 | 5 |
| Light | 6 | 16 |
| Excavators | 6 | 11 |
| TOTAL | 22 | 36 |
| Table 2: Number of machines used in demining in Croatia. | | |

In 1996 and 1997, only the manual demining method was used with an extremely high level of risk, at a slow rate and at a high price. In 1998, when demining machines were first deployed and began being tested, these parameters changed. The number of machines used is constantly increasing, as well as the surface area cleared mechanically, while the area where manual method was used as a primary method decreases.

We may expect a growth of 90–95 percent in mechanical demining. One should consider reduced danger and risk for deminers if they work after a machine in comparison to when manual demining was the primary method.

In addition to results of machine testing and productivity achieved in subsequent use of the machines in demining operations, the following achievements are worth mentioning as well:

- Establishment of standards and rules for the use of demining machines.
- Safety of machine operators (there have not been any injuries among machine operators, nor demining accidents among deminers working on verification of a mechanically demined area).
- Best practice in organization and use of demining machines is being established (for each project, a machine is selected that will be able to achieve optimum efficiency, and different machines are combined to achieve best results and maximum efficiency).
- Increased quality of machine work.
- Increased efficiency.

- Development of technology enabled.

On the basis of experience in testing demining machines, a draft of "Rules and Regulations on the Testing and Accreditation of Demining Machines" has been developed. It regulates the criteria, procedures and organization of testing and is a contribution toward the establishment of international standards.

Each demining machine has specific characteristics, strengths and weaknesses, which are identified and recorded during testing. This will be the basis for the selection of the optimum method of use for a specific machine, in which its strengths will be maximized and its weaknesses minimized. This was not easy to achieve in the beginning, but when good results of such use were perceived, such an attitude was accepted among users. Today, different demining machines are used on one demining worksite, and with their combined action, optimum results are achieved.

Development of Demining Machines in the Future

Over the last five years of using demining machines in Croatia, valuable experience has been gained, both in technological development and in standardization of the methods of machine use in demining. The following may be expected in the future:

- Technological development
- Development and establishment of standards and norms
- Establishment of legislature
- Exchange of experience, monitoring of results and unification of these results on a regional level

Concerning a technological development, a goal is to develop a machine that will be fully efficient in different conditions (maneuverability, protection, way of operation). Flails and mills are used as working tools, but other solutions capable of achieving better results are also to be expected. A method of operation is important for the safety of machine operators, but also for the longevity of the machines. Operation by remote controls is tiresome, and visibility and precision are significantly reduced. If video cameras are integrated, problems are caused by huge dust clouds and damage to the cameras caused by vegetation or detonations. After mechanical demining, a verification method is necessary, using either a manual method or mine detection dogs (MDDs). Currently in Croatia, a mechanical demining capacity exceeds by far the capacity of a verification method. For that reason, it is necessary to use mechanical detection as soon as possible, in order for machines to be used to their fullest extent.

It is also necessary to establish legislation that will regulate procedures of the testing of machines as well as their use in demining operations. Existing legislation does not encompass all the aspects of testing and use of demining machines.

It is necessary to perform the testing on a test site, in controlled conditions prior to testing on a real minefield, in order to measure all the parameters (repeatedly, if needed). Modified mines could be used as well, in order to obtain information on the impact of a machine on them, in relation to their type, layout and depth in the ground. A number of live mines used in testing instances to date may not be a statistical representation, but only an indication of possible results. These are the grounds for establishing a test site for demining machines.

In mine-affected countries in southeastern Europe, some of the same or similar conditions for use of demining machines may be found, including:

- Mines (the same)
- UXO (similar)
- Ground conditions (the same or similar in microlocations)
- Climatic conditions (the same)

In Croatia, the testing and use of demining machines are performed, while in other countries of the region there is no testing in general, and completely different criteria are used for accreditation. In order to enable fluctuation of demining machines in the region,

and in order to avoid repeated (unnecessary) testing, sharing experience, monitoring results, unifying results, and establishing common criteria and acceptability should be achieved. This is one of the ideas shared among Southeastern Europe Mine Action Coordination Council (SEEMACC) members.

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Contact Information

Ivan Steker, M.Sc.
CROMAC - Center for Testing, Development and Training
A. Kovacica 10
44000, Sisak
Croatia
Tel: +385-44-554-112
Mobile: +385-98-430-847
E-mail: i.steker@hcr.hr