Research of new tools for deminers by ARTID

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Abstract

ARTID, for "Association de Recherche de Techniques Innovantes en Déminage humanitaire" is a small organization whose object is to find new tools for the deminers. It shares information for scientists using its web site www.artid.org, motivates students by its ideas contest ("Brain StorMINE"), initiates studies for students and performs its own research. Some new ideas will be reported, for instance improving the prodding in hard soils, cleaning vegetation more efficiently, and performing mechanical mine clearance using the free fall of heavy chains. This last idea is currently being developed a project: DEMICHAIN. Tests with impulse probes show it can be efficient to set off landmines.

1. Purpose of ARTID

Several scientists of the French-German Research Institute of SAINT-LOUIS (ISL) noted that R&D on demining techniques is mainly performed on a commercial basis, as opposed to the political and medical aspects of mine problem, in which the NGO play the first role and act in a non-commercial, but humanitarian way.
They decided to start an association, called ARTID for "Association de Recherches de Techniques Innovantes en Déminage", which means "association for research of innovative techniques in mine clearance".
The purpose of ARTID is to find new tools for the deminers, and therefore to make or to initiate scientific research and technical studies on a volunteer basis.
1. As its first task, ARTID makes the scientific and technical worlds aware of the technical problems of demining by delivering detailed information about these problems through its website www.artid.org.
2. Secondly, ARTID initiates studies and projects by students, who have to make a project in the framework of their studies.
3. Lastly, ARTID is developing its own mechanical demining tool: DEMICHAIN.

2. Information and awareness

2.1. Our website www.artid.org

A lot of information about mines and demining techniques exists on the web. Most of these are in English. French-speaking people appreciate being able to read them in French, therefore we built up several pages summarizing the problem of mines and demining techniques. Many links are provided to get the complete information at the original sources.
The new techniques are summarized, however, emphasis is placed on how the mine clearance is actually done and which improvements will increase the efficiency of the deminer.

2.2. New ideas

Several pages of our website describe **new ideas**: for each aspect of the mine clearance process, an analysis of the problems to be solved is given and some ideas are suggested. Most of them consist of low-technology developments, to improve the tools of the deminers.
For instance, the following issues are taken into account:

Vegetation cutting: conventional motorized lawnmowers, edge cutters or hand-held mowers are well developed for gardeners of the rich countries. Would they be useful for cutting the vegetation ? How can the trip wires be detected ?

Prodding: The main problem is to prod in hard soil. A high force is required to push the needle into the soil and this operation becomes dangerous [2]. Several ideas have been proposed: the rotary prodder, a vibrating prodder, and introducing water at the tip of the needle.

Excavation: (also in hard soil) is more dangerous than prodding, as shown by recent statistics of demining accidents [1]. It is suggested to use a sort of brush, a vibrating tool or a high-pressure water jet.

Neutralization of the landmine: instead of neutralizing the APL after excavation, is it possible to extract or to neutralize it just after having localized it by prodding and

without excavating it, for instance by hardening the surrounding soil by injection of a cement or a glue.
It would be also possible to burn the explosive, either by a small blowtorch or by a laser, in both cases the heat source being at the tip of a slender rod introduced in the vicinity of the body of the APL as if it were a prodder.

Active detection: for improving the infrared detection, it is suggested to heat the soil by pouring hot water on the surface [3]. This water will stagnate at the places where an obstacle is hidden in the soil. The surface temperature at these places will be higher than the surrounding and the places where an item is hidden in the soil can be shown by a thermal camera.

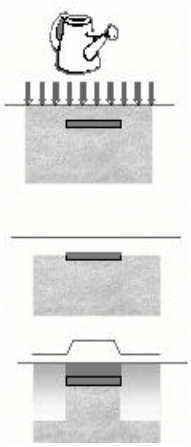

Fig. 1: principle of active detection

As compared to the passive detection consisting of using the sun as a heater, the temperature difference will be higher, allowing far less expensive infrared cameras to be used. Moreover, the deminer will have full control of the heat source and will be able to adapt all the parameters to the ground under investigation.
Heat works as a marker in water. Other types of markers can be considered: ions, magnetic particles, chemical species. The detector associated with the marker has to be determined taking into account the sensitivity, the cost of the marker and of the detection system.

Marker diluted in water	Parameter measured at the surface
Heat	Temperature
Ions	Electrical conductivity
Magnetic particles	Magnetic field
Chemical species	Chemical concentration

Table 1: Combinations of markers and parameters for revealing buried items

The procedure generally used in manual demining consists of first to looking for a metallic item buried in the soil and then checking the presence of an obstacle by prodding. In the presence of many metallic items, a lot of false alarms take place, resulting in unnecessary, boring and expensive prodding and excavation work.
In case of the presence of a lot of metallic items in the field (and if there are few stones in the soil), the active detection technique can be a good alternative to the usual process because one will first seek the presence of an obstacle and then check if a metallic object is also hidden at this place. The number of false alarms will then be drastically reduced.

DEMICHAIN: A new idea of mechanical mine clearance is under study by ARTID (see § 4). ARTID suggests several studies, more academic, as for instance to describe the physical processes occurring when heavy chains hit the ground, to build up a model allowing for simulation of the process.

2.3. Ideas contest *Brain StorMINE*

In order to raise the awareness of young scientists or technicians, ARTID has launched an idea contest named Brain StorMINE. The first version of this contest took place from mid-2000 to June 2002. It is based on the use of INTERNET. The candidates are asked to develop (in a report, but also if possible with a prototype) a new idea of a demining tool. Detailed information about this contest are to be found on our website.

3. Projects for students

During their schooling, students in scientific and technical areas have to carry out a project, giving them the opportunity to test their knowledge on a practical case.
ARTID has contacted several schools teaching engineers and skilled technicians and proposed to students and teachers to work on the new ideas as developed above.
Up to now, more than ten projects have been performed. Most of them are issued from the IUT Mulhouse [4]. They concern all the ideas presented in § 2, except of DEMICHAIN.
Several “products” will be discussed below. They primarily deal with one of the problems of the deminers: prodding in hard soil.

3.1. Force sensitive prodder

Fig. 2: force-sensitive prodder

This project has been developed by Céline ROTH and Grégory JOST. It consists in a prodder whose needle is held by a spring. When the deminer pushes on the handle to force the prodder to penetrate into the soil, the spring is

compressed and a part of the handle indicates the strength of the applied force. This meters the force and allows the deminer to control it and to keep it under a dangerous level.

3.2. Rotating prodder

(Project of Alexandre LE-BIGOT and Olivier HELLIN). The idea of facilitating the penetration of the prodder by putting a milling tip on the prodder and by rotating it in order to drill into the soil has already been studied [1]. Here, the set-up was simplified assuming that the loosened soil occupies less volume that the original soil.

Fig. 3: rotating prodder

3.3. Water prodder

(project of Nicolas HOUILLON and Marco DOS SANTOS) This set-up allows for inserting water at the tip of the prodder in order to locally moisten the soil and to facilitate the penetration of the needle. The water flow rate depends of the force exerted on the prodder: when the soil is hard, the deminer increases the force and the water flow increases, making the penetration of the tip easier.

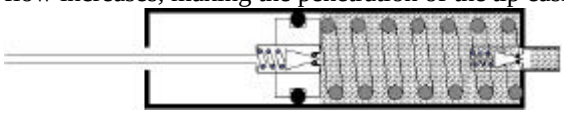

Fig. 4: sketch of the water prodder

3.4. Other projects

The other projects deal with several phases of manual mine clearance.

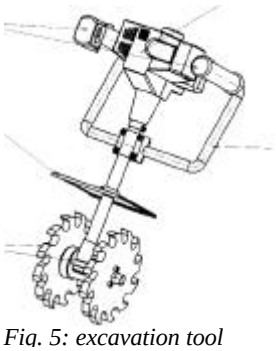

Fig. 5: excavation tool

Vegetation clearing: two projects consist of using common motorized tools for gardeners, as for instance edge cutters and mechanical clearing devices.

Improvements have been fitted on these devices: a detector allows for seeking the trip wires and the cut vegetation is mulched and evacuated by a fan for cleaning the treated area.

Metal detector: one project consists of mounting the metal detector on a small scale car (1/8 for instance) driven by a thermal motor, for increasing the checked domain.

***Excavation*:** In this domain, two proposals, also adapted to the hard soil case, are given here. The first one consists of a circular type of saw powered by an electrical motor, which extracts a cylinder of ground containing the APL.
In the second one (Daniel JECKERT and Raphaël BITTIGHOFFER), two saw-drills are fitted on a small gasoline motor of an edge-cutter and can dig a small ditch 10 cm in depth around the APL (Fig. 5).

3.5. What to do now ?

All these projects are very far from the field. However, it is already time to check with deminers if the ideas presented may be of interest to the field. Therefore, they have to be brought to the knowledge of the demining community.

4. DEMICHAIN

Jacques DEMICHELIS found out that heavy chains dropped on the ground deliver high energy and high pressures, which in turn can trigger the APL. He joined ARTID, who began to study and develop this idea. This gave rise to the DEMICHAIN project.

4.1. Description of the DEMICHAIN system

A web of heavy chains (about 10 kg/m) is mounted in a frame ; the weight per unit surface ranges from 150 to 250 kg/m². DEMICHAIN is fixed on a crane equipped with a free fall winch. A free fall of several meters (4 to 6 m) delivers a mechanical impulse in the ground which is expected to trigger all types of landmines. At the same time, the vegetation is crushed. The chains are likely to resist the blast of the explosion.
Two types of arrangements of heavy chains have been used: in the first one (vertical), bundles of chains are suspended at the knots of a 2D array of chains; in the second one (horizontal), both ends of the chains are fixed at an horizontal square frame, in such a way that all chains are parallel and adjacent.
While the first arrangement is more convenient for very uneven grounds, the second one presents a more uniform distribution of the generated forces. The kinetic energy (≈10 000 J/m²) is coupled to the ground for a short duration, generating high mechanical impulses.

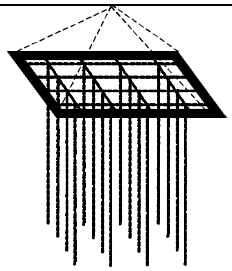

Fig. 6: DEMICHAIN 1, vertical heavy chains

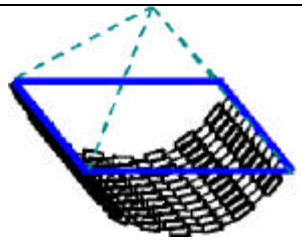

Fig. 7: DEMICHAIN 2, horizontal heavy chains

A direct hit on the triggering device of an APL lying on the ground, or of a trip wire, produces the detonation of the APL. If the latter is buried in the soil, the links of the chains penetrate into the soil (if this last is soft) and release part of the kinetic energy into compaction of the soil. Most of the energy propagates in-depth in the form of a "pressure wave", which triggers the landmines.

4.2. Measurement of the effects

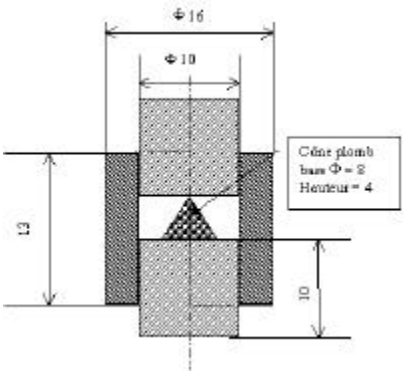

Fig 8: force probe

In order to evaluate the efficiency of this concept, tests on real mines must be carried out (and this will be done as soon as possible).

However, before performing these final tests, a knowledge of the forces generated by the free fall of a DEMICHAIN device will help to correctly dimension the parameters of the mount.

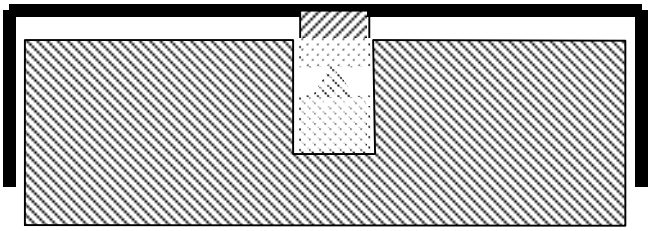

Fig. 9: mine-like measurement set-up

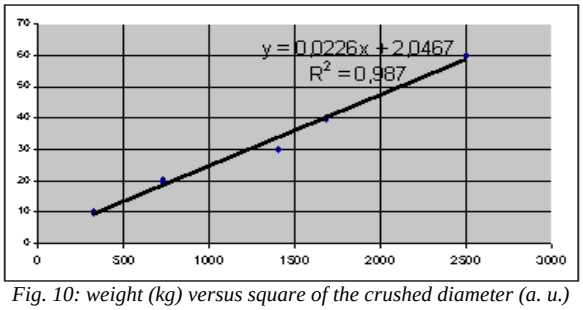

Fig. 10: weight (kg) versus square of the crushed diameter (a. u.)

"Crushers" are devices measuring the mechanical impulse released by a fast phenomenon by the permanent deformation of an item made of a plastic material. For our problem, we have chosen to use small cones made of a soft lead alloy. These cones are inserted in a hammer - anvil steel device (see Fig. 8).

The force probe is inserted in a mine-like container (Fig. 9), which diameter is 80 mm. If it is buried into the soil, it is wrapped by a fine plastic sheet, which prevents the soil from penetrating between the cover and the body. The crushed surface is proportional to the mechanical impulse exerted on the anvil.

The set-up shown Fig. 9 measures the mechanical impulse received by the whole surface of the device. Another arrangement exhibits a reduced pressure plateau (4 cm in diameter).

A calibration using weights ranging from 5 kg to 50 kg was carried out, showing that the diameter of the crushed surface is significant in this range of forces (Fig. 10).

4.3. Testing DEMICHAIN

First tests: 1.5 m² device on real grounds

The first tests were carried out in the CORBIERES hills, end of February 2002.

Fig. 11: DEMCHAIN 1 during the first test program

The first version which was tested has a size of 1.5 m², a total weight of 230 kg, and 16 vertical 10 kg/m chains 1.7 m in length. A small excavator was used to lift the device and a rotation of the bucket releases the free fall of DEMICHAIN. The height of the fall varies from 1.7 m (lower part of the device) to 3.5 m (frame).

Force probes were placed on the ground for several tests. The results exhibit a broad dispersion, resulting from an uneven distribution of the vertical chains on the ground.

Fig. 12: DEMICHAIN 2

However, the mean value of the measured diameters of the crushed cones is equivalent to the diameter generated by a 20 kg weight, which is larger than the force needed to set off the APL.

Several other tests have been performed, and their conclusions are summarized here.

The device works well on force probes located on the bottom of a ditch.

Other chains arrangements have been tested, as for instance the DEMICHAIN 2 parallel horizontal chains, which gives a more even distribution of the forces.

The resistance of the device to explosions has been checked using up to 400 g of explosives. Except for a deformation of a part of the metallic frame, the chains behaved well.

Several tests have been made on bush. The chains crush the vegetation, the links reach the ground, the crushed bush lies on the ground. It is possible that a part of the kinetic energy is absorbed by the vegetation during a first fall. With a second fall on the crushed vegetation, the APL will receive the full energy of the system and will then be triggered.

Analytical parametric study

A small device (50 x 50 cm²) has been recently set up under a shed. The 40 kg of chains fall on a 1 m² size, 40 cm deep soil bin. The purpose is to carry out parametric studies on the variation of the forces with:

- Depth of the mine in the soil
- Height of fall of the chains
- Number of falls on the same force probes
- Time-dependant variation of the pressure
- Density of chains

Fig. 13: analytical test set-up

One of the first tests was to perform several free falls on the same probes. It shows that the crushed surface on the cones increases with the number of falls: after three falls, this surface increases by a factor of 2.

This results from the fact that our test device is not really a force probe, but an impulse measurement device. Successive falls on the same probe increase the area of the crushed surface. In several triggering systems (as for instance in the PMA1 landmine), this cumulative effect increases the likelihood of triggering the explosion.

Other tests have been performed on probes introduced in different depths under the surface. Results are shown in Fig. 14. For the blue series, the probes are located just

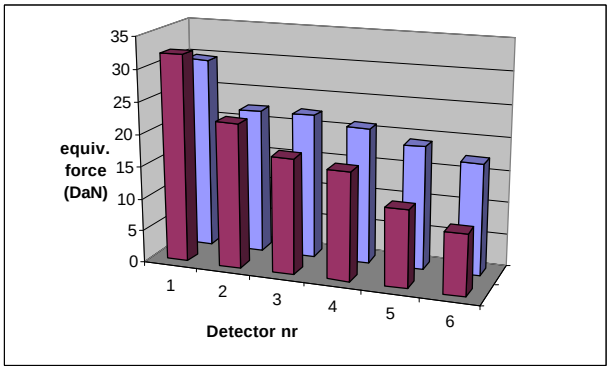

Fig. 14: Mechanical impulses for APL near the surface or buried in-depth

under the surface, whereas they are about 15 cm under it for the red series. They show that the mechanical impulses (graduated in static forces producing the same crushing) do not decrease significantly in-depth. It can be also seen that the measures are rather dispersed. Careful investigations are needed to study the rather large dispersion of the measured impulses.

4.4. Advantages

Fig. 15: DEMICHAIN2 on a ditch

Types of grounds

This system can be easily adapted to the morphology of the ground which has to be demined. If there are holes,

ditches, humps, small rocks, barbed wires, slopes, the system can be easily used or adapted.
The upper layer of soil is not pulverized and is unaffected for agriculture. DEMICHAIN can be employed on roads or trails.

Vegetation
A free fall of the system pulverizes the vegetation, provided the bush is not too dense. It would be necessary to make several free falls on the same surface, the first ones crushing the bush and the last ones triggering the APL.

Types of mines
It must be carefully checked if all types of active landmines are triggered by this system. In certain cases, DEMICHAIN can be adapted in order to deliver short duration impulses, or longer impulses (which may be required for triggering mines like the VS50, which has a pneumatic delay to avoid being setting off by an explosion).

Antitank landmines
The set off of an antitank landmine triggered by a magnetic mass is likely to occur during the free fall of the chains, which are a large mechanical mass. A careful investigation of the behavior of DEMICHAIN falling on antitank landmines must be performed, because DEMICHAIN must trigger all antitank landmines and also survive the setting off of an antitank landmine

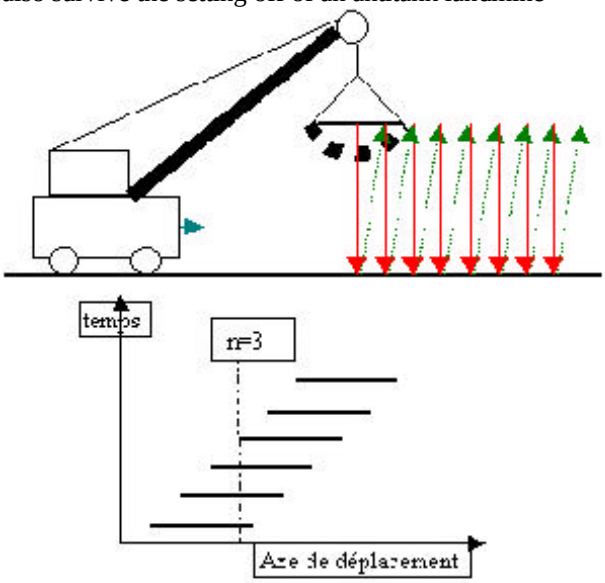

Fig. 16: DEMICHAIN on a continuous moving carrier, with 3 free falls on each place

It can be moved on the ground to trigger all trip wires and position-sensitive APL.

System
DEMICHAIN is a **tool** which has to be lifted over the ground to be cleared and then dropped by its own weight ; the carrier needs only to be able to lift and then to release DEMICHAIN in a free fall and to be lightly armored (as is usual for demining tasks). The carrier and DEMICHAIN are coupled by a cable. In case of a strong effect on DEMICHAIN (explosion of a large landmine), this does not affect the carrier, provided that the distance between the chains and the carrier is large enough.
This carrier can be any type of vehicle in use in civil engineering, readily available on the demining sites, and needs to be equipped with a free fall winch.

Flexibility
DEMICHAIN consists of a web of heavy chains (about 10 kg/m) on a frame ; the weight per unit surface ranges from 150 to 250 kg/m². The dimension of the frame and the arrangement of the chains can be adjusted to the requirements of the work to be done as well as to the available carrier. It is very **flexible**.

Costs
Chains are cheap. Mounting them in a frame can be carried out on every demining site. Maintenance is simple, it constitutes a very homely tool. No patent is registered on this device.

4.5. Tests with real mines

In a few months, the opportunity to carry out a first series of tests of the DEMICHAIN system on real APL will occur. A system with a realistic size (3 m X 3 m) will be built and tests will be made on blast mines, buried under different heights of soil. This test program will be performed in the ETBS organization, in BOURGES.

4.6. Demining with DEMICHAIN

Use of the DEMICHAIN system
As compared to other mechanical demining systems, DEMICHAIN is a “pulsed” system, which works on a given surface in one fall (or a limited number of falls). However, each fall must be prepared by a lift sequence, and the whole process is discontinuous. Therefore, the system must be operated in a quasi-continuous way, linking a succession of lifts and falls, the carrier moving continuously. The speed of this carrier can be adjusted so that every point of the surface will be affected by several falls, increasing the efficiency (Fig. 16).

Comparison of DEMICHAIN with other systems

The main difference of DEMICHAIN principle with the flails consists in the area of action of the mass.
For the flails, the hammers work along a straight line which moves continuously. The resulting mechanical impulse in the ground varies inversely proportional to the depth. In comparison, DEMICHAIN falls over a whole surface, yielding a flat pressure wave which decreases in-depth only by losses, like compaction.
In order to keep a continuous circular motion of the flails, the angle of attack of the hammer with the ground (Fig. 17) must be shallow and the vertical component of the exerted force (which triggers the landmines) is small as compared to the horizontal component, which produces the unwanted effect of pulverizing the soil. This pulverization effect alters the upper layer of the ground and may greatly affect its agricultural capacity.

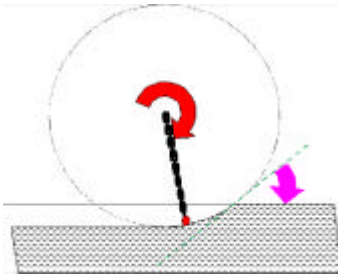

Fig. 17: motion of the hammer of a flail

On the contrary, DEMICHAIN exerts only a vertical component, which produces only a certain compaction of the soil (if this is loose), but does not alter the structure of the ground. It simulates the forces generated by a person, which the landmines are built to be triggered by.

4.7. How to bring DEMICHAIN to the field ?

A lot of studies and tests have to be done before DEMICHAIN will be qualified to perform mine clearance.
The first sensitive point will be to determine which type of chains, which arrangement of the chains, which operation mode will guarantee that all the surface to be demined will receive the appropriate hits for triggering all active mines?
Another question: how to reach and to guarantee the overall efficiency of the system (the famous >99,6%) ?
A general call for comments and for propositions of co-operation is launched hereby: join us on the website www.artid.org.

5. Conclusion

ARTID wants to be a “mine of ideas” and to do research and development, maybe not of sophisticated technologies, but rather of the simple tools which deminers need.
We would warmly welcome any remarks, comments, suggestions and helps of both deminers and scientists. We are eager to build up any kind of co-operation, on a non-profit basis.

Acknowledgement

I wish to thank Jacques DEMICHELIS, who brought his idea to ARTID and helps in the development of it.
Many thanks also to Bernard SCHLEGEL, Professor at the IUT of MULHOUSE, and to Maurice SAROCCA, Director of the GMP Department of the IUT MULHOUSE, for raising the interest of their students for demining problems.

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