Machine-Integrated Magnetic Collector: Design and Testing

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Motivation

- Mechanical systems can greatly increase the effectiveness, safety, and efficiency of mine clearance operations.
- They aid in clearing/releasing large areas more quickly and safely than using manual demining alone.
- Typically, national standards require some form of manual follow-up
  - Ranges from visual inspection to full manual clearance sometimes with a requirement to remove all metal debris.
  - Follow-up can be painstakingly slow when there is a high level of metal contamination
Background – Previous Testing

• The GICHD has previously tested a combined flail/magnet system using a Bozena-5 that towed a permanent magnet

• An operational assessment was conducted in Azerbaijan between January and March 2010

• The towed magnet did pick up some ferrous debris but, overall, recovery effectiveness was very low

Purpose of Most Recent Testing

Evaluate the feasibility and effectiveness of using a truly machine-integrated magnetic collector (MMC).

The goal of testing was to determine if:

• Metal debris could be collected during flailing operations;
• The amount of collected debris could increase the efficiency of demining operations by speeding up manual follow-up
• Collected debris could be utilized to support technical survey operations.
Machines used in testing:
- DOK-ING MV-4 with flail working tool

Test Location:
- A prepared lane at DOK-ING’s main production facility in Zagreb, Croatia.
- Test lane 45m x 4m x 0.5m filled with relatively fine river-bed soil/sand

Test Assets: Magnetic Collection System
- Magnetic Roller:
  - 220mm in diameter and 1740mm wide)
  - Installed directly behind flail head
  - 242 neodymium permanent magnets with field strength of 0.17 Tesla on dorsal/ventral faces and 0.34 Tesla on lateral faces

- Magnetic Catch:
  - 500mm tall and 1740mm wide)
  - Installed in place of chain guard
  - 175 neodymium permanent magnets with field strength of 0.2 Tesla on sheet surface

- Magnetic Sheet:
  - 500mm tall and 1740mm wide)
  - Installed in place of chain guard
  - 175 neodymium permanent magnets with field strength of 0.2 Tesla on sheet surface
The testing was divided into two separate phases:

1. **Functional Testing:** during the functional tests, the setup and configuration of the magnetic collection system was varied in order to identify the most effective arrangement.

2. **Performance Testing:** the performance testing focused on generating a consistent, significant data set from which debris-recovery percentages could be estimated.
Optimal Collector Configuration

• magnetic roller placed in its lowest position
• magnetic sheet positioned directly behind the roller
• upper catch placed at the front of the flail shield

Performance Testing Setup

Magnetic Collector Setup:
• Magnetic roller - centerline of roller approximately 5 cm above the flail skids
• magnetic sheet - hanging immediately behind the roller

Machine Setup
• working depth approximately 15 cm
• machine speed approximately 1.5 km/h
• flail head speed approximately 450 rpm (50% of maximum)

Test Lane Setup
• Lane was divided into four boxes, each 7m long, with 4m between each box
• Each box was seeded with 68 targets for a total of 272 seeded items for each test.
• Debris was buried to varying depths up to 15 cm
Results

Over 60% of seeded debris was recovered during first 2 passes of machine.

Debris recovery by pass:
- **1st Pass**: 44% (240 of 544 pieces)
- **2nd Pass**: 34% (102 of 304) of the remaining debris
- **3rd and 4th Pass**: ≤ 8% (17 of 202) of the remaining debris
• Light debris (washers, nails, wires), were mostly collected by the roller
• Larger/heavy debris (medium and small slugs) mostly collected by catch
• In general, all three components contributed significantly to recovery

Results – Debris Recovery Location

Results - Qualitative Test

• A purely qualitative test was performed in a topsoil area adjacent to the facility that was known to be contaminated with ferrous material.
• A section ~2m in length was flailed to a depth of 15 cm.
• Several handfuls of metal debris, ranging from small particles to large chunks, were collected.
• The result suggests that the configuration is likely to be effective in soil conditions other than dry, loose sand.
• It also shows that magnets are effective at capturing ferrous debris that is covered with substantial oxidation and other surface contamination, conditions that are likely to be found in the field.
Why was the integrated magnetic collector more effective?

• The testing showed that the action of the flail hammers tended to deposit metal debris in the loose soil behind the flail head and the majority of the debris remained below the surface of the flailed soil.

• Permanent magnets do not typically have sufficient strength to pull material through any appreciable amount of soil, which is why collectors that are pulled behind machines have very low effectiveness.

• In order to increase the collection, it is necessary to increase the percentage of the soil that comes into direct contact with a magnetic surface.

Debris removal

• It was relatively time-consuming to hand remove debris from the magnetic surfaces

• While this was acceptable for testing, during actual clearance operations in heavily contaminated areas, metal debris accumulation may be so rapid that the magnets may need to be cleared at frequent intervals

• Debris removal method and frequency needs to be a focus of any operational assessment
Machine-integrated magnet can be effective at collecting ferrous debris

- Although the testing was conducted in dry, loose sand using seeded debris, collection % is sufficiently high to suggest that machine-integrated magnets could dramatically reduce the amount of ferrous material remaining in the field following flailing operations.

- Reducing metal detector indications during follow-up will dramatically increase deminer speed, which improves overall operational efficiency

- Results also suggest that machine-integrated magnets can provide beneficial data on minefield contamination when used during technical survey operations.

It is recommended that an operational assessment is done in a more representative field environment to measure the actual impact on manual follow-up

Conclusions – Collector Optimization

The flail shroud could be designed to efficiently guide the soil deposited behind the flail head to the magnetic collection area.

- A ramped surface immediately behind the flail head (in place of the roller) would allow soil to be thrown upwards and funneled into channels, maximizing the exposure to magnetic surfaces.

- A larger upper catch would further improve collection effectiveness.

- In addition, any integrated magnetic collector must include provisions to easily clear debris from the collection surfaces.
QUESTIONS?