MineWolf Flail and Tiller Machines: Testing the Differences between two Demining Technologies

MineWolf is the first demining concept, manufactured in Germany by *Arthur Willibald Maschinenbau GmbH (AHWI)*, that overcomes the limitations of flail and tiller machines by combining the advantages of both systems. Extensive tests with live anti-tank and fragmentation mines were carried out at the German Army proving ground to determine whether the MineWolf meets the operational requirements for humanitarian demining. The aim was to discover the effects of detonations on the operator, MineWolf, clearing tools and cabin, and to work out instructions for reparability.

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The MineWolf is a mine-clearing device developed especially for humanitarian mine-clearance. It is used for area clearing and clears up to 2,800 square metres per hour (3,349 square yards/hour), allowing for fast quality control on a demined area. The MineWolf system consists of a fragment-proof AHWI crawler tractor, a protected driver's cab and a mechanically driven mine-clearing device. Both a flail device and a tiller are available.

The flail is likely to initiate or destroy anti-tank mines. With the tiller, the remains of AT mines, the fuzes and all AP mines left are crushed or initiated. Clearance depths of up to 30 centimetres (11.8 inches) in the soil are achieved with the tiller. Live AT mines, including DM 21, TM 57 and TM 62[1] mines, have been cleared.

Figure 1: The MineWolf in action.
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The MineWolf was subject to extensive tests with live anti-tank mines, undertaken in Meppen, Lower Saxony, Germany, at the Army proving ground. The tests were conducted with a fully operational MineWolf using both types of mine-clearing devices (i.e., flail and tiller). The vehicle was operated by both remote- and operator-control. During four tests an instrumented Anthropometric Test Device (fully instrumented test dummy) was placed on the driver's seat. The measured values had to be evaluated to view possible risks to the operator during mine clearance.

A total of six remote clearance tests were conducted against live anti-tank mines. Four of these tests led to the detonation of the cleared AT mines and thus to measurable results that could be used to analyze the damage to the demining tool and the MineWolf. Two tests each with the two mine-clearing devices (flail and tiller) were conducted against one DM 21 and TM 57 AT mine each. In order to be able to rule out uncontrolled movements of the MineWolf, it was secured to a recovery tank during the tests by a steel rope. The mines to be cleared were laid one by one centrally and offset in front of the clearing device. After a detonation, the vehicle was stopped immediately and the effects were documented. If required, the clearing device was repaired prior to the next test run.

Test schedule. The testing of the method and timing were conducted in the following order:

1. MineWolf remote-control tests with flail and tiller and a fully instrumented test dummy (ATD)
2. AT mine tests (DM 21, TM 57 and TM 62)
3. Biomechanical tests with an ATD
4. MineWolf manned tests with flail and tiller using three different operators
5. Fragmentation mine tests (DM 31)
6. Tests with three detonations without repair to investigate quality of demining operations

Figure 2: A fully instrumented dummy.

Figure 3: A typical mine crater after clearing a TM 57 or TM 62 AT mine.

Recording. Tests performed on the MineWolf included the following:

- Video recording from outside
- Video recording inside the driver's cab
- Blast pressure measurement inside the driver's cab
- Acceleration measurement inside the driver's cab
- Measurements taken by the ATD
- Pictures of damage to flail and tiller
- Pictures of flail and tiller repaired

Remote-control Tests

Tests performed remotely using the flail and tiller apparatuses were conducted with AT mines TM 57 (6.5 kg TNT), TM 62 P3 (6.5 kg TNT) and DM 21 (5 kg TNT).

The remote-control tests were necessary to record the physical effects and potential risks for the operator and MineWolf. These effects were measured by means of an instrumented test dummy, in order to be able to perform a human-related biomechanical assessment.

To record the measured values, an ATD was placed on the driver's seat and was fitted with various sensors to measure human-relevant impact information.

A total of six remote clearing tests were conducted against live AT mines. Four of these tests led to the detonation; two of the mines were crushed. Little or no flail repair work was necessary after the unmanned test. Damage to the tiller device is shown in Figures 4 and 5. The repairs shown in Figure 6 are mainly welding work, which could be performed on-site the same day.

Figure 4: Damage after clearing TM 62 AT mine.

Figure 5: Damage after clearing TM 57 AT mine.

Figure 6: Tiller repaired.

Biomechanical Results[2]

The remote-control tests were a necessary prerequisite to performing the manned tests. The results of the biomechanical assessment and the blast-pressure measurement had to rule out any hazard to the operator when clearing live anti-tank mines.

The results of the biomechanical measurements with the fully instrumented dummy were within a very acceptable range. This statement applies to the examined AT mine types DM 21, TM 57 and TM 62 and refers to mine detonations that occurred in the area of the clearing device.

The assessment of the blast pressure load in the driver's cab showed that the blast pressure load is very low in the cabin and damage to the ears is not expected if adequate ear protection is worn.

In summary, it can be stated that the operator in the driver's cab of the MineWolf is not subjected to an intolerable risk of injury by the explosion of a DM 21 or TM 57 anti-tank mine if the mine detonates in the area of the mine-clearing device (both types were successfully detonated during the test). The risk of injury is very low and far below the allowed limits for mine-protected vehicles of the German Army, which are based on international standards. Even in the case of repeated successive loads, no serious consequences are expected. Temporary light disturbances like headaches or muscular pain, however, cannot be excluded.

During the four tests, all human-related criteria were tested to the extent that they could be evaluated.

Due to the principle of operation of the MineWolf, the detonation of a mine underneath the vehicle hull or a track during mine-clearing is not very likely but cannot be ruled out. Based on the available measured data, the effects that an explosion underneath the hull or a track would have on the vehicle and the mounted operator cannot be assessed. It is definitely possible, however, that this would lead to critical loads. It is therefore recommended that these cases be investigated—e.g., detonation underneath the vehicle hull or a track—by static contact detonation tests to ensure the highest degree of safety for the MineWolf operator.

Figure 7: Damage after clearing a TM 62 P3 AT mine.

Manned Tests

Test personnel conducted the manned tests with the AT mines TM 57 (6.5 kg TNT) and TM 62 P3 (6.5 kg TNT).

As the biomechanical measurements with the fully instrumented dummy did not show any risk, manned tests were approved by the firing controller.

Tests were tightened by clearing mines off-centre—detonation occurred on the left- or right-hand side of the demining tool with both flail and tiller—to find out whether the drive train would suffer irreparable damage and whether the demining quality would be affected.

The three consecutive manned tests, using the tiller to clear live AT mines, were carried out, without repair after each detonation. This was to find out whether tiller, drive train and the quality of demining were still acceptable. Two typical examples of consecutive tests, taken from the German Federal Armed Forces Technical Center for Weapons and Ammunition's *Final Report: MineWolf Clearing of Live Mines*,[3] are described below.

The AT mine TM 62 P3 detonated on-site upon contact with the mine-clearing device. The hit occurred approximately 0.5 metre (1.6 feet) off the left-hand side of the device.

Figure 8: Damage after clearing a TM 57 AT mine.

Figure 9: The operability of the MineWolf was not affected by fragment hits from the AP fragmentation mine DM 31.

Damage to the clearance machine included one worn chisel and two bent cross-spars (the cross-spars, or strut braces, were deformed by an area of 30 by 130 centimetres [11.8 by 51.2 inches]). The damage seemed to be minor as compared to the previous tests with the TM 57. The mine crater in the ground was of normal size. The machine could continue clearing despite the damage it suffered.

The TM 57 also detonated on-site upon contact with the mine-clearing device. The hit occurred approximately 0.2 metre (0.66 foot) off the right-hand outer edge of the tiller.

Damage to the Minewolf included one outer tooth that was bent outwards and four cross-spars that were deformed by an area of 30 by 130 centimetres (11.8 by 51.2 inches). Two cross-spars were torn off at the end of the weld seam. The depth-control device was bent outwards but still functioning. After some provisional work lasting about 15 minutes, a test run with the tiller was performed. The tiller performance was still sufficient. The mine-clearing tool and drive train with power bands were still in repairable condition. The clearing quality was still good as shown by the ground appearance.

Fragmentation Mine Tests with AP Mine DM 31

Two contact detonations with AP fragmentation mine DM 31 were performed. The mines were placed on solid ground 10 metres and five metres (32.8 and 16.4 feet) from the tiller on the left-hand (fully armoured) side of the mine-clearing vehicle and the mine fuze DM 56A1B1 was initiated by a detonator placed on top of it. After approximately two seconds, the explosive device of the mine jumped from the launch box and detonated about one metre (3.3 feet) above the ground.

At a 10-metre (32.8-foot) distance, there were only a few fragment hits on the equipment. There were only small marks on the six-millimetre (0.24-inch) armour plates; there were two dents in the three-millimetre (0.12-inch) instrument box, one hit was found on the cabin glass. At a five-metre (16.4-foot) distance, the fragment hits were more severe: slight dents in the six-millimetre (0.24-inch) armour plates. No fragment penetrations through the protected operator cab were detected. The operability of the MineWolf was not affected by the fragment hits.

Final Summary of Results

The complete and final summary of results from testing is taken from the German Federal Armed Forces Technical Center for Weapons and Ammunition's Final Report: MineWolf Clearing of Live Mines.[3]

The mine-clearing MineWolf system with both accessory devices is suitable for clearing live anti-tank mines. The use of the flail device for clearing live anti-tank mines caused only minor damage that could be repaired with a limited effort or did not necessitate any repairs at all. The use of the tiller against live anti-tank mines, however, resulted in considerably greater damage, which could only be repaired with a substantially greater effort than those caused with the flail. The repairs, mainly welding work, could be performed on-site that same day.

The load on the operator by mine detonations is within the admissible and acceptable range. This finding is a result of the biomechanical evaluation of ATD dummy measurements and through questioning of the three operators. It applies to the examined mine types DM 21, TM 62 and TM 57 and only refers to mine detonations that occur in the area of the clearing device.

In addition, taking into account the results achieved by MineWolf during operations in Bosnia-Herzegovina, Croatia and southern Sudan, these results confirmed that the new concept is the basis for developing the demining process from ground preparation to mine clearance and shows improvement over other methods and systems with regards to effectiveness, quality and cost.

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