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Assessment of the technical condition of mines with mechanical fuses

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Abstract

Contemporary armed conflicts reveal that the use of effective mine barriers has a significant impact on the course of hostilities. Therefore, the Polish Armed Forces selected reliable and effective explosive ordnance as a priority, both newly-acquired material and those currently in operation. For this reason, among others, strict supervision over the technical condition of mines is exercised, in particular during their long-term storage. The reasons behind the increased mine unreliability may include physical and chemical changes in the construction materials used (corrosion, deformations, loss of strength properties), deterioration of the physicochemical properties of the main charge, booster and primer-detonator, inadequate technical condition of the safety components, or the failure of mine fuse mechanisms. In order to assess the mine's operational reliability, each mine fuse subassembly is examined and then a check of the entire assembled mine is performed. This requires proper planning of the full test cycle and the use of inspected and calibrated measuring devices and test stands enabling the precise adjustment of mechanical and climatic stress parameters.

Keywords: mines, mechanical fuses, technical condition assessment

1. Introduction

Mines, due to the low production and operating costs (inc. storage, transport and use), the relative ease with which they can be used, and the high effectiveness are very often employed in warfare, in various tactical situations, such as delaying the enemy's attack, defence of own forces, transition to counterattack, etc. The experience of armed conflicts reveals that properly planned and emplaced mine barriers, combined with the high efficiency of the mines used, have a beneficial effect on the course of the war effort. It is due to this fact that the priority in the Polish Armed Forces is to have at their disposal reliable and effective mines and mine barriers, both in relation to the newly-acquired ordnance and those which have been in operation for years, as the reliability of the material has a direct impact on the technical readiness of combat systems, and thus on the combat readiness of the military unit (Folkin, 1973; Center for International Stabilization and Recovery, 2009).

For this purpose, the technical condition of mines is subject to detailed supervision at every stage of the material life cycle: from research and development, through production and storage (stockpiling) to the use on the battlefield. At the storage stage, this is achieved by carrying out periodic diagnostic tests, using the capabilities of research centres with proper technical acumen. The publication (Fonrobert, 2011; Chant et al., 2005) underlines the significance of information obtained from the users of explosive ordnance regarding irregularities which they had observed during training or their combat use (jamming mechanisms, partial detonation of explosives, etc.). Such data can be an additional, important element in making decisions about the technical condition of mines. Immediately following production, mines are characterised by high efficiency. However, long-term storage in warehouses means that their operational reliability may be impaired. This is due to changes occurring in the construction materials (corrosion, deformation, drying out, loss of strength properties – in case of plastics etc.), as well as physiochemical changes in explosives as a result of environmental factors, including fluctuations in temperature, atmospheric pressure and humidity in warehouses. Therefore, during research, great attention is paid to identifying those mine batches whose efficiency has been adversely impacted (deteriorated) as the result of the passage of time. Experience to date shows that the prevailing reasons for the increased mine unreliability include deterioration in the reliability of mechanical safety mechanisms, impact/percussion mechanisms, primers and physicochemical changes in the mine explosives themselves.

2. Issues encountered in the life-cycle assessment of mines with mechanical fuses

Depending on the design of the mine, and in particular the construction of its fuse, the course and type of mine testing is subject to detailed procedures. The purpose of this planning is to determine the scope of tests and their order, so that it is possible to fully assess the technical condition of both mine components and the entire mine. For this purpose, firstly each component is individually examined (e.g. additional safety device during transportation, arming delay mechanism, interruption in the train of fire) and then the check of the entire mine is performed.

3. Assessment of technical condition of mines with mechanical fuses

During the assessment of the technical condition of mines with mechanical fuses, special attention is be paid to the assessment of the technical condition of the fuses themselves. They are in fact the components of major impact on the operational reliability and operational safety of the mine, and in particular its employment (mine emplacement).

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The effectiveness of mine fuses, depending on their design, is assessed on the basis of tests which include, among others, the following checks:
- appearance, relative to the presence of corrosion or mechanical damage (e.g. dents or chipping of structural elements);
- correct seating and good technical condition of additional safety devices during transport (e.g. shear pins);
- operating times of delay fuse mechanisms delaying the arming of fuses;
- verification of the fuse design – if it is hermetically sealed;
- vibration resistance;
- resistance to changes in ambient temperatures;
- correct operation of the explosive train (transfer of detonation from primer-detonator to booster).

Final mine surveys include verification of:
- physicochemical properties of the mine explosive;
- comprehensive operation of the mine.

Detonation of the mine during the comprehensive operation test means that the fuse safety features and the explosive train have been correctly activated (transfer of detonation from the booster to the main charge took place).

Performing the abovementioned examinations and checks is crucial in the correct assessment of the mine's technical condition. If technical parameters are found to exceed the admissible values provided in the design documentation, technical conditions or defence standards, it is an indication of the possible deterioration of the mine.

The following sections present selected tests performed on mines equipped with mechanical fuses.

3.1. Verification of the correct operation of MPB-ZK off-route mine with contact fuse

The tests of correct functioning of the mine fuse of the MPB-ZK mine include checking its pressure sensors. This is done via moving a wheel simulating a combat vehicle driving over the mine fuse. A special test stand developed at the Military Institute of Engineer Technology (WITI) in Wroclaw (Figure 1) is used to test the correct functioning of pressure-operated fuses (RWU.070345). The station includes a frame with wheels, which serves as a guide for a carriage with a wheel swinging frame, simulating a combat vehicle load. The wheel frame has a shaft with a hub mounted on it, to which the pressure wheel is bolted. Baskets in which loads are placed are attached to the trolley. Their weight depends on the wheel pressure which is to be obtained. Using a mobile weighbridge, the pressure generated by the pressure wheel on the ground was measured, as determined by the amount and distribution of the cast iron loads.

Testing the correct operation of the MPB-ZK mine fuse is carried out by setting a pressure sensor along the route of the wheel to which a twin-core wire contact

Fig. 1. Contact fuse operation testing device: 1 – frame, 2 – trolley, 3 – wheel frame, 4 – shaft with hub, 5 – pressure wheel, 6 – load basket, 7 – loads. Source: own study

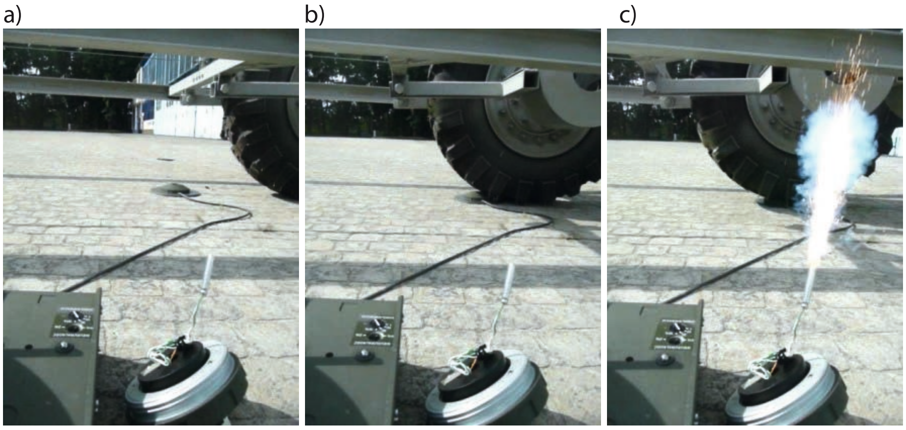

Fig. 2. Stages of testing the contact fuse using the proprietary test stand: a) contact fuse with the pressure sensor, b) wheel moving over the pressure sensor, c) triggering of the mine train of fire of the mine using the ERG-type blasting cap. Source: own study

fuse is mounted. Prior to the test, a practice version of an electric blasting cap (ERG-type) is connected to the contact fuse primer (as a substitution for the ZE standard electric primer). The pressure wheel is moved by winding the rope on a winch located on the frame of the station or via a passenger car hauling the station using a drawbar. Operation of the contact fuse is signalled by the activation of the practice electric blasting cap (the ERG-type) training version of the ERG-type electric detonator. The individual stages of fuse testing are shown in Figure 2.

3.2. Verification of the correct operation of the MWCz-62 fuse

Testing mines with MWCz-62 pressure-operated fuses is carried out in accordance with the approved test methodology (Kubecki et al., 2019). Prior to testing, the booster charge is removed from the fuse and replaced with a mock-up. The casing of an inert TM-62M mine with the fuse is placed on the ground along the route of the pressure wheel of the stand for testing pressure-operated fuses (Figure 1). This is performed in accordance with applicable instructions (Inż. 414/78, 1978; Inż. 572/94, 1994). After the wheel had run over the mine fuse, the fuse was unscrewed from the mine casing and the bottom cover of the mine was also unscrewed in order to carry out a visual assessment of the correct operation of the fuse and M-1 stab-sensitive primer-detonator. The test results were then subjected to analyses and decisions were then made as to how to proceed with the given batch of fuses (e.g. referral for servicing – replacing plastic cams with metal cams). Test results with regard to the force required for the MWCz-62 fuse to perform its function should be consistent with the provisions contained in technical conditions (Nr ChF4.029.047 TU/S).

3.3. Verification of the correct operation of the ZK-1 fuse of the PMK-1 mine

Testing the correct function of ZK-1 fuses with a cocked striker is conducted on a dedicated stand, which was developed by WITI (Figure 3). This test station consists of the main load (6) being suspending on the bolt (8) of the guide (9) and an additional load located on the base with a rod (12). This allows for precise adjustment of the force exerted on the ZK-1 fuse. The MD-5M stab-sensitive primer-detonator assembly is screwed into the threaded hole in the mounting plate, which is then screwed onto the ZK-1 fuse. In accordance with the fuse technical manual, the clearance between the ZK-1 fuse head and the bottom of the main load is eliminated.

A safety clip is pulled out of the ZK-1 fuse from a safe distance using a line. Then, remotely using a wire, the pin is removed from the lug of the main load, which releases the main load and its weight falls unto the head of the ZK-1 fuse. As a result, the ZK cocked striker strikes the MD-5M stab-sensitive primer-detonator causing its detonation.

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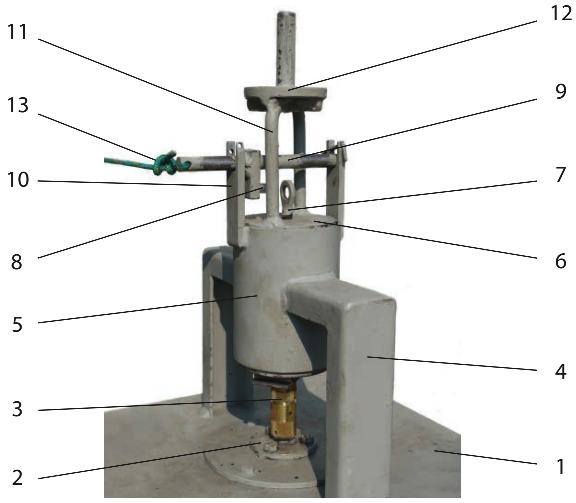

Fig. 3. ZK-1 fuse test station (for PMK-1 mines): 1 – base, 2 – MD-5M primer-detonator mounting plate, 3 –ZK-1 fuse, 4 – support, 5 – guide, 6 – main load, 7 – lug, 8 – bolt, 9 – slider, 10 – slider support, 11 – load support, 12 – base with rod, 13 – line.
Source: own study

Fig. 4. Proper operation of the MD-5M stab-sensitive primer-detonator of the ZK-1 mine fuse as the result of test weight loading
Source: own study

Figure 4 illustrates the detonation of the primer of the MD-5M stab-sensitive primer-detonator, as a result of the ZK-1 fuse impact mechanism operating properly.

Test results with regard to the force required for the MD-5M stab-sensitive detonator of the ZK-1 fuse to perform its function should be consistent with the provisions contained in technical specification (arch. WITI nr 14/09/9).

3.4. Verification of the correct functioning of the MPP-61 mine

MPP-61 mines have plastic casing with a pressure plate containing an additional safety device during transportation. This sort of measure prevents the MUND-62 mine fuse from being triggered when the pressure plate is unintentionally pressed upon (e.g. due to pressure exerted on it by a running soldier). In the case of MPP-61 mines, tests were carried out to verify the strength of the safety pin and the correct operation of the mine both in the laboratory and under field conditions. The Loads imposed during tests should be compliant with the technical conditions for mine production and acceptance (WT-226/Inż).

Testing of the fuse begins with setting the knob on the mine cover to the appropriate position: "O" meaning that the mine is armed or in the "Z" safe position, with the safety device engaged, the mine is unarmed. Then, the MUND-62 fuse is inserted into the fuse well with the ZOD stab-sensitive inert primer-detonator. The test is used to evaluate the proper seating of the MUND-62 fuse in the well (Figure 5). Afterwards, the mine cap is screwed up.

Pressure is applied to the mine cover to simulate the passage of a vehicle and observations are performed on whether the pressure plate has collapsed (Figure 6). The cap is then unscrewed and the ZOD stab-sensitive inert detonator is examined for piercing by the striker in the MUND-62 impact mechanism (Figure 7).

a) b)

Fig. 5. Preparation of the MPP-61 mine for testing the effectiveness of the safety pin: a) MUND 62's impact mechanism with the ZOD stab-sensitive inert detonator, b) assessment of the seating of the fuse in fuse well, using the MPP-61 gauge. Source: own study

Fig. 6. Test of the proper functioning of the MPP-61 mine. Source: own study

a) b)

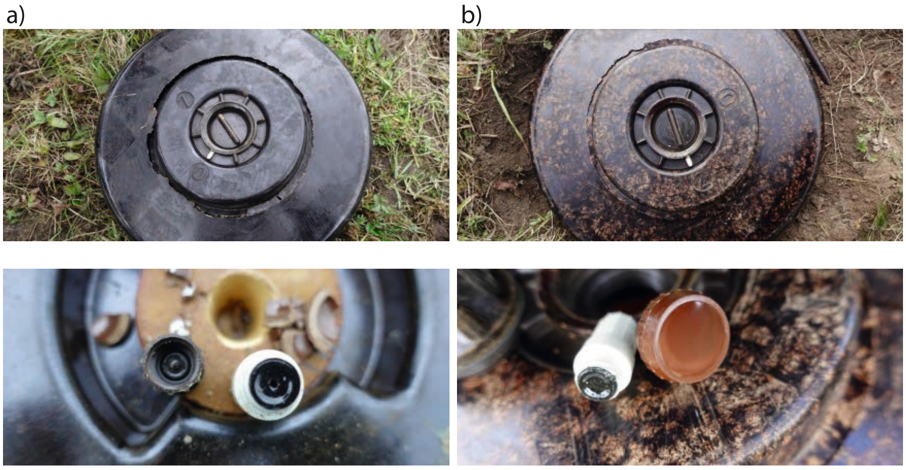

Fig. 7. MPP-61 mines following the load test using pressure wheel: in the "O" (armed) position, b) in the "Z" (safe) position. Source: own study

After the above tests have been performed, the mines are examined. These include the firing chain functioning as required and the course of detonation ensuing correctly.

3.5. Verification of the correct operation of the MUND-62 fuse impact mechanism

The test is carried out on a testing machine (Figure 9). A flat bottom clamp (1) is mounted to the upper mount of the machine, while a holder with the MUND-62 impact mechanism (2) is mounted to the lower mount of the machine. A compression test of the impact mechanism is then carried out until it is actuated.

From each batch, three MUND-62 impact mechanisms are tested. During the tests, what is recorded is the dependence of the deflection of the impact mechanism as a function of force (Figure 8). The analysis of the chart reveals that triggering of the mechanisms took place when the force ranged from 310 N to 430 N. The test results are compared with the requirements contained in the technical conditions for the production and acceptance of the mine (Nr ChF4.029.047 TU/S).

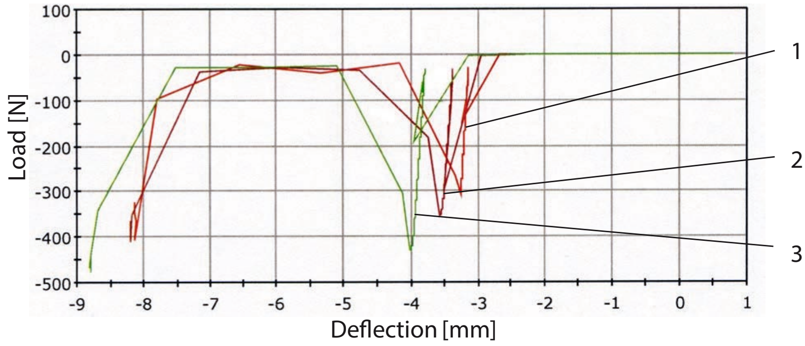

Fig. 8. Graphs illustrating the dependence of deflection as a function of force triggering MUND-62 mechanism (3 trials). Source: own study

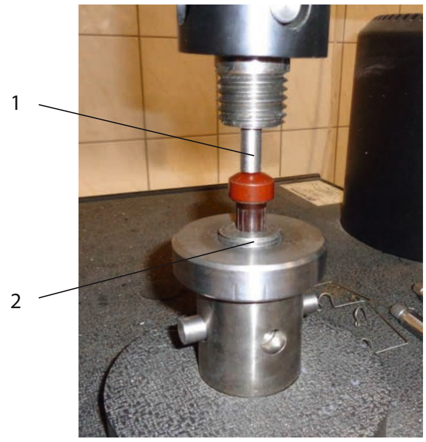

Fig. 9. Stand prepared for testing the triggering force of the MUND-62 striker mechanism: 1 – flat bottom clamp, 2 – MUND-62 mechanism holder. Source: own study

3.6. Verification of the correct functioning of the RO-2 fuse impact mechanism (cocked striker) for the PT-Mi-Ba-III mine

The test is carried out on a testing machine (Figure 10). A punch with a concave bottom is attached to the upper mount of the machine, while the base of the device is attached to the lower mount of the machine, to which the holder with the RO-2 impact mechanism is attached. A shear test of the striker mechanism is then conducted until it is activated.

During the tests, the relationship between the shear force of the striker mechanism head and its displacement is recorded (Figure 11).

What results from the analysis is the fact that the activation of the striker mechanisms occurs within the force range of 790 N to 1100 N. The test results are compared with the requirements contained in the technical specification (arch. WITI nr 14/09/9).

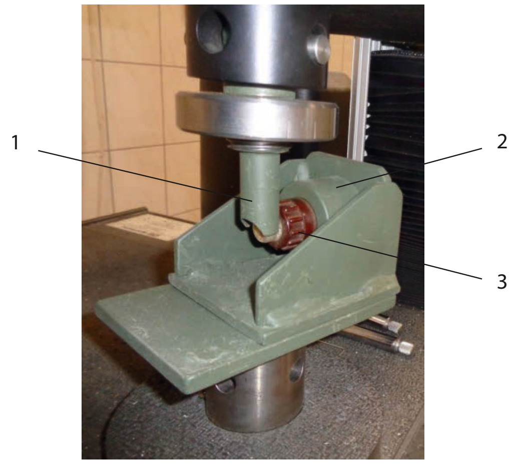

Fig. 10. Stand prepared for testing the triggering force of the RO-2 striker mechanism: 1 – concave bottom stamp, 2 – MUND-62 mechanism holder, 3 – RO-2 striker mechanism. Source: own study

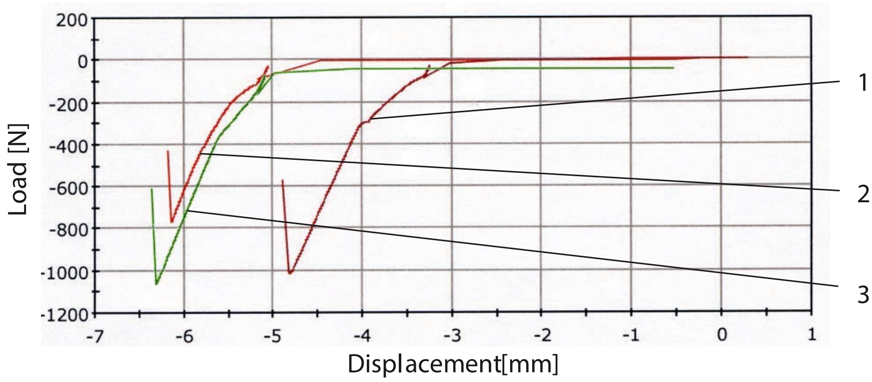

Fig. 11. Graphs illustrating the dependence of deflection in function of force triggering RO-2 striker mechanism (3 trials). Source: own study

3.7. Verification of correct functioning of WPDM-1M tilt-rod fuse of PDM-1M mine

The PDM-1M mine is an anti-amphibious mine with a mechanical tilt rod fuse. It consists of a mine casing, a WPDM-1M fuse, a rod and a ballast plate. It is to be installed in the coastal, near-shore and inland water areas at a depth of up to 2 m and it is employed to combat fighting vehicles and light surface vessels. The proper functioning of the WPDM-1M fuse is tested on a special stand designed for this purpose by WITI. The stand for testing the operation of mechanical fuses (Figure 12) consists of a test stand frame (1) with a set of shields (2), a top shield and a bottom shield (3). They protect the staff against fragments generated by the detonation of the M-1 stab-sensitive primer-detonator after being pierced by the striker. A hook balance (4) is mounted in the upper part of the stand frame (1), , which is used to register the force necessary for the actuation of the tilt rod fuse impact mechanism. A manual cable winch (5) is attached to the stand frame (1), below the hook balance (4). The winch is attached to the fuse rod holder by means of a steel cable (6) drawn through pulleys (7). The use of a system of pulleys enables impacting the fuses with a force in the same direction as in the actual operating conditions for the fuse.

The system of pulleys causes the hook balance (4) to show twice the value of the fuse actuation force, which is taken into account when recording the results. The design of the stand also enables the testing of mechanical fuses for MPR anti-amphibious mines used inland (Figure 12) and tilt rod fuses used in

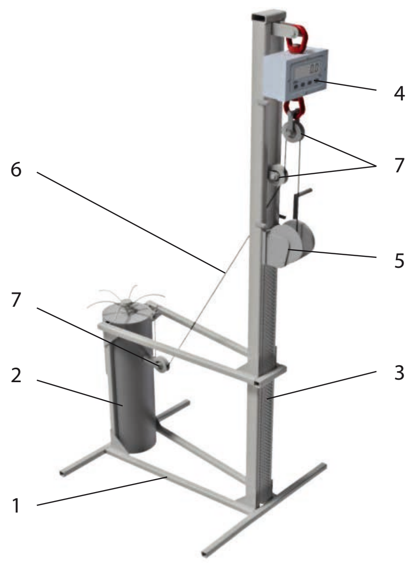

Fig. 12. Digital model of the stand for testing mechanical fuses – view without the top cover, with the mechanical impact fuse attached to the MPR mine: 1 – stand frame, 2 – shield assembly, 3 – bottom shield, 4 – hook balance, 5 – cable winch, 6 – steel cord, 7 – pulleys. Source: own study

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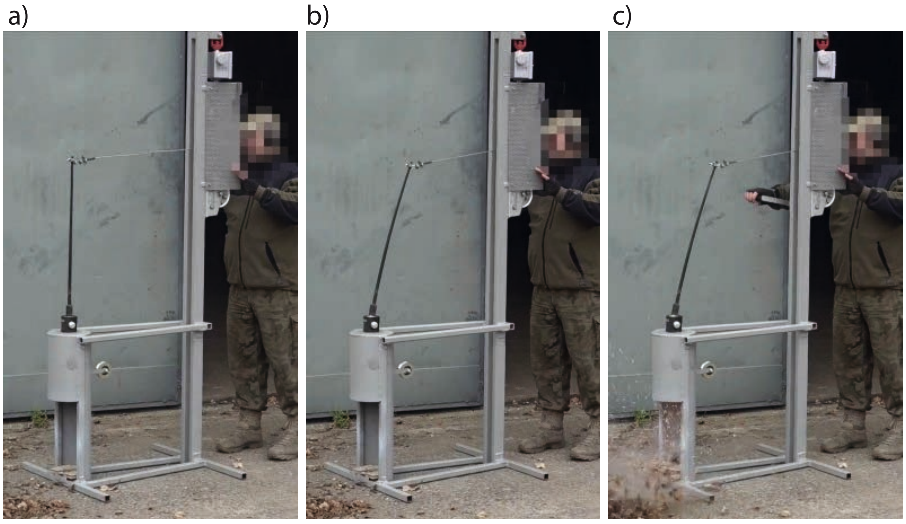

Fig. 13. Individual stages of the WPDM-1M tilt-rod fuse test: a) beginning of the test, b) bending of the rod as a result of force applied, c) activation of the M-1 stab-sensitive primer-detonator due to the action of WPDM-1M fuse impact mechanism. Source: own study

MKU mines which employed shaped charges. The results of the measurements of the force necessary to actuate the fuses should be in accordance with the requirements of the relevant technical specification [WT-0199/Inż; WT-0198/Inż]. Figure 13 shows the various stages of testing the WPDM-1M tilt rod fuse.

3.8. Verification of the correct functioning of the firing chain and the course of detonation of the TM-62M mine with the MWCz-62 contact fuse

Testing the functioning of pressure fuses by driving a test stand wheel over them provides vital information on the technical condition of the fuse safety features and mechanisms. However, with regard to the full assessment of the explosive device itself, the most important check concerns the correct functioning of the mine's firing chain and the course of its detonation. The Military Institute of Engineer Technology developed a device for testing pressure-operated mines (W.129234). This device is used to verify whether the mine's firing chain and the detonation function as required. This is achieved by simulating a vehicle driving over the mine with a wheel of a combat vehicle by rolling a concrete roller over the fuse cover.

The device (Figure 14) consists of a steel structure (1), a wooden structure (2) acting as a ramp and a mechanism for releasing the roller (4), a device (5) for holding the roller in the top position, which also serves as a mechanical safety precaution against accidental release of the roller. The mechanical safety device is removed via the rope (6) as soon as the research personnel moves to the command post. The element used to release the concrete roller (5) is the sling (3), which is explosively cut using an ERG-type electric detonator.

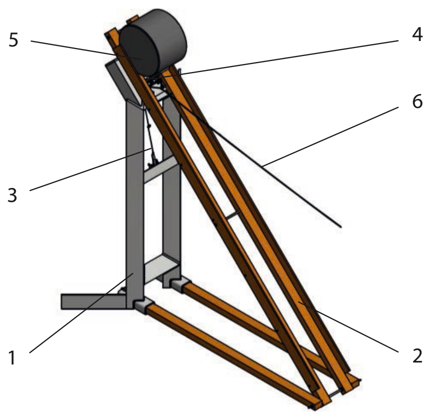

Fig. 14. Digital model of the test stand for testing of mine with pressure-activated fuses: 1 – steel structure, 2 – wooden structure, 3 – sling, 4 – roller release mechanism, 5 – concrete roller, 6 – cord. Source: own study

The stand has an open-structure design which reduces the impact of the shock wave generated during the mine detonation. In addition, the lack of special element fastening the wooden structure to the steel structure and the significant distance between the steel structure and the mine significantly reduces the transfer of the mine's explosion energy to the steel structure. In order to confirm the appropriate selection of the inclination angle of the ramp and the mass of the concrete cylinder, a test version of the station was fabricated. For the test, the function of a concrete cylinder was performed by an anchor of an anti-amphibious mine used in rivers (MPR), the weight of which corresponded to the design premises of the tests station. The impact of the concrete cylinder on the training version of the TM-62M mine with the MWCz-62 pressure fuse was tested, as shown in Figure 15.

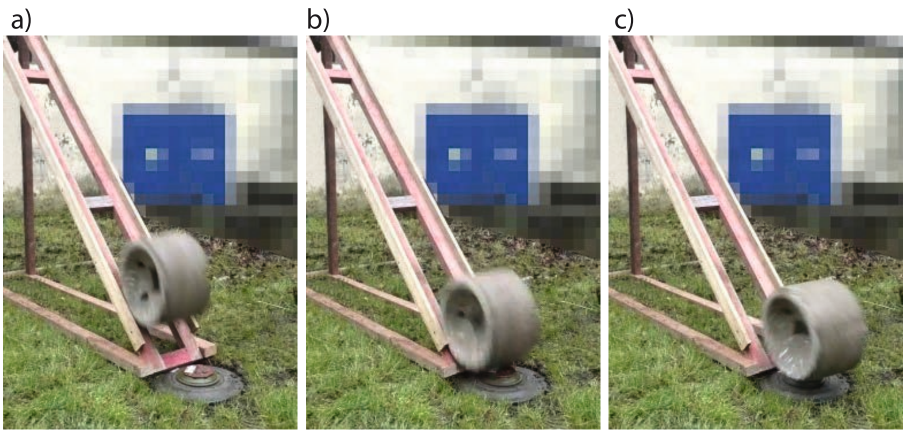

Fig. 15. Stages of testing the MWCz-62 inert fuse fitted into the TM-62M inert mine with the use of the developed stand: a) concrete cylinder rolls down along the guides, b) concrete cylinder approaches the fuse, c) cylinder rolls over the fuse. Source: own study

The test was repeated several times, each time producing a positive result of the simulation of the impact of a vehicle wheel on the TM-62M inert mine with the MWCz-62 inert fuse. The analysis of the proper dynamics of the collapse of the pressure plate and the functioning of the MWCz-62 fuse components and mechanisms enabled the correct assessment of the operational reliability of these mines under real conditions. The test results for two MWCz-62 inert fuses are shown in Figure 16.

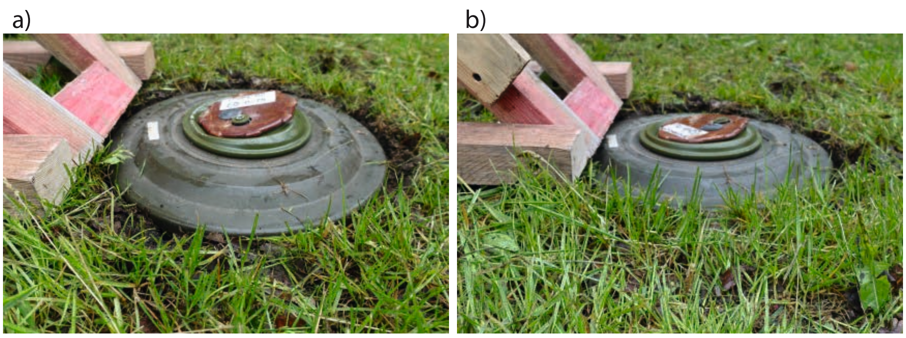

Fig. 16. Results of the impact of concrete cylinder on the MWCz-62 inert contact fuses in the TM-62M inert mines using the proprietary stand. Source: own study

4. Conclusions

Ensuring high level of combat readiness and operational safety, and in particular the use (emplacement) of mines under combat conditions, requires periodic assessment of their technical condition during long-term stockpiling.

A properly planned test cycle is crucial for a comprehensive assessment of the technical condition of the entire mine batch.

In order to assess the technical condition of the mine, it is necessary to check each of the mine's components independently and then perform a comprehensive check of the entire mine in conditions resembling real operating conditions.

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This allows for the identification of components that may require repairing or upgrading.

Access to supervised measuring equipment and test stands enabling precise adjustment of the mine exposure parameters is required, which in turn has a significant impact on accuracy of the mine technical condition assessment.

The acquisition of new mining equipment by the Polish Armed Forces will require the development of new methodologies and dedicated test stands for comprehensive assessment of the technical conditions of mines throughout all the stages of their life.

References

Center for International Stabilization and Recovery, (2009). *Scoping Study of the Effects of Aging on Landmines*. Global CWD Repository. 21. https://commons.lib.jmu.edu/cisr-globalcwd/21 (date of access: 15/09/2021).

Chant, I., Lee, D., Ireland, D. (2005). *DSTO Landmine Detection Test Targets*. Edinburgh South Australia: DSTO Systems Sciences Laboratory.

Dokumentacja techniczna na minę kolejową PMK-1, arch. WITI nr 14/09/9.

Fokin, J.G. (1973). *Niezawodność eksploatacyjna urządzeń technicznych*. Warszawa: Wydawnictwo Ministerstwa Obrony Narodowej.

Fonrobert, P., Stępień, L., Terenowski, H. (2011). Podejmowanie decyzji o dalszej eksploatacji środków bojowych na podstawie informacji o ich eksploatacji. *Problemy Techniki Uzbrojenia*, R. 40, z. 120(4), 93–101. Zielonka: Wojskowy Instytut Techniczny Uzbrojenia.

Kubecki, A., Śliwiński, J., Lubach, I. (2019). *Metodyka badań min przeciwpancernych TM-62M z zapalnikami MWCz-62 w procesie eksploatacji*. Wrocław: Military Institute of Engineer Technology.

Mina przeciwdesantowa denna PDM-1M, Warunki Techniczne WT-0199/Inż.

Mina przeciwdesantowa rzeczna MPR z zapalnikami mechanicznego działania, Warunki Techniczne WT-0198/Inż.

Mina przeciwpancerna MPP-61 z zapalnikiem MUND-62, Warunki Techniczne WT-226/Inż.

Mina przeciwpancerna PT Mi-Ba-III z zapalnikiem Ro-2, Warunki Techniczne WT-0374/Inż.

Sztab Generalny Wojska Polskiego, Szefostwo Wojsk Inżynieryjnych, Inż. 414/78 (1978). *Środki minowania i rozminowania: opis i użytkowanie.* Warszawa: Ministerstwo Obrony Narodowej.

Sztab Generalny Wojska Polskiego, Szefostwo Wojsk Inżynieryjnych, Inż. 572/94 (1994). *Prace minerskie i niszczenia*. Warszawa: Minosterstwo Obrony Narodowej.

Urządzenie do badania min z zapalnikiem o działaniu naciskowym, application for utility model, no. W.129234.

Urządzenie do badania zapalników naciskowych, utility model no. RWU.070345.

Warunki Techniczne na odbiór zapalnika MWCz-62, Nr ChF4.029.047 TU/S.

Ocena stanu technicznego zapalników min o działaniu mechanicznym

Streszczenie

Współczesne konflikty zbrojne pokazują, iż stosowanie skutecznych zapór minowych ma znaczący wpływ na przebieg działań wojennych. Z uwagi na ten fakt, w Siłach Zbrojnych RP priorytetem jest posiadanie niezawodnych i efektywnych środków minersko-zaporowych, zarówno nowo pozyskanych jak i tych będących w eksploatacji. Z tego też powodu prowadzi się między innymi szczegółowy nadzór nad stanem technicznym min, zwłaszcza w okresie ich długotrwałego przechowywania. Przyczynami zwiększonej zawodności działania min mogą być: fizykochemiczne zmiany w materiałach konstrukcyjnych (korozja, deformacje, utrata właściwości wytrzymałościowych) pogorszenie się właściwości fizykochemicznych zasadniczego materiału wybuchowego miny, detonatora pośredniego i spłonki pobudzającej, zły stan techniczny podzespołów zabezpieczeń lub niesprawność mechanizmów zapalnika miny. W celu oceny niezawodności działania miny wykonuje się sprawdzenie niezależnie każdego podzespołu zapalnika miny, a następnie kompleksowe sprawdzenie jej stanu technicznego. Wymaga to prawidłowego zaplanowania pełnego cyklu badań oraz stosowanie nadzorowanego wyposażenia pomiarowego i stanowisk badawczych umożliwiających, w czasie badań, precyzyjną nastawę zadawanych parametrów narażeń mechanicznych i klimatycznych.

Słowa kluczowe: miny, zapalniki mechaniczne, ocena stanu technicznego