Offshore unexploded ordnance recovery and disposal

An article by JAN KÖLBEL and DAVID ROSE

Millions of tons of unexploded ordnance (UXO) and discarded explosive remnants from war can be found in European waters and beyond. Many of them are next to the shoreline, dispensing toxics to the environment. Dumping of ammunition, military practice and warfare are the main source for this large amount posing a risk for the offshore industry besides the undeniable impact this also causes to the environment. With increasing utilisation of offshore areas, the activities in offshore UXO clearance have increased. Due to the governmental commitment and planning of increased usage of offshore wind energy in Germany, research has been conducted to solve the technical question of unexploded ordnance recovery and disposal. Within the last five years, the market for offshore UXO detection and removal has multiplied as well as experience increased, research has also lead to better analytical results during the UXO survey campaign which has helped achieve fewer false alarms. Better techniques and the development of specialist equipment for the removal results in smaller time frames in which the clearance can be done as well as lower risk for equipment and personnel. Research is also being conducted on how to handle ammunition safely which is classified as not save to transport without the normal demolition procedure.

UXO | unexploded ordnance | investigation | metal detector | recovery | disposal | underwater positioning

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1 Introduction

Boskalis Hirdes is currently removing UXO on several offshore projects in Germany. Also a growing amount of new UXO removal projects is expected to be related to the increasing industrial and touristic use of coastal offshore areas. Besides UXO at offshore locations, dumped World War II munitions all over the world and in particular within German waters will become a greater concern. The high density of these World War II dump locations, large amounts of contaminated material, the deteriorating condition and close vicinity to ports and places of interest in German waters make these locations the most feasible for munition dumpsite cleaning programs.

2 Technique

A complete UXO removal campaign consists mainly of three different stages.

The first stage is a desk study, the UXO survey campaign, which results in the generating of a list of possible UXO targets. Different survey techniques with varying capabilities are used to obtain a target list which covers the possible UXO types relevant to that specific area as identified in the desktop study.

In the second stage, the recovery and identification of the potential hazard will take place. Therefore, a precise relocation of the anomalies is necessary. After positive identification, the Explosive Ordnance Disposal Technical Advisor (EOD TA) classifies whether the UXO is safe for transport or not.

In the third stage, depending on type and condition of the UXO, the safe disposal either in situ or by recovery to shore is conducted.

2.1 Survey

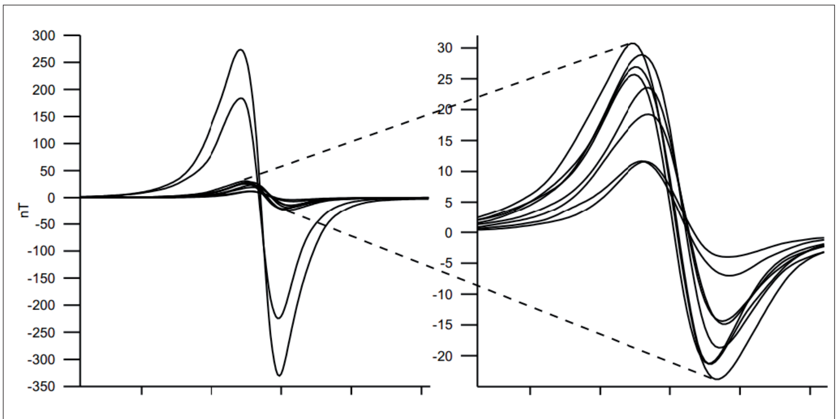
Magnetometer survey

Fig. 1 shows some results from a trial carried out by Dr. Kay Winkelmann, formally of Sensys GmbH using ten identical 2 cm projectiles (Winkelmann and Fischer 2009). The results clearly show the magnetic response from each item, even though identical are different for each one. There are many factors which influence the permanent and induced magnetic fields on an object, and therefore trying to reproduce the size and shape of a UXO using modern materials cannot replicate the magnetic signature of UXO.

This results in a very careful processing of magnetic data and indicates also the unnecessity for testing with surrogate items. Nevertheless, the magnetometer survey in combination with a multibeam and side-scan sonar is very popular. Surfaced objects can be found by the high-resolution side-scan sonar and verified by the magnetic response.

However, experience has shown that especially in sandy and muddy maritime environments, the

Fig. 1: Results for measuring ten identical 2 cm projectiles



majority of objects are not found on the seabed surface. Almost 90 % of these objects are completely buried. In areas with a minor tidal influence these objects are buried no deeper than 1.5 m below the surface. Nevertheless, a careful survey design with sufficient line spacing as well as the magnetometer altitude is a key element. The table shows the expected minimum anomaly amplitudes for certain ferrous UXO.

This means that a 155 mm shell with up to 20 kg of explosives, can only be found in one metre depth with considerable luck or with a very precise survey design. As shown in Fig. 2, the setup would be difficult to achieve. Under consideration of the table, the maximum height would be around 2 m and the line spacing should not exceed 3 m using a TVG with 1.5 m separation.

Metal detector survey

A metal detector uses pulse induction to generate a secondary field in conductive materials. Such systems are usually mounted on work class ROVs and the survey is conducted very close to the ground since the detection depth range is considerably less than the one from magnetometers. This type is usually only used to relocate magnetic targets, however, it is also the only commercial type of detector currently available in the case of non-ferrous targets like German aluminium naval mines, or very cluttered areas.

Advanced metal detector

The Advanced Boskalis Metal Detector (ABMD) system is a new and specific kind of metal detector, using as other metal detectors the transient electromagnetics or time domain electromagnetics to generate magnetic fields in the three spatial directions. Measuring the decay of these fields also in all spatial directions allows deduction of the geometry and thus a much more efficient discrimination between clutter and UXO (Fig. 3).

The ABMD system is able to make continuous measurements and can be towed next to the seabed like a conventional magnetometer array. Furthermore, exact mapping of the conductive background, the ability to work in cluttered areas and the ability for depth of burial surveys makes the ABMD system a much more advanced tool which far exceeds the current technical standards.

Acoustic survey

The broad range of possible acoustic surveys depends on application. Side-scan sonar and multibeam echo sounder are usually applied as auxiliary sensors on each magnetometer survey.

However, these systems are unable to detect or map buried objects. Other types of bottom penetrating acoustic systems operating at low frequencies suffer from limited resolution and have a very limited capability to distinguish between buried UXO and false alarms.

Magnetometer Altitude above Object [m]	Total Field Amplitude Observed for Object Oriented S-N with only Induced Magnetization					
	Shell 105mm	Shell 155mm	Bomb 100lbs	Bomb 250lbs	Bomb 500lbs	G.Mine MKIV
2	11 nT	41 nT	75 nT	160 nT	300 nT	1,350 nT
3	3 nT	12 nT	23 nT	49 nT	91 nT	485 nT
4	<2 nT	5 nT	10 nT	21 nT	40 nT	223 nT
5	<1 nT	2.5 nT	5 nT	10.5 nT	20 nT	120 nT
6	<0.5 nT	<2 nT	3 nT	6 nT	12 nT	70 nT
8	<<0.5 nT	<1 nT	1 nT	2.5 nT	5 nT	30 nT
10	<0.1 nT	<0.5 nT	0.5 nT	1 nT	2.5 nT	16 nT
(green)	Clearly detectable and distinguishable from geogenous objects					
(orange)	Still detectable but not distinguishable from geogenous objects					
(red)	Undetectable even in good offshore magnetometer surveys					

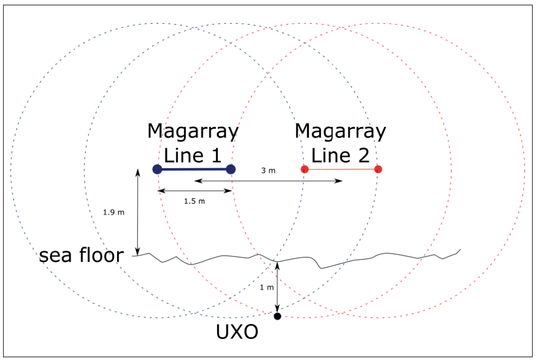


Fig. 2: Magnetometer array with 3 m line spacing to detect 150 mm shell in 1 m depth of burial

2.2 Recovery

In the last decade the increasing amount of UXO surveys and the shorter time frames for the removal lead to an exclusive use of work class ROVs on many projects. ROVs have several advantages over divers, namely elimination of exposure of the human element to unexploded ordnance, longer endurance, and higher weather criteria, as well as more versatile tools (acoustic sensors and imaging systems, cameras and lights, metal detector, magnetometers, manipulators) and higher lifting capacity.

While in some cases inspection class ROVs may be sufficient for simple camera inspections in calm waters, work class ROVs (WROV, Fig. 4) have been found to be a more reliable, robust platform for offshore UXO inspection, recovery and removal operations because of their higher weather criteria (in particular waves, current), and more versatile usability (multiple tools and sensors).

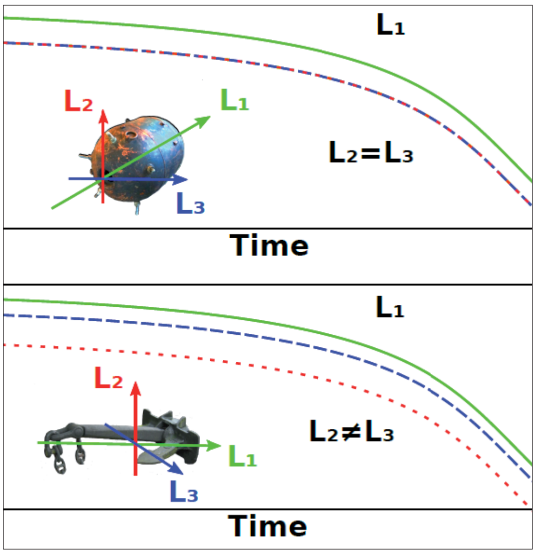


Fig. 3: Schematic decay of the magnetic field along three different axes for a symmetric and an unsymmetrical object

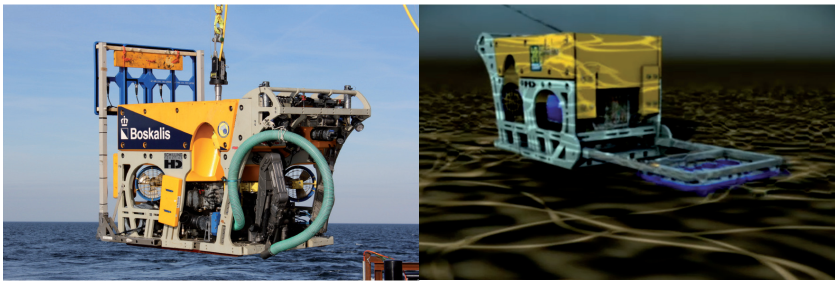


Fig. 4: Heavy duty work class ROVs

Based on the target coordinates given by the client each target will be approached by the ROV installed on the ROV support vessel. A survey grid of 6 × 6 m is placed over the target coordinate on the navigation screen, which is then systematically investigated in a track distance of 2 m, while the readings of the TSS-440 pulse induction detector are recorded. If the target is measured, the WROV only has to rotate 180 degrees and the identification of the target can begin right away. In the event the target is not measured at given location, the survey grid can be extended in 1 m steps, in close liaison with the clients representative on board.

The WROV-pilot has a permanent view of the investigation area so that any surface contacts can also be visually identified and recorded on video. To avoid direct contact with objects lying on the surface we have equipped the WROV with a forward-looking sonar system in addition to its HD video cameras.

After detection, the measurement data is verified, and the list of objects utilised as a basis for identification/recovery is updated accordingly.

In case the target is covered with sediment and thus not visible on the seabed, a dredge pump fitted on the WROV will be employed which enables us to remove any sediment covering the relocated target.

After identification of the EOD TA the UXO can either be left in situ, or wet stored in a known location or brought to deck if safe for transport.

2.3 Disposal

UXO disposal is a key element in the removal campaign. Depending on federal law, different disposal techniques are available, but a demolition is normally the method to deal with UXO which is classified as not safe for transport.

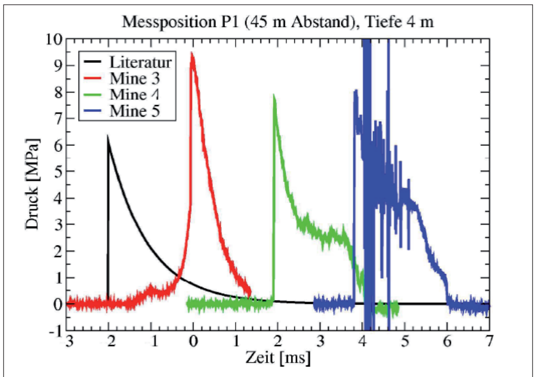
In order to keep the risk to personnel and technology as low as possible demolition operations are conducted without the use of divers. For this reason, the actual placement of the demolition charge is made with the project ROV support vessel and directly with the WROV.

Hereby, demolition charges especially produced for this purpose are used, which can be flexibly and variably scaled to fit the type of ordnance to be destroyed. Once the UXO has been identified and prepared for demolition and with all the information gathered from the investigation, the EOD TA will decide which explosive charge, in his professional opinion will produce the optimum results in the destruction of the UXO. It is at the sole discretion of the EOD TA on which explosive charge is to be utilised. This decision will also be based on several factors which include the type, state of deterioration and position of UXO to be destroyed.

With the demolition of non-transportable ordnance, such as mines, torpedoes, depth charges, etc., by underwater explosion local shock waves are produced with significant amplitude.

In order to minimise the possible damage to the marine environment by these shock waves as much as possible, bubble curtains to dampen the shock waves are used. This is also normally requested from the relevant regulatory agency as we have experienced in the past.

To verify the effectiveness of these bubble veils extensive tests were carried out in 2010 with good results (Schmidtke 2010) (Fig. 5).



	Mine 3	Mine 4	Mine 5
P_{max} [MPa] bei P1	9,3	7,6	7,5
P_{max} [MPa] bei P3	0,42	1,50	0,45
Abnahme [dB]	19	6	16

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Fig. 5: Time courses of the shock waves of three blasts in comparison with literature values. The time zero points of the individual measurements are for clarity arbitrarily shifted against each other. The table shows the pressure peaks and their reduction. The shock wave loss has already been eliminated

The dampening degree of the shock pressure signals from the demolition of three anchor mines each with 300 kg explosive material (45 % TNT, 5 % hexanitrodiphenylamine, 20 % aluminium powder, 30 % ammonium nitrate) was investigated on passage of the shock signals through an air bubble curtain. By the passage through a fully developed bubble curtain a reduction of the pressure peaks of 16 dB to 19 dB could be achieved, even with an incomplete bubble curtain a reduction of peak pressure of 6 dB were achieved. Spectrally at frequencies greater than 500 Hz a dampening of at least 5 dB with the full-blown bubble curtain in comparison with the incomplete which demonstrated that reduction of the equivalent continuous sound level is in these cases at 7 dB to 8 dB.

Maximum shock reduction is achieved with the placing off a bubble curtain at a diameter of 90 m being provided around the target object.

Nevertheless, demolition is not an option for chemical warfare or dump sites were big amounts of DMM can be found next to each other.

For these cases research is currently in progress and cycles are being developed for each different type of munitions to disarm and salvage them without demolition. ⚓

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