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Experience with the use of a rigidly-mounted side-scan sonar in a harbour basin bottom investigation

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ABSTRACT

The issue of investigating seabed clearance is particularly important in harbour areas where depths are often only slightly greater than ship drafts. Additionally, the threat of usage of mine-like objects (MLOs) in harbour areas should also be considered because of the increasing number of terrorist attacks. This kind of threat also requires frequent sonar surveys in such areas. These survey operations need specific procedures and special equipment to ensure survey correctness. However, a given port's infrastructure, small depths and vessel traffic affect the survey process in a specific manner. A typical towed side-scan sonar (SSS) is difficult to use because of restrictions in the vessels' manoeuvring.

In this paper the option of attaching a towfish to the hull of a survey vessel was examined . The results obtained during a real survey in Gdynia harbour along with the choice of survey vessel, way of fixing the transducer to the hull and the selection of appropriate sonar operational parameters are presented.

1. Introduction

Harbour areas (basins, fairways, routes, channels) are, in terms of operation, characterised by comparatively small depths, a complex infrastructure and relatively high vessel traffic. They can be considered to be restricted areas where manoeuvring (especially of large vessels) is impeded and requires adequate experience. Oceanographic vessels, research platforms or survey ships conducting surveys on high seas cannot be used in such areas and conditions because of their dimensions. Small vessels (boats) are preferable because their manoeuvrability allows them to stay on the survey line even with low speed, under 2 knots. This is a well-known practice and has been described many times (Johnson, 2005; IHO Standards, 2008; Ai and Parent, 2011; Brown et al., 2002; Chavez and Karl, 1995; Bennel, 2001; Johnson and Helferty, 1990). Small motorboats, hydrographic launches or RIBs are mobile, so the time response for a threat can be reduced.

Such a survey platform must be provided with an adequate power source, preferably 230V, and sufficient space for assembly of sensors, antennas and other survey equipment. There might be no power source on board very small survey platforms, particularly a rigid-hulled inflatable boat, which makes it necessary to use a mobile power generator. It is also desirable to have a cabin to protect the equipment from rough weather conditions. Taking all of the above into consideration, an optimal survey platform for harbour surveys seems to be a 10–12 m long hydrographic launch or a motorboat with a cabin which is equipped with systems dedicated to shallow water surveys.

Due to numerous limitations, it is not efficient to tow a side-scan sonar in harbour basins (Felski and Hac, 1997; Akal and Jensen, 2005; Fish and Carr, 1990; Towed, 2009), and some authors suggest that a transducer be attached to the vessel's hull (e.g. see Overmeeren (2006), Penrose et al. (2005)). An important advantage of this approach is the easier monitoring of the sonar altitude above the sea bottom; a similar suggestion can be found, e.g. in Glynn et al. (2007), Duxfield et al. (2004). Manoeuvrability of such a vessel is better than when towing a towfish. A significant disadvantage of this technique is the limited capability of flying the towfish at different depths to provide optimal geometry for signal propagation (Brissette, 2006).

2. Materials and methods

Allowance must be made for the general conditionings of the technology of hydrographic measurement. The sonar mounting site affects the quality of the recorded data and the efficiency of sonar operation. Improperly mounting the transducer in relation to the hull may result in the phenomenon of the hydroacoustic shadow of the hull's submersed parts (Armentor and Martin, 2008). This may

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greatly reduce the operational sonar range (Grządziel, 2006). The literature suggests a number of possible options to "rigidly" attach the sonar to the hull, e.g. under the keel, to the side or to the bow (Glynn et al., 2007; Duxfield et al., 2004). Other suggestions regarding integrating SSS with other systems can be found in Pøhner et al. (2007). It is absolutely unacceptable to fix a towfish behind a propeller because aeration of water takes place, as air bubbles reflect acoustic energy and noise interference causes a strong reduction of the sonar range. The methods of mounting a side-scan sonar to the hull of the survey vessel are shown in Fig. 1. A towfish fitted to a steel pole and directly connected to the side of the vessel is often applied for ease of operation, but this method allows for the use of only one channel. Due to the shape of the acoustic beam pattern, the internal channel (from the hull side) is disturbed. The least noise is introduced when the sonar is fixed to the bow of the survey vessel (Fig. 2).

Both the literature and an analysis of the pros and cons of different options led the authors of this paper to the conclusion that the optimal technique of sonar survey in shallow water and in harbour areas is to use a side-scan sonar that is rigidly mounted to the bow of the survey platform. The perfect solution for this application is to use an aluminium pole fitted rigidly to the vessel.

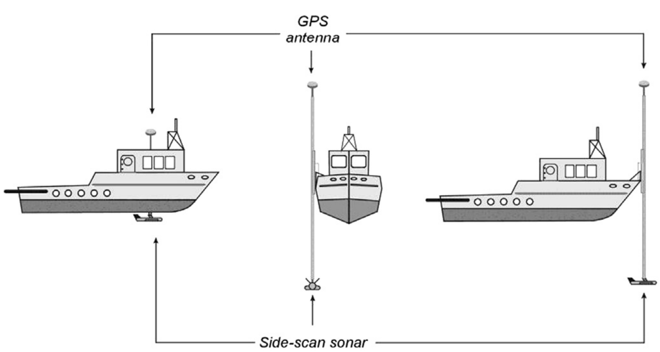

Fig. 1. Methods of mounting a side-scan sonar to the hull of the survey vessel.

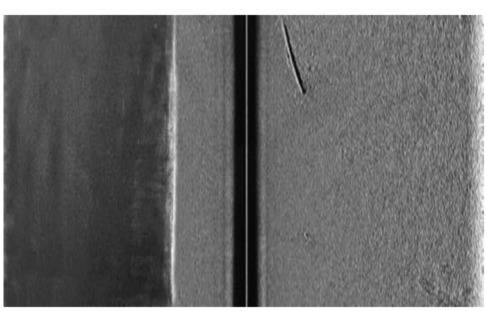

Fig. 2. Side-scan sonar track recorded by a towfish fixed to the vessel, positioned on the starboard side (the reflection of the hull is visible).

If the GPS antenna is mounted on top of the pole, exactly above the towfish, then the problem of offsets between the sonar and the satellite receiver antenna is solved.

Special aluminium frames designed to fit a towfish were built and mounted in the bow sections of two vessels (Figs. 3 and 4). The first one was an *m/v Puck* 18 m (L), 4.5 m (B), 1.5 m (D) and displacement 46 t. The other one was a survey launch 9 m (L), 2.7 m (B) and 0.65 m (D).

The construction consisted of a mounting plate, foundation, cradle, antenna mast, sonar pole and guy cables (Fig. 4). The masts and cables were portable elements. The towfish was screwed by two screws to the lower end of the mast. The mast with the attached sonar was passed from the pier to the vessel's bow section and connected with the cradle (part of the foundation). The GPS antenna was placed at the top of the upper mast. The position of the GPS antenna over the towfish is very important because a harbour survey in good weather conditions means a lack of the swing. In that case the problem of offset for the mutual position of these elements can be omitted. The sonar pole might be set up in several positions, thus enabling the operator to adjust the value of the towfish draft. The maximum draft of the sonar is 2 m below the sea surface, and the length of the pole was almost 5 m.

During the research we noticed that a critical element of the construction is the length adjustment of the lower part of the mast and the speed of the boat. The height of the whole construction on the larger vessel turned out to be problematic, as in some conditions the towfish got into vibrations. On the smaller boat the distance of the towfish from the point of support was less than 3 m, and with maximum boat speed (3 knots) the system worked properly. However, on the bigger boat, when this distance was almost 5 m and the speed of the boat was 6 knots, the system was exposed to vibrations because of its length. This made effective sonar operation impossible (Grządziel and Felski, 2012). In this paper we present a continuation of this work. First, some design modifications were required, e.g. additional ribs or the use of textile ropes which stabilised the frame better due to their elasticity. Finally, the aluminium-pipe replacement (lower part of the mast) to a steel one gave satisfactory results.

The survey was conducted from May to October 2012 and additionally in July of 2014 in one of Gdynia's harbour basins. The main goals of the research were to:

a. verify the prototype aluminium construction designed to fit the towfish to the vessel hull and to assess its usability;
b. perform a hydroacoustic sea bottom search by means of a side-scan sonar in order to verify the methodology of conducting measurements as well as to gather data about the presence and types of sea bottom objects;
c. evaluate the sonar's detection capabilities and measurements of discovered targets.

Fig. 3. *M/v Puck* (left) and hydrographic launch (right) (photo: Grządziel).