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Measurement of radiated underwater noise from a small research vessel in shallow water[☆]

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ABSTRACT

The impact of man-made underwater noise on the marine environment has recently received increased attention from regulatory authorities, as evidenced by inclusion in the Marine Strategy Framework Directive (MSFD). Radiated underwater noise from ships, primarily resulting from propeller cavitation, has for many years been understood to be one of the major contributors to ambient ocean noise. Civilian research in this area has to date been relatively limited; standards covering the measurement of radiated noise from ships in deep water and associated data analysis procedures have only recently been published by national and international standards institutes. Less attention has so far been paid to the measurement of radiated noise from ships in shallow water environments. This is of interest as shallow water areas are more likely to be used by civilian researchers due to the logistical problems involved in undertaking trials in deep water. The issue of shipping noise has been identified as one requiring further research, indicated by the recent funding of several large collaborative projects by the EU (e.g. the SILENV, AQUO and SONIC projects). This paper presents ship radiated noise data measured using a three hydrophone array during a sea trial undertaken as part of the SONIC project.

1. Introduction

Interest in the environmental impact of man-made underwater noise has increased considerably in the last two decades driven by a recognition of the increasing demands placed on the marine environment by, for example, the oil and gas, renewable energy and transport industries as well as an improving understanding of the sensitivity of marine fauna to underwater noise pollution. The inclusion of underwater noise as a key indicator of environmental status in the European Marine Strategy Framework Directive (MSFD) is testament to this interest.

Many studies have identified radiated underwater noise from merchant ships, predominantly resulting from propeller cavitation, as a major contributor to ambient noise levels in the oceans (e.g. Wenz (1962), Urick (1975) and Ross (2005)). More recent studies have presented data indicating that shipping noise levels are increasing (Andrew et al., 2011; McDonald et al., 2006; McDonald et al., 2008). Consequently, any effort to determine the current status of the marine environment should consider shipping noise in detail.

The measurement of radiated noise from ships has historically been undertaken for military purposes using fixed noise ranges. More recently, researchers from both military (e.g. Wales and Heitmeyer (2002) and Scrimger and Heitmeyer (1991)) and civilian (e.g. McKenna et al. (2012), Merchant et al. (2014) and Hallett (2004)) backgrounds have used short or long term mobile deployed systems to measure shipping noise. While these have been a valuable contribution to the field, the lack of a standardised methodology for measurement, data analysis and reporting often hinders the comparison of different datasets.

The recent publication of internationally agreed standards (ANSI/ASA, 2009b; ISO, 2012) is the first step towards rectifying this issue and it is encouraging to see many researchers adopting these methods as closely as possible (Bahtiarian and Fischer, 2006; De Robertis et al. 2012; Peña et al., 2011). The fact that these researchers appear to have found it challenging to meet some of the requirements for the highest measurement precision methodology set out in the standards highlights the difficulty of undertaking these measurements in practice.

This paper concentrates on the results of full scale trials to measure radiated noise from a vessel following, as closely as possible, the methodology recommended in the standards cited above. As well as presenting some key results from the trials the methodology used is discussed and any departures from the standards are highlighted.

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2. The SONIC project

Funded under the European Union (EU) Seventh Framework Programme (FP7) the three year SONIC (Suppression Of underwater Noise Induced by Cavitation) project commenced in October 2012. It is a multinational collaborative project involving thirteen organisations from five European countries including universities, classification societies and naval, marine engineering and technical research institutes.

The funding of the project is in response to the requirement of the MSFD (European Parliament and the Council of the European Union, 2008) to achieve Good Environmental Status (GES) of EU marine waters by 2020. GES is defined in the MSFD by eleven qualitative descriptors, Descriptor 11 of which states that:

"Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment".

The investigation of anthropogenic underwater noise is therefore a key element in achieving the goals of the MSFD. As discussed in the preceding section, shipping is a major contributor to the overall levels of noise in the oceans and therefore requires detailed consideration. The aim of the SONIC project is to investigate radiated noise from ships, primarily concentrating on underwater noise from propeller cavitation, and to deliver tools to improve the measurement, mapping and mitigation of cavitation noise.

The project has three principal aspects. The first is to develop techniques for the accurate prediction of ship radiated noise levels from scale model tests. A number of approaches to improve the accuracy of these predictions are being explored. These include novel experimental and computational techniques for the measurement of cavitation noise in scale model facilities such as cavitation tunnels and towing tanks, taking into account the acoustically reverberant nature of these environments.

The second aspect of the project is to carry out measurements of radiated noise from a full scale ship at sea to provide data to validate the scale model predictions. The target vessel used for these full scale sea trials was the research vessel Princess Royal operated by the University of Newcastle. The first of these trials was undertaken in September 2013 and aimed to measure radiated noise using a deployed hydrophone array and similar methodology to recently published international standards.

The third aspect of the project focuses on mitigation. It aims to develop an underwater noise propagation model to estimate the "noise footprint" of an individual vessel and a "noise map" showing the contribution to the overall underwater noise levels in an area of ocean from multiple vessels transiting through the region over a period of time. Other than the noise propagation model itself, the inputs to this final stage include an empirical ship source level model that has been developed using a database of existing ship radiated noise level data compiled for the SONIC project. In addition, other mitigation measures relating to design and operation of propellers and the reduction of machinery noise are being investigated.

3. ISO Publicly Available Specification for ship radiated noise measurements

The American National Standards Institute (ANSI) standard (and the International Organization for Standardization (ISO) Publicly Available Specification (PAS) subsequently based upon it) provides recommendations covering environmental conditions, suitable locations, specification and setup of measurement equipment, behaviour of the target vessel, post-processing of data and the metrics by which to report the data. It also provides three grades of measurement standard from Grade A, which provides the most stringent set of conditions, to Grade C which allows for a reduced degree of measurement detail with corresponding increase in uncertainty. It is, therefore, a very comprehensive guide for researchers undertaking ship radiated noise measurements which takes into account a number of common issues.

Fig. 1 shows the recommended hydrophone setup geometry relative to the target vessel for Grade A measurements. The depths of the hydrophones are defined in relation to the distance at Closest Point of Approach (CPA) of the vessel and specified elevation angles of 15°, 30° and 45°. Assuming a vessel of less than 100 m in length (as is the case for the present study) the depth of the shallowest hydrophone, d_1, is recommended as 27 m, $d_2 = 58$ m and $d_3 = 100$ m. This, however, is based on the trials being undertaken at a location that meets the minimum water depth requirements, that is the greater of 300 m or 3 × ship length for Grade A measurements, 150 m or 1.5 × ship length for Grade B measurements and 75 m or 1 × ship length for Grade C measurements.

The standard also covers the manoeuvring of the vessel during the measurements. The recommended test sequence is shown in Fig. 2 for the measurement of radiated noise from the starboard side of the vessel. The procedure requires the vessel to transit along a pre-determined path such that it passes the hydrophone array at the CPA point, perform a Williamson turn and return along the same track so that measurements of radiated noise from both port and starboard sides are made. The Data Window Length (DWL) is the distance between two points along the track either side of the CPA point defined by a ±30° angle about the hydrophone array position. The COMEX and FINEX points define the start and end of the run respectively with each point a distance 2 × DWL either side of the CPA point. Between the COMEX and FINEX points the vessel must maintain constant speed and running conditions with minimal use of rudder to maintain course along the track.

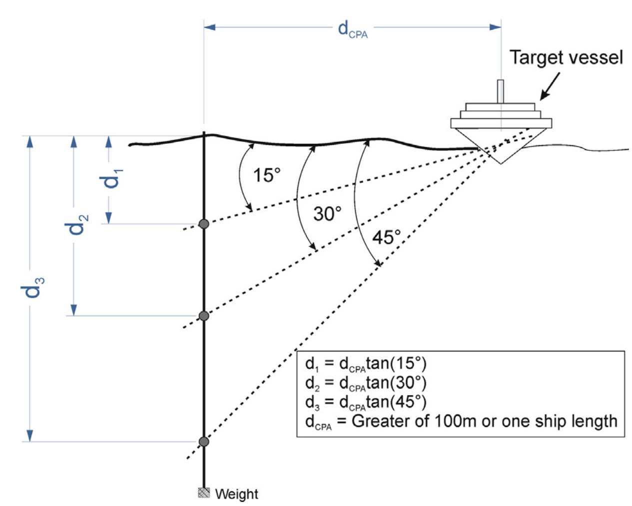

Fig. 1. Hydrophone array geometry recommended by the ANSI/ISO standards.

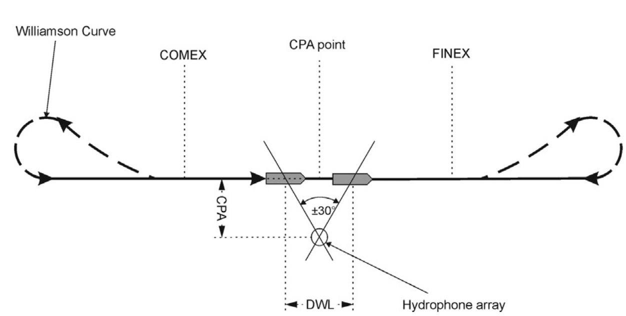

Fig. 2. ANSI/ISO recommended vessel test course (starboard side run).