ANALYSIS OF DREDGER NOISE BASED ON EXPERIMENTAL AND SIMULATED SOURCE LEVEL CALCULATIONS

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Abstract: *This contribution is part of a dredger innovation project (ECODRAGA) aimed at reducing the pollution produced by suction dredging operations where one of the objectives was to evaluate the effect of the dredger modifications over the underwater noise generated. Measurements of the dredger working in ECO and conventional mode were made, also a methodology to obtain Source Levels was proposed with both experimental and software methods. Hydrophone measurements of the dredger were made in Moaña port in Pontevedra (North West Spain), a shallow water zone in Ría de Vigo (a drowned river valley). Noise measurements where accompanied with oceanographic sonde (CTD) measures, obtaining salinity, temperature and speed of sound depth profiles of the measurements zone. To obtain Source Levels of the Eco-dredger two propagation losses calculation methods were used: the first experimental one consists in the use of a calibrated source emitting single tones, in the same position as the dredger during the measurements, to calculate propagation losses of each 1/3 octave band from 125Hz to 4kHz. The second one is a simulation and analysis of the first setup using the software "dBSea". "dBSea" is the first commercial software of 3D underwater noise estimation with 3D bathymetry and 3 different calculation algorithms: parabolic equation, normal modes and ray tracing. All algorithms were tested and analysed to determine which one fits better with the measurements made. Conclusions compare the use of both propagation losses calculation methods and their application to the computation of the dredger source level.*

Keywords: *Dredger noise, propagation losses, dBSea*

1. INTRODUCTION

The work described in this contribution is part of a research project whose aim is to redesign a suction dredging boat to operate in a less polluting way. A suction dredger works by sucking thin sediments (sand, mud and gravel) through a long tube. The kind of suction dredger we are working on is a trailing suction hopper dredger (TSHD), that trails its suction pipe when working, and loads the dredge spoil into a hopper in the vessel. When the hopper is full of dredging material, the TSHD sails to a disposal area and dumps the material through doors in the hull.

During dredging process, hopper rapidly gets filled with water from the suction pipe. This water has dredged particles in suspension and, when the hopper is filled, overflow occurs, leaving a pollutant stain all around the dredging area.

One of the targets for the first year of the project was to evaluate the operating parameters of the dredger, to provide an initial reference to compare the results of the modifications to be introduced. To establish the starting point in terms of underwater acoustics impact, noise produced while the boat was dredging in the outer port in La Coruña (Spain) was measured [1].

After evaluation tasks, the dredger was redesigned in order to solve some of their environmental impacts. Main ECODRAGA (Eco-dredger) feature was a circuit to redirect the water overflow from the hopper to the suction spot. This water is also injected in the seafloor below suction head, helping suction process and avoiding pollutant stains.

Once evaluations tasks and eco-modifications were made in the dredger, noise of the dredger ECODRAGA was measured again to be compared with previous results in La Coruña. Source Level estimations were calculated as a function of received level (RL) and propagation losses (PL):

$$SL(f) = RL(f,r) + PL(f,r) \tag{1}$$

Section 2.1 explains experimental setup for Received Level (RL) calculations. Propagation losses were measured in situ as explained in section 2.2 and calculated with prediction software dBSea [2] as in section 2.3. Section 3 will show results comparisons and section 4 will present the work conclusions.

2. EXPERIMENTAL SETUP

In the design of the measurement setup, two main references have been considered. The first one is the standard ANSI 12.64-2009 Part 1 [3], which describes methods to measure noise radiated from ships. These methods are based on a "pass-by" measurement, but paying special attention to the vertical radiation pattern. This standard was the main reference but not strictly applied, it was adapted to work on shallow waters.

Another important reference is a study of the noise generated by UK dredgers [4]. Its main target is to obtain good estimates of the typical source level under normal operating conditions, but it also includes the study of the possible variations in the noise due to the operating modes of the ship, the dredging area, or the type of material being dredged. Source level comparison between UK dredgers and the unmodified dredger can be found in [1].

2.1 Eco-dredging sound pressure level measurement

Measurements to obtain eco-dredging levels were made during March 2014 close to Moaña (Pontevedra, Spain) port. Adricristuy dredger [5] was available during two days to test the new modifications. Figure 1 shows experimental setup for sound pressure measurements:

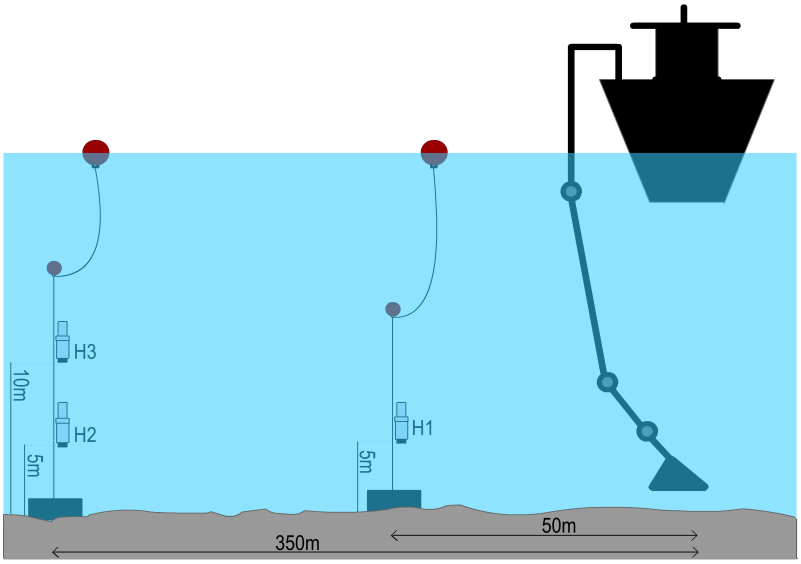

Figure 1: Experimental setup for sound pressure measurements

As can be seen in figure 1, experimental setup has 3 hydrophones for underwater noise measurement of Adricristuy dredger, 2 distant ones placed at 350m from the source and one at 50m (in practice this distances are approximated).

The distant position supports 1 hydrophone at 5m and other at 10m over the seafloor, while the close one only planned one hydrophone at 5m height.

Measurements were made at Moaña port during a morning of calm sea and clear sky. The seafloor in the port zone is mud type with small parts of sand and gravel [6], getting thin dredging fundamentally.

The dredger made parallel passes to the dock, the hydrophones were placed in an orthogonal trajectory to the dredger direction, approximately in the central point of the passes. Hydrophone positions, and also dredger passes sampling, were positioned and synchronized through GPS.

2.2 Propagation losses measurement

After the experience [1] with a propagation losses model based on virtual image (ImTL in [3]) comparisons obtained with other results pointed that the model used underestimated losses. Furthermore it did not take into account the peculiarities of the terrain or the type of seabed. Therefore, it was decided to estimate the calculation of the propagation losses by a second experimental setup consisting of an underwater source emitting tones to 2 hydrophones placed at the same positions of the dredge measurement session (50 and 350m) and a close hydrophone at 1m. It is about building an interpolation model based on field recordings at the same place where the dredge was measured, trying to include all the peculiarities of underwater propagation experimentally.

The same setup that the one for dredger measurement (Figure 1) was used, with the provisos that the dredger was replaced by a calibrated underwater loudspeaker and the hydrophone H3 was placed at 1m from the underwater source, both at 1m depth. Underwater source and H3 were attached to an auxiliary boat moored at the central position of the dredger passes, this way a 3 points measuring line perpendicular to the dock was set by: H3 at 1m, H1 at 50m and H2 at 350m.

The underwater source emitted tones in 1/3 octave between 125Hz and 4000Hz. These tones were measured in the 3 positions located at 1, 50 and 350 meters and propagation losses at each point were calculated as differences in sound pressure level between the hydrophone at 1m and each one of the other two. Postprocessing details in [1].

2.3 Propagation losses calculations with dBSea

'dBSea' [5] is a new prediction software for underwater acoustics that has modelling features as 3D bathymetry, water properties (speed of sound profile, salinity, temperature) and seafloor attenuation layers, among others. The software was configured using the data from the CTD (Conductivity, Temperature, and Depth) sensors deployed the same day of the acoustical measurements, 3D bathymetry provided by [7]. Seafloor was modelled as a three layer group of one meter of mud, one of sand and one of gravel based on [6].

Source was positioned in the same GPS location as the calibrated source in the experimental setup of section 2.2, and also the probes in the software match the positions of the hydrophones in the in situ measurements. H1 was 11m deep and H2 14m.

The source was modelled as omnidirectional emitting a flat spectrum (from 125 to 4000 Hz) with a source level of 200dB re 1uPa. Propagation losses were calculated as differences between the SL and the RL at the hydrophone/probes positions.

Three different types of solver algorithms were tested over the whole frequency band: parabolic equation, normal modes (both applicable at low frequencies) and ray tracing (applicable at high frequencies).

3. RESULTS

Figure 2 shows the comparison of the propagation losses calculated with the in situ measurements, as explained in 2.2, versus dBSea calculations, explicated in 2.3. Best fitting was obtained using only ray tracing in the close position H1 because parabolic equation didn't work well in such low depth. Parabolic equation (from 125-500 Hz) and ray tracing (from 600-4000 Hz) were used in the far position H2. Normal modes didn't fit well because this algorithm is not intended for shallow waters.

As can be seen, fitting at close position H1 is worst (differences around 6dB on average) than at H2 position (3dB on average) probably because low deep at H1 causes difficulties in these algorithms performance.

Information from seabed contained in [6] has only percentage values instead of width of sediment layers; other layer widths were tested with small result variations in average.

dBSea simulations also revealed that one meter variations in depth positioning of the hydrophone/probes can produce variations up to 10dB in the RL at certain frequencies/positions. This could explain such big valleys and mountains at certain frequencies of figure 2.

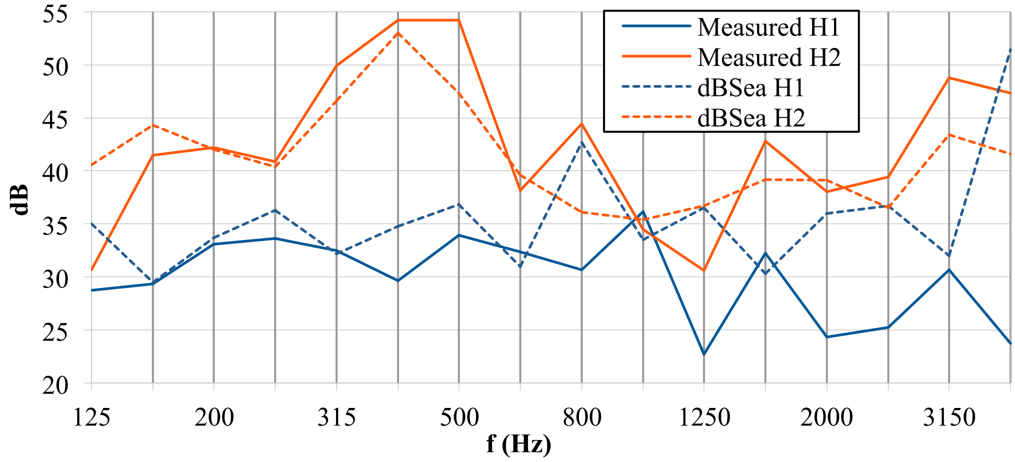

Figure 2: Comparison of the in situ measurements of propagation losses with best dBSea result

Received levels of four dredger passes has been averaged at positions H1 and H2. According to formula (1) source levels at both positions were obtained using propagation losses calculations from measured and dBSea methods. Each final SL is an average between source levels calculated at both positions. Details on calculations can be found in [1].

Figure 3 compares dredger SL obtained from both PL calculation methods: measured and estimated with dBSea. There's a good fitting from 160 to 1000 Hz, with differences under 2dB on average. Fitting from 1250-4000 Hz is worst, as said, possibly caused by depth positioning of the probes/hydrophones which seems to be more sensible for high frequencies. Discrepancies at 125Hz (even 160Hz) could be caused because this frequency is outside the useful band of the calibrated source (200-20.000 Hz).

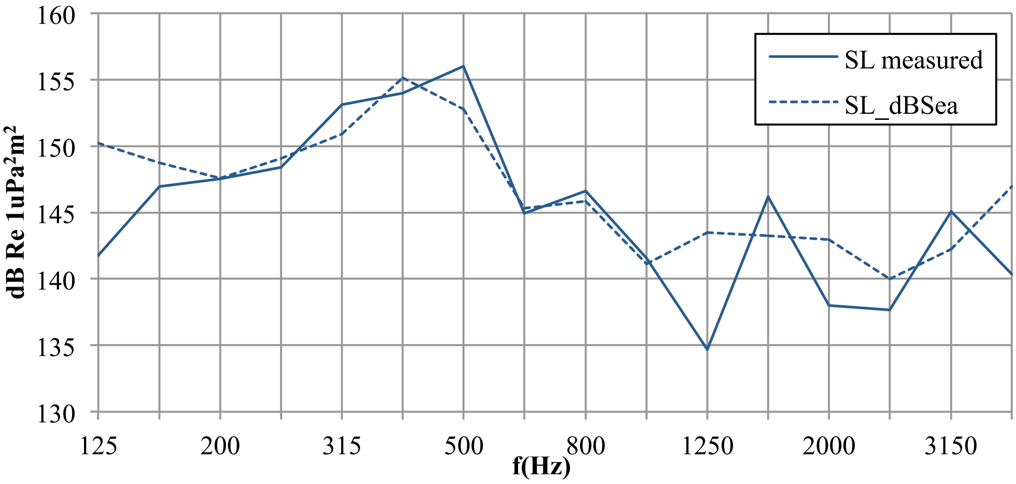

Figure 3: Comparison of both SL calculation methods

4. CONCLUSIONS

This document describes the measurements made during ECODRAGA testing carried out in Moaña port in Pontevedra (NW Spain) in 2014 and compares 2 methodologies to obtain propagation losses, one based on experimental measurements and the other one based on dBSea.

Information about best fitting dBSea algorithm was obtained for this scenario as a function of distance and frequency.

After propagation losses averaging at two positions, SL fitting between both methods is good from 160-1000 Hz, above 1kHz gets worse but still acceptable.

In view of the results, the use of this software to compute propagation losses is reasonable under conditions of reliable information about bathymetry, sound speed profile and water and seafloor properties.

Further work is required in order to get a quantification of the validity of the results depending on the quantity and quality of dBSea configuration parameters.

5. ACKNOWLEDGEMENTS

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