Meeting International Standards For Low Frequency Underwater Radiated Noise From Ships

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1. INTRODUCTION

There is a renewed concern to minimize the underwater radiated noise from commercial vessels and, in particular, fisheries research vessels. The International Council for the Exploration of the Sea (ICES) has issued recommendations for maximum radiated noise levels over a broad spectrum [1]. This includes very low frequency (less than 50 Hz) narrowband noise, which is not amenable to prediction with energy-based or empirical methods. DRDC has developed methods for predicting such radiated noise using a combination of finite element and boundary element techniques incorporated into a computer code called AVAST [2]. This paper will demonstrate the procedure for such a noise prediction using a generic ship model with excitation provided by sample vibrations measured on engine mounts. The analysis will proceed from a coarse MAESTRO [3] model of the vessel, through to a finite element model where the loads will be applied and the natural frequencies calculated, to a radiated noise prediction using the AVAST software. The resulting prediction will be compared to the ICES recommendations up to a frequency of about 50 Hz.

2. NUMERICAL MODELLING

A generic ship model was constructed using the MAESTRO software, which allows for the rapid generation of a coarse finite element (FE) model of a vessel. The vessel has a length of 75m (BP), a beam of 12m, and a draft of 3.5m. The FE model is shown below in Figure 1 and contains 3566 nodes and 8041 elements.

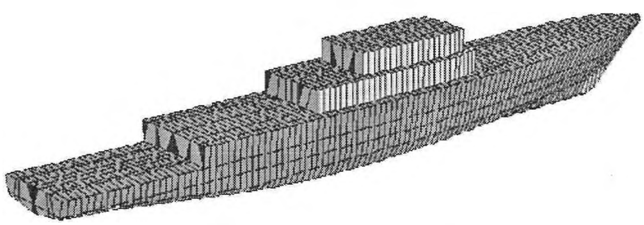

Figure 1: Structural Finite Element Model

This specialized MAESTRO model can be converted to a standard FE model using available translators. An in-air dynamic analyses of the model was performed to determine the *dry* natural frequencies of the ship which are required input for the AVAST analysis. As well, loads were applied to the model to simulate dynamic engine loads from a diesel generator. To determine the appropriate load levels, unit loads were applied, a modal frequency response analysis performed, and the resulting accelerations of the engine mounts (with the ship in water) were compared to some values available in the literature [4,5]. The applied loads were scaled to correct for the differences between the predicted and measured amounts. This procedure was iterated until convergence. The resulting loads were then available for the radiated noise analysis. While there was some variation in the measured data, the loads were assumed to be constant with respect to frequency to ease the analysis. An average over the frequency range was used resulting in a vertical displacement amplitude of 1.3 E-06m and a transverse amplitude of 5.0 E-07m at each engine load point. Modal damping factors were assumed to be a consistent value of 0.002 based in part on data measured on a scientific research vessel.

Given a description of the dry natural frequencies and a load file, the boundary element based AVAST code can be used to predict low frequency radiated noise. The program requires only a model of the wetted surface of the vessel and the required model (containing 1132 panels) is shown in Figure 2.

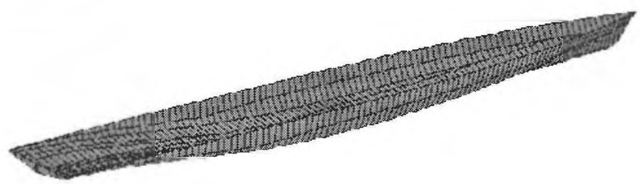

Figure 2: Wetted Surface Boundary Element Model

Once the model is read and the modes and forces input, the user must generate a set of field points for the radiated noise prediction. For this analysis, the field points were located at a depth of 10m from the surface and a range of 100m from the approximate X-Y centre of the fluid model (with Z vertical). 36 field points spaced every 10° were used. The user indicates that there is a reflecting surface (located at the draft line) and also inputs the fluid properties (density of 1025 kg/m^3 and sound speed of 1500 m/s) and the frequency for this analysis. As the fluid matrix properties vary with frequency, multiple analyses were run with a frequency increment of roughly 2 Hz. Once this data is input, the type of analysis is selected. Upon choosing elastic radiation, the user may then vary the modal damping ratios from the default values of 0.002.

AVAST calculates the resulting acoustic radiation at the input frequency and at all modes above that frequency. The resulting radiated noise pattern may be viewed onscreen or, as in this case, the results may be copied to a spreadsheet for further analysis.

3. RESULTS & DISCUSSION

The predicted radiated noise level at the 100m distance is plotted versus frequency in Figure 3. The lower three curves show the sound level for the broadside and bow aspects, as well as the maximum at each frequency. The strongly radiating resonances can clearly be seen as can the variation of the maximum with respect to aspect (no single aspect dominates).

The primary reason for this analysis was to compare the ship's signature with that recommended by ICES. In the frequency range used here, the recommended ICES source level limit (SL) in dB is given in [1] as SL = 135–1.66 log(f) where f is the frequency in Hz. The above results in Figure 3 are not given as source level, which is in dB re 1 μPa at 1m. If one assumes simple spherical spreading, one can convert an omni-directional pattern to a source level by adding 20 log (r) where r is the field point radius in metres (40 dB in this case). The assumption was thus made to use the maximum at each frequency and use spherical spreading. The results are also shown in Figure 3, together with the ICES level for this frequency band. Note that, at first, only the resonant peaks exceed the ICES level, but after about 10 Hz, the radiated source level completely exceeds the recommended level. As this was an artificial analysis to some extent, there is no real concern, however, this type of analysis can show where problems might occur and possible solutions could be examined at the design stage.

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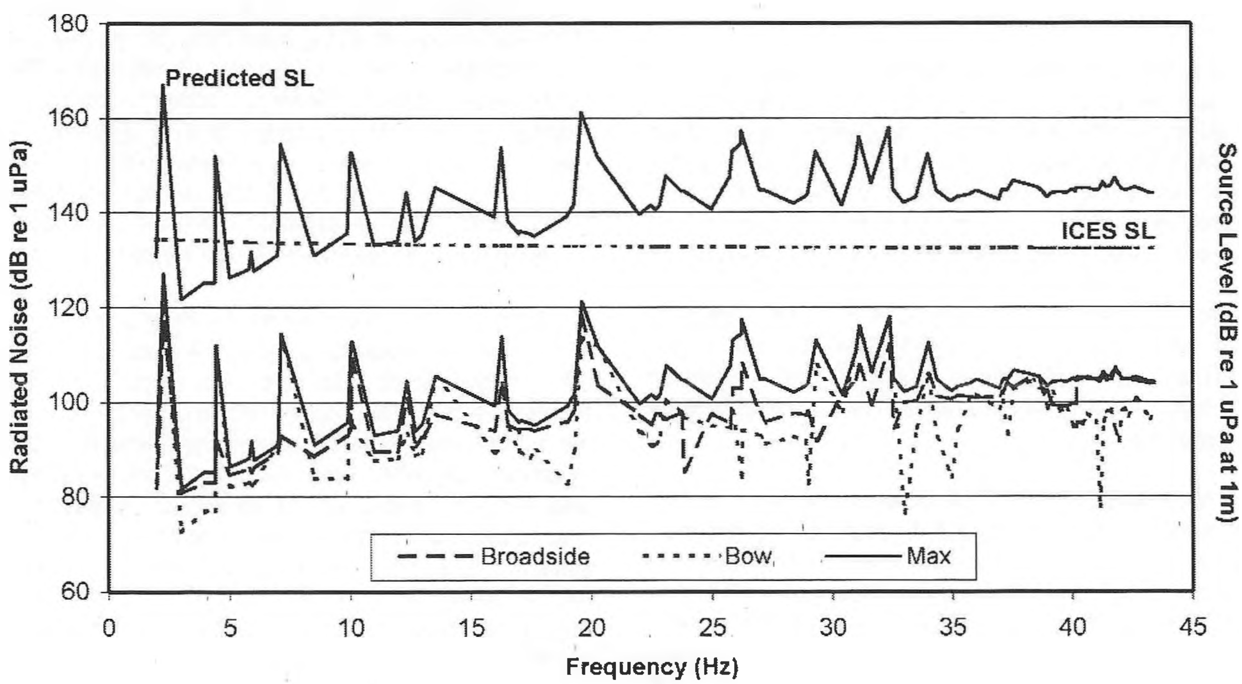

Figure 3:Radiated Sound Level and Source Level vs. Frequency