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Possibilities for Assessment of Underwater Radiated Noise from Ships

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The field of underwater radiated noise was for a long time only of interest for naval or special purpose (e.g. Research) vessels. As the underwater noise pollution of the ocean from ships underlies an ongoing increase, the need for limitation of the noise to a non-harmful level for marine life is brought to focus on regional level by states and on international level by the International Maritime Organization (IMO). By this change in perspective, the topic of underwater radiated noise becomes now a much wider application, also in commercial shipping.

Depending on the type of application, a certain acceptable, frequency dependent noise level can be defined (limit curve), where the radiated noise of the ship under consideration should stay below. For naval and research vessels this level is defined by operational requirements, as e.g. distance of detection (for naval vessels the enemy, and for research vessels marine life) and usability of measurement devices (e.g. sonars, hydrophones). For commercial vessels, the limit curve is defined by a source level which is considered to be non-harmful to marine life. Ships are sailing globally and the marine life, which needs to be protected differs strongly dependent on the current location. And with each species, also the relevant frequency range and corresponding limiting sound level differs.

To design a new ship or improve an existing vessel, the topic of radiated noise should be considered right from the project start. For the assessment of the underwater radiated noise, different approaches exist, which all have their own advantages or disadvantages. Therefore, the choice should be evaluated based on the requirements and constraints of the project.

Already in the very early design stage, empirical methods can be applied to get first estimations of the radiated noise. These methods base their prediction on a limited amount of input data, which is beneficial as many parameters are not fixed at this stage. Also it pays of, when the access to required input data is restricted. Although the prediction accuracy is limited, a first prediction can be provided in a timely and costly manner. Furthermore, the influence of key parameters on the radiated noise can be investigated. A drawback is that, not all design decisions or changes in design make a difference to the prediction. This of course lies inherently in the procedure and rough scale of input data, but one needs to be aware of this when making decisions based on empirical models.

The prediction accuracy can be increased by modelling the different parts more in detail and coming to a fully numerical approach. The fundamental physical equations describing the processes involved in underwater sound generation and radiation are well known in principle; however, due to significant temporal and spatial scale differences between involved phenomena, they are challenging to solve numerically, which is why simplified models and assumptions are introduced.

A significant advantage of numerical approaches is their high flexibility: different design variants, operating conditions, and boundary conditions can be efficiently investigated under consistent, isolated (i.e., interference-free) operating conditions. This allows noise-critical components to be identified and optimized early in the design process. In addition, numerical models allow direct scaling to real ship sizes, whereas model tests are often subject to scaling effects.

Nevertheless, the accuracy of the numeric results depends heavily on the underlying model assumptions, the quality of the input parameters, and the representation of complex physical effects. In particular, the realistic simulation of cavitation, structural vibrations, and their acoustic radiation remains a significant challenge.

Even with steady growing possibilities in numerical assessments, model tests still play a key role in the assessment of the performance of ships. This is also valid for the field of cavitation tests including the prediction of underwater radiated noise. For many new building and retrofit projects, the evaluation of the risk for erosion on the propeller and the measurement of pressure pulses belong to the standard model test extent. The measurement of the underwater radiated noise can be well integrated into such a test campaign with manageable effort. As in the numeric assessment, model tests offer a high flexibility of the setup with measurements under consistent, isolated operating conditions. The accuracy of the relative comparison of different configurations is very high during model tests. Even though the model test results need to be scaled from model to full scale, the prediction of the full scale radiated noise shows satisfying accuracy. Model tests are carried out at a project stage, where the ship design, including hull, rudder and propeller, is often already on a high fidelity level. Nevertheless, changes in the design are still possible with reasonable effort.

Although a cavitating propeller often dominates the radiated noise over a wide frequency range, it is also the only noise source, which is considered during model tests. Other noise sources, such as machinery or structure borne noise, are not modeled. When the propeller is free from cavitation, the radiated noise from the propeller is often below or very close to the background noise of the test facility. If the back ground noise becomes the dominant noise source, no prediction of the radiated noise from the propeller can be derived. Further challenges arise from the fact that not all scaling laws can be fulfilled at the same time during model tests, which is why the cavitation pattern might differ from the full scale patterns. For fully pronounced cavitation patterns, this is not an issue and when looking at inception points, one can circumvent this shortcoming by closely evaluating the contribution of the different cavitation pattern. Finally, limitations arise regarding low frequency far field noise. These limitations and their impact depend on the individual test facility.

Once the ship is built and in operation, the actual underwater radiated noise can be measured in service. This has the great advantage that all specific noise sources are recorded, including the ship's engines, which might also be contributing in a specific frequency range. By means of full scale measurements, the effect of the ship under real conditions can be quantified. At the same time, this presents the greatest challenges. The ship's operating conditions including the distance from the hydrophone must be clearly defined. Environmental conditions such as wind, current, sea state, rain and seabed have an impact on the result. The conversion to source levels can be subject to considerable uncertainties. Consequently, the precise underwater noise assessment of a ship is expensive and time-consuming.

Long-term measurements are a special kind of the full scale measurements using permanently installed measurement systems. This allows a large amount of data to be collected, which is important for a statistical assessment and monitoring of the underwater radiated noise. Such data can be used in early ship design to make estimates with few input parameters, similar to empirical approaches.

However, the sensitivity of the prediction is correspondingly low. Compared to dedicated full scale measurements, the results of long-term measurements are subject to higher uncertainty.

The prediction and measurement of underwater radiated noise from ships remains a challenging task. The need for accurate predictions and measurement rises with increasing awareness for protection of marine life and potential upcoming regulation of the radiated noise from ships. The presentation shows different approaches to assess the underwater radiated noise from ships. The project stage, data or ship availability, budget and desired prediction accuracy should be closely weighted to find the project specific most promising approach.