Silent vessels

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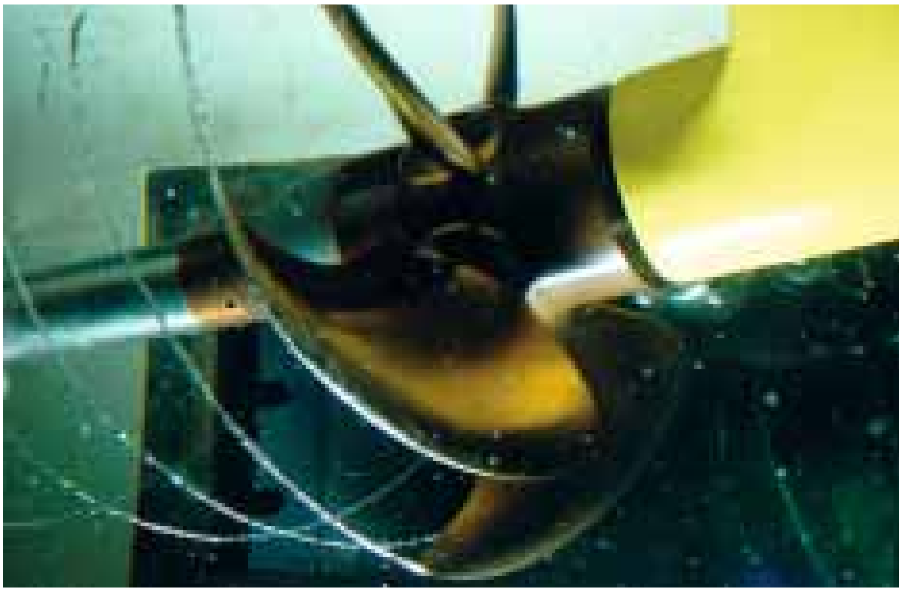

Fig. 1 – Propeller model during testing at BVT's cavitation tunnel in Portsmouth.

The notion of "silence" might seem obvious to us, but its meaning has huge variations, depending on the environment we are familiar with. In the naval forum, silence is a common desire or need and this in turn, places specific requirements on equipment makers.

There are in fact three distinctly different types of noise:

Airborne noise

This noise is created by pressure variations in the air (compressible fluid) and can simply be called "sound". This principally concerns airborne noise levels that are lower than those set by marine regulations. The main technical solution for limiting airborne noise disturbance is to insulate the entire engine room, or the engine itself, by using an acoustic enclosure.

Structure-borne noise

This noise is created by vibrations of onboard equipment, which is transmitted to the hull. This is a concern in almost all applications and at various severities, but there is a simple technical solution in the form of anti-vibration mounts. Sometimes, the requirement for limiting vibrations transmitted to the hull is such that it is necessary to consider two stages of resilient mounts (called "double resilient mounting").

Underwater radiated noise

This noise is created by pressure variations in water (uncompressible fluid). These fluctuations are due to the hull's residual vibrations that excite water (due mainly to structure-borne noise, and to a limited extent, airborne noise), and by rotating elements and appendages in the water.

This is the noise that fish and sonar can detect, and is obviously a main issue for Oceanographic Research vessels (so as not to disturb the fish under observation) and most naval vessels (so as not to be detected by sonar). As a rough guide, it can be estimated that for research vessels, ½ the underwater-radiated noise is from the propeller, ¼ is from the generator sets, and ¼ from the electric motors.

Noise abatement is an everyday concern in the naval environment. Wärtsilä has developed either dedicated solutions, or has adapted COTS (commerical off-the-shelf) equipment to meet these design challenges. A good illustration of the know-how and capabilities of Wärtsilä in this domain is the propulsion solution adopted for the MEDUSA project, the new Oceanographic Research Vessel made by the Chilean Navy, presented at the end of this article.

Welcome to the world of silence.

Silent propellers

All parts of a vessel contribute to underwater-radiated noise, including the active inner parts such as machinery, and the passive outer parts, meaning the hull and its appendages, due to turbulence in the flow on these surfaces. The propellers become one of the essential sources of noise as the vessel increases speed because of the occurrence, and the extension of the cavitation phenomenon, which dramatically increases the noise levels at all frequencies. Low signature vessels are those for which the radiated noise spectrum is as low as possible at all frequencies.

International Council for the Exploration of the Sea (ICES)

For research ships, the Cooperative Research Project n°209 from the International Council for the Exploration of the Sea (ICES) [1] gives recommendations concerning underwater-radiated noise. The main objective of these recommendations is to define a spectrum of acceptable underwater-radiated noise levels to avoid “any disturbance of the natural distribution of the fish”, but also to “ensure that the fish target distributions and echo-integrator results are free of bias due to high-frequency noise”. The noise levels should be measured for a ship sailing at 11 knots (Figure 2).

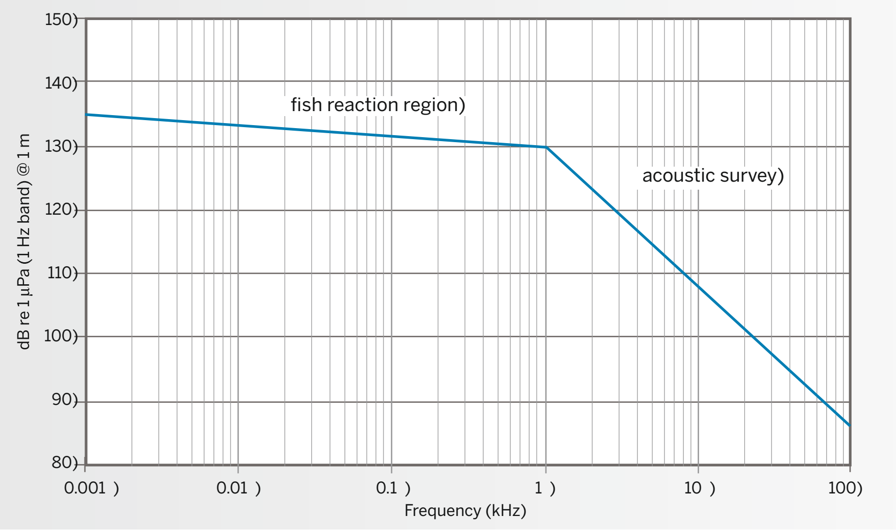

Fig. 2 – ICES 209 underwater-radiated noise specification at 11 knots.

Cavitation Inception Speed (CIS)

Up to now, the radiated noise of a propeller cannot be predicted with sufficient accuracy to directly select those geometrical characteristics that would control and reduce this radiated noise. As cavitation is an important source of noise, the wet parts of the ship, especially the propeller, should be free of any type of cavitation at the sailing speed of 11 knots, which means that the Cavitation Inception Speed (CIS) should be higher than 11 knots to ensure radiated noise levels as low as possible. An indirect strategy for noise reduction has been developed to delay the inception of cavitation.

The main tool for evaluating the design performance of a propeller in this process is the so-called Sigma-(KT) diagram (Figure 3). The vertical axis gives the cavitation number σ_n; and the horizontal axis the thrust coefficient KT. The various curves on this diagram are the cavitation inception data of the various cavitation patterns: sheet, bubbles, root and tip vortex, on the suction side and on the pressure side (Figure 4).

The accuracy of the numerical tools used to predict such a diagram is not sufficient to avoid model testing, even if the application of Computational Fluid Dynamics (CFD) is very promising in this field. In the model tests performed to get this diagram, it is not possible to fulfil both geometrical and viscous scale laws, so viscous effects are not properly taken into account. As the cavitation of the tip vortex is considered to be highly dependant upon its viscous core, a specific extrapolation scheme is necessary to estimate the full-scale inception conditions of this peculiar phenomenon. This is explicitly displayed

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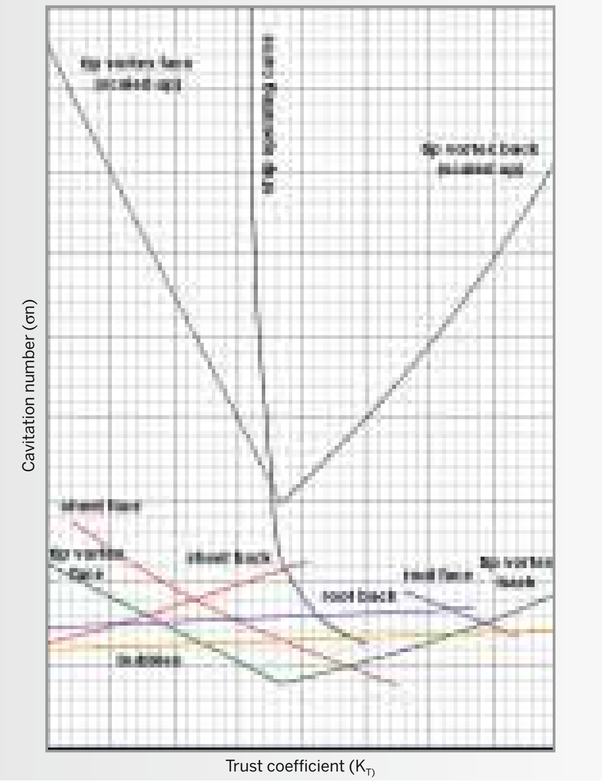


Fig. 3 – Cavitation inception diagram.

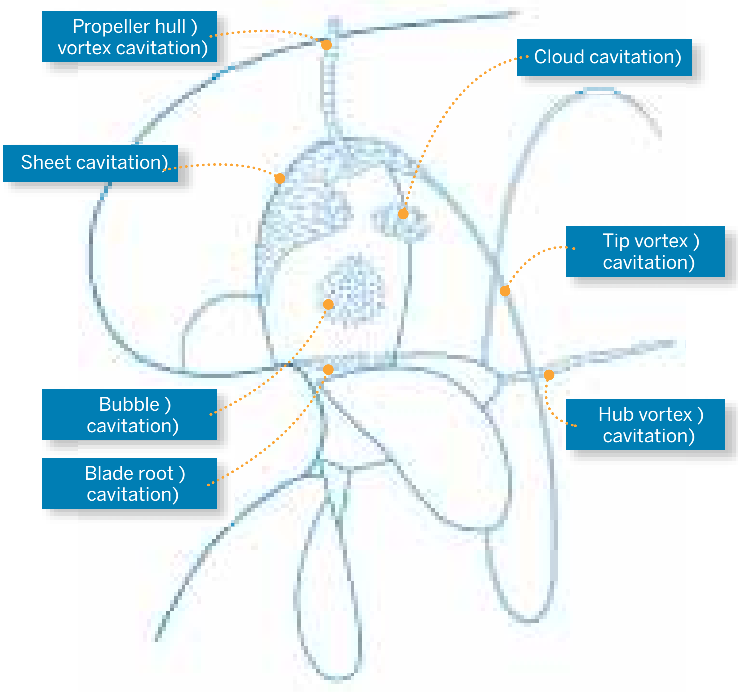
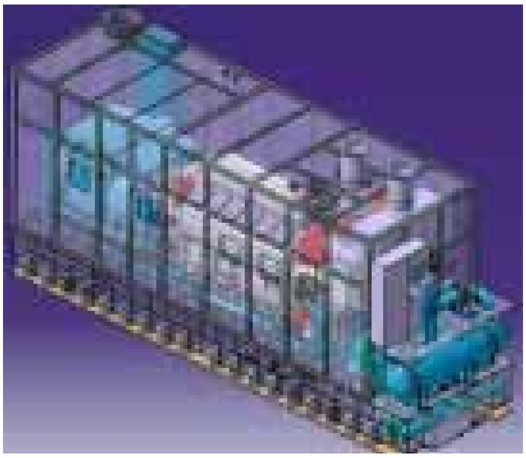
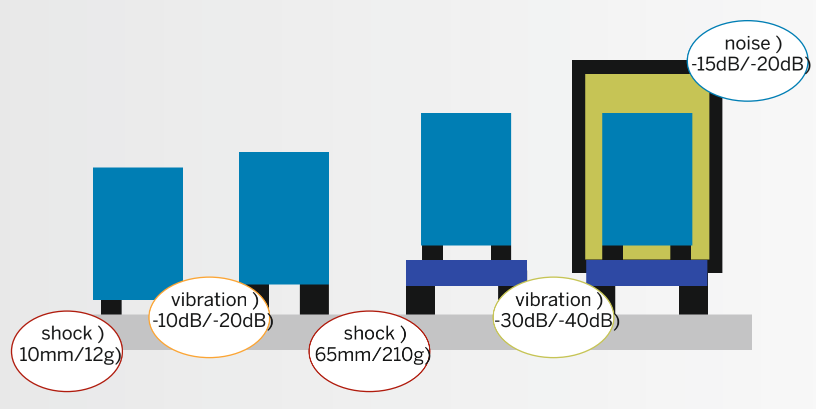


Fig. 4 – Different types of cavitation, drawing courtesy of MARIN.



■ Fig. 5 – Wärtsilä 12V26 DG set.



■ Fig. 6 – One/two stages resilient mounting.

on the diagram by the scaled up curves and fully described by Mc Cormick [2].

The intersection of the ship's operating curve with the scaled up tip vortex bucket defines the CIS of the tested design. The design challenge is to achieve a wide and deep tip vortex cavitation bucket, the bottom of which is pierced by the ship operating curve, in a balanced manner between face (pressure side) and back (suction side) of the propeller blade.

Wärtsilä has developed its expertise with the co-operation of the major institutions and model basins in this field of research.

Radiated noise from the diesel generator set

From radiated noise to inboard vibrations

From the underwater radiated noise criterion (sound pressure level) a 'reverse' calculation procedure, based on a database of similar ships or a noise radiation model, is used in order to define the structure-borne noise. This is done at the ship's hull plating, and continues with the noise and vibration levels/limits at the inboard machinery foundations. The typical frequency range of interest for machinery vibrations limits is 10 Hz to 10,000 Hz.

Excitation sources

The excitation forces from the engine (mass and gas excitations), from the generator (unbalance, electrical excitations), and from the DG (diesel generator) set auxiliaries; pumps, fans and piping, will be the determinants for the noise and vibration levels of the DG set. The reduction of these excitations has to be investigated, as far as is possible, at the level of the excitation source. In practice, this is limited by the laws of physics, the practicality of solutions (balancing, bearing selection, the Eigen frequency analysis, fluids velocities etc.), and cost reasons (development and implementation).

DG set engineering

The remaining and most efficient means of decreasing the force transmissibility from the excitation source to the machinery foundation, can be achieved through the mounting of the noise sources in accordance with the following main design features:

- Installation of the engine, generator and auxiliaries on a common base frame. A static and dynamic analysis of the base frame design (stiffness of the seatings below the engine and generator fittings, natural frequencies and mode shapes) is generally done through a Finite Element Model. (Figures 5 and 7).
- Selection of the number of resilient mount stages; at least one stage of resilient mounts between the common base frame and the machinery foundation on the ship's hull plating. If needed, in addition to the previous stage, a second resilient mounts stage is fitted between the engine and the base frame (and for some applications, between the generator and the base frame). (Figure 6).
- Selection of the type of resilient mounts (natural frequencies generally in the range of 3 to 10 Hz, displacement capability from 10 mm up to 70 mm for some Navy applications with shock requirements).

■ Fig. 7 – Diesel generator set with double resilient mounting and acoustic enclosure.

- Design of the auxiliaries fitting and pipe clamping, which may have a significant influence on the resilient mounting efficiency.

For some projects, an acoustic enclosure might be needed when the noise level in the engine room has to be below the standard engine airborne noise, or when the vibrations have been reduced to a very low level whereupon the underwater-radiated noise may be influenced by the airborne noise of the DG set. ●

REFERENCES

1. RB Mitson, "Underwater Noise of Research) Vessels, review and Recommendations",) International Council for the Exploration of) the Sea, 1995.)
2. BW McCormick, "On cavitation produced) by a vortex trailing from a lifting surface",) ASME Journal of Basic Engineering,) September 1962.)