HYDROACOUSTICS
4, 165-168 (2001)

UNDERWATER NOISE RADIATED BY SHIPS, THEIR PROPULSION AND AUXILIARY MACHINERY, AND PROPELLERS

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These underwater radiated noise and vibration measurements were conducted on a full-scale ship in August 2000. During the trails it was found that several spike noises are dominant. To find the location of high vibration level places and its frequencies, and the machines, which generated high level point noise components, 4 accelerometers were fixed in the engine and auxiliary rooms .We were using this system to find the relationship between certain manoeuvres and the vibration level caused by them. Propellers and engines are usually the major sources of noise in ships but gearboxes can also be significant contributors. The way of mounting of the machines and the resulting vibration of the hull are determining issues in the radiation of underwater noise. Naval Test and Evaluation Acoustic Ranges contain an accurate radiated noise measurement system consisting of a bottom-mounted hydrophone array for sailing condition and a stationary range. The sophisticated digital narrow-band instruments and analogue recorders were used by us.

INTRODUCTION

The methods to measure the rotational and translation components of the vibration or structure-born sound levels on a stationary vessel and a moving ship are a mixture of analogue and digital techniques. The ways of determining an acoustic field generated by a surface ship from regular vibration distributions are not complicated, but some difficulties can be caused by irregular vibration sources.

A ship's diesel generator radiates a series of tonal components at the fundamental frequency and their harmonics that are independent of ship speed. Rotating unbalanced and reciprocating (explosions in cylinders) elements create a line-component spectrum in which the noise is dominated by discrete field. The main sources mechanism of the diesel engine is the hit of the piston against wall of the cylinder or so called "piston slap". Note (3) that its radiated power W at the basic firing rate frequency F is related to engine horsepower H as: $W \sim (HF)^2$.

The main acoustic source on vessels is propeller and its cavitation, which characteristically generates both a continuous spectrum component and a set of line components. These discrete components are produced by the changes in the total volume during ship's propeller revolutions, and consist of a group of harmonically related lines with the basic frequency equal to the propeller blade rate (usually in the 0.1-20Hz band), but when the rotation speed is adequately high, a cavity will be created.

1.RADIATED NOISE SOURCES

The problem of underwater noise is caused by closely packed high-powered equipment, confined in a small metal or plastic vessel. Shipboard noise is generally created by poor or improper vessel acoustical design. In average speeds, the noisiest piece of equipment on any ship is usually a diesel engine. Being a reciprocating machine, the diesel is very loud and also generates a great deal of vibration. All ships, even quiet ones have noisy or even extremely noise, engine rooms. Problems occur when a vessel's design provides transmission paths for noise to travel from the noisy engine room through the hull into the water. As we mentioned at low ship speeds the ship diesel generates produce discrete lines, which dominate in the spectrum. The main component is a strong discrete line at 25 Hz and its harmonic at 50 Hz. These frequencies are from rotation speed of auxiliary machinery components. Because our diesel generator was power by a four-stroke six-cylinder diesel engine, that vibrated with firing rate equal to 37.5 Hz. Therefore we have two main lines at 25 and 37.5 Hz and their fundamental harmonics at 50 and 75 Hz.

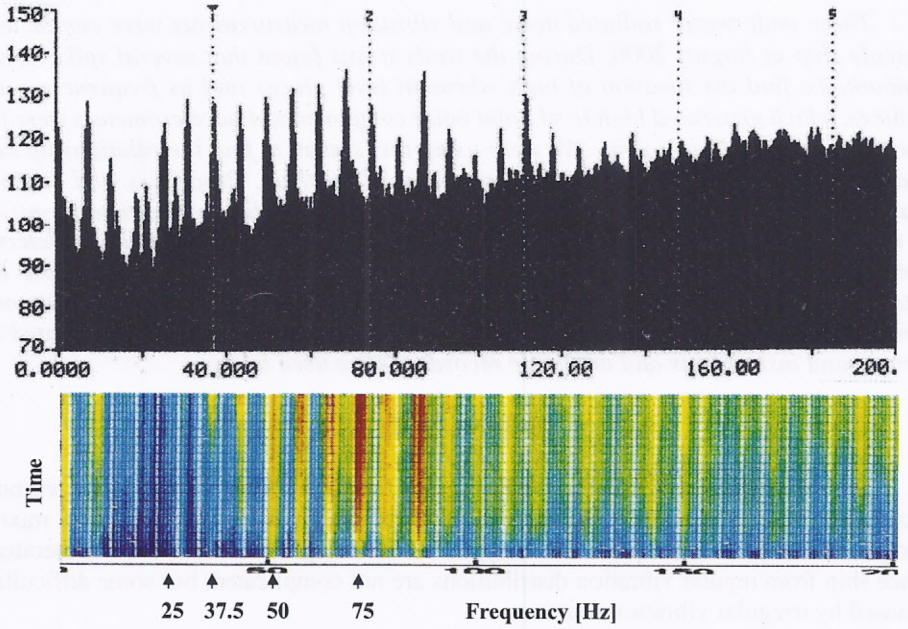


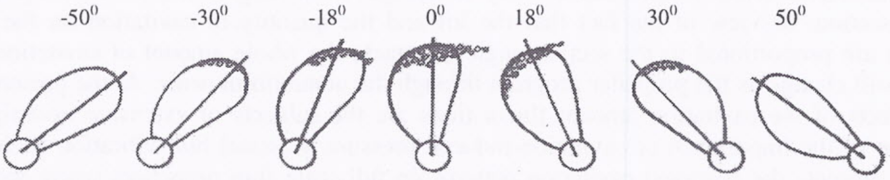
Fig.1.Sound spectrogram of a surface ship at a speed of 4 kn and her high-resolution narrow-band spectrum at 8 kn. The bandwidth is 0.5 Hz.

A propeller noise is commonly divided into two main types:

a) cavitation noise radiated by the implosion of bubbles which can be formed around the edge of the blade, across the low-pressure area of the blade and in the vortex behind the hub of the blade. This is a broadband high-frequency noise.

b) blade noise, which is radiated by the thickness of the blade and the loading on the blade when it rotates. This gives rise to narrow-band low-frequency noise.

The cavitation patterns observed on suction side are presented in Fig.2. The maximum sheet cavity on this propeller covers only small part of the blade surface. The cavity exists here in the area of small wake velocities. The quantity of unsteady cavitation on a propeller in a nonuniform wake is connected with ship vibration, propeller efficiency and its erosion. In order to decrease the intensity of cavitation, the propeller blade region should be enlarged.



FULL-SCALE CAVITATION OBSERVED ON SUCTION SIDE OF A SURFACE SHIP PROPELLER: 4 BLADES, 1,5-m DIAMETER

Fig.2.Full-scale cavitation patterns observed on suction side of a surface ship. View from forward looking aft.

Histories of propeller cavitation during a revolution is observed on full-scale ships, these have been reported in the literature (1,2). On a single –screw vessel, there also exists a significant irregular thrust component due to the fact that the inflow to the propeller is noticeably nonuniform over the propeller disk. Fig.3. is a schematic of the stern of a vessel showing a ship's propeller and the inflow(ship wake field) for a typical vessel. The contours represent the axial wake velocities normalized by ship speed. It is important to notice that a region of low wake velocities exists near the top of the propeller disk.

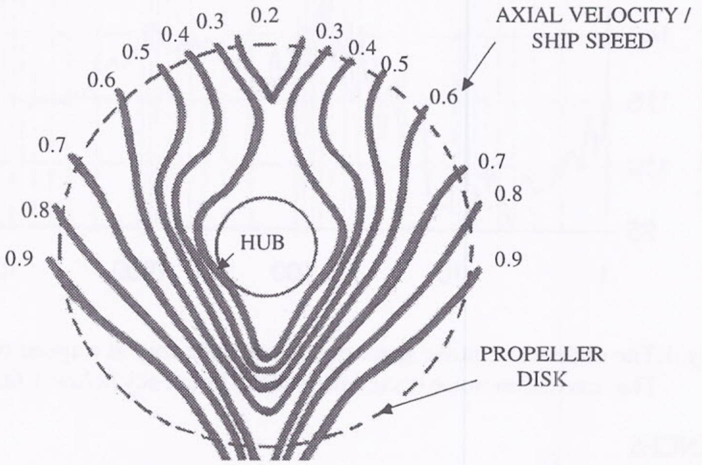


Fig.3. Isovelocity wake contours for axial velocity in propeller plane.

The cavities can be formed not only at the ends of the propeller blades which are closely associated the vortex stream left behind the rotating propeller, but also on blade-surface, where the generating region lies at front or back sides of the propeller blades.

Vessel screws are designed to produce a given amount of thrust with a given flow to the propeller. This thrust represents itself as a pressure reduction on the blades. If the pressure reduction on the suction side is adequately harsh, cavitation will occur. A significant irregular thrust component exists due to the fact that the inflow to the propeller is significantly nonuniform over the propeller disk, because we have here a double-screw vessel. The inflow to the propeller disk is affected by the hull boundary layer right away to the screw. An example of this inflow for a representative single-screw ship is shown in Fig. 3. Changes in the axial inflow velocity correlated directly to changes in the angle of attack of the propeller blade section. In view of the fact that the lift and the quantity of cavitation on the blade section are proportional to the section angle of attack, the whole amount of cavitation on a blade will change as the propeller progress through the nonuniform wake. At the present time the effects of the cavitation amount fluctuations are the subjects of extensive investigation because of the importance of cavitation-induced pressure in vessel hull vibration excitation. Fig. 2 presents the observed cavitation patterns on full-scale ship propellers where were the maximum cavity on these screws covers roughly 10% of the blade surface. The amount of uneven cavitation on a given propeller in a nonuniform wake is surrounded by considerations of propeller efficiency, wearing away its parts, erosion, and vibration of a ship. With the purpose of reducing the intensity of cavitation on a propeller, its blade area must be increased, which causes a reduction in propeller efficiency and an increase in propeller weight.

Figure 4 shows a peak in the spectrum of cavitation noise which , for surface ships and submarines, usually occurs within the frequency band from 100 Hz up to 1kHz. The place of the peak in the spectrum moves to lower frequencies at higher ship's speeds and at smaller depths.

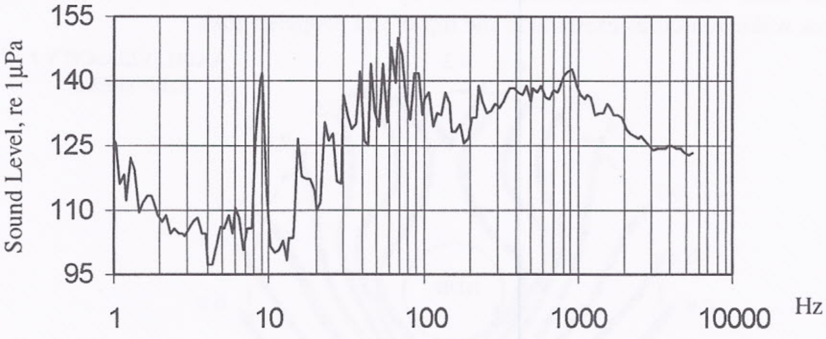


Fig.4.The underwater noise spectrum of a surface ship at a speed of 16 kn.
The cavitation noise occurs here at the frequency below 1,000 Hz.

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