UNDERWATER NOISE PRODUCED BY SHIPS IN SHALLOW WATER

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Abstract

The investigations of vibrating and acoustic activity of a ship is a topic of interest for technical diagnostic, ecological and navy reasons. The underwater ship noise is a subject of interest from a few points of view. Two of them are worth to mention. The first one is the fact that both the merchant and military shipping constitutes a major source of noise in the sea. The second one is the important application of underwater noise features in the underwater warfare. The paper presents some summarized knowledge on the underwater sound generated by ships.

INTRODUCTION

A ship is complex source of noise, which is a topic of interest for a few reasons. Each machine working on board has its own sound characteristics. Increase of the pressure level of any of the sound spectrum components may be a sign of deterioration of its technical condition. A ship producing sound of a higher level is more detectable by the passive hydroacoustic systems. It can also activate the mines which react to the increase of the sound pressure. Noise disturbs the work of hydroacoustic devices mounted on a ship and is undesired for ecological reasons.

The interest in underwater sound generated by ships has a reach history. It begins from the World War II. The results of investigations of that period were described in a textbook by Urick [4]. Many European researchers in Germany, Norway, Sweden, Russia, Finland and Poland have contributed to ship noise and propeller investigation.

A lot of older results of measurements were obtained with third-octave' bandwidth analysis, which is too wide for separation of the individual features of radiated ship noise. Furthermore the data were obtained as a result of measurements in the shallow water, so they may not be representative of free-field values. Taking into account the above mention facts and also high cost of ship time and measurement facilities and military application of data it is not surprising that detailed results of measurements of ship are difficult to available.

CHARACTERISTICS OF UNDERWATER NOISE RADIATED BY THE SHIP

One can separate a few independent sources of underwater noise produced by a moving ship. The main sources of the ship noise are as follow:

- ship's service diesel generator,
- propulsion engine,
- ship propeller.

At the low ship speeds the ship's service generator is the main source of the underwater noise generated by ship. It radiates tonal components that contribute almost all of the radiated noise power of the ship. They are independent of ship speed. Few of components are enough strong to be contributors to high-speed signature. The tonal levels of ship's service diesel generator are nearly stable in amplitude and frequency. The wide-band energy of the noise generated by ship's service generator is proportional to the square of generated power.

NOISE GENERATED BY A PROPULSION ENGINE

The propulsion engine is a main source of underwater noise for moderate speed of ship. The tonal components are connected with firing rate. For the two-stroke x-cylinder diesel engine the firing rate is defined as:

$$\text{Firing rate (FR)} = \frac{x \cdot rpm}{60} \qquad (1)$$

where x- number of cylinders.

The tonal level is not stable in general because of variations of loading as is propeller for different sea state. The radiated power at the fundamental firing rate frequency F is related to engine horsepower H as:

$$W \sim (H.F)^2 \qquad (2)$$

Analyzing the vibration engine caused by diesel engine that is converted into acoustic energy one should take into account the possibility occurring structural resonances these may play a great role in determining the radiation efficiency of the ship's engine tones.

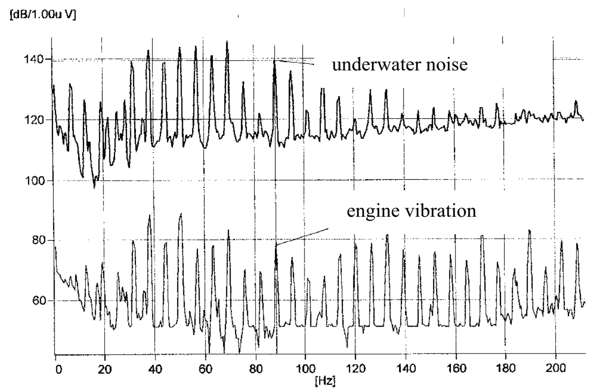

Fig.1. Spectra of acceleration of main engine vibration and of total underwater noise

NOISE GENERATED BY A PROPELLER

The most efficient underwater noise source on the ship is the propeller noise. One part of it is so called blade rate, that is a signal at the blade passing frequency and its harmonics. This gives usually the dominant contribution to low frequency tonal level at high speeds of ship, when the propeller is heavily cavitating.

Because the work of propeller is near the hull, the inflow velocity is reduced significantly near the top of the propeller. A surface ship propeller operates behind the hull which creates a nonuniform wake inflow velocity and variation of the sea surface due to wind causes that the upper region of the propeller blades motion is the lowest pressure as usually. For the high rotation speed a cavity can be formed that collapses when the pressure increases during the blade downward. Because the collapse of a cavity occurs every time a blade passes through the region of low pressure, noise has fundamental harmonic equals the blade rate, and its harmonics.

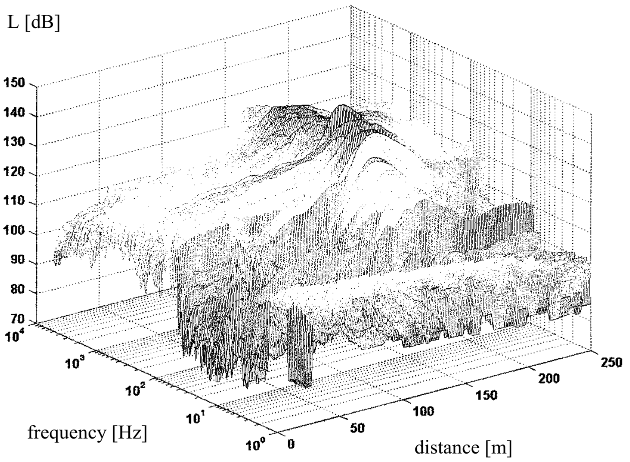

Fig. 2. Underwater noise in 3D form

Estimation of the sound pressure generated by cavitating area can be done by assuming that the pulsation of cavity may be approximated by a monopole source. Because the process take place in the vicinity of the free-pressure surface so the nearly perfect reflections of the sound waves occur as the second source. In result of them the radiation pattern of the propeller noise has a dipole character with a dipole directivity pattern.

The simple expression described the dipole pressure P_d is as follow:

$$P_d(t) = \frac{d\rho}{2\Pi rc}\frac{d^3V(t)}{dt^3} \qquad (4)$$

where: r - distance from the source, ρ - density, d - source depth, c – speed of sound, V(t) – instantanous cavity volume, t – time.

MEASUREMENT FACILITY

The best location of the measurement facility is that where the ambient noise is the smallest and the depth of sea is enough high that the bottom is reflectionless one. The best location of hydrophones array for this purpose is a bottom-mounted set-up. The good hydrophone array has 3D form because this allows to determine the complex acoustic directivity pattern of noise radiated by the ship. The runs are recorded by means of multichannel tape recorder. The resulting data as the spectra are used to provide an input to special directivity analysis procedure that allows to obtain the directivity plots.

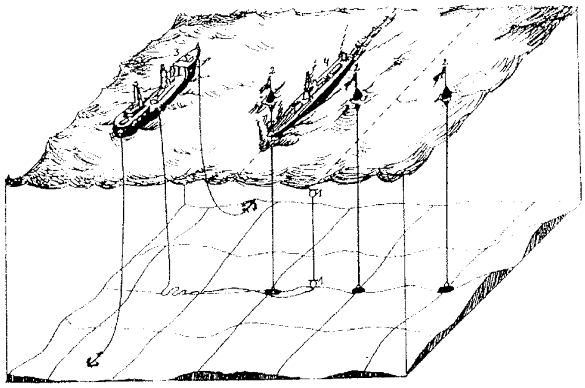

Fig. 3. Measurement range

At the same time on-board measurement of the main engine and service diesel generator vibration are carried out. On the base of result of this measurements one can determine the bandwidth from the ship, diesel engine cylinder pressure spectra, engine vibration transmission paths, ship hull "beam mode" response and at last the transfer function between the on-board instalated sources of vibration and outside radiation level.

Some measurements carried out during the investigation of the ship noise are illustrated below.

SUMMARY

The investigations of the acoustic signature of ships are very expensive procedure as well as time consuming. These investigations should be carried out at the same time both on-board and out-board. This allows to determine connections between sources installated on- board and near the hull (ship propeller) and radiated level as well as their spectra.

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