THE METHOD OF DETERMINATION OF THE ACOUSTIC CHARACTERISTICS OF THE SHIP

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The results of the research on the structure of the emission of the noise that are generated by the ship into the water environment are presented in this paper.

The results are representative for the measurements that are carried out in the shallow water and presented in spectrograms and diagrams.

INTRODUCTION

The measurements of the emission of the ship's noise generated into the water environment are repeated cyclically during the operating of the ships.

The knowledge of the acoustic field and its acoustic characteristics is used during the operating of the ship for the need of remote diagnostics. The ship is compound source of the sound emission into the water environment and acoustic disturbances are the sum of disturbances from working ship's mechanisms.

While the research was carried out the ships were passing the measurement ranging with the fixed parameters of the power unit.

The required parameters of the ship's units are made earlier in the settled distance from the measurement's sensors and are permanent in the section of the measurement ranging.

The measurements of the acoustic pressure that are made in the specific distance in front of the bow and behind the stern make possible to identify the characteristics of the underwater disturbances of the ship.

1. ACOUSTIC CHARACERISTICS OF THE SHIP

It is very common to present the passing of the ship through the control measurement station as the dependence of the acoustic pressure in time and frequency function. The registered noise is presented in the figure 1.

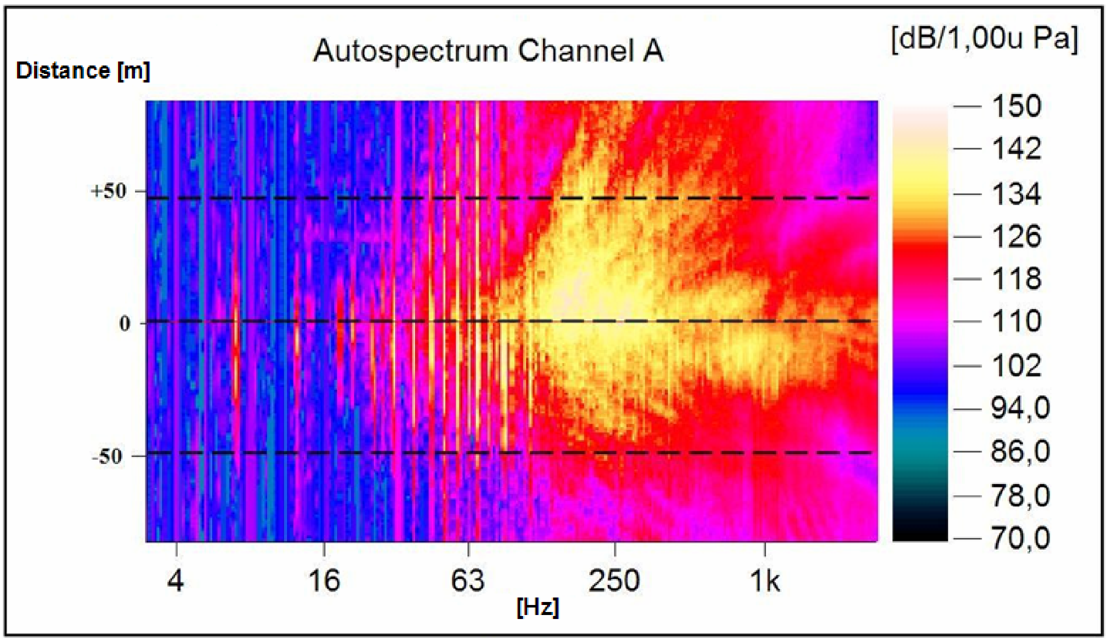

Fig.1 The spectrogram of the acoustic field of the passing ship with the speed of 4 knots

The spectrogram consists of 299 registered every 312 [ms] spectrum, with the resolution of 0,04167 octave in the range of frequency from 3[Hz] to 2,818[kHz].

The dashed lines show the ship's distance from the hydrophone.

There are two visible areas in the spectrogram.

The first one is from 3 [Hz] to about 100[Hz]. In this area might be separated characteristic components of the spectrum that are caused by working ship's units. The second area is visible from 100[Hz] to 2.8[kHz] and has the characteristics of the continuous spectrum. This area of the spectrum is connected with the work of the cavitating ship's propeller, turbulent flow in pipelines, flow noise, air flow in ventilation systems. The analysis enables the selection of the components of the spectrum in any area of research.

Figure 2 shows the spectrums of acoustic pressure that are generated by the ship to the water environment. They are registered in the marked areas in the spectrogram.

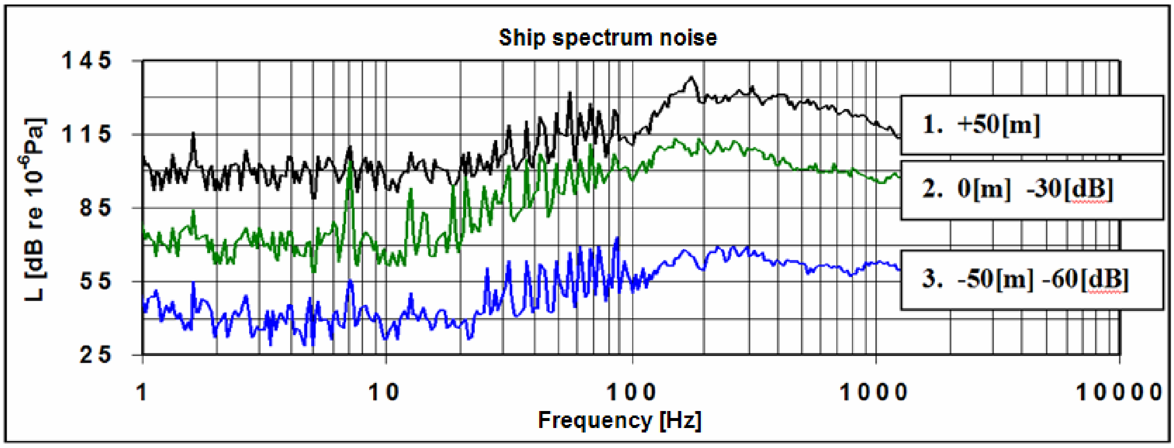

Fig.2 The spectrum of the acoustic pressure in the three distances from the hydrophone. 1 - the spectrum of ship's noises registered 50[m] behind the acoustic sensors; 2 - the spectrum of ship's noises registered when the noisiest part of the ship was above the acoustic sensors; 3 - the spectrum of ship's noises registered 50[m] before the acoustic sensors

The first spectrum was registered when the noisiest part of the ship was 50[m] before the acoustic sensor. The second spectrum when the source of the disturbances was just above the sensor, and the third spectrum in the distance of 50[m] behind the sensor.

There are two visible areas of the spectrum that were mentioned before.

It is noticeable that before the control measurement station, the ship emits the waves connected with the work of mechanisms and the ship's devices. Behind the measurement ranging the dominant waves are connected with the work of the ship's propeller. To present the figures in the more visible way the registered signal was 30[dB] and 60[dB] attenuated respectively when the ship was above the hydrophone, and in the distance of 50[m] behind the measurement ranging.

One of the method of identification of the ship's underwater noises is studying of the acoustic pressure spectrum. Visible in the first area, the characteristic components may be attributed to working mechanisms and ship's devices.

To identify the components mostly the research is carried out in the two stages. The fist stage includes the measurements of the mooring ship.

The measurements depend on measurement of the vibrations of the main ship's mechanisms and auxillary units with the measurement of the acoustic pressure at the same time in the sea.

In the second stage the ship is passing through the dynamic measurement ranging with the differently set power units.

There are underwater noises and vibration of the chosen mechanisms and units registered during the measurements.

On the basis of research it is possible to make the characteristics of visible components that are presented in the first area and their valuation in the area of the higher frequency.

To identify the components it is very common to analyze using the filters that have the constant width of frequency in the studied frequency band.

The representative analysis of identification of the spectrum of the passing ship is presented in figure 3.

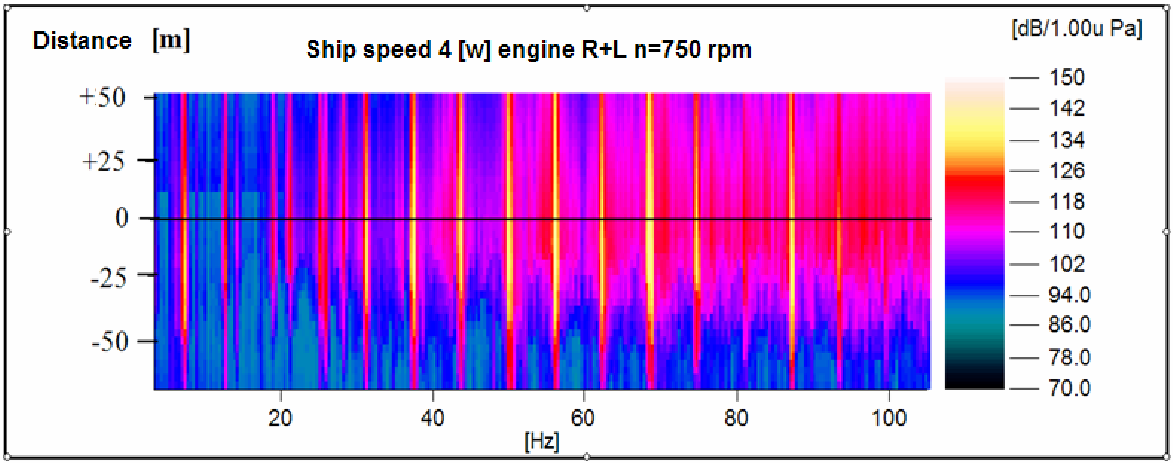

Fig.3 The spectrogram of acoustic field of the ship passing with the speed of 4 knots that was made in the band below 100[Hz]

In the figure below the spectrum when the engine room was situated above the acoustic sensor is shown (the area marked by the black line).

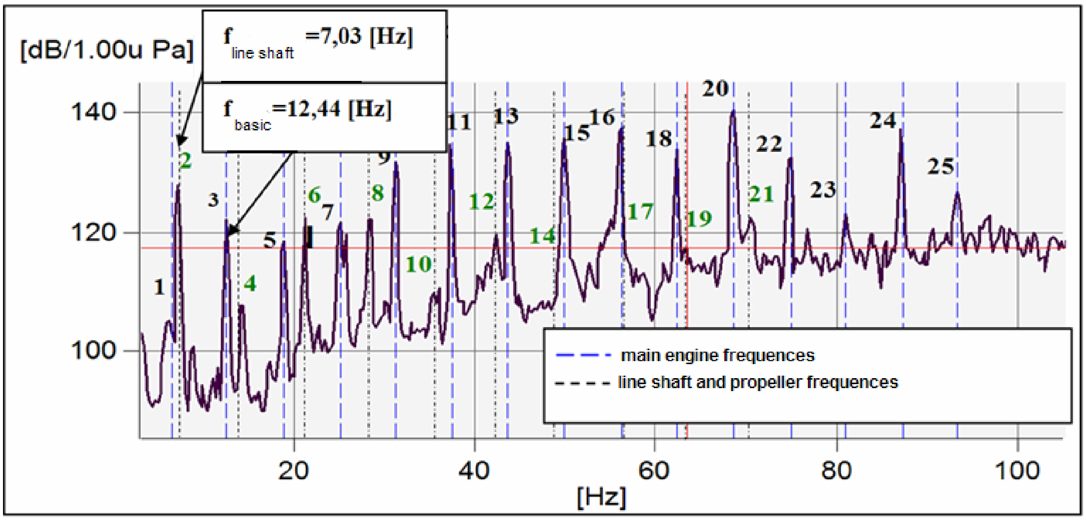

Fig.4 The spectrum of the acoustic field of the ship that was made in the distance „0", marked in the spectrogram presented in figure 3

In figure 4 there are presented selected discrete spectral lines from the working main engines, shaft line, and propellers and one single red spectral line marked as number I from working generators sets. Every discrete spectral line is marked by consecutive number.

The green numbers present the spectral lines from ship's propellers and shaft line. The black numbers present the spectral lines from working main engines. Additionally every discrete spectral lines marked as dotted present: blue ones – frequencies connected with work of main engines, black ones – frequencies connected with work of the shaft line and ship's propellers. The results of this research were frequently publicated [3, 5, 6].

In this paper the only one analysis is presented for the specific set of parameters of machinery components.

In the registry there are research effects of the identification of the different class of the ships that were carried out for specific set of their power system.

The above presented characteristics are very common to show the dependencies of characteristics of the level of acoustic pressure in the function of frequency for any period of time for the ship passing above the hydrophone, as well as:

a) the level of the acoustic pressure in the function of the distance
b) the level of acoustic pressure in the function of the speed of the ship and the depth of the sea
c) dependencies between the noises of the underwater ship and the vibration of the ship's units.

Exemplary characteristics of the dependence between the level of the acoustic pressure in function of the ship's distance from the sensor and in function of the speed of the ship are presented in fig. 5 and 6. The characteristic curves are on the bases of repeated measurements of the ship that were made in the same place of research and the same set of parameters of machinery components.

The results of these measurements were statistically elaborated and approximated. To approximate dependence between the level of the pressure in the function of the distance, depth and the speed of the ship the polynomial of second and third degree is used.

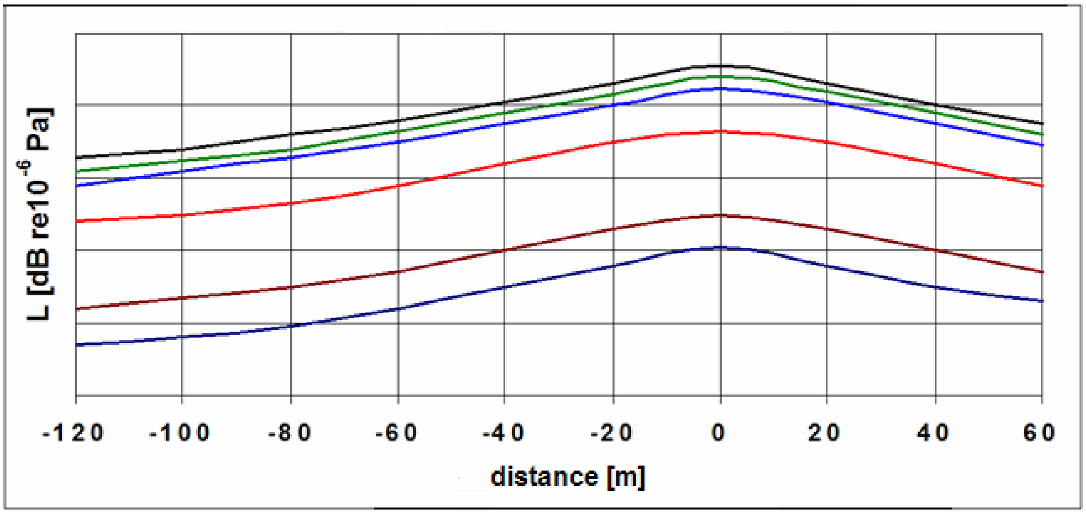

Fig.5 The characteristics of the dependence of the level of acoustic pressure in the function of the ship's distance from the sensor. The measurements were made in the depth of h=30 [m]

1. — measurements made in the speed of v=14.5[w],
2. — measurements made in the speed of v=12.5[w],
3. — measurements made in the speed of v=10.5[w],
4. — measurements made in the speed of v=8.5[w],
5. — measurements made in the speed of v=3.5[w],
6. — measurements made in the speed of v=2.5[w].

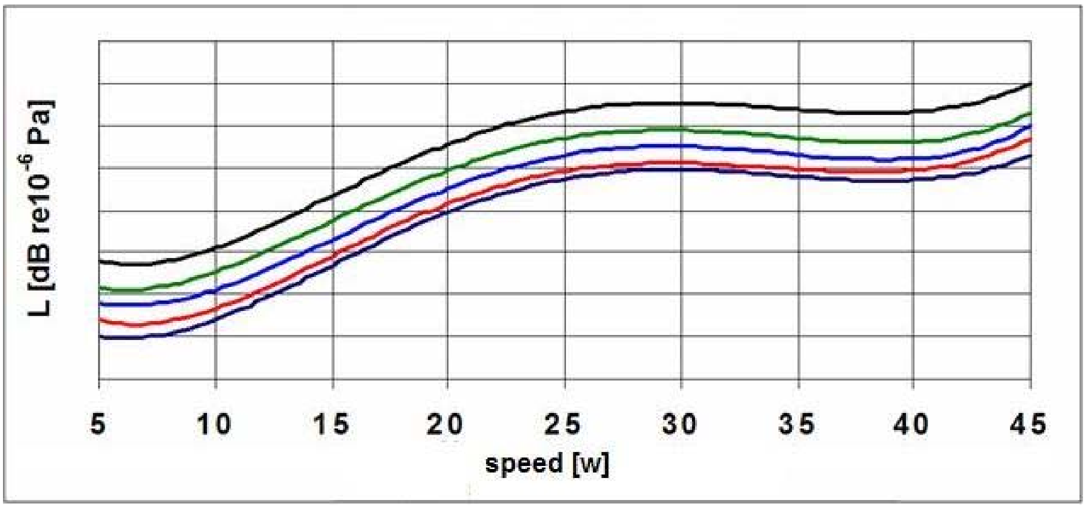

Fig.6 The dependence between the level of acoustic pressure and the speed of the ship

1. —— measurements made in the depth of 10[m],
2. —— measurements made in the depth of 20[m],
3. —— measurements made in the depth of 30[m],
4. —— measurements made in the depth of 40[m],
5. —— measurements made in the depth of 50[m].

2. MEASUREMENT VERIFICATION

To check the proper results, data acquired from the hydrophones used to measure the intensity level, were compared with the data of measurements made in this research. The hydrophones that were laboratory tested and especially chosen were put in the track of the passing ship. The result of this comparison are presented in fig. 7.

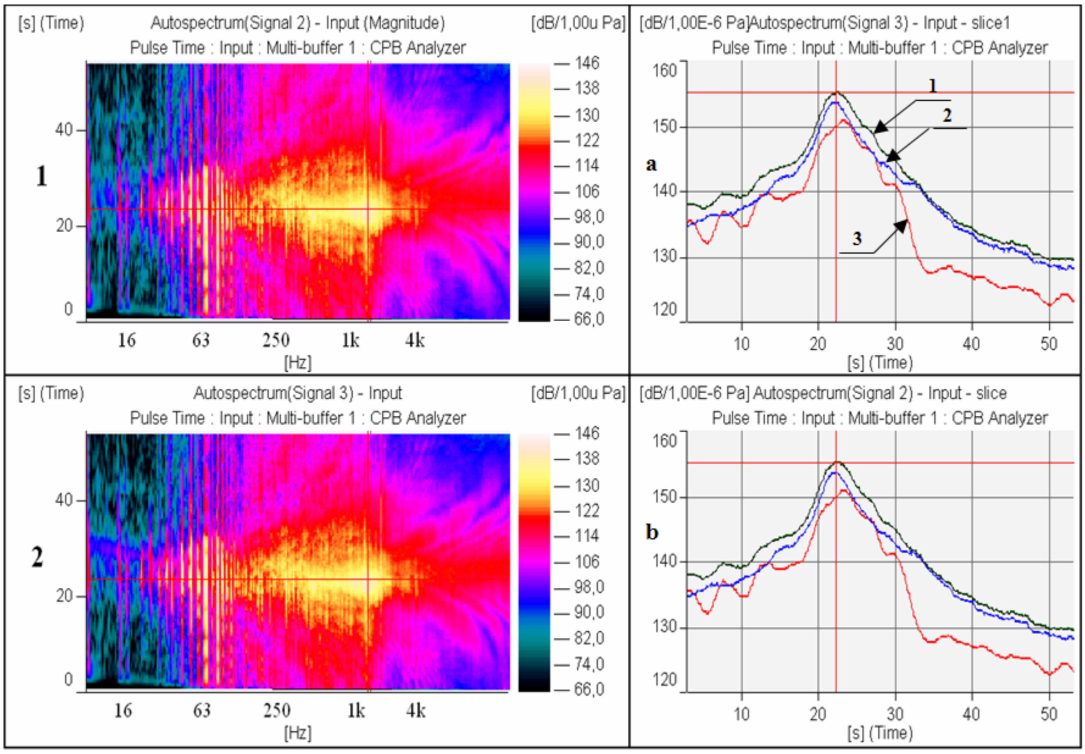

Fig.7 The results of the measurements of the hydroacoustic pressure level for the ship passing with the speed of 6,6 knots registered by the sound intensity probe

1, 2. The Spectrograms of the acoustic field taken from the sensors of the sounder in the range of frequency from 6,9 [Hz] to 11,22 [kHz]

a, b. The dependency of the level of the pressure in the function of the time of the ship's passing through measurement ranging in the selected frequency bands.

1. —The value of the pressure L = 155 [dB] in the band from 6,9 [Hz] to 11,22 [kHz],
2. —The value of the pressure L = 154 [dB]] in the band from 100 [Hz] to 11,22 [kHz],
3. —The value of the pressure L = 151 [dB]] in the band from 6,9 [Hz] to 100 [Hz].

3. CONCLUSIONS

The same values of the levels of the acoustic pressure that were got from the sensors of the sounder in the place marked by the cursor in spectrograms (L=138 [dB] , f= 930,6 [Hz] , t = 23,10 [s]) in the considered bands of frequency as well as the character of the distribution of the underwater noise confirmed the possibility of verification of measured data and possibility of making the mutual analysis of checked sounder, that should enrich the knowledge about the underwater noises. One of the basic attribute that differ the measurement of the intensity of the sound from the acoustic pressure is possibility of determination of difference between the active and passive part of the acoustic field [4], what enables to determine the direction of the propagated waves in water environment. The signaled topic is outsider the scope of his paper and will be the subject of the next publication.

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