1P6-1

Simulation of propagation of ship propeller cavitation pulse in shallow water area

船舶プロペラキャビテーションパルスの浅海域における伝搬シミュレーション

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1. Introduction

Ocean noise pollution is getting to be a major issue for the environmental assessment of maritime transportation and engineering. Evidences to estimate the effect of noise on marine creatures are urgently required. A Japanese team consist of government agency, universities, and research institu-tions launched a new project to observe possible effects of ship noise on humpback whales in Ogasawara Is. about 1000km from south of Tokyo. Propeller cavitation is a problem among ship's noises. The cavitation generates high power sound pulses with broadband spectrum.Our responsibility in this project is to investigate the propagation process.I actually acquired received data in the Ogasawara islands in mid May in this year[1]. Therefore, we report the result of comparing the received noise data from cruise ship with the model by simulation.

2. The ship subject to noise measurement

The subject ship is a cargo ship going round and trip between Chichijima and Hahajima . The size of the cargo ship is 490 GT and the length is about 60 m. The radiated noise from cargo ship is measured in advance in the shipyard of Mainland Japan. The fig.1 shows the noise spectrum of the ship due to the difference in driving mode. From this figure, the noise of the ship does not have characteristic pure tone. Therefore, the main noise source is presumed to be a propeller cavitation pulses.

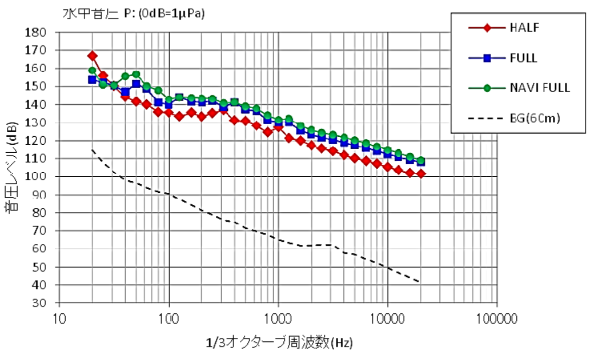

Fig. 1 Radiated Noise Level of Small Cargo Passenger Ship "Hahajimamaru"

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2. Ship noise measurement on Chichijima

A small fishing boat was used for measuring radiated noise. The Ocean Sonic's hydrophone was hung from a small plastic buoy to a depth of 20 m or 10m. Received data was recorded for two hours until the ship arrived at Hahajima from Chichijima. Received data recorded in the memory was analyzed after returning to Chichijima. Figure 2 shows the positional relationship between the received point in Futami Bay and the moving the cargo ship. The nearest distance is 0.85km, the furthest distance is 5 km.

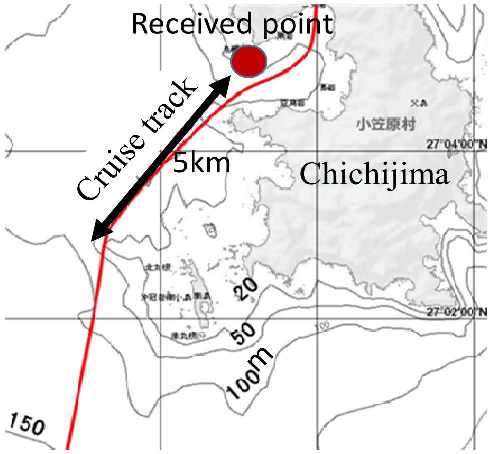

Fig. 2 Position relationship between the received point and moving the cargo ship

Figure 3 is a received spectrum diagram of the cargo ship. The vertical axis shows the 1/3 octave frequency, and the horizontal axis shows the propagated distance converted from the elapsed time. Received levels are indicated by color. The level increases from blue to red. From fig.3, the closest distance from the hydrophone to the ship is 850 m. The furthest received distance is 5 km.

The pulse width arriving from the frequency band of Fig. 3 was obtained. The frequency band at the closest approach distance 0.85km is approximately 10 kHz (120dB re 1μPa) and the pulse width is about 0.1 msec. At the maximum distance of 5 km, the pulse width is estimated to be about 8 msec from the bandwidth 125 Hz (110dB). The reason why the received frequency band

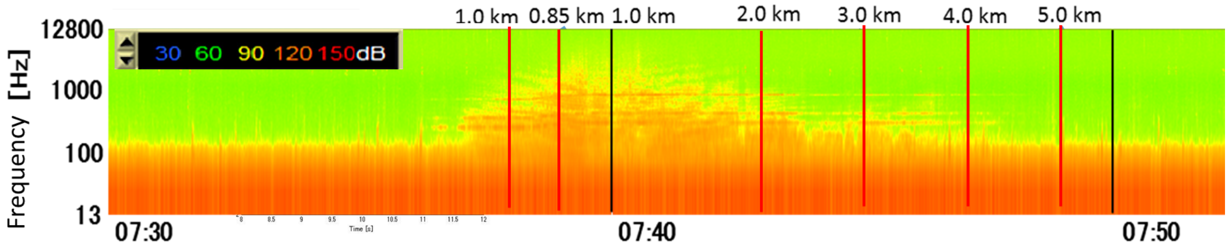

Fig. 3 Measured spectrum graph of the small cargo ship at near Chichijima

narrows as the distance increases is because sound absorption loss in sea water increases with distance. The received level is almost similar to the simulation results.

4. Pulses propagation simulation

The received pulse width extends because many reflection signals with different propagation times from the bottom on the propagation path overlap. However, the bottom reflection situation varies depending on bottom sediment. The precision of the maritime deposit map prepared by the Japan Coast Guard is not precise. We conducted a simulation to investigate the relation between the propagation distance and the received pulse in case of changing bottom sediment. We used a parabolic equation as simulation model. FOR3D [2] was used as a parabolic equation calculation program. For pulse calculation, the propagation loss was calculated every 1 Hz for all frequencies within the noise source bandwidth. The calculated result was converted to a pulse by inverse Fourier transform. In addition, the sound speed profile was calculated from the temperature and salinity measured by CTD using UNESCO equation[3]. The sound speed profile in this area is almost constant from the bottom to the surface. The depth of the propagation path was read from FIG. The water depth of the propagation path is shallower than 100 m.

Figure 4 shows the simulation results of the shape of the pulses that will be received in the course of the sound source going away. The left side of the figure is the propagation attenuation of each distance. This figure shows the change in waveform of received pulses due to difference in bottom sediment. Until a distance of 3km, the difference between sediment map and fine sand is very small. However, if the bottom sediment is basalt, the pulses propagate a long distance through the bottom and the pulse width extends to few seconds. The result shows that the case where all the bottom sediment is fine sand is closest to the measured value. Therefore, actual measurement shows that the reflection of the seabed is small in this area. Observation of short cavitation pulses is difficult because there is no synchronization signal between the ship's sound source and the receiving side during navigation. Pulses generated from the tip of the propeller are continuously overlapped, so estimation of pulses by simulation is important.

5. Summary

We are investigating the impact of ship's radiated noise on marine mammals. Based on the results measured on Chichijima, a simulation of propeller cavitation pulses was conducted. As a result, stretching of pulses was not recognized much in this area.

Acknowledgment

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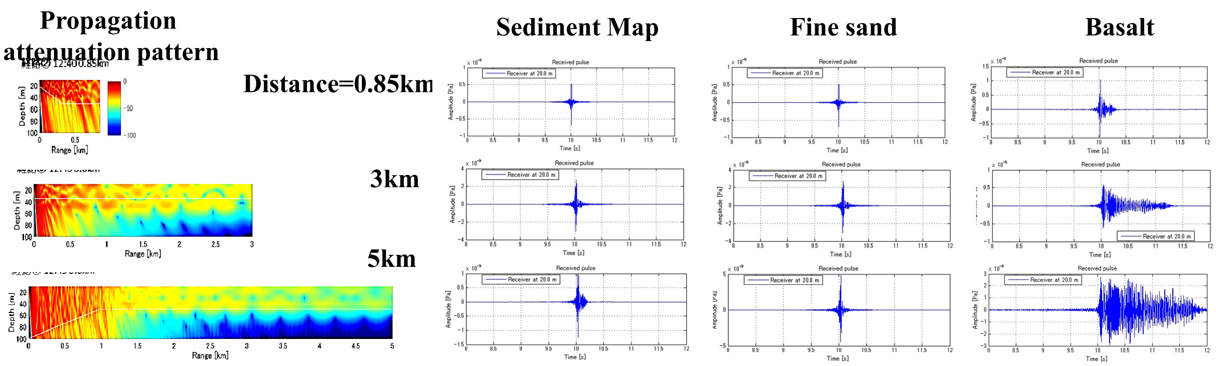

Fig. 4 Changes in received pulse shape due to difference in propagation distance and bottom sediment