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Discussion on the Application of Water Acoustic Instrument in Port Dredging

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Abstract. The measurement and dredging of sediments in ports and waterways is increasing. The most common and cost-effective method for detecting the structure and properties of underwater sediments is to use acoustic principles to detect them. In this paper, the principle of shallow depth profiler and multi-beam sounding system is introduced. The principle of acoustic sounding instrument in dredging measurement is introduced. The feasibility and application scope of such acoustic instrument in port dredging measurement are discussed.

1. Introduction

After the hard work of nearly 50 years, the port construction of China has experienced multiple periods, multiple positioning and development in multiple directions. The port throughput of China has ranked the first in the world. At the same time, as the rapid development of the port, the demand for the capacity of the channel and the dredging of ports and navigation channels have followed. Sediment backflow caused the water depth of the port's waters (ports, waterways) to become shallow, it is seriously threatening the safety of ships entering and leaving, and the economic benefits of the harbor, and some even endangered the value of existence^[1]. Acoustic sounding instruments provide a means of dredging for measurement in turbid muddy water. In such a water environment, optical or other methods are ineffective, and acoustic sounding instruments are an effective tool for measuring sediment and water depth during dredging.

As a geological interface of great significance, the seabed has always been a hot spot in marine scientific research. Submarine sedimentation research is the basis of seabed research. In addition, submarine sediments are an important part of the marine environment and the main content of marine surveying and mapping, in marine geology, ocean engineering, marine environmental science, hydrographic survey and marine resource development. It plays an important role in the use and has been highly valued by experts and scholars at home and abroad.

The traditional submarine sediment classification is usually carried out by means of box sampling, gravity sampling, visual grabbing, etc., and is sampled on a discrete grid in situ, and the type of sediment is classified by indoor test analysis. Although this method can intuitively judge the bottom quality, it has low efficiency, limited sampling, high operating cost, difficulty in implementation in deep water, and the type of sediment between grid nodes is not affected by various factors, and the reliability is not high enough to meet the modern ocean. Research and development needs.

Acoustic measurements and observations use a method of emitting an acoustic pulse into the water. The energy of the acoustic pulse propagates through the water. Any object that is affected by the



acoustic wave will reflect a portion of the acoustic energy. The reflected acoustic energy is received by a receiving transducer (usually receiving both the transducer and the transmitting transducer). The time that it takes for the sound wave to travel from the transmitting transducer to the target and back from the target to the receiving transducer, and then the time is converted to the distance from the transducer to the target.

The absorption attenuation of sound waves in seabed sediments is related to the frequency of sound waves and the physical properties of the deposits (porosity, average particle size, etc.).

$$\text{Silt: } \alpha_s = (0.1 \text{---} 0.3) / \lambda \text{ dB/m} \quad (1)$$

$$\text{Sand: } \alpha_s = (1 \text{---} 2) / \lambda \text{ dB/m} \quad (2)$$

α_s —Attenuation coefficient, λ —wavelength

Acoustic instruments can be used in port dredging by using different attenuation coefficients of sound waves in different media.

2. Multi-beam sounding system principle

After the multi-beam sounding system emits an acoustic pulse to the seabed, the generated sound wave propagates in the seawater. When it encounters the seabed interface, it returns to the transducer receiving array through reflection and scattering, and the transducer receiving array is recorded in real time. The arrival of the wave and the time of propagation between the sound waves in the seawater are discussed. Different from the traditional single beam, the modern multi-beam sounding system transmits a wide beam to the seabed (the beam is wide in the horizontal direction and narrow in the ship's direction), and uses the receiving array and beam control technology to form several spaces. Receiving beams (beams with a narrow transverse direction and a wide ship's direction) cross spatial intersection with the transmit beam (Mills Cross technology), forming multiple narrow beams^[2]. The spatial position of the submarine point corresponding to each beam is calculated according to the beam emission angle and the round-trip propagation time of the acoustic wave. Some multi-beam sounding systems simultaneously record the echo intensity data sequence of each beam. In this way, after a plurality of launch cycles, a strip-shaped water depth map and sonar image centered on the ship's track are obtained, realizing full coverage and high efficiency seabed topography measurement.

3. Multi-beam sounding system detects the substrate

The type of sediment on the seabed is highly correlated with the backscattering intensity. The backscattering intensity can determine the type of sediment to a large extent. Therefore, the fine processing of multi-beam backscattering intensity data is to accurately obtain the characteristics of the sea floor and improve the bottom. The premise basis and important guarantee of quality classification accuracy.

With the innovation of computer technology, digital image processing and recognition technology, and the continuous development of emerging technologies such as machine learning, artificial intelligence, and big data, the multi-beam sonar image quality classification has transitioned from traditional statistics to semi-automatic and fully automatic classification. The impact of the classification work intensity and subjective discrimination of seabed sediments is greatly reduced.

The use of multi-beam to the sawtooth mud surface formed by the dredging process is very obvious. Traditional single-beam linear measurement often leads to missed measurement, and most construction shallow points cannot be collected. Especially the construction results of the squirting boat are particularly obvious. Multi-beam can accurately collect all data, shallow points will not miss the measurement, and the output of the result can be the grid data graph and the shallow data graph in the grid. For the progress earthwork calculation, grid data can be used, and the construction can be used to take shallow data. For example, the construction inspection of the second phase preparatory project of the Guangzhou Port uses the multi-beam measurement shallow point without missing, the field time is far less than the single beam measurement, and it can be used for each construction. The ship provides accurate shallow documents, greatly improving the efficiency of offshore construction.

4. Working principle of shallow formation profiler

The common shallow profiler can be divided into linear and non-linear sound sources from the acoustic mechanism. Linear sound source power penetration depth deep, but bulky. The nonlinear sound source is small and light, but has a shallow penetration depth^[3]. At present, the shallow profiler commonly used in China's market mainly has the following types: DPS series in the US, shallow profiler such as EG&G and OR E, and SES-96 parameter array sounding/shallow formation profiler produced in Germany. Domestically, the Chinese Academy of Sciences and other units have also developed the GPY series shallow formation profiler. When sound waves are a form of matter motion, they are produced by the mechanical motion of matter, and the vibration propagates from near to far through the interaction between particles^[4]. Sound waves travel at different speeds in different media. When the reflection coefficients of the two media are large, the received reflected signals are stronger, and vice versa. Thus, the received reflected signal carries a large amount of useful geological information from the subterranean formation. By observing and analyzing the reflection of seafloor sediments on sound waves, we can understand the geological properties of sediments and visually identify the geological structures of the strata^[5]. The shallow formation profiler can continuously and efficiently perform submarine detection because it can provide a variety of geophysical parameters and detailed geological information.

5. Application of shallow formation profiler and multi-beam in dredging measurement

On the dredging measurement of the port, the multi-beam is used to detect the submarine quality by means of the time-varying sequence of the analysis of the echo intensity. The acoustic principle of the submarine substrate detection is consistent with other acoustic detection instruments. Different from the others, in addition to recording the change of echo intensity with time^[6], the multi-beam also records the beam information of the echo intensity. that is, which beam the echo intensity belongs to, so that the relationship between the echo intensity and the seabed topography can be established, thereby Eliminate the influence of factors such as seabed topography on echo intensity, and obtain submarine backscattering intensity data that only reflects the change of substrate quality.

The measurement method of the shallow layer profiler for the detection of the substrate is the navigation measurement, and the acquired data can be processed to obtain continuous layer thickness data, which can effectively separate the surface layer of the substrate, compared with other detection methods. Its emission frequency can ensure its penetration thickness and density of the mud layer, which is a relatively efficient, economical and accurate detection method^[7].

6. Conclusion

- The echo intensity data acquired by the multi-beam sounding system provide an effective information basis for detecting the type of submarine sediment. The multi-beam detection data is used to interpolate or extrapolate the region of the sampling point to achieve a rapid and systematic grasp of the type and distribution of the sedimentary sea area.
 - For the measurement area with complex seabed topography and large detection area, it is recommended to use single beam depth sounder, side sweep sonar and shallow formation profiler to detect surface mud. Firstly, a single-beam depth sounder and side-scan sonar are used to measure the topography of the whole survey area to define the terrain and key of the survey area, and then use the shallow layer profiler to follow the grid method. The survey area is targeted for scanning.
 - At present, the submarine classification of single equipment has limited classification accuracy, poor universality of model algorithm and poor reliability. In future studies, the correlation between multi-source observation data and seafloor sediments can be improved, and the understanding and measurement of seafloor sediments in dredging measurements can be improved.
 - In addition to acoustic instruments, the mud measurement also includes speculation, but it is difficult to provide large-area, accurate sludge thickness. The application of multi-beam sounding system and shallow profiler not only provides a measure for accurately measuring sludge thickness but also bring huge benefits to the production of the port through the application of this technology. It can

be expected that more ports and scientific research institutions will invest in the research of seaworthy water depth technology, and further promote the continuous measurement technology of China to move forward.

- Shallow stratigraphic profile measurement system is to detect shallow structure of the sea floor, sedimentary characteristics of the seabed, and investigate submarine disasters
- Geological factors and importance means of surface mineral distribution. Multi-beam sideways systems are also widely used in ocean sounding and seabed topography, but the shallow profiler and multibeam sounder currently used in China not much. Many of the supporting data processing software relies on imports. Therefore, the development of high-performance domestic shallow profiler, domestic shallow multi-beam echo sounder and data processing software is an unstoppable task and is an unshirkable responsibility of all our marine geophysical workers^[8].

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