International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 30, No. 2, June 2020, pp. 202–208; https://doi.org/10.17736/ijope.2020.jc765

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Underwater Temperature Measurement and Variation Analysis During the Ice-covered Period in Liaodong Bay

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Sea ice seriously threatens safety during the exploration and development of resources, shipping, and scientific investigations in cold regions. This study on the vertical stratification of water temperatures in seawater may provide the basis for predicting the freezing and melting processes of sea ice and guaranteeing the safety of marine activities. In the seawater temperature profile measurement system established in this study, the seawater temperature profile data measured by multiple sensors in a sea pond in the cold region of the Bohai Sea were collected through LabVIEW programming, and the real-time data were released to the Internet through the data transfer unit (DTU) module and remotely stored on the server. In this way, the real-time monitoring of the under-ice seawater temperature profile of Liaodong Bay was realized by the Internet of Things. Then the variations of seawater temperature at different depths in the observation area in different sea ice growth stages were analyzed. The overall fluctuation of water temperature at different depths was relatively flat and basically consistent with the changing trend of air temperature. The water temperature at the bottom of the sea pond varied greatly. The continuous air temperature decrease in winter led to seawater icing. Underwater temperature rose slowly as a result of heat release during the seawater icing process. These data and conclusions provide the basis for this study on the prediction methods of the freezing and melting processes of sea ice in Liaodong Bay. The seawater parameter real-time measurement technology established in this study is applicable to the real-time measurement of seawater parameters in the Bohai Sea and other ice-covered sea regions.

INTRODUCTION

Sea ice directly threatens the safety of activities in cold areas, such as exploration, development, and scientific study. Ice-resistant structures in the Bohai Sea and the cold regions of other countries have collapsed and overturned because of the action of sea ice, causing a relatively large economic loss (Wang et al., 2012; Bruun and Gudmestad, 2006). The navigation period of the Arctic routes affecting the global economic structure is closely related to the freezing and melting processes of sea ice in the Arctic sea regions (Sun and Liu, 2015). In addition, sea ice also affects the ocean aquaculture by changing the oxygen content of seawater solar transmittance, water temperature, and other parameters (Sun and Shi, 2012). Therefore, seawater temperature observation during the initial icing period plays an important role in the freezing and melting processes of sea ice and the environmental impact of seawater.

The Bohai Sea is the freezing sea area with the lowest latitude in the world. There are only 3–4 months of ice period since the warm winter. Therefore, the sea temperature influences the icing and melting process significantly, and the variation in ice conditions is an important indicative parameter of the global climate change. However, there are seldom directly measured ice condition data in both the temporal and spatial distributions, so it is impossible to obtain ice condition development trends. Therefore, it is necessary to carry out water temperature measurement, to explore the relationships among water temperature, air temperature, and ice condition and then to use the historic record of air temperature and water temperature. At last, the variation trends of ice conditions with the temperature change in the Bohai Sea could be understood under the global climate change.

At present, underwater temperature monitoring is seldom performed in freezing waters in the Bohai Sea (Xu et al., 2018). Xu et al. (2018) carried out seawater temperature profile monitoring work on an oil platform and a wind power platform in the ice-covered areas of the Bohai Bay, in winter. In seawater temperature profile monitoring, it is necessary to consider the effects of icing on the measurement system, including the wear on sensor leads caused by sea ice, the decrease in measurement accuracy caused by voltage loss and signal loss of long-distance data transmission, and the real-time data transmission.

This study aims to continuously monitor seawater temperature at different depths during the initial icing period and analyze the correlation between temperature changes at different water depths and the initial icing period for the analysis and prediction of the freezing and melting processes of sea ice. A remote automatic measuring system for water temperature and depth was established in this study. The system can realize real-time monitoring of water temperature at different depths of seawater, upload monitoring data to the data server in real time through the network, and provide automatic monitoring of on-site sea temperatures and depths through publishing web pages. In the system, low-power

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Received December 12, 2018; updated and further revised manuscript received by the editors July 2, 2019. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-eighth International Ocean and Polar Engineering Conference (ISOPE-2018), Sapporo, Japan, June 10–15, 2018.
KEY WORDS: Temperature stratification, profile measurement, freezing and melting processes of sea ice, remote transmission, Liaodong Bay.