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Risk Assessment and Case Analysis of Sea Ice Dynamic Accumulation in Water Intakes of Nuclear Power Plants

Peng Xu
China Nuclear Energy Association
Beijing, China

Ning Xu
National Marine Environmental Monitoring Center
Dalian, Liaoning, China

Yanlin Wang*†
School of Ocean Science and Technology, Dalian University of Technology
Panjin, Liaoning, China

Shanshan Sun
School of Physics, Dalian University of Technology
Panjin, Liaoning, China

Boqiang Zhao
Liaoning Hongyanhe Nuclear Power Co., Ltd.
Wafangdian, Liaoning, China

Shuai Yuan, Wenqi Shi and Yuxian Ma
National Marine Environmental Monitoring Center
Dalian, Liaoning, China

Sea ice is the main source of risk for cold-water acquisition of coastal nuclear power plants at high latitudes. In waters with better hydrodynamic conditions, crushed ice accumulation is the main cause of blocked cooling water intakes of nuclear power plants. Therefore, the risk of sea ice accumulation should be assessed for nuclear power plants. In this study, risk assessment and case analysis of sea ice dynamic accumulation in front of nuclear power intakes were performed. First, theoretical analysis and historical case analysis indicated that the main risk indicators of sea ice dynamic accumulation are ice thickness, concentration, velocity, size, and duration. Second, the technical process of risk assessment of dynamic sea ice accumulation at the intake port was established based on simulation. The sea ice accumulation risk should be considered depending on sea ice environmental conditions. Finally, a coastal nuclear power plant in the Bohai Sea was selected as an example to verify the assessment model. With the dilated disk discrete element model, sea ice dynamic accumulation was simulated. The degree of ice blockage in the water intake channel was selected as the indicator for risk grading. The thresholds of sea ice risk levels corresponding to different blockage levels of the intake channel, as well as corresponding design recurrence periods, were calculated. The overall ice accumulation was also evaluated. The assessment method of dynamic sea ice accumulation risk proposed in this paper can be applied in the risk management of equipment involving the cold-water intake function in ice-covered sea areas.

INTRODUCTION

The normal operation of cooling water intake in nuclear power plants (NPPs) is important. At low latitudes, the blockage by marine flora and fauna outbreaks is one of the main factors affecting the safety of cooling water intake in NPPs (Fu et al., 2020; Tang et al., 2020). However, in high-latitude frozen water such as Bohai Bay in China, the intake of the cooling water system of NPPs not only needs to address biological blockage but also blockage by winter sea ice. Blockage by sea ice and blockage by marine organisms differ. First, blockage by marine organisms mainly occurs in spring and summer, while blockage by sea ice occurs in winter. Different seasons result in different currents and different wave situations. Second, marine blockages are randomly distributed in depth and require intercepting nets extending from the seafloor to above the surface of the seawater. Because the density of sea ice is less than that of seawater, the ice load on a structure mainly occurs in the upper layer of seawater; therefore, a water intake in the middle or lower layers of seawater is less likely to be blocked by sea ice. Nuclear power projects in the cold region of China face the risks associated with cold water intakes, especially the risks posed by sea ice. Experience in operating nuclear power projects in these cold regions of China is not enough, especially if the anti-icing design standard of cold-water intake projects is unavailable. In addition, the mechanism of the

*ISOPE Member; †Corresponding author.

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KEY WORDS: Coastal nuclear power, water intake blockage, discrete element method, ice floe accumulation.