Ice Load Analysis Method Based on CFD-DEM Coupling Method

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ABSTRACT

In this paper, a numerical calculation method of coupling CFD (Computational Fluid Dynamics) and DEM (discrete element method) is proposed. Some technical issues are discussed, including the establishment of numerical ice pools, calibration of the parameters of the sea ice discrete element model, adaptability analysis of structures in marine environment in ice area, etc. Aiming at the problem of ice load in ice area, this paper presents a numerical calculation method by coupling CFD with DEM, establishes a real sea ice model and a numerical ice pond, and studies the ice resistance of Sandglass-type FPSO by using this method. This paper provides a numerical calculation method for adaptability analysis of structures in marine environment in ice area. The numerical sea ice model provided in this paper can simulate the real mechanical properties of sea ice. Compared with the calculation of cylindrical floating body, Sandglass-type FPSO can significantly reduce the ice load. This research on ice load in ice area has a good application value.

KEY WORDS: Discrete element; Coupling calculation; Computational Fluid Dynamics; Sandglass-type FPSO

INTRODUCTION

The Arctic region has a large number of resources, of which the unexplored oil resources account for 25% of the world's unexplored oil resources. At the same time, the Arctic channel can save about 40% of the voyage than the commonly used channel bypassing the Suez Canal and Panama Canal in the south (Wang, 2009). However, ships and other offshore structures working in the ice area will face serious sea ice engineering problems. In January 2000, JZ20-2 oil and gas platform JZ20-2 oil and gas platform is subjected to sea ice dynamic pressure. Finally, due to the fact that the natural frequency of the structure was close to the fracture frequency of sea ice, the fatigue fracture failure of oil and gas pipelines was caused, resulting in serious economic losses (Yue, 2003). Ohio, sailing in the ice area, came into contact with icebergs in 1994, resulting in damage not only to the ballast tank but also to the bulbous bow (Hill, 2006). People's lack of understanding of ice load is the main reason for the damage accidents of offshore structures in these ice areas. Therefore, more in-depth research and exploration are needed to accurately predict ice load and design new offshore structures to improve ice resistance, which is also an important engineering demand at present.

The traditional research focuses on prototype observation and model experiment. However, both methods require high cost and time. In terms of prototype observation, the monitoring data and information provided by it are important, but the monitoring targets depend on the measurement system and measurement technology. At present, the measurement data that can be directly used for analysis and research are very limited (Timco, 2006). In the model experiment, due to the scale effect and non-simultaneous failure, the ice force calculated by the formula obtained from the model experiment is more than 10 times larger than the actual ice force. Therefore, if we can reasonably abstract and simplify the problem and apply numerical analysis to explain the formation mechanism of ice load (Timco, 2009), predict, analyze and study ice load, it can greatly reduce the cost and has very important engineering significance. In recent years, numerical simulation technology has become an important way to study ice load. At present, numerical simulation is mainly carried out by finite element method and discrete element method, but this method needs further development.

NUMERICAL ANALYSIS METHOD BASED ON COUPLING OF CFD AND DEM

CFD-DEM Coupling Calculation Method

The marine environment in ice area is actually a system of sea ice, fluid and structure solid coupling. For the coupling problem between fluid and solid, SPH method is mainly used at present. Because it does not need grid, this method avoids the calculation impact caused by large grid deformation due to large changes in flow field. However, for large-scale wind wave flow field with small changes in flow field, the calculation will be more difficult and the calculation efficiency will be reduced. Therefore, CFD method is used to couple with sea ice in this paper. For the coupling between solid and solid, as shown in Figure 1, it is a real sea ice slice. It can be found that sea ice is mainly composed of ice crystal particles. Considering the real composition of sea ice, the discrete element method is decided in this paper. In conclusion, this paper uses dem-cfd coupling to establish a numerical ice pool for research.