Seakeeping Performance Study on a Drillship with Varied Moonpool Configurations Based on Recess-type Moonpool

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ABSTRACT
Moonpools are vertical openings applied on the marine ships and offshore platforms to lower the equipment into the sea. The arrangement of moonpool configuration has notable influence on the hydrodynamic performance of a drillship. In the present study, vessel response with varied moonpools in the proximity of moonpool resonance is investigated. The influence of moonpool configurations on the ship motions at four forward speeds and two drafts is discussed. To validate the numerical results, moonpool resonance frequencies are compared with Molin’s (2001) theoretical and Fukuda’s (1977) empirical formulas. Numerical results show good agreement with theoretical and empirical formulas. The numerical results suggest that arranging the notch on the recess decreases the piston and 1st sloshing-mode natural frequencies. In addition, the drillship’s motion response is related to the moonpool’s piston and sloshing-mode resonance.

KEY WORDS: moonpool, piston motion, sloshing motion, potential flow

INTRODUCTION
With the development of natural gas hydrate engineering, drillships and the influence of the moonpools on them in terms of hydrodynamic performance have attracted widespread interest. Due to the presence of free surface, piston and sloshing motions occur in the moonpool, which are closely related to the motion resonance characteristics of the drillship.

Over the past 20 years, researches on resonant frequencies of the moonpool have drawn a great deal of attention. Molin derived piston and sloshing modes of moonpools in both infinite and finite depth based on the linear potential flow theory in frequency domain (Molin, 2017, 2001; Molin et al., 2018). Newman (2018) studied the natural frequencies of recess-type moonpool numerically and theoretically based on WAMIT and analysis of solutions, respectively. Based on modified Fourier series method, Zeyu Shi presented a method to analyze the fluid natural oscillation characteristics in the moonpool (Shi et al., 2019, 2020).

For the purpose of facilitating operation, the moonpool is generally left open during transit. Due to the ship motions and navigation speeds, violent fluid motions occur in the moonpool, which significantly increases the encountered resistance, especially for the wave conditions. Several attempts have been made to improve the resistance performance of a drillship with a moonpool. Based on Shipflow, Sivabalabalam simulated the total resistance of a drillship with moonpool and studied the influence of varying cross-section in the moonpool on drillship resistance performance (Ponnappan and Sankunniy, 2018). To investigate the modified moonpool configurations on resistance performance of a drillship, Mao et al. (2021) performed numerical simulations on a drillship at different navigation speeds. In addition, the regularities of moonpool configurations on drillship resistance performance and flow pattern characteristics were investigated. Considering wave effect, Lee and Xu (2020) conducted CFD numerical simulations for drillship transit in waves under 12 wave frequencies and validated their numerical setup using calm water experimental data. Based on open-source code OpenFOAM, Sun et al., (2023) investigated the resistance performance of a drillship with varied moonpool configurations under both calm water and regular wave conditions. Numerical results suggest that the piston-mode motion has larger influence on the moonpool added resistance.

There have been many attempts to optimize the moonpool configurations in the past. But most of the proposed optimized configurations are for the rectangular moonpools, such as introducing a partition wall and baffles or setting the rear wall of the moonpool into a wall with cut-off angles. In recent years, recess-type moonpools have become popular due to their excellent hydrodynamic performance and operability (Guo et al., 2017; Xu et al., 2020; Zhang et al., 2021; Zhang and Li, 2022).

As presented in our previous work, we considered implementing the notch on the recess of the moonpool to optimize moonpool’s hydrodynamic performance. Numerical results suggest that the resistance performance of the drillship was optimized (Sun et al., 2022, 2023). In the present work, the influence of moonpool configurations on the ship motions at four forward speeds and two drafts is also discussed to investigate the influence of the above mentioned optimized moonpool configuration on the drillship’s seakeeping performance.

MATHEMATICAL FORMULATION
Geometric models
The drillship adopted in this work is shown in Fig. 1, where Fig. 1(a) presents drillship with recess-type moonpool and Fig. 1(b) depicts drillship with optimized moonpool based on recess-type moonpool. The