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An Introduction and Global Performance Analysis of a Donut-Type Platform Suitable for SCRs

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To tackle the challenges confronted by traditional deep-draft SEMI, a novel donut-type platform featuring a large moon pool is put forward. The computational fluid dynamics method integrated with wind tunnel and wave basin experiments has been employed for moon pool response analysis and for time-domain coupling analysis of the mooring system and steel catenary risers (SCRs). The results show that the donut-type platform has good global performance benefiting from the moon pool damping effect, and the feasibility for SCR application is demonstrated. With additional advantages such as lower topside elevation, larger storage capacity, higher hull structural strength, and better constructability, the donut-type platform could be a competitive new conceptual hull option for SCR utilization.

INTRODUCTION

As the first offshore field development in China, the Lingshui 17-2 project adopted the deep-draft semi-submersible platform (DeepSea No. 1) as its floating system with storage capability. This floater type has its technical and economic advantages due to its optimized deep draft and relatively small area of water plane. These features make the motion characteristics compatible with the steel catenary riser (SCR) option (You et al., 2022).

The SEMI concept has been widely used in the drilling and production of offshore oil and gas field development due to its good wave resistance. The discrete column structure arrangement allows waves to pass through the platform, which can effectively reduce the wave load and improve the motion performance. However, there are still some technical challenges and limitations for this floater type, which can be summarized as follows:

• The requirement for an air gap leads to large column heights, which significantly increases the topside center of gravity (COG), elevation, and wind load.

• Small area of water plane and high COG result in stability challenges, which in turn require a larger floater size, such as pontoon size and column spacing.

• Deep draft requirement could limit construction docks and towing channel selection. Pontoon aspect ratio needs to be increased to achieve a smaller lightweight draft, which could cause structural fatigue problems for the pontoon (Yang et al., 2023). Meanwhile, a wider pontoon will be subjected to greater vertical load, which adversely affects the motion performance of the platform with greater challenges of SCR fatigue (Zhu and Li, 2021).

• Large-scale integral truss-type modules are adopted for most SEMIs, which poses challenges to topside module lifting and integration (You et al., 2020).

By contrast, the traditional ship-type or cylindrical FPSO does not have air gap and stability problems, as the total height of topsides is relatively low, while it can also withstand harsh sea states. Smaller and modular topsides designed for FPSOs could also eliminate the need for heavy lifting resources. The typhoon resistance capabilities and cost effectiveness of the FPSOs have been proven in massive engineering practices in ship-type FPSOs globally and the cylindrical FPSOs in the North Sea, although they are generally not suitable for SCRs.

Aarsnas et al. (2010) investigated the feasibility of applying SCRs with a comprehensively improved cylindrical FPSO (CFPSO) with increased draft, smaller waterline cross section, and bigger bilge ring size. Numerical simulations have been carried out to verify the motion characteristics and SCRs' strength and fatigue. Vidic-Perunovic et al. (2014, 2017) studied the feasibility of SCR for another optimized CFPSO with a "bilge box" extension at the lower section, which was optimized to improve hull motions under a relative smaller draft. Both numerical simulations and model tests were carried out to demonstrate the feasibility. Note that all these CFPSOs require a huge damping plate/box to improve the hull motion, which will face strength and fatigue problems at the root of the damping plate/box, as well as construction problems for its size.

The mono-column FPSO is another potential hull concept suitable for SCR application (Gonçalves et al., 2010). Compared with the CFPSO, the mono-column has a larger diameter hull and is fitted with a large moon pool along with a deeper draft. This results in a relatively larger displacement, a smaller waterline area, and excellent heave motion characteristics similar to those of a SPAR platform.

Sphaier et al. (2007) studied the influence of the opening size at the bottom of the moonpool on the vertical motion of a mono-column FPSO through experimental methods, which showed it was possible to determine an opening that minimizes the motion. However, the oversized size of the mono-column FPSO also led to difficulties in its construction along with increased investment.

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KEY WORDS: Donut-type platform, moon pool, mooring system, global performance, steel catenary riser.