Numerical Investigations of Wave and Current Incoming Directions on SPAR Motions

Guochun Xu a, Q. W. Ma a, b, Shan Ma a and Liping Sun a

aCollege of Shipbuilding Engineering, Harbin Engineering University, Harbin, Heilongjiang Province, China
b School of Engineering and Mathematical Sciences, City University, Northampton Square, London, UK

ABSTRACT

Although engineers often assume that waves and currents are collinear, they propagate in different (unparallel) directions, i.e. the incoming angle between waves and currents is not generally zero or 180° in reality. This paper makes a special effort to investigate how the different incoming directions affect motions of a Truss SPAR platform. In order to achieve this, the six degrees of freedom motion of the platform is considered with the wave and current loads evaluated by a slender body formulation. Various cases with different wave and current parameters are calculated and the effects of waves and currents on mean offset and oscillation motions of Truss SPAR are investigated.

KEY WORDS: Truss SPAR; Motions; Wave and Current; Prediction; Investigation

INTRODUCTION

With the development of offshore oil industry, the exploitation for oil and gas has been transferred to deep or ultra deep water field. Meanwhile, the corresponding equipments used has been being improved and innovated, for instance, mounted-bed platform, gravity concrete platform and jack -up platform, employed in shallow water have been replaced by TLP (Tension Leg Platform ), SPAR Platform (included classic SPAR, Truss SPAR and its renovation forms), Semi-submersible platforms and others floating production system in deep water locations. Among these floating platforms, SPAR platform is one of the most popular platforms, because it has relatively small heave motion in waves and risers can be linked with platform by dry-tree style. They could provide stable working ability for oil production and could reduce the maintaining costs of platform. Up to now, it is about a few decades that SPAR platforms are used by offshore engineering, and SPAR platforms are always being innovated for meeting the demand in practice. At first, SPARs are named Classic SPAR, which only had a long cylindrical structure with larger diameter, and then so as to save building costs and reduce gravity loads, part of Classic SPAR hull is modified into truss section with heave plates and soft tank. This renovating SPAR structure is called Truss SPAR. Now many Truss SPARs are utilized to drill wells and exploiting oils in deep water fields such as Gulf of Mexico. Recently on the base of the concept of Truss SPAR, some newly revolutions have emerged, like semi-Truss Platform (Chakrabarti et al, 2007), Cell Truss SPAR (Zhang et al, 2008) and S-SPAR (Sun and Huang, 2012) and so on. Although these SPARs have some differences to some extent, they all have the similar outer characteristic, i.e. their length is far larger than their diameter, and it is just this kind of shape that makes its heave period well away from wave periods.

In order to design SPARs with good working ability, assessing dynamic behaviors of SPARs due to waves, current and mooring lines has been carried out by many researchers by numerical simulations and model tests in wave tank. Chitrapu et all (1998) solved motion response of SPAR platform in random waves and current in time domain, by hydrodynamic loads was evaluated by Morison equations. The research results showed that the presence of current in waves could significantly affect the low-frequency response of SPAR platform. Liu et al (2010) compared the first-order hydrodynamic forces on a Truss SPAR in waves with following and adverse currents by a higher-order boundary element method, while Kurian et al (2012) and Sun et all (2011) predicting Truss SPAR motions in wave, considering current in the velocity of water particles by adding current velocity. Ran et al (1996) employed the complete first and second-order diffraction/radiation theory and the viscous drag forces to compute the response of a SPAR in random waves and currents, compared to model test data, and it was found that the slowly varying responses were appreciably reduced due to the presence of currents. Zhang et al (2012) investigated on the added mass coefficient of a Truss SPAR subjected vortex-induced motions in a wave tank.

From the above works, it can be known that effects of current on SPAR motions are considered by some researchers, but the most of simulation results are assumed that current is following or opposite waves, whereas in real ocean environments, currents may come from different direction. How the direction angle of current affect the dynamic response is not clear yet. On the other hand, it is not easy to make arbitrary directional current and waves in wave tank to investigate motion response of Truss SPAR.

In this paper, motions of a Truss SPAR under waves and currents with different incoming directions will be investigated. The hydrodynamic loads on the hull of Truss SPAR are calculated by a slender formulation (Rainy 1995) and current force is considered by adding current velocity to the velocity of water particles due to waves, considering current effects on wave dispersion equation but ignoring other effects if the interaction between waves and currents. When waves and currents are from different orientations, the SPAR will do motions with six-degree freedom. To predict SPAR motions with six-degree freedom in time domain, a set of nonlinear equations of rigid body was solved by Runge-Kutta-Fehlberg Method. Then, the effects on mean offset and