Hydrodynamic Loads on Jack-up Legs Due to Oceanic Internal Waves

Sing-Kwan Lee
Technology, ABS
Houston, Texas, USA

Deguang Yan
Singapore Offshore Technology Center, ABS
Singapore

ABSTRACT

It has been reported many times that due to the occurrence of internal waves in certain sea areas, offshore exploration and drilling operations have been disrupted. Of particular concern, in some of these events drilling units were severely damaged. In open seas, internal waves often exist as a type of nonlinear, internal solitary wave, which can retain its shape, speed, and energy during propagation. Reportedly, in the deep central basin of the South China Sea, with water depths more than 400m, an internal wave can reach amplitudes of 170m and a wave length of 6km. This kind of large internal wave can propagate to shallower water areas and risk the safety of offshore structures located in the vicinity. As a common drilling unit in the South China Sea, the jack-up platform is subject to the threat of internal waves. In this paper, with a typical jack-up leg configuration selected, the investigation of the internal wave loading on jack-up legs has been performed using Computational Fluid Dynamics (CFD) methodology. Systematic parametric studies are conducted to determine the dependence between the hydrodynamic load and internal wave amplitude under different incident wave directions. Through this study, useful information on hydrodynamic load ranges of internal waves can be obtained for future jack-up design.

KEY WORDS: Jack-up, Hydrodynamic loads, CFD, Internal waves, KdV theory

BACKGROUND AND MOTIVATION

Internal waves in the sea are analogous to surface waves but occur on the horizontal interfaces between waters of different densities. Sea regions with complex coastline geometry and bathymetry, narrow passages, stratified waters and strong tidal current are favorable places for the generation of intensive oceanic internal waves. Internal solitons are the common internal wave type being observed in nature. This is a type of large amplitude undersea internal wave associated with strong currents that vary rapidly in time and flow in opposite directions above and below the density interface along which they propagate. Reportedly, in the deep central basin of the South China Sea, with water depths greater than 400m, internal waves can reach amplitudes of 170m and a wave length of 6km. This kind of large internal wave can propagate to shallower water areas and risk the safety of offshore structures located in the vicinity.

Over the past three decades, many theories and models have been developed and/or improved for studying the internal solitary waves. These theories include KdV model, eKdV model, and mKdV, etc. Apel et al. (1998) comprehensively explained these theories and described the global experimental and observational data. Another review work by Helfrich and Melville (2006) provides insightful discussions on the strongly nonlinear internal solitary waves. Basically, most of the work on internal waves primarily focuses on the processes of wave generation and evolution, and very few work pays attention to the local flow field interacting with marine structures and loading analysis. Recently, using Morison’s empirical method, modal separation and linear regression analysis, Cai et al. (2008) investigated the forces and torques exerted by an internal soliton on a cylindrical pile. The prediction of loadings on an offshore structure due to internal waves has become more and more important, since in many ocean areas the drilling units are subject to the potential threat from the internal wave damage (Osborne and Burch, 1980).

Self-elevating jack-up units installed in oceanic regions with internal waves may be subject to localized structural damage and structural instability. This is primarily due to the effects of turbulence and mixing of flows with different densities or of relatively large temperature variations, which result in inertia motion and buoyancy oscillation acting on jack-up legs and their foundation. Internal waves may propagate in any direction depending on motion characteristics, thus making it difficult to monitor and measure the wave on site. Although, there are many jack-up unit damages occurring in the South China Sea, the study of hydrodynamic loads due to internal solitons is rare. To date this issue has not been considered in industry standards for jack-up design.

In this paper, Computational Fluid Dynamics (CFD) simulations for stratified water flow are performed in order to investigate the internal wave loading on jack-up legs. Systematic parametric studies for different internal waves are also carried out to determine the dependence between the hydrodynamic load and internal wave amplitude. Without the inclusion of internal wave loads, critical