Structural Performance of Deepwater Lazy-Wave Steel Catenary Risers for FPSOs

Seungjun Kim¹, Moo-Hyun Kim¹, Sanghoon Shim², Sungwoo Im²
¹Coastal and Ocean Engineering Division, Zachry Department of Civil Engineering, Texas A&M University
College Station, Texas, USA
²Steel Structure Research Division, Research Institute of Industrial Science & Technology, Inchon, Korea

ABSTRACT

In this paper, the structural performance of deepwater lazy-wave steel catenary risers (LWSCRs) connected to a FPSO is investigated by using hull/mooring/riser coupled dynamic analysis program. Conventional deepwater steel catenary risers (SCRs) connected to the same FPSO hull exhibit significant dynamic responses, which induces large structural stress amplification and local dynamic buckling at the members nearby touchdown region. The corresponding short-term fatigue damage is also serious. On the other hand, LWSCRs eliminate the possibility of local dynamic buckling and significantly reduce the maximum stress level near TDZ (touch-down zone). It is because the riser motion can be isolated from the motion of the floater by the intermediate sag and arch members in the lazy-wave configuration. The general performance of SCRs and LWSCRs is directly compared under the same environmental and floater conditions in terms of ultimate limit state and fatigue limit state. It is shown that LWSCRs show excellent structural performance under severe environmental condition because of the motion isolation effect induced by the geometric characteristics. In addition, the effect of the curvature of the sag and arch members on the dynamic response of LWSCR is also studied to seek the optimal shape.

KEY WORDS: Lazy-wave steel catenary riser; hull/mooring/riser coupled dynamic analysis; FPSO; local dynamic buckling; ultimate limit state; stress amplification, TDZ (touch-down zone), fatigue damage

INTRODUCTION

In general, steel catenary risers (SCRs) have been widely used because of their cost efficiency and structural simplicity. However, for semisubmersibles and FPSOs (Floating Production Storage Offloading) in deepwater field, conventional SCRs should be carefully analyzed and designed because of the possibilities of high structural stresses, global buckling, and fatigue failure induced by floater motions. The sectional failure is also closely related to high internal and external pressures. When a floating platform makes large motions due to severe environmental loadings, the motion of the platform is directly transferred to the attached mooring lines and risers. The force induced by the motion of the platform as well as the additional force directly applied to risers, may cause severe dynamic responses of risers. Additional forces may also occur as a result of interactions between riser and seabed. About the issue related with the feasibility of conventional SCRs in deepwater development, several researchers have claimed that the conventional SCRs may not be appropriate for deepwater FPSOs because of their highly amplified dynamic responses under severe environmental conditions (Wu and Huang 2007; Yue et al., 2010; Yue et al., 2011; Yang and Li, 2011). Due to the highly amplified dynamic response, the excessive structural stress may occur at hangoff and touchdown zones (TDZ). In addition, the frequently occurring large fluctuating stresses significantly reduce fatigue life of deepwater SCRs. In such a case, a lazy-wave steel catenary riser (LWSCR) is one of the alternative types to be considered for mitigating the dynamic response amplification induced by the motion of the vessels. The “lazy-wave” configuration of LWSCRs was basically suggested to isolate the riser motion from the vessel motion through the factitious sag and arch regions. By the motion isolation effect, LWSCRs may avoid suffering the heavy dynamic behavior induced by the motion of floats (Jacob et al., 1999; Torres et al., 2002; Torres et al., 2003; Li and Nguyen, 2010; Yue et al., 2011; Yang and Li, 2011).

In this study, the structural performance of deepwater LWSCRs is investigated by performing hull/mooring/riser coupled dynamic analysis under harsh environmental conditions. The obtained various structural responses are directly compared to those of the conventional SCRs to verify the structural advantage of the LWSCRs. In addition to the maximum structural stresses, the fatigue damages by the applied environmental conditions are also directly compared with each other. In addition, the effect of the intermediate lazy-wave shape on the structural performance of LWSCRs is investigated based on the relevant parametric study, which can lead to the optimal design for the given input parameters.

CONFIGURATION OF LWSCRs

The initial configuration of catenary risers can simply be described by the equation of conventional catenary cables. Also, for describing the initial configuration of LWSCRs, total three individual equations for hanging, buoyancy, and touchdown catenaries, are used. Fig.1 shows