1. Introduction

Spar platform is a type of floating structure utilized for oil and gas exploration and production in deep and ultra-deep waters. Coupled analysis in present study considers Spar mooring lines as an integrated system. It incorporates the contribution of drag and inertia forces of mooring lines. A rigid classical Spar cylinder connected by four tensioned catenary mooring lines has been modeled and analysed using finite element approach. Mooring system has been modeled as hybrid beam elements. The Studies cover surge, heave, pitch and mooring line tension responses, highlighting the coupling effect. The non-linearities present in the coupled system leads to irregular behavior under regular sea states. The coupled model noticeably confirms its importance in terms of hydrodynamic damping on mooring system. There is a key variance in behavior found with and without drag and inertia forces on mooring system.

Keywords: hull-mooring interaction, spar platform, deep-water mooring lines, coupled dynamic analysis, floating structures
moored by taut mooring lines. They also calculated the top tension on the lines using the time domain method. (Chen et al., 2014) investigated the impacts of heave motion on riser’s vortex-induced vibration by means of finite element simulations. They developed a coupled hydrodynamic force approach, which takes into account of the interaction between instantaneous structure motion and fluid dynamics. Jameel et al., 2011a, 2011b, 2012a, 2012b, 2013 and 2014 investigated various issues related to Spar platform such as fatigue reliability of Spar mooring system, effect of shorter and longer duration of wave loading on coupled analysis of Spar-mooring system, response of Spar platform under random waves and wind induced nonlinear response of Spar-mooring-riser system.

In most of these conventional procedures of analysis, Vessel fairleads and mooring heads responses are iteratively matched at each time increment but the acceleration and velocity did not converge. Motion equation involving damping, inertia, restoring, and exciting force vector of the Spar-mooring system is the stiffness matrix, \( \mathbf{K} \) is the exciting force vector of the Spar-mooring system. \( \mathbf{X} \) represent the six degrees of freedom structural displacements and the dot symbolizes differentiation in time. The total mass matrix of the Spar-mooring system involves the structural and the added mass components. The structural mass consists of the moorings elemental consistent mass matrices and the rigid Spar hull lumped mass. The Spar hull lumped mass properties are assumed to be concentrated at the Spar hull CG Wheeler’s approach adopted to simulate the variable submergence effect caused by the free surface oscillation.

The stiffness matrix \( \mathbf{K} \) comprises of geometric and elastic stiffness matrices. The total system damping is induced by the hydrodynamic and the structural damping. The hydrodynamic induced damping is the major part of the system damping. Rayleigh damping is adopted to simulate the structural damping. The force vector \( \{F(t)\} \) is summation of force applied on a catenary mooring line per unit length and the total force per unit length of the rigid spar. The structural damping can be computed by Eq. (2), where \( \zeta \) is structural damping ratio, \( \Phi \) is modal matrix, \( \omega_0 \) is natural frequency and \( m_i \) is generalized mass.

\[
\Phi^T \{C \} \equiv \frac{1}{\zeta} m_i \omega_0^2 \Phi = [2 \zeta \omega_0 m_i]
\]

Therefore the equation of motion for spar hull leads to

\[
[M] \ddot{\mathbf{X}} + \{C\} \dot{\mathbf{X}} + \{K\} \mathbf{X} = \{F(t)\}
\]

Where, \( [M] \) is the total mass matrix, \( [C] \) is the damping matrix, \( [K] \) is the stiffness matrix, \( \{F(t)\} \) is the exciting force vector of the Spar-mooring system. \( \mathbf{X} \) represent the six degrees of freedom structural displacements and the dot symbolizes differentiation in time. The total mass matrix of the Spar-mooring system involves the structural and the added mass components. The structural mass consists of the moorings elemental consistent mass matrices and the rigid Spar hull lumped mass. The Spar hull lumped mass properties are assumed to be concentrated at the Spar hull CG Wheeler’s approach adopted to simulate the variable submergence effect caused by the free surface oscillation.

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