Study on the Nonlinear Dynamic Characteristics of a Truss Spar

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ABSTRACT

The heave-pitch coupled equation of Truss Spar platform under random waves is established considering the static stability and drainage volume changes, including higher order nonlinear term and the effects of instantaneous free surface. The motion responses are calculated, and the impact of damping factor is analyzed. The results show that, when the characteristic frequency of stochastic wave is close to the heave natural frequency of heave, the large amplitude pitch motion is induced under the random parametric-forced excitation, when the significant wave height reaches a certain value. Increasing the heave damping or increasing the pitch damping is the most effective mean to suppress the pitch instability. Therefore, when design the platform, the number and the structure of heave plate and the reasonable arrangement of spiral side plates are important.

KEY WORDS: Truss Spar; heave-pitch coupled; random sea; parametric-forced excitation; heave plate.

INTRODUCTION

As the coupling between heave and pitch motion of Spar platform is strong, so the response of heave motion plays a very important role in the stability of the whole platform. Because the draft of Spar body is large, the high frequency part of wave excitation force on Spar body decreases with the increasing of water depth, and then the low frequency wave load plays a leading role in the heave motion. There will be heave resonance movement under the effect of swell, and the heave amplitude will be large, which make the volume and shape of Spar immersed in water change constantly. Displacement volume and metacentric height are not fixed but time-dependent. So the restoring moment is a function of metacentric height and displacement volume. The values of \( G_M \) and \( V \) change with the heave amplitude \( \xi_3 \) and wave elevation \( \eta \). The coupling between the two degrees of freedom is shown in Fig.1.

According to Newton’s second law of motion, the coupled nonlinear heave and pitch motion can be written as following:

\[
(m + m_{33}) \ddot{\xi}_3 + B_3 \dot{\xi}_3 + B_{33} \dot{\xi}_3 + \rho g A_w (\dot{\xi}_3 - \eta - \frac{\xi_3}{2} H_g + \frac{\xi_3^2}{2}) = F_3 \tag{1}
\]

\[
(I + I_{55}) \dot{\xi}_5 + B_{53} \dot{\xi}_3 + B_{55} \dot{\xi}_5 + \rho g V G_M \xi_3 + \left( \frac{1}{2} \rho g V + \rho A_w G_M \eta \right) \xi_5 - \left( \frac{1}{2} \rho g V + \rho A_w G_M \eta \right) \xi_5^3 = M_5 \tag{2}
\]

Where, \( m \) and \( m_{33} \) are the body mass and body’s added mass, respectively. \( I \) and \( I_{55} \) are pitch moment and added moment of inertia, respectively. \( F_3 \) and \( M_5 \) are random wave force and random wave moment, respectively.