Nonlinear Coupled Dynamic Response of a Semi-submersible Platform

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ABSTRACT
The dynamic behavior of a conventional semi-submersible was investigated both numerically and experimentally in regular and irregular waves. In the mathematical model, the dynamic equilibrium equations were developed and solved in time domain using a common reference axis system fixed on the mean sea water level. The wave force calculations were based on the modified version of Morison Equation applied at the displaced position of the structure. Mooring system contribution to dynamic behavior was evaluated numerically using nonlinear catenary equations. Experimentally, a twin hulled semi-submersible with a scale of 1:100 was tested in regular and irregular waves with the model oriented in the head, beam and quartering directions. The experimental measurements validated the accuracy of the numerical model.

KEYWORDS: Equation of motion (EOM); Fast Fourier transformation (FFT); Response amplitude operator (RAO); Semi-submersible model; Time domain analysis; Wave basin testing.

NOMENCLATURE

\[ A_r, A_w \]
\[ C_d, C_m \]
\[ \{F\} \]
\[ F_{x_{\text{hull1,2}}}, F_{y_{\text{hull1,2}}}, F_{z_{\text{hull1,2}}} \]
\[ x_{l_{\text{hull1,2}}}, y_{l_{\text{hull1,2}}} \]
\[ [\mathbf{K}], [\mathbf{K}_h], [\mathbf{K}_m] \]

Response and wave amplitudes
Drift and inertia force transfer coefficients
Excitation force vector.
Resultant force due to dynamic pressure applied on hull faces.
Total surge, sway and heave forces
Y-component of total horizontal force
Total vertical wave force on hulls
Total, hydro-static and mooring stiffness matrices

\[ k_x, k_y, k_z \]
\[ [M], [M_d], [M_a] \]
\[ M_{l_{x}}, M_{d_{l_{x}}}, M_{a_{l_{x}}} \]
\[ M_{x_{\text{hull1,2}}}, M_{y_{\text{hull1,2}}}, M_{z_{\text{hull1,2}}} \]
\[ M_{x_{l_{\text{hull1,2}}}}, M_{y_{l_{\text{hull1,2}}}}, M_{z_{l_{\text{hull1,2}}}} \]
\[ [\mathbf{K}_s], [\mathbf{K}_a] \]

Mooring line spring constants in x, y and z direction
Total, structure and added mass matrices
Moments due to the horizontal inertia and drag forces on column i about axis perpendicular to wave direction
Moments of the horizontal wave forces on the hulls about x and z axes
Total roll, pitch and yaw moments
Moments due to the vertical wave forces on the hulls about z-axis
Moments due to dynamic pressure on hull faces about y-axis
Physical mass of the vessel
Response amplitude operator for regular and irregular wave
Radius of gyration for roll, pitch and yaw motions radius of gyration
Response and wave energy values at frequency f
Horizontal and vertical wave velocity measured in the direction of the wave propagation

\[ \mathbf{X}, \{X\}, [X] \]
\[ \{x\}, \{y\}, \{z\} \]
\[ y_i \]
\[ \rho \]

Platform acceleration and displacement vector
Fairleader coordinates relative to the vessel CG
Yaw moment lever arm for the force on column i
Vertical distance to the vessel CG measured from the SWL
Velocity, acceleration, angular velocity and angular acceleration of the vessel CG
Fluid mass density
Angle of incident wave or angle of model orientation