Local and Global Hydrodynamic Loads on the FPSO 'Glas Dowr' for Fatigue Assessments

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Abstract

Two studies focussing at the hydrodynamic loading of a FPSO tanker have been carried out. The first study is an analysis of the external wave pressure loading at the side shell of the FPSO 'Glas Dowr' considering the accumulation of fatigue damage. Main attention is paid to the nonlinearity of this load in the splash zone. A frequency domain calculation procedure has been verified by a time domain procedure.

The second study focusses on the combination of the local external wave pressure and vertical wave bending induced stresses. Because of the nonlinearity of the local load this is not a straight forward procedure. A simple formula, combining the separately calculated local and global fatigue damages, is presented taking correlation into account.

This study is heavily liaised with, but not part of, the Joint Industry Project 'FPSO Integrity'. All calculations have been carried out for the measurement sections of the vessel, see appendix.

Keywords: side shell fatigue, nonlinear external pressure, relative wave motion, hull girder bending, load combination

Nomenclature

\[C = \text{SN-curve constant}\]
\[D = \text{fatigue damage}\]
\[\varepsilon_r = \text{vertical position neutral axis from base}\]
\[g = \text{gravity acceleration}\]
\[H_{RF} = \text{transfer function relative wave motion}\]
\[H_{RM} = \text{transfer function wave bending moment}\]
\[I_N = \text{moment of inertia cross section at neutral axis}\]
\[k = \text{wave number}\]
\[l_e = \text{effective length longitudinal}\]
\[m = \text{SN curve slope parameter}\]
\[m_n = \text{n-th moment of power spectrum}\]
\[M = \text{bending moment}\]
\[N = \text{number wave components}\]
\[N_c = \text{number cycles}\]
\[p = \text{pressure}\]
\[r_p = \text{end connection type reduction factor}\]
\[s = \text{longitudinal spacing}\]
\[S_{wc} = \text{wave spectrum}\]
\[S_{wc} = \text{relative wave motion spectrum}\]
\[T_r = \text{zero up-crossing period}\]
\[T_d = \text{time duration in seastate i for heading j}\]
\[W = \text{section modulus}\]
\[x_p = \text{x-value arbitrary point at mwl}\]
\[y_p = \text{y-value arbitrary point at mwl}\]
\[z = \text{vertical coordinate measured from mwl}\]
\[z_0 = \text{heave displacement COG}\]
\[\Gamma = \text{gamma function}\]
\[\varepsilon = \text{spectral bandwidth parameter}\]
\[\psi_{inc} = \text{phase angle incident wave}\]
\[\psi_R = \text{phase angle relative wave motion}\]
\[\psi_M = \text{phase angle wave bending moment}\]
\[\zeta = \text{wave elevation measured from mwl}\]
\[\zeta_0 = \text{wave amplitude measured from mwl}\]
\[\theta = \text{pitch angle}\]
\[\lambda = \text{bandwidth correction factor}\]
\[\rho = \text{density of se water}\]
\[\rho_c = \text{correlation coefficient}\]
\[\sigma = \text{stress}\]
\[\phi = \text{roll angle}\]
\[\psi = \text{wave heading}\]
\[\omega = \text{frequency}\]

1. Introduction

FPSO tankers are increasingly used for offshore oil production, because they are easy to install, remove and reuse. Even marginal oil fields in harsh environments can thus be exploited profitable. These severe environmental conditions, like the North Sea, demand a highly reliable structural design. One of the main structural subjects is the accumulation of fatigue damage.

Fatigue assessments are thus necessary and have been carried out for the North Sea FPSOs of Bluewater. In order to improve the calculation procedures a large full-scale measurement program has been set up in close cooperation with MARIN Wageningen. Other companies have joined as well. This research program is called 'FPSO integrity', a Joint Industry Project (JIP). Motions, wave heights and periods, relative wave heights, wave pressures and stresses will be measured. The database of signals thus obtained will be used for validation of existing procedures and to develop tools and integrate these tools in a general methodology for fatigue assessments of tankers. In advance of the measurements and the outcome a