Response-based analysis of FPSO systems for squall loadings

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Introduction
Research goals

Presentation outline

• Characterize the available squalls
• Influence of the individual squall parameters
• Compare the current design practice to a response based method
Squall characterization

- Rising slope
- Peak wind speed
- Decay (half-life) time

OMAE2006-92328
OMAE2011-49855
Squall characterization

Correlations and distributions

- Current Practice Design Value
- Sample Distribution
- GPD fit
- 58 Unscaled Squalls

Offset [m] vs. Probability of Exceedance $P_E$

- 100 year return values
Spread Mooring Analysis
Spread Mooring Analysis

Response Characteristics

- Peak wind speed $u_0$ [m/s]
- Normalized offset
- Rising slope $s_r$ [m/s²]
- Normalized offset
- Decay half life time $\tau$ [min]
- Normalized offset

Graphs showing the relationship between peak wind speed and normalized offset, rising slope and normalized offset, and decay half life time and normalized offset.
Spread Mooring Analysis

Response Characteristics

\[ y_{st} = \frac{\rho C_w A_y}{2k} u_0^2 = C_{st} u_0^2 \]

\[ \alpha = \frac{y_{dyn}}{y_{st}} \]
Spread Mooring Analysis
Response Characteristics

$\zeta = 0.2$
$\zeta = 0.3$
$\zeta = 0.4$
$\zeta = 0.5$

$T_n = 100s$
$T_n = 130s$
$T_n = 160s$
$T_n = 190s$
$T_n = 220s$
$T_n = 250s$
$T_n = 280s$
$T_n = 310s$
$T_n = 340s$
$T_n = 370s$
$T_n = 400s$
Design Value Estimation

“The 100 year event”

• Current Design Practice
• Response Based Methods

• Spread moored FPSO
• 800m water depth
• $T_n = 290s$
• $\xi = 0.4$
Design Value Estimation

Current Design Practice

\[ u_{100} = 27.3 \text{m/s} \]
Design Value Estimation

Current Design Practice

\[ y_{100} = 35.8 \text{m} \]
Design Value Estimation
Response based on dynamic amplification

\[ y_{st} = \frac{\rho C_w A_y}{2k} u_0^2 = C_{st} u_0^2 = 0.0402 \times u_0^2 \]
Design Value Estimation

Peak wind speed relation and dynamic amplification

\[ E\langle s_r, \tau \rangle \rightarrow \alpha = 1.024 \]
Design Value Estimation

Peak wind speed relation and dynamic amplification

\[ y_{dy} = \alpha y_{st}(u_0) = \alpha C_{st} u_0^2 \]

\[ P_E(y_{dy}) = 1 - \exp \left( - \left[ 1 + \xi \left( \frac{\sqrt{y/\alpha C_{st}} - \mu}{\sigma} \right) \right]^{-\frac{1}{\xi}} \right) \]
Design Value Estimation

Peak wind speed relation and dynamic amplification

- Case I  Expected Values
- Case II  Maximum Observed Values
- Case III 100 Year Return Values
Design Value Estimation

Peak wind speed relation and dynamic amplification

\[ \alpha = 1.024 \quad \alpha = 1.110 \quad \alpha = 1.213 \]
Conclusions

- Characterized the squall events
- Found the governing response characteristics
- Compared the different DVE methods
- CDP for spread moored is highly conservative
- Best method is based on response knowledge
Thank you for your attention!
14 Bachelor Programs
38 Master Programs
16,400 students

Master Program “Offshore Engineering”
• Partly Civil Engineering
• Partly Mechanical Engineering
• Partly Maritime Engineering
21 Challenge the future
Introduction
Design Value Estimation

Direct Extrapolation

\[ y_{100} = 37.6m \]
Design Value Estimation
Monte Carlo Simulations

\[ y_{100} = 30.0m \]
Design Value Estimation

Peak wind speed relation and dynamic amplification

- Sample Distribution
- Current Design Practice
- Static Offset Values
- PWS relation $\alpha = 1.027$
- Step Response $\alpha = 1.255$
- Direct Extrapolation
- Monte Carlo Simulations

100 year return values
Turret Mooring
Turret Mooring

Response characteristics

![Graph showing response characteristics for different offset angles and time.]
Turret Mooring

Response characteristics

- Peak wind speed [m/s]
- Offset [m]
- 0 deg
- 45 deg
- 90 deg
- 135 deg
- 180 deg
Turret Mooring
Response characteristics
Turret Mooring

Current Design Practice

\[ y_{100} = 35.7 m \]
Turret Mooring

Dynamic Amplification limitations

\[ \alpha = 2.60 \quad \alpha = 2.67 \]
Turret Mooring

Dynamic Amplification limitations
Turret Mooring

Dynamic Amplification limitations

![Graph showing probability of exceedance vs. offset, with lines for current practice design value, static response, maximum DA, maximum observed DA, and 100 year return DA. The graph includes 100 year return values highlighted.]