On the Challenges of Analysis and Design of Turret-Moored FPSOs in Squalls (2)

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Overview

• Background –
  – Squalls Yet Another Environmental Phenomena
  – Current Design Practice
  – Our Proposal (previous paper)
• Further Discussion on Design Value
Background – Squall Characteristics

• Squall: A sudden onset of **Strong Winds** with speeds increasing to at least 8 m/s and sustained at 11 m/s for at least 1-minute. The **Intensity and Duration** is longer than that of a Gust.
Background – Squall Characteristics

- Squall 1-Min Wind Speed

- Squall Wind Direction
Background – Analysis

• Analysis For Squalls
  – Scale the measured squalls (from 9 to 100+ timeseries) to 100yr RP wind speed (commonly up to 36m/sec) – Scale the time as well?
    • Run squalls from all plausible headings.
      – Squall Heading is commonly defined as the heading at peak velocity
    • Various vessel loading conditions
    • Various ambient wave and current combinations (zero wave and current!)
    • Various riser arrangements
Background – Design Value (Class Society)

- **DNV-OS-E301 (Oct. 2010):**
  - The extreme value of the mooring line tension and offset shall be taken as the maximum value for the time series of the actual responses.

- **DNV-OS-E301 (Oct. 2013):**
  - “As a minimum the maximum tension from at least 20 representative squalls is required.”…
  - “If a much better basis in data is available a 95% fractile as the characteristic load may be accepted. The set of scaled squalls considered shall be much larger than 20 representative cases (e.g. 100 representative squalls).”

- **NR 493 DT R02 E (April 2012):**
  - “Design response (of tension, offset,...) is the maximum responses obtained over all the squall cases except otherwise agreed.”
Background – Design Value (Argument)

- From a Designer Perspective:
  - Most critical value is the most sensitive estimate
    - Input squalls (scaling, quality of measurements, etc.)
    - Numerical modeling
  - Most critical value is the most unreliable (uncertain) statistics
    - Could significantly change in time
    - Tends to increase with sample size increase
Background – Design Value (Argument)

From a Designer Perspective

- Maximum overall response is the most sensitive estimate
  - Input squalls (scaling, quality of measurements, etc.)
  - Numerical modeling

- Maximum overall response is the most unreliable (uncertain) statistics
  - Sample size effect
  - Could significantly change in time
  - Tends to increase with sample size increase

- Most critical expected maximum response of large enough sample is not significantly sensitive to input uncertainties.

- Most critical expected maximum response of large enough sample is significantly less uncertain and less sensitive to sample size.
Background – Design Value (our proposal)

- 19th SNAME TX Offshore Symposium Feb. 2014:
  - Choose ~ 35 squalls that require minimal “scaling” for desired return period
  - Run simulations changing other variables (loading condition, ambient environment, squall heading, riser arrangements, etc.)
  - Treat the squalls as independent realizations of the same phenomena and estimate the Expected Maximum of the 35 observed maxima
    - The only random variables are squall intensity and directionality
  - The design value is the most critical Expected Maximum
Question?

• “Are we fair to spread moored FPSOs?”
  – The design value for spread moored FPSOs is estimated as the expected value of response to squalls approaching the vessel from a certain angle (e.g. beam on).
  – The design value for turret moored FPSOs is estimated as the expected value of response to squalls approaching the vessel with a specific heading but individual maximum response could happen at different relative headings.
Spread Moored vs. Turret Moored
Response – First Reaction

Spread-Moored

Turret-Moored
Earth Fixed vs Vessel Fixed Angles
Further Discussion on Design Value

• Case Study
  – A typical deep-water turret moored FPSO designed for West Africa environment
  – Taut chain-polyester-chain mooring legs
  – 3G*3L mooring leg arrangement
  – 73 squalls, 24 headings (360deg, 15deg resolution)
    • Most critical draft
    • Most critical riser arrangement
    • Most critical ambient environment
    • 1752 cases
A More Careful Look at Offset
A More Careful Look at Offset
A More Careful Look at Offset

- Offset (m) vs. t (sec)
- Squall Speed (m/sec) vs. t (sec)
- Squall Heading (deg) vs. t (sec)
- Rel. Heading (deg) vs. t (sec)
A More Careful Look at Offset

At the time of Max Offset
A More Careful Look at Offset
Offset Design Value – Original Proposal

Squall Heading (deg)

Offset Radius (m)

Expected (Max)
Min (Max)
Max (Max)

Probability of Exceedance

Data Points
GEV

Squall Angle = 300deg
Offset Design Value – Offset Direction

Method | E [Max Offset] (KN)
---|---
Expected Value – Squall Heading | 63.9
Expected Value – Offset Direction | 64.4
A More Careful Look at Tension
A More Careful Look at Tension
A More Careful Look at Tension

- Tension (KN)

- Squall Speed (m/sec)

- Squall Heading (deg)

- Relative Heading (deg)
A More Careful Look at Tension

At the time of Max Tension in Most Critical Line
Tension Design Value – Original Proposal

![Graph showing tension design value](image)

- **Squall Heading (deg)**: 0 to 360
- **Tension (KN)**: 1500 to 4000
- **Expected (Max)**
- **Min (Max)**
- **Max (Max)**

Data Points:
- Expected (Max)
- Min (Max)
- Max (Max)

Additional Graph:
- Squall Heading = 120 deg, Leg 2
- Probability of Exceedance
- Tension (KN)
- Probability of Exceedance

Legend:
- Blue: Expected (Max)
- Green: Min (Max)
- Red: Max (Max)

Data Points:
- Blue: Data Points
- Black: GEV
Tension Design Value – Most Critical Line

<table>
<thead>
<tr>
<th>Method</th>
<th>E [Max Tension] (KN)</th>
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<tr>
<td>Expected Value – Individual Leg</td>
<td>2835</td>
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<tr>
<td>Expected Value – Most Critical Leg</td>
<td>2863</td>
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Next Steps

• Response – Based Analysis of Turret Moored FPSOs in Squalls
  – Challenges
    • Scaling Issues
    • Synthetic Squalls (intensity and directionality)
    • Extrapolating Inputs or Responses
Thank You!