The Design Envelope Dilemma: Why Do Mooring Systems Fail?

WELAPTEGA CAPABILITIES

- Mooring Measurement Campaigns
- Class Compliant Campaigns (Annual, 2,5, UWild, 5 Yearly)
- Baseline Inspection
- Mooring Life Extensions
- Damage Assessments
- Mooring Fitness for Purpose Assessments
OPERATING WORLDWIDE

20 Years experience in the United Kingdom, Norway, Canada, Gulf of Mexico, West Africa, Australia, South East Asia, and India.

- Welaptega Global Projects
  - Agents:
    - IEV
    - Accron
    - Beijing Safetech
    - GCA Energy


OUR VALUED CLIENTS

Welaptega operates globally with clients and projects in just about every region of the offshore oil and gas industry.
WHY ARE MOORINGS IMPORTANT?
BECAUSE RISERS ARE IMPORTANT

- Banff FPSO 5 of 10 mooring lines failed
  Risers broken
- Gryphon Alpha 4 of 8 mooring lines failed
  Risers broken, seabed infrastructure damaged
- Nan Hai Fa Xian 4 of 8 mooring lines failed
  Risers broken
- Nan Hai Sheng Li 7 of 10 mooring lines failed
  Risers broken

MOORING SYSTEM DESIGN ENVELOPE

Moorings are designed to meet riser excursion limitations and necessary strength and fatigue requirements.

The "Design Envelope" is a unique set of criteria where the Excursion, Strength, and Fatigue requirements are all satisfied.

1. More conservative design broadens the allowable operating conditions, but increases cost
2. Mooring designs often meet minimum requirements to optimize cost
3. Increasing one may lead to trade-offs on another
DESIGN & OPERATING CRITERIA

Controllable Design Inputs
- Corrosion Allowance
  0.2mm/yr → +1 mm/yr
- Return Period
  100yr → 10,000yr
- Line Redundancy
  1 or 2 line failure?
- Safety Factors
  Strength: FoS = 1.67+
  Fatigue: FoS = 3 to 10

Inherent Design Assumptions
- Axial loading vs bending or torsional
- Rotational freedom between components
- Proper component assembly
- Equal load sharing between adjacent lines
- Proper pre-tensioning of lines
- Working anodes
- Minimal seabed scour and trenching
- No damage from external sources

Where Problems Arise
- Design analysis is based on hindcast data which is assumed will be relevant into the future
- Designed to standards of the time, not necessarily standard at present
- Degradation, corrosion, wear & tear, and unanticipated operating conditions can bring the system outside of this envelope
- Once outside of the envelope, original analysis and design safety factors are invalid

Were the initial estimates and assumptions sufficiently accurate to ensure the mooring system is still fit for purpose within its service life?
What to do About it?

Feedback loops to validate original design assumptions

- Monitoring: Validation of mooring performance (line tensions, excursions, and metocean conditions experienced).
- Comparison to updated Standards: Have improved standards and industry experience identify any risks that were not known at the time of original design?
- Inspection: Is the present day condition of the mooring system congruent with the expected condition at this time, and how does this extrapolate into the future?

CORROSION PROFILE

Chain Intergrip Diameter vs. Depth

<table>
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<tr>
<th>Water Depth (m)</th>
<th>Diameter (mm)</th>
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<tbody>
<tr>
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MICROBIOLOGICALLY INFLUENCED CORROSION (MIC) AT THE TOUCHDOWN ZONE

Does unanticipated corrosion phenomenon impact strength and design life?

INSTALLATION DAMAGE AND IMPROPER HANDLING

Is a damaged component still fit for service? Are the consequences of the damage immediate or long term? Must the component be replaced immediately or following first oil?
ISSUES AT THE TOUCHDOWN POINT
Failure of clump weights and drape chains

How do failure of weighted elements affect vessel excursions?

At what point is the seabed holding capacity insufficient?

Sonar model of trenching into suction pile


WIRE ROPE DEGRADATION

Wire ropes have great strength and fatigue properties, but no consideration for:
- Corrosion
- Bending
- Low tension or compression
- Snap loads

How does unexpected loading and degradation affect strength and fatigue performance?

Statoil safety alert: Volve FSU Mooring
2nd Advanced FPSO Forum – OMV - RAROA The Return

MOORING RISK MITIGATION

**MONITORING:** to ensure that design assumptions and predictions remain valid:
- Line tensions (or line angles)
- Vessel excursions
- Metocean conditions

**INSPECTION:** to determine if present-day condition and predict future condition:
- Quantify component degradation to remove uncertainty
- Are all components deteriorating at anticipated rates?
- Are critical design assumptions valid?
- Use this data to inform reassessments

**ENGINEERING REASSESSMENTS:** to ensure the mooring system is still fit for purpose when monitoring and inspection show that it’s operating outside its intended design envelope.

Ensure the system still meets allowable excursions and minimum safety factors for intact, damaged, and fatigue limit states?

RESPONSIBLE FORWARD THINKING

System failure is unacceptable by all stakeholders of a project

Were your design criteria and assumptions right? Quantified proof of criteria removes uncertainty in assessments

Operating within the design envelope is proof that it will likely reach the intended design life

Moving outside of the envelope should trigger review of reassessment requirements using real world data and results
CONTACT

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