OIL & GAS

Inspection Planning for Offshore Structures to Identify Fatigue Cracking (and corrosion / coating damage ?)
WJS and ICorr

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Overview

Why do we inspect?

When do we inspect?

DNVGL-RP-F0001

Fracture mechanics approaches to inspection planning

Probabilistic methods and calibration of models

Typical results and example inspection plans

Coating degradation and corrosion of FPSO tanks
Why do we inspect?

Does my structure have adequate structural integrity?

- Degradation (fatigue cracking, corrosion...)
- Fabrication defects or installation damage
- Environmental overload
- Accidental loads or damage
- Design errors
What / where do we inspect?
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What / where do we inspect?
What / where do we inspect?
When do we inspect?

Time based approach
- Fixed interval
- Class or other regulatory requirements

Risk based approach
- Variable interval dependant on probability and consequence of failure
- Qualitative or quantitative approaches

2.4.4 Renewal survey schedule is as follows:
   - The due date is set at 5 years interval and corresponds to the expiry date of the classification certificate.

3.2.1 Structural Continuous is a survey arrangement whereby the survey items in the hull list established for the unit are subject to separate surveys with interval 5 years. The arrangement shall provide for survey of approximately 20% of the total number of survey items during each year of the five-year class period.

1.2.7 The extent of examination specified in the referred tables may be refined by use of RBI / RCM methodologies.

For further guidance on RBI see also DNVGL-RP-0001 Probabilistic methods for planning of inspection for fatigue cracks in offshore structures and DNVGL-RP-0178 Risk Based Corrosion Management.
DNVGL-RP-0001

Scope

• Jackets, semisubmersibles, FPSOs
• Probabilistic fracture mechanics model for fatigue cracking
• Structural analysis requirements
• Inspection methods
• Weld improvement methods
• Validation of results
Fracture mechanics approaches to inspection planning

- How long does it take for a fatigue crack to grow through the wall thickness?
- Input parameters
  - Initial flaw sizes (at fabrication or at last inspection)
  - Material properties (fatigue crack growth rate law C, m)
  - Applied stresses (global and local)

\[
\frac{da}{dN} = C (\Delta K(a,c))^m
\]
Fracture mechanics approaches to inspection planning

**Deterministic approach**

- Consider worst-case flaw size that “might have been missed” at last inspection
- Worst case (or design) fatigue loads
- Worst case material properties (e.g. upper bound crack growth rate)
- Demonstrate that time taken > proposed inspection interval
- Fracture mechanics (only) – more conservative than S-N fatigue design
Fracture mechanics approaches to inspection planning

Probabilistic approach

• Consider distribution of possible flaw sizes at fabrication
• Distribution of fatigue loads including modelling uncertainty
• Distribution of material properties based on observed scatter
• Demonstrate that POF remains “acceptable” over the proposed inspection interval

• Take account of inspection findings (e.g. if no cracking observed with MPI/EC)
• Take account of weld improvements such as toe grinding
Fracture mechanics approaches to inspection planning

- Initial defect distribution
- Crack size
- Critical crack size
- "Time to failure" distribution
- Updated "Time to failure" distribution
- Expected crack growth
- Updated expected crack growth
- Defect distribution at time = t1
- Defect distribution after inspection
- Probability of failure
- PoF_{crit}
- Maximum acceptable failure probability
- Inspection
- Probability of failure
- Updated probability of failure
- Time
- t1, t2, t3
Calibration of models

- Calibrate FM model to be consistent with S-N fatigue design
- POF associated with S-N analysis can be derived from design curves and specified CoV on load / resistance
Calibration of models
Calibration of models

Toe grinding

- SN data quantify extent of improvement (and change in slope)
- FM model incorporates
  - Initiation time before crack appears
  - Reduced stress concentration at the weld ($M_k$)
Calibration of models

Figure D-26 Comparison of calculated fatigue failure probabilities using fracture mechanics and S-N based fatigue model for a ground butt weld
Typical methodology (overview)

- Collate drawings, inspection history etc.
- Perform structural analysis (if not already available)
- Perform quantitative RBI at selected hotspots (low life, history of cracking or high consequence)
- NDT at interval determined by RBI
- Visual inspection of other details
Typical methodology (structural analysis)

- Global structural model and mass model
- Hydrodynamic model
- Local sub-models with fine mesh at selected hotspot areas

<table>
<thead>
<tr>
<th>Analysis method</th>
<th>Stress concentration model</th>
<th>CoV</th>
</tr>
</thead>
<tbody>
<tr>
<td>complete shell model with sub-modelling</td>
<td>hot spot from sub-model</td>
<td>0.12</td>
</tr>
<tr>
<td>complete shell model</td>
<td>SCF from local models</td>
<td>0.16</td>
</tr>
<tr>
<td>combined beam and shell model</td>
<td>SCF from literature</td>
<td>0.25</td>
</tr>
<tr>
<td>simplified method - beam model</td>
<td>SCF from literature</td>
<td>0.40</td>
</tr>
</tbody>
</table>
Example (Doubling plate on pontoon of semi-sub)

- 15 years old with EC every 5th year
- S-N fatigue life 20 yrs
- Is continued inspection every 5yrs ok?
Example (Topside support on FPSO)

- Just going into service (no history)
- S-N fatigue life 30 yrs
- Time to first inspection and interval?
Example (Topside support on FPSO)

- After 15 yrs FPSO relocates
- More severe loading, x2 fatigue damage rate
- Adjust inspection plan?
- Toe-grind at selected locations to improve schedule?

![Diagram of Topside support on FPSO]

![Graph showing accumulated failure probability vs service time (years)]
Summary

- Method provides a rational basis for inspection planning taking account of
  - Inspection history
  - Uncertainties on input parameters (flaw size, applied loads, material properties, POD...)

- Determine time to first inspection and interval
  - Determine where improvements are required (for desired interval)
  - Optimise for minimum cost if data for cost of inspection/repairs are available
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Coating degradation and corrosion

- Various approaches to “RBI”
  - Qualitative
  - “Semi” Quantitative
Coating degradation and corrosion

• JIP “Life Cycle Management of Hull Structures”
• Quantitative Coating Lifetime Prediction Model
• Modelled using parameters such as
  – Target useful life (depending on coating specification)
  – Surface preparation factor (cleanliness)
  – Environmental exposure factor (type and temperature of tank contents)
  – Osmosis factor (salts on surface or solvents in paint)
  – Cathodic disbondment (type of coating and test results)
  – Other factors may also be included such as flexibility of coating, resistance to shrinkage etc.
Coating degradation

- Probabilistic aspects need to be developed
  - Uncertainties
  - Correlations (e.g. between those tanks inspected and those not)
- Inspection updating procedure could be similar to that used for fatigue cracks
- “Acceptance criteria” needs to be established.
  - Expected coating condition falling below threshold
  - Alternatively, plans can be developed to minimise cost (while maintaining adequate safety)
Summary

• Where both fatigue and corrosion are of concern when setting an inspection period, e.g. fatigue hotspots inside storage/ballast tanks

• Plans may be optimised in a number of ways, e.g.
  – minimise cost associated with coating damage / corrosion (e.g. inspection, repairs, re-coating)
  – determine weld improvements required at fatigue hotspots so that these may be inspected at the same interval?
  – Number of tank inspections required to provide sufficient reliability