DNV·GL

OIL & GAS

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

WJS and ICorr

David Baxter

2015-09-29

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 ?

Degradation (fatigue cracking, corrosion…)

Fabrication defects or installation damage

Does my structure have adequate structural integrity ?

Design errors

Environmental overload

Accidental loads or damage

What / where do we inspect ?

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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

DNVGL-RU-OU-0102_2015

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

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DNVGL-RP-0001 Edition May 2015

Probabilistic methods for planning of inspection for fatigue cracks in offshore structures

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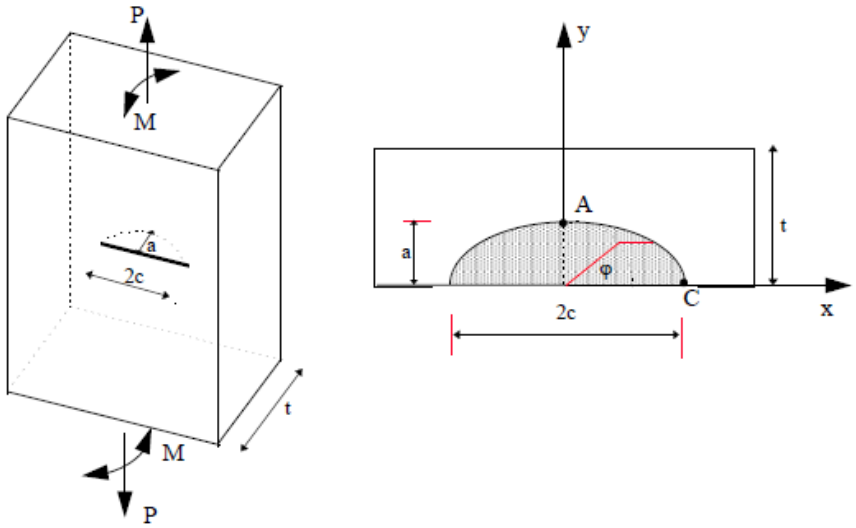
Fracture mechanics approaches to inspection planning

- 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)

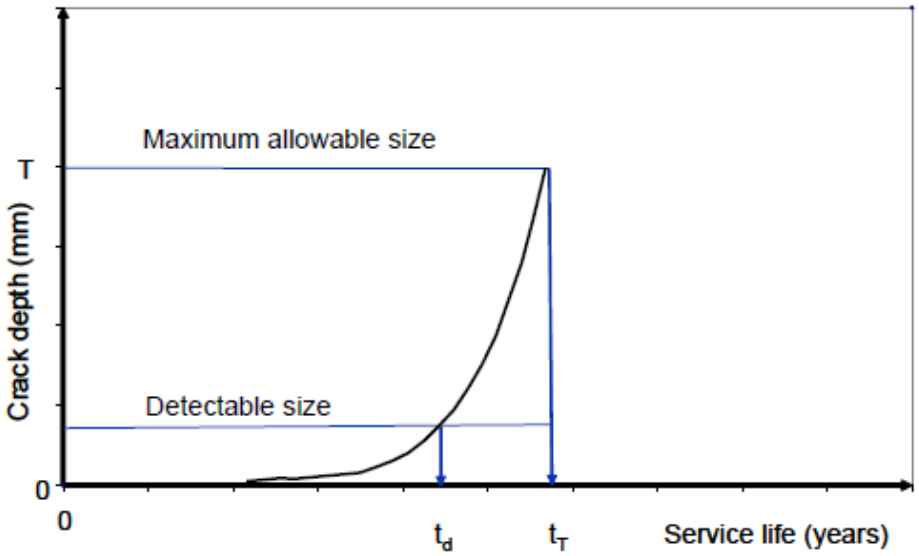


$$\frac{da}{dN} = C\left(\Delta K(a,c)\right)^m$$

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

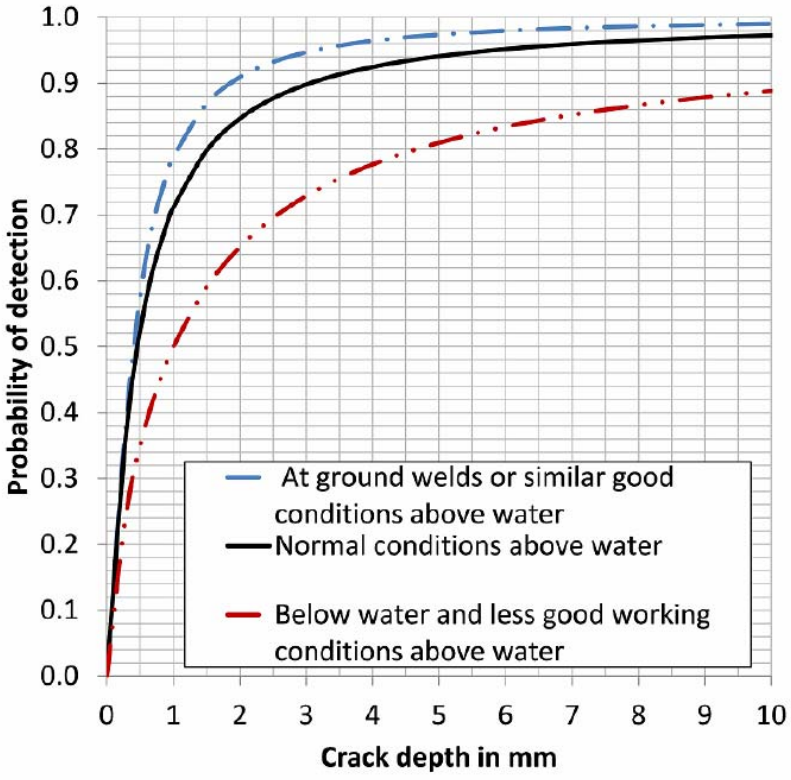


Fracture mechanics approaches to inspection planning

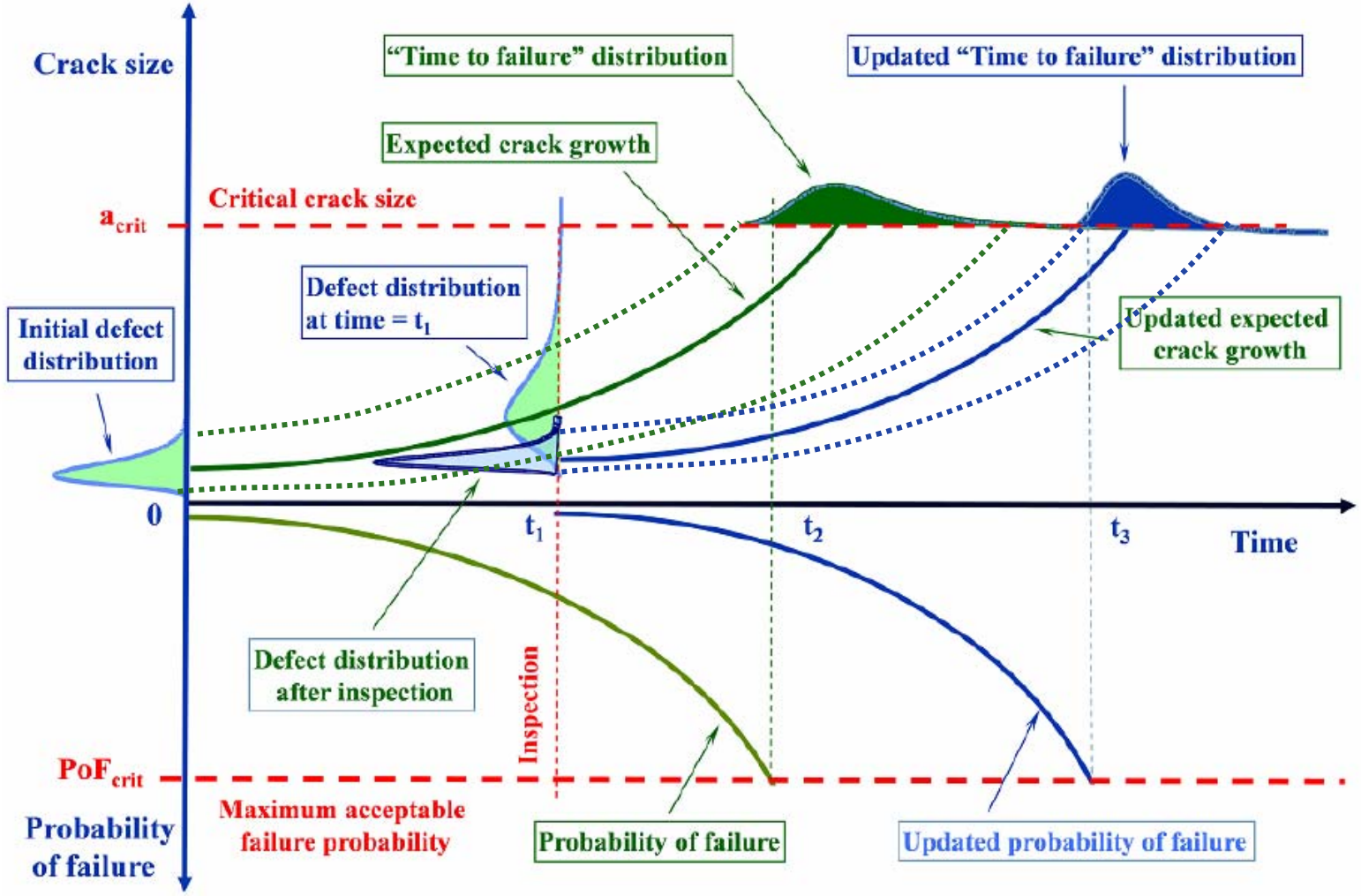
Probabilistic approach

- 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**

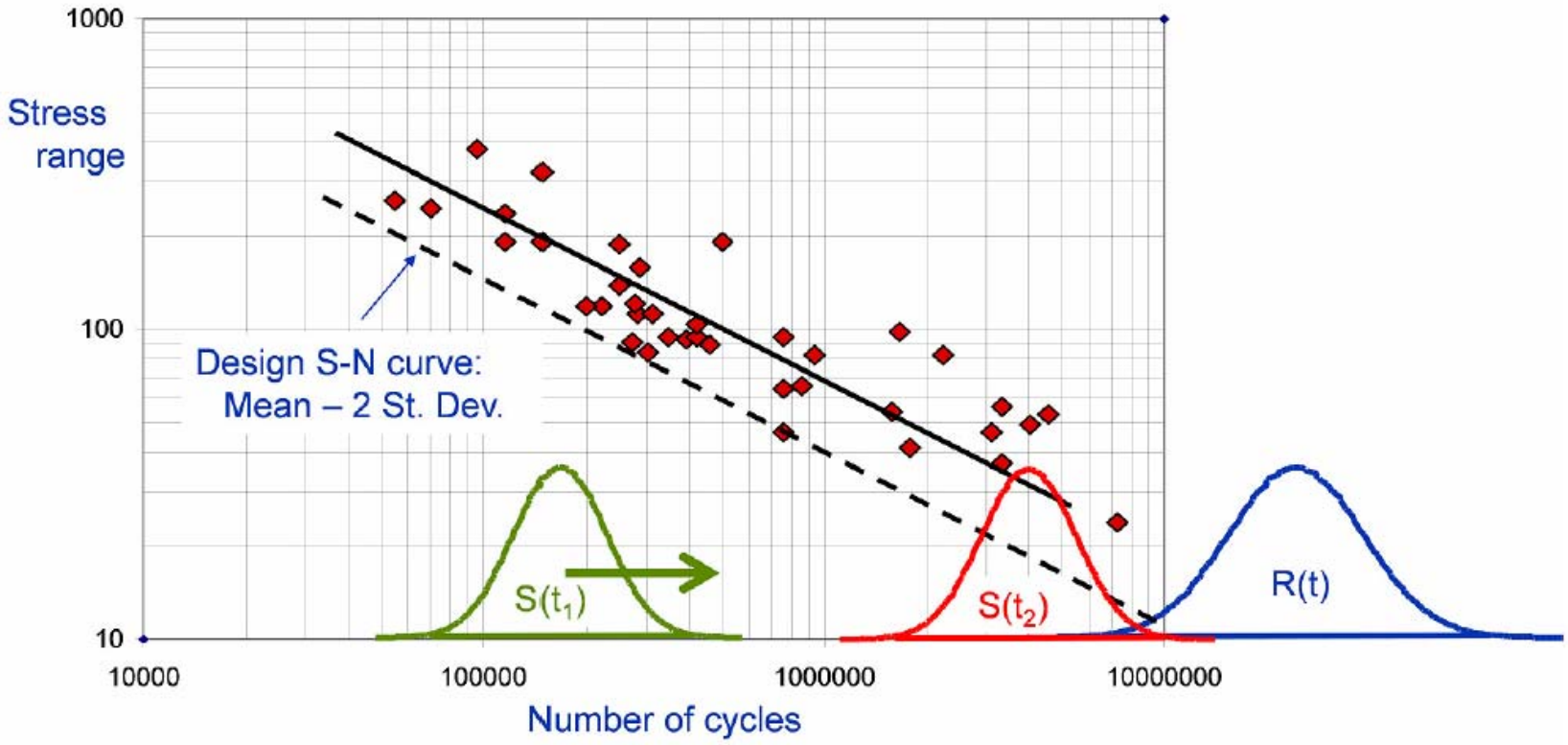


Fracture mechanics approaches to inspection planning

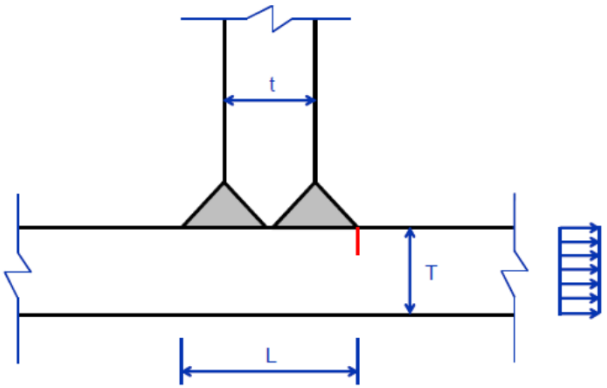


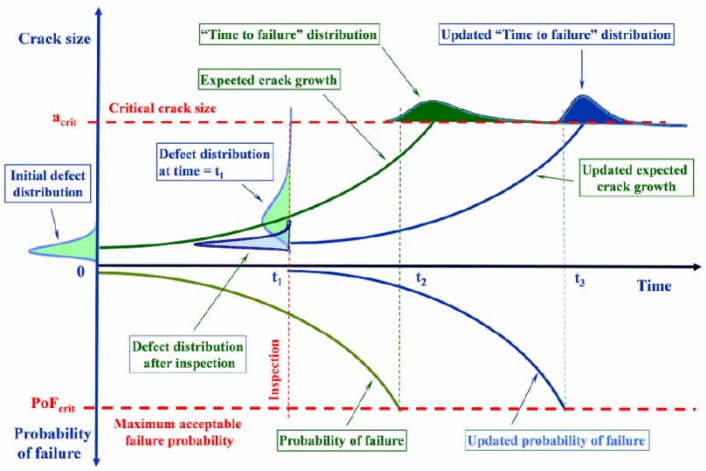
Calibration of models

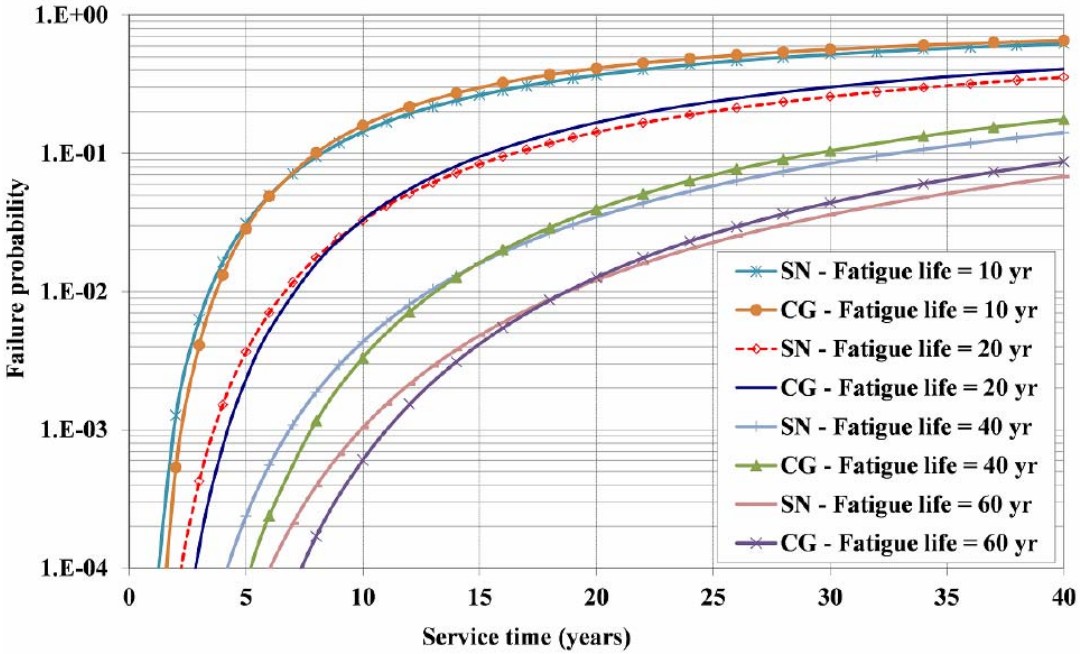
- Calibrate FM model to be consistent with S-N fatigue design
- POF associated with S-N analysis can be derived from design curves and specified CoV on load / resistance



Calibration of models



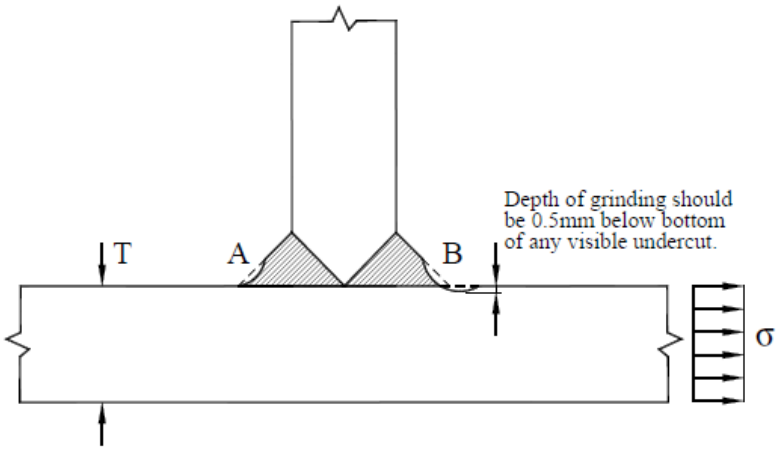


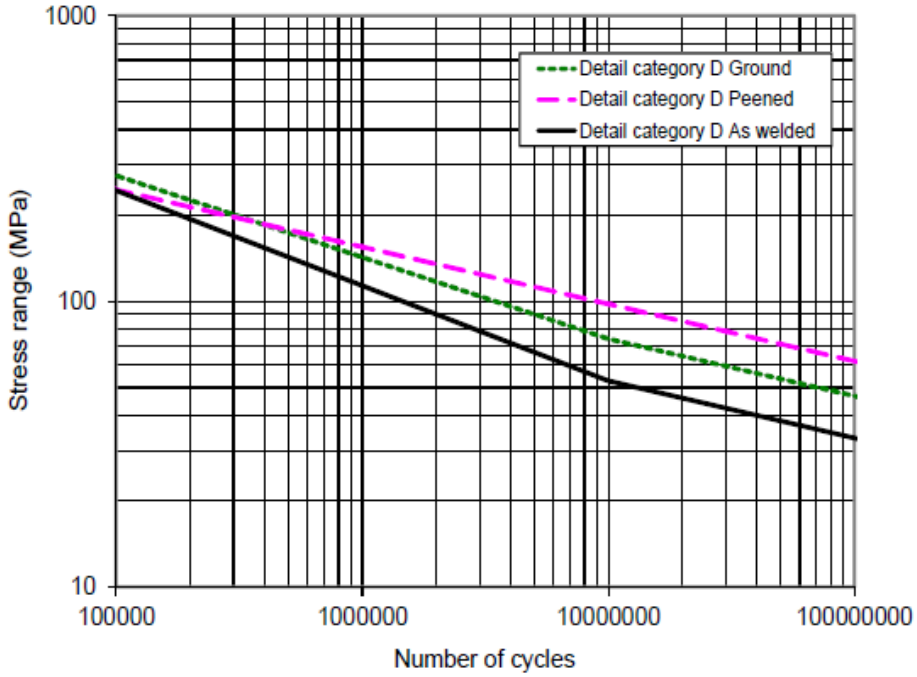


Calibration of models

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

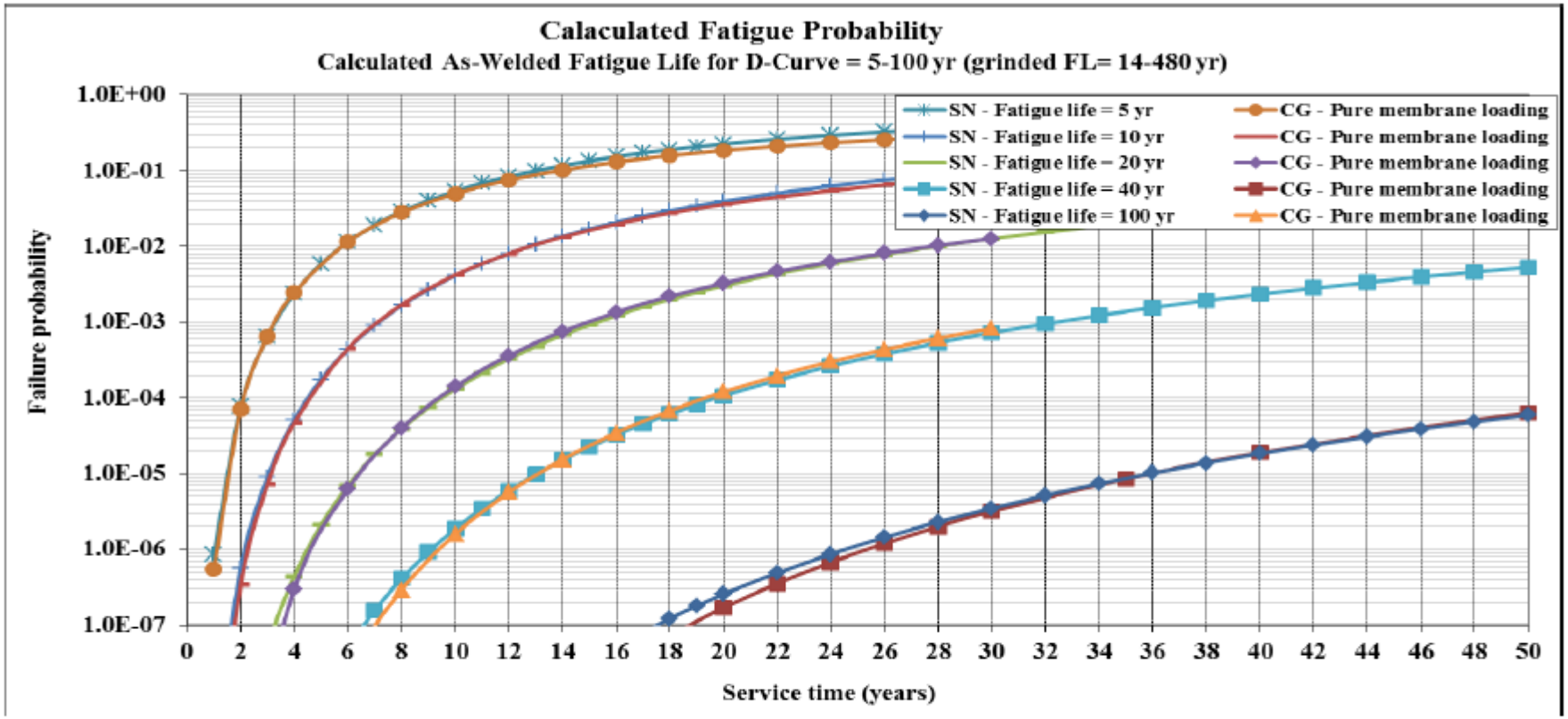
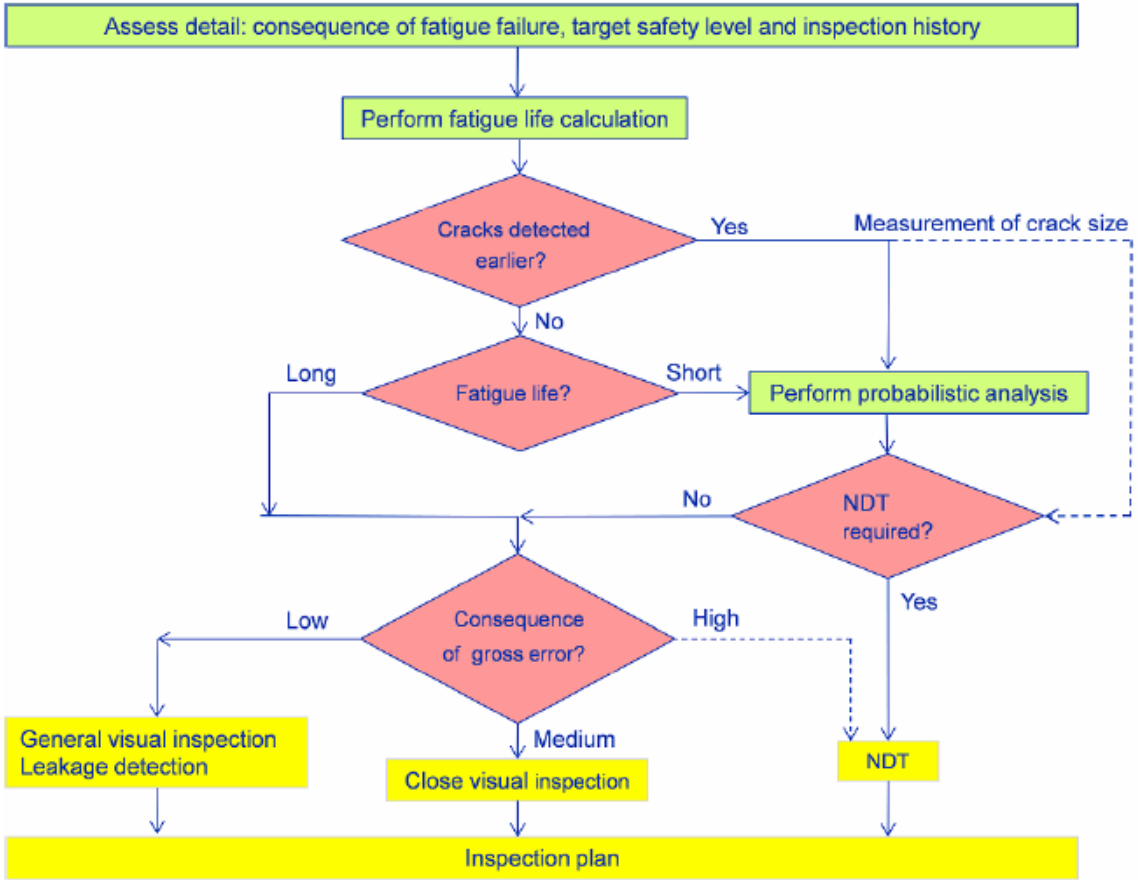


Figure D-26 Comparison of calculated fatigue failure probabilities using fracture mechanics and S-N based fatigue model for a ground butt weld

Typical methodology (overview)

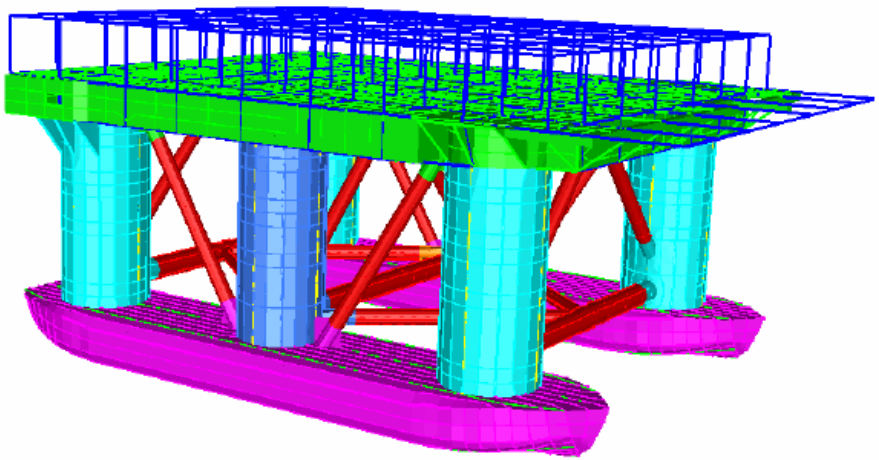
- Collate drawings, inspection history etc.
- Perform structural analysis (if not already available)
- Perform quantitative RBI at selected hotspots (low life, history of cracking or high consequence)

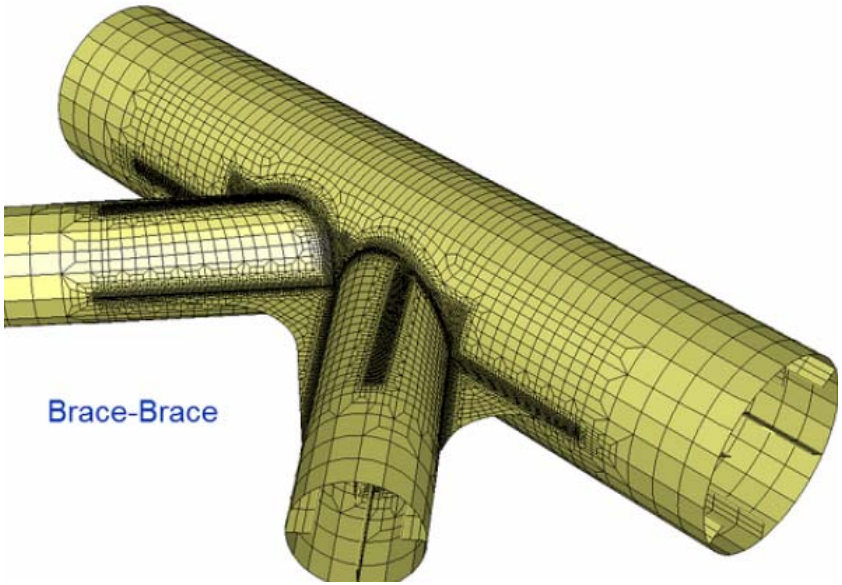
- NDT at interval determined by RBI
- Visual inspection of other details



Typical methodology (structural analysis)

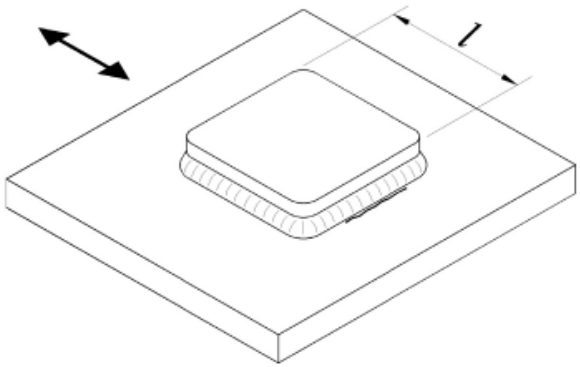
- Global structural model and mass model
- Hydrodynamic model
- Local sub-models with fine mesh at selected hotspot areas



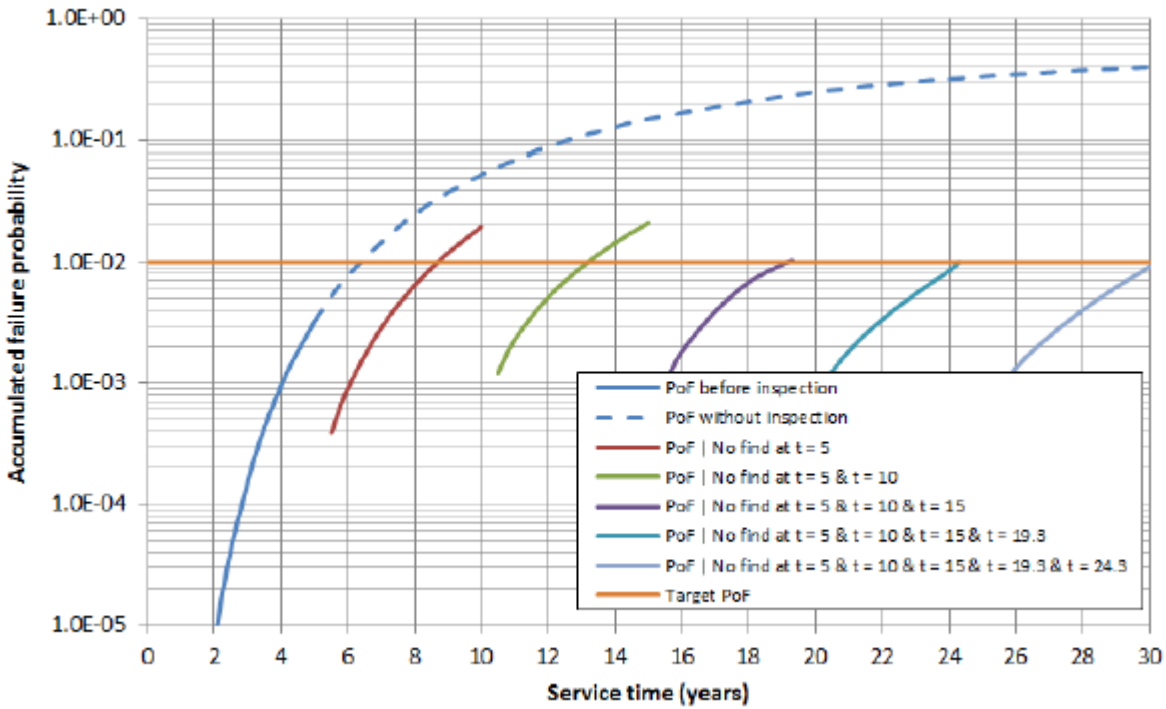


Analysis method	*Stress concentration model*	*CoV*
complete shell model with sub-modelling	hot spot from sub-model	0.12
complete shell model	SCF from local models	0.16
combined beam and shell model	SCF from literature	0.25
simplified method - beam model	SCF from literature	0.40

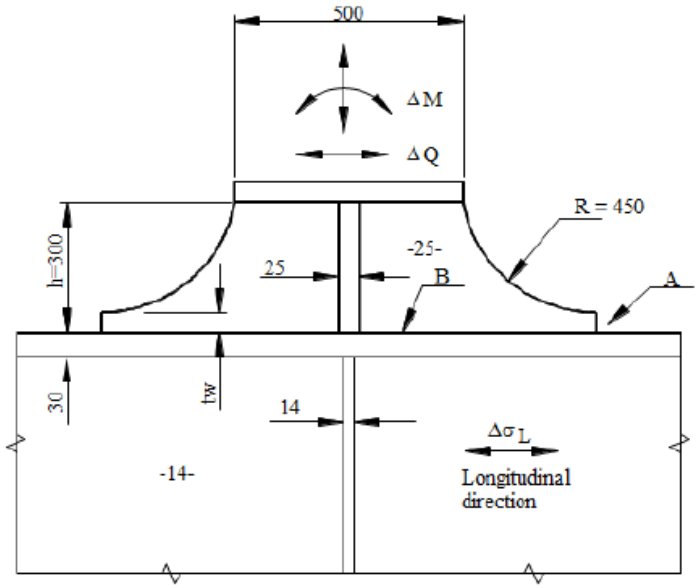
Example (Doubling plate on pontoon of semi-sub)



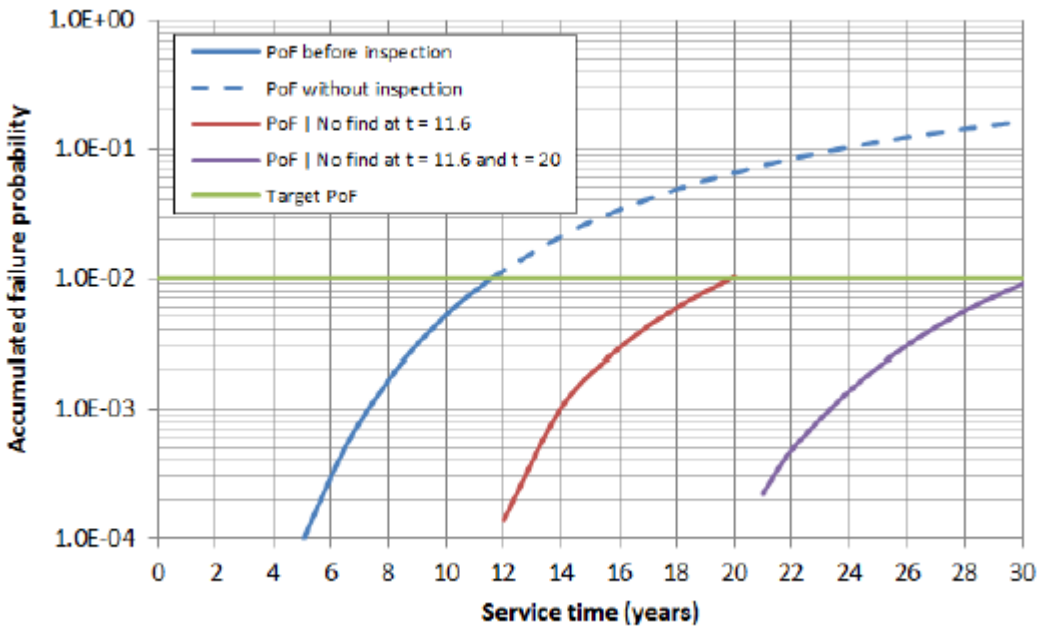
- 15 years old with EC every 5th year
- S-N fatigue life 20 yrs
- Is continued inspection every 5yrs ok ?



Example (Topside support on FPSO)



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



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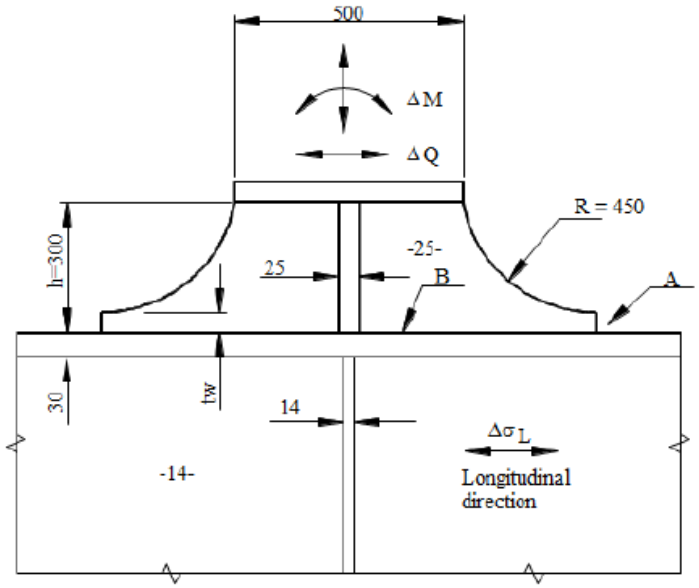
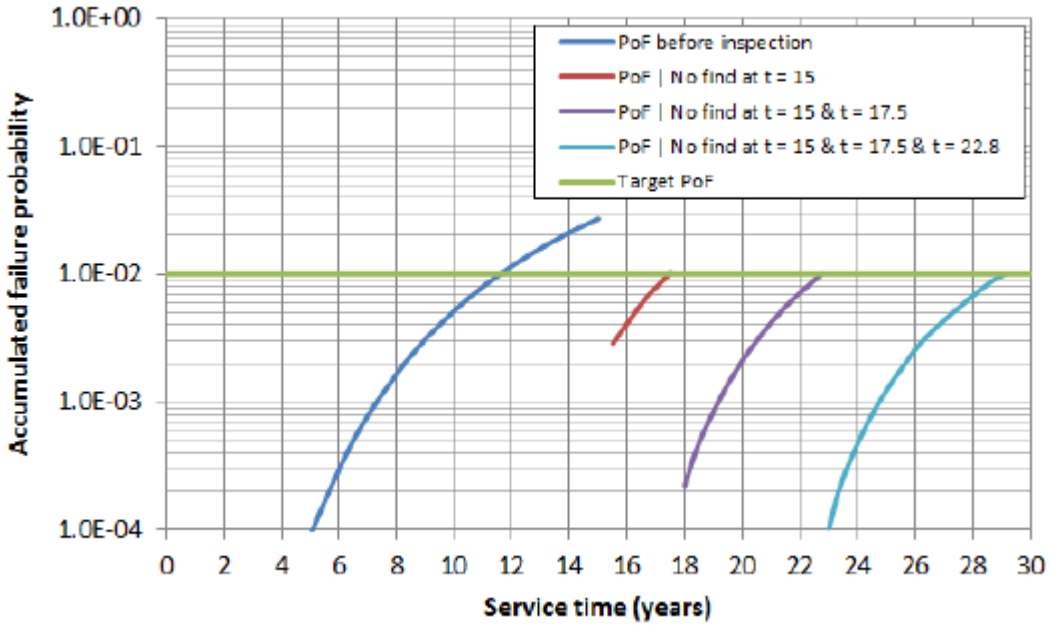


- After 15 yrs FPSO relocates
- More severe loading, x2 fatigue damage rate
- Adjust inspection plan ?
- Toe-grind at selected locations to improve schedule ?



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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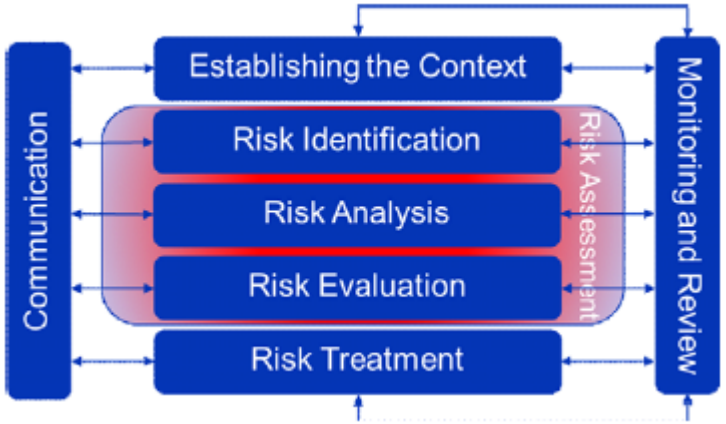
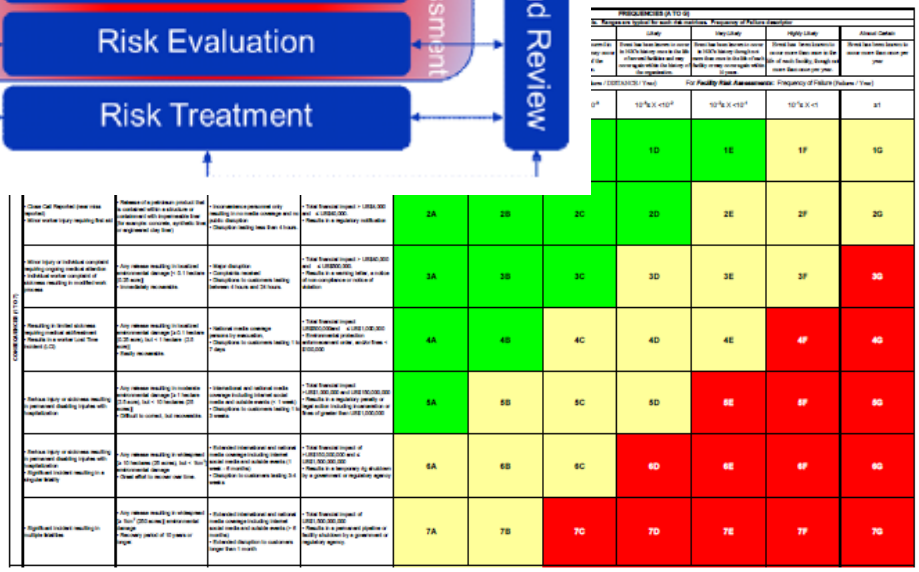
- *Coating degradation and corrosion of FPSO tanks*

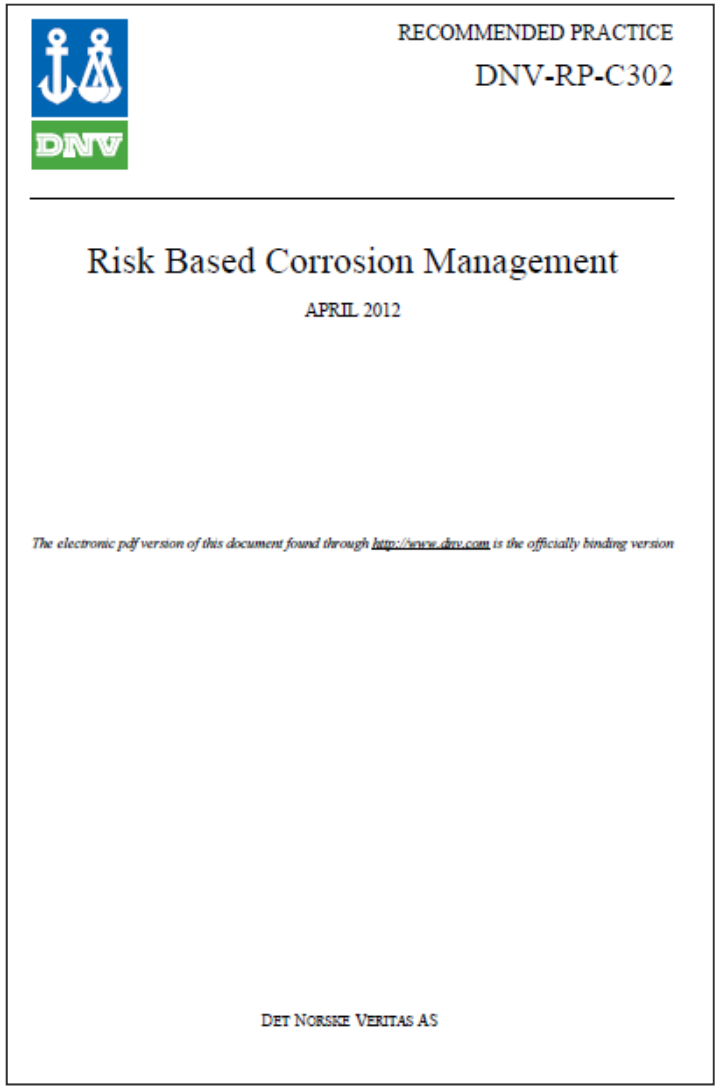
Coating degradation and corrosion

- Various approaches to "RBI"
  - Qualitative
  - "Semi" Quantitative





1D	1E	1F	1G			
2A	2B	2C	2D	2E	2F	2G
3A	3B	3C	3D	3E	3F	3G
4A	4B	4C	4D	4E	4F	4G
5A	5B	5C	5D	5E	5F	5G
6A	6B	6C	6D	6E	6F	6G
7A	7B	7C	7D	7E	7F	7G



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DNV-RP-C302

Risk Based Corrosion Management

APRIL 2012

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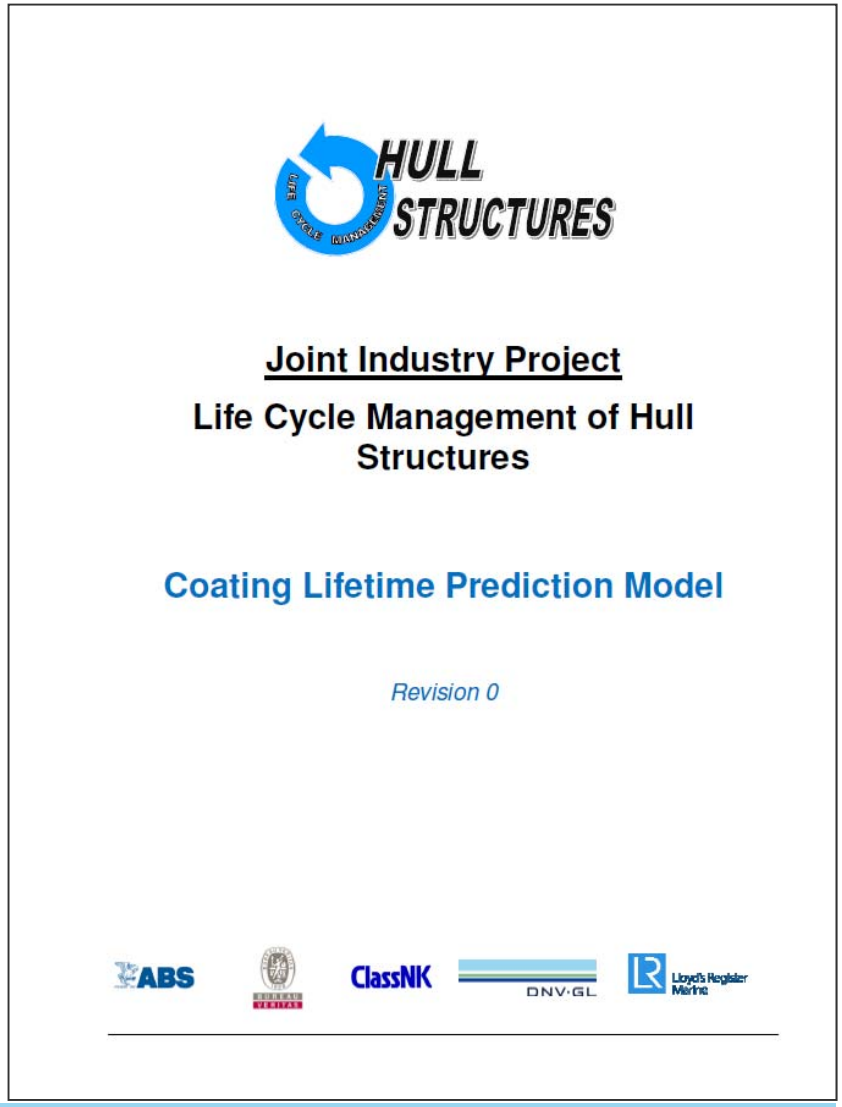
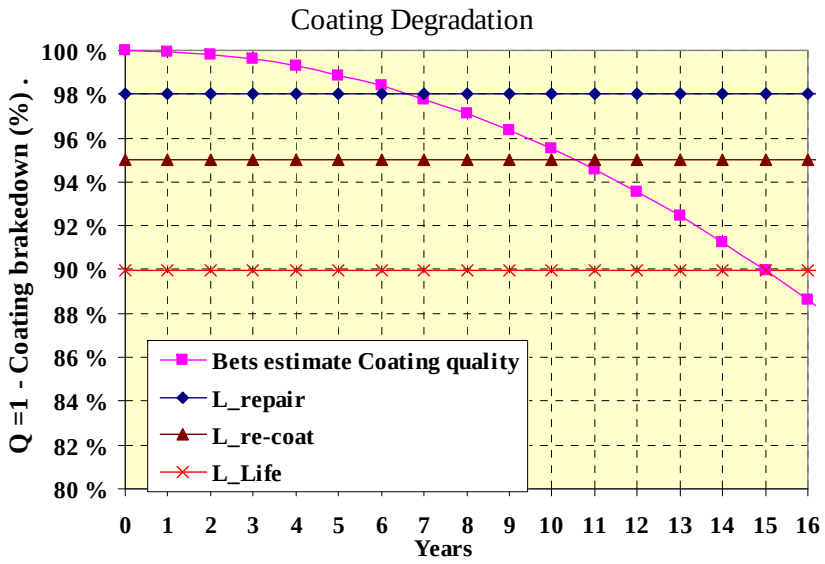
Coating degradation and corrosion

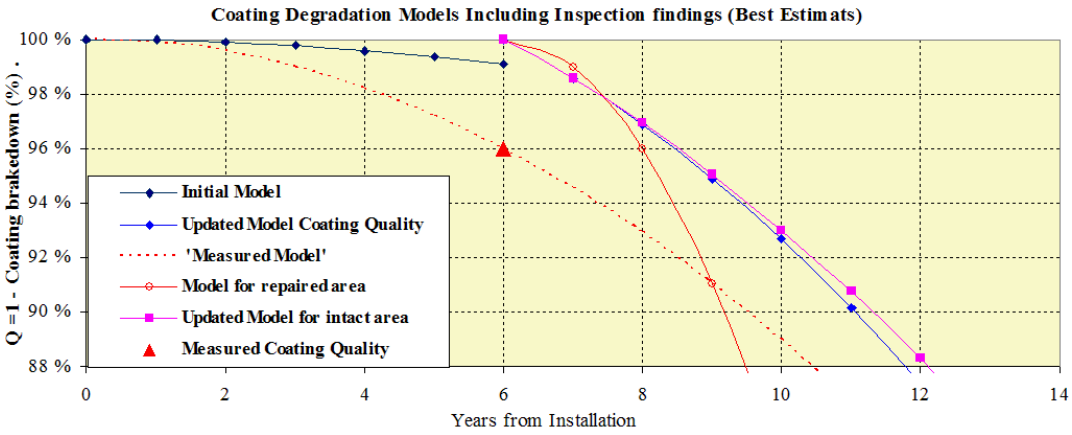
- JIP "Life Cycle Management of Hull Structures"
- Quantitative Coating Lifetime Prediction Model
- Modelled using parameters such as
  - Target useful life (depending on coating specification)
  - Surface preparation factor (cleanliness)
  - Environmental exposure factor (type and temperature of tank 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

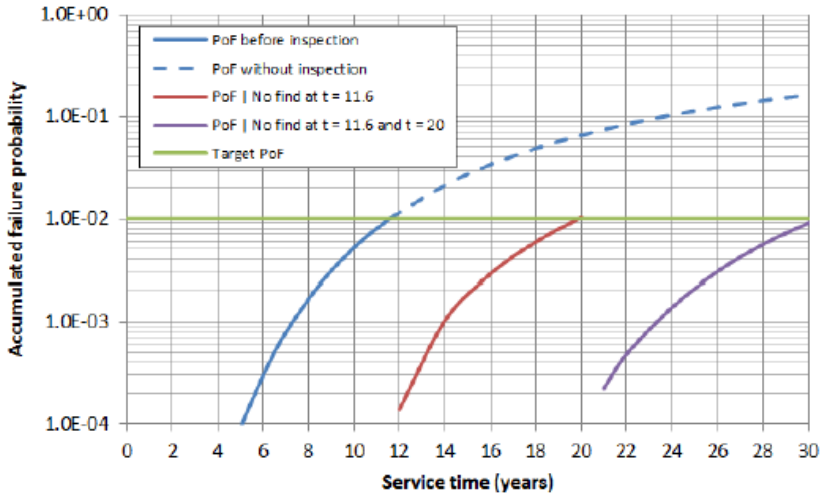
- Probabilistic aspects need to be developed
  - Uncertainties
  - Correlations
    (e.g. between those tanks inspected and those not)
- Inspection updating procedure could be similar to that used for fatigue cracks
- "Acceptance criteria" needs to be established.
  - Expected coating condition falling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

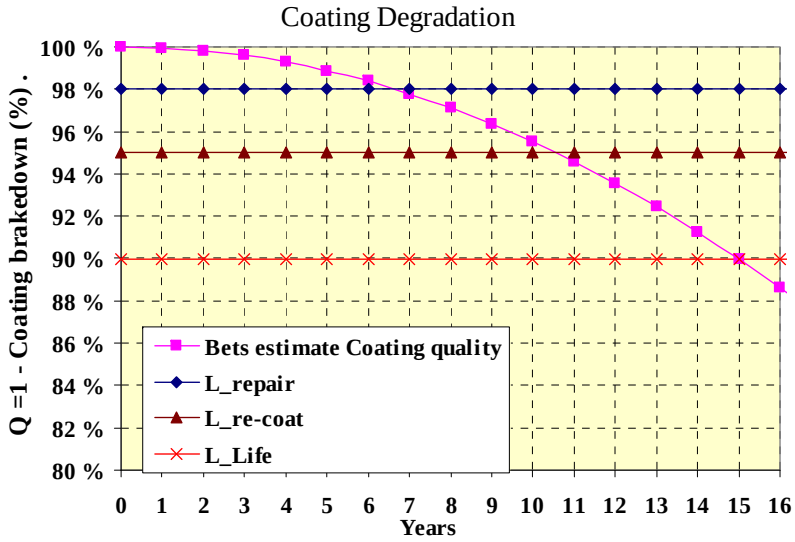




Summary

- 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





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