Fatigue Assessment Diagram in Updating Failure Probability

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1. Introduction

Jacket foundation in the "alpha-ventus" wind farm
(photograph taken by Matthias Ibeler)

The support structure contributes to a significant part of the Levelized Cost Of Energy

- Reduce O&M costs is the key!
- How?
  - Reliability- and risk-based maintenance strategies
  - Updating of the reliability based on e.g. inspections performed during the design lifetime.

The aim of this research:

Update failure probability using the Fatigue Assessment Diagram as a Limit State Function

2. Fatigue Assessment Diagram

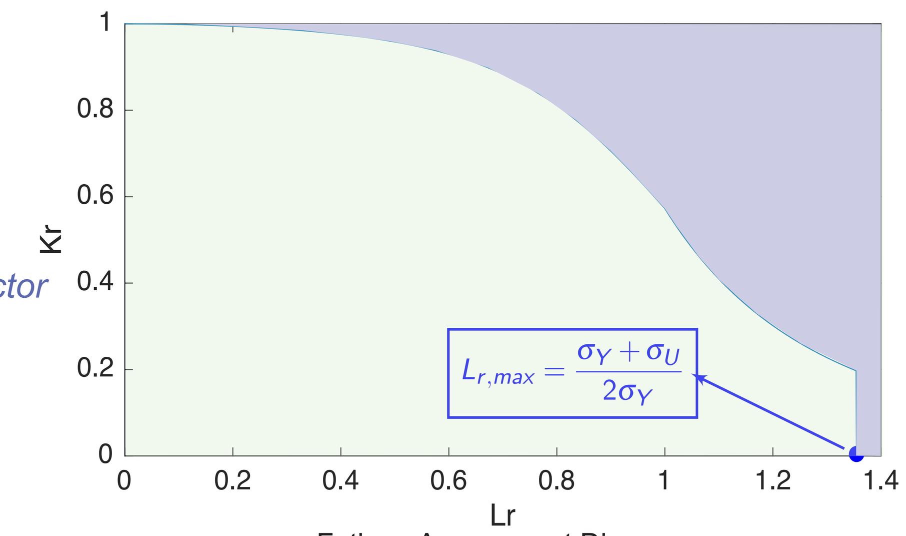
- A method for assessing the acceptability of cracks in metallic structures, following BS 7910
- The acceptable region area decreases when more information about stress/strain data available

The coordinate of an assessment point:

Reference stress, f(joint type, crack size) — *Stress Intensity Factor*

$$\left(L_r = \frac{\sigma_{ref}}{\sigma_Y};\ K_r = \frac{K_I}{K_{mat}}\right)$$

Yield strength — *Fracture Toughness*

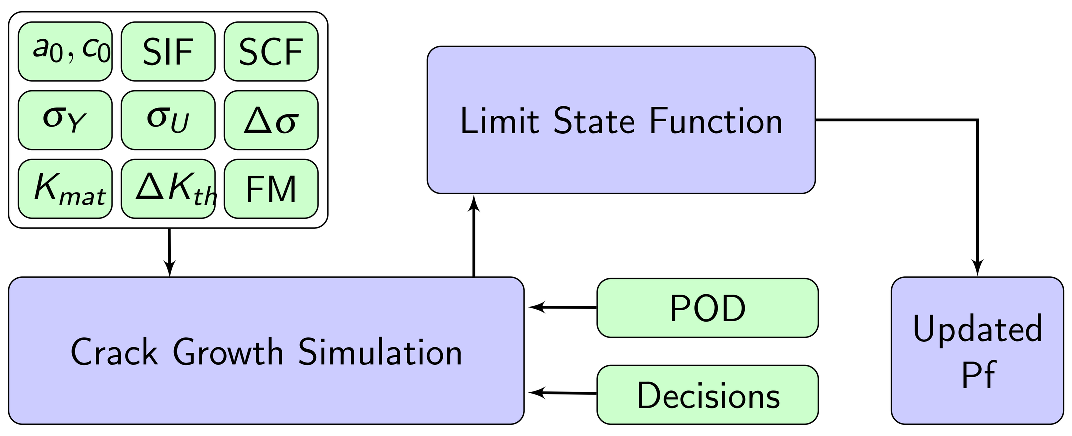


Fatigue Assessment Diagram
acceptable; unacceptable

3. Methodology

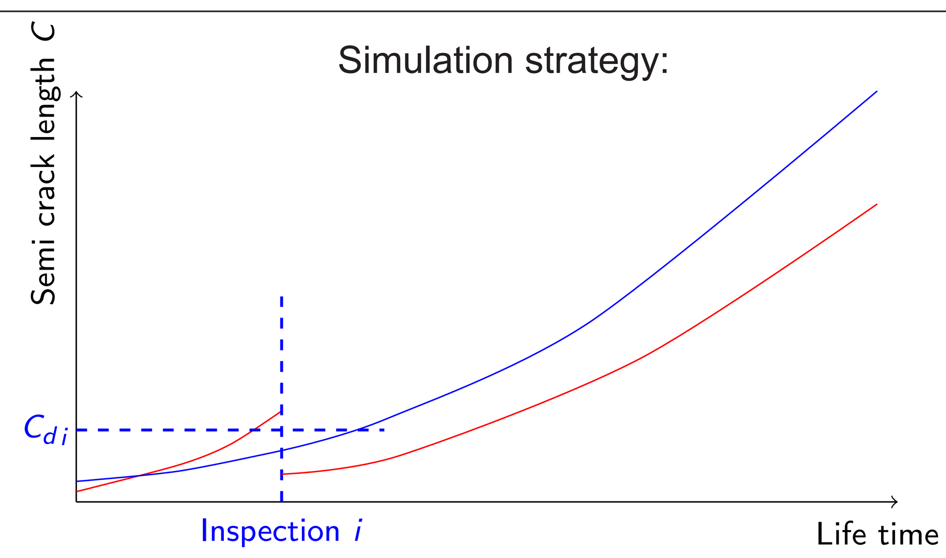
	Variable	Distr.	Mean	CoV
S	Stress range [MPa]	W	k=0.8	$N(\mu,\sigma)$
σ_Y	Yield strength [MPa]	LN	368.75	0.07
σ_U	Ultimate strength [MPa]	LN	750	0.04
ΔK_{th}	SIF range threshold	LN	160	0.4
K_{mat}	Fracture toughness	3p W	-	-
C_1	Paris law, 1st line	LN	4.8×10^{-18}	1.7
C_2	Paris law, 2nd line	LN	5.86×10^{-13}	0.6
a_0	Initial crack depth	LN	0.15	0.66
a_0/c_0	Initial aspect ratio	LN	0.6	0.40
B_{scf}	Uncertainty in SCF	LN	1	0.05
B_{sif}	Uncertainty in SIF	LN	1	0.05

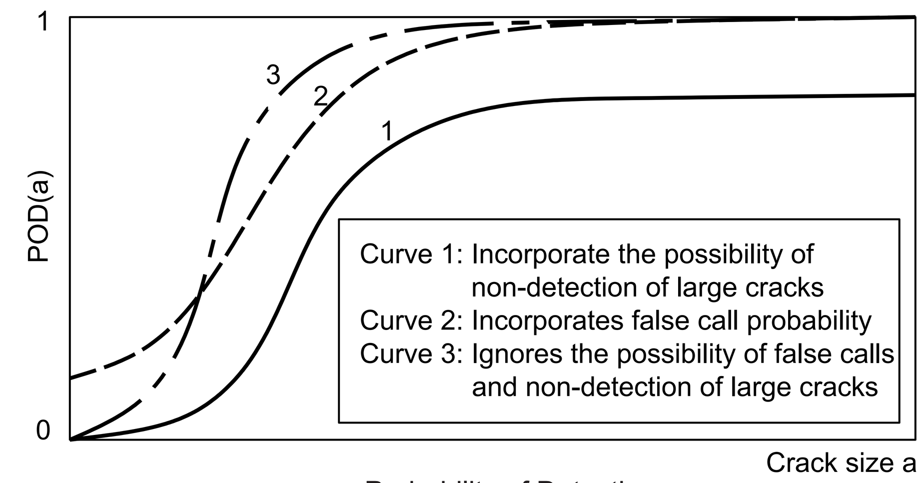
Parameters of the random variables



- Semi-elliptical surface crack
- Paris-Erdogan law
- Coupled depth and length
- Constant stress-range for short periods of time

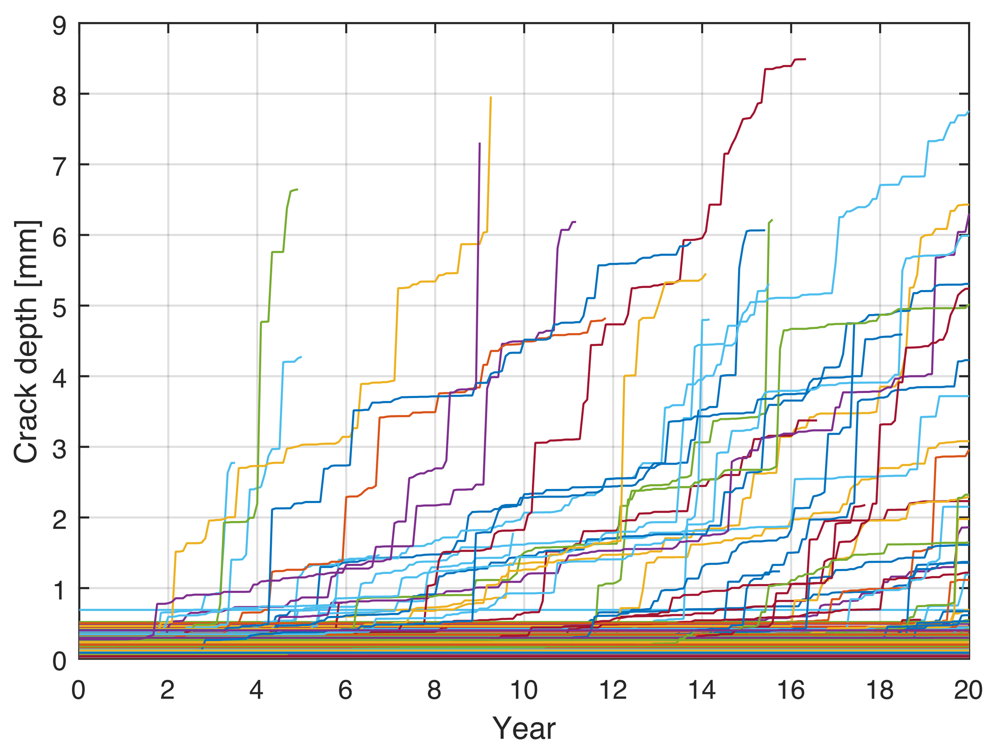
- No crack detected
- Crack detected & repaired:
  - normal repair
  - perfect repair
- Crack detected, not repaired



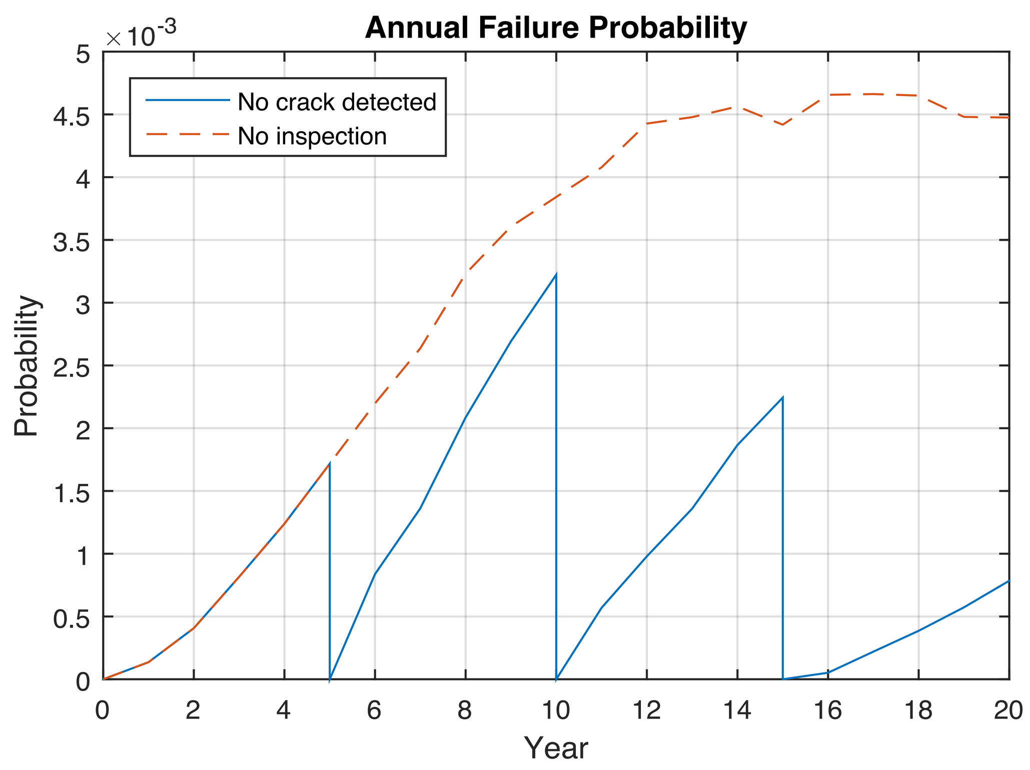


Probability of Detection

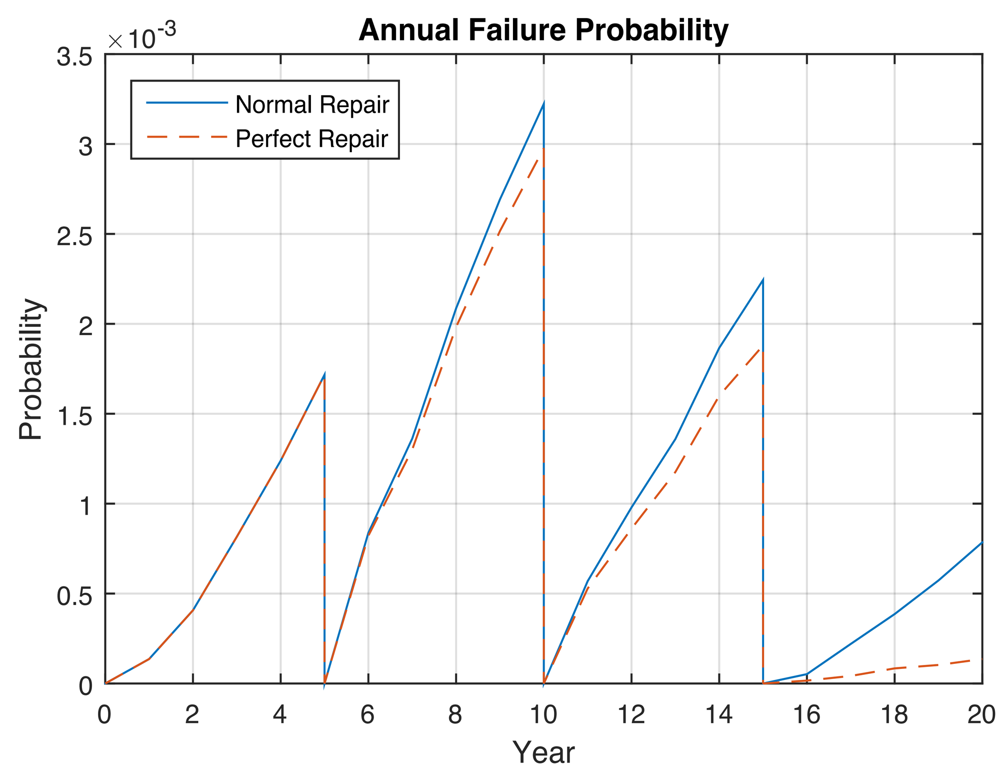
4. Results



Crack growth with random loading!



Inspection improves reliability!



Perfect repair improves reliability!

5. Conclusion and Perspective

- For surface cracks, FAD and the conventional LSFs give similar failure probabilities.
- FAD can be used to assess failure for crack depths larger than plate thickness.
- The FAD approach showed to work well in up- dating failure probability of a joint.

FAD approach can be used further in inspection planning for OWT support structures:

- to include systems effects,
- and for reducing the required safety factors at the design stage

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