UPDATING FAILURE PROBABILITY

OF A WELDED JOINT IN OWT SUBSTRUCTURES

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Motivation

Reduce O&M Costs ← RBI ← Update Pf (insp.) ← Limit State Function

Message Objective

Fatigue Assessment Diagram can be used to **update the failure probability** of an existing OWT substructure when **new information** about either loading, structural responses or inspections is available.

Outline

Fatigue Assessment Diagram

Updating Probability of Failure

Results

Outline

Fatigue Assessment Diagram

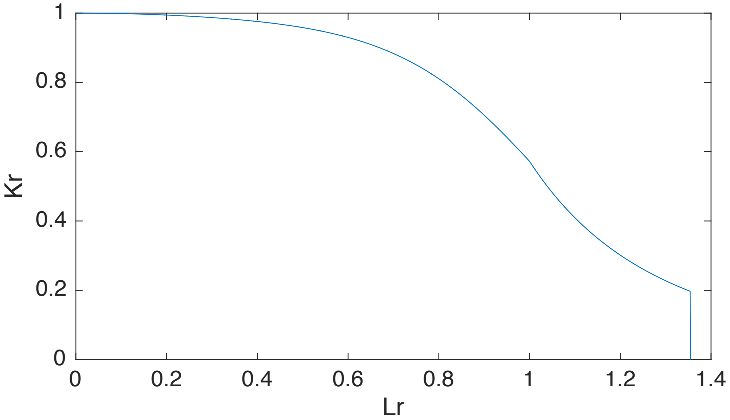
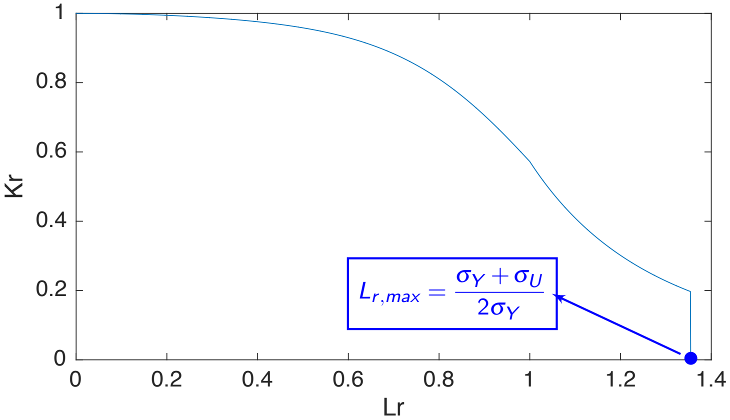


Figure: Level 2A Fatigue Assessment Diagram

BS-7910, 2005. Guide to Methods for Assessing the Acceptability of Flaws in Metallic Structures. British Standard Institution (BSi).

Fatigue Assessment Diagram



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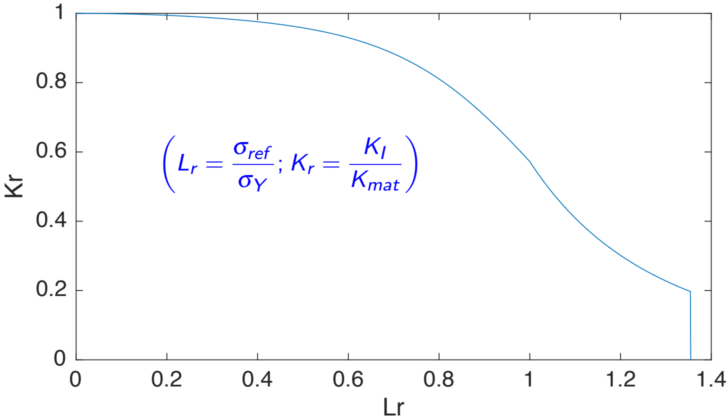
Fatigue Assessment Diagram



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

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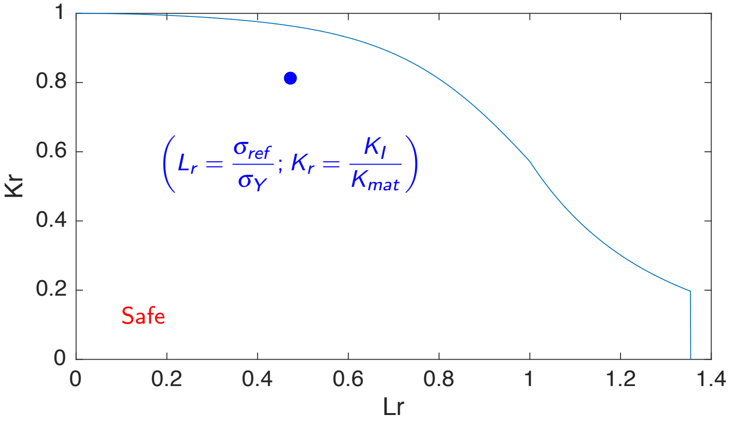

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Fatigue Assessment Diagram

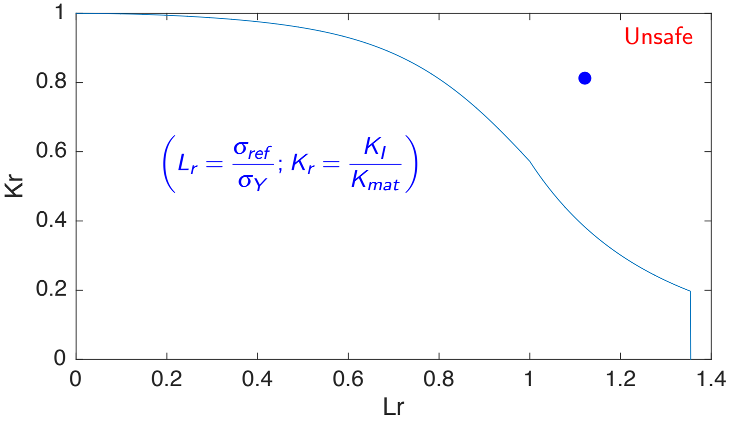

Figure: Level 2A Fatigue Assessment Diagram

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Outline

Uncertainties

	Variable	Value
ν	No. of cycle/year	1×10^7
t	Steel thickness [mm]	65
R	Outer radius [mm]	79.5
L	Joint length [mm]	100
η_σ	Bend. to memb. ratio	0.81
ΔK_{tr}	Transition SIF range	196
m_1	Paris law, 1^{st} line	5.10
m_2	Paris law, 2^{nd} line	2.88
C_a/C_c	C ratio for a and c	0.9

	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, 1^{st} line	LN	4.8×10^{-18}	1.7
C_2	Paris law, 2^{nd} 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

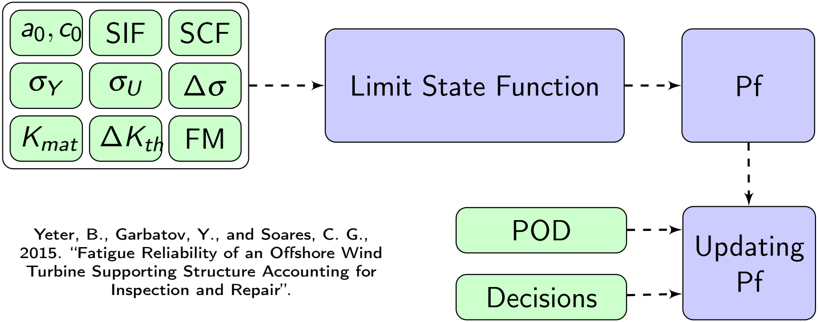
Updating method

Uncertainties

Updating method

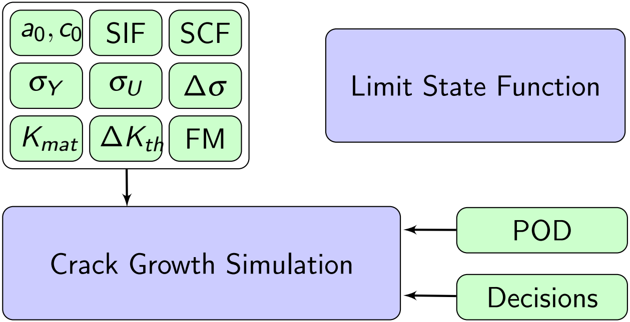
a_0, c_0	SIF	SCF
σ_Y	σ_U	$\Delta\sigma$
K_{mat}	ΔK_{th}	FM

Updating method

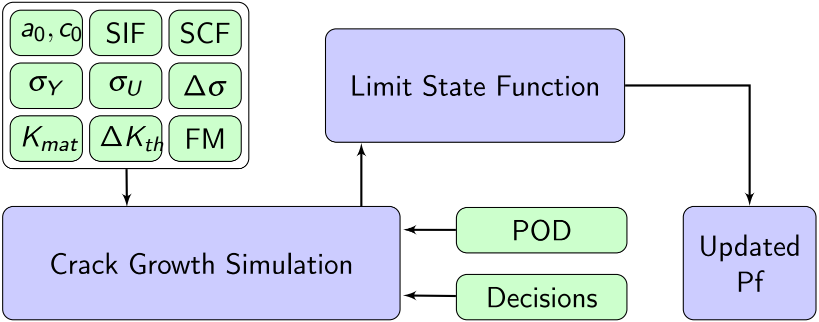


Yeter, B., Garbatov, Y., and Soares, C. G., 2015. "Fatigue Reliability of an Offshore Wind Turbine Supporting Structure Accounting for Inspection and Repair".

Updating method



Updating method



Crack Growth Simulation

Crack depth a and crack length $2c$ are coupled during the simulation.

$$\begin{cases} \frac{da}{dN} = C_a (\Delta K_a)^m & \Delta K_a \geq \Delta K_{th} \\ \frac{dc}{dN} = C_c (\Delta K_c)^m & \Delta K_c \geq \Delta K_{th} \end{cases} \tag{1}$$

$$\Delta K_a = S Y_a \sqrt{\pi a} \tag{2}$$

$$\Delta K_c = S Y_c \sqrt{\pi a} \tag{3}$$

Crack Growth Simulation

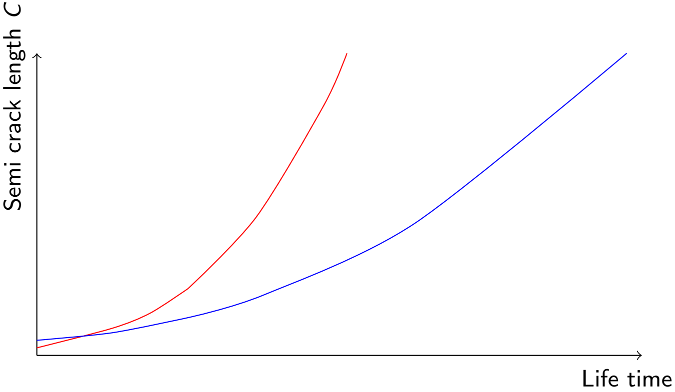
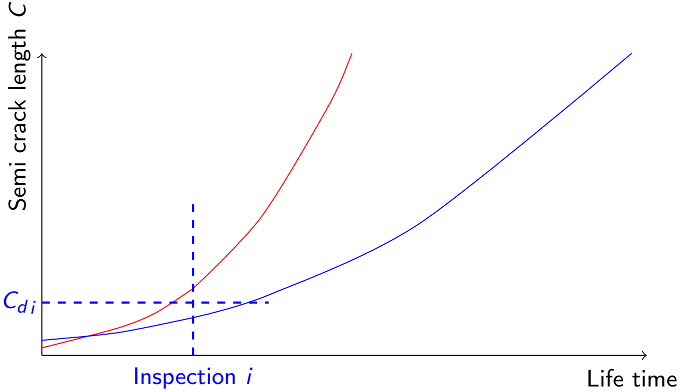


Figure: Crack growth in combination with inspections

Crack Growth Simulation



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Crack Growth Simulation

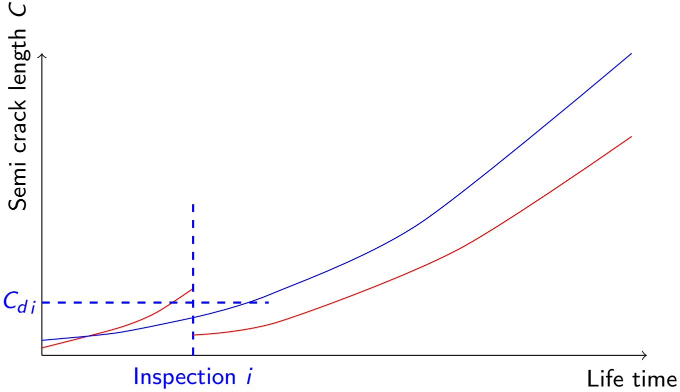

Figure: Crack growth in combination with inspections

Outline

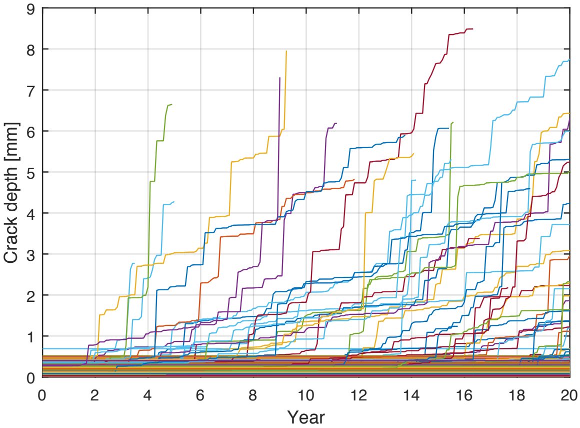

Figure: Crack propagation

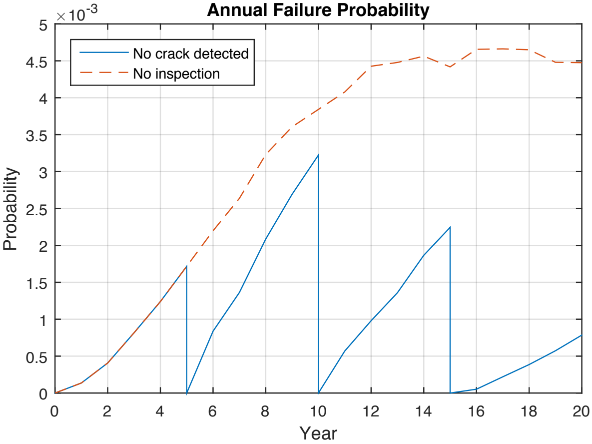

Figure: Annual POF

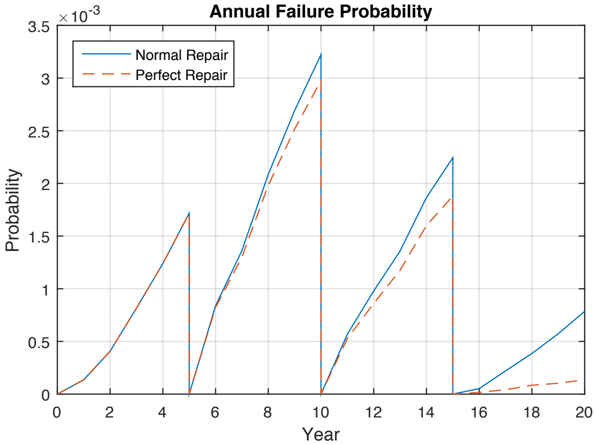

Figure: Annual POF

Summary

Fatigue Assessment Diagram can be used to **update the failure probability** of an existing OWT substructure when **new information** about either loading, structural responses or inspections is available.

- Outlook
  - Reduction of uncertainty related to stress-ranges given new information about loading and structural response
  - Improved modelling of crack growth after reaching the wall thickness.

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