POMDP-Based Risk Maintenance Planning for Offshore Wind Substructures

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ABSTRACT

This work presents a novel methodology to identify the optimal maintenance strategy for an offshore wind structural component, providing a flexible and reliable support to decision-making and balancing inspection, repair and failure costs.

The methodology is tested for a tubular joint through a 60-states POMDP, obtaining the optimal maintenance policy in low computational time and in good agreement with common Risk-Based Inspection (RBI) methods.

1. INTRODUCTION

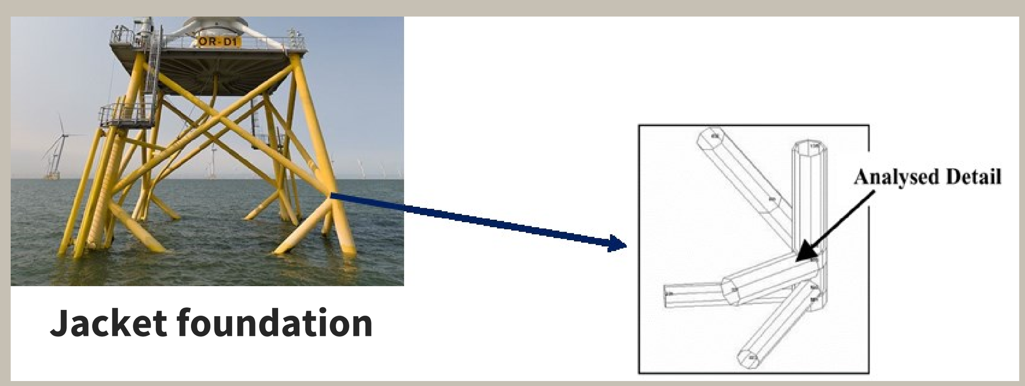
Context:
Wind farms farther from shore
Complicated maintenance tasks

Research Aim:
To identify the optimal maintenance strategy

Impact:
O&M cost (≈ 25% LCOE)
Lifetime Extension

Offshore wind crew transfer vessel

2. FATIGUE DETERIORATION MODEL



Jacket foundation

Structural joint

The calibration of the fracture mechanics (FM) model based on the SN-Miner's model provides a deterioration framework where inspections outcomes can be incorporated while keeping the model related to SN empirical data which is employed during the design stage.

SN-Miner's model – Limit state:

$$g_{SN(t)} = \Delta - \frac{v_0 t}{\eta}\left[\frac{\boldsymbol{q}^{m_1}}{\boldsymbol{a_1}}\Gamma\left(1+\frac{m_1}{h};\left(\frac{S_1}{\boldsymbol{q}}\right)^h\right) + \frac{q^{m_2}}{a_2}\gamma\left(1+\frac{m_2}{h};\left(\frac{S_1}{\boldsymbol{q}}\right)^h\right)\right]$$

Fracture mechanics model - Limit state:

$$g_{FM(t)} = a_c - \left[\left(1-\frac{m}{2}\right)\boldsymbol{C}K^m\pi^{\frac{m}{2}}\boldsymbol{q}^m\Gamma\left(1+\frac{m}{h}\right)\Delta n + a_{t-1}\left(1-\frac{m}{2}\right)\right]^{\frac{2}{2-m}};$$

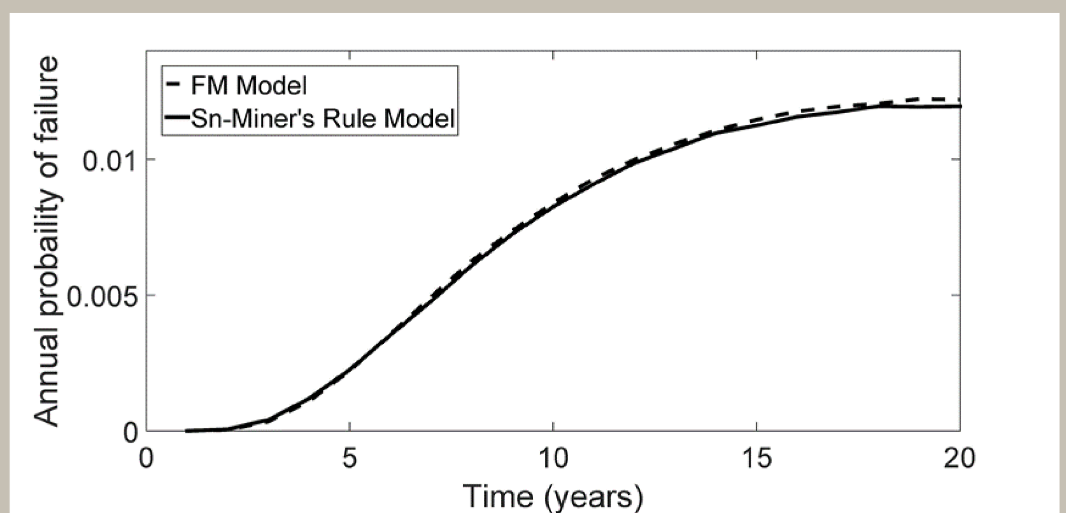
given $\boldsymbol{a_0}$

SN-Miner's model - Variables

Variable	Distribution	Parameters
m_1	Deterministic	3
m_2	Deterministic	5
$\log_{10}(a_1)$	Normal	$\mu = 12.88\,; SD = 0.2$
$\log_{10}(a_2)$	Normal	$*$ *Fully correlated with* $\log_{10}(a_1)$
Δ	Lognormal	$\mu = 1\,; CoV = 0.3$
q	Weibull	$\mu = 13.0\,; CoV = 0.25$
h	Deterministic	0.8

Fracture mechanics model - Variables

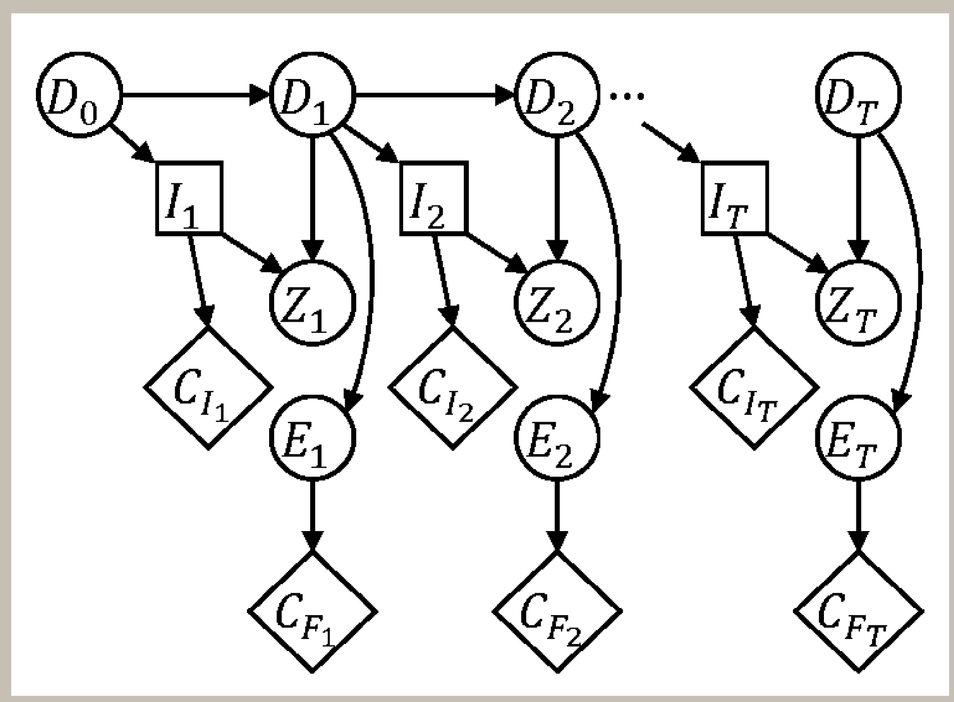
Variable	Distribution	Parameters
a_0	Exponential	$\mu = 0.057$
$\log(C)$	Deterministic	$\mu = -12.7\,; CoV = 0.19$
q (*)	Normal	$\mu = 13.0\,; CoV = 0.25$
h	Deterministic	0.8
v_0	Deterministic	5045760
K	Deterministic	1
m	Deterministic	3
a_c	Deterministic	25



Calibration fracture mechanics – SN/Miner - reliability

3. RISK-BASED POMDP MODEL

The influence diagram below displays how the sequential decision problem is approached. The damage evolving over time is represented by the chance node D_t and it is possible to choose an inspection method in the node I_t .

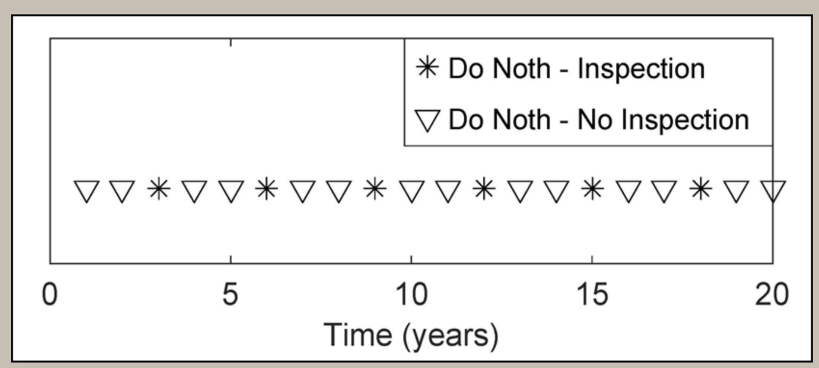


Sequential decision problem

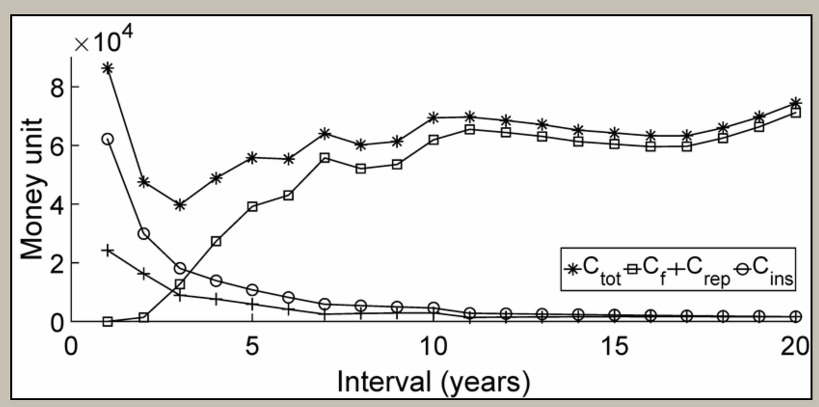
The chance node Z_t indicates the quality of the inspection method. Additionally, the node E_t tracks the failure probability. The utility nodes C_F and C_I assign a cost of failure and a cost of inspection, respectively. The chance node Rt represents the decision of whether to perform a repair or not.

4. RESULTS – POMDP POLICY

The optimal maintenance strategy for a tubular joint is identified by a 60-states "point-based" Partially Observable Markov Decision Process (POMDP). The obtained PODMP policy provides similar results as a common risk-based heuristic model.



POMDP Policy



Heuristic Policies

5. CONCLUSION

The 60 states infinite horizon POMDP has been solved providing the optimal maintenance policy for a tubular joint in only **0.32 seconds of computational time**.

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