Development of a Bayesian Network Updating Model for O&M planning of Offshore Wind Structures

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Research Background

- Operation and maintenance (O&M) is one of the critical <u>cost-driving</u> activities throughout the life cycle of wind farms.

- Accounting for about 15-30% of the levelized cost of energy (LCOE).

- O&M planning and decision-making should be optimised to take into account new information obtained via inspections or <u>condition monitoring</u>.

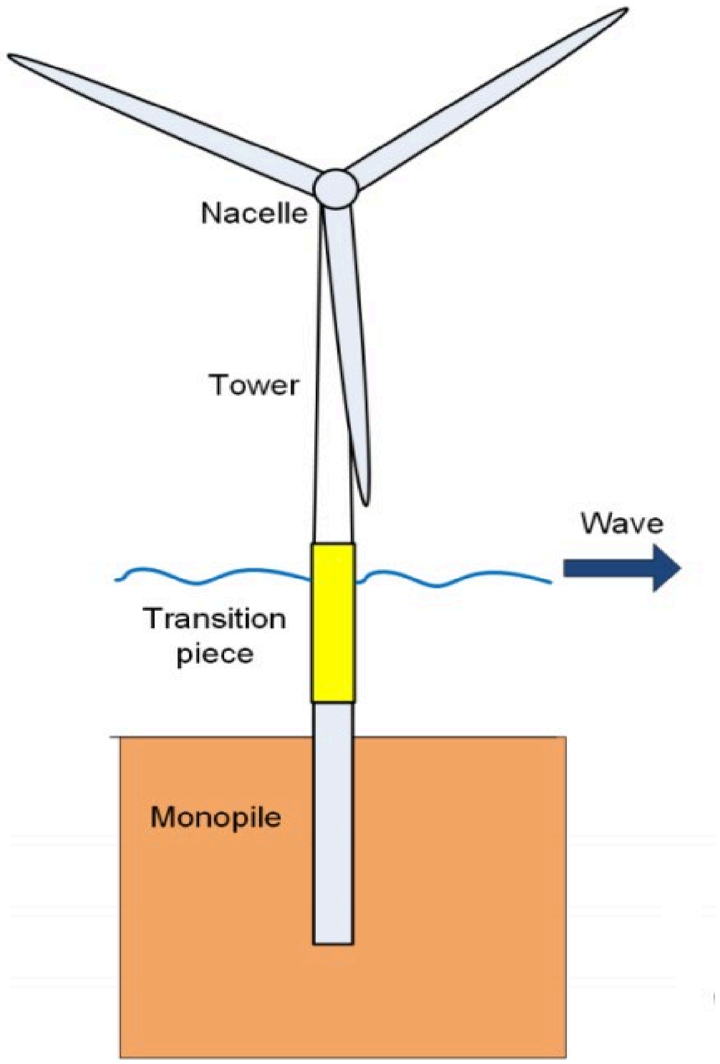

Fig 1. Simple representation of OWT with monopile foundation

Research Background

- The design of OWT monopiles is driven by fatigue limit state.

- This emphasises the importance of investigations into fatigue-based deterioration.

- The Bayesian networks (BN) technique is used for this study.

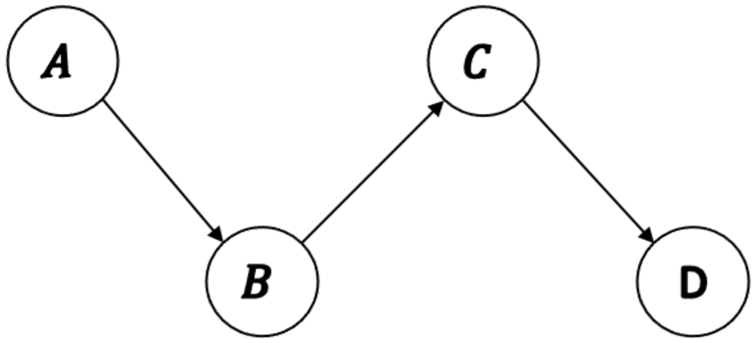

Fig 2. Simple BN

- Very flexible in that it allows for the use of both objective and subjective inputs in the model.

- Can allow updating based on new information.

Methodology – Fatigue Crack Growth Modelling

- Fatigue-based crack growth is accurately predicted using the <u>Paris-Edrogan equation</u>, more commonly known as the Paris law:

$$\frac{da}{dN} = C(\Delta K)^m \tag{1}$$

- Solving for crack size at time *t* and integrating:

$$a_t = \left[\left(1 - \frac{m}{2}\right) C \Delta S^m \pi^{m/2} \Delta N + a_{t-1}^{(1-m/2)}\right]^{(1-m/2)^{-1}} \tag{2}$$

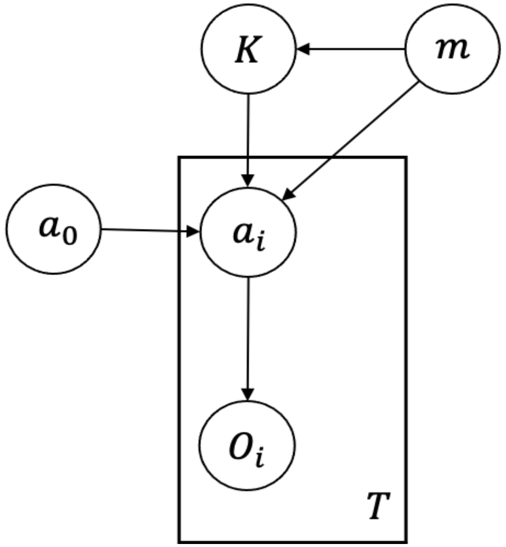

Fig 3. Fatigue crack growth plate model

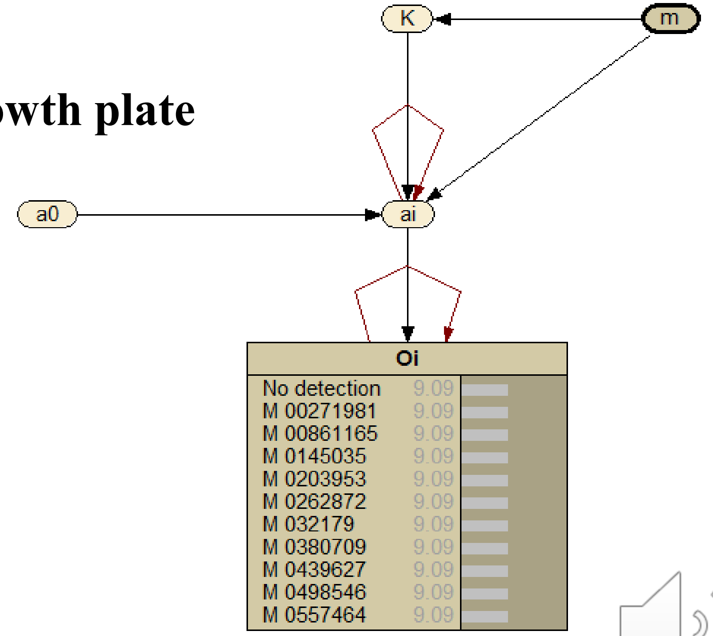

Fig 4. Netica representation of fatigue crack growth model

OWT Case Study

- The monopile considered in this study is taken from a generic offshore wind turbine used in phase I of the OC3 project.

- The monopile supports an NREL 5MW reference turbine and is located in 20m water depth.

Table 1. Variables in stochastic crack growth model

Variable	Mean	Standard Deviation	Distribution
Initial crack size, a_0 (mm)	0.5	0.05	Exponential
Crack growth model constant, m	3.0	0.15	Normal
Crack growth model constant, C	3.322×10^{-13}	1.660×10^{-13}	Normal
Stress range, S_{re} $(MPa\ or\ Nmm^{-2})$	60	10	Normal
Number of cycles, N (cycles/hr)	1.14×10^2	-	Deterministic
Geometric parameter (G)	1	–	Deterministic

Model Development – Costs of Implementing CBM

- The fatigue crack growth over time can be seen in figure 5.
- The time being observed for this study is 24 hours.
- However, it can be inferred from the model how crack length can be measured given observations in real-time with remote condition monitoring systems.

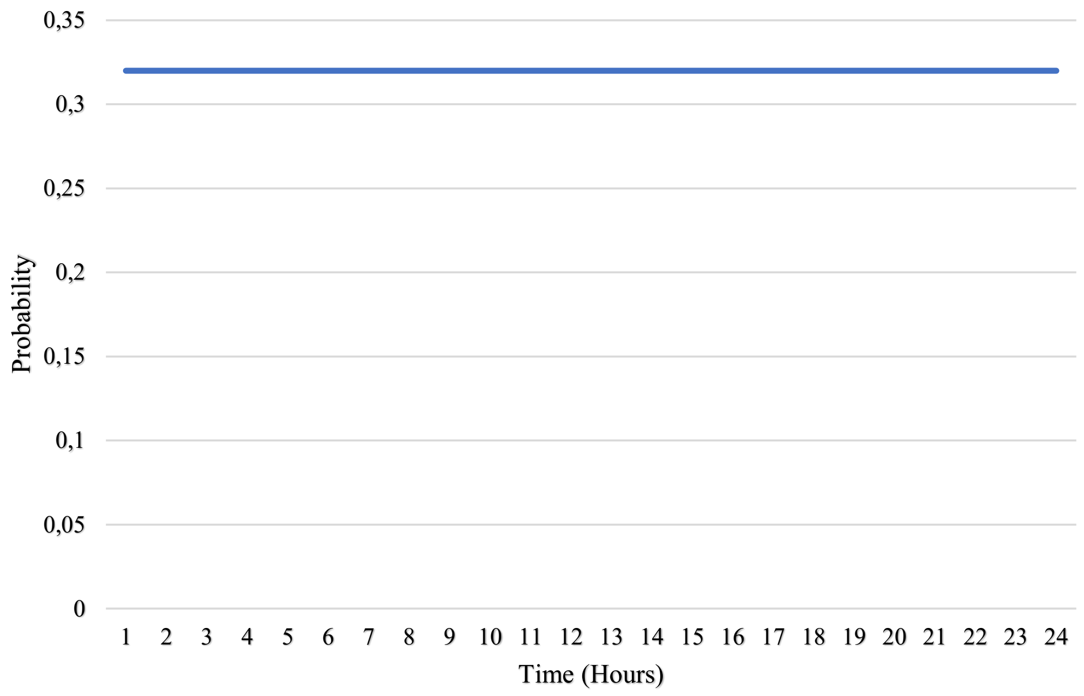

Fig 5. Probability of fatigue crack length in the range (0.38mm-0.43mm) as a function of time

Questions