



Lifetime extension of offshore wind monopiles



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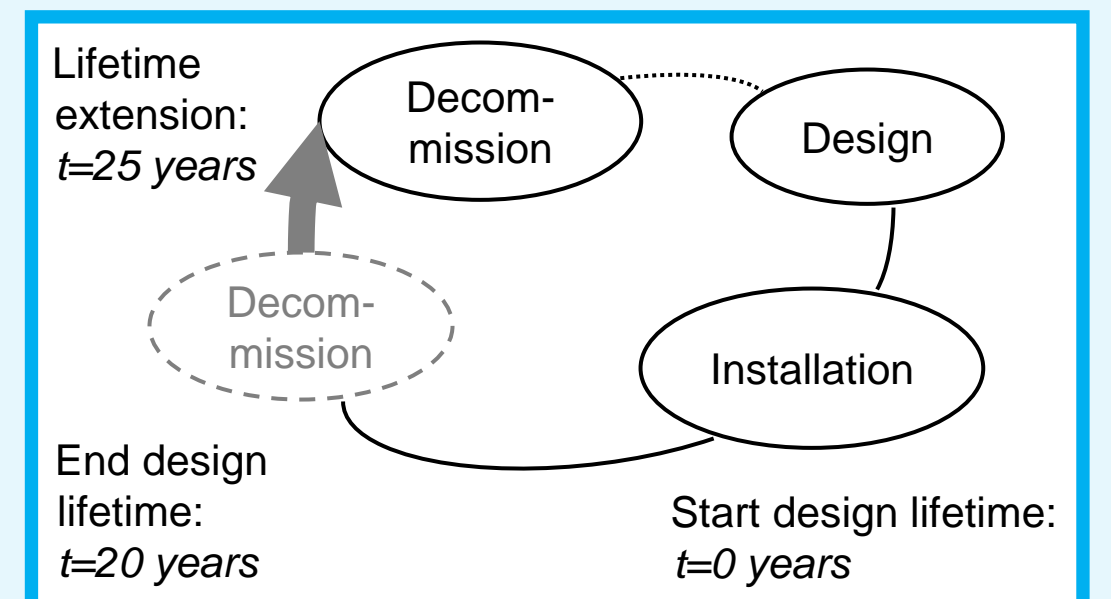
Lifetime extension is a today's problem!

Trends in offshore wind industry:

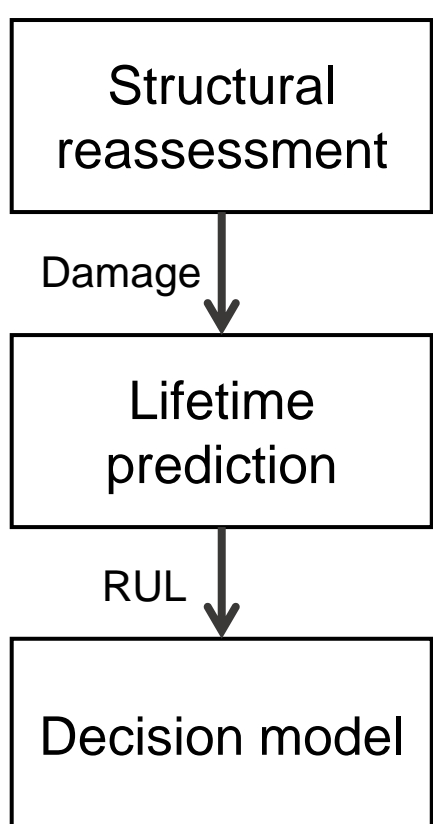
1. Aging wind farms
2. O&M costs increase
3. Low-cost monitoring solutions available



- Decision on lifetime extension soon necessary
- New standard [1] but no experience yet
- When and what should be monitored?



Assess damage, predict lifetime, decide...



Material degradation:

Fatigue, corrosion, scour, extreme loads, accidental damage

Three-step process:

1. Reassess current damage status
2. Predict remaining useful lifetime
3. Apply decision model

Are crack inspections relevant for life extension?

- Probability of detection of fatigue cracks depends on crack size, inspection method, access
- Need to remove marine growth
- High costs associated with offshore risks

$$PoD(x) = 1 - \frac{1}{1 + \left(\frac{x}{X_0}\right)^b}$$

	ACFM	VI
x	crack depth	crack length
B	0.9	1.079
X ₀	1.16	83.03

ACFM: alternating current field measurement, VI: visual inspection [2]

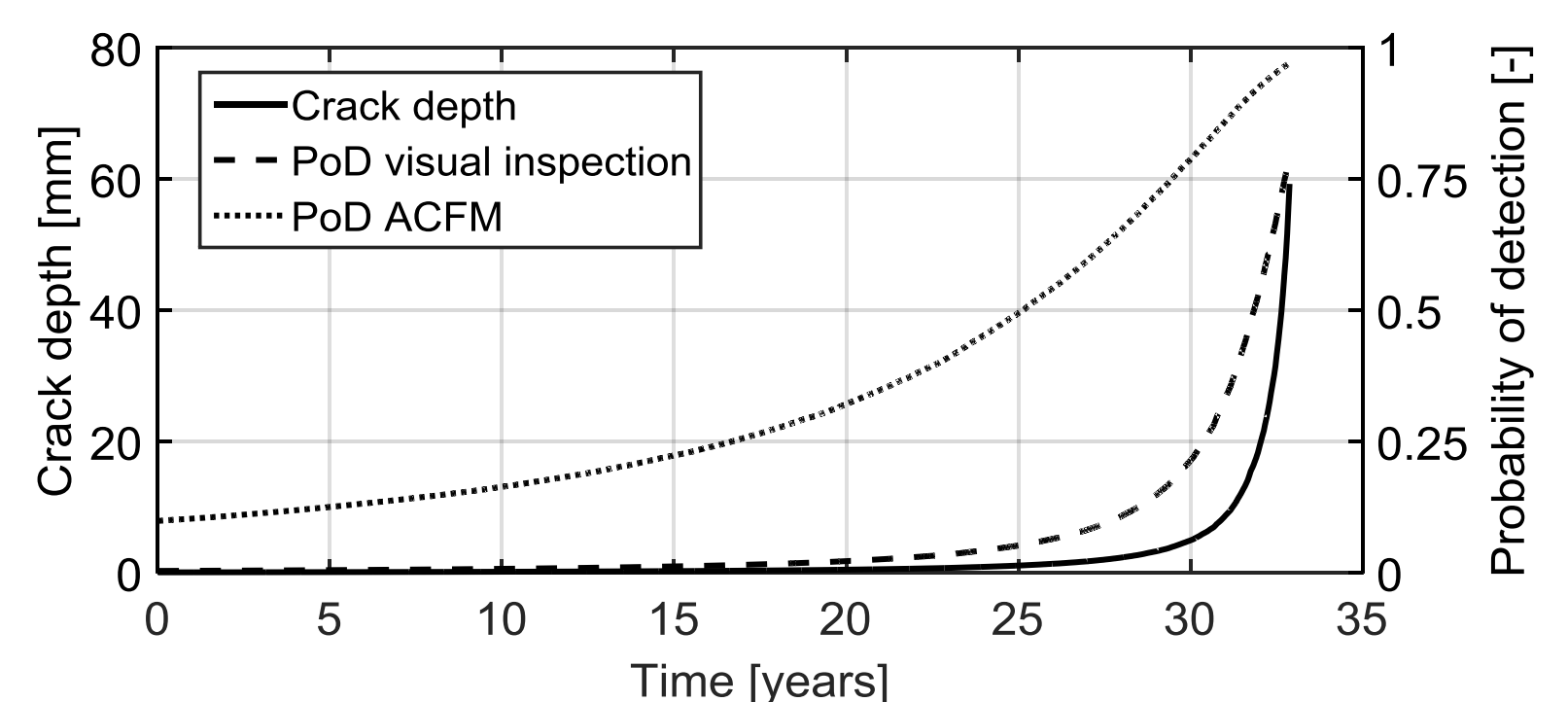
Reduction of uncertainty is the challenge.

- Uncertain parameters in design
 - Conservative assumptions
- New knowledge available during service phase
 - Reduce level of uncertainty
 - Decrease conservatism = increase lifetime

Uncertainty	Parameters
Environmental	Soil condition, wind speed, turbulence intensity, sea state, marine growth
Operational	Time in operation and idling, start-ups, shut-downs, failures, maintenance, repair
Model	FE model, load model, scour, SN-curve, corrosion

Results for 5MW turbine with OC3 monopile:

- Simulation of crack growth with Paris law (see [3])
- Low PoD of cracks after 20 years
- 10 years lifetime extension requires detection of crack with 0.8mm depth



References

- [1] DNVGL. 2016. Lifetime extension of wind turbines. *DNVGL-ST-0262*.
- [2] DNVGL. 2015. Probabilistic methods for planning of inspection for fatigue cracks in offshore structures. *DNVGLRP-C210*.
- [3] Ziegler L, Schafhirt S, Scheu M & Muskulus M. To appear. Effect of load sequence and weather seasonality on fatigue crack growth for monopile-based offshore wind turbines. *Energy Procedia*.

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Conclusion: Lifetime extension requires...

1. Monitoring and re-simulation to assess remaining useful lifetime
2. Inspections to rule out gross errors