Climate Informed Engineering

TUHH

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Project C3: Design of nano-multilayer coatings for repair of cracks in monopile-based offshore wind turbines

Offshore wind turbines form a cornerstone of the energy transition, yet their structural components, particularly monopile foundations, are increasingly exposed to extreme environmental loading. Climate change is intensifying wind speeds, wave heights and storm frequencies, leading to higher cyclic stresses and accelerated fatigue damage in offshore steel structures. As a result, existing monopiles are at growing risk of crack initiation and propagation, threatening structural integrity, operational safety, and service life.

Conventional repair methods for offshore structures are often costly, time-consuming and limited in effectiveness under severe cyclic loading. In recent years, nanopatch repair concepts have emerged as a promising alternative. A nanopatch consists of a two-dimensional nanostructured thin film applied locally to a damaged area, where it modifies the stress state of the substrate and suppresses fatigue crack initiation. Recent studies have demonstrated that residual stresses induced by such nano-multilayer coatings play a decisive role in repair performance, particularly by introducing beneficial compressive stresses that delay crack growth and enhance fatigue resistance.

However, the effectiveness of nanopatch repairs under climate-informed extreme loading conditions has not yet been systematically investigated. In particular, the relationship between coating architecture, induced residual stress state and structural performance under peak wind- and wave-induced loads remains poorly understood. This project aims to design and optimize nano-multilayer nanopatches tailored to induce controlled compressive stresses in monopile steels, ensuring the survival of repaired structures under future climate scenarios.

By combining materials-level engineering, experimental fatigue testing and high-resolution climate information, Project C3 seeks to develop climate-resilient repair strategies for offshore wind turbine foundations. The results will contribute to extending the service life, reliability, and safety of offshore infrastructure and support the development of adaptive and resilient structural systems.

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