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Fatigue damage prediction and reliability modeling of subsea wellhead system based on multi-factor coupling

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Subsea wellhead system services for long periods of time at hundreds and thousands of meters below the ocean floor, as the vital equipment to provide an access to casing hanger, sealing the locking face of the subsea BOP and riser, structural resistance and pressure-bearing interfaces during drilling and production process. However, due to the complexity of the marine environment and operating condition, this kind of structure is prone to the failure caused by cumulative effects of the fatigue and degradation of the components subject to loads from currents, waves, internal solitary waves, and soil, as well as large tension and bending moments caused by platform movement. This paper presents an integrated approach to comprehensively predict the fatigue damage and reliability of subsea wellhead systems and diagnose the underlying root cause during its service life. Multi-factor impacts on system performance are considered for modeling. A multistate transition model of wellhead components is proposed to analyze system degradation. A finite element model is established for fatigue damage prediction of key components of subsea wellhead to explore the mechanical property change law and failure influencing factors under the different operational scenarios. Reliability evaluation of the critical component is performed and verified by introducing the Monte Carlo simulation-based method which is also used to solve the problem of insufficient data for subsea wellhead fatigue prediction. By embedding multi-factor effects and multistate transition into DBN, the system state can be updated in an effectively means. The effects of multi-factors coupling, fatigue damage, degradation and material aging on the subsea wellhead system are considered. An example of subsea wellhead system demonstrates the application of the approach, through which the system reliability during its service life is predicted, and the most vulnerable components and the greatest contribution factors to the system reliability as well as deserve special attention are identified.

Keywords: Subsea wellhead, Monte Carlo simulation, Dynamic Bayesian network, Multistate transition model, Fatigue damage prediction, Reliability analysis.

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