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Monitoring Offshore Monopile Fatigue
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Abstract
Fatigue loading on subsea equipment is not a unique problem to the oil and gas industry as wind turbine monopiles also face large cyclic loading over extended life times. This challenge has prompted the widespread implementation of monitoring systems to confirm predictions of monopile loading and fatigue and ensure that: operations are conducted safely, inspection regimes may be properly specified, and viability of life extension is properly evaluated. Considerations include what to measure, instrument accuracy, power and data transmission, methods of attachment, data processing, and data storage. The evaluation will determine the suitability of off-the-shelf equipment or the need for application specific devices.

System Specification
Instrumentation for measurement of monopile fatigue must be specified and selected with the same level of attention as any other piece of equipment used offshore. The design requirements of this type of equipment are often inadequately defined which can lead to gathering of data that is incomplete and of low quality. Measurement systems for derivation of monopile fatigue require complete evaluation of the expected response through to the methods by which the data will be processed. The steps involved are as follows:
- Define objectives
- Define target fatigue life
- Set threshold measurement target
- Select measurement system — e.g. strain, displacement, angle
- Define response corresponding to threshold fatigue life
- Assess implications of instrument noise on threshold measurements
- Define data processing requirements

Data Review
Prior to calculating monopile fatigue damage quality checks should be performed on the monitoring data in both the time and frequency domains. Checks should range from the basic, for example, events occur simultaneously on all devices, devices are calibrated properly and that data correlates with expected events. Gravity contamination should also be removed from acceleration data using angular rate sensors. Noise should be removed along with high frequency and low frequency response that will not contribute to fatigue.

Time domain statistics can provide an overview of the quality of the campaign, however, frequency domain screening is key as detailed behaviour of the system response can be ascertained in order to calibrate analytical models. Below a frequency spectrometer of accelerations reveals multimode vortex induced vibration of the monopile that can be observed in line with the fluctuating tidal current that is driving the response.

Fatigue Assessment
CONVERTING MEASUREMENTS TO FATIGUE DAMAGE

Analytical models need to be calibrated prior to fatigue calculations [1]. Global and local frequency response of the model may be compared to observations from monitoring as well as amplitudes of monopile movement from known environmental loading. Uncertainties in the model, such as soil characteristics and scour may then be calibrated [2].

Conclusions
Monitoring can provide a useful tool for validating and calibrating analytical predictions of monopile fatigue. Monitoring systems should be designed in collaboration with the operator, hardware supplier and design team in order to achieve the required objectives. Calibrating global response in this way can reduce conservatisms in analysis and increase predicted fatigue lives. Benefits include a higher predictability in system structural response, extended monopile life and future CAPEX reductions.

References