Editorial

Load sequence effects on fatigue resistance of offshore wind turbine support structures

Offshore wind turbines are loaded by fluctuating loads of various magnitude. Small stress cycles may thus be followed by large stress cycles and vice versa. Welded joints, being the locations with high local stresses that may have initial defects, are the critical parts of the support structure of wind turbines from fatigue point of view. Fatigue damage can result in (sudden) collapse of the structure if not properly monitored. The design challenge is to balance fatigue performance (lowering local stresses) and structural weight (lowering installation and manufacturing costs).

Many studies have shown that the sequences of stress cycles may alter the crack growth rate in fatigue and thereby influence the fatigue life of a structure. A relatively simple load sequence effect is the retardation of crack growth after the introduction of an overload (Fig. 1). The fatigue life increases in such a simple load case. In case of a variable amplitude load spectrum with a sufficiently mixed sequence, the load sequence effect may be entirely different and result either in crack growth retardation or acceleration, depending on the load, material and geometry. The load sequence effects in variable amplitude loading are not yet well understood and explored.

The sequence effect of stress cycles on the fatigue life introduces a new challenge to offshore wind turbines: Standards and guidelines for fatigue of civil engineering structures are mainly based on research into and experience with structures such as offshore platforms, crane runways, and bridges. Wind turbine support structures, however, are subjected to a significantly different sequences of stress cycles, because of the turbine rotating in the wind direction. The stress history of a certain critical detail in the support structure is therefore subjected to large stress cycles – changing the stress e.g. from tension to compression – in addition to the 'usual', smaller stress cycles induced by wind gusts, rotating blades, and waves. Variable amplitude tests carried out in the past that form the basis of the current standards and guidelines often employed a Rayleigh spectrum load with a constant maximum, a constant minimum, or a constant average stress. The results of these tests may not be representative for offshore wind turbine support structures because of the significantly different load sequence.

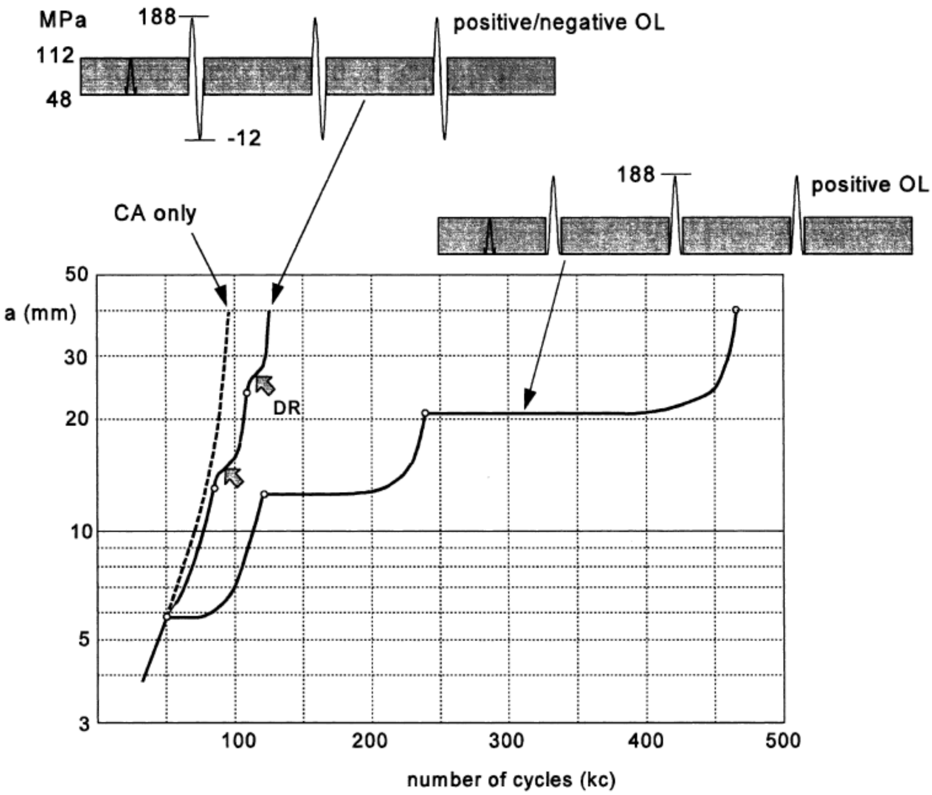

Figure 1: The effect of overloads (OL) on fatigue crack growth in sheet specimens of the aluminium alloy 2024-T3, [J Schijve, 1960, reprinted from Jaap Schijve & others, 2001].

This Heron issue considers the effects of load sequences on the fatigue life of offshore wind turbine support structures. Typical load patterns for these types of structures have been explored. Fatigue tests were carried out on small scale specimens – with emphasis on the determination of crack growth rates and crack growth retardation and acceleration – and on full scale tubular joints for jacket support structures – with an emphasis on the net effect of realistic stress range sequences on the fatigue life. Theoretical examination of the stress field near the crack tip and of plasticity induced crack closure in the crack wake was performed using the finite element method. An analytical prediction model for the crack growth rate followed from it. A probabilistic inspection planning software tool was developed that uses either structural failure or cost optimization as the criterion for planning fatigue inspections. This Heron publication provides the results of these studies.

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