Unlocking insights: Fatigue damage detection and monitoring using Lock-In Thermography

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Early detection of fatigue cracks and accurate measurements of the crack growth play an important role in the maintenance and repair strategies of steel and composite structures exposed to cyclic loads during their service life. Commonly used non-destructive techniques such as strain gauges, clip gauges, ultrasound, etc. used for detection and monitoring of fatigue damage are contact-based and perform local measurements. In addition, complex full-field techniques are commonly investigated, such as digital image correlation (DIC) and infrared thermography (IRT). In this work, a specific implementation of IRT, called lock-in IRT, is implemented for fatigue damage detection. This technique evaluates the thermal stress response of test specimens, specifically focusing or "locking-in" on the frequency of applied cyclic loads. Three different test scenarios are presented. First, a section of a wind turbine rotor blade made of a glass fibre reinforced plastic (GFRP) shell structure under cyclic load was examined with Lock-In IRT along with DIC. The primary advantage of Lock-In IRT in this test setup was that it required no sample preparation, as compared to the painting and speckle pattern required for DIC. In the frequency domain, specifically the frequency of applied cyclic load, it was possible to extract local directional inhomogeneous loading within the shell structure due to progressive damage, confirmed with the deformation obtained from DIC results. Second, thick welded specimens made of structural steel S355 were subjected to multiple NDT methods such as strain gauges, crack luminescence penetration (developed specifically at BAM), ultrasound, and IRT, with the aim of investigating the ability of each technique to detect fatigue damage initiation as early as possible in the total fatigue life of the specimen. Amongst the range of implemented techniques, Lock-In IRT provided the first indication of fatigue crack initiation at the weld toe of the specimens. This was validated with the other techniques as well as fractography. Third, steel S355 specimens used to manufacture offshore wind turbine monopiles were tested. The specimens were extracted from a plate that was submerged in a marine environment, resulting in a corroded surface with corrosion pits. These specimens were subjected to cyclic tensile loads without removing the corrosion pits. The fatigue tests were monitored using IRT in a special full-field capturing setup that enables both sides of the specimen to be examined with one IRT camera. This allowed the entire pitted surface to be monitored for fatigue damage initiation at the same time. With the implementation of Lock In IRT, the surface stress distribution could be captured (the stress concentration at the pits), and fatigue crack initiation could be detected and linked with specific corrosion pits.