Lifetime Prediction and Management of Fatigue Loaded Welded Steel Structures Based on Structural Health Monitoring

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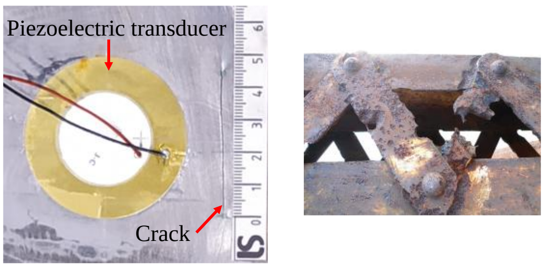
MOTIVATION

Steel infrastructure is exposed to different damage mechanisms due to mechanical loading and environmental impact. Several installations are reaching the end of their design life and decisions need to be made with respect to their continued operation. If damages are timely and accurately detected, targeted maintenance can be scheduled and continued safe operation can be guaranteed. A variety of inspection and monitoring techniques are used in research and industry for the purpose of crack detection. Among these, the electromechanical impedance-based method is a promising technique for crack propagation. It uses low-cost, small and lightweight piezoelectric transducers (Fig. 1) that are minimally invasive and have been successfully applied for damage monitoring in e.g. composite panels.



(a)EMI/SHM for crack monitoring

Severe damage because of corrosion

Fig. 1: (a) Application of EMI for crack monitoring, (b) Importance of corrosion monitoring.

1Corrosion constantly threatens the structural integrity, Fig. 1. The traditional method used for corrosion monitoring is visual inspection, which is time-consuming for vast areas, impossible for inaccessible areas and subjective for non-experts. The way to overcome the aforementioned drawbacks is to develop an artificial intelligence-based algorithm that can recognize corroded regions in a series of photographic images.

2OBJECTIVES

The two objectives of this Ph.D. project are:

1. Fatigue crack detection, quantification and localization using the electromechanical impedance structural health monitoring technique. The technique should be robust against environmental noises and temperature variation.
2. Automated corrosion detection using an artificial neural network. The technique should be robust against non-uniform illumination, environmental background and rust bleeding.

APPROACH

The electromechanical impedance-based method makes use of piezoelectric transducers serving as actuator and as sensor to detect damage. An elastic wave will be generated by the transducer and propagate through the structure. The wave recorded with the transducer contains information on the structure's condition. Calibration of the sensors and post-processing of the transducer signals to distinguish between healthy and damaged structures are crucial to interpret the measurements correctly. Fig. 2 shows a typical signal (conductance as a function of frequency) of a piezoelectric transducer.

A feasibility study has been carried out using different small-scale specimens made of aluminium, steel and polycarbonate. Attention was paid towards the implementation of data acquisition (hard- and software) and post-processing algorithms. The effect of structural damage, ambient temperature and quality of the bond between transducer and host structure on electromechanical signatures were studied.

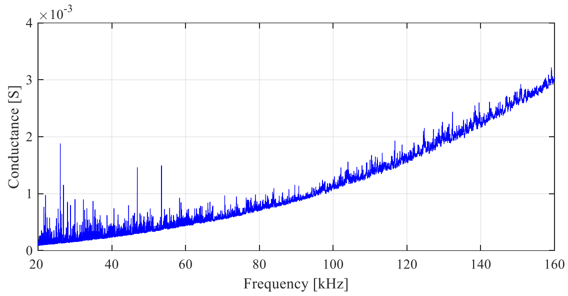


Fig. 2: A typical measurement of a transducer contains hundreds of peaks making the post-processing complex.

In addition, a medium-scale girder resembling an industrially relevant structure was instrumented with several piezoelectric transducers to evaluate the damage quantification capability of the EMI method, Fig. 3.

Fig. 3: Medium-scale girder Instrumented with piezo transducers.

Classical damage metrics proposed in literature to reduce the complex transducer signals to simple numerical values, e.g. calculating the root mean square deviation between two signals, have been evaluated. Novel approaches, e.g. based on the so-called Fréchet distance, have been developed and implemented. The broad range of experimental results (supported with numerical simulations) showed that the traditional metrics are only capable of a qualitative detection of damage. The first results indicate that new metrics also show potential for quantification of damage. In future work, the feasibility for damage localization will be analysed as well.

Corrosion detection has been initiated by developing an image processing algorithm that combines and quantifies two visual aspects – roughness and color –to locate the corroded area in a given image. For the roughness analysis, a uniformity metric calculated from the gray-level co-occurrence matrix is considered. The histogram of corrosion-representative colors extracted from a data-set in HSV color space is used for the color analysis. presents the result of the used image processing algorithm for corrosion detection. A machine learning algorithm was developed in the next step to automate the corrosion detection, Fig. 5. This effort resulted in a neural network outperforming the previous image processing algorithm for a database including challenging images, e.g. with different levels of illumination and misleading objects. In a final step, a deep learning-based algorithm will be developed that also allows to take the context of the 'corroded' component into account.

Fig. 4: Image processing technique uses color and texture features in a given image to detect corrosion

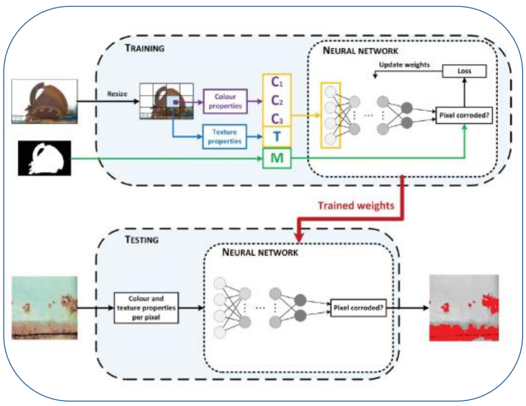


Fig. 5: Corrosion detection using a neural network

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