Evaluation of the Metal Fatigue Solutions Electrochemical Fatigue Sensor System

tech transfer summary

Assessments of the electrochemical fatigue sensor system determined that it is an effective tool for identifying cracks and whether they are growing.

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RESEARCH PROJECT TITLE
Evaluation of the Metal Fatigue Solutions Electrochemical Fatigue Sensor System

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The Bridge Engineering Center (BEC) is part of the Institute for Transportation (InTrans) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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Objective

The main objective of this work was to evaluate, through a laboratory test and field monitoring, short-term (CrackChek) and long-term (FatigueWatch) fatigue crack monitoring technologies and understand how, when, and where to deploy the electrochemical fatigue sensor (EFS) system.

Problem Statement

Identifying fatigue cracks in bridges and other structures is very difficult. An even more difficult task is identifying whether something that looks like a fatigue crack is an actively growing crack that could induce serious structural damage.

Background

In the early 1990s, work was begun to develop a nondestructive evaluation (NDE) technique for identifying fatigue cracks in small, inaccessible aircraft parts. Initial efforts focused on the measurement of corrosion fatigue. The initial research on an NDE technique based on electrochemical principles quickly revealed that corrosion current could be measured with unusual precision.

With this fundamental basis and a basic understanding of the fatigue cracking process, the initial efforts focused on developing a crack detection technique that was actually based on the detection of the growth of corrosion products. The resulting technology has a reported capability for detecting very small fatigue cracks that are actively growing.

Project Description

The laboratory test program consisted of evaluating the adequacy of CrackChek sensors for crack detection. A pair of CrackChek sensors were installed on a standard steel plate adjacent to an electrical discharge machining (EDM) notch that was created at mid-length of the steel plate, where a crack was expected to form after cyclic loadings.

After more than 120,000 loading cycles, a crack formed at the bottom of the steel plate instead of the notch tip, so another pair of sensors were installed adjacent to the crack location. Variables considered during the investigation included load application intensity and type of excitation (regular or variable).

The field monitoring program consisted of installing a pair FatigueWatch sensors on a sacrificial specimen and a pair on a bridge girder web at the Cherry Creek Bridge eastbound, which is on I-80 near Newton, Iowa.

The sacrificial specimen was a standard steel plate exactly the same as the one used for evaluating the CrackChek sensors in the laboratory. The EDM notch was also generated in the edge and mid-length of the specimen. The pair of sensors were installed near the notch tip, and the specimen was clamped to the girder bottom flange of the Cherry Creek Bridge.

The pair of sensors installed on the Cherry Creek Bridge girder web were placed at the top region near the diaphragm location known to be fatigue-sensitive. A strain gage was also installed on the steel plate to evaluate the stress levels in the monitored location.

A sensor installation verification test was also conducted on the Cherry Creek Bridge.

Key Findings

- Analysis of the results and the measured data from the laboratory test program showed that the CrackChek Sensors successfully detected the crack in the steel plate.
- According to the strain magnitudes from the strain gage on the Cherry Creek Bridge, the collected EFS signal would be sufficient for data analysis in terms of crack detection, but stress levels may not be large enough to cause crack growth.
- Indeed, the field monitoring program found after 13 months of data collection and analysis that no crack formed in either the sacrificial specimen or the bridge girder web where the sensors were installed.
- The sensor installation verification test conducted on the Cherry Creek Bridge verified that the installed sensors functioned well after installation.

Implementation Readiness and Benefits

An effective sensor system that can identify cracks and monitor their possible growth would be beneficial. This work and other reviewed work indicate that the EFS system is very capable at determining when cracks in steel members are growing. In many cases, the detectable cracks can be very small.

While the system is not capable of assessing the urgency of reacting to a growing crack or aiding in determining the best reaction, the system can be a valuable tool for deciding when further engineering assessments of safety are needed.

As a result of the training and evaluation completed as part of this work, the Iowa State University Bridge Engineering Center (BEC) is ready to deploy the EFS system when needed. Deployment of the EFS system, and its CrackChek and FatigueWatch sensors, can typically be accomplished in less than one hour per location, and the BEC can be ready to mobilize with relatively short notice.