The Exploratory Advanced Research Program Fact Sheet

Real-Time Bridge Monitoring

Developing Wireless Nanosensors to Monitor Structural Integrity

Exploratory Advanced Research . . . Next Generation Transportation Solutions

With steel bridges representing approximately 34 percent of the nearly 600,000 highway bridges in the United States, continual monitoring and early detection of deterioration in these structures is vital to prevent expensive repairs or catastrophic failures. Developing a solution for autonomous crack monitoring is the goal of "Low-Cost Self-Powered Wireless Nanosensors for Real-Time Structural Integrity Monitoring of Steel Bridges," an Exploratory Advanced Research (EAR) Program project launched by the Federal Highway Administration (FHWA) in 2009 and conducted by the Georgia Institute of Technology.

Addressing Fatigue

According to the American Society of Civil Engineers' *2009 Report Card for America's Infrastructure*, eliminating all bridge deficiencies in the United States within the next 50 years would require an investment of over $17 billion each year.[1] The development of effective rating tools to prioritize bridge projects and maximize efficiency is therefore a high priority for Federal and State agencies.

Metal fatigue in bridges begins with tiny fatigue cracks caused by the constant movement of car and truck traffic. These cracks usually initiate at the fatigue prone areas of the bridge and grow under repetitive loads until they can reach a critical size and eventually cause structural failure. To tackle this problem, engineers require the ability to determine the presence of fatigue cracks, calculate the rate of growth, and identify at what stage of fatigue is the structure. There are a number of tools and technologies currently in use to locate fatigue cracks in steel bridge members; however, current sensing systems often require lengthy cables, are limited in coverage, or require manual control. These factors make such systems impractical for continual operation and large-scale deployment.

Detecting Cracks

To detect cracks at an early stage, this project explores a real-time, rugged, low-cost, and autonomous wireless-sensing system based on state-of-the-art wireless and nano technologies. The sensing network that forms the core of this project is capable of quantifying multiple small cracks using either passive or active millimeter-wave antennas as sensors.

The individual sensing elements that form the network can be constructed by printing conductive inks on a flexible material, using inkjet printers, to form a conductive thin film. The printed antenna and supporting circuits result in a wireless radio-frequency sensor able to monitor cracks in real time. The low cost offered by this inkjet printing technique also offers potential for large-scale monitoring at a reasonable cost.

These antennas can be distributed over areas of a bridge that are known to be vulnerable to fatigue and cracking. The sensor network can then be periodically interrogated using a solar-powered radio frequency identification reader. When a small crack develops, antennas in the immediate area can measure the crack length based on the frequency shift caused by the deformation. As the crack length increases, the loss of signal power of the antenna covering that crack will increase until the antenna can no longer radiate a signal and is considered damaged. At this point the rest of the sensing network can continue to function normally and provide additional information on the orientation and length of the developing crack.

[1] See http://www.infrastructurereportcard.org/fact-sheet/bridges

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Material Challenges

One of the challenges faced by this project is ensuring the environmental protection of the antenna and successfully incorporating all the required materials into the electrical modeling—a key requirement for the design process. The surface roughness of the weld connections on the bridge beam will also be a challenge because conventional operation of the antennas requires minimal surface roughness to correctly detect cracks underneath.

New materials will also need to be investigated for efficient power sourcing and antenna radiation. Solar cells are one option that has been identified for further investigation. Although nanomaterials have already been developed in other studies for piezoelectric generators, it is necessary to align nanowires in a specific way that is not currently possible with inkjet printing. Furthermore, various inkjet printing procedures are being investigated to optimize conductivity of the printed thin film, which is essential for antenna radiation efficiency.

Improving Bridge Maintenance and Repair

The project aims to overcome the technical and cost obstacles to measuring in-situ bridge conditions and deliver a product with far greater ease than any current technique. It is expected that the system will ultimately improve the efficiency of bridge maintenance and repair, providing substantial savings in operations and increase in safety. In time this technology has the potential to transform the inspection and maintenance process for steel bridges and eventually expand into other classes of key infrastructure components.

Learn More

For more information on this project, contact Hamid Ghasemi, FHWA Office of Infrastructure Research and Development, at 202-493-3042 (email: hamid.ghasemi@dot.gov).

EXPLORATORY ADVANCED **RESEARCH**

What Is the Exploratory Advanced Research Program?

FHWA's Exploratory Advanced Research (EAR) Program focuses on long-term, high-risk research with a high payoff potential. The program addresses underlying gaps faced by applied highway research programs, anticipates emerging issues with national implications, and reflects broad transportation industry goals and objectives.

To learn more about the EAR Program, visit the Exploratory Advanced Research Web site at www.fhwa.dot.gov/advancedresearch. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events. For additional information, contact David Kuehn at FHWA, 202-493-3414 (email: david.kuehn@dot.gov), or Terry Halkyard at FHWA, 202-493-3467 (email: terry.halkyard@dot.gov).

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