2014 NETL Crosscutting Research Review Meeting
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Pittsburgh, PA

EMBEDDED ACTIVE FIBER OPTIC SENSING NETWORK FOR STRUCTURAL HEALTH MONITORING IN HARSH ENVIRONMENTS

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Outline

• Motivation and Objectives
• Background and Fundamental Technology
• Project Progress
• Summary
MOTIVATION AND OBJECTIVES
Motivation

• Health condition monitoring of key materials and structures can ensure safety and minimize system shutdowns.

• Challenges from a new set of extreme physical and chemical conditions:
  • Ultrahigh temperature
  • High pressure
  • Severe chemical corrosion
Impacts

- Currently available methods:
  - X-ray defect detection
  - Ultrasonic tomography
  - Remote techniques using piezoelectric transducers

- Advantage of new fiber-based technology:
  - Can be attached or embedded
  - Multi-parameters monitoring with single sensor
  - High temperature
  - Remote, no on-site power required
  - Potential of multiplexing
Project Overview & Objectives

- Three-year project beginning 4/1/2013.

- Objectives:
  - Develop a fiber-based multi-parameter (temperature, strain, corrosion, and defects) health monitoring sensor
  - Develop the attachment or embedment technology of the sensor to steel
  - Demonstrate the feasibility of sensor multiplexing
BACKGROUND AND FUNDAMENTAL TECHNOLOGY
Ultrasonic Non-Destructive Evaluation (NDE)

• Widely used and versatile technique of material defect detection.
  • One-side access needed
  • Deep detection

* Figure from www.ndt-ed.org
Active Fiber-Optic Non-Destructive Evaluation (FO-NDE)

- An acoustic wave is generated to detect defects optically in a fiber.

- A Fiber Bragg Grating (FBG) is used to detect the acoustic signal modulated by the material as well as other parameters.
PROJECT PROGRESS
Computational Modeling

• A 2D computational model was built to simulate acoustic propagation in a bulk material.

• Cracks and corrosions were placed on the block to simulate acoustic responses of the system.
Acoustic Wave Simulation

- Elastic wave propagation model
- Simulated
  - P-wave
  - S-wave
  - Surface wave
  - Reflection
- Demonstrated acoustic propagation in a specimen with crack and corrosion
Crack Detection

- Crack-induced acoustic signal
Corrosion Detection

- Corrosion induced acoustic signal change
Sensor Element Design

- Two acoustic generation candidates
  - Laser Induced Plasma (LIP)
  - Erbium-Doped Fiber (EDF)

![Surface attached LIP & FBG based FO-NDE element](image1)

![Surface attached EDF & FBG based FO-NDE element](image2)
LIP Based Sensor Design

- Metal film embedded in multimode fiber
- Confined LIP
- Multiplexing through partial absorption on each element
- Pro: high acoustic signal level
- Con: dual fiber system, complicated sensor fabrication
**LIP Based Acoustic Generator Fabrication**

A. Well drilled on fiber end;

B. Well filled with platinum using Focused Ion Beam (FIB);

C. Microscope image;

D. Splicing;

E. Completed unit.
LIP Based Sensor Preliminary Test

- Strong acoustic wave generated by single unit in water
EDF Based Sensor Design

- Using the absorption and thermal relaxing of EDF for acoustic generation
- Pro: easier fabrication, single fiber structure
- Con: weak acoustic signal
EDF Based System Design

- Wavelength Division Multiplexing (WDM) technique for signal demodulation in a multiplexed system
Next Steps

- Develop of both LIP and EDF based acoustic generation units, and compare their performance and choose one for the final scheme
- Fabricate and demonstrate a complete single FO-NDE unit
- Develop fiber sensor embedding technique in target metal
- Demonstrate sensor unit multiplexing
Task Status

1. Project Management & Planning
2. Acoustic Generation, Propagation and Detection Modeling
3. Sensor Element Design
4. Demonstrate FO-NDE Element
5. Design, Implement and Demonstrate Sensor Network
6. Test Sensor in the Simulated Environment
7. Prepare Final Report
## Project Progress Summary

### Task Description

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<tr>
<th>Task</th>
<th>Description</th>
<th>Start Date</th>
<th>End Date</th>
<th>Cost</th>
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### Technical Progress Reports

- **Q**: Quarterly
- **F**: Final

### Notes

- **Project Milestone**
- **Umbrella Task**
- **Task Continuation**
- **No-Cost Extension**

Reports: **Q** - Quarterly, **F** - Final
THE END