Repair and Load Rating Verification by Detecting Structural Damage

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Outline

- Background
  - Fatigue Cracking in steel bridges
- The Electrochemical Fatigue Sensor (EFS) Technology
  - How EFS works
- The EFS in the field
  - EFS bridge instrumentation
  - Data collection on load tested bridges
  - Testing and results

Background

- The U.S. has 614,387 bridges
  - 40% are 50+ years old
- Almost 10% were structurally deficient in 2016
- Current structural rehabilitation costs exceeds $100 Billion
- Posting bridges help enable bridge integrity
  - Posted bridges load rating changes with time

Monitoring Cracks on Steel Bridges

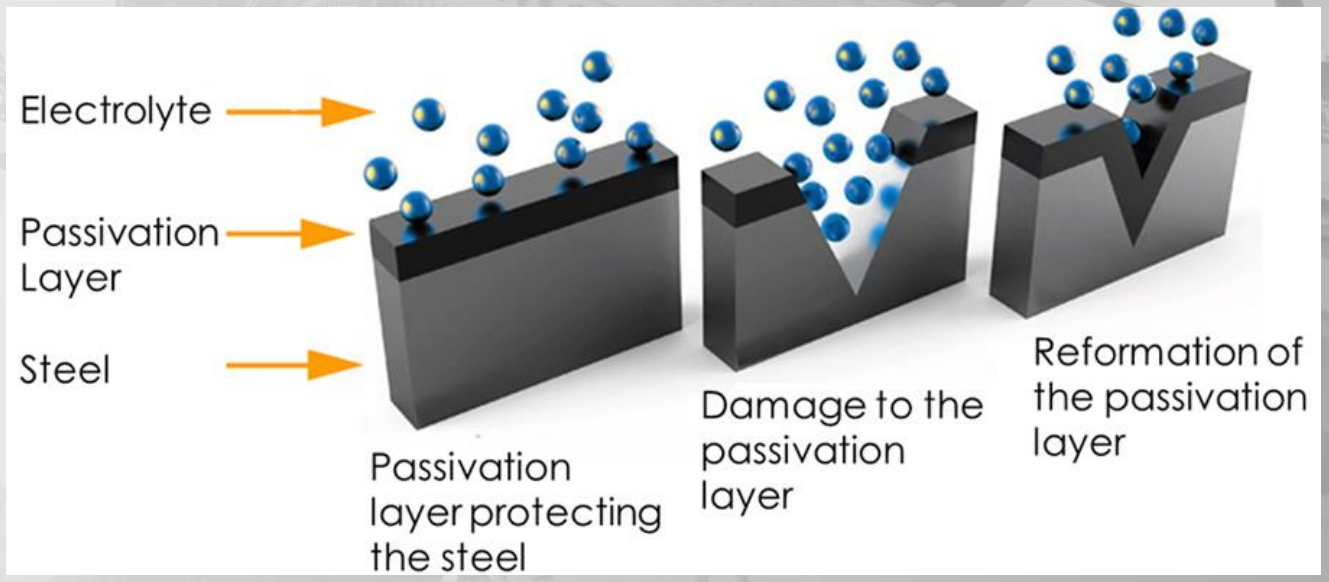
- Increased truck load limits leads to rapid accumulation of loading cycles
- Studies show:
  - >90% of cracks are missed with visual inspection
  - >80% of areas called out as cracks are false positives

The Electrochemical Fatigue Sensor (EFS) Technology

- EFS is an NDT method
  - Determines if a fatigue crack is actively growing
- Detects microplasticity
- Immediately verifies efficacy of repairs/retrofits

How the EFS works

- Similar to a medical EKG
- Uses an electrolyte to create an electrical circuit in the structure
  - Apply constant voltage, read back current
- Changes in current from the sensor → Crack growth

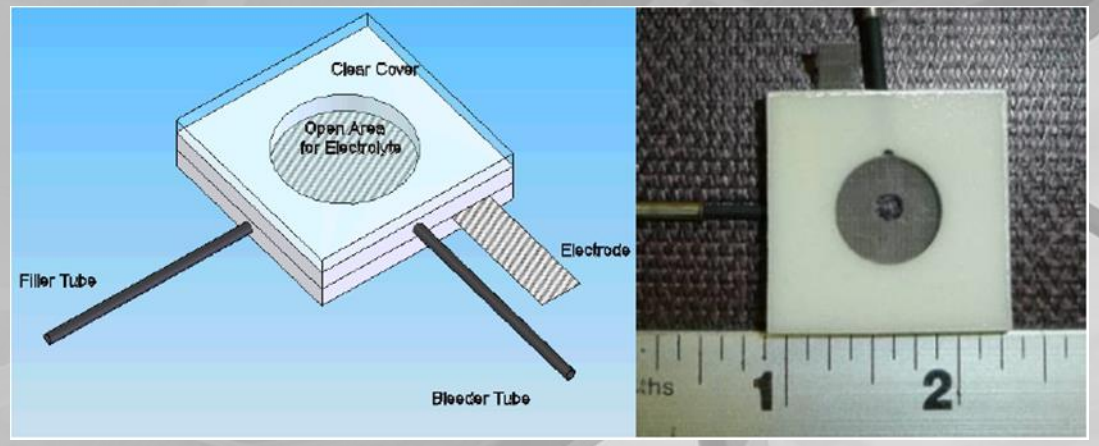


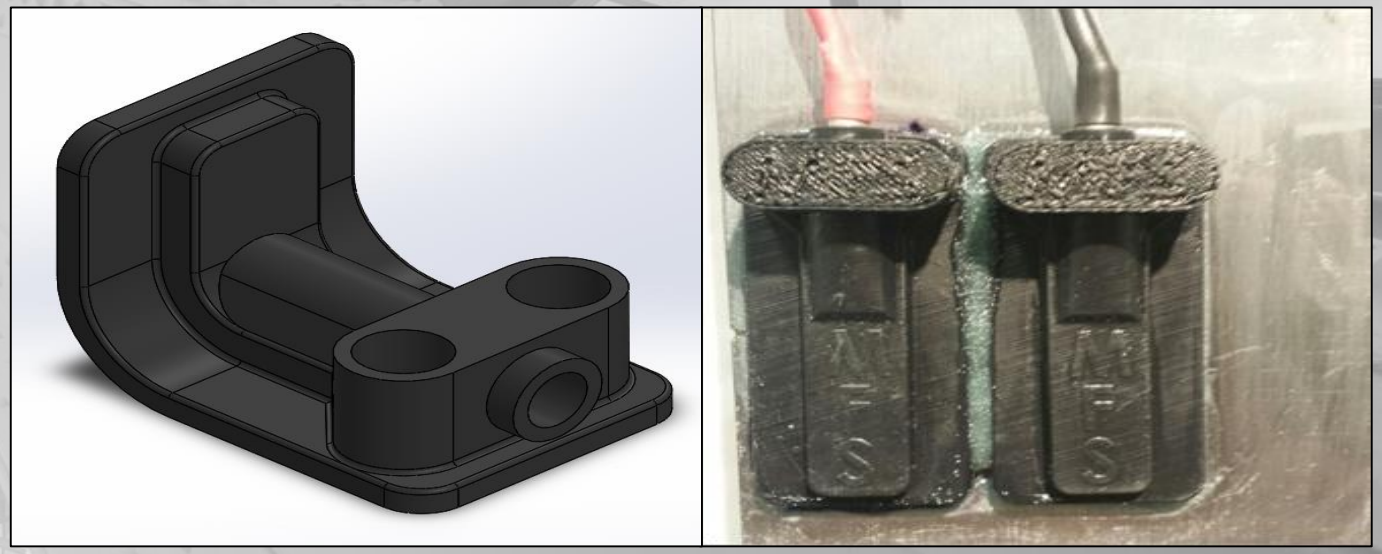
EFS System

- 4 Major components:
  - EFS Sensors (short term or long term)
  - Data collection hardware
  - Data analyzer (software)
  - Wireless communication (Wi-Fi or LTE)

EFS Components

- Non-Conductive casing
- Liquid electrolyte
- Stainless steel mesh





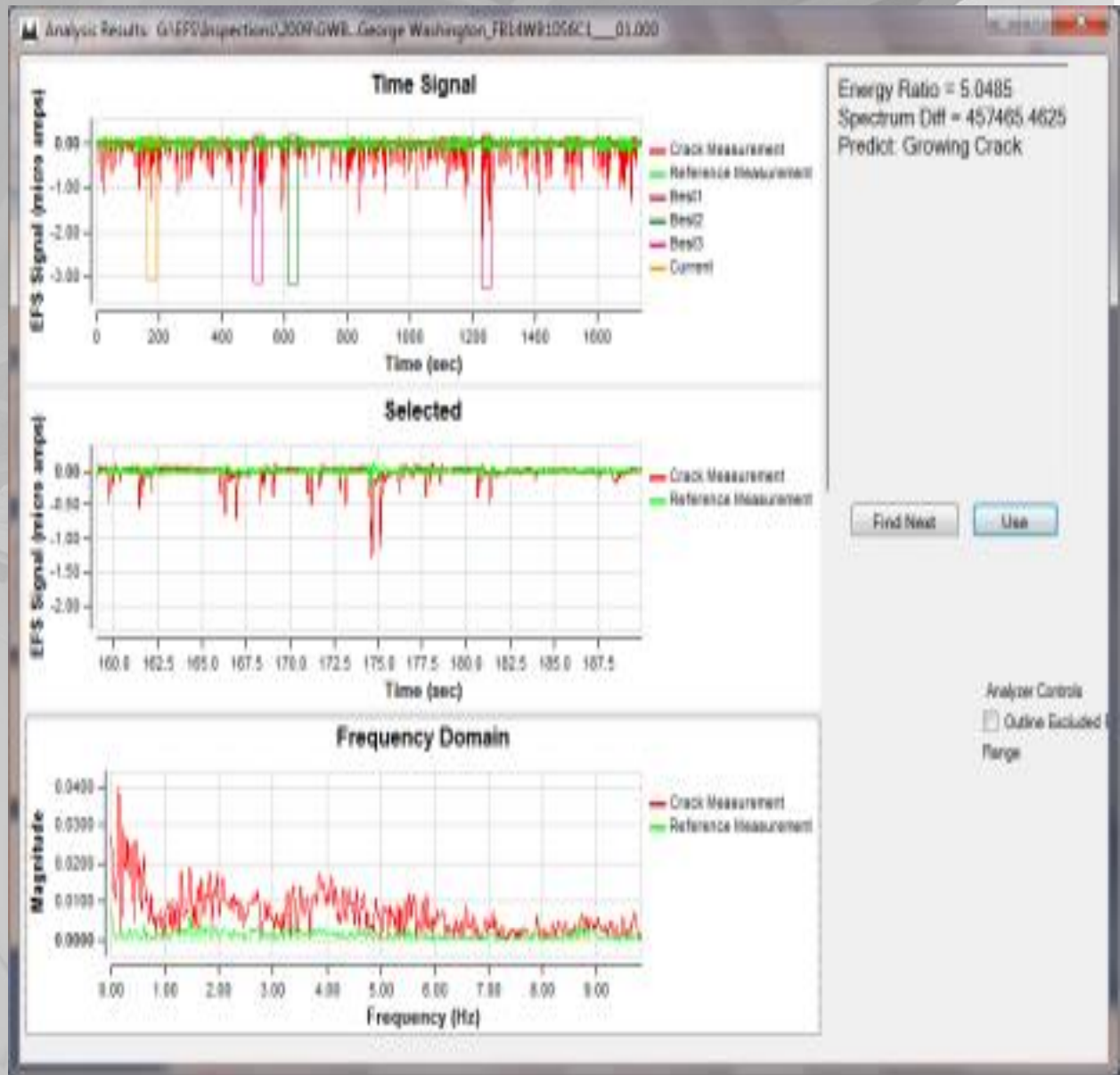
Data Collection Hardware

- Precisely controls the EFS sensor array voltage
- Measures the current flow for the two sensors
- Stores all the data on an SD card.
  - Data is retrieved/stream wirelessly

Data Analyzer (Software)

- Frequency content and magnitude differences indicate crack condition
- Energy Ratio (ER) is crack growth indicator
  - No growth<1.5
  - 1.5<Potential Growth<1.9
  - 1.9<Active crack growth

$$ER = \frac{\text{Area under } C_{sensor}}{\text{Area under } Ref_{sensor}}$$



The EFS in the Field – ADOT, I-15 River Bridges

- EFS was installed in 4 different structures
- 19 locations were monitored with EFS
  - 15 locations had visible cracks
  - 4 retrofit locations

EFS Installation Example

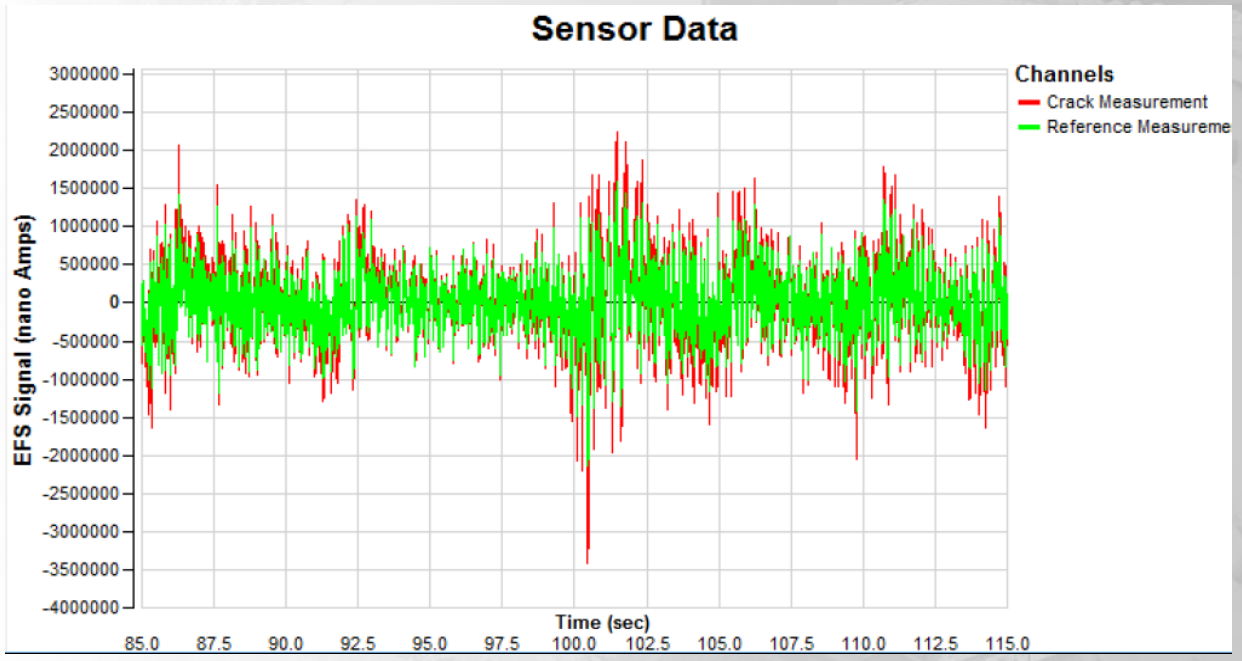
- Short term sensor
- Longitudinal crack in the girder web near the top flange

EFS Data Collection on Load Tested Bridges

- Two load test
  - Ambient traffic
  - Roll test
- Roll test parameters:
  - Gross vehicle weight was 63,000 lb
  - 5 MPH and 65 MPH

Testing Results for All Bridges

- From the 15 visible cracks locations:
  - 4 were actively growing
  - 5 showed potential to grow
  - 6 were not actively growing



- From the 4 retrofit locations:
  - 1 was not working (active crack growth)
  - 2 showed precursors to crack growth
  - 1 was working (No active crack growth)

Note: Roll test at low speed (less than 5 MPH) did not provide usable data

Conclusions

- The EFS is an NDT technology
  - Identifies the crack activity in real time
- Needs dynamic loading for accurate reading
- Verifies repairs and retrofits prior to changing load limits
- By measuring direct damage occurring on the structures, more accurate load ratings are achieved

Questions?