TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): ____IOWA DOT______________________________________

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

<table>
<tr><td colspan="2">Transportation Pooled Fund Program Project #
TPF-5(449)</td><td>Transportation Pooled Fund Program - Report Period:
X Quarter 1 (January 1 – March 31, 2021)
Quarter 2 (April 1 – June 30, 2021)
Quarter 3 (July 1 – September 30, 2021)
Quarter 4 (October 1 – December 31, 2021)</td></tr>
<tr><td colspan="3">Project Title:
Robust wireless skin sensor networks for long-term fatigue crack monitoring of bridges</td></tr>
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<tr><td>Lead Agency Project ID:</td><td>Other Project ID (i.e., contract #):
Addendum 736</td><td>Project Start Date:
May 15, 2020</td></tr>
<tr><td>Original Project End Date:
May 14, 2023</td><td>Contract End Date:
May 14, 2023</td><td>Number of Extensions:</td></tr>
</table>

Project schedule status:

X On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Total Percentage of Work Completed
$ 540,000	$67,874.63	15%

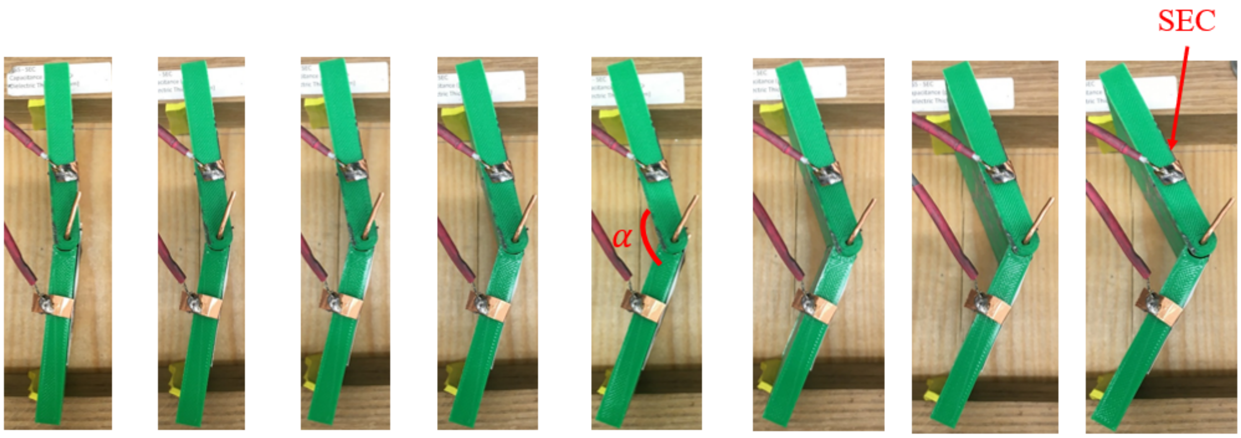
Quarterly Project Statistics:

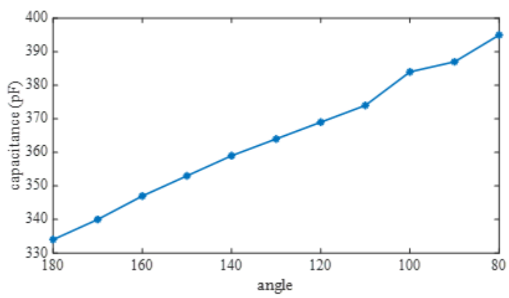
Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$67,874.63		

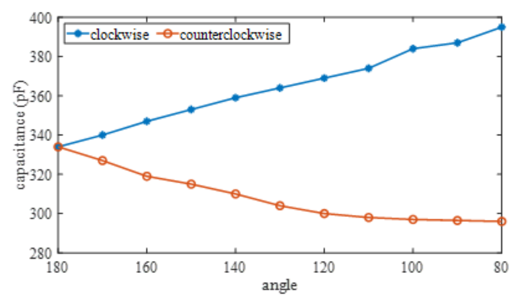
Project Description:

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

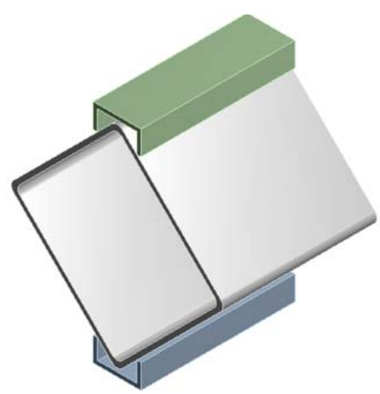
- TAC meeting on Jan 13th 2021 (TAC meeting on April 21st 2021 planned).
- ISU analyzed results from the mode-1 failure tests and wrote a journal paper to be submitted.
- ISU conducted preliminary tests on the SEC for measuring deformations in a folded configuration. The figure below shows the sensor installed over a hinge, with capacitance data clearly showing a trend as a function of the folded angle.



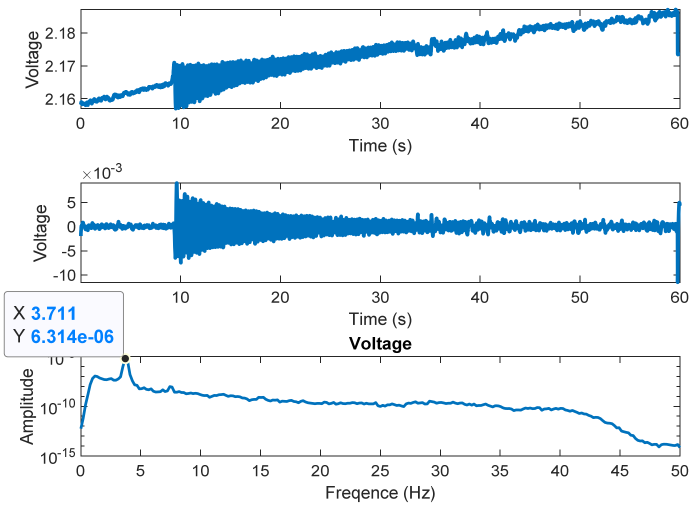




- ISU designed and prepared tests to evaluate the performance of the SEC at measuring strain in a folded configuration. Tests will be conducted by deploying the sensor onto the interior angle of an HSS section. Figure below shows the sensors deployed inside the HSS (left). A finite element model (right) of the HSS (middle) was created and validated.



- KU tested five small SECs and a strain gauge to investigate the issues uncovered during the previous quarter. All five sensor boards were successfully balanced. Figure below shows the time histories acquired by an Xnode wireless sensor. A solution for addressing Issue #2 (linear drift) was proposed through signal processing, specifically using a high pass filter. As shown in the Figure 1, after high-pass filtering (middle), the linear drift is removed, leaving the corrected capacitance data.



- KU tested three new SECs. The goal was to test if the new textured SECs would work with the old UA boards. Results show that the old sensor board were successfully balanced with the new textured SEC. The measurement results based on NI DAQ are shown in the figure below, indicating successful collection of data.

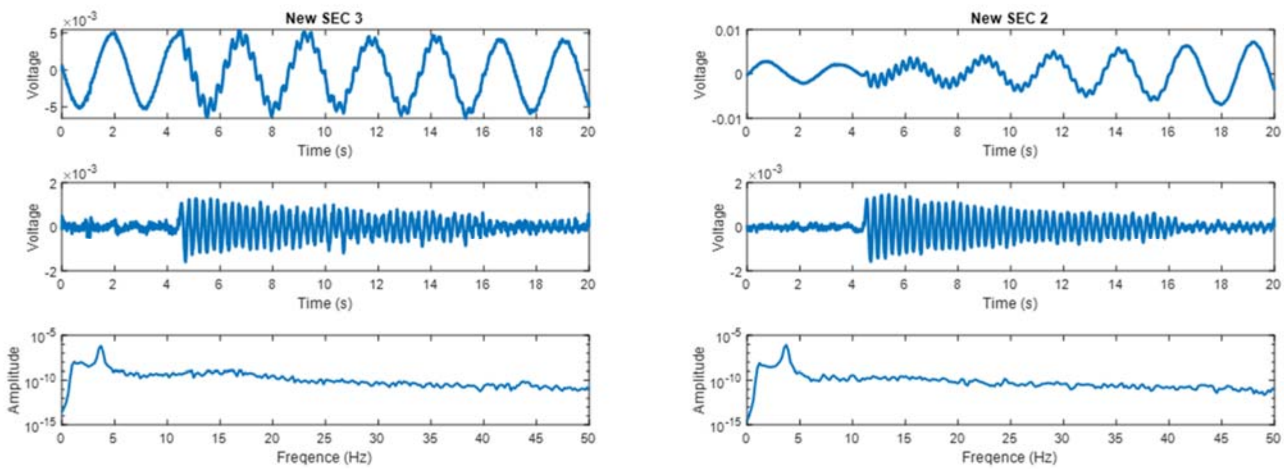
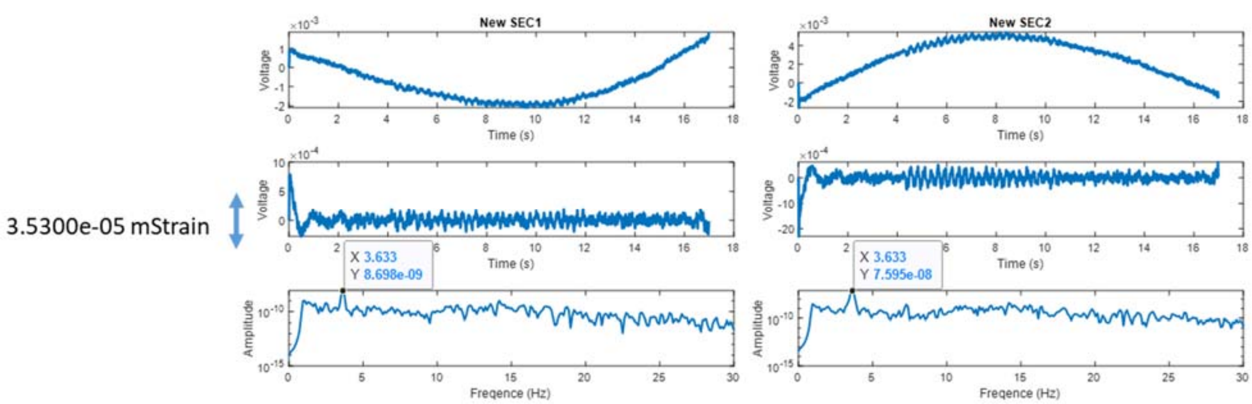
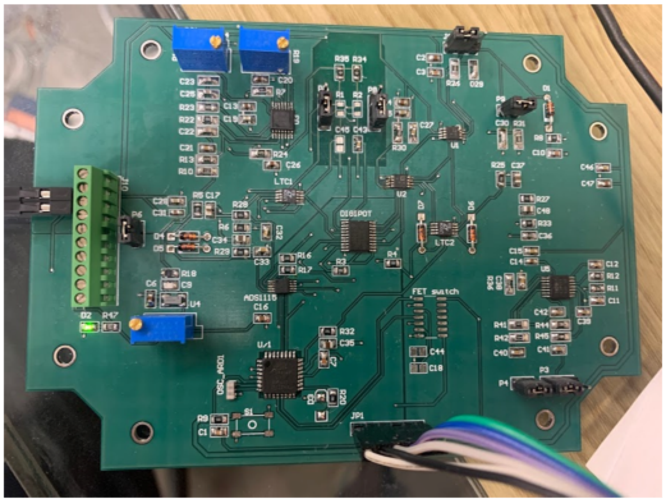


Figure 3. Data collected from the new textured SECs with the old UA boards

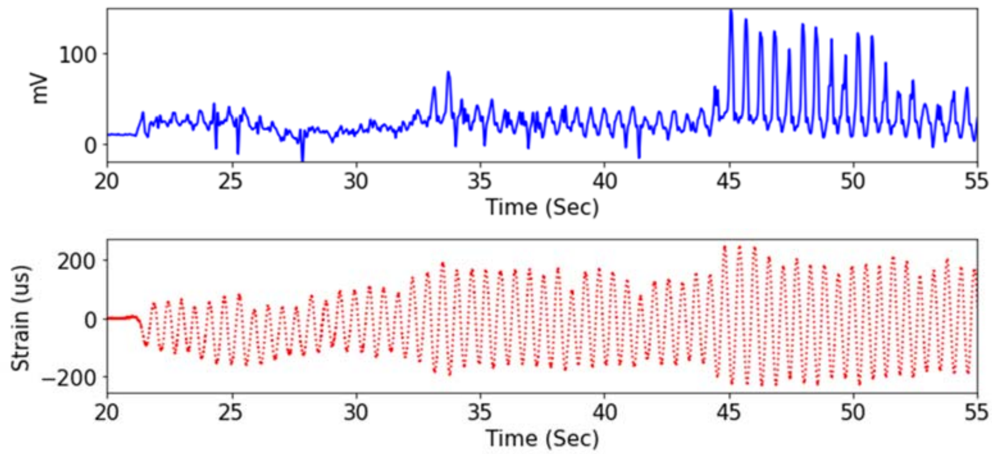
- KU investigated the quality of data from the new textured SECs under low strain levels. Figure below shows the measured capacitance data of the new SECs under 15 $\mu\varepsilon$, indicating satisfactory results.



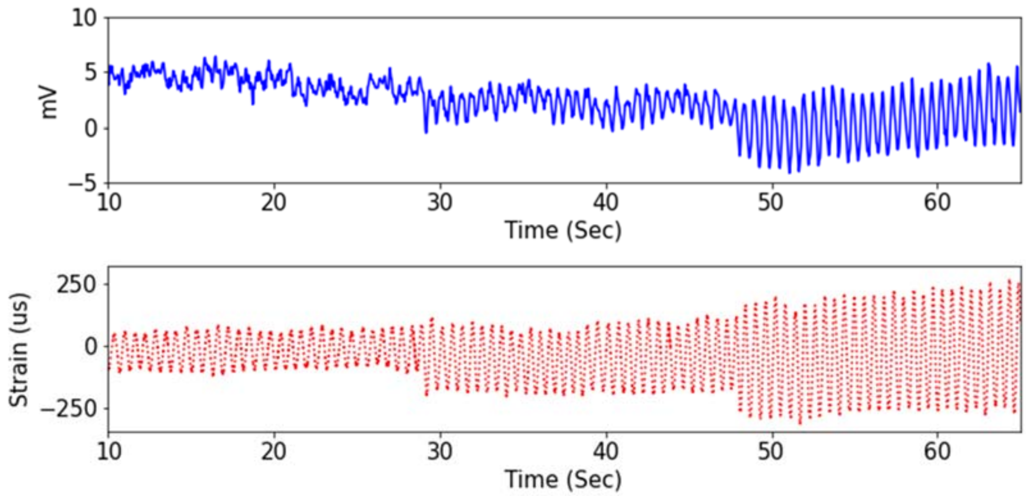
- KU worked on setting up the event-triggered sensing strategy by communicating with the manufacturer of Xnode. In this new version of sensor network, the gateway node will be equipped with a wireless modem to upload data to the cloud server. Data can be access remotely through a website.
- UA ordered and assembled new sensor board shown below.



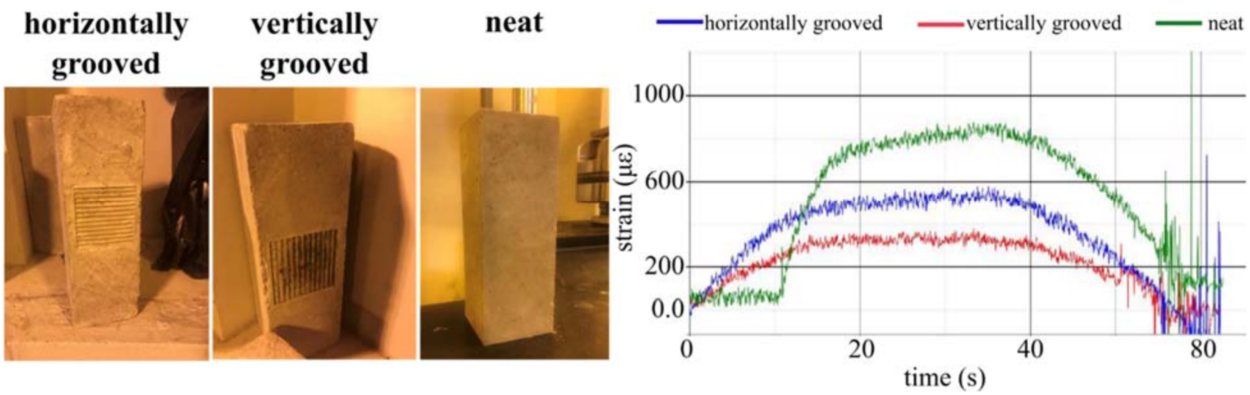
- UA developed software, uploaded to new sensorboard and tested the functionalities. The figure below shows the bending test result with new developed SEC (with grid, nominal capacitance = 270pF) compared with strain gauge measurement. The new SEC shows the bending trend but showed noisy measurement.



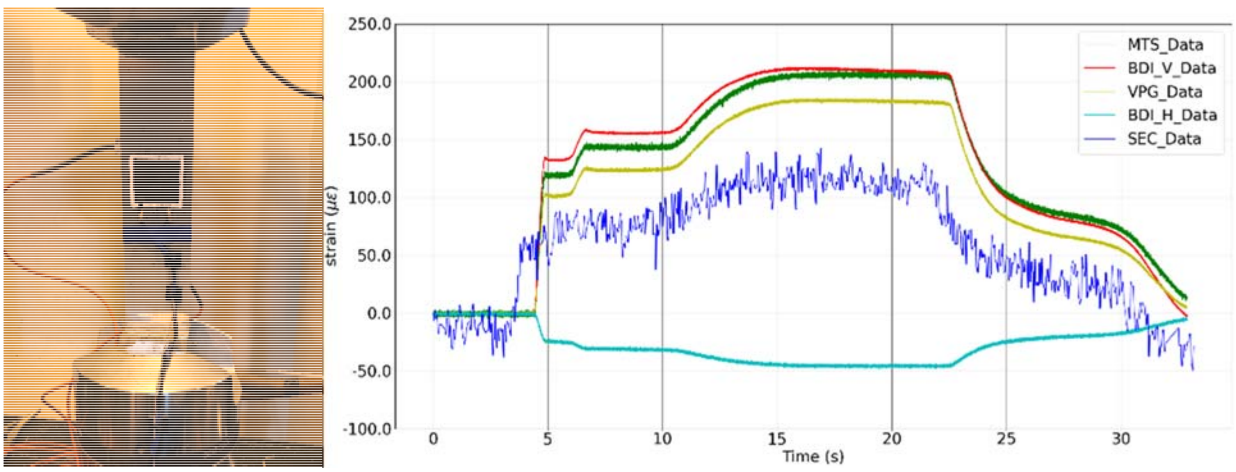
- UA repeated tests on an older generation SEC. Figure below shows the test result with an SEC of 870pF nominal capacitance. Same automated bridge balancing worked well and showed reasonable measurement result. However, further precise software optimization is required for better sensitivity.



- UA developed a DC Wheatstone bridge for onboard strain sensing.
- USC conducted further tests on concrete specimens under uniaxial compression, as shown in the figure below. Results demonstrate that for the same loading, the surface texture of the concrete results in a change in the response measured by the SEC.



- USC compared SEC data (in blue, figure below) against those from the testing machine (MTS) and off-the-shelf strain sensors (BDI). Results from the SEC agreed with the MTS and BDI for that test (the SEC measured the additive in-plane strain).



Anticipated work next quarter:

- ISU will conduct an initial series of tests on angled folds on steel.
- KU will continue to work on testing the event-triggered sensing strategy.
- KU will work with the Arizona team to fabricate enclosures for the UA boards to support field deployment.
- UA will optimize automated bridge balancing / shunt calibration software for better sensitivity.
- USC will run tests on concrete assisted with digital image correlation (DIC) to further the understanding of the SEC on concrete.

Significant Results:

- Tests on mode-1 failure on steel finished and results analyzed.
- Tests on angled folds designed and prepared.
- Solutions for signal Issues #2 and #3 found through signal post processing.
- Investigations on the old UA board demonstrated data collection capabilities for the new textured SECs.
- New sensorboard PCB ordered and assembled; automated bridge balancing and shunt calibration verified.

- Tests on concrete revealed that the SEC may have outperformed a traditional measurement system, because the SEC did not add stiffness to the setup.
- Tests on concrete showed that measured response from the SEC is depended on the surface texture to which it is applied. DIC will be used to further study these responses.

Circumstance affecting project or budget (Describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope, and fiscal constraints set forth in the agreement, along with recommended solutions to those problems). N/A