Fluorescent Chemical Sensor Array for Detecting and Locating Pipeline Internal Corrosive Environment

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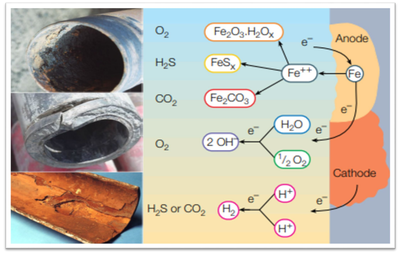
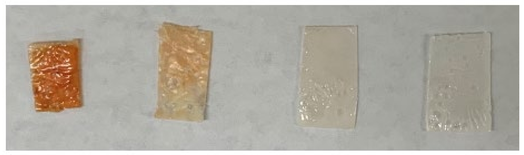
Background and Objectives

This project proposes to develop a passive colorimetric/fluorescent chemical sensor array which is capable to work with fluorescent cameras on ILI tools for locating and detecting corrosive water inside metallic pipelines. The sensor array will have several separate sensors in a roll. In each sensor, specially designed organic chemicals will be synergized inside polymer base to detect the changes of one specific chemical components inside oil/water environment such as HCO_3^- /CO_3^{2-}, S^{2-}, Fe^{3+}, and H^+, which are the environmental parameters most important for corrosion progressing.



Internal corrosion mechanisms

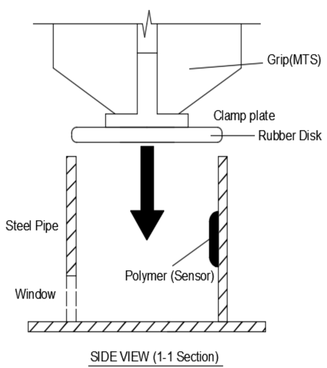


5% 1% 0.1% 0%

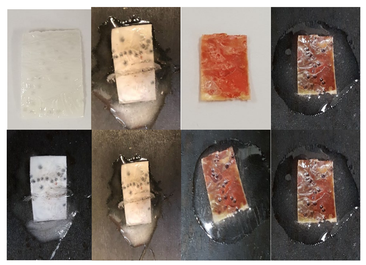
Sensor film color change as Fe^{3+} concentration changes

Sensor Development & Experiments of Sensor Survivability in Oil/Water Environment

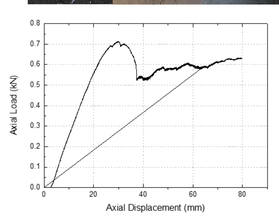
- ✓ Sensor films to detect Fe^{2+} and Fe^{3+} were successfully developed by writing chemical sensing compounds inside PMMA/CA polymer films.
- ✓ To experimentally test the survivability of the sensor array, we successfully designed a test procedure in laboratory to simulate and test the sensor performance when a PIG is passing the sensor. Based on the designed tests, experiments were performed on some possible example sensors under PIG activities.



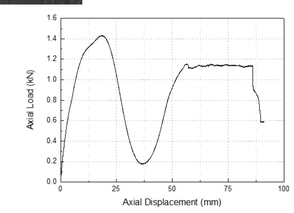
Experimental test arrangement



Sample outlook, treated with 0%, 5% Ge3+ solution and gasoline



(a) Load-displacement curve of sensor film without immersed gasoline (disk moving in)



(a) Load-displacement curve of sensor film without immersed in gasoline (disk moving out)

Test results

Public Project Page

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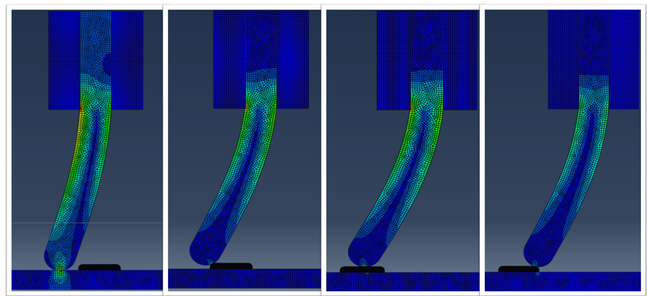
https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=786

FEM Simulation of Sensor Survivability

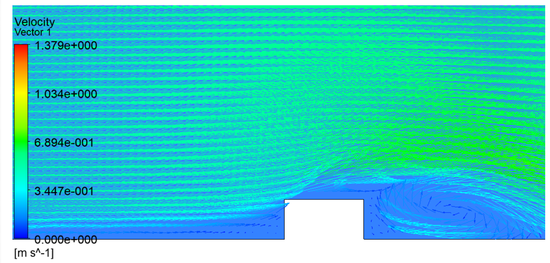
Similar as in the experiments, a two-dimensional slice Finite Element Model (FEM) was employed to analyze the passing of a regular oil/gas flow (at 0.5 m/s) and a passage of a pigging process.

Detail parameters of FEM model

Pipe inner diameter(mm)	Pipe thickness(mm)	Clamp plates thickness(mm)	Clamp plates outer diameter(mm)	Sealing disk thickness(mm)	Sealing disk outer diameter(mm)
324	8	15	200	15	340 (5% oversised)



Deformation of sealing disk with PIG passing



Numerical analysis with Oil/gas flow passing the sensor film

Preliminary Results to date:

1. Membrane with embedded sensors to detect Fe^{2+} /HCO_3^- /CO_3^{2-} and Fe^{3+} were successfully developed by using PMMA and CA polymer films;
2. The color change stayed unchanged after immersing the sensor film in gas/oil in atmospheric condition, indicating that no cleaning service is needed for the application of the detection of color changes of the sensor film;
3. The expected force on the sensor film from the regular oil/gas flow (at 0.5 m/s) was estimated to be around 8 N and from passing a cleaning pig was estimated to be around 100 N, indicating that the cleaning service would control the sensor size design;
4. The attached sensor film maintained their color and function during lab simulated cleaning service, indicating that the sensor film can survive and maintain functional when a cleaning/inspection pig passing.

References

1. U.S. liquid pipeline usage and mileage report, October 2014 from Association of oil pipelines (AOPL)
2. Y. Huang, Z. Gao, Z. Zhou, G. Chen, and H. Xiao, “Long period fiber grating sensors coated with nano iron/silica particles for corrosion monitoring”, Smart Materials and Structure, 22, pp. 075018, 2013

Acknowledgments

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