Revised Quarterly Report

Date of Report: September 7, 2005

Contract Number: DTRS56005-T-0003

Prepared for: DOT RSPA

Project Title: Model Modules to Assist Assessing and Controlling Stress Corrosion Cracking #126

Prepared by: Battelle

For quarterly period ending: August 31, 2005

Activities/Deliverables Completed

	SCH Date	CMPL Date
Task #1: Mechanism for NNSCC developed	06/30/2005	**07/30/2005**
Task #2: Optimum conditions for kinetics via beaker studies developed.	06/03/2005	**06/30/2005**
Task #6: Evaluate practices to quantify hydrogen effects on microplasticity.	06/30/2005	**07/01/2005**

- Technical Status – Thermodynamic basis for NNSCC mechanism is considered based on prior experimental results from the electrolyte composition and precipitation of the species at the surface of the metallic structure. This theoretical approach predicts the formation of specific corrosion products which controls anodic dissolution when unloaded conditions are presented. Electrochemical approach based on kinetics principles at the interface for hydrogen formation is considered for the NNSCC theoretical model. We proposed an algorithm that considers the flux of the species to the interface (metal-solution) from the bulk that includes the hydrogen ions, bicarbonate ions that are the reactants that form the hydrogen gas. This algorithm is based on prior models that consider thermodynamics and kinetics for steel corrosion in CO_2 aqueous solutions under unstressed conditions, like Nesic et al[1-4], which describe the fluid flow of ionic species from the bulk solution to the electrode and reacts at the interface, Mishra et al[5] shows possible corrosion mechanisms for steel exposed to CO_2 conditions by direct reduction of H_2CO_3 and reduction of HCO_3^-. F.M. Song[6] explained the boundary layer formation of iron carbonate and corrosion products in terms of equilibrium reactions. Experimental set up for unloaded conditions is currently running to study the interface for different bulk concentrations and variables that affect real conditions of a buried metallic structure, like electrolyte concentration, polarization conditions, pH, and temperature by means of time domain techniques.

  - Experimental set up was designed to followed hydrogen diffusion within metallic structures permeation of hydrogen is measured quantitatively and qualitatively with electrochemical methods.
  - Total hydrogen formation will be calculated theoretically from the flux of the reactant species that will form hydrogen gas. Experimental results for unloaded conditions will characterize the amount of hydrogen that diffuses through the metallic structure and the one that is released to the atmosphere. We are collecting data and completing an experimental matrix that relates important system variables with the production of hydrogen and the final destination of the gas in order to quantify the amount of gas that diffuses and concentrates within the metallic structure, and

initiation of experimental design to load conditions in order to correlate load, electrochemical with microplasticity phenomenon.

Figure 1. Hydrogen permeation cell, left side is the exit anodic side and the right side is the cathodic or entrance side.

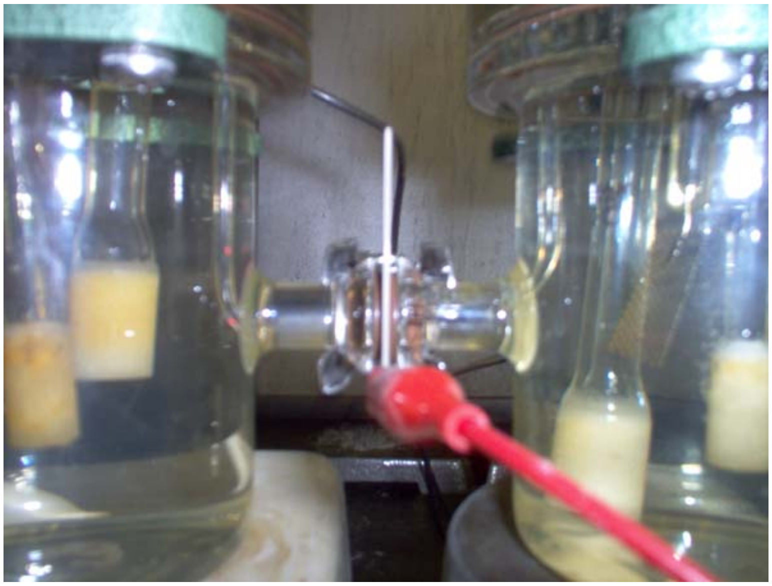

Figure 2. Steel plate for hydrogen permeation, steel sample is 1cm in thickness.

– Experimental Set Up and Discussion. A permeation cell made of glass has been fabricated capacity of 500ml in each chamber. A circular permeation window with a surface area of 1 cm^2 is incorporated in this design as shown in Figure 1. The input side (the cathodic chamber) contains the same solution (pH, concentration, and temperature) as the anodic chamber in order to obtain ionic H^+ at the surface and atomic H within the metallic structure. The output side (the anodic chamber) of the cell is polarized to motivate hydrogen permeation, with the line-pipe steel specimen located as usual between the chambers as show in Figure 2. Total current is recorded from the output side in order to follow the hydrogen transport within the metallic structure while the potentiostatic experiment is run. The diffusion coefficient will be calculated and reported for each variable that affect the transport conditions of atomic hydrogen within the metallic structure, like ionic species, temperature and pH. The thickness of the pipeline steel-membrane is 1 mm, with one face of the plate covered by palladium, which metal avoids any oxidation when exposed in solution making the surface stable. Each chamber has inlet port that holds injection dispersion glass devices for gas, and ports for temperature measurement. Both chambers are standing on a heat plate to facilitate control of solution temperature.

References.

1. S. Nesic and L.J. Lee, Corrosion, Vol. 59, No. 7 2003.
2. S. Nesic, M. Norsdveen, R. Nyborg, and A. Stangeland, Corrosion, Vol. 59, No.6, 2003.
3. S. Mesic, M. Nordsveen, R. Nyborg, and Stangeland, Corrosion, Col. 59, No.6, 2003.
4. S.Nesic, J. Postlehwaite, Corrosion, Vol. 52, No. 4, 1996.
5. F. M. Song, D.W. Kirk, J.W. Graydon, and D.E. Cormack, Corrosion Vol. 60, No.8, 2004.
6. B. Mishra, S.Al-Hassan, D.L. Olson, and M.M. Salama, Corrosion, Vol. 53, No. 11, 1997.

- Business Status – Cell design is considered to be novel and the hydrogen permeation to the metallic structure and load conditions will allow correlating two important parameters for life prediction.
- Schedule –Task #1 is one month different from schedule because the experimental part is still running and the mechanism proposed changes continuously with experimental evidence. Task #7 requires experimental results in order to establish criterion for the NNSCC process.
- Payable Milestones – There are no payable milestones this quarter.

Results and Conclusions

Mechanistic model is developed in conjunction with laboratory data. Cell design is considered important for the following of the total hydrogen, diffusion and concentrated hydrogen within the metallic structure under load conditions.

Quantification of the gas that diffuses and forms will allow contributing to the phenomenological aspects of the microplasticity under stress corrosion cracking process.

Issues, Problems or Challenges

Nothing unplanned has occurred.

Plans for Future Activity

Experimental procedure is going to be performed during the next few months, where sensitivity analysis will discriminate the hydrogen that diffuses to the hydrogen released outside the structure from the total hydrogen formed under unloaded and loaded conditions.

After completion of experimental unloaded conditions the model will be validated at the first stage, where the total hydrogen will be subtracted from the permeation hydrogen. Once the model is validated with experimental results the loaded conditions are going to be included in the experimental procedure. Design of new cell under load conditions will start during the next month and completed in one month after starting.

The experimental results from electrochemical testing combined with loaded capabilities will give semi-empirical relations or parametric expressions that relate hydrogen formation with SCC conditions under different magnitudes. From this point we will use a standard cell for NNSCC testing.

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We introduced a simple algorithm to the mechanism for NNSCC. We also have initiated experiments designed to establish the optimum condition for cracking kinetics via beaker studies and quantification of hydrogen permeation under unload conditions. Work will continue on experimental testing over the next several monthly reporting periods combined with theoretical validation of proposed models.

Electrochemical kinetics and transport phenomena approach is converted in a simple algorithm based on the species presented in the solution, and prior steady state experimental results helped to correlate theoretical algorithm with laboratory results for the species presented in the electrolyte.
Kinetic parameters of the system such as the current are driven by the ionic species and monitored by electrochemical techniques.

Work thus far has focused on improving the mechanism for near-neutral SCC (NNSCC), by evaluating methodologies and practices to characterize the hydrogen effect that exists within a metallic structure that results from hydrogen diffusion and accumulation within the metallic structure. Furthermore, laboratory experiments that are underway will result in data for further validation of the theoretical approach. From experimental results, experimental cell design for load conditions was initiated.