Materials Technology Institute

"Maximizing resources through a global network of materials specialists"

Minutes

Microbiological Corrosion of Super, Hyper Duplex Stainless Steels (Project 301)

Meeting Purpose: Discuss questions posed by the team with SwRI experts Jim Dante, Erica Macha, Amy De Los Santos, and Spring Cabiness.

Date, Time, Place

Date: Tuesday, February 20, 2018
Place: Doubletree – SeaWorld, Orlando, FL
Time: 1:30 – 2:20 p.m. Eastern Time

Attendees:

Company	First Name	Last Name
Albemarle	Xiaowei	Ren
ATI	David	Hasek
Chemours	Jennifer	Larimore
Chemours	Steve	Springer
Chemours	Andres	Trevino
DuPont	Richard	Clapp
MTI	Pradip	Khaladkar
Neotiss	Wendy	McGowan
New Castle Stainless Plate	Frank	Alvin
New Castle Stainless Plate	Tony	Palermo
NobelClad	Curtis	Prothe
Noram Engineering	David	Clift
Rolled Alloys	Rick	Duncan
Sandvik	Marcelo	Senatore
Sandvik	Katie	Day
Shell	Jorge	Penso
University of Akron	David	Bastidas
Ward Vessel & Exchanger	Bryan	Boudet

Agenda

Topic	Leader	Time (min.)
Introduction	Katie Day	5
Discussion with Jim Dante (SwRI)	Katie Day	45
Path Forward	Katie Day	10

The following questions were sent to Jim Dante of SwRI which he attempted to answer:

1) Can you tell us about the procedure for transporting plant water? How will this assure that the bacterial are maintained?

2) Can we analyze several plant waters for bacteria commonalities and create an artificial solution for testing based on that?
3) How can we assure that we will get MIC?
4) What happens if we don't get MIC attack?
5) Should we be testing with aerated water or dearated water?
6) What temperature should we be testing at? Room temperature?
7) What temperature would culturing be done to categorize the bacteria?
8) Do you have a suggestion for identifying MIC with pitting depth? Is there a certain depth you'd recommend we use as the criteria?
9) I would like to know what experience and success SWRI has had in simulating the plant water system in the lab, what is their methodology for implementing it and monitoring it, and for how long?
10) Have they been able to reproduce MIC seen in the field with mic seen in the lab using the same plant water?
11) What are the parameters that will be monitored, e.g., planktonic counts, sessile counts, DNA's, etc.?
12) What is the typical timeframe you do for MIC testing? How long should we expect these tests to take?
13) Can you create an artificial MIC solution? How would you go about doing this?
14) Would it make sense for us to focus on a single bacteria type? Or should we be looking at several, all at once? Or one at a time?

Jim Dante provided the following answers by email:

1. Can you tell us about the procedure for transporting plant water?

   It is important to minimize the holding time for microbiological samples to 24 hours or less. Thus, it is best to ship overnight or transport plant water for processing within 24 hours if possible. It is also an option to send to the sponsor, inoculation bottles so that a 'neat' and 'immediate' sample can be extracted and characterized based on whether anything changes with the transported sample that is then characterized once received by the lab. We would be able to see if any of the major bacterial MIC families change during the transport process.

   How will this assure that the bacterial are maintained?

   Ideally samples would be shipped at the relative conditions in which they were collected (temperature, pressure, and degree of aeration). We have various receptacles and transport containers that can maintain heat and pressure, if required. We also have, and are able to build specialized containers/rig for maintaining environment conditions, if required.

2. Can we analyze several plant waters for bacteria commonalities and create an artificial solution for testing based on that?

   Yes, it would be best to characterize several plant waters that have experienced MIC related issues in the past. Different regional samples would allow for more diversity especially if collected during peak MIC season events and/or immediately following rain/flooding which increases runoff carrying increased contaminates (fecal coliforms). Collection can be supplied from cooling ponds, municipal water supply, water storage tank, or dead leg region that the users associate with most like source of contaminants. Sources may be different for each facility.

   Site Collection: location, temperature, pressure, pH, total dissolved solids

Baseline analysis:

- Collection location

Temperature

pH

cATP

DNA analysis: reports the percentage of bacterial DNA found in the sample for each bacterial genus from the test library (cannot be used to identify unknown species)

NACE Standard Test Method (TM0794-2004) for Field Monitoring of Bacterial Growth in Oil and Gas Systems:

- Acid-Producing Bacteria (APB) – Phenol Red Dextrose (PRD)
- Acid-Producing Anaerobic Bacteria (AnAPB) – Anaerobic Phenol Red Dextrose (AnPRD)
- Sulfate-Reducing Bacteria (SRB) – Modified Postgate Medium B (MPB)

(11, 13, & 14) Overall Approach:
There are two potential approaches. The first is to develop a "standardized" test solution. The second approach would involve a fit-for-service type approach. The second approach would require testing in specific water and conditions experienced at the given plant. A "standardized" test solution would allow for a screening test of different materials to determine rank order of resistance to MIC for "generic" test conditions. The generic test environment would consist of a collection of species common to the locations where MIC has been observed in the past from many plants and will have a defined ratio of the types of species found (i.e. APB, SRB, etc.). The steps to developing this standardized test environment are as follows:

i. Analyze plant waters from different facilities as outlined above in #1

ii. Data collected will be correlated with literature a search for most aggressive MIC organisms

iii. Determination of which of these organisms can be obtained from approved suppliers list (quality vetted) and if possible, co-cultured

iv. Bench-level R&D of selected "soup" (mixed or single culture) to determine the growth curve for the culture

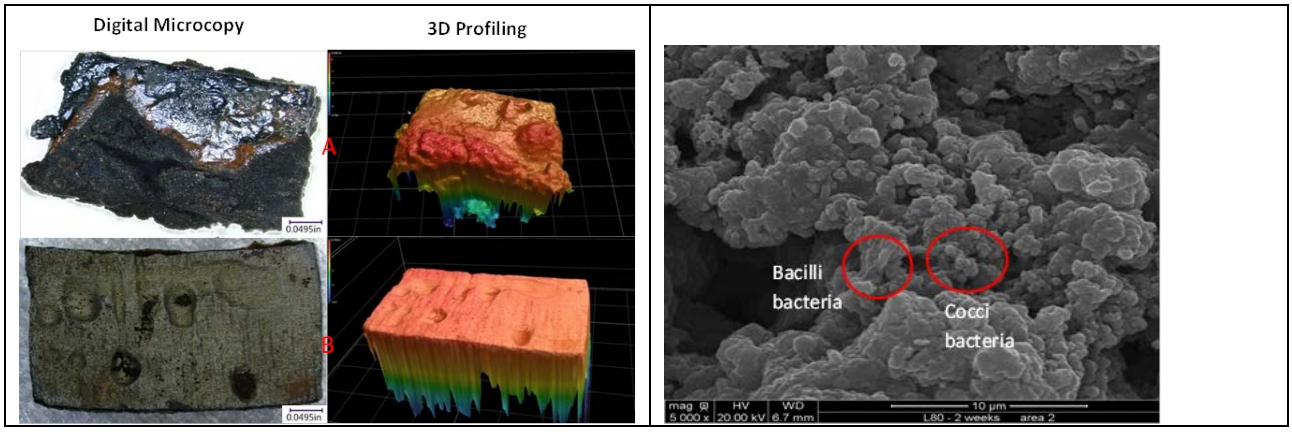
v. Perform materials testing [(static or low flow) until MIC is observed. Media refresh rate would be based on R&D (iv.)]. Multiple materials will be analyzed to determine the rank order of MIC resistance.

*If using an artificial soup instead of actual plant source water, the best growth conditions for the particular organism(s) might not mimic plant conditions, but might provide a more aggressive test which would provide a more conservative materials ranking. As mentioned during the call, it is important for all parties to understand that making of the artificial soup may not give a relevant depiction of the community and interlacing interactions occurring during the plant process (e.g. rise of one population and decline of another or participation by unknown and unidentified bacterial species). If we can produce MIC, with the standard test solution, it will help provide rankings but observed corrosion rates may not be a direct correlation in the field environment.

vi. Post analysis (coupons)

- Imaging (Example images are of bare steel controls used in recent materials testing)

  a. ESEM
  b. Biofilm (by weight) and/or pit (swab/flush) tATP
  c. 3D surface profiling
  d. 3D microscopy



3. How can we assure that we will get MIC?

   We cannot assure that we will get MIC. However, there are a number of things we can do to improve the chances that we will observe MIC:

   - Comparing observed species from the plant water with literature observations will provide some information regarding aggressiveness of species that will be used in the "soup"
   - Use only welded samples
   - Acquire water samples from facilities where aggressive MIC has been observed and during seasons in which MIC is most prevalent.
   - Include several controls. For example, one set of materials should be known to corrode by MIC to ensure MIC can occur. Also, sterile solutions will be used for negative controls and saline solutions for non-MIC corrosion controls will be used.

4. What happens if we don't get MIC attack?

   As with any testing, we will mimic the 'problem' conditions as best possible, which will be best accomplished with input from the sponsors facilities we receive samples from. If MIC does not occur, testing will stop and re-access with sponsors.

5. Should we be testing with aerated water or deaerated water?

   If using plant water for testing then it would be performed at site conditions. If using artificial "soup" then the exposure would be done using inoculated DI water and providing a nutrient source to sustain the microbial population. Temperature, pressure, and aeration conditions for the testing will mimic those found generally in regions where MIC is observed within operator facilities.

6. What temperature should we be testing at?

   Same as question #5.

7. What temperature would culturing be done to categorize the bacteria?

   Culturing the bacteria would be extremely cost prohibitive. Some species may be unculturable. Further, up to half of the organisms identified may be unknowns. This would not be the path we would take for this testing. See #2 above for our approach.

8. Do you have a suggestion for identifying MIC with pitting depth? Is there a certain depth you'd recommend we use as the criteria?

   The pitting depth criterion was developed to distinguish between pitting corrosion in saline solution (or sea water) from MIC in the same solution. This is possible because there is a maximum pit depth for a saline solution (albeit different for different stainless alloys). Pitting deeper than this maximum depth is assumed to be the result of microbial attack. The primary water source for refineries and chemical plants is from municipal water or cooling water lakes where the halide content is relatively low. Further, MIC within the refinery or chemical plant is the result of the specific operating environment experienced. In our approach, control samples (as mentioned previously) that are not inoculated would be used to distinguish MIC from non-MIC corrosion.

9. I would like to know what experience and success SWRI has had in simulating the plant water system in the lab, what is their methodology for implementing it and monitoring it, and for how long?

   At this point, we have not developed a simulated soup to act as a standard test environment. We do have experience and capabilities to carry out the individual tasks needed to develop such a standard exposure condition. Our past MIC studies, for various sponsors, have included use of their actual source water as the inoculum so we have demonstrated the ability to transport and maintain source solutions. We have also studied MIC using specific bacteria (such as SRB's) that we are able to procure from ATCC. We have also been involved with the development of test standards for other applications (e.g. atmospheric corrosion) so understand the process needed to develop a generalized exposure.

10. Have they been able to reproduce MIC seen in the field with mic seen in the lab using the same plant water?

    Yes, see example images above.

11. What are the parameters that will be monitored, e.g., planktonic counts, sessile counts, DNA's etc.?

    See question #2.

12. What is the typical timeframe you do for MIC testing? How long should we expect these tests to take?

    This cannot be known *a priori*. Some guidance can be gained based on past experience. We have performed testing with collected source water that lasted one month. For test times longer than one month, the test volume would require refreshing with source water. This would be similar if testing is performed with artificial solution which would need to be refreshed to maintain culture viability. We have also conducted flow loop testing to study MIC, and that test ran 1 to 2 weeks while refreshing growth media every 3 days. Based on comments from the committee, MIC has been observed seasonally or as the result of plant upset conditions where contaminant water is introduced or inhibitor not added. These comments suggest that MIC occurs rather quickly. It is likely that a 30 day exposure would be sufficient but exposure greater than 90 days would not be justified.

13. Can you create an artificial MIC solution? How would you go about doing this?

    See question #2.

14. Would it make sense for us to focus on a single bacteria type? Or should we be looking at several, all at once? Or one at a time?

    See question #2. Ideally, in the field it is the community of different bacterial families that work together to establish a biofilm and it is their direct metabolic processes or byproducts of metabolism that create MIC issues. The viability of individual species within these communities (and hence the biofilm as a whole) rises and falls creating a dynamic system. The severity of MIC will be driven by the dynamics of the biofilm system. For example, extra cellular membranes and metabolic by-products of aerobic species may provide a suitable environment for the growth of more aggressive SRB species within the biofilm. Without knowing the specific species or types of species responsible for MIC in the environments of interest, we feel it is best to provide multiple types of known species (identified from the different water sources) to the standard test solution and allow a biofilm and subsequent MIC to developed based on the exposure conditions of the test rather than target a singular inoculum.

Summary of Action Items

Path Forward	Responsible	Due Date
Team to provide feedback to Champion and Pradip Khaladkar	All	April 15

Future Meetings TBD