Computational Galvanic Corrosion Prediction 2011

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Galvanic issues – where mix ‘match is a bad plan

- C fiber
- CRES alloys
- Steels
- Al
- Sacrificial coatings

anodic
cathodic
Fundamental Electrochemical Equations

- Multi-ion transport and reaction model & electroneutrality

Chemistry \( \frac{\partial c_k}{\partial t} + \bar{v} \cdot \nabla c_k = z_k F \nabla (\nu_k c_k \nabla U) + \nabla \left( D_k \nabla c_k \right), \quad k = 1 \ldots J \)

Time Flow Electricity Diffusion

- Potential Model
  - Laplace equation
  - Ohm’s Law
  - Electrode Kinetics

\( \nabla \left( - \sigma \nabla U \right) = 0 \)

\( \bar{J} = -\frac{1}{\rho} \nabla U \)

\( \eta(J) = V - U \)
Elsyca GalvanicMaster
FEA boundary conditions defined by Integrates into CAD model
Elsyca GalvanicMaster
Measurement-based

Measured polarization data
- Substrate/coating/treatment
  - Electrolyte
  - Rotating electrode

This is the more familiar plot
Elsyca GalvanicMaster

Manual materials assignment, automatic calculation

Assign material/coatings in CAD

Design engineer simply brings the CAD STL output file into Galvanic Master, assigns materials, hits the Calc Button.
Galvanic software computation flow

- Material Identification
- Environment and Product Location Wizard
- Meshing (STL to mesh)
- Solving Automatic Reporting

Identify materials, coatings on CAD dwg
Define electrolyte and service environment
Automaticall y remeshes for accurate FEA calculation
Automaticall y solves and produces report

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Elsyca GalvanicMaster
Visualization – produces 3-D galvanic corrosion picture that engineer can view, turn, zoom

Corrosion currents

Corrosion rates

2-D map, 3-D visualization to examine

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What does it do/not yet do?

- Predicts $t=0$ corrosion current (rate)
  - Will tend to be high as initial corrosion rate only
- Can include any surface treatment provided polarization data can be obtained/ measured for surface material and electrolyte
- Full or partial liquid coverage
- Makes 3-D output to examine and manipulate

- Changes in surface as corrosion products build up
- Changes in chemistry of surface liquid films
- Corrosion rate variation with time

So, it will predict the “hot spots” and how hot they are likely to be, but does not yet predict long term corrosion rate.

Does this

Does not yet include
What if you connect an EN plated plug to a Cd plated socket?

Ni

Cd

Al backplane corrodes right at socket to protect Ni

ZnNi on socket corrodes to protect electroless Ni on connector

If water accumulates around connector, corrosion worse

But EN-PTFE is not Ni. We have no galvanic data for it. So, what will really happen with EN-PTFE? Data generation to be done soon.
Computational Corrosion Prediction for DoD

- NAVAIR Durable Aircraft program
  - Corrdesa LLC awarded Phase 1 SBIR from ONR for development of Elsyca Galvanic Master for ultimate integration into design (and redesign)
  - Phase 1 just to demo that approach works to show “hot spots”
  - Ultimate aim is to develop an add-in for CAD packages such as Catia, SolidWorks, Autocad, etc. that includes corrosion product build-up, etc. and operates directly from within CAD package
    - Will include alloys, composites, coatings, sealants (so could do water penetration around electronics and between panels)
    - Aim is that it must not require any FEA or galvanic model understanding – just a design tool
    - Even I can do it!
Development for ships, aircraft, vehicles

- NRL Future Naval Capabilities, Design Modules for Corrosion Prevention (DMCP)
  - Aim is to integrate models for corrosion into design (galvanic, pitting, crevice, etc.)
  - Teams and programs being assembled, White Papers due Nov 14
  - Have sent in white paper for galvanic corrosion
  - Ultimate aim is similar to Corrdesa aim for galvanic, but extended to all corrosion mechanisms
    - Dealing with IP on the package with half a dozen companies will be fun!
Conclusion

- Galvanic prediction available now for complex assemblies
- Shows hot spots and initial corrosion rates directly on 3-D CAD drawing
  - A good way to check drawing changes or fixes
- Not yet a tool for long term corrosion rate prediction
- Not yet ready for direct integration with CAD design packages