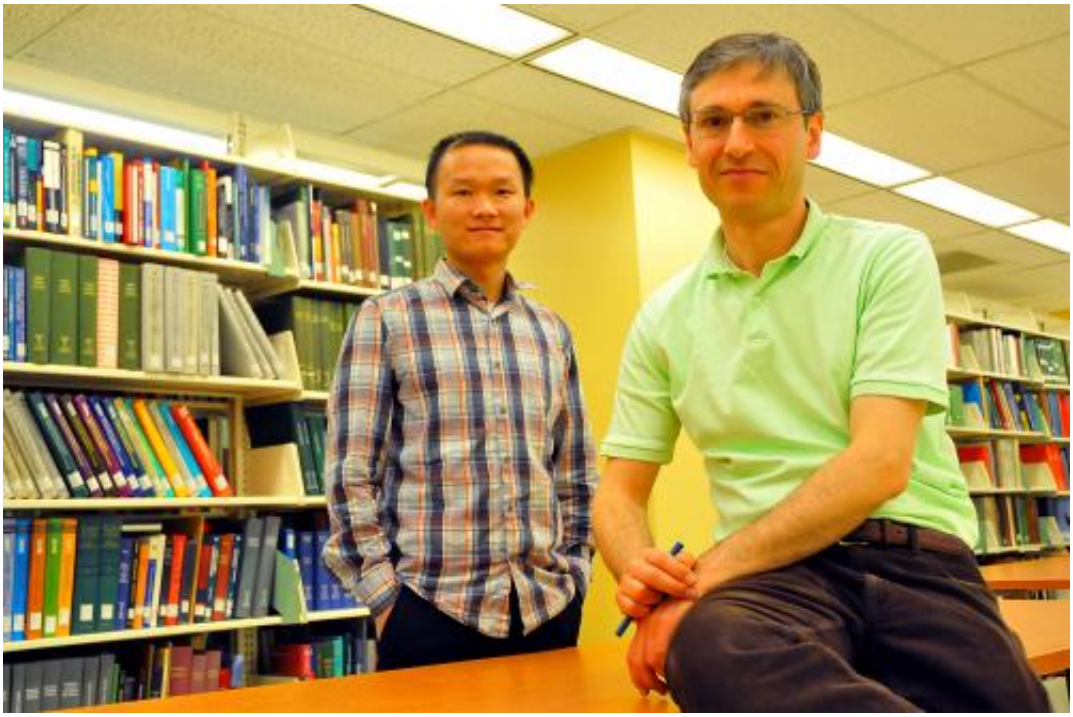
Model captures new dynamics of corrosion damage

March 19 2015, by Scott Schrage



Research by UNL's (from left) Ziguang Chen and Florin Bobaru has led to the creation of a new model that better predicts the effects of corrosion. The study was published in the Feb. 27 online edition of the Journal of the Mechanics and Physics of Solids. Credit: Scott Schrage/University Communications

University of Nebraska-Lincoln engineers have become the first to develop a model that literally looks beyond the surface of corrosion to better predict its spread.

The model's unique capabilities could allow engineers to more precisely forecast catastrophic structural failures and design materials less susceptible to the widespread issue, the researchers reported.

The new model simulates the rate and profile of pitting corrosion, an especially potent form of degradation that is difficult to detect yet can ultimately trigger the collapse of an entire structure.

Corrosion typically arises from chemical interactions between a surface and a liquid solution such as water. True to its name, pitting corrosion specifically produces cavities that can compromise structural integrity from the inside out.

"If you can model a process, that's a great first step in trying to improve the design of a material or structure," said Florin Bobaru, the model's co-creator and professor of mechanical and materials engineering. "Once you have that understanding, you can say, 'I know this piece is corroded, but it's going to last two more years,' or, 'I better replace this next month because there's a high potential that a crack will run through and damage the whole structure.'"

While formulating their model, Bobaru and postdoctoral researcher Ziguang Chen examined existing experimental data on corrosion in one-dimensional components that included wire. They then calibrated the parameters of their model accordingly, finding that its simulations of corrosion-related damage closely resembled the experimental outcomes.

After modifying their math and associated code, Bobaru and Chen expanded the model to replicate corrosion of two- and three-dimensional structures. The team's model can be applied to both metallic and non-metallic materials, whether capturing the growth of rust on a steel pillar or the evolution of a pothole in a concrete street.

"People have been trying to model this for many years, but they've struggled because it's difficult to track how the interface between a corroding solution and the solid material evolves over time," Bobaru said.

These struggles stemmed in part from misconceptions of that interface, which previous research had usually conceived as a membrane separating the pristine metal surface from the corrosive solution, according to Bobaru.

Inspired by more recent atomic-scale investigations, Bobaru and Chen instead treated the interface as an initial layer of corrosion that indicated the presence of fainter but advancing degradation just beneath the surface.

"Our contribution was the modeling of this sub-surface layer as one that eventually weakens a material and could influence how potential cracks grow from there," Bobaru said.

The new model essentially simulates two separate yet related processes. It first captures the corrosion that occurs via the escape of unbalanced atoms known as ions, which begin migrating from undisturbed metal to the interface of a corroded pit.

The presence of an encroaching liquid solution, such as rainwater that might cling to the surface of a bridge, accelerates the loss of ions by dissolving the metal that resides near the interface. The departing ions leave empty space in their wake, effectively poking holes in the material.

The model then calculates how this diminishing concentration of ions contributes to the deterioration of a structure's mechanical bonds—the physical linkages that help maintain its solid form.

"It tells us what concentration of ions we have to lose in order for a mechanical bond to break," Bobaru said. "So the ion diffusion problem is coupled with the mechanical damage to the material."

Though the new corrosion model cannot yet simulate the fractures that result from broken mechanical bonds, Bobaru and Chen are now attempting to incorporate them.

"This is, in a sense, just a first step," he said. "Once you have corrosion pits forming, a crack can emerge. This crack growth is influenced by corrosion, and the corrosion is influenced by the crack growth. The solution can get in there, speeding up the material degradation and potential catastrophic failure of your system. So we're now exploring that."

A study describing the new corrosion model appeared in the Feb. 27 online edition of the *Journal of the Mechanics and Physics of Solids.*

Provided by University of Nebraska-Lincoln