# Numerical Simulation of Carbon Steel Corrosion Exposed to Flowing NaCl Solutions Through an Annular Duct

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## Abstract

Carbon steel corrosion by sodium chloride solutions have been extensively studied under a large variety of conditions mostly on planar surfaces, as circular or square geometries, which for the modeling and simulation, the analysis can be reduced to a two dimensional problem [1]. In this work, a three-dimensional mathematical model under stationary conditions was established for the corrosion of carbon steel devoid of any oxide film. The analysis considers three mechanisms of mass transfer, by molecular diffusion, migration and convection based on Nernst-Planck equation and coupled to the Navier-Stokes equation to describe the fluid motion. The finite element method, implemented in COMSOL Multiphysics® software, was used to simulate the corrosion of carbon steel immersed under an axial flow of unbuffered and aerated NaCl solution at low Reynolds-numbers. The geometrical model consists of a cylindrical sample sealed at both end with non-conductive materials and arranged vertically and concentrically into the corrosion cell to form the annular body (Figure 1). Kinetic parameters for the electrochemical reactions of oxygen reduction and hydrogen evolution at the cathodic side, and iron oxidation at the anodic side, were determined from the fit of experimental current density-potential curves using the mixed potential theory [2]. The finite element method provides fundamental information to explain various aspects of the corrosion behavior, such as the concentration profile of ionic species at the solid-liquid interface (Cl-, OH-, Fe+2, H+) as well as the oxygen concentration profile (Figure 2), which are related to the oxide film stability and pitting formation. A good agreement was obtained between the experimental and calculated result, which shows that the concentration of species at the specimen surface is strongly affected by the fluid flow in comparison with stagnant conditions (Figure 3). Furthermore, with the use of this model, the results clearly show that in unbuffered solutions the surface-pH is much different from the bulk solution pH. These changes are attributed at the high reaction rate to produce hydroxyl anions from the cathodic reactions on the carbon steel surface.

## Reference

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## Figures used in the abstract

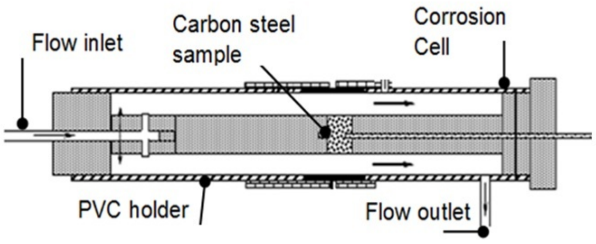

**Figure 1**: Corrosion cell setup used for the electrochemical experiments.

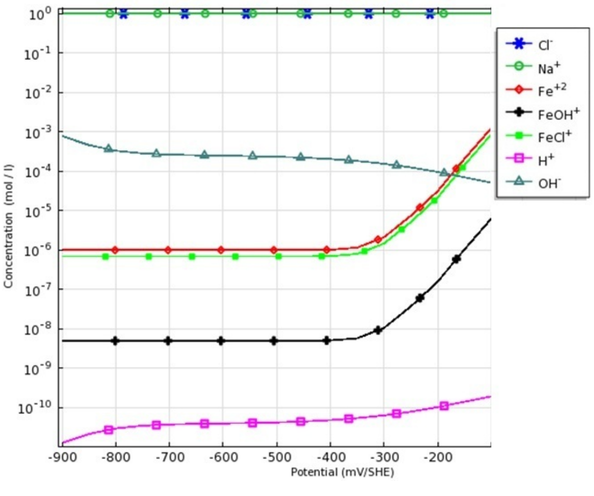

**Figure 2**: Ions concentrations at the carbon steel surface as a function of applied potential.

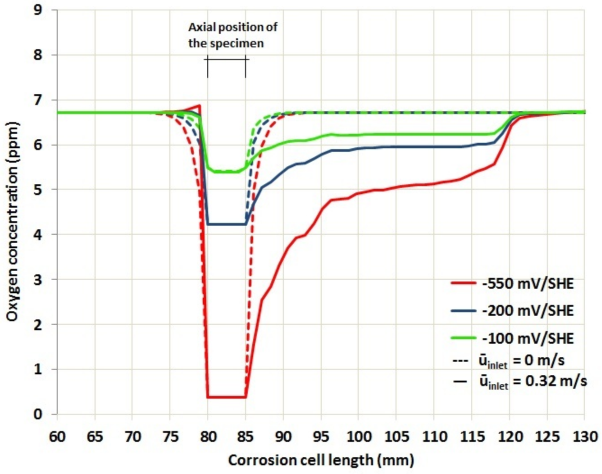

**Figure 3**: Axial oxygen concentration profile at the specimen surface under stagnant (dashed line) and dynamic conditions (continuous line) measured at different applied potentials.