FEM-DNS OF COUPLED FLOW AND TRANSPORT IN ROTATING-DISK ELECTROCHEMICAL CELLS

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We consider the rotating disk flow coupled, through the fluid viscosity, to the mass concentration field of a chemical species. This configuration refers to an electrochemical cell with an working electrode consisting of an iron rotating rod which is dissolved in the electrolyte, a 1 **M** $\mathbf{H_2SO_4}$ solution. Polarization curves obtained in such cells present a current instability at the beginning of the region where the current is controlled by the mass transport. The instability appears at a certain value of the applied potential and is suppressed beyond another value. Dissolution of the electrode gives rise to a thin concentration boundary layer, which, together with the potential applied to the electrode, results in an increase in the fluid viscosity and in a decrease in the diffusion coefficient, both affecting the current.

This work deals with the Direct Numerical Simulation (DNS) of the coupled hydrodynamic and concentration fields. A phenomenological law is assumed, relating the fluid viscosity to the concentration of a relevant chemical species. Parameters appearing in this law are evaluated based on experimental electrochemical data. The Finite Element Method (FEM) is employed to solve the coupled incompressible Navier-Stokes and chemical species transport equations, using a tetrahedral mesh with MINI element. A semi-Lagrangian technique [1] is employed for the discretization of the material derivatives, and the temporal-spatial discretization is made through the implicit Taylor-Galerkin method, obtaining an unconditionally stable scheme suitable for large Reynolds and CFL numbers. Pressure and velocity are solved using a segregated LU factorization scheme. The resulting symmetric and positive-definite systems are solved by the Preconditioned Conjugate Gradient method. The numerical simulation results show stability properties in good agreement with those obtained by linear stability analysis [2], that link the stability of the fields to the current instabilities observed in the experimental setups.

References

[1] A. Robert, "A stable numerical integration scheme for the primitive meteorological equations," *Atmos. Ocean*, p. 19-35, 1981.

[2] J. Pontes, N. Mangiavacchi, A. R. Conceição, O. E. Barcia, O. E. Mattos, and B. Tribollet, "Rotating Disk Flow Stability in Electrochemical Cells: Effect of Viscosity Stratification," *Phys. Fluids*, v. 16 (3), p. 707-716, 2004.