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Modelling the two-phase flow and current distribution along a vertical gas-evolving electrode

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The bubbly two-phase flow and electric current density distribution along a single, vertical, gas-evolving electrode are modelled and the results of a boundary layer analysis are presented. Existing empirical models for particle transport in sheared and sedimenting suspensions are adopted for the bubble mixture to close the two-phase model. Ionic species concentrations are shown to be essentially homogeneous as the mixing effect of the bubble suspension usually is much larger than dispersion by molecular diffusion even at laminar flow conditions. The non-uniformity of the bubble distribution along the electrode results in a non-uniform current density distribution, which agrees well with existing experimental findings in the literature.

1. Introduction

Gas-evolving electrodes frequently occur in industrial applications of electrochemical processes, as well as increasingly being the subject of basic research in chemical engineering. An industrial example is the chlorate process where sodium chlorate is produced under the development of hydrogen and oxygen gas. Mostly, an electrode and its counter electrode are positioned vertically, i.e. with the largest reactive surface facing the horizontal direction. The evolved gas is thus free to move-upwards so as not to accumulate on any of the electrodes. Nevertheless, the presence of gas, often in the form of small bubbles, and its motion have great impact on the performance of the electrode. A description of the phenomena involved, both from an electrochemical and a fluid dynamical point of view, is given below.

A general description of gas-evolving electrodes, and the state of the art of modelling such systems, is given by Vogt (1983). Of all the various regimes of gas evolution we are here interested in cases of nucleate gas evolution. This means that if the supersaturation of dissolved gas in the liquid adjacent to the electrode surface is sufficiently high, gas bubbles will form at predetermined nucleation sites on the surface. The bubbles grow as a result of the supply of dissolved gas from the electrolyte. In the nucleation regime, the gas bubbles leave their nucleation sites when they reach a size at which buoyancy and shear forces of the liquid are large enough to exceed the interfacial tension force by which the bubbles adhere.

From a hydrodynamic point of view the problem essentially is that of describing the two-phase flow of a bubble suspension. Experimental data, describing elements of the two-phase flow in a small electrolytic cell developing hydrogen bubbles, are given by e.g. Boissonneau & Byrne (2000). Such systems often develop turbulent flow but there are also laminar regimes of practical interest. Of particular interest here are