



Analysis of liquid circulation and mixing in a partitioned electrolytic tank

B. Ashraf Ali, S. Pushpavanam*

Department of Chemical Engineering, IIT-Madras, Chennai 600 036, TN, India

ARTICLE INFO

Article history:

Received 16 February 2011
 Received in revised form 3 June 2011
 Accepted 6 June 2011
 Available online 20 July 2011

Keywords:

Gas evolution electrodes
 PIV
 Turbulence
 Electrolysis of water
 Mixing of acid–base chemicals

ABSTRACT

The performance of an electrochemical process depends critically on the mobility of the reacting species or ions towards the electrode surface. In this work, a partitioned electrolytic cell is studied. Here the fluid flow is induced by gases which evolve at the electrode surface. The liquid circulation induced by the rising bubbles is primarily responsible for mixing. In this study, the liquid circulation in a cell where an alkaline solution of water is electrolyzed using different Nickel designs of electrodes is investigated using PIV. For each electrode, the optimum operating conditions such as voltage and concentration of electrolyte which resulted in good mixing are found. The flow-field is quantified by calculating time averaged velocity profiles along the horizontal line and by analyzing the temporal variation of liquid velocity at a point. It is found that there are differences in the circulation and hence vorticity in the two compartments, anode and cathode. The effect of gas evolution on mixing between the two chambers is studied by taking uric acid in the cathode half and NaOH in the anode half. The flow induced by the evolved gas bubbles leads to convective mixing in the two chambers. The mixing time is calculated by measuring the variation of current with time under potentiostatic conditions. This is verified by measuring the pH in anode and cathode compartments during the electrolysis.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

In several electrolytic processes such as chlorine production, water electrolysis, there is gas evolution at the electrode surface (Philippe et al., 2005). The performance of such electrolytic processes is intrinsically related to mass transfer effects which are influenced by hydrodynamics. This has led to an increase in investigations on the role of hydrodynamics in electrochemistry. The dispersed phase (gas bubbles) modifies the electrical and thermal properties of the electrolyte, diffusive transport of electro active species and current density. This in turn, affects the macroscopic cell performance. Fluid flow in the cell depends on the release of gas bubbles, which in turn depends on the cell design. Thus, the understanding of gas–liquid flows in electrolytic systems is very important from the view-point of enhancing mass transport, system optimization and improving efficiency (Mat and Aldasb, 2005). The gases released at the electrode surfaces move upward due to buoyancy. The presence of the gas phase at the electrodes can be detrimental to the process as it blocks the active surface area of the electrodes and increases the resistance of the electrolyte (Boissonneau and Byrne, 2000). The presence of gas, in the form of small bubbles, and its motion has a significant impact on the performance of the electrolytic cell (Dahlkild, 2001).

Boissonneau and Byrne (2000) investigated the velocity field in an electrolytic cell with vertical electrodes through Laser Doppler Anemometry and Particle Image Velocimetry. Their experiment relates gas evolution to the hydrodynamics of electrolyte flow through a narrow vertical channel. They showed that although the flow is laminar in terms of the Reynolds number range considered, the bubbles induce local turbulence which causes velocity fluctuations due to the interactions with continuous phase.

Sasaki et al. (2003) analyzed the behavior of the gas bubbles for optimizing the electrode spacing through PIV. They have shown that when the electrode spacing is shortened, the average rising velocity of bubbles decreases considerably due to wall friction. Their results also indicate that the hydrogen bubbles induce a faster flow locally near the electrode surface, while the oxygen bubbles rise at a relatively slow rate.

Philippe et al. (2005) discussed the hydrodynamic and electrical properties in a laboratory scale electrolysis cell through CFD simulations based on a Lagrangian approach. They concluded that the fluid flow induced by bubble release from the electrodes had an important influence on the cell performance.

Jupudi et al. (2009) studied the effect of bubbles on the current density distribution in an alkaline electrolyzer using a two-dimensional Euler–Eulerian model. They found that their CFD model captures the effect of cell voltage and inter-electrode gap on current density accurately.

Sun et al. (2009) investigated the flow in an electrolyzer using a three-dimensional CFD model. The computational model was validated for electrolysis of a zinc sulfate solution from PIV data.

* Corresponding author. Tel.: +91 44 22574161; fax: +91 44 22570509/22570545.
 E-mail address: spush@iitm.ac.in (S. Pushpavanam).

Aldas (2004) investigated gas evolution in a vertical electrolytic cell with a two-phase flow model developed in PHOENICS. The model showed that gas release is enhanced at high current density. However, a layer of gas accumulates on the electrode surface, decreasing the active area of reaction and adversely affecting the reaction rate. It was concluded that for electrolysis to proceed efficiently, the gas released should be removed from the reaction sites to increase surface area available for reaction.

Most of the electrolysis studies so far were carried out using a porous or a membrane partition separating the cathode and the anode compartments. This allows transportation of ions between the chambers. In several systems such as electrolysis of magnesium chloride, there is a non porous barrier between the two chambers and a small gap at the bottom through which ion transport takes place. In such systems, it is possible to investigate the effect of gas evolution on the hydrodynamics in the two halves. The two halves are essentially decoupled except for the small opening below the partition. The gas evolution at the surface of the electrodes creates a two-phase flow in each half. In such a system, the reactions at each electrode can be studied in view of the partition. The two halves behave differently as the gases liberated at the two electrodes are different. This design can also be used to determine macroscopic information on mixing between two halves of such electrolytic systems.

Our objective is to understand the liquid flow-field in water electrolysis for different electrode designs using PIV. Nickel is used as the electrode material and the electrolysis of an alkaline solution of water is studied. Based on the hydrodynamics, a suitable electrode design and optimum operating conditions such as voltage and concentration of electrolyte is chosen. To understand mixing in the system, electrolysis is then carried out by keeping uric acid solution in the cathode half and NaOH solution in the anode half of the partitioned cell. This helps to understand the effect of gas evolution on fluid flow in each half and mixing.

The paper is structured as follows. We first describe the experimental setup for carrying out hydrodynamic as well as mixing studies. The results are quantified in Section 3. We summarize our findings in the last section.

2. Experimental description

In this work, focus is on an electrolytic system where gas evolution occurs from the surface of the electrode. For this, electrolysis of a solution of a 1 M NaOH was conducted in a transparent rectangular acrylic tank 30 cm high, 20 cm wide and 2.5 cm deep. The tank was partitioned at the middle using a Perspex sheet (Fig. 1a) and there was a gap of 1 cm at the bottom through which

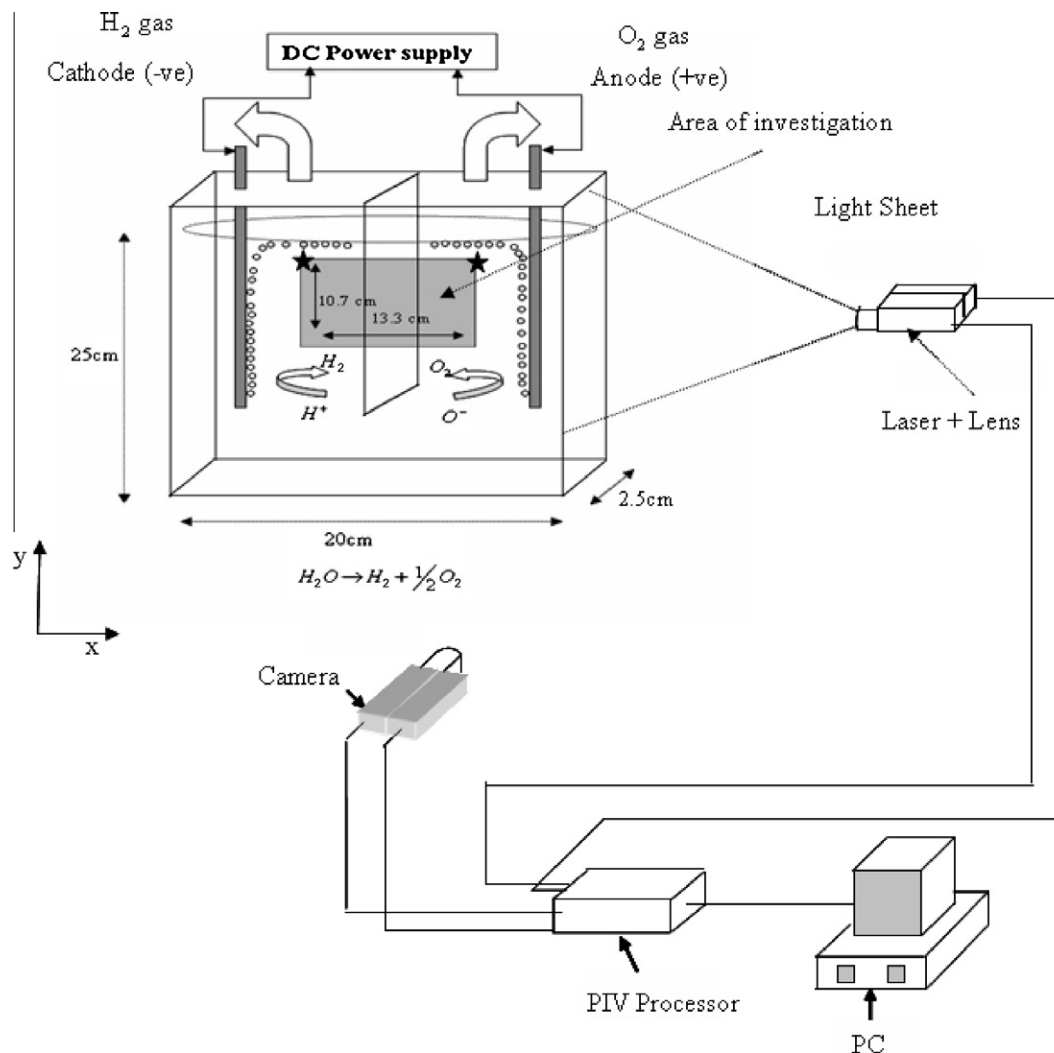


Fig. 1a. Experimental setup for PIV analysis of water electrolysis system.

Download English Version:

<https://daneshyari.com/en/article/667761>

Download Persian Version:

<https://daneshyari.com/article/667761>

[Daneshyari.com](https://daneshyari.com)