Electrolysers for hydrogen production
- effect of flow behaviour on performance

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Abstract

Water electrolysis is one of the cleanest pathways for hydrogen production. During the industrial water electrolysis process, the evolving gas bubbles form bubble curtain that covers the electrode surface, which contributes about 1/3 of the total energy loss in the electrolyser. Understanding the gas bubble behaviour in water electrolysers holds the key to improve the performance of water electrolysis cell.

This project aims to develop an understanding of bubble behaviour and ionic mass transport in water electrolysis process, and to identify potential solutions to accelerate bubble departure and enhance ionic mass transport to improve the electrolyser cell performance. Using analytical and experimental method (bubble & particle image velocimetry), the project will develop the understanding of the influence of gas volume fraction and electrolyte flow on the current density distribution, ionic mass transport and performance of a water electrolysis cell. The project will also investigate the sensitivity of the flow velocity field on the behaviour of gas bubbles in an electrolyser. The mechanism of gas bubble induced ionic mass transport in a water electrolysis cell will be proposed.

Background

- More than 90% of global hydrogen is produced from the syngas by cracking fossil fuels, which contributes to global warming. Green hydrogen produced from water electrolysis meets 4% of global hydrogen demand.
- Industrial water electrolysers (alkaline water electrolyser and proton exchange membrane electrolyser) suffers from energy loss due to the gas bubble coverage over their electrodes.
- There is a lack of understanding of the mechanism of how electrolyte flow field can enhance bubble removal and ionic mass transport in the industrial electrolysers.

Aim

To develop a high-fidelity validated model of bubble behaviour and ionic mass transport in the water electrolysis process sensitive to flow field parameters.

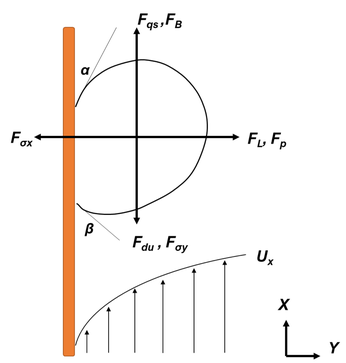
Objectives

- To develop the understanding of the influence of flow behaviour on the current density distribution, void fraction and performance of a water electrolysis cell.
- To investigate the effect of the flow velocity field on the behaviour of gas bubbles in an electrolyser.
- To investigate the effect of gas bubbles on the ionic mass transport.

Methodology

- **Bubble growth on electrode surface**

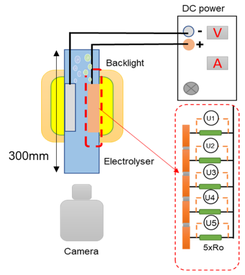
➢ Force balance analysis for bubble departure is conducted.
➢ Bubble departure size will be validated with experimental results.



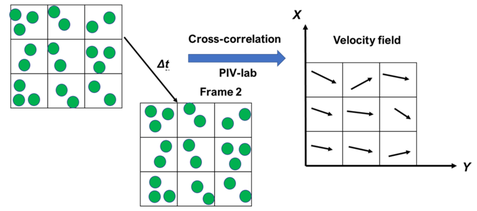
Forces on a growing bubble at electrode surface subjected to electrolyte flow. F_{qs}: quasi-steady drag. F_B: buoyance force. F_{du}: unsteady drag (growth force). F_L: lift force. F_p: pressure force. F_σ: surface tension. u – electrolyte velocity.

- **Bubble visualisation & image velocimetry**

➢ Use laser sheet / LED backlight as light source.
➢ Use cross-correlation technique to calculate velocity field of the bubbly flow in the electrolyser.



Schematic diagram of the developed electrolysis test rig with local current density measurements. The bubbly flow is captured by the camera at 240fps with LED backlight.

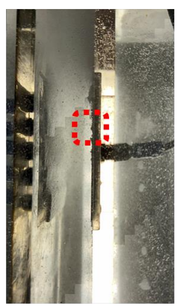


An illustration of cross-correlation technique for the post-processing of images from PIV camera. Adopted from Raffel (2018).

Results

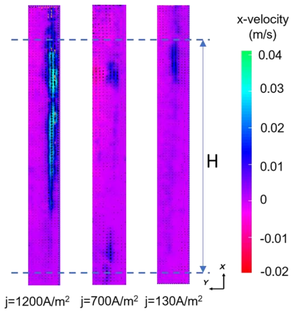
- **Bubble image velocimetry - Preliminary study**

➢ Image velocimetry setup obtains velocity field of bubbly flow in the electrolyser.
➢ Bubble size and x-velocity increase with the increase of current density.

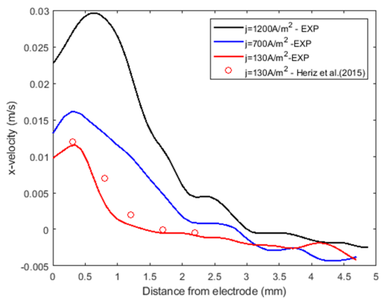


Water electrolysis test under a current density of 1200A/m^2.

Hydrogen gas bubble evolving from electrode surface under a current density of 1200A/m^2.



A comparison of average flow x-velocity derived from post-processing. Window size: 32x32. Pixel size: 12.5μm.



Dependence of x-velocity on the distance from electrode for various current densities.

Future Work

- To investigate the behaviour of gas bubble subjected to forced convection.
- To improve the technique for the visualisation of electrolyte flow field around a gas bubble.
- To develop the mechanism of gas bubble induced ionic mass transport and its effect on the performance of a water electrolyser.

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Zoom link: https://adelaide.zoom.us/j/4368859056?pwd=aFBzSVFwWG93TTg4a3ZWZ3F6QkYxdz09