Comprehensive Modeling and Analysis of Bubble Dynamics and its Impact on PEM Water Electrolysis Performance

Zerrougui Islam[1], Zhongliang Li[1*], Daniel Hissel[1,2]
[1]*Université de Franche-Comté, UTBM, CNRS, institut FEMTO-ST, FCLAB, Belfort, France*
[2]*Institut Universitaire de France*

PEM (Proton Exchange Membrane) electrolysis is a promising technology for energy storage and green energy applications. It is a type of electrolysis that uses a solid polymer electrolyte membrane to facilitate the splitting of water molecules into hydrogen and oxygen gases.

During PEM electrolysis, gas generation occurs in the form of micro bubbles that form on the Porous Transport Layer (PTL) surface. These bubbles can significantly impact the overall performance of the cell and can contribute to degradation mechanisms by obstructing the active sites involved in electrochemical reactions [1]. This obstruction can lead to an uneven distribution of currents across the membrane's surface, which can result in the formation of localized areas of intense heat known as hotspots. The presence of hotspots has a detrimental effect on the durability of the cell, causing accelerated degradation over time and a decrease in overall cell durability [2]. However, the current state of research lacks a comprehensive model that accurately captures the behavior of bubbles and their specific impacts on overall cell performance in which most of the available model on literature are made up with empirical equation which do not provide a complete understanding of the underlying phenomena.

This study presents a modeling approach for PEM electrolysis that incorporates a multi-physics model and a bubble generation model. The multi-physic model is used to determine the overall functioning of the PEM electrolysis including the different mass flows and voltage under various operation conditions. Additionally, a force balance model is developed to investigate the dynamics of bubbles along the x-axis that is vertical to electrolysis MEA surface. The bubble model enables the study of the impact of temperature, pressure, contact angle, and current density on bubble growth, as well as the effect of water flow on bubble detachment from the PTL surface (figure 1 a). The two models are combined into a single system, and the influence of bubbles on the electrolysis performance is demonstrated (figure 1 b). This integrated model can be further utilized for optimal control strategies aimed at enhancing cell efficiency.

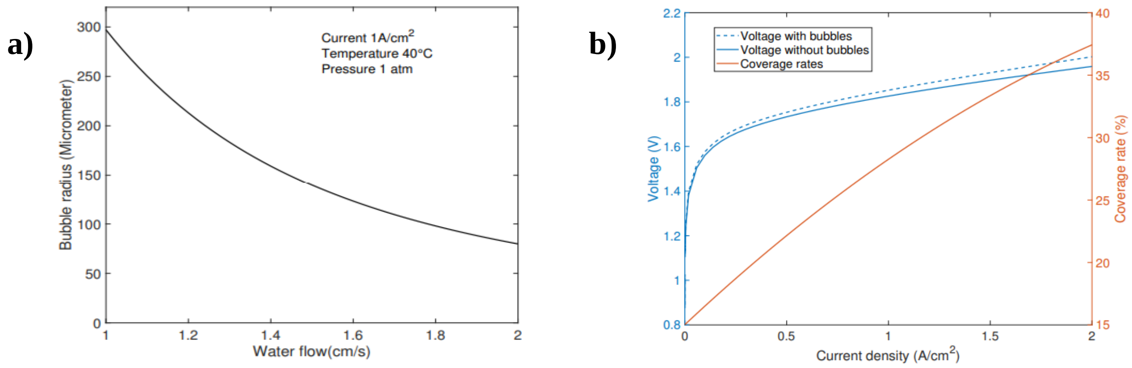

Figure 1. a) bubble detachment radius as function of water flow ,b) polarization curve with/without bubble consideration and coverage rates

[1] A. Angulo, P. van der Linde, H. Gardeniers, M. Modestino, and D. F. Rivas. Influence of bubbles on the energy conversion efficiency of electrochemical reactors. Joule, 4(3):555–579, 2020

[2] Q. Feng, G. Liu, B. Wei, et al. A review of proton exchange membrane water electrolysis on degradation mechanisms and mitigation strategies. Journal of Power Sources, 366:33–55, 2017.

*author to whom correspondence should be addressed: zhongliang.li@univ-fcomte.fr