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Flow Pattern Prediction in the Cooling Circuit of the PEM-Electrolysis using Machine Learning

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Extended Abstract

Gas-liquid two-phase flow systems are frequently encountered in various industrial applications. Proton-Exchange-Membrane (PEM) electrolysis is a promising technology for hydrogen production. This process produces oxygen at the anode. In the cooling circuit on the anode side, supersaturated water streams and oxygen exist in two forms: as dissolved molecules in water and as a gas phase. The amount of oxygen formed is one of the important factors influencing the flow pattern, along with the properties of the phases and the geometry. Moreover, the modelling of two-phase flow and heat transfer in the heat exchanger is highly dependent on the flow pattern. It is therefore necessary to predict the flow pattern before proceeding with the flow and heat transfer modelling.

The present study focuses on predicting the flow pattern in horizontal pipe flow, where five flow patterns can be observed: dispersed bubbly, intermittent, annular, smooth stratified, and wavy stratified [1]. Over the last decades, several models have been developed based on the physics describing two-phase flow and empirical correlations. In this study, the mechanistic model of [2] Taitel et al. (1976) is used. The numerical algorithm was verified by comparison with experimental results. In addition to mechanistic modelling, machine learning has recently gained interest in the field of two-phase flow [3, 4]. The prediction of flow patterns appears to be a classification task that can be solved by machine learning. This is motivated by the availability of a collected dataset from different experimental investigations that can be used to train machine learning models. This study focuses specifically on the data set for an inclination range of -10° to 10°, where the five flow patterns can occur. At the begin, the data has been prepared, and relevant features were selected. The relevant features for this study include pipe diameter, pipe inclination, operational parameters such as superficial velocities, and thermodynamic properties of the involved phases. Overall, five machine learning models were trained and evaluated using common metrics such as accuracy, cross-validation, and confusion matrix. After completing the training and test, an additional test was conducted on a third-party dataset to ensure unbiased performance evaluation.

The investigation shows that the highest performing classifier achieves an accuracy of 95%, while the lowest performing classifier has an accuracy of 75%. Next, the model of Taitel et al. (1976) and the best machine learning classifier were used to generate a flow map of water oxygen flow. To do this, we implemented an algorithm that identifies and plots transition points. This allows the graphical definition of transition lines.

Keywords: two-phase flow, machine learning, flow pattern prediction, electrolysis

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