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Bubble Evolution in the Cooling-Circuit of the PEM-Electrolysis

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Extended Abstract

The expected demand for hydrogen in the process of decarbonisation of the economy and the energy production leads to an upscaling of the hydrogen production based on electricity from renewable energies. The polymer-electrolyte-membrane (PEM)- electrolysis has an advantageous load change behaviour. Therefore, it can be operated both dynamically and at part-load, which means that it can be easily combined with highly fluctuating power from renewables such as wind and solar energy [1].

Overall, there is a creation of molecular oxygen at the anode of the electrolysis cell due to the chemical reaction $2H_20 \rightarrow O_2 + 4H^+ + 4e^-$ [1]. Initially, the oxygen molecules are dissolved in water. Because of the high amount of produced oxygen, the solubility of water is exceeded. This event is called super-saturation and it leads to an oxygen bubble evolution. In the case of the PEM-electrolysis, the super-saturated water enters a cooling circuit after it flows through the anode site of the electrolysis stack. This results in an ongoing bubble evolution in the cooling circuit. If the water is still super-saturated after the gas-liquid separator, the bubble evolution will even influence the heat transfer in the heat exchanger.

The scope of our research is to investigate the described bubble evolution in the cooling-circuit of the PEM-electrolysis and to examine the influence of the bubbles on the heat exchange. Overall, the process of bubble evolution can be divided into five steps: nucleation at grooves in the pipe surfaces, bubble growth, detachment from the nucleation site, rise in the liquid flow with further growth and coalescence [2]. Each of these steps will be described with an analytical-empirical model. For this purpose, appropriate approaches from the literature will be adapted and applied to the described cooling-circuit. A corresponding model for the calculation of the bubble departure diameter has already been presented [3] and the next steps are currently being worked on. Furthermore, the models will be verified experimentally. Therefore, a corresponding experimental plant is currently under construction. With this system it will be possible to produce a defined super-saturation through a pressure reduction. This will enable the investigation of the bubble evolution in different devices like a pipe, a rectangular flow channel and a plate heat exchanger. Thereby, the first two devices are designed to be transparent so that all steps of the bubble formation can be observed with a high-speed camera, while the heat exchanger is used to study heat transfer.

The main objective of this project is to create a calculation tool which will estimate the bubble evolution at a given flow condition and super-saturation. The focus here is primarily on estimating the duration of bubble evolution in the flow, the bubble size distribution and the number of bubbles that are created. We also want to investigate how long it takes for the dissolved oxygen concentration in the flow to approach solubility. The information gained can be used for the design and improvement of the devices of the cooling circuit, like the liquid-gas separator and the heat exchanger. Furthermore, an optimization of the heat transfer is targeted.

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