Molecular Hydrogen Tracking In An Electrolytic Polishing Process

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COMSOL Conference 2016 Munich

Introduction

In a water based electrolytic polishing process, the formation of molecular hydrogen at the cathode is unavoidable and it can contribute to the formation of surface defects at the anode side. This paper presents the work to model and simulate the molecular hydrogen flow inside radio frequency cavity geometries and compares it with the presence, type and relative position of certain defects in real radio frequency components that went through an electrolytic polishing process. Geometry and flow optimisation hints to reduce molecular hydrogen induced surface defects are also presented.

Input data and assumptions

Geometry: Old and new cathode geometry were assessed.

Hydrogen bubble size: bellow 1 mm in diameter

Bath flow: 5 to 20 litres per minute

Hydrogen mass flow: 0.23 to 0.50 µg.s^{-1}

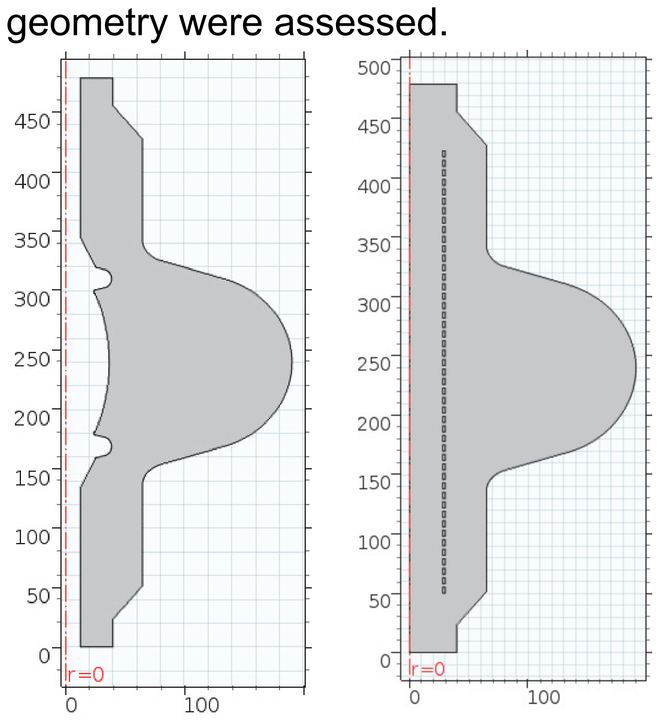

Figure 1. Old cathode (left) and new cathode (right) axisymmetric geometry representation. Axis values are in mm.

COMSOL model

The model presented here used the Turbulent Bubbly Flow physics module and followed some suggestions found on the airlift loop reactor application (Application ID: 10356) [6].

The study was done as time dependent in order to evaluate the time needed to reach a stationary regime in comparison with the process running time.

Reynold number values barely overcomes 2100 threshold value for turbulent flow, but complexity of the geometry and the added flow dynamics accounted for the hydrogen bubbles might explain why the Laminar Bubbly Flow module was unable to reproduce experimental observations as the turbulent module did.

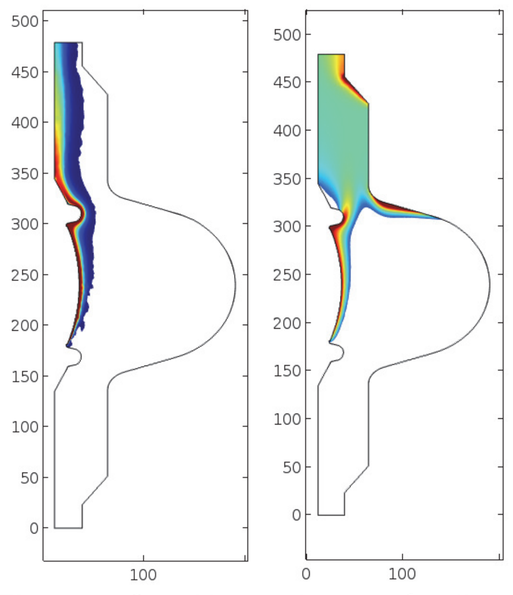

Figure 2. H_2 volume fraction distribution simulated with the laminar module (left) and turbulent module (right) on the old cathode 2D axisymmetric geometry. White surface represents the absence of H_2 phase.

Results and discussion

In line with expectations, the new cathode geometry presents a lower H_2 volume fraction at the anode wall if compared with the old cathode; higher bath flows improves H_2 flushing and higher H_2 mass flows provide higher H_2 volume fraction at the anode wall. On the other hand, hydrogen bubbles size provided a better understanding on possible behaviours inside the electrochemical cell.

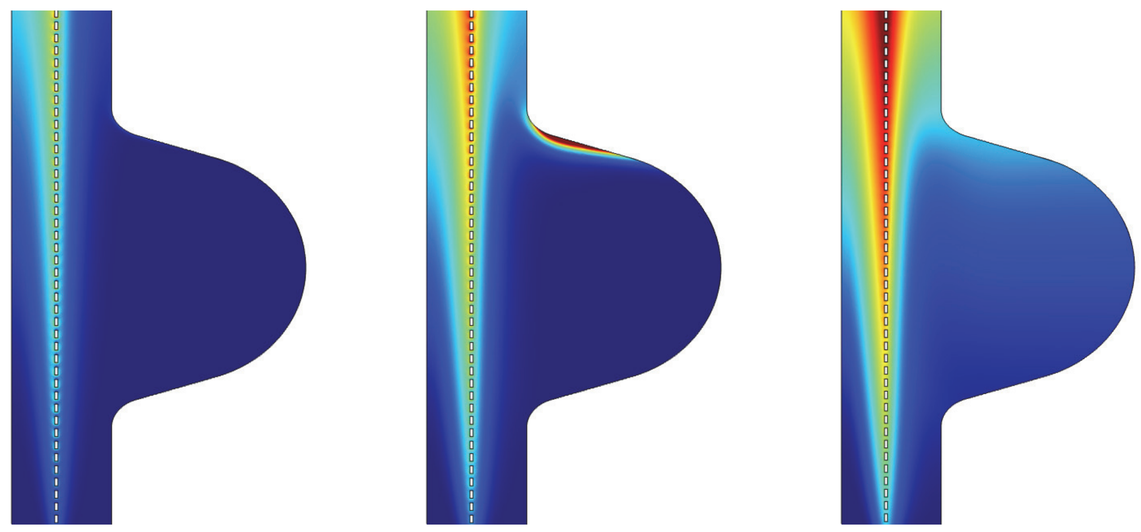

Figure 3. H_2 volume fraction distribution for different hydrogen bubble sizes: 1 mm (left); 0.55 mm (centre) and 0.1 mm (right).

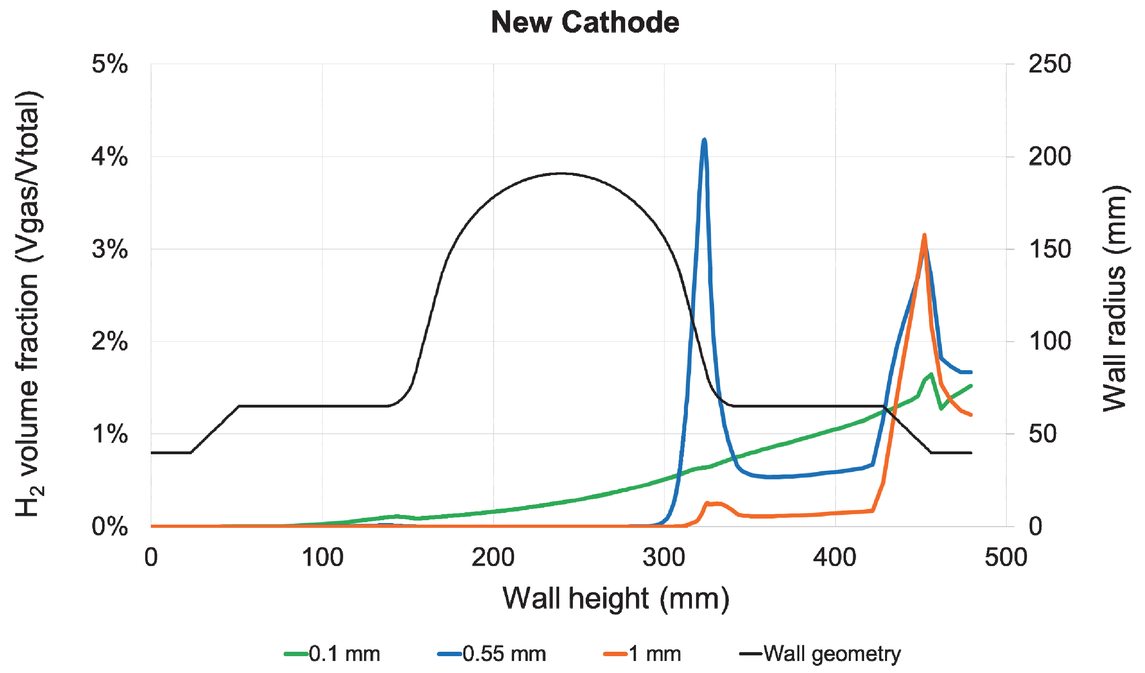

Figure 4. H_2 volume fraction at the anode wall in function of the hydrogen bubble diameter.

Conclusions

The present work allowed to understand how H_2 bubbles behave as a function of working parameters and to quantify their distribution inside a defined electrochemical cell geometry.

The time resolved study concluded that after a few minutes, the electrochemical cell was able to reach stationary conditions; this duration is negligible if compared with the process running time that counts for several hours.

From this study the hydrogen bubbles size results to be the most important variable. Above 1 mm in diameter, bubbles are prone to move mainly upwards, while below 0.1 mm they are prone to move also horizontally, without sticking to the anode wall. This leaves an intermediate range of bubbles diameter where they are prone to accumulate on wall segments that hinder their upward movement.

This work gives the orientation for future optimisation paths. It's fundamental to measure precisely the real size of the H_2 bubbles as their behaviour depends on it and this for a relatively narrow range. A membrane might be a solution to trap bubbles avoiding that they reach the anode wall. The cathode geometry can be further optimised by moving the active cathode surface to a more axial position, well apart from the anode.

References

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