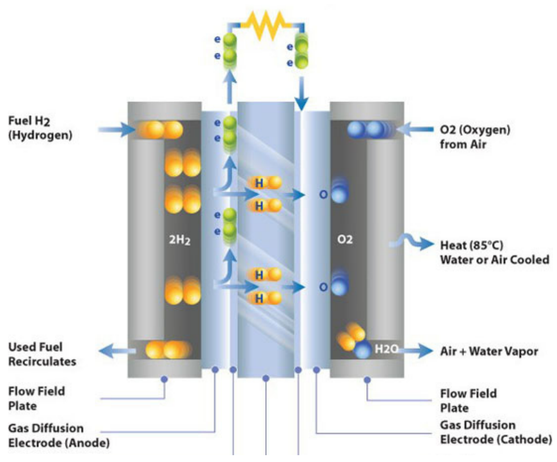
FUEL CELL MULTIPHASE MODELLING AND MATERIALS DESIGN OPTIMIZATION: METHODOLOGY

Supervisor: Dario Maggiolo
By: Klara Mattsson and Harikrishnan Muralidharan
Course: TRA105 Fuel Cell Systems
Department: Maritime Sciences (M2)

INTRODUCTION

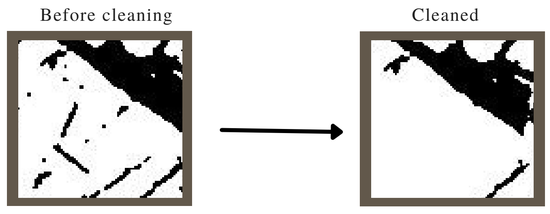


https://commons.wikimedia.org/wiki/File:Membrane_Electrode_Assembly_-_Electro-Chemical_Reaction_Diagram.jpg

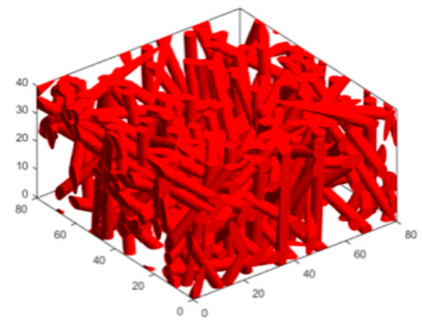
Membrane Electrode Assembly is the core component of a fuel cell. It consists of a Polymer Electrolyte Membrane, 2 catalysts layers and 2 gas diffusion layers. The main function of the MEA is to control the flow of electrons liberated at the anode to the cathode. In a fuel cell, mass transport plays a very crucial role in its efficiency. Hindrance to mass transport is mainly due to the resistance in the gas diffusion layer. Presence of liquid water in the diffusion layer is one of the main causes of mass transport limitations. So the present study is based on the pore size distribution of the material used for the diffusion layer and understanding the mass transport mechanism of the same.

GEOMETRY ANALYSIS

An X-ray tomography of the carbon material computes a geometry reconstruction. This is done by having a picture of each layer in the material, which Matlab creates a 3D binary matrix of. Each layer is then a binary 2D matrix, which is cleaned by removing the pores which are too small. This is done by removing the small clusters in the binary matrix.



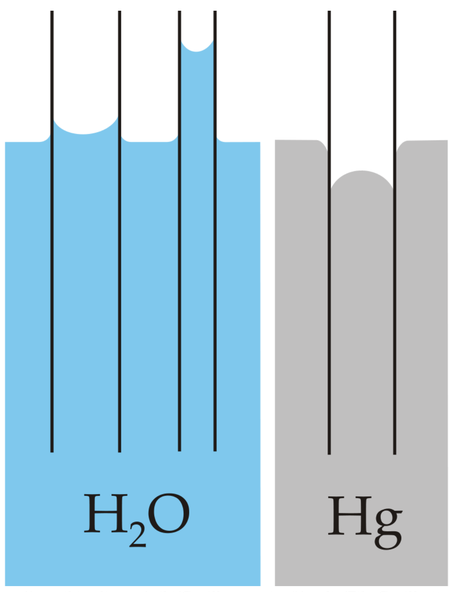
After the binary matrix is cleaned, it is possible to calculate the pores radius in each layer, by assuming each pore is a circle. The probability (frequency) of the pore dimensions are analyzed and related to the mass transport efficiency of the gas diffusion layer.



Gao, Y.; Jin, T.; Wu, X.; Zhang, T. The Effect of Fiber Orientation on Stochastic Reconstruction and Permeability of a Carbon Paper Gas Diffusion Layer. Energies 2019, 12, 2808. https://doi.org/10.3390/en12142808

Binary matrix, built up by zeros and ones

MULTIPHASE TRANSPORT



https://en.wikipedia.org/wiki/Capillary_action#/media/File:Capillarity.svg

When liquid enters the porous membrane, the wetting of the fiber surface increases which eventually leads to an increase in the viscous forces . So the transport becomes depended on the viscous forces as well as the capillary pressure forces . This naturally leads to a decrease in the liquid infiltration rate. This is related by the formula:

$$\frac{dh}{dt} = \frac{K_{cap}\Delta P}{\mu_w H}$$

Integrating the above equation, we obtain the time of penetration, given by:

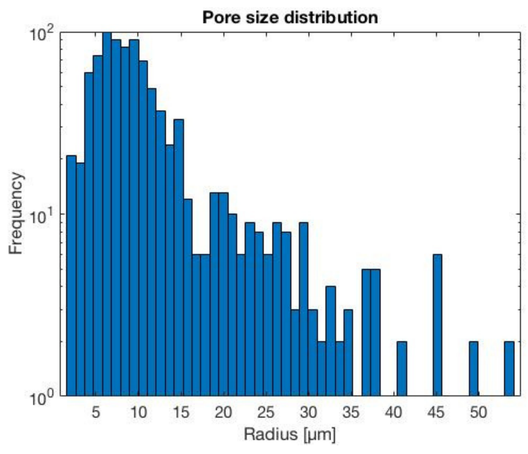
$$t = \frac{\mu \cdot H^2}{2 \cdot \Delta P \cdot K_{cap}} \quad \text{where}$$

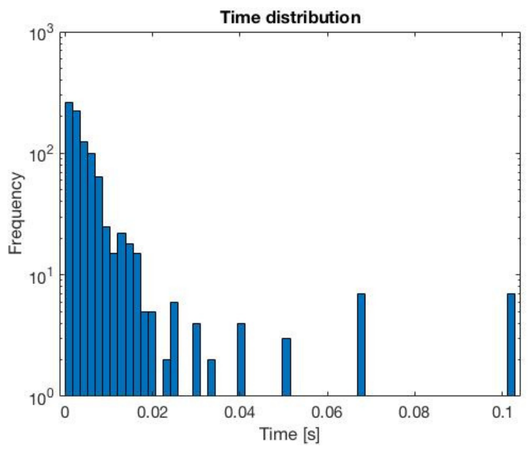
$$K_{cap} = K_{flat} \cdot \alpha \quad \text{and} \quad K_{flat} = \frac{radius^2}{4}$$

K_{flat} is the permeability constant
K_{cap} is the permeability constant with capillary forces
μ_w is the dynamic viscosity of water
ΔP is the pressure difference between the GDL
H is the thickness of the gas diffusion layer
α is the constant that accounts for the capillary forces

DISCUSSION AND CONCLUSION

The plots to the right are describing the distribution of the radiuses and the time for Spectracarb gas diffusion layer. The bigger the radius of the pores is, the less time it takes for the water to penetrate the gas diffusion layer. Therefore the velocity of the water is higher if it is going through bigger pores. It is possible to see that the peaks for the radiuses in the pore size distribution correspond to the graph of the time distribution, where they give two different water ejection times.





CHALMERS UNIVERSITY OF TECHNOLOGY