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The impact of fibre surface morphology on the effective thermal conductivity of a PEMFC gas diffusion layer

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Polymer electrolyte membrane (PEM) fuel cells are electrochemical energy conversion devices that have the potential to generate electricity with zero local greenhouse gas emissions. While the inlet fuel and oxidant gases to the PEM fuel cells are typically heated, heat is also produced from electrochemical reactions and water phase change, resulting in temperature gradients that can affect the conditions of the cell. Pathways for effective heat conduction are vital for avoiding excessive condensation of water from cooling, or material dry-out from overheating. Before PEM fuel cells can reach widespread adoption, effective thermal management must be achieved in order to reach the performance and durability levels required for commercialization.

Isolating the coupled effects of operating conditions, such as humidity levels, heat loss, and mechanical compression, can be challenging when performing in-situ PEM fuel cell experimentation. As a result, several attempts have been made in characterizing the thermal performance numerically [1-4]. In particular, the effective thermal conductivity of the cathodic gas diffusion layer (GDL) has been studied using lattice Boltzmann methods [1], resistance network modelling [2, 3], and computational fluid dynamics [4]. This previous work has provided important insight into the thermal transport considerations of the GDL, though further investigation is needed to understand the impact of the fibre surface morphology.

The purpose of this study is to develop a comprehensive model for determining the effective through-plane thermal conductivity of the GDL of a PEM fuel cell. In this work, we will take fibre surface morphology and non-stochastic resistance networks into consideration with the model developed by Yablecki et al. [2]. Preferentially stacked fibre networks analyzed in this study are generated computationally, and are informed by experimental data obtained via micro-computed tomography [5] and atomic force microscopy (AFM) measurements. Fibre contact areas, which affect the thermal contact resistances, are computed using the mechanical properties and surface features of the carbon fibres, as well as the orientation angle of fibres in contact. These simulations were completed for various compressive loads, representing different clamping pressures experienced by the GDL, neglecting actual bending of individual fibres.

It is hypothesized that the effect of incorporating fibre surface features into the thermal contact area will reduce the effective thermal conductivity. We also expect that the effect of introducing a non-stochastic resistance network on the effective thermal conductivity will be case dependent. By accounting for the effects of fibre surface morphology, over the more commonly used smooth-fibre approximation, the analysis conducted in this study will provide insight into a more realistic thermal model of the GDL of a PEM fuel cell.

References:

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