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Multiphase Flow Through Rough Porous Layers in Proton-Exchange Membrane Fuel Cells (PEMFCs)

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Polymer electrolyte membrane fuel cells (PEMFCs) have emerged as ideal energy-conversion devices for hydrogen energy applications. The performance of PEMFCs is significantly affected by the accumulation and transport of water inside porous components and flow channels. Here, we focus on investigating the role of surface roughness on the fluid transport and droplet impact behaviours in the porous components of PEMFC. We start by examining the fluid transport characteristics at the interfacial region of microporous layer (MPL) and catalyst layer (CL), considering the effects of compression stress, porosity, and wettability. Liquid and gas permeabilities are also investigated to assess water drainage and fuel supply efficiency with different compression conditions. Then, surface roughness effects of gas diffusion layer (GDL) on liquid droplet removal inside a flow channel are investigated. We simulated the complete process of droplet removal in flow channel, including emergence, growth, detachment, and removal. We also identified different regimes of detachment modes based on the droplet breakup location and detachment ratio. Finally, we experimentally examined the liquid droplet impact dynamics on rough surfaces with various topological parameters. We observed different modes of droplet spreading and bouncing behaviour, and droplet impact outcome transition from bouncing to no bouncing is identified. To quantify the influence of surface wetting area on the bouncing-wetting transition, we proposed a modified Weber number that incorporates a combined effect of droplet kinetic energy, surface energy, and adhesion force. We found that the droplet impact outcomes in the transition regime can be accurately described by a single curve as a function of the modified Weber number. The results can provide valuable insights into selecting appropriate parameters of diffusion media for optimising water management and fuel supply during fuel cell operation processes.

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