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A Calorimetric Approach to Ultrasonic Absorption Measurement in Dynamic Fluid Media

Liam Horrigan[1*], Marina Friere-Gormaly[2]
[1]Department of Mechanical Engineering, York University, Toronto, Canada
[2]Department of Mechanical Engineering, York University, Toronto, Canada
*liam.horrigan@sympatico.ca

Abstract

This paper investigates approximations of the relationship between fluid temperature and ultrasonic activity within cross-flow reverse osmosis filtration modules, as part of a broader investigation of ultrasonic fouling mitigation for small-industrial-scale reverse osmosis systems. Two discrete models approximating the temperature distributions within imperfectly thermally insulated channels subject to diffusion and axial flow were developed and compared. One model neglects the effects of temperature on diffusion in the interest of model simplicity, while the other explicitly accounts for these effects. Neglecting temperature effects on diffusion allows for the decoupling of the mass transfer and heat transfer problems, allowing a single mass transfer solution to be used to develop multiple heat transfer solutions without re-solving the mass transfer model. In this work, an analytical solution to the mass transfer problem is adapted from existing literature for use in this de-coupled case. The second model accounts for the coupling effects by solving the heat and mass problem concurrently, improving the fidelity of the model in exchange for greater computational demand. Both models require the flow properties at the channel inlet as inputs. When applied in the context of a simulation using parameters representative of a typical small-scale industrial spiral-wound reverse osmosis module, the two models are effectively identical in their temperature distribution predictions despite differing slightly in their permeate flux predictions. The models both predicted temperature increases on the order of 0.1 K along the length of the module, depending on the parameters used. Future work will focus on the experimental validation of these two numerical models.