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Flow and Temperature Front Correlation in Phase Change Porous Media Measured by MRI

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Fluid flow and heat transfer characteristics in packed beds are an important area of study with many applications in industry including design of catalytic beds and thermal heat storage units. Understanding of fluid flow and heat transfer at the pore scale is lacking due to the difficulty obtaining velocity and energy transport measurements in opaque systems. The use of macro scale correlations in packed bed design is still prevalent due to deficiency and low spatial resolution of experimental data in these systems. Current methods make use of fixed thermocouples that provide coarse temperature measurements along the packed bed, or only obtain flow and temperature measurements at the input and output. Magnetic resonance imaging (MRI) techniques are ideally suited for probing heat transfer in packed beds as they can non-invasively obtain velocity information, and many parameters are sensitive to temperature. MRI velocimetry techniques have been proven to provide spatially resolved velocity measurements at the 100 μm scale. In addition, local diffusion coefficients can be found though propagator measurements and T2 intensity images can be obtained bed material. The experimental work presented here incorporates a packed bed formed from an eicosane wax encapsulated in a plastic shell with a fluorinated fluid in the pore space. Heating the flowing fluid above the melting temperature of the wax provides a novel approach to track the melt temperature front in a non-isothermal packed bed by taking advantage of the change in T2 associated with phase change. This approach uses the 1H signal from the packing and the 19F signal from the fluid to allow for monitoring of both bed structure and flow velocities in the same sample via the use of a dual tuning rf 19F/1H coil. The velocimetry sequence provides 2D pore scale velocity measurements in three coordinate directions in both the longitudinal and transverse planes. T2 intensity images are captured in 1D and 2D to track phase/temperature in the bed over time. This allows for the observation of inter and intra particle melting, coupling heat transfer and fluid flow experimentally at length scales smaller than any other existing method. Current work has involved observation of liquid, gas and supercritical fluid flow in the packed bed. Natural convection of supercritical fluids was also observed in these settings. Future work will include calibration of temperature as a function of T2 in the hopes of creating a robust method for measuring temperature with T2 and calculation of local heat transfer coefficients.

References

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